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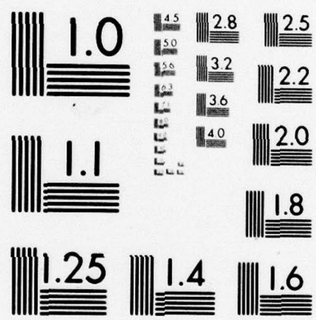

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A COMBINED ENVIRONMENTS RELIABILITY TEST (CERT) FACILITY FOR TESTING AIRBORNE EQUIPMENT

Environmental Control Branch
Vehicle Equipment Division

September 1979

TECHNICAL REPORT AFFDL-TR-79-3079

Final Report for Period June 1976 to October 1978

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HARRIMAN E. REYNOLDS
Combined Environments Test Group
Environmental Control Branch
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FOR THE COMMANDER

AMBROSE B. NUTT, Director
Vehicle Equipment Division

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A third combined environment reliability test facility has been developed with improved capability to simulate the dynamic combined environments that internally carried aircraft equipment is exposed to in modern high performance military aircraft. An electro-pneumatic control system individually controls compartment temperature, humidity, air mass flow and altitude, and equipment cooling air temperature, humidity, and mass flow from a tape deck according to aircraft ground and flight profiles programmed on magnetic tape. Random mechanical vibration control is semi-automatic. The design, engineering development, and partial performance capabilities are documented.

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FOREWORD

This report was prepared by the Combined Environments Test Group, Environmental Control Branch, Vehicle Equipment Division, Air Force Flight Dynamics Laboratory. The work described was conducted under Project 2402, Task 240204, Work Unit 24020413.

The author expresses his appreciation to Carl Williams, Elbert E. Ruddell, Herbert N. Knick, and William A. Hunk for their contributions during the final construction and initial checkout phases of the facility. The author is indebted to Jack J. Fedderke for his dedicated efforts in procuring mechanical and instrumentation equipment. Finally, the author is indebted to Dr. Arnold H. Mayer for his guidance in the development of the temperature conditioning system for the airflows and to Dr. Alan H. Burkhard who initiated the work effort, managed the effort in the early phases, and provided guidance through to the completion.

The performance period for the work was from June 1976 through October 1978. This report was submitted in April 1979 by the author.

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NOMENCLATURE AND SYMBOLS

Symbol	Definition
cfm	Cubic feet per minute
H_x	Air-to-water or brine heat exchanger
I/P	Current-to-air pressure transducer
K_1, K_2, K_3	Controller function weighting factors
LN_2	Liquid nitrogen
ma	Milliamperes
P	Pump
PR	Air pressure regulator
psig	Pressure in pounds per square inch gage
PV	Process variable (feedback voltage)
R	Reverse acting or normally open
R_{HP}	Relay, higher of two air pressures
S	Supply air to I/Ps
S_O	I/P air pressure to valve operator
S1	I/P air pressure to chamber altitude butterfly valve operators
$S2_A$, $S7_A$	I/P air pressure to ambient air leg gate valve operators
$S2_C$, $S7_C$	I/P air pressure to cold air leg gate valve operators
$S2_H$, $S7_H$	I/P air pressure to hot air leg gate valve operators
S3, S5	I/P air pressure to air mass flow gate valve operators
S4, S6	I/P air pressure to humidity (steam) gate valve operators
scfm	Cubic feet per minute of air (standard conditions)
SP	Set point

NOMENCLATURE AND SYMBOLS
(Cont'd)

Symbol	Definition
VDC	Voltage direct current
V_O	Transducer output voltage
V_{dP1}, V_{dP2}	Hygrometer (dewpoint temperature) output voltage
V_P	Pressure strain gage (altitude) output voltage
V_{T1}, V_{T2}	Thermocouple (Type T) output voltage
V_{W1}, V_{W2}	Mass flow meter output voltage
ΔP	Pressure difference

SUMMARY

A third experimental Combined Environment Reliability Test (CERT) facility has been developed to support an extensive test program designed to evaluate the CERT concept as a realistic and cost effective means of predicting the service life of internally carried aircraft avionics equipment. A recommendation based on operational experience with a prototype facility was incorporated into the facility design to improve the dynamic response of the aircraft bay environment simulation and reduce operating costs. The recommendation was to use a temperature and humidity controlled airflow rather than the LN_2 cooled cold wall-heat lamp arrangement used in the prototype facility to simulate bay temperature and humidity. This fixed the design of the facility as one having two process airflows: one for bay environment simulation, and one for aircraft equipment cooling air simulation.

The facility has a test chamber (5ft x 5ft x 5ft inside dimensions) with a penetration in the floor for coupling the equipment under test to an externally mounted electro-mechanical shaker. The two process airflows are piped into the chamber for bay environment simulation and for aircraft equipment cooling air simulation. Evacuation of the chamber for altitude simulation is provided by a water seal balanced rotor vacuum pump. Metering and mixing of the process airflows for mass flow, temperature, and humidity control is performed external to the test chamber, as is the bleeding of atmospheric air into the vacuum circuit for chamber altitude control.

An electro-pneumatic control system automatically controls the mass flow, temperature, and humidity functions of the airflows and the altitude function of the test chamber. Each function is independently controlled without coupling to another function. The system is such that the control input can be made from either a manual set point station or from a tape

deck with preprogrammed magnetic tape that is tailored to simulate the dynamic environmental profiles which the avionics equipment is exposed to in military aircraft.

A semi-automatic electronic system controls the electro-mechanical shaker for aircraft vibration simulation. The system has the capacity to store up to 50 vibration spectra. However, operator action is required to recall and change spectra according to the flight profile during the course of a test.

The design goals for the facility are as follows.

Chamber

Altitude	0 to 70,000 ft	+10,000 ft/min ascending -20,000 ft/min descending
Airflows	two independently controlled	

Airflow Capabilities (each flow)

	Range:	Rate:
Mass Flow	0 - 7.5 lb/min	± 100 lb/min/min
Temperature	-65°F - +160°F	± 120F°/min
Humidity	0.00001 to 0.04 lbs H_2O/lb dry air	± 0.04 lbs H_2O/lb dry air/min
Vibration	0 - 2000 Hz 17,500 lb force	random or sinusoidal up to ± 1/2 in. amplitude

The facility has been placed in service to support a CERT validation test on an avionics equipment item without completing tests to verify the full range of facility capability.

