AEROSPACE INFORMATION REPORT

AIR806™	REV. B

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Superseding AIR806A

Air Conditioning of Aircraft Cargo

RATIONALE

AIR806B has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

The report presents air conditioning data for aircraft cargo which is affected by temperature, humidity, ventilation rate and atmospheric pressure. The major emphasis is on conditioning of perishable products and warm-blooded animals. The report also covers topics peculiar to cargo aircraft or which are related to the handling of cargo.

1.1 Purpose:

The purpose of this Aerospace Information Report (AIR) is to provide design information related to the air conditioning of cargo transported by commercial and military aircraft. Affected cargo includes perishable products, live animals and hazardous materials.

2. REFERENCES:

1. SAE ARP85 - Air Conditioning Equipment, General Requirements for Subsonic Airplanes.
2. SAE ARP89 - Temperature Control Equipment, Automatic, Airplane Cabins.
3. SAE ARP367 - Airplane Cabin Pressurization.
4. SAE ARP699 - High Temperature Pneumatic Duct Systems for Aircraft.
5. SAE AIR795 - Air Conditioning of Subsonic Aircraft at High Altitude.
6. SAE ARP1270 - Cabin Pressure Control Criteria.
7. SAE ARP1395 - Minimum Requirements for Future Wide-Body Aircraft Cargo Systems and Compartments.
8. Unit Load Devices Manual - International Air Transport Assoc., P.O. Box 160, 1212 Cointrin, Geneva, Switzerland.
9. ASHRAE Handbook and Product Directory and ASHRAE Handbook of Fundamentals - American Society of Heating, Refrigerating and Air Conditioning Engineers.
10. Part 25, Federal Aviation Regulations - Airworthiness Standards, Transport Category Airplanes.
11. Part 121, Para. 288 of the Federal Air Regulations.
12. FAA Advisory Circular 103-4, Hazards Associated with Sublimation of Solid Carbon Dioxide Aboard Aircraft.

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http://www.sae.org/technical/standards/AIR806B

2. (Continued):

13. U.S. Air Force Manual 71-4, Packing and Handling of Dangerous Materials and Transport by Military Aircraft.
14. U.S. Dept. of Agriculture, APHIS 91-21 - Environmental Considerations for Shipment of Livestock by Air Freight.

3. PUBLICATIONS:

1. University of California Agriculture Extension Service Publication No. 36, Why Perishables are Cooled, August 1974
2. University of California Manual No. 43 - Commercial Cooling of Fruits and Vegetables
3. USDA MRR 421 - Factors Influencing heat loss in cantaloupes during hydrocooling
4. USDA MRR 600 - Vacuum precooling, a comparison of the cooling of different vegetables
5. USDA MRR 636 - Hydrocooling vegetables
6. USDA ARS 52-12 - Hydrocooling stacked crates of celery and sweet corn
7. USDA ARS 52-70 - Forced-air precooling of citrus fruit on a moving conveyor
8. USDA AMS 469 - Vacuum Cooling lettuce in commercial plants
9. USDA Technical Bulletin No. 1292 - Thermal characteristics of peaches as related to hydrocooling
10. American Society of Agricultural Engineers Paper No. 875 - Forced-air cooling of palletized fresh fruit
11. American Society of Agricultural Engineers Special Publication S-01-72: 38-41 - Forced-air cooling of fruit in bulk bins
12. University of California Agricultural Extension Service Miscellaneous Publication - Precooling cantaloupes, a guide for shippers
13. University of California, Cooperative Extension OSA 674 - Forced-air unit to rapidly cool small lots of produce
14. Cornell Extension Bulletin No. 1012 - Vacuum cooling vegetables
15. Western Grower and Shipper 42 (8): 19, 27 - Progress in mechanicals, new top-icing method for melons solves problems
16. Western Grower and Shipper 43 (3): 29-20 - Improved method, window top-icing cools celery faster
17. Western Grower and Shipper 45 (2) L10, 27 - Hydrocooler damage, answer found for vegetable water beating
18. International Journal of Biometeorology, Vol. 20, No. 2, pp 139-156: The Significance of Meteorology in Animal Production

All USDA publications may be obtained from the Office of Information, U.S. Department of Agriculture, Washington, DC 20250. All University of California publications may be obtained from the Public Service Office, University of California, Davis, California 95616. Other publications should be obtained directly from the source.

