R-27-26

LAND SEA AIR SPACE

AEROSPACE RECOMMENDED PRACTICE

Society of Automotive Engineers, Inc.
TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

ARP 217B

Issued 3-15-51
Revised 10-15-73

TESTING OF COMMERCIAL AIRPLANE ENVIRONMENTAL CONTROL SYSTEMS

1. PURPOSE

Ø To provide the aircraft industry with recommended practices for testing commercial aircraft environmental control systems when installed in aircraft to prove airworthiness and to demonstrate acceptable performance and functions.

2. SCOPE

2.1 Ø These recommendations are written to cover the testing of environmental control equipment, functioning as a complete and installed system in civil aircraft for the purpose of:

a. Demonstrating the safety of the installation and equipment.

b. Demonstrating proper functioning of the installation and equipment.

c. Demonstrating performance of the installation and equipment.

d. Obtaining data for future design and to aid in the analysis of in-service performance of the system and equipment.

2.2 The testing shall include but not be limited to the following areas related to the aircraft environmental control system:

a. Sources of heat
b. Sources of fresh air and/or ventilation
c. The refrigeration systems
d. The heat sinks
e. Distribution systems including ducting, joints, etc.
f. Water separation and anti-ice controls
g. Exhaust systems
h. Temperature control systems
i. Cabin and compartment pressurization systems including flow and pressure controls

3. GENERAL EQUIPMENT REQUIREMENTS

3.1 Suitable instrumentation should be installed to determine the weight flow of air, the temperature and temperature differentials, and the pressure drop to each of the major components of the environmental control system. The accuracy of instrumentation for temperature measurements between 0 and 100 F should be $\pm$ 1 F, temperatures above and below this, $\pm$ 3% of the scale of the instrument, pressure measurements accurate within $\pm$ 1% and flow measurements accurate within $\pm$ 5% unless specific requirements dictate tighter tolerances.

3.2 Ø Instrumentation should be provided to determine the temperature distribution from forward to rear and top to bottom of spaces occupied by passengers or crew personnel, cargo, accessory, and avionics compartments, and any other areas served by the environmental control system.

3.3 Provisions should be made for determining the concentration of hazardous gases and obnoxious odors in spaces occupied by passengers or crew and cargo or accessory compartments served by the environmental control system. If instrumentation or chemical analysis will not determine the concentration of obnoxious gases, then it should be determined on a comparative basis by at least three observers, i.e. none, faint but acceptable, intolerable, etc.

3.4 ∅ Equipment should be provided to determine the direction of airflow in each compartment listed in 3.2. In addition, this equipment shall be of a type to determine air velocities throughout each occupied compartment of the aircraft under typical flight conditions. If velocities are too low to be measured by instrumentation (less than approximately 15 FPM) they may be considered negligible.

3.5 Equipment should be provided to determine the moisture content of the ambient air (on the ground) and the air in the crew, passenger, cargo, and equipment compartments. Instrumentation accuracy shall be specified prior to conducting the tests.

3.6 Equipment should be provided to indicate the position of pertinent valves or actuators which are remotely installed and not available for visual observation during flight.

3.7 ∅ Final acceptance tests should be conducted with 100% of passenger accommodations and full crew accommodations occupied during cooling tests and with a maximum of 20% of the passenger accommodations and full crew accommodations occupied during heating tests. Furthermore, consideration should be given to the various cabin loading conditions such as might exist for first class and tourist arrangements, particularly when such arrangements call for compartmentation. Simulation of passenger loads may be made by the use of heaters and humidifiers. (Ref. ARP 85)

3.8 ∅ Suitable instrumentation should be installed to evaluate fault isolation equipment that is integrated into the design of the environmental control system. Acceptable performance of their required functions should be demonstrated.

3.9 ∅ Equipment should be provided to determine the acoustical noise levels in the crew and passenger areas during significant ground and flight operating conditions. The test airplane must be insulated per the production configuration and seats, furnishings, equipment etc., must be in place. In addition, measurements of environmental control noise sources should be made during ground modes at external locations relating to passenger loading, baggage handling, ground crew servicing, etc.

4. GENERAL OPERATIONAL REQUIREMENTS

4.1 Tests should be conducted to demonstrate safe and proper operation of the system and component parts during steady state and transient periods under the following conditions:

a. Ground Operation

b. Pressurized Flight

c. Unpressurized Flight

d. Controlled Rapid Decompression - Decompression of this type is a deliberate procedure usually resorted to, to prevent exposure to explosive decompression as the result of an initial hazard of compartment fire, mechanical failure or damage, etc. Such a test may or may not be a part of 4.2.

e. ∅ Abnormal Conditions - Simulate malfunctioning or inoperative equipment such as an engine, bleed air source system or refrigeration system.

4.2 Smoke or fumes removal procedures should be demonstrated to show that proposed methods of elimination are adequate to clear areas occupied by passengers or crew of hazardous concentrations of smoke or fumes within a safe period of time.

4.3 Final acceptance tests of the cooling system should be conducted during the daytime to determine the adequacy of the system with full sun effect and with maximum daylight electrical load within the fuselage applied. An area of high humidity is desirable.

