



AEROSPACE INFORMATION REPORT

AIR1609™**REV. B**

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Superseding AIR1609A

(R) Aircraft Humidification

RATIONALE

The purpose of the revision is to update the AIR per the latest technology references, instrumentations, and other related subjects

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Documents

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1. SCOPE

This SAE Aerospace Information Report (AIR) covers the design parameters for various methods of humidification applicable to aircraft, the physiological aspects of low humidities, the possible benefits of controlling cabin humidity, the penalties associated with humidification, and the problems which must be solved for practical aircraft humidification systems. The design information is applicable to commercial and military aircraft. The physiological aspects cover all aircraft environmental control applications.

1.1 Purpose

The purpose of this AIR is to provide guidelines for the design of aircraft humidification and supporting systems. Physiological effects of humidity levels on crew and passengers are reviewed, as well as effects on cabin system designs. Various techniques used for cabin humidification are discussed and evaluated. Various technical issues are addressed, and effects associated with humidification systems are described.

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 regulations unless a specific exemption has been obtained.

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.

AIR1168/3	SAE Aerospace Applied Thermodynamics Manual Aerothermodynamic Systems Engineering and Design
AIR1204	Control of Water Carryover from the Environmental Control System and Condensation on the Structure
ARP987	The Control of Excess Humidity in Avionics Cooling

2.1.2 Government Publications

Copies of this document are available online at <https://ntrl.ntis.gov/NTRL>.

Food and Drug Administration Public Health Service Publication No. 308, Handbook on Sanitation of Airlines, PB216691.

2.1.3 Other Publications

Anderson, L. B., Lundquist, G. R., Jensen, P. L., and Proctor, D. F., "Human Response to 78 Hour Exposure to Dry Air," Arch. Environmental Health, Vol. 29, Dec. 1974.

ASHRAE Handbook, Fundamentals Volume, 2018.

Carrier, W. H., "Rational Psychrometric Formulae," Transactions ASME, 1911.

Dunklin, E. W. and Puck, T. T., "The Lethal Effect of Relative Humidity on Airborne Bacteria," Journal of Experimental Medicine 87:87, Feb. 1948.

McIntyre, D. A., "Indoor Climate," Applied Science, 1980.

2.2 Nomenclature

This list contains symbols used in equations, charts, and descriptions in this AIR.

ET*	Effective temperature
G	Water added to increase humidity, kg/s (lb/s)
gr	Grain = 0.0000648 kg (7000 gr = 1 pound)
m _c	Average moisture generated per crew member, kg/s (lb/s)
m _p	Average moisture generated per passenger, kg/s (lb/s)
n _c	Number of crew members
n _p	Number of passengers
P _c	Cabin pressure, kPa absolute (psia)
P _v	Saturated vapor pressure of water at the dry bulb temperature, kPa absolute (psia)
RH	Relative humidity, %
W _a	Outside air flow rate into the cabin, kg/s (lb/s)
W _r	Recirculated air, kg/s (lb/s)
x	Ratio of moisture in recirculated air to moisture in cabin air
ω _a	Specific humidity, ambient, kg/kg (lb/lb) of dry air
ω _c	Specific humidity, cabin, kg/kg (lb/lb) of dry air
ω _s	Water vapor at saturation at dry bulb temperature and at the cabin pressure, kg/kg (lb/lb) of dry air

2.3 Units

All equations in this AIR may be used with metric (SI) or English units if consistency is maintained.

3. GENERAL BACKGROUND

World-wide variations in relative humidity range from as little as 6% in desert areas to 100% when rain is falling or the temperature is equal to or just below the dew point. The absolute (specific) humidity or water content shows an equally wide variation, being less than 2 g of water per kilogram of dry air (14 gr/lb) in cold winter climates to as high as 29 g/kg (200 gr/lb) during summer months in tropical areas.