SECTION I

INTRODUCTION

1. PURPOSE OF THE REPORT

This report documents the design, development, operation, and preliminary performance characteristics of a laboratory type of Combined Environments Reliability Test facility, CERT III. The need for this facility is discussed in Paragraph 2 of this section. Section II discusses the basis for the design of the facility, the performance goals, and the selection of equipment and components to achieve the design goals. Section III presents limited performance characteristics of the facility based on incomplete checkout tests and the initial phases of a CERT test on an item of avionics equipment. Section IV presents the conclusions, and Section V presents recommendations.

2. NEED FOR AN ADDITIONAL COMBINED ENVIRONMENTS RELIABILITY TEST FACILITY

The Combined Environments Reliability Test (CERT) concept is an approach based on laboratory tests to determine realistic service life of aircraft equipment and identify component weaknesses that adversely impact the field service life of the equipment. The objective of CERT is to provide substantially more effective techniques for evaluating the reliability of aircraft equipment prior to extensive deployment into the field than has been realized by applying current and past test methods derived from MIL-STD-781 and MIL-STD-810.

In CERT testing, airborne equipment is subjected to the same environmental stresses that simulate what the equipment would be exposed to when installed in an aircraft. The test chamber in which the equipment is placed represents the aircraft bay or compartment, and processed air which is ducted to the equipment represents aircraft equipment cooling air. The equipment is mounted on a fixture that is attached to a shaker for aircraft vibration simulation. Chamber air pressure (altitude), temperature and humidity, equipment cooling air temperature, humidity and mass flow, and vibration are simultaneously varied in accordance with flight environment profiles that the equipment would experience in an aircraft. The equipment is operated as though it were in the aircraft and continuously monitored to detect failures or deviations from specifications. In essence, the equipment "flies" in the test chamber as though it were installed in an aircraft from a combined environment stress standpoint.

The potential of the CERT concept to more realistically predict service life of aircraft equipment and thereby substantially reduce Air Force costs and improve Air Force effectiveness resulted first in the modification of an existing climatic/altitude chamber to support CERT test experiments. The modification of the test chamber (CERT I) and the test capabilities obtained are reported in Reference 1. Concurrently, an extensive test program was developed to validate the CERT concept.

Selection of aircraft equipment for test in the validation program was made jointly with the ASD PRAM Program Office. It was determined that the equipment selected would be restricted to internally carried avionics equipment, which is a class of equipment that has low field reliability and is a high maintenance cost driver to the Air Force. Identified and scheduled for test were a variety of avionics equipment with established field service histories and field mean time between failures (MTBFs) that would be required to validate the CERT concept. The field MTBFs of these equipment items typically fell far short of the MTBFs that had been demonstrated using conventional test methods.

The scope of the resulting validation test program was of such magnitude that a second climatic/altitude chamber was modified to provide CERT capabilities; and a third chamber, all new and the subject of this report, was built to expedite the CERT Evaluation Program (Reference 2).

SECTION II

DESIGN AND DEVELOPMENT OF THE CERT III FACILITY

1. DESIGN APPROACH

Features considered in the development of the design of the facility were improved capability to simulate the dynamic environments that current and future internally carried avionics would be exposed to in modern high performance aircraft, simplicity of operation, and low operational costs. Unlike the prototype facility (CERT I) and the second facility (CERT II), the design would not be constrained by the requirement to use existing equipment. All existing equipment had been committed and new equipment would be procured specifically for this application. Cost would be the limiting factor in obtaining the desired features.

Experience gained in the operation of the CERT I facility demonstrated that the massive LN_2 cold wall and heat lamp concept used to simulate bay temperature should be abandoned in favor of an airflow system with independent temperature and mass flow functions to obtain improved dynamic temperature response.

The choice of airflow as a means to simulate bay temperature fixed the design of the facility to the extent that two airflows would be required: one for bay environment simulation, and one for aircraft equipment cooling air simulation. It was determined that each airflow would have the same independently controlled capabilities for reasons of commonality and interchangeability.

Problems inherent with LN_2 that included high cost, hazards associated with cryogenic fluids, and interruptions to test programs due to inconsistent resupply led to the selection of a mechanical chiller/cold brine arrangement to provide cooling for the two airflows. Also, an electrical resistance boiler/hot brine arrangement was selected for providing heating for the two airflows. Simplicity of operation and precision in duplicating flight profiles dictated that the facility be automated.

The shaker system and the vibration control system used in the CERT I facility lacked the capability, flexibility, or ease of programming desired for the new facility. Therefore, it was determined that a higher capacity shaker system with an improved control system should be procured for the facility.

2. DESIGN REQUIREMENTS

The requirement for the facility was to provide a test chamber with approximately 5 ft x 5 ft x 5 ft inside dimensions with two independently controlled airflows. One airflow would be for aircraft bay environment simulation, and the other for avionics equipment cooling simulation. The chamber would be designed to withstand pressures from ground level to 70,000 ft altitude, high humidity, free moisture, and temperatures from -100°F to +300°F. Provisions would be made to prevent pressurization of the chamber above ambient pressure, and minimize heat losses through the chamber walls.

The design of the two airflow systems would be identical. Each system would have independently controlled mass flow, temperature, and humidity functions. The maximum mass flow from each system would be 7.5 lb/min for a total mass flow of 15 lb/min.