4.4 Final acceptance tests on heating equipment should be conducted during night-time to eliminate the sun effect. Tests should be conducted with maximum and minimum electrical load applied within the aircraft cabin to determine the adequacy of the system under both conditions.

4.5 In the event ambient conditions representing the extreme heating and cooling requirements of the aircraft
Ø cannot be encountered, sufficient data should be obtained so that accurate extrapolations can be made. The moisture content of the ambient air should be determined and corrections made to the extrapolations.

5. APPLICABLE DOCUMENTS

The following SAE Documents should be complied with as pertains to the individual equipment items and sys-
Ø tems that go to make up the environmental control system as a whole where applicable:

ARP 85	Air Conditioning for Subsonic Airplanes
ARP 367	Airplane Cabin Pressurization
ARP 699	High Temperature Pneumatic Duct Systems for Aircraft
ARP 731	General Requirements for Application of Vapor Cycle Refrigeration Systems for Aircraft
AIR 746	Environmental Control for Civil Supersonic Transports
AIR 795	Air Conditioning of Aircraft at High Altitude
AIR 806	Air Conditioning Design Information for Cargo and High Density Passenger Transport Airplanes

6. INSTRUMENTATION

6.1 Air Flow Measurements:

6.1.1 Calibrated sections of duct in the normal ducting system should be used to determine the air flow in each component part of the environmental control system wherever appropriate.

6.1.2 Calibrated orifices or venturis may be used in ducting systems where added pressure drop does not affect distribution or restrict air flow.

6.1.3 In the event calibrated sections of duct or orifices cannot be used, the use of calibrated pitot-static tubes is permissible. Icing of instrument must be prevented to preclude erroneous data.

6.1.4 Pressures should be recorded simultaneously at regular intervals. A common reference pressure should be used for pressures recorded.

6.2 Temperature Measurements:

6.2.1 Air temperatures should be measured by use of thermocouples or equivalent. In addition to the air tem-
Ø peratures, surface temperature measurements should be made at significant locations of the walls, windows, ceiling, and floors in occupied and cargo areas.

6.2.2 Temperatures should be recorded at regular intervals. The frequency of recordings should permit a comprehensive study of the system characteristics under both transient and steady state conditions.

6.2.3 Thermocouples should be located in the bleed air control system, the cabin air conditioning system and in the cabin itself, including but not limited to the following significant locations:

a. Outside free air

b. Outside skin

c. Inlets and outlets of:

1. cabin air compressors
2. bleed air source components
3. heaters
4. heat exchangers
5. refrigeration units
6. fans
7. wall panels
8. window panels
9. electrical and electronic equipment
10. distribution and recirculation ducting

d. Head level (standing), shoulder level (sitting), floor level and floor surface at forward, center, and rear of passenger and crew compartments. An adequate number of points shall be measured to accurately determine the temperature gradients including spanwise distribution.

e. Air adjacent to temperature sensing element

f. Forward, center and rear at top and bottom of cargo and accessory compartments

g. Heated panel surface temperature at several points throughout the aircraft, if used

h. Inner surface temperature of cabin and cockpit windows

ø i. Compartment temperature behind instrument panels

j. Exposed hardware on armrests or wall panels that connect through to outer structure which may come in contact with exposed skin of passenger or crew.

6.3 Pressure Measurements:

6.3.1 Pressure taps should be located to minimize the effect of turbulence caused by valves, elbows, or orifices.

6.3.2 Pressure sensors should be located to determine at least the following pressure indications:

a. Cabin rate of pressure change

b. Cabin altitude and pressure differential

c. Airplane rate of climb or descent

d. Airplane altitude

e. Airplane indicated air speed

f. Inlet and outlet of cabin air compressors

g. Inlets and outlets of refrigeration units

h. Inlets and outlets of heaters and heat exchangers

i. Inlets and outlets of recirculating fans

j. Bleed air at source and at control valves

k. Ram air inlets and outlets

l. Duct pressure drop through appropriate branches of the system

m. At other points of appreciable pressure drop in the system.

6.4 Humidity Measurement: Humidity measurements should be taken within the cabin at regular intervals. Equipment for determining the humidity of the ambient air should be available for use on the ground during periods of operation of the refrigeration system.

6.5 Air Velocity Measurements:

6.5.1 Air velocities at significant locations in the passenger and crew compartments should be determined during pressurized and unpressurized flight as specified in ARP 85.

6.5.2 Air velocities across the cabin temperature control sensing elements and temperature indicating sensors should be determined during pressurized and unpressurized flight.

6.6 Rotative Equipment Speed: High speed rotating equipment should be instrumented with devices to measure
ø speed which should be recorded frequently to provide correlation with other system data.

6.7 Electrical Measurements: Input power characteristics to the air conditioning equipment should be mea-
ø sured and recorded at frequent periods so effects of switching and changes in load may be observed.

6.8 Dynamic Measurements: It may be desirable to locate accelerometers in critical areas where environ-
ø mental control equipment is installed to verify that maximum design loads have not been exceeded.

