



Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences



Memo

AERO_M_SAE_on_Cabin_Air_14-04-09.pdf

<https://doi.org/10.48441/4427.2647>

Date: 2014-04-09

Liana Urseanu, Dieter Scholz

Aircraft Design and Systems Group (AERO)

Department of Automotive and Aeronautical Engineering

Hamburg University of Applied Sciences

Berliner Tor 9, 20099 Hamburg

Statements in SAE Standards Related to Cabin Air Quality

Contents

1	Introduction.....	2
2	Collected Statements.....	6
2.1	SAE AIR 1168-7: Aerospace Pressurization System Design.....	6
2.2	SAE ARP 1796: Engine Bleed Air Systems for Aircraft	6
2.3	SAE ARP 85E: Air Conditioning Systems for Subsonic Airplanes	7
2.4	SAE AIR 806A: Air Conditioning of Aircraft Cargo	7
2.5	SAE ARP 217B: Testing of Commercial Airplane Environmental Control Systems	7
2.6	SAE AIR 1116: Fluid Properties	8
3	Summary and Conclusions	9
Appendix A	Important Content from New SAE Standards	10

1 Introduction

SAE International (<http://www.sae.org>) is "The Engineering Society for Advancing Mobility – Land, Sea, Air, and Space". It maintains a set of standards related to Aircraft Bleed Air and Environmental Control Systems (Table 1). Responsible for the work is the Aircraft Environmental Systems Committee (AC-9). For some of these standards work is in progress (WIP). See Table 2 for details. Further standards, which are not part of AC-9, but nevertheless of interest, are given in Table 3. This Memo summarizes important statements from these SAE standards related to cabin air quality.

Table 1 SAE Standards by the Aircraft Environmental Systems Committee (AC-9) (<https://standardsworks.sae.org/standards-committees/ac-9-aircraft-environmental-systems-committee>). Highlighted are the standards related to cabin air quality that are addressed here in this Memo.

Document	Title	Date	Status
AIR1102B	Transparent Area Washing Systems for Aircraft	Aug 10, 2011	Stabilized
AIR1103	Introduction to Pressure Suite Assemblies	Sep 01, 1980	Canceled
AIR1168/1	Thermodynamics of Incompressible and Compressible Fluid Flow	Jun 20, 2011	Reaffirmed
AIR1168/10 *	Thermophysical Characteristics of Working Fluids and Heat Transfer Fluids	Jun 21, 2011	Reaffirmed
AIR1168/11A	Spacecraft Boost and Entry Heat Transfer	Jul 25, 2011	Stabilized
AIR1168/12A	Spacecraft Thermal Balance	Jul 25, 2011	Stabilized
AIR1168/13A	Spacecraft Equipment Environmental Control	Jul 25, 2011	Stabilized
AIR1168/14A	Spacecraft Life Support Systems	Okt 15, 2012	Stabilized
AIR1168/2A	Heat and Mass Transfer and Air-Water Mixtures	Jul 25, 2011	Stabilized
AIR1168/3 *	Aerothermodynamic Systems Engineering and Design	Jun 20, 2011	Reaffirmed
AIR1168/5A	Aerothermodynamic Test Instrumentation and Measurement	Jul 25, 2011	Stabilized
AIR1168/6A	Aircraft Fuel Weight Penalty Due to Air Conditioning	Jul 25, 2011	Stabilized
AIR1168/7A	Aerospace Pressurization System Design	Jul 25, 2011	Stabilized
AIR1168/8A	Aircraft Fuel Weight Penalty Due to Air Conditioning	Jul 25, 2011	Stabilized
AIR1168/9A	Thermophysical Properties of the Natural Environment, Gases, Liquids, and Solids	Jul 25, 2011	Stabilized
AIR1204A	Control of Water Carryover from the Environmental Control System and Condensation on the Structure	Jun 05, 2009	Revised
AIR1266A	Fault Isolation in Environmental Controls Systems of Commercial Transports	Jun 20, 2011	Reaffirmed
AIR1277B	Cooling of Military Avionic Equipment	Mai 03, 2010	Reaffirmed
AIR1539B	Environmental Control System Contamination	Jul 12, 2012	Reaffirmed
AIR1600A *	Animal Environment in Cargo Compartments	Jun 21, 2011	Reaffirmed
AIR1609A	Aircraft Humidification	Mai 27, 2010	Reaffirmed