An electromagnetic shaker system was specified to simulate aircraft vibration. The vibration requirement of the system was from 5 to 2000 Hz in either the sinusoidal or random mode, 17,500 lbs maximum force, and ±1/2 in. maximum amplitude. All of the shaker system except the shaker fixture would be outside the chamber to minimize the thermal loads and effects of the chamber. The fixture would attach to the shaker through a penetration centered in the floor of the chamber. A seal to prevent air leakage into the chamber would be required that encloses the space between the shaker and chamber without restricting arma-

ture travel. Since the shaker armature is sealed in the body of the shaker to form a closed cavity and the cavity is pressurized to position the armature, a pressure equalizer line between the cavity and the test chamber would be required to prevent changes of chamber pressure acting on the top of the armature from pulling it out of position. Ease of servicing and repairing the shaker was desired. Therefore, it was required that the shaker be floor mounted and the chamber support structure be so designed as to permit lateral installation and removal of the shaker with minimal disruption of the chamber.

Because of the numerous number of parameters and the anticipated round-the-clock utilization of the chamber, it was required that the control of the chamber altitude and airflow functions be automated. The programmable hybrid (digital/analog) electropneumatic control system such as used in the CERT I facility was specified for the facility. This system has the option of control from a manual station, as well as a programmed tape.

A summary of the performance goals for the facility is presented in Table I.

TABLE I: CERT III PERFORMANCE GOALS

	Chamber	
Size	5ft x 5ft x 5ft inside dimensions	
Altitude	0 to 70,000 ft	+10,000 ft/min ascending -20,000 ft/min descending
Airflows	two independently controlled	
	Airflow Capabilities (each flow)	
	Range	Change Rate
Mass Flow	0 to 7.5 lb/min	±100 lb/min/min
Temperature	-65°F to +160°F	±120F°/min
Humidity	0.00001 to 0.04 lb H_2O/ lb dry air	±0.04 lb H_2O/lb dry air/min
Vibration	0 to 2000 Hz 17,500 lb force	random or sinusoidal up to ±1/2in. amplitude

3. DESIGN OF THE FACILITY

a. Overview of the Facility

The arrangement of the equipment selected to meet the design goals of the facility is shown in the schematic diagram in Figure 1. Two notable features of the arrangement deserve comment. These are the extent of equipment used to clean and dry the air and the use of the three-legged airflows to achieve temperature control of the process airflows. Clean air is essential to prevent fouling of the instrumentation and test specimen; and although dry air is required for humidity control, substantially drier air (dewpoint less than -105°F) is essential to prevent frosting and freeze-up of the airflow through the heat exchangers chilled by the -105°F cold brine. The three-legged air temperature control with ambient air as the third leg was adopted to reduce operating costs. Rather than proportion hot and cold air to obtain the desired control temperature, as is done with a two-legged hot/cold system, ambient air is proportioned with cold air for control temperatures below ambient and proportioned with hot air for control temperature above ambient. For minimum temperature, full flow is through the cold leg; and for maximum temperature, full flow is through the hot leg.

As can be seen, one process airflow provides the temperature and humidity functions for bay environment simulation; and the other airflow provides the mass flow, temperature, and humidity functions for aircraft equipment cooling air simulation. The pressure function (altitude) for bay environment simulation is provided by the vacuum pump and atmospheric bleed valve arrangement. Each of the functions of mass flow, temperature, humidity, and pressure are individually controlled by means of independent control loops. Mechanical vibration shaped to simulate aircraft vibration is applied to the test specimen in the chamber by an electromagnetic shaker located below the chamber.

