



AEROSPACE RECOMMENDED PRACTICE

ARP147™**REV. E**

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Superseding ARP147D

(R) Environmental Control Systems Terminology

RATIONALE

ARP147E has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE:

This ARP provides the definition of terms commonly used in aircraft environmental control system (ECS) design and analysis. Many of the terms may be used as guidelines for establishing standard ECS nomenclature. Some general thermodynamic terms are included that are frequently used in ECS analysis, but this document is not meant to be an inclusive list of such terms.

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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP780 Environmental Systems Schematic Symbols
AIR1168 SAE Aerospace Applied Thermodynamics Manual

2.1.2 U.S. Government Publications: Available from Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954, or online from www.bookstore.gpo.gov.

U.S. Standard Atmosphere, 1976, U.S. Government Printing Office, Washington, D.C., 1976

2.1.3 International Civil Aeronautical Organization (ICAO) Publications: Available from ICAO, Document Sales Unit 999 University Street, Montreal, Quebec H3C 5H7, Canada.

ICAO Doc 7488, Manual of the ICAO Standard Atmosphere (extended to 80 kilometres (262 500 feet), 3rd edition, 1993

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3. GENERAL DISCUSSION:

Earlier versions of this document were primarily intended as a list of nomenclature to be used for naming ECS components and subsystems. Later versions added terms used in ECS design and analysis. In its expanded role, the document provides definitions of ECS terms helpful to personnel new to ECS technology. The definition of terms provided herein is intended to provide a brief understanding of the terms and their usage. The symbols used to illustrate terms are taken from ARP780. For more in-depth description of cycles, components, thermodynamic processes, etc., AIR1168 should be consulted. Words with capital letters used in the definition are cross references to other terms defined in the document.

4. LIST OF ENVIRONMENTAL CONTROL SYSTEM TERMS:

ADIABATIC: Adiabatic describes a process in which a state change is accomplished on or by a fluid without heat transfer to or from the surroundings.

AIR, BLEED: Air bled from the compressor of a gas turbine engine.

AIR, COMPARTMENT:

- a. Air flowing into a compartment.
- b. Air in a compartment proper - the condition of compartment air is normally determined at a point where the air leaves the compartment. (The cabin is considered to be a compartment.)

AIR, COOLING: A stream of air used as a heat sink.

AIR, RECIRCULATED: Compartment air introduced into the distribution system by mechanical means (fans, blowers, or ejectors).

AIR, STANDARD SEA LEVEL: Dry air at 288 K and 101.35 kPa absolute (59 °F and 14.7 psia).

AIR CYCLE MACHINE: The basic component of an air cycle refrigeration system. The device consists of an air expansion turbine that is connected by a shaft to a compressor, a fan or both. The power generated in the expansion turbine is used to drive the compressor, the fan or both. The extraction of power results in a reduction of the air enthalