



# AEROSPACE INFORMATION REPORT

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Superseding AIR64B

(R) Electrical and Electronic Equipment Cooling  
in Commercial Transports

## RATIONALE

This document is being revised to update references and formatting to the latest style manual and includes other minor changes.

## FOREWORD

Commercial transport airplanes have become increasingly dependent on electronics for navigation, guidance, communication, and other airplanes subsystem control functions. The dissipation of heat from these items of electrical and electronic (E/E) equipment is a problem requiring coordinated effort by both the equipment supplier and the airframe manufacturer. The environment in which equipment is installed, the average and local temperatures within the equipment case, and the method of cooling employed have a distinct bearing on the design and reliability of the equipment.

There are two basic methods of cooling the E/E equipment:

- a. Passive cooling
- b. Active cooling

The passive method relies on free or natural convective cooling to the ambient air surrounding the equipment. The active cooling technique is, in most cases, forced-air convective cooling with the air being either drawn or forced through the equipment case or directed around it. Cold plate cooling using air or some other heat transport fluid is also a suitable design solution for certain active cooling problems.

The current practice is to allocate a small area within the pressurized shell of the airplane for installation of most of the avionic equipment. Being in the pressurized area, the equipment is normally subject to pressures which vary between a maximum (ground) pressure equivalent of -1000 feet (-305 m) and a minimum (flight) equivalent of 8000 feet (2438 m) altitude. Under abnormal flight conditions, such as depressurization on a passenger airplane or during a firefighting procedure on a freighter airplane, continuous operation at pressures equivalent to approximately 15000 feet (4573 m) or 25000 feet (7622 m), respectively, may occur. Considering worst-case transient conditions, such as explosive decompression, exposure may be to pressures approaching the maximum certified altitude of the airplane. This latter condition is, of course, of low probability and short duration such that thermal effects are not usually critical. Considering ground operation, the equipment can be exposed to the maximum certified altitude, which is frequently 14000 feet (4268 m).

For airplanes designed in the 1960s, the predominant cooling system was classified as either "downward draw-through" or "area-cooling" for racked equipment. "Area-cooling" does not force air through the equipment being cooled, but does provide a system to remove heat from the area of the equipment external to the equipment case. For flight deck controls and displays, cooling was generally by the "area-cooling" concept or had no direct cooling at all.

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For more information on this standard, visit  
<https://www.sae.org/standards/content/AIR64C>

Documents

Document Sharing Hub

The great increase in digital and compactly packaged equipment and the advent of modern flight deck displays resulted in a corresponding increase in equipment cost and a greater payback resulting from increasing component reliability. This focused attention on cooling and resulted in new ARINC specifications and in more attention to the interface between the airplane cooling system and the E/E equipment. As thermal management has become more important to the continued operation of E/E equipment, more emphasis has been placed on cooling system performance and reliability.

As new E/E equipment is developed, and where reliability sensitivity to temperature can be shown to be reduced, the requirements for cooling that particular equipment may be reduced.

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## 1. SCOPE

This document considers the cooling of equipment installed in equipment centers, which usually consist of rack-mounted equipment and panel mounted equipment in the flight deck. Instances where these two locations result in different requirements are identified. This document generally refers to the cooled equipment as E/E equipment, denoting that both electrical and electronic equipment is considered, or as an E/E equipment line-replaceable-unit (LRU). The majority of cooled equipment takes the form of LRUs. The primary focus of this document is E/E equipment which uses forced air cooling to keep the equipment within acceptable environmental limits. These limits ensure the equipment operates reliably and within acceptable tolerances. Cooling may be supplied internally or externally to the E/E equipment case. Some E/E equipment is cooled solely by natural convection, conduction, and radiation to the surrounding environment.

This document discusses specification requirements, system design considerations, component design, and system testing. It also discusses the analysis and test considerations for the thermal design of the avionic equipment. The discussion of supplementary cooling systems includes consideration of a refrigeration system.

This document just covers air cooling of equipment. AIR1811 should be consulted for information on liquid cooling of equipment.

Although this document is targeted at transport category airplanes, most of the material applies to other classes of aircraft with possible adaptations.

### 1.1 Purpose

The purpose of this document is to provide information and guidelines for the analysis, design, installation, and testing of E/E equipment cooling systems on commercial transport airplanes.

## 2. REFERENCES

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 regulations unless a specific exemption has been obtained.

### 2.1 Applicable Documents

#### 2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

|         |                                                                                        |
|---------|----------------------------------------------------------------------------------------|
| AIR1812 | Environmental Control Systems Life Cycle Cost                                          |
| ARP85   | Air Conditioning Systems in Subsonic Airplanes                                         |
| ARP731  | General Requirements for Application of Vapor Cycle Refrigeration Systems for Aircraft |
| ARP987  | The Control of Excess Humidity in Avionics Cooling                                     |

#### 2.1.2 ARINC IA Publications

Available from SAE ITC, ARINC Industry Activities, 16701 Melford Blvd, Suite 120, Bowie, MD 20715, Tel: +1 240-334-2578, <https://www.aviation-ia.com/>.

|              |                                             |
|--------------|---------------------------------------------|
| ARINC 404A   | Air Transport Equipment Cases and Racking   |
| ARINC 408A   | Air Transport Indicator Cases and Mounting  |
| ARINC 600-20 | Air Transport Avionics Equipment Interfaces |

ARINC 601 Control/Display Interfaces

ARINC 728 Avionics Refrigeration Cooling System

#### 2.1.3 ASHRAE Publications

Available from ASHRAE Headquarters, 1791 Tullie Circle, NE, Atlanta GA 30329, Tel: 800-527-4723 (U.S. and Canada only) or 404-636-8400, [www.ashrae.org](http://www.ashrae.org).

Standard 52.2 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

#### 2.1.4 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany (for visitors and for mail over 1 kg) and Postfach 10 12 53, D-50452 Cologne, Germany (for mail 1 kg or less); Tel: +49 221 8999 000, [www.easa.europa.eu](http://www.easa.europa.eu).

AMC 25.1309 System Design and Analysis

CS-25 Certification Specifications for Large Aeroplanes

#### 2.1.5 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, [www.faa.gov](http://www.faa.gov).

14 CFR Part 25 Airworthiness Standards: Transport Category Airplanes

AC 25.1309-1A System Design and Analysis

#### 2.1.6 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, [www.rtca.org](http://www.rtca.org).

DO-160 Environmental Conditions and Test Procedures for Airborne Equipment

### 2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

#### 2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

AIR1277 Cooling of Military Electronic Equipment

## 3. REQUIREMENTS

### 3.1 Government Requirements

Primary Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA) requirements are given in Title 14 Code of Federal Regulations (CFR)/Certification Standard (CS) 25.1301 and 25.1309. 14 CFR/CS 25.1301 states that the system shall accomplish its intended function. 14 CFR/CS 25.1309 requires that the system shall perform its function under any foreseeable operating condition, within the airplane operating envelope. AC/AMC 25.1309 clarifies the method of applying 14 CFR/CS 25.1309.

Further discussion of civil certification requirements is provided in Section 9.

## 3.2 ARINC Specifications

### 3.2.1 Rack Mounted Equipment

Aeronautical Radio Inc. (ARINC) specifications for rack mounted equipment are contained in ARINC 404A and ARINC 600. Included in these specifications is a complete design guide for the equipment manufacturer and for the airframe manufacturer. ARINC 404A is not superseded by ARINC 600, but is supplemented by it. In terms of cooling, a major difference is that ARINC 600 specifies that forced air cooling, where required, should be through the cooled equipment in the upward direction. ARINC 404A specifies a downward flow. The ARINC 600 Phase 1 LRUs should also operate in an ARINC 404A airplane cooling system in order to allow new LRUs to be used on airplanes with ARINC 404A cooling.

There is also a series of ARINC 700 specifications which define avionic systems. These systems then interface with ARINC 600 for cooling and installation. Similarly, there is a series of ARINC 500 LRU specifications that interface with ARINC 404A cooling.

### 3.2.2 Controls and Displays

ARINC cooling specifications for controls and displays are contained in ARINC 408A and ARINC 601. Included in these specifications is a complete design guide for the equipment manufacturer and for the airframe manufacturer. ARINC 601 provides guidance for the cooling of panel mounted cathode ray tube displays (CRTs), controls and displays, and glareshield mounted equipment.

The ARINC 700 series specifications (discussed in 3.2.1) include controls and displays.

## 3.3 Other Requirements

Other requirements include airplane imposed design, installed performance, testing, and installation requirements. The ambient temperature and altitude (ground and flight) operating envelopes of the airplane are important items in these requirements. These are determined by a combination of airplane model, airline, and special requirements by the manufacturer of the cooled equipment. In order to ensure a clear relationship between the equipment design and the installed environment, the airframe manufacturer should document testing, environment, performance, and interface/mounting requirements. Installation requirements relate to airplane operating characteristics and procedures and to system reliability and maintainability.

With careful consideration of the installation environment, the manufacturer of the equipment should use all available reliability data to determine what minimum amount of cooling is required.

Cooling system capacity should include an allowance for probable future increases in the amount of equipment requiring cooling.

## 4. SYSTEM DESIGN CONSIDERATIONS

### 4.1 Cooling System Performance

Cooling system performance is ultimately defined by the ability to efficiently maintain an acceptable thermal environment for the E/E cooled equipment for both normal conditions and abnormal conditions. Specifically, the performance is measured against the cooling airflow rate requirements at an acceptable temperature. The minimum acceptable cooling performance should be identified.

Of primary importance is the determination of a realistic heat load for the cooled equipment for both ground and flight operating conditions. This is further discussed in 4.7.

In obtaining the required performance it should be an objective to minimize fan power requirements. Since airflow rate is established by the heat load and the appropriate ARINC specification, this can only be accomplished by minimizing fan air pressure requirements. System pressure losses and, therefore, velocities, are critical to sizing the fan. Air velocities of 2000 to 3000 ft/min (10.2 to 15.2 m/s) are considered desirable, especially in the equipment racking. However, when these velocities are exceeded (in long straight ducts, for instance), noise considerations should be observed (see 4.10).

## 4.2 Cooling System Integration

### 4.2.1 General

The system for providing cooling to E/E equipment must be integrated with other environmental control systems (such as cabin air conditioning) with regard to cooling air temperature, flow rate, and moisture management.

The maximum allowable cooling air supply or environmental temperatures for E/E equipment are usually higher than those for crew and passenger comfort. Consequently, the serial use of conditioned air, first for human comfort then for equipment cooling, should be considered to minimize the conditioned airflow requirements.

The E/E thermal design engineer should consider the integration of the airplane cooling system with the equipment installation and internal thermal design. This is especially critical for rack mounted equipment where the rack forms a critical element of the airplane cooling system and where numerous items of equipment designed by various manufacturers are required to meet with a specific airplane cooling design concept.

### 4.2.2 Rack Mounted Equipment

Rack mounted equipment normally consist of LRUs installed on a system of shelves grouped in a centralized location in the airplane. Because of the compact arrangement, which is usually employed, it is common for a rack mounted LRU to have other LRUs above, below, and to the left and right of it.

There are normally interfaces between the cabin air conditioning system and the rack mounted equipment cooling system at both rack air inlet and air exhaust locations. At the air inlet location, the operation of the cabin air conditioning system may significantly affect the temperature of the equipment cooling air. At the air exhaust location, heat being removed from the rack mounted equipment may impact the cabin air conditioning system.

The described interface arrangement would be different for a closed loop cooling system. This is further discussed in 4.3.

The air conditioning system distributes conditioned air to the various airplane zones. There may be little benefit in using air directly from the air conditioning packs for the rack cooling system. This is not recommended. However, it could be considered, provided special attention is given to moisture control.

With the heat produced from E/E equipment, there is the potential of using the discharge air to heat areas such as cargo compartments. In this situation, care should be taken to evaluate heating capability. The heat available will be less than rated equipment heat load. A range of 50 to 70% of rated heat load is considered realistic, unless an overall heat load duty cycle is defined (see 4.7.1). Airplane test experience for similar configurations should be used to define the value to be used.

The airflow rate, inlet temperature to the rack, and allowable pressure drop through the rack and E/E equipment LRUs are key cooling interface parameters which should be coordinated with the rack and LRU designers and ultimately specified in an interface control drawing. Figure 1 is a sketch of the interface of the forced convection cooling air to an avionic rack. The air enters the rack, is ducted between the walls of the rack, and is distributed by a shelf duct which supplies air to each individual LRU. The air exits the LRU through exit holes in the top of the unit and, subsequently, enters the exhaust air return duct.

Several aspects of the rack design impact the airplane cooling system requirements and the overall effectiveness of E/E cooling. The rack pressure loss should be the minimum value consistent with weight, noises, and air distribution considerations. Sufficient pressure drop should be allowed to distribute the air among the various shelves and items of equipment and to effectively collect the spent air exhausting from the units for ARINC 600 designs. Insufficient pressure drop across the exhaust flow control orifices will result in "short circuits" with no air being exhausted from portions of the rack.