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Aero

# Memo (DRAFT)

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# Statements in SAE Standards Related to Cabin Air Quality

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# 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 not part of AC-9, but nevertheless of interest, are given in Table 3. This Memo summarizes statements that can be related to cabin air quality in these SAE standards.

**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 Avoinic 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 |

* Work in Progress (WIP), i.e. Standard under revision. See Table 2 for details.
Considered in this Draft version of this Memo.
To be considered also in the final version of this Memo.

**Table 2** SAE Standards by the Aircraft Environmental Systems Committee (AC-9) related to cabin air quality with "Work In Progress" (WIP) status.

| Project | Title | Sponsor | Date |
|---|---|---|---|
| AIR1168/10A | Thermophysical Characteristics of Working Fluids and Heat Transfer Fluids | Gary Barker | Okt 02, 2012 |
| AIR1168/3A | Aerothermodynamic Systems Engineering and Design | James McNamara | Jul 01, 2013 |
| AIR1600B | Animal Environment in Cargo Compartments | Ahmet Kayihan Kiryaman | Okt 06, 2010 |
| AIR1826A | Acoustical Considerations for Aircraft Environmental Control System Design | Mario Roma | Dez 17, 2009 |
| AIR1957A | Heat Sinks for Airborne Vehicles | Jones Muller | Jul 07, 2010 |
| AIR4362A | NBC Protection Considerations for ECS Design | James McNamara | Mrz 14, 2014 |
| AIR5744 | Aircraft Thermal Management System Engineering | Gino Balducci | Okt 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 | Mai 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 | Mrz 16, 2009 |
| ARP986D | Guide for Qualification Testing of Aircraft Air Valves | Gary Barker | Okt 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 | Status |
|---|---|---|---|
| AIR1116B | Fluid Properties | June 18, 2013 | Stabilized |
| AIR5784 | A Review of Literatur on the Relationship between Gas Turbine Engine Lubricants and Cabin Air Quality | March 2002 | Susan, Ref 164 and 343 |
| AS5780 | Specification for Aero and Aero-Derived Gas Turbine Engine Lubricants | 2005 | Susan, Ref. 91, 192, 565 |
| AIR1539B | see above | | Susan, Ref. 44, 73, 80, 234 |
| ARP4418A | Procedure for Sampling and Measurement of Engine and APU Generated Contaminants in Bleed Air Supplies from Aircraft Engines | 2008 | Susan, Ref. 21 |
| AIR4766 | see above | | Susan, Ref. 11 and 358 |
| AIR4766/2 | see above | | Susan, Ref. 10, 60, 124 |
| APR1796 | see above | | Susan, Ref. 502 |

# 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 today.

| | | | |
|---|---|---|---|
| **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 AIR 1168-7: Aerospace Pressurization System Design**

**SAE ARP 1796: Engine Bleed Air Systems for Aircraft**

**SAE ARP 85: Air Conditioning Systems for Subsonic Airplanes**

**SAE AIR 806: Air Conditioning of Aircraft Cargo**

**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 this:

> *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.*