AIR1706C	The Advanced Environmental Control System (AECS) Computer Program for Steady State Analysis and Preliminary System Sizing	Jan 08, 2010	Canceled
AIR1811A	Liquid Cooling Systems	Jan 20, 2010	Reaffirmed
AIR1812A	Environmental Control Systems Life Cycle Cost	Jan 20, 2010	Reaffirmed
AIR1823B	Engineering Analysis System (EASY) Computer Program for Dynamic Analysis of Aircraft ECS	Mai 25, 2011	Canceled
AIR1826 *	Acoustical Considerations for Aircraft Environmental Control System Design	Jan 14, 2011	Reaffirmed
AIR1957 *	Heat Sinks for Airborne Vehicles	Jul 12, 2012	Reaffirmed
AIR25	Airplane Air Conditioning Engineering Data: Thermodynamics	Mai 01, 1990	Canceled
AIR4362 *	NBC Protection Considerations for ECS Design	Aug 19, 2008	Issued
AIR4766	Air Quality for Commercial Aircraft Cabins	Jul 12, 2012	Reaffirmed
AIR4766/1	Air Quality for Commercial Aircraft Cabin Particulate Contaminants	Jan 06, 2011	Reaffirmed
AIR4766/2	Airborne Chemicals in Aircraft Cabins	Jan 06, 2011	Reaffirmed
AIR5661	Compartment Venting Analysis	Feb 12, 2010	Issued
AIR6	Oil Dilution and Cold Starting of Aircraft Engines	Dez 01, 1996	Canceled
AIR64B *	Electrical and Electronic Equipment Cooling in Commercial Transports	Jan 20, 2010	Reaffirmed
AIR728A	Electronic Equipment Cooling Design Concepts for High Mach Number Aircraft	Mrz 01, 1984	Canceled
AIR732	Heat Transfer Problems Associated With Aerospace Vehicles	Apr 01, 1978	Canceled
AIR746C	Environmental Control for Civil Supersonic Transport	Aug 10, 2011	Stabilized
AIR795A	Air Conditioning of Subsonic Aircraft At High Altitude	Mrz 01, 1984	Canceled
AIR805C	Jet Blast Windshield Rain Removal Systems for Commercial Transport Aircraft	Aug 19, 2011	Revised
AIR806B	Air Conditioning of Aircraft Cargo	Jan 17, 2011	Reaffirmed
AIR860B	Aircraft Electrical Heating Systems	Okt 17, 2011	Stabilized
AIR910C	Ozone in High Altitude Aircraft	Okt 17, 2011	Stabilized
ARP1270B	Aircraft Cabin Pressurization Criteria	Mai 11, 2010	Revised
ARP147E	Environmental Control Systems Terminology	Jul 12, 2012	Reaffirmed
ARP1623A	Guide for Preparing An Ecs Computer Program UserS Manual	Mrz 01, 1992	Canceled
ARP1796A *	Engine Bleed Air Systems for Aircraft	Mrz 22, 2007	Revised
ARP217D	Testing of Airplane Installed Environmental Control Systems (ECS)	Jun 21, 2011	Reaffirmed
ARP266A	Installation, Heaters, Airplane, Internal Combustion Heater Exchange Type	Apr 01, 2001	Canceled
ARP292C	Environmental Control Systems for Helicopters	Nov 06, 2008	Reaffirmed
ARP367C	Airplane Cabin Pressurization	Mrz 01, 1984	Canceled