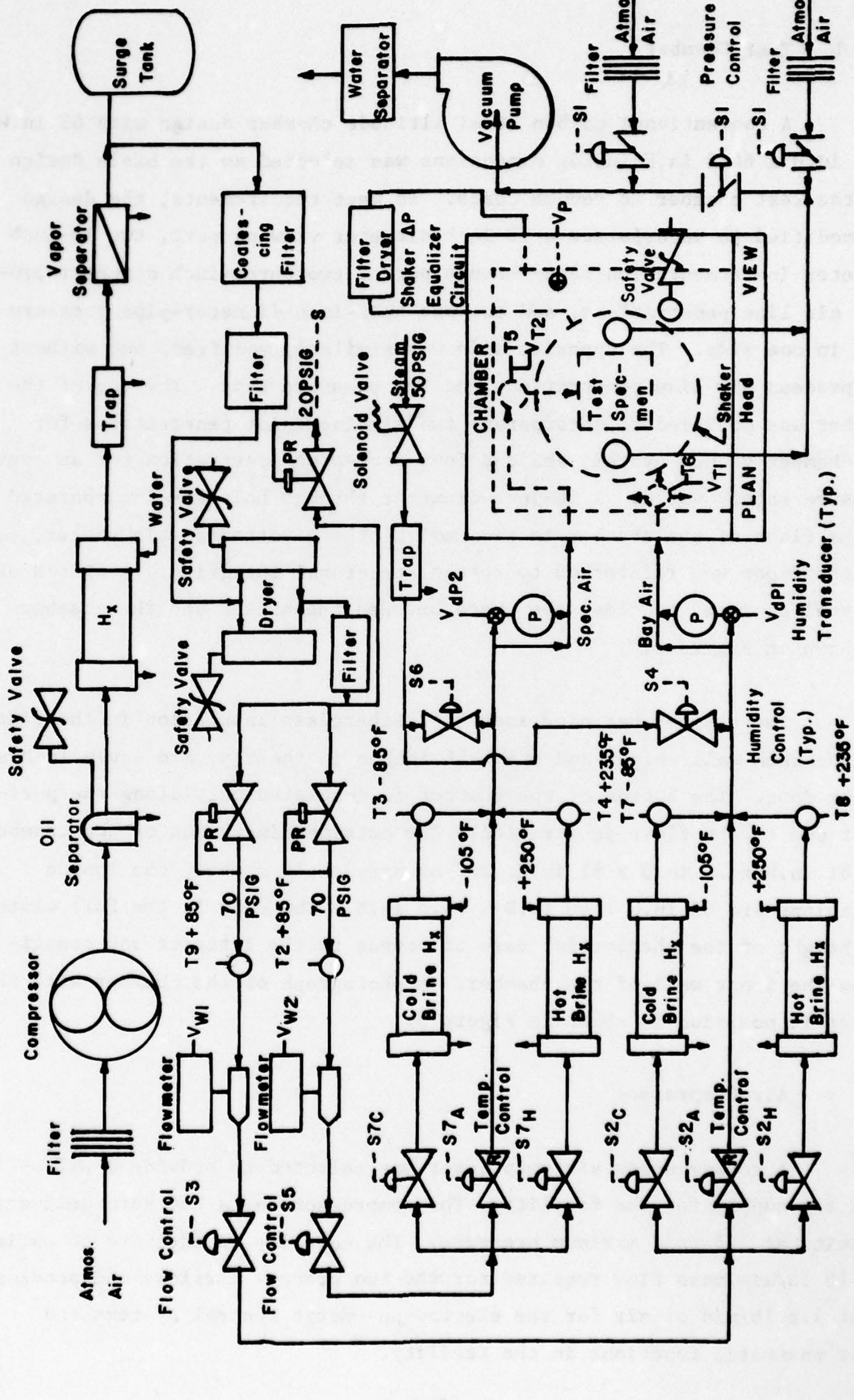

Figure 1. Schematic Diagram of CERT III Facility

b. Test Chamber

A conventional carbon steel altitude chamber design with 63 in.W x 60 in.D x 64.5 in.H inside dimensions was selected as the basic design for the test chamber to reduce costs. To meet requirements, the design was modified to incorporate a 13-inch diameter viewing port, two 12-inch diameter instrumentation feed-through ports, two three-inch diameter process air line penetrations, and two one-half-inch-diameter-pipe pressure taps in one side. The opposite side was similarly modified, but without the process air line penetrations and the pressure taps. The top of the chamber was modified to incorporate two six-inch-pipe penetrations for the chamber vacuum system, and one four-inch-pipe penetration for an over-pressure safety valve. A 28-inch-diameter through hole was incorporated in the floor of the chamber to accommodate the electromagnetic shaker, and the floor was reinforced to retain structural integrity. A sketch of the seal designed to close the space between the shaker and the chamber is shown in Figure 2.

The chamber has nine inches of fiberglass insulation in the sides and the back wall, eight and one-half inches in the top, and seven inches in the door. The bottom of the chamber is insulated only along the perimeter due to the floor penetration. The outside dimensions of the chamber are 81 in.W x 78 in.D x 81 in.H; and as previously stated, the inside dimensions are 63 in.W x 60 in.D x 64.5 in.H. The door is the full width and height of the chamber for ease of access to the interior and constitutes the front wall of the chamber. A photograph of the chamber with the shaker in position is shown in Figure 3.

c. Air Compressor

A rotary screw air compressor was selected to provide a pulse-free air supply for the facility. The compressor has a 260 scfm delivery capacity at 125 psig maximum pressure. The capacity is adequate to satisfy the 15 lb/min mass flow required for the two process airflows and provide about 4.8 lb/min of air for the electro-pneumatic control systems and other pneumatic functions in the facility.