4. TYPES OF AIRCRAFT:

4.1 Cargo or Freighter:

These aircraft are designed specifically to transport cargo, and include features such as large doors, cargo loading and handling devices, heavy duty floors and hardboard interior liners. See ARP1395 for information on future cargo aircraft.

4.2 Passenger:

These aircraft carry cargo in compartments below the cabin floor. Large aircraft are fitted with special cargo handling devices.

4.3 Mixed:

These aircraft are capable of transporting a mixed load of cargo and passengers within the main cabin.

4.4 Convertible:

These aircraft can be converted from a passenger configuration to a cargo configuration by removing seats and other passenger equipment.

5. CARGO CATEGORIES:

5.1 Perishables:

Includes food, meat, fish, fruits, vegetables, flowers and frozen products.

5.2 Live:

Covers all kinds of animals, fowl, fish, reptiles, etc.

5.3 Hazardous:

Covers explosives, combustibles, chemicals and radioactive material.

5.4 General:

Includes all other types of cargo transported by air.

6. GENERAL INFORMATION:

6.1 Passenger Ventilation:

Fresh air ventilation requirements for passengers and flight crew are given in SAE ARP85.

6.1.1 Cargo Ventilation: In general, the minimum ventilation rate for cargo will depend upon that needed for proper temperature control. The quantity of ventilating air may have to be adjusted in special cases to control odors, prevent a hazardous concentration of contaminants, or to prevent dehydration of fresh produce. Compartments in which warm-blooded animals are carried should be adequately ventilated. The ventilation openings in animal containers should not be obstructed due to initial loading or by the shirting of other cargo after loading.

6.2 Heating and Cooling:

Heating and cooling requirements for the crew and passengers are given in SAE ARP85.

6.3 Temperature Control:

Design information on various types of aircraft temperature control systems is presented in SAE ARP89.

6.3.1 Cargo Temperature Control: As a minimum, cargo compartment temperature should be maintained at a level sufficient to prevent freezing of the contents. Special temperature control provisions are applicable to perishables, as indicated in Table 1. Temperature-controlled containers, with integral refrigeration equipment, are generally used to transport perishables. Data on these containers are presented in the IATA Unit Load Devices Manual.

Some warm-blooded animals require special temperature control. For example, the temperature environment for Rhesus monkeys should be controlled within a 70° to 74 °F (21.1° to 23.3 °C) band. Baby chicks and tropical fish are other examples of live cargo which must be maintained within a limited temperature range. Further information on temperature control requirements for animals may be found in the Air Transport Chapter of the Applications Volume of the ASHRAE Handbook and Product Directory.