The majority of people who are airline passengers live in areas where the relative humidity is between 30 to 60% most of the time. Exposure to a combination of high temperature and humidity causes almost immediate discomfort. The effect of exposure to very low levels of humidity takes considerably longer to be noticeable. Flight and cabin crews of long-range aircraft, having frequent extended-duration exposures, are among the most susceptible to the effects of low humidity, as typically aircraft humidity in cruise is often substantially lower than 30%. This is the consequence of flying at altitudes where the ambient air contains no or very little humidity. Ambient air is compressed and used to provide air conditioning inflow to the cabin.

4. PHYSIOLOGICAL EFFECTS OF LOW HUMIDITY

Ambient temperature and humidity affect the temperature and water balance of the human body. The inspired air is brought to body temperature and a saturated level prior to reaching the lungs by extracting heat and water from the mucosa lining the upper respiratory tract. This process cools and dries the surface mucosa. During expiration, both heat and water are recovered from the alveolar air, 37 °C (98 °F) and 100% RH as it contacts the colder mucosa of the nasopharynx. This net transfer of heat and moisture is dependent on ambient humidity and temperature.

The physiological effects of low humidity, as can be found in aircraft cabins during cruise, are unclear. There are numerous reported instances of airline passengers and crew complaining of dry noses and throats and "gritty" eyes. The sensation of dryness of the nose is attributed to drying out of the mucosa. Most of the evidence of discomfort related to low humidity is difficult to evaluate (refer to McIntyre, D. A.). Some investigations, under carefully controlled conditions, have concluded that there is no physiological need for humidification of air (refer to Anderson, L. B., Lundquist, G. R., Jensen, P. L., and Proctor, D. F. and ASHRAE Handbook, Fundamentals Volume).

It should be noted that in cold climates, the relative humidity inside buildings can be quite low. For example, if the outside air is saturated at -6.7 °C (20 °F), the RH at 23.9 °C (75 °F) is only 11%. Many people are exposed to such humidity levels for long durations, apparently without significant adverse effects or discomfort.

4.1 Performance

No adverse effect of low humidity on performance has been established. USAF School of Aerospace Medicine experiments showed that environments of 0.5 mm Hg (66.5 Pa) vapor pressure and/or simulated 2.44 km (8000 feet) barometric pressure with a moisture content of about 0.6 g/kg (4 gr/lb) had no adverse effects on performance during four 36-hour chamber exposures. Department of Transportation/Federal Aviation Administration investigations have been conducted to evaluate any performance effects of low humidity. These studies concluded that the information presented with regard to humidity effects did not show that low humidity had safety implications.

4.2 Respiratory Effects

Many medical practitioners believe that low winter humidities predispose individuals towards infection and have recommended humidification for those who suffer from respiratory troubles. The dispersal of bacteria is affected by humidity, in that bacteria are carried on small dust particles (refer to Carrier, W. H.). Increasing relative humidity encourages the particles to agglomerate, which will increase the rate at which they settle out of the atmosphere. Humidification systems may, therefore, be desirable in military airplanes used as mobile hospitals.

Some epidemiological investigations have been made which point to low atmospheric humidities as a factor in increasing the incidence of infection. Although these investigations support each other, none can really be considered conclusive (refer to McIntyre, D. A.).

4.3 Effective Temperature

The effective temperature (ET*) is an index that combines into a single value the effects of dry-bulb temperature, relative humidity, and air velocity on the sensation of comfort (refer to ASHRAE Handbook, Fundamentals Volume). It is similar to the older effective temperature used earlier by the American Society of Heating Refrigeration and Air Conditioning Engineers, but it is based upon more current tests on effects of environment on human comfort. The index shows that as humidity is decreased, dry bulb temperature must be increased to achieve the same sensation of warmth.

4.4 Exposure Time

Any effects of low humidity are not immediate. The incidence of passenger complaints tends to be associated with flights of 3 to 4 hours or longer, increasing with flight time. Crew discomfort is more prevalent due to their more frequent exposure to low humidity conditions. Military crews on flights lasting up to approximately 24 hours have experienced discomfort due to low humidities. Commercial flights can last up to approximately 14 hours on intercontinental routes, so commercial flight crews may experience similar effects. Frequent intake of water may reduce this discomfort.