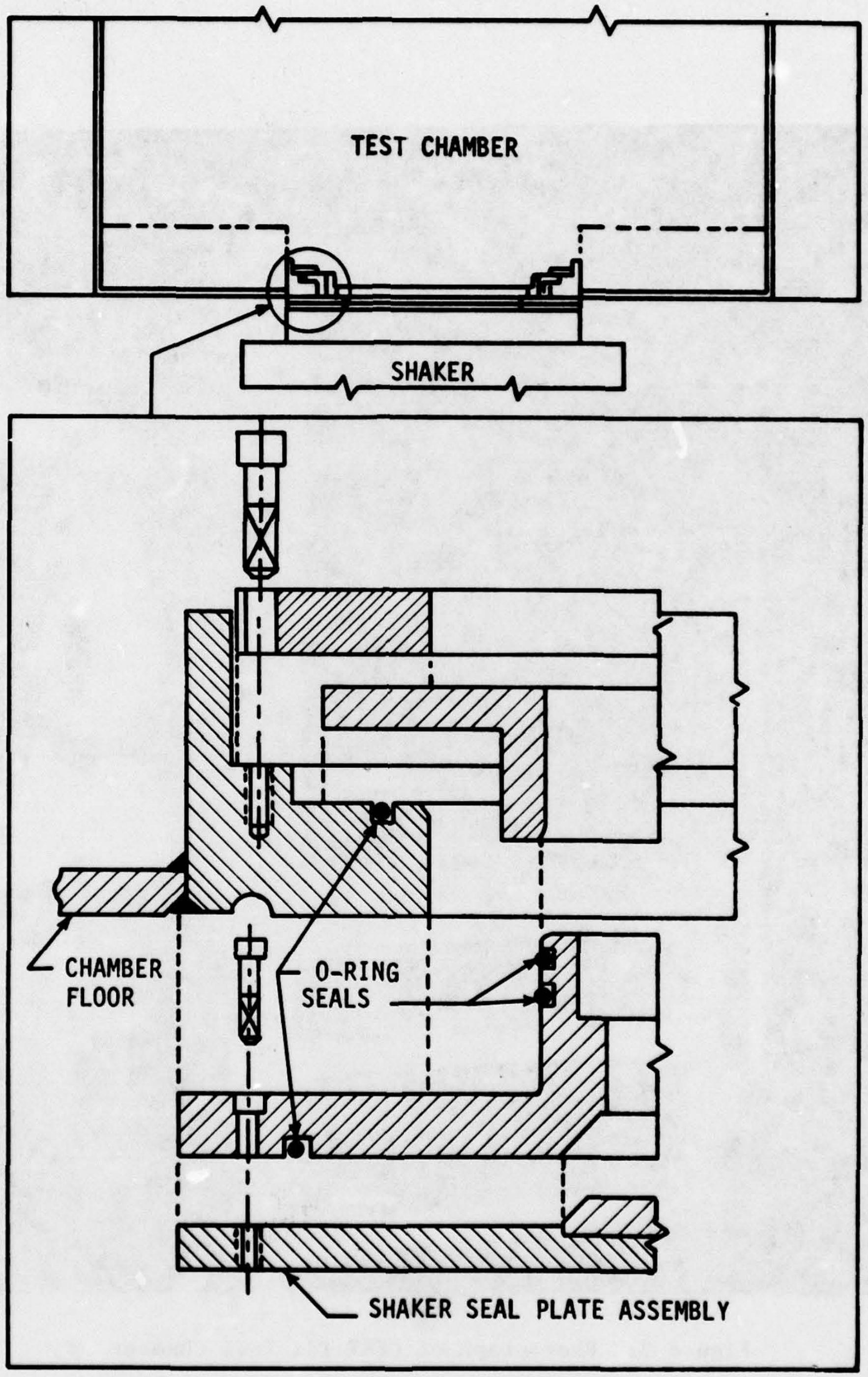

Figure 2. Sketch of the Test Chamber to Shaker Air Seal

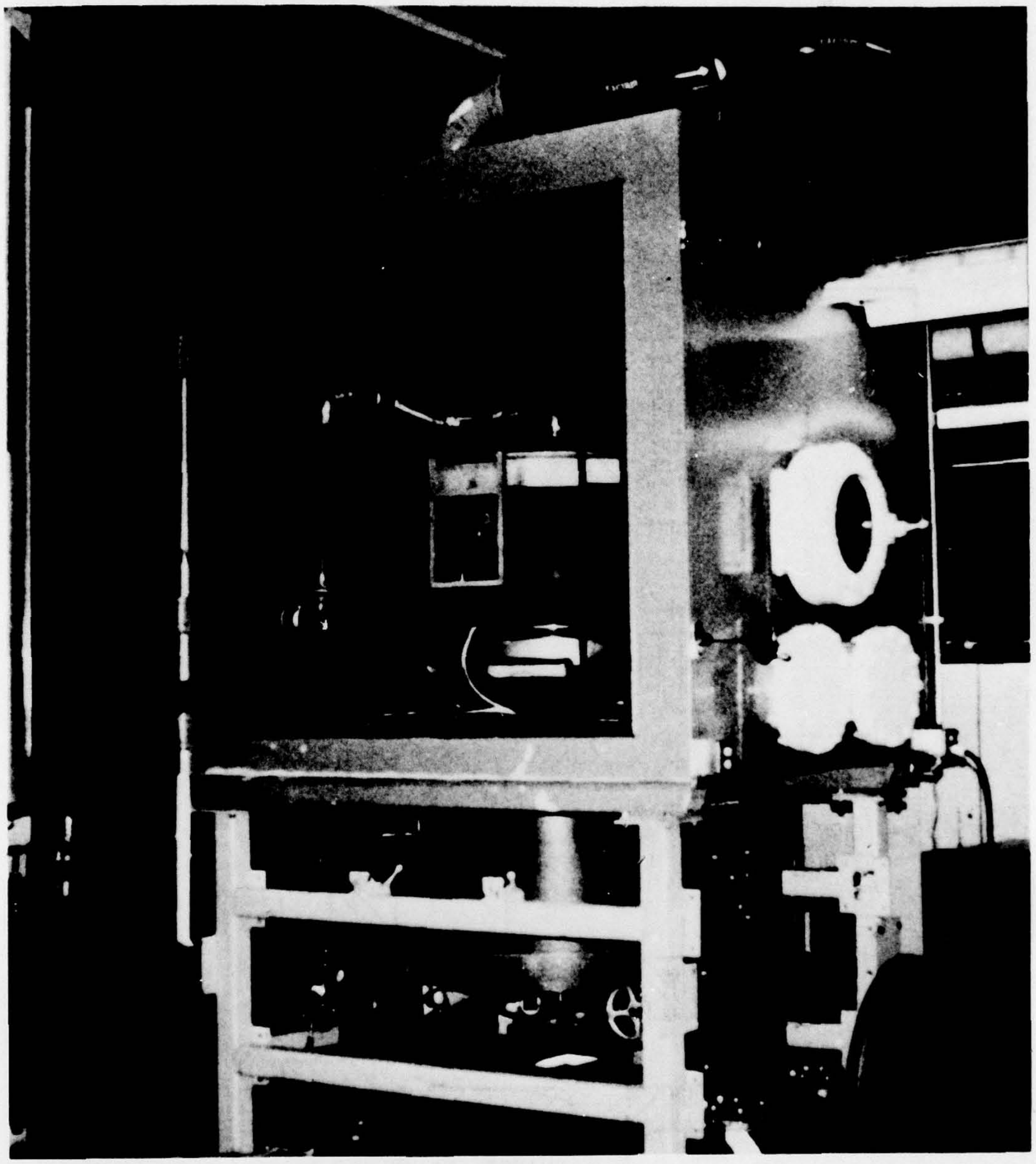

Figure 3. Photograph of CERT III Test Chamber

The compressor was procured as a packaged unit that has an inlet air filter, a water-to-air heat exchanger to cool the air, an oil separator, and a moisture trap downstream from the air cooler. The compressor is set to discharge air at 120 psig, and the heat exchanger is set to cool the air to +85°F. The air discharged under these settings is semi-polished with a specific humidity of about 22 grains of water per pound of dry air (28°F dewpoint at sea level).

d. Air Cleaning and Drying Equipment

A coalescing filter, an absorption filter, a dryer, and an after filter were selected to clean up the air from the compressor unit and are arranged to process the air in the order listed. The coalescing filter and the absorption filter were each sized to handle the rated flow of the compressor at a maximum pressure drop of one psi. A feature of the absorption filter is a color changing filter element that indicates the condition of the element as oil is absorbed.