TABLE 1 - Temperatures for Perishables in Transit

Commodity	Minimum °F	Minimum (°C)	Maximum °F	Maximum (°C)	Commodity	Minimum °F	Minimum (°C)	Maximum °F	Maximum (°C)
Apples	38	(3.3)	42	(5.6)	Milk	40	(4.4)	45	(7.2)
Asparagus	40	(4.4)	--	--	Mushrooms	32	(0)	35	(1.7)
Bananas	56	(13.3)	60	(15.6)	Nut Meats	35	(1.7)	40	(4.4)
Beans, green	40	(4.4)	45	(7.2)	Oleomargarine	34	(1.1)	36	(2.2)
Beets	45	(7.2)	50	(10.0)	Onions	50	(10.0)	60	(15.6)
Blackberries	42	(5.6)	45	(7.2)	Oranges	50	(10.0)	--	--
Broccoli	40	(4.4)	45	(7.2)	Oysters	32	(0)	35	(1.7)
Butter	45	(7.2)	50	(10.0)	Parsnips	34	(1.1)	40	(4.4)
Cabbage	45	(7.2)	--	--	Peaches	50	(10.0)	--	--
Carrots	40	(4.4)	45	(7.2)	Peas, green	40	(4.4)	45	(7.2)
Cauliflower	40	(4.4)	45	(7.2)	Peppers	40	(4.4)	45	(7.2)
Celery	45	(7.2)	50	(10.0)	Pineapple, ripe	50	(10.0)	--	--
Cheese	39	(3.9)	45	(7.2)	Plums	40	(4.4)	45	(7.2)
Chocolate candies	68	(20.0)	70	(21.1)	Potatoes, sweet	55	(12.8)	60	(15.6)
Cherries	40	(4.4)	--	--	Potatoes, white	45	(7.2)	60	(15.6)
Corn, sweet	45	(7.2)	--	--	Poultry, dressed	29	(-1.7)	32	(0)
Cranberries	36	(2.2)	40	(4.4)	Poultry, frozen	0	(-17.8)	10	(-12.2)
Cream	40	(4.4)	45	(7.2)	Pumpkin & squash	55	(12.8)	60	(15.6)
Cucumbers	45	(7.2)	50	(10.0)	Quinces	40	(4.4)	45	(7.2)
Dates, cured	55	(12.8)	60	(15.6)	Raspberries	40	(4.4)	45	(7.2)
Eggplant	45	(7.2)	50	(10.0)	Spinach	45	(7.2)	50	(10.0)
Eggs, fresh	38	(3.3)	45	(7.2)	Tomatoes, ripe	55	(12.8)	70	(21.1)
Fish, Fresh, iced	32	(0)	36	(2.2)	Turnips	40	(4.4)	45	(7.2)
Fish, Frozen	0	(-17.8)	5	(-15.0)	Yeast	38	(3.3)	42	(5.6)
Fish, smoked	40	(4.4)	50	(10.0)					
Flowers	45	(7.2)	50	(10.0)	MEAT				
Frozen fruits, veg. and concentrates	-5	(-20.6)	0	(-17.8)	Bacon, fresh	36	(2.2)	40	(4.4)
Grapefruit	32	(0)	50	(10.0)	Bacon, smoked	60	(15.6)	65	(18.3)
Grapes	35	(1.7)	40	(4.4)	Beef, fresh	32	(0)	38	(3.3)
Honey	45	(7.2)	50	(10.0)	Beef, frozen	0	(-17.8)	10	(-12.2)
Ice cream	-5	(-20.6)	0	(-17.8)	Fatback	38	(3.3)	42	(5.6)
Lard	40	(4.4)	45	(7.2)	Ham, fresh	38	(3.3)	42	(5.6)
Lemons	55	(12.8)	58	(14.4)	Ham, frozen	0	(-17.8)	10	(-12.2)
Lettuce	45	(7.2)	--	--	Ham, cured	60	(15.6)	65	(18.3)
Melons	40	(4.4)	45	(7.2)	Lamb, fresh	34	(1.1)	42	(5.6)
					Pork, fresh	36	(2.2)	40	(4.4)
					Pork, frozen	0	(-17.8)	10	(-12.2)
					Sausage	40	(4.4)	45	(7.2)
					Veal	36	(2.2)	40	(4.4)

The above recommendations are taken from the American Society of Refrigeration Engineers publication and other commercial sources, and generally conform to commercial practices. Because certain foods may be cooled by the vacuum process, they may require lower carrying temperatures. Other foods may also require special temperatures. The shipper should therefore be consulted.

6.4 Moisture Control:

The quantity of moisture produced by livestock animals can be sufficient enough to create condensation problems on cool interior surfaces of the cargo compartment. Potential solutions to this problem are dehydration of the animal prior to shipping, moisture removal equipment in the cargo compartment and corrosion-preventive treatment of exposed surfaces. Data on moisture dissipation by animals may be found in the ASHRAE Handbooks and in U.S. Dept. of Agriculture, APHIS 91-21.

Some perishables require a relatively high moisture level in order to prevent shrinkage or a deterioration in appearance. These types of cargo should be shipped in special containers that include moisture control.

6.5 Pressurization Requirements:

Many kinds of cargo are not affected by changes in barometric pressure. SAE ARP1395 recommends a minimum pressurization requirement of 18,000 ft (5490 m) for future freighter aircraft. Live cargo should be transported in compartments which do not exceed an 8000 ft (2440 m) pressure altitude. Refer to SAE ARP367 and ARP1270 for details on pressurization system design requirements.

6.6 Ground Cooling and Heating:

It should be possible to operate the air conditioning system on the ground by furnishing the required services from an onboard APU or from ground equipment. The air conditioning capacity on the ground will depend upon the specific applications involved.

6.7 Fire Protection:

For Class E cargo compartments, as defined in Part 25 of the Federal Air Regulations, means must be provided to shut off the ventilation airflow to or within the compartment. The shutoff controls should be accessible in the crew compartment. The fire protection requirements for other class cargo compartments may be found in Para. 25.857 of FAR Part 25.