ARP4014 *	Aircraft Turbine Engine Pneumatic Component Contaminated Air Endurance Test	Dez 06, 2012	Reaffirmed
ARP699E	High Temperature Pneumatic Duct Systems for Aircraft	Jun 20, 2011	Reaffirmed
ARP731C	General Requirements for Application of Vapor Cycle Refrigeration Systems for Aircraft	Jan 20, 2010	Reaffirmed
ARP735A	Aerospace Vehicle Cryogenic Duct System	Aug 10, 2011	Stabilized
ARP780B	Environmental Systems Schematic Symbols	Jan 20, 2010	Reaffirmed
ARP85F	Air Conditioning Systems for Subsonic Airplanes	Okt 09, 2012	Revised
ARP86C	Heater, Airplane, Engine Exhaust Gas to Air Heat Exchanger Type	Aug 10, 2011	Stabilized
ARP89D	Aircraft Compartment Automatic Temperature Control Systems	Jul 12, 2012	Reaffirmed
ARP986C *	Guide for Qualification Testing of Aircraft Air Valves	Nov 06, 2008	Reaffirmed
ARP987B	The Control of Excess Humidity in Avionics Cooling	Jun 17, 2010	Revised
AS143C	Heaters, Aircraft, Internal Combustion Heat Exchanger Type	Dez 01, 1992	Canceled
AS4073A	Air Cycle Air Conditioning Systems for Military Air Vehicles	Aug 06, 2013	Revised
AS5379A	Valves, Safety, Cabin Air, General Specification For	Apr 26, 2011	Canceled
AS6144A	Sound and Thermal Insulation for Aircraft, General Specification for the Installation Of	Okt 17, 2011	Stabilized
AS8040B	Heater, Aircraft Internal Combustion Heat Exchanger Type	Feb 14, 2013	Revised

* Considered in this Memo.
Work in Progress (WIP), i.e. Standard under revision. See Table 2 for details.

Table 2 SAE Standards by the Aircraft Environmental Systems Committee (AC-9) related to cabin air quality with “Work In Progress” (WIP) status at time of publication of the Memo.

Project	Title	Sponsor	Date
AIR1168/10A	Thermophysical Characteristics of Working Fluids and Heat Transfer Fluids	Gary Barker	Oct 02, 2012
AIR1168/3A	Aerothermodynamic Systems Engineering and Design	James McNamara	Jul 01, 2013
AIR1600B	Animal Environment in Cargo Compartments	Ahmet Kayihan Kiryaman	Oct 06, 2010
AIR1826A	Acoustical Considerations for Aircraft Environmental Control System Design	Mario Roma	Dec 17, 2009
AIR1957A	Heat Sinks for Airborne Vehicles	Jones Muller	Jul 07, 2010
AIR4362A	NBC Protection Considerations for ECS Design	James McNamara	Mar 14, 2014
AIR5744	Aircraft Thermal Management System Engineering	Gino Balducci	Oct 26, 2007
AIR64C	Electrical and Electronic Equipment Cooling in Commercial Transports	Steven Raine Warwick	Nov 12, 2009
ARP1796B	Engine Bleed Air Systems for Aircraft	Michel A. Jonqueres	Apr 24, 2012
ARP4014A	Aircraft Turbine Engine Pneumatic Component Contaminated Air Endurance Test	Paul McMurtry	May 13, 2010
ARP5743	Aircraft Galley Refrigeration Equipment Installation and Integration Recommendations	Vandaud Imani-Boorkhili	Sep 11, 2007
ARP6035	Discussion of the pressurization comfort criteria during transient and adequate instrumentation for flight tests	Clenilson Jordao Goncalves	Mar 16, 2009
ARP986D	Guide for Qualification Testing of Aircraft Air Valves	Gary Barker	Oct 13, 2008
AS6263	Bleed Air Contamination Limits for Safety, Health, and Comfort of Aircraft Occupants	Richard B. Fox	Aug 15, 2012

Table 3 Other SAE Standards related to cabin air quality.

Document	Title	Date
AIR1116B	Fluid Properties	June 18, 2013
AIR5784	A Review of Literatur on the Relationship between Gas Turbine Engine Lubricants and Cabin Air Quality	March 2002
AS5780	Specification for Aero and Aero-Derived Gas Turbine Engine Lubricants	2005
ARP4418A	Procedure for Sampling and Measurement of Engine and APU Generated Contaminants in Bleed Air Supplies from Aircraft Engines	2008

2 Collected Statements

This section copies all statements from SAE standards that can be related to the topic of cabin air quality. The statements have been retrieved from standards in an edition 20 years old (Table 4). Pending is still the work to compare these statements with how they appear in the same standards today after several revisions.

2.1 SAE AIR 1168-7: Aerospace Pressurization System Design

2.1 Cabin Air Supply ...

The major factors influencing the selection of the cabin air sources are: ...