The dryer is a fully automatic twin tower silica gel/molecular sieve type dryer that is reactivated by electrical resistance heating. The dryer is sized so that each tower has the capacity to dry 270 scfm of 75°F, 100 psig saturated air to a -120°F, 100 psig dewpoint effluent for eight continuous hours. The dryer alternates between towers in a 16-hour cycle. Reactivation of a wet tower occurs during the first four hours of service that a dry tower is on the line. After drying, the airstream passes through a four micron after filter to remove particles of silica gel and molecular sieve that may have been picked up in the dryer.

e. Air Cooling

A two-stage mechanical chiller was procured to furnish the cooling for the process air. The chiller utilizes "MF" (trichlorofluoromethane) brine as the medium for heat exchange and has the capacity to remove 45,000 BTUs per hour at a -105°F temperature. Individual pumps circulate brine to the brine-to-air heat exchangers in the cold legs of the process airflows. The heat exchangers are sized to cool 7.5 lb/min of air from +85°F to -85°F in each leg using -105°F brine. Circulation of brine through the heat exchangers is continuous without throttling for temperature control. Therefore, as airflow decreases below the 7.5 lb/min figure, the airflow temperature approaches that of the brine.

f. Air Heating

Two nine KW electrical resistance heated boilers were procured to provide hot brine for the hot legs of the two process airflows. A mixture of 50% ethylene glycol and 50% water is used as the heat transfer fluid. The systems are pressurized to 15 psig to insure a fluid boiling point temperature in excess of 250°F. The heat exchangers are sized to heat 7.5 lb/min of air from +85°F to +235°F in each leg using +250°F hot brine. Circulation of brine through the heat exchangers is provided by individual pumps and is continuous without throttling for temperature control. As in the case of air cooling, the air temperature approaches the brine temperature as airflow decreases from the 7.5 lb/min figure.

g. Humidification

A 58 KW, 250 psig electrical resistance-heated steam boiler was selected to generate clean steam for humidity injection in the process airflows. Feed water for the boiler is filtered and softened using an ion exchange treatment to minimize the formation of hard scale and reduce the carryover of contaminants into the airstream by the steam used for humidification. The boiler capacity well exceeds the capacity required for humidification and can serve as an alternate heat source for the hot legs of the process airflows if desired. Immediately downstream from the point of steam injection, a small diaphragm pump and air loop arrangement is incorporated to recirculate air in each airflow to improve humidity sensing during low flow conditions.

h. Vacuum Pump

A water seal balanced rotor vacuum pump was selected to provide the vacuum for altitude pressure simulation in the test chamber. This type of pump is capable of handling a continuous through flow of wet air without damage and discharges air that is oil free. However, the maximum vacuum capability of this type of pump is sensitive to the vapor pressure of the seal water and requires that the seal water temperature be less than +85°F, preferably +60°F, so as not to impair the capability of the pump at altitudes near the 70,000 ft design goal.

The pump procured for the facility has an approximate inlet capacity of 1,700 cfm at ground level, 2,450 cfm at 7 in. Hg (35,000 ft altitude) and 1,700 cfm at 3 in. Hg (53,000 ft altitude) with 60°F seal water. Air injection is required to obtain pressures below 3 in. Hg; and with injection, the inlet capacity is approximately 1,500 cfm at 1.31 in. Hg (70,000 ft altitude). A comparison of the vacuum pump mass flow capacity with the design flows of the two process airflows into the test chamber shows that the pump capacity exceeds the 15 lb/min maximum flow of the process air at all inlet pressures down to 2.86 in. Hg (54,000 ft altitude). Below 2.86 in. Hg pressure, the pump capacity decreases until at the 70,000 ft design altitude the flow is 6.7 lb/min.

i. Valves

Pneumatically operated metal-to-metal sliding gate valves are used for the air mass flow, temperature, and humidity control functions of the facility. Self-operated metal-to-metal sliding gate valves are used to regulate air pressure. These valves have linear flow coefficients which facilitate precision metering for control. Since tight valve shutoff is critical for humidity control, and metal-to-metal valves tend to leak with use, non-metallic seat off-on solenoid valves are included in line with the gate valves in the humidity circuit for tight shutoff of the steam.

Pneumatically operated butterfly valves are used for the altitude control function. The selection was based on the low flow resistance of the butterfly valve, the relatively low cost, and capacity to throttle.

j. Control System

The automated control system used in the facility is the type of system that is in use in the prototype facility. Details of the system are presented in Reference 1. The use of a temperature conditioned airflow to simulate bay temperature rather than the cold wall/heat lamp arrangement and the addition of humidification to the bay airflow increased the required number of controlled functions from five to seven channels when compared to the prototype facility.

A schematic diagram of the basic control circuit used in the facility is shown in Figure 4. Bay pressure, bay air mass flow, bay humidity, specimen air mass flow, and specimen air humidity are controlled using this type of circuit.

The temperature control function of the bay airflow and the specimen airflow are attained by mixing temperature conditioned air. Rather than mix only hot and cold air to attain the controlled temperature, as is done in the prototype facility, an ambient temperature air leg is included to reduce the cost of operation and conserve energy. For controlled temperatures below ambient temperature, ambient air and chilled air are mixed; and for controlled temperatures above ambient temperature, ambient air and hot air are mixed. No hot air is used below ambient temperature, and no cold air is used above ambient temperature. A schematic diagram of the temperature control circuit is shown in Figure 5. Notice that a reverse acting I/P transducer with a 4 ma to 12 ma input current range controls the cold air leg, and a direct acting I/P transducer with a 12 ma to 20 ma input current range controls the hot