6.8 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. In view of the sublimation of dry ice into CO_2, special ventilation rates may be necessary. Assuming that the dry ice is stored in an insulated container, the required ventilation rate to preclude a hazardous concentration of CO_2 (0.5%) can be estimated as follows:

$$\text{Air changes/hour} = \frac{\text{Wt. of ice in pounds x 32.2}}{\text{Compt. Vol. in ft}^3 \text{ x 0.47}} \quad \text{(Eq.1)}$$

$$\text{Air changes/hour} = \frac{\text{Wt. of ice in kg x 14.6}}{\text{Compt. Vol. in m}^3 \text{ x 0.0133}} \quad \text{(Eq.2)}$$

The above formula is taken from Air Force Manual 71-4. Precautions concerning the sublimation of dry ice within cargo compartments may also be found in FAA Advisory Circular 103-4.

Precautions should be taken to preclude the direct passage of any contaminate into the flight station or passenger compartment.

6.9 Air Conditioning System Design:

The design of the air conditioning system should be such that no single failure will cause a complete loss of supply air or temperature control. One failure should not induce other failures which would result in a loss of supply air. Redundancy of equipment and components should be determined by a failure effects analysis. Refer to SAE AIR795 for requirements pertaining to high altitude aircraft systems. Bleed air ducting systems should be designed in accordance with SAE ARP699.

6.10 Temperature Control System Design:

Refer to SAE ARP89 for the design of temperature control systems. Cargo aircraft may require a lower temperature setting on the automatic selector to satisfy the in-flight cooling demands. For mixed loadings of cargo and passengers, zone temperature control may be desirable to provide passenger comfort.

6.11 Miscellaneous Design Features:

Thermal insulation material should not be installed under the floor, unless it is impervious to the leakage of fluids. Drain holes should be located in the skin area under the cargo compartment floor. Corrosion-preventative treatment should be applied to all areas subject to fluid spillage.

7. ENVIRONMENTAL REQUIREMENTS FOR VARIOUS TYPES OF CARGO:

7.1 Perishables:

Environmental factors affecting perishables include temperature, humidity and atmospheric pressure.

7.1.1 Fish: Inasmuch as fish begin to deteriorate immediately upon leaving the water, rapid delivery to the consumer market is important. See ASHRAE for packaging information on fresh fish.

7.1.2 Fruits and Vegetables: High temperatures during shipping accelerates ripening and leads to decay. As indicated in Table 1, most produce should be maintained in the 36 - 40 °F (2.2 - 4.4 °C) range during shipment. The University of California Agriculture Extension Service Publication No. 36 (listed in Section 3) is an excellent article on the cooling of perishable commodities. Low humidity promotes desiccation of fresh produce. Low atmospheric pressure (altitudes up to 30,000 ft (9140 m)) does not cause any damage. The commodities must be loaded in a manner to allow air circulation. Information related to the pre-cooling of fruits and vegetables can be found in the publications listed in Section 3. The average freezing temperature, water content and heat of respiration for some common fruits and vegetables are given in Table 2.

7.1.3 Flowers and Plants: Alternate warming and cooling causes most flowers to deteriorate in appearance. Excessive heat causes dehydration. Plants and flowers that have been exposed to high temperature are most susceptible to freezing. Altitude effects are negligible.

7.1.4 Commodity Storage: Information concerning environmental storage requirements for perishable commodities is given in the ASHRAE Handbooks.

7.2 Animals:

Cargo compartments designed for the transportation of animals should provide acceptable levels of temperature, ventilation rate, humidity, air movement (velocity) and barometric pressure.

7.2.1 Temperature and Ventilation Rate: Table 3 shows the recommended temperature and ventilation ranges for livestock. This table and other recommendations pertaining to animal environmental factors are taken from U.S. Dept. of Agriculture, APHIS 91-21. The fresh air ventilation rates shown in Table 3 are the minimum based on oxygen requirements. The actual quantity of fresh air will usually be dictated by the amount of animal sensible heat and water vapor to be removed. Data on sensible and latent heat production are given in U.S. Dept. of Agriculture, APHIS 91-21.

7.2.2 Humidity: The humidity level within animal compartments should be maintained between 30 and 70% (RH). High humidity combined with high temperature results in an unacceptable condition.

7.2.3 Air Movement: Adequate air circulation should be provided within all types of containers or enclosures for animals. An air velocity of at least 40 ft/min (20 cm/second) should be obtained at the animal's surface. As might be expected, circulation within the center portion of the enclosure is the most difficult to achieve, and special air distribution ducting may be necessary.