2. Risk of oil contamination, which can occur in using compressor bleed air from the main engines

2.1.1.1 Direct Bleed

Compressor bleed from turbine engines is attractive because of the mechanical simplicity of the system and the reliability of the source. Fuel consumption penalties due to bleeding the engines tend to be greater than those incurred when power is extracted from the engine accessory drive pad. This is because the energy contained in the engine compressor air is at a higher level than is required for the cabin, and because at rated thrust levels the effect of bleed on engine turbine inlet temperature is disproportionately higher than the energy extracted. In high performance fighters, the bleed quantity is usually small and the bleed penalty is low. Thus the bleed system may be preferred to other systems if the air is known to be sufficiently free of lubricating oil.

Turboprop transport bleed requirements are relatively high and the engine air flow low, resulting in significant fuel consumption penalties. Popular opinion regarding the risk of obtaining contaminated air from the engine may preclude its use for transport aircraft, regardless of other reasons.

2.2 SAE ARP 1796: Engine Bleed Air Systems for Aircraft

4.11 Bleed Air Quality: Requirements should be imposed on the engine manufacturer regarding the quality of the bleed air supplied to occupied compartments. Recommendations are as follows:

Under normal operating conditions, the engine bleed air shall be free of engine-generated objectional odors, irritants, and/or toxic or incapacitating foreign materials, and shall comply with References 14 and 15.

Following any type of engine or engine component failure, the engine bleed air shall not contain the above substances to a harmful degree.

The engine bleed air ports shall be designed to minimize the amount of solid particles in the bleed air, whether these particles are contributed by engine operation or are contained in the air entering the engine inlet. The engine bleed air shall be sufficiently free of solid particle contamination that bleed air system or other using-system equipment service life will not be significantly degraded. To achieve this cleanliness, the engine bleed port configuration shall incorporate design features that provide efficient particle separation, or bleed air systems should incorporate a bleed air cleaner. Refer to AIR 1539 (reference 16) for more detailed information.

Ref. 14: Code of Federal Regulation, Title 29, Part 1910 Occupational Safety and Health Standards, Section 1910.93 Air Contaminants.

Ref. 15: Air Force Office of Safety and Health (AFOSH) Standard 161-8 Permissible Exposure Limits for Chemical Substances.

Ref. 16: Society of Automotive Engineers, Aerospace Information Report, AIR 1539 Environmental Control System Contamination.

2.3 SAE ARP 85E: Air Conditioning Systems for Subsonic Airplanes

3.3.1.b: Noxious or toxic substances should be prevented from entering the cabin or flight deck either through the primary air conditioning system or the recirculation system. Special attention should be given to hydraulic fluids and lubricants.

5.2.2.d: Bearings: Air cycle machines typically use precision angular contact ball bearings or air bearings. In either case, the bearing system should be self-contained, requiring no external oil supply or external pressurizing air source. Oil sumps should have provisions to facilitate the in-place checking and replenishment of the oil. The air cycle machine design should minimize the possibility of moisture entering or condensing in the lubrication system.

2.4 SAE AIR 806A: Air Conditioning of Aircraft Cargo

5.8 Flight and Passenger Compartment Contamination: Means shall be provided to prevent hazardous quantities of contaminants, fumes or gases from entering the flight crew or passenger compartments. Of special concern are potential contamination sources such as dry ice, chemicals and radioactive materials. ... Precautions should be taken to preclude the direct passage of any contaminate into the flight station or passenger compartment.

2.5 SAE ARP 217B: Testing of Commercial Airplane Environmental Control Systems

4. General Operational Requirements

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.

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.

7.2.2 Performance Tests

7.2.2.1 Pressurized Flight

7.2.2.1.11: During the entire flight the cabin should be observed to detect noticeable odors or smoke accumulations. Correlate observations both with and without galley operation.