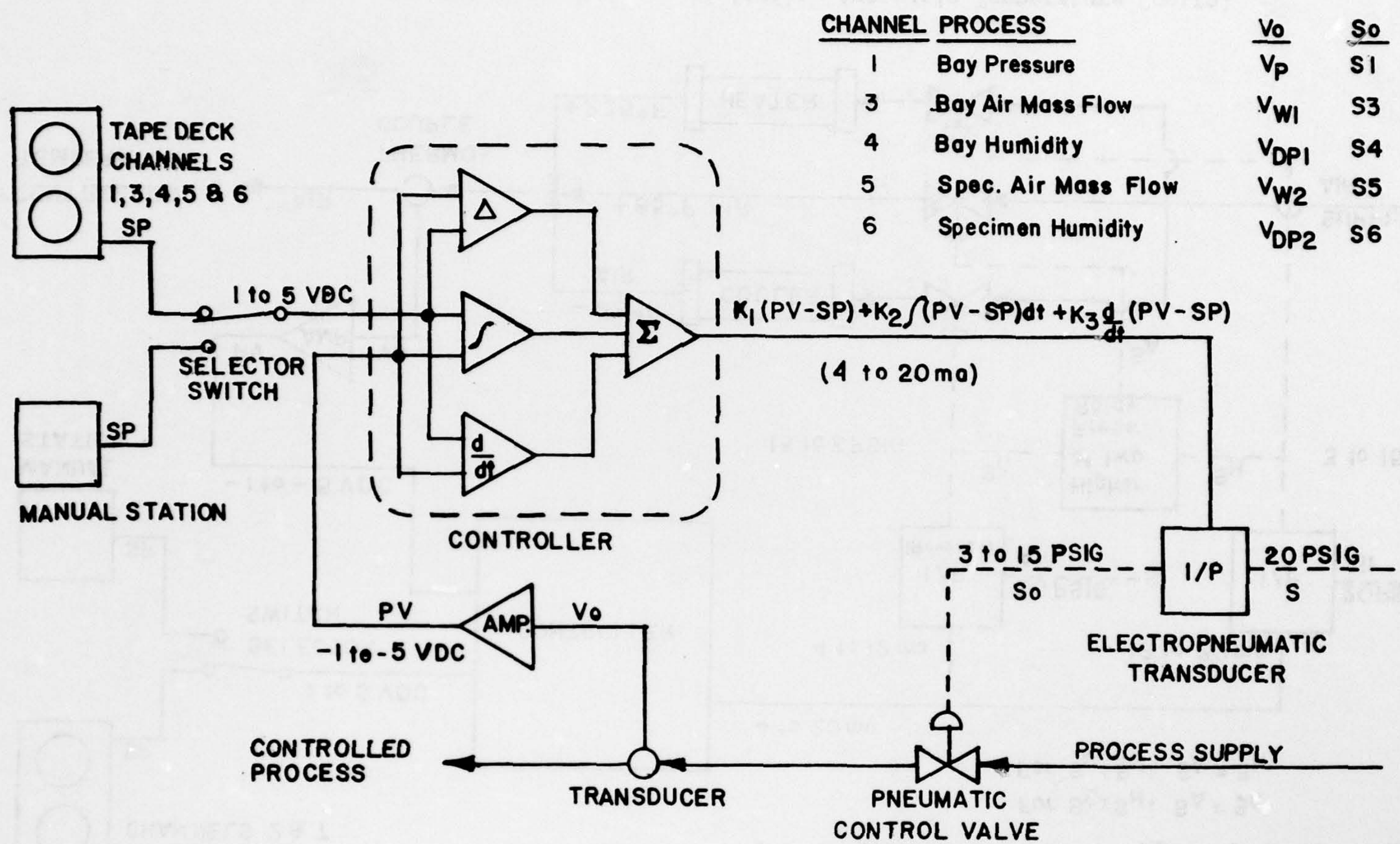

Figure 4. Schematic Diagram of Basic Automatic Control Systems for CERT III Facility

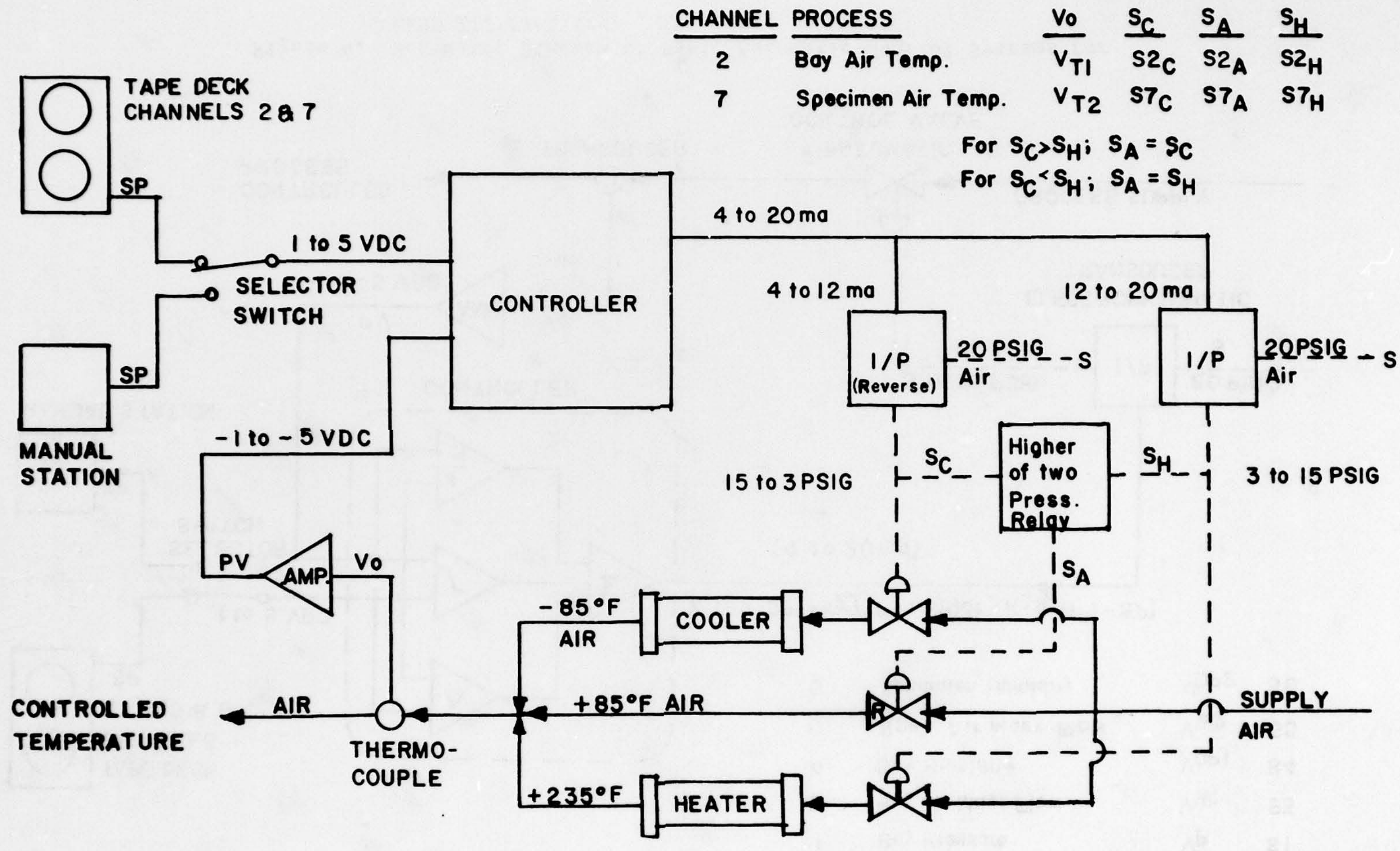

Figure 5. Schematic Diagram of Airflow Automatic Temperature Control Systems for CERT III Facility

