



AEROSPACE RECOMMENDED PRACTICE

ARP217™

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Superseding ARP217C

Testing of Airplane Installed Environmental Control Systems (ECS)

RATIONALE

ARP217D has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

This document deals with ground and flight test of airplane installed Environmental Control Systems (ECS), Figure 1. The ECS provide an environment, controlled within specified operational limits of comfort and safety, for humans, animals, and equipment. These limits include the following: pressure, temperature, humidity, ventilation air velocity, ventilation rate, wall temperature, audible noise, vibration, and environment composition (ozone, contaminants, etc.). The ECS are composed of equipment, controls, and indicators that supply, distribute, recycle and exhaust air to maintain the desired environment.

1.1 Purpose:

This document defines recommended tests and test procedures for airplane installed ECS. The purpose of these tests is to:

- a. verify system pressure integrity (leakage),
- b. verify integration and compatibility of ECS with other airplane systems, and
- c. determine overall system performance in conditions representative of those which may be encountered during operations.

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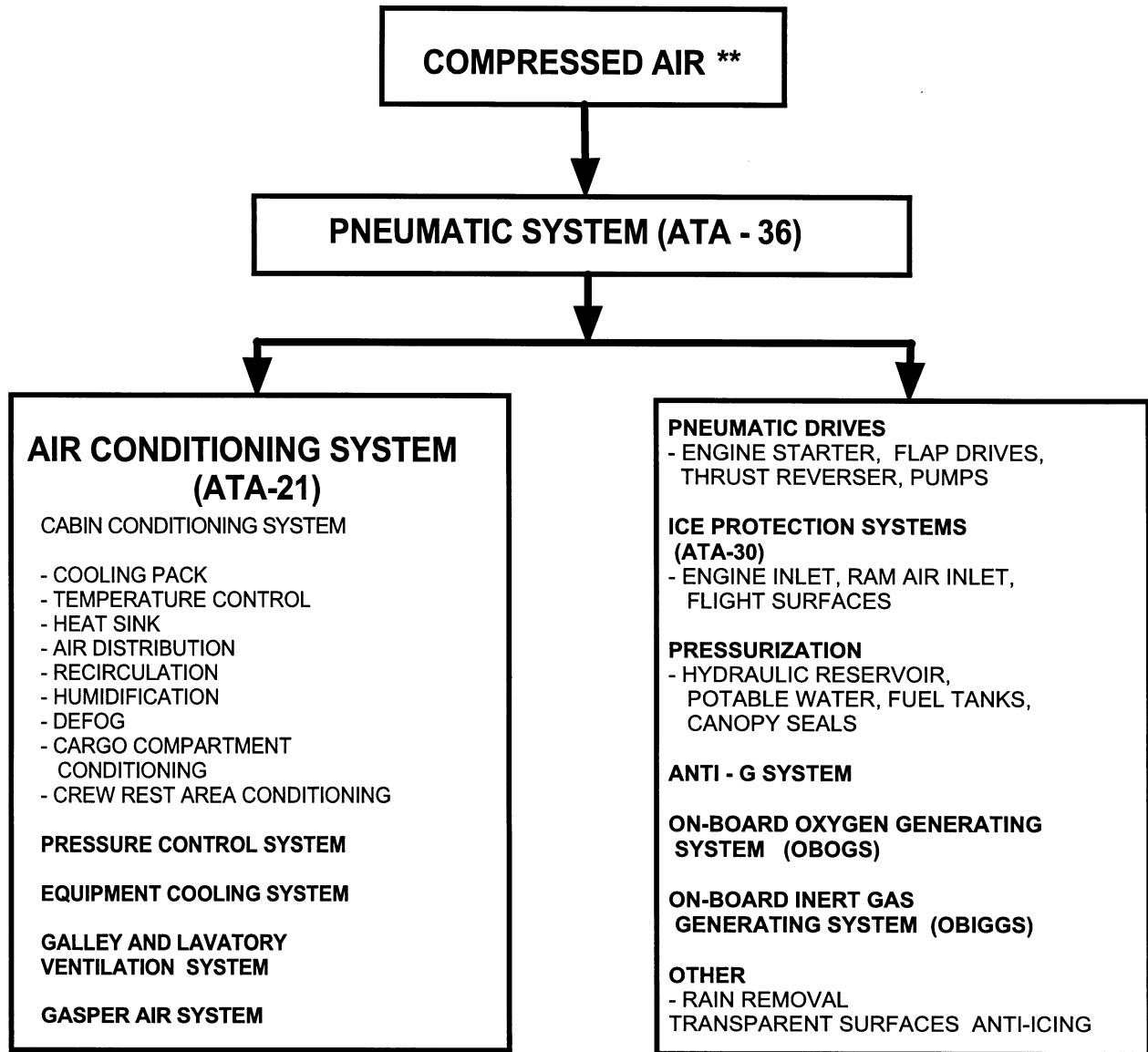
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** FROM ONE OR MORE OF THE FOLLOWING