7. TEST PROCEDURES

7.1 Ground Tests:

7.1.1 Safety Tests:

7.1.1.1 Inspect the aircraft to determine that air entries and exits are so located that no normal drain of flammable or hazardous fluids can enter these openings during flight or on the ground. The inspection should take into account the influence of aerodynamic and gravitational forces on these fluids with the airplane in normal in-flight and ground attitudes. For the ground conditions, account shall be made for the influence of various ground winds combined with propeller or jet blast.

7.1.1.2 Connect the external power sources to the aircraft as required, and adjust the power to the nominal levels used by the aircraft systems.

7.1.1.3 Connect the external power sources to the aircraft as required and check functional operation of components. Turn on environmental control system and check for normal operation. Adjust system as required.

7.1.1.4 Establish ground operation of the system and accomplish the following tests:

7.1.1.4.1 For aircraft utilizing a D.C. system for primary electrical power, determine that no unsafe condition shall be created by low voltage conditions by decreasing the voltage to 50% of the normal aircraft system voltage or until all components of the system cease to operate. Follow by gradually increasing the voltage to the normal system voltage and determine that all components of the system safely resume operation.

7.1.1.4.2 For aircraft utilizing an A.C. system for primary electrical power, determine that no unsafe condition will be created by varying the voltage and frequency throughout the full range of control provided by the voltage and frequency control limits of the protective cutout components of the electrical power system. The test power supply may provide voltage variances; for example, ranging from 98 to 124 volts (RMS) and frequencies ranging from 380 to 420 cycles per second.

7.1.1.5 Simulate flight operation of the system and repeat the tests called for in 7.1.1.4.1 and 7.1.1.4.2.

7.1.1.6 If icing or snow blockage of the ram air inlets is a design safety consideration, with the system operat-
ø ing normally in the ground configuration, disconnect or deactivate the ram air cooling sources to determine that the overtemperature sensor and other protective devices prevent unsafe conditions from being created.

7.1.1.7 With the pressurization system operating, override the normal controls to cause the safety valves to operate. Determine that the safety controls function properly and that no hazardous condition exists.

7.1.1.8 Override the normal temperature controls and increase the supply air temperature beyond the set point of each overtemperature switch. Determine that no unsafe condition exists at the temperatures
ø encountered and that the overheat protection devices function properly. Check heater overtemperature devices by reducing air flow across the heater after deactivating normal temperature control.

7.1.2 Performance Tests:

7.1.2.1 Ground tests should be conducted on aircraft equipped with self-contained ground conditioning equipment to determine if specified temperatures and air flow rates have been met during both cooling and
ø heating conditions. This should include hot and cold soak conditions to demonstrate pull-down and pull-up capabilities. Avionics and electrical equipment should be operated to simulate normal usage.

7.1.2.2 Pressurized aircraft should be pressurized to design differential to determine if air flow and leakage requirements as specified in ARP 367 have been met. Pressure controls, flow controls and pressure relief valves should be checked to ascertain that the units are operating properly.

7.1.2.3 During unpressurized and pressurized conditions the air distribution should be observed and flow rates measured to determine proper balance of the system.

7.1.2.4 Temperatures, pressures, air velocities, etc., specified in Section 6 should be recorded.

7.1.2.5 The environmental control system should be tested to determine its performance in hot and cold weather while the aircraft is taxiing and waiting for clearance. Use passenger loads specified in 3.7. This test should be conducted both with full air conditioning capacity and with one or more air conditioning systems inoperative as permitted by aircraft operating limitations.

7.2 Flight Tests:

7.2.1 Safety Tests:

7.2.1.1 Pressurize the cabin to maximum differential pressure. Protect crew members and observers with suitable protective masks and discharge or manufacture sufficient smoke to fill the airplane cabin.
ø Carry out smoke removal procedures (previously established) and record time required to remove smoke from crew and passenger compartments. Repeat for passenger cabin only to determine that smoke does not enter crew compartment. Verify proper operation of the smoke detectors, if installed.

7.2.1.2 Unless depressurization of the cabin was required in 7.2.1.1, the cabin should be depressurized and the smoke removal procedure repeated under these conditions.

7.2.1.3 Tests should be conducted to determine that the cabin altitude will not exceed the specified limit when
ø various system failures occur. These tests may include failures requiring an emergency descent from the maximum certified flight altitude.

7.2.1.4 Test the negative cabin pressure relief provisions. With the aircraft flying at 25,000 to 30,000 ft, increase the cabin pressure altitude to 15,000 feet. With the cabin air supply shut off, descend the aircraft at the maximum rate allowable for an emergency condition to permit the ambient pressure to exceed the cabin pressure. Observe cabin pressure differential continuously during this maneuver so that the descent may be promptly terminated at a predetermined negative pressure differential in the event the negative relief provisions fail to operate. The predetermined negative differential should provide an adequate margin so the design negative differential will not be exceeded.

7.2.1.5 Test the capacity of the safety valves at a maximum rate of climb at low altitudes. To do this it will
ø be necessary to make the normal cabin pressure controls and one safety valve inoperative up to the relief valve settings.