air leg. The higher of two pressures relay senses the output pressures of the two I/Ps and applies the higher pressure to control the reverse acting ambient air control valve. The control action is such that at 12 ma controller current, the entire airflow is through the ambient air leg. As the controller current decreases, air from the cold leg is increasingly proportioned with the ambient air until at 4 ma controller current, the entire airflow is through the cold air leg. Conversely, as the controller current increases above 12 ma, the air from the hot air leg is increasingly proportioned with the ambient air until, at 20 ma controller current, the entire airflow is through the hot air leg.

k. Vibration

The vibration capability of the facility is provided by a 17,500 lb force electromagnetic shaker that has a 5 to 2000 Hz frequency response and a one-inch peak-to-peak maximum displacement. A digital vibration control system is used to control the shaker. This system was purchased as an off-the-shelf package representative of the state-of-the-art in electronic vibration control. The system is capable of closed loop control of random, transient, and quadruple sine test excitations and has rapid access up to 50 stored random test spectra. The system is semi-automatic in that an operator is required to recall, and set in random, test spectra according to vibration profiles during the course of a test.

SECTION III
FACILITY PERFORMANCE

A review of initial test results showed that the facility had sufficiently demonstrated capability to support a high priority combined environment reliability test on an avionics equipment which was scheduled for accomplishment immediately after the facility checkout. However, an inadvertent failure of the filter and heater system damaged the flow meters making it necessary to terminate checkout. Rather than allow the facility to remain idle while awaiting the return of the flow meters, it was decided that the test on the avionics equipment would be started and the checkout tests would be resumed after the equipment test was completed in late 1979. It should be noted that the avionics equipment test required only aircraft bay environment and aircraft vibration simulation. The equipment had a self-contained cooling fan that draws upon bay air for internal cooling. Therefore, aircraft equipment cooling airflow measurement was not a requirement. Air mass flow was critical only to the extent that the flow was adequate to control bay pressure, temperature, and humidity according to the test profiles. As of this writing, the test of the equipment is continuing.

During checkout, the 70,000 ft altitude goal was attained at reduced airflow, and the two airflows were cooled below the -65°F temperature goal and heated above the +160°F temperature goal. The temperature control afforded by the three-legged, cold-ambient, and ambient-hot air mixing arrangement was good and is obviously more economical and energy efficient than that afforded by mixing only cold and hot air for temperature control. Concern that a flat band or step change may exist at ambient temperature where the air mix switches from cold to hot or hot to cold air legs during temperature sweeps was alleviated by tests that demonstrated smooth temperature change rate profiles at the transition temperature.

It was found that the single atmospheric vent line was inadequately sized (six inches) to vent the chamber altitude down to ground level with the vacuum pump running. A second parallel eight-inch vent line was fabricated and installed, which corrected the deficiency. The facility schematic diagram (Figure 1) shows the two vent lines, whereas only one vent line adequately sized would have been required.

The performance of the facility during the avionics equipment test has been accompanied by the usual problems that are associated with a new facility. These problems have been for the most part equipment problems that were not related to the facility design or application. However, a design deficiency became apparent, and that was the location of the humidity sensor in the airflow line to the chamber. That location was too remote and the chamber volume too large to give accurate control of the humidity within the chamber. Humidity control was substantially improved by fabricating and placing a shroud around the avionics equipment, piping the airflow to the shroud, and locating the humidity sensor within the shroud.

The use of the shroud, tailored to the size of the avionics equipment to improve bay environment simulation, demonstrates the flexibility and merit of using an airflow for bay environment simulation in contrast to a cold wall/heat lamp arrangement in which bay size is fixed and locks in the performance capability. Furthermore, the dynamic performance obtained with the airflow has been better than that experienced with a cold wall/heat lamp arrangement.

The merits of using the mechanical chiller/cold brine system instead of LN_2 for cooling the airflows are being demonstrated as the test of the avionics equipment progresses. Other than mechanical problems encountered during the chiller checkout and a period thereafter, interruptions to the test due to lack of cooling capability has been minimal and without the delays experienced with inconsistent LN_2 resupply. Also, the overall operating costs of the system are proving to be more economical than had LN_2 been used.

SECTION IV
CONCLUSIONS

A follow-on improved Combined Environment Reliability Test facility (CERT III) has been designed, constructed, and placed in service to support an extensive test program designed to validate the CERT concept. The features of the improved facility are documented in this report.

The principal conclusions resulting from the design and development effort are:

1. The three-legged process air arrangement in which ambient temperature air is proportioned with chilled air or heated air to achieve set temperature provides good temperature control, conserves energy, and reduces operational costs compared with a two-legged, hot-cold, air mixing arrangement.

2. The use of a conditioned airflow to simulate bay temperature and bay humidity environments in the chamber provides improved dynamic performance compared to an LN_2 cold wall/heat lamp arrangement, and provides the flexibility to tailor bay volume to the size of the equipment under test.

3. Completion of the checkout program is required to map the performance capabilities of the facility.

SECTION V
RECOMMENDATIONS

Based on the experience obtained with the facility described in this report, it is recommended that:

1. The completion of the checkout tests be scheduled as soon as feasible to determine the full performance capabilities of the facility.

2. Experiments be conducted on the humidity systems to optimize the location of humidity injection and sensing since tests have shown that the locations in the design are too remote from the test article for precise control.

REFERENCES

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