2.6 SAE AIR 1116: Fluid Properties

2.3.9 Toxicity

Toxicity is indicated by the tendency of a fluid or its vapors to cause external irritation or have undesirable effects when inhaled or ingested. Determining the complete scope of the toxicity of a fluid requires extensive, costly, and time-consuming tests with several species of animals. Chemical relation to materials of known toxicological behavior provides a helpful indication. The following are some of the conditions involved in study:

- (1) Epidermal application
 - (a) Effect of a single large dose
 - (b) Effect of repeated dosage
- (2) Oral Ingestion
- (3) Eye irritation
- (4) Subcutaneous injection
- (5) Exposure to mist
- (6) Exposure to vapor
- (7) Periodic tests of blood and urine
- (8) Pathological effects

Until adequate toxicity data are available precautions must be observed in handling any unfamiliar fluid.

Table 4 Comparison of SAE Standards used in this study and in effect at time of publication of the Memo.

Aerospace Pressurization System Design			
Used:	AIR 1168/7	Issued	1991
Today:	AIR 1168/7A	Stabilized	2011
Air Conditioning of Aircraft Cargo			
Used:	AIR 806A	Reaffirmed	1992
Today:	AIR 806B	Reaffirmed	2011
Engine Bleed Air Systems for Aircraft			
Used:	APR 1796	Issued	1987
Today:	APR 1796A	Revised	2007
WIP:	APR 1796B	since	2012
Testing of Airplane Installed Environmental Control Systems (ECS)			
Used:	ARP 217B	Revised	1973
(Original title: "Testing of Commercial Airplane Environmental Control Systems")			
Today:	ARP 217D	Reaffirmed	2011
Air Conditioning Systems for Subsonic Airplanes			
Used:	ARP 85E	Revised	1991
Today:	ARP 85F	Revised	2012
Fluid Properties			
Used:	AIR 1116	Reaffirmed	1992
Today:	AIR 1116B	Stabilized	2013

3 Summary and Conclusions

The standards are very clear about the potential hazards when taking bleed air from the engine compressor and using it for cabin and flight deck environmental control.

These are probably the most profound statements:

“Compressor bleed from turbine engines is attractive because of the mechanical simplicity of the system.” However, “oil contamination ... can occur in using compressor bleed air from the main engines.” **“Popular opinion regarding the risk of obtaining contaminated air from the engine may preclude its use for transport aircraft, regardless of other reasons.”** (SAE AIR 1168-7)

“Requirements should be imposed on the engine manufacturer regarding the quality of the bleed air supplied to occupied compartments. Recommendations are as follows: Under normal operating conditions, the engine bleed air shall be free of engine-generated objectional odors, irritants, and/or toxic or incapacitating foreign materials” (SAE ARP 1796)

“Noxious or toxic substances should be prevented from entering the cabin or flight deck either through the primary air conditioning system or the recirculation system. **Special attention should be given to hydraulic fluids and lubricants.**” (SAE ARP 85E)

“Until adequate toxicity data are available precautions must be observed in handling any unfamiliar fluid.” (SAE AIR 1116)

This means:

- It is not the task of passengers and crew to prove that engine oils and hydraulic fluids as used today are dangerous. Just on the contrary, industry has to prove that fluids are safe before they intend to use them.
- There may be a tendency that aircraft manufacturer, engine manufacturer, oil manufacturer and manufacturer of ECS components declare – each by themselves –not being responsible, but only the other one is. Following SAE 1796, the engine manufacturer is responsible regarding the quality of the bleed air supplied. This seems logical, because only the engine manufacturer knows the details of engine lubrication and sealing and the potential quality of the bleed air. The aircraft manufacturer, however, should consider using other sources than bleed air, as it is known that the use of bleed air from the engine carries the “risk of obtaining contaminated air” (SAE AIR 1168-7).
- It may not be necessary to invoke new standards on the topic of cabin air quality, but rather to take the old standards serious, to enforce and to apply them.

Appendix A

Important Content from New SAE Standards

SAE ARP 217D: Testing of Airplane Installed Environmental Control Systems (ECS)

The ARP has a new structure. It is essentially a new text when comparing with SAE ARP 217B. Text with relevance to cabin air quality is:

The pneumatic system may include other functions such as, ozone converter to dissociate ambient ozone and / or air filters to remove particulate matter.

4.5.1.3

...

Air quality tests are generally not performed on installed systems. Air samples from the engine bleed-air and APU bleed-air are taken and analyzed for engine ingested and engine generated contaminants. Generally, the allowable limit for the contaminants is specified in the engine procurement specification and bleed-air quality testing forms a part of the engine qualification program.