- ENGINE COMPRESSOR
- ON -BOARD COMPRESSOR (ENGINE SHAFT OR ELECTRICALLY DRIVEN)
- AUXILIARY POWER UNIT (APU)
- GROUND EQUIPMENT

FIGURE 1 - Environmental Control Systems

1.2 Field of Application:

These tests (and procedures) may be used for commercial and military airplane certification (test of first article) or for production airplane (to ensure built as design) tests. The selection of the appropriate test conditions, instrumentation, and test procedures depends on a large number of variables (airplane configuration, system concept, hardware, integration with other on-board systems, certification or production airplane, etc.). Thus, these are addressed in general terms. This document is intended to serve as a guide in the planning and conduct of tests. The specification or contractual or regulatory (Federal Aviation Regulations (FAR), Joint Airworthiness Regulations (JAR)) requirements should be considered. The test plan and procedure should be coordinated with the appropriate agency.

Test data may be used to show compliance with the applicable airplane specification, contractual, or regulatory requirements and to verify analytical simulation models. If the former is intended, it is extremely important to obtain prior approval of the test plan and procedure from the appropriate agency.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and laws unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-001.

ARP1307	Measurement of Exterior Noise Produced by Airplane Auxiliary Power Units and Associated Equipment during Ground Operations
ARP1323	Type Measurement of Airplane Interior Sound Pressure Levels in Cruise
AIR806	Air Conditioning Design Information for Cargo and High Density Passenger Transport Planes
AIR1266	Fault Isolation in Environmental Control Systems of Commercial Transports
AIR1706	The Advanced Environmental Control Systems (AECS) Computer Program for Steady State Analysis and Preliminary System sizing
AIR1823	Transient ECS Computer Program
AIR1826	Airplane Environmental Systems Acoustical Design Considerations
ARP85	Air Conditioning Equipment, General requirements for Subsonic Airplanes
ARP89	Temperature Control Equipment, Automatic Airplane Compartment
ARP292	Air Conditioning, Helicopter, General requirements for
ARP699	High Temperature Pneumatic Duct Systems for Airplane

2.1.1 (Continued):

ARP731	General Requirements for Application of Vapor Cycle Refrigeration Systems for Airplane
ARP1270	Airplane Pressurization Control Criteria
ARP1796	Engine Bleed Air Systems for Airplane
ARP4073	Air Cycle Air Conditioning Systems for Military Air Vehicles

2.2 Other Applicable References:

AFGS 87145	General Design Specification Environmental Control, Airborne
MIL-D-8708	Demonstration Requirements for Airplanes
MIL-E-18927	Environmental Control Systems, Airplane, General Requirements for
MIL-T-18606	Test Procedures for Airplane Environmental Systems
STANAG 2895	Extreme Climate Conditions and Derived Conditions for Use in Defining Design/Test Criteria for NATO Forces

2.3 Acronyms:

ACM	Air Cycle Machine
AFB	Air Force Base
APU	Auxiliary Power Unit
ARP	Aerospace Recommended Practice
ATA	Air Transport Association
BITE	Built-In-Test Equipment
CFR	Code of Federal Regulations
DER	Designated Engineering Representatives
DMIR	Designated Manufacturing Inspection Representatives
ECS	Environmental Control Systems
EGT	Exhaust Gas Temperature
EICAS	Engine Indicating and Crew Alerting System
EPR	Engine Pressure Ratio
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
JAA	Joint Aviation Authorities
JAR	Joint Airworthiness Regulation
OBOGS	On-Board Oxygen Generating System
OBIGGS	On-Board Inert Gas Generating System
PRSOV	Pressure Regulating and Shut Off Valve
TAI	Thermal Anti-Ice

3. ENVIRONMENTAL CONTROL SYSTEMS:

The ECS typically consists of the following two major systems.

3.1 Pneumatic System (ATA 36):

The pneumatic system delivers compressed air from the source(s) to on-board services such as, the air-conditioning system packs; engine inlets, ram air inlets and flight surfaces anti-icing or de-icing systems; drives for thrust reverser, flaps, hydraulic pumps, and engine start motor; pressurization of hydraulic fluid reservoir, fuel tanks, and potable water; rain removal and anti-icing of transparencies; etc.

In military airplane, the system may also service the following systems.

- a. On-Board Oxygen Generating System (OBOGS) which extracts oxygen from the air for crew and passengers use;
- b. On-Board Inert Gas Generating System (OBIGGS) which extracts nitrogen from the air for fuel tank inerting;
- c. Canopy seals;
- d. Anti-G system that utilizes the pressure and flow of air to pressurize the anti-g suit. The suit on pressurization restricts the flow of blood to the lower extremities thus providing protection (loss of consciousness) against gravitational (Gz) forces.
- e. Radar pressurization system.

There are no restrictions on the use of pneumatic power for operating other systems. The above list identifies systems commonly serviced by the pneumatic system.

The typical air-sources of the pneumatic system are the propulsive engines, on-board compressors, on-board Auxiliary Power Unit (APU), and external ground air supply (ground air cart or terminal built-in-compressed air supply system). The system receives compressed air from the above sources, controls its routing, and delivers it to the using systems. Cross-bleed and isolation valves are included in the distribution manifold to maintain essential functions in the event of supply or using system failure. Check that pressure regulating and shut off valves are incorporated to ensure delivery of air within pressure limits to the using systems. Heat exchangers, temperature controllers and over-temperature shut-off features are added to control and/or limit supply air temperature. To ensure proper operation, monitoring of performance, and to facilitate trouble-shooting and maintenance, sensors and controllers are added as required. A typical pneumatic system is described in 4.4.

3.2 Air Conditioning System (ATA 21):

The air conditioning system consists of the following significant subsystems.

- a. The cabin (passenger and flight crew compartments) conditioning system controls and conditions cabin air supply (fresh and recirculated). It consists of the air conditioning pack(s) including heat sink(s), the cabin-air recirculation system components, and the air distribution and exhaust ducting. It interfaces with the pneumatic system at the flow control valve of the pack. Cabin temperature controllers and cabin temperature sensors are part of this system. A cabin-air humidification system may form a part of the cabin conditioning system. This system increases the relative humidity of selected compartments, such as flight deck, crew rest and passenger.
- b. The cabin pressure control system controls air flow overboard to maintain cabin altitude and altitude rates of change within designed limits. It consists of the pressure controller, selector, and valve(s) to control overboard discharge of cabin air to limit maximum and minimum cabin pressures. Safety valves (positive and negative pressure) are included to safeguard structure during failure or abnormal conditions.
- c. The equipment cooling system provides cooling air for the electrical or electronic equipment. In military airplane the system may also have liquid coolant loops for cooling high density avionics or dielectric coolant.
- d. The galley and lavatory ventilation systems provide for removal of odors.
- e. Defog system prevents fog formation on transparent surfaces; this provides improved visibility.
- f. Large transports may have a cargo compartment conditioning (or heating) system for the carriage of animals and perishable cargo.
- g. On long range airplanes, special areas may be reserved for crew rest and they may have air conditioning systems that can be independently controlled.
- h. Emergency ventilation (ram-air) system for cabin conditioning in the event of loss of all in-flow or for smoke evacuation.
- i. Heating provisions for areas such as galleys, doors, etc., that tend to get cold during flight.
- j. In military airplane air conditioning system may include special filters (or equipment) to protect the occupants from nuclear biological and chemical agents.

3.3 Applicable Regulations and Requirements:

The regulations and requirements applicable to ECS depend on the airplane category.

- 3.3.1 Civil Airplane: In the United States, the Federal Aviation Administration (FAA) of the Department of Transportation has jurisdiction to certify civil aircraft as safe. Other nations have similar agencies. Twenty-nine Authorities in Europe have formed Joint Aviation Authorities (JAA). JAA has developed Joint Aviation Requirements (JARs) in the field of design and manufacture, operations and maintenance of aircraft and in the field of personnel licensing. It ensures uniform implementation of JARs so that certificates, approvals, licenses, etc., granted by one of its full members can be accepted by the others. Its goal is to promote European Safety System world-wide.

Code of Federal Regulations (CFR), Title 14 Parts 23 and 25 contain FAA transport category airplane airworthiness standards. Part 23 deals with normal, utility, acrobatic and commuter category airplanes, and Part 25 deals with transport category airplanes. JAR-25 contains JAA airworthiness standards for large turbine airplanes and JAR-23 contains JAA airworthiness standards for normal, aerobatics, utility and commuter categories. This ARP deals primarily with Part 25 airplanes. However, the tests and procedures presented herein, with modifications due to differences in regulations, may be used for Part 23 airplanes. The FAR Part 25 and JAR Part 25 regulations relevant to ECS, for transport category airplanes, are as follows:

FAR or JAR Section

25.831	Ventilation
25.832	Cabin Ozone Concentration
25.833	Heating Systems
25.841	Pressurized Cabins
25.843	Tests for Pressurized Cabins
25.857	Cargo Compartment Classification
25.1301	Function and Installation
25.1309	Equipment, Systems, and Installations
25.1322	Warning, Caution, and Advisory lights
25.1438	Pressurization & Pneumatic Systems
25.1439	Protective Breathing Equipment
25.1461	Equipment containing high energy rotors

The above regulations specify minimum acceptable design requirements and performance standards. However, airplane designed to a manufacturer's proprietary airplane specification (model specification) may contain more demanding design or performance standards. It is suggested that the test engineer review the applicable documents prior to planning of tests and preparation of test procedures.

- 3.3.2 Military Airplane: Military airplane performance and test requirements are contained in the airplane specification and the referenced specifications. Military specifications commonly referenced are:

AFGS 87145	General Design Specification Environmental Control, Airborne
MIL-D-8708	Demonstration Requirements for Airplanes
MIL-E-18927	Environmental Control Systems, Airplane, General Requirements for
MIL-T-18606	Test Procedures for Airplane Environmental Systems
STANAG 2895	Extreme Climate Conditions and Derived Conditions for Use in Defining Design /Test Criteria for NATO Forces

A review of the airplane and its referenced specifications is suggested prior to the start of test plan development.

3.4 Test Planning and Coordination:

The planning and coordination depend on the intent of the test. The effort required for development and certification test (new airplanes) is significantly different from that required for production airplanes.

- 3.4.1 Development and Certification Airplanes: The intent of these tests is to (1) develop the ECS and (2) to demonstrate compliance to the applicable specification, contractual or certification requirements.

Airplane ground and flight tests require large resources. Significant savings can be achieved by planning and coordination with other disciplines (propulsion, performance, etc.). For example, resources can be shared by concurrent ground test of engine bleed-air system and engine nacelle cooling. Similar opportunities also exist in the conduct of flight tests. Such opportunities must be investigated.

In test planning, efforts should be made to conduct tests under controlled conditions (ambient temperature and pressure, flight Mach number and engine power conditions, heat load, etc.) representative of conditions in the specification. This facilitates compliance demonstration and validation of the analytical simulation model. A simulation model validated by test may then be used to estimate system performance at extreme environment conditions. The use of such an approach to show compliance with specification, contractual or certification requirements should be coordinated with the appropriate agency in advance.

In addition to performance tests, the test plans should make provisions to verify and evaluate other system attributes such as, indication and warning, protective devices, Built-In-Test Equipment (BITE), and selected failure modes that can only be verified by airplane tests. These tests assure integration and compatibility with on-board systems.

- 3.4.2 Production Airplanes: The intent of these tests is to verify that the systems have been properly installed and that they perform intended function. Some of these tests (pressure integrity or leakage) may be conducted in the factory and others during airplane check out during ground and flight operations. Coordination between various groups is thus essential.

3.5 Instrumentation:

In planning for instrumentation, the test purpose should be kept in mind as instrumentation of installed systems and acquisition of data is difficult. In addition to the installation bosses required for sensors to be actually installed in the test item, provisions should be made available for other sensors that may be required to debug failures or perform other tests. Removing sensors from one location and reinstalling them in another location for other tests can save investments.

- 3.5.1 Development and Certification Airplanes: To minimize instrumentation requirements should be a goal. However, if performance testing is to be performed in environments less stringent than those specified, and computer models are to be used to predict performance, additional instrumentation may be necessary to validate the computer model. To minimize instrumentation channels, use of airplane installed instruments and data buses should be considered. However, precaution must be taken to ensure such use does not compromise system performance or test data.

In planning for instrumentation, one should also consider the instrumentation requirements of the interface systems. Preparation of an instrumentation list, identifying sensor location, type, range, accuracy, sampling rate, recording method, etc., is suggested. The effect of each sensor failure on the success of the test should be evaluated and a list of critical sensors for the success of each test should be prepared. Time synchronized video cameras provide an effective method to record flight deck data.

If digital data acquisition equipment is used, the selected scanning rate should be compatible with the intent of the test. Provisions should be made on the airplane for real time scanning of items critical for safety.

The test ambient conditions, sensor range, and accuracy of instrumentation must be carefully evaluated to assure compatibility. All test limits should be adjusted to allow for instrumentation tolerance.

- 3.5.2 Production Airplane: Production airplane tests are verification tests conducted to ensure that the systems are properly installed and that they perform as intended. These tests are generally conducted using airplane installed instruments, special tooling (for leakage and pressurization), and portable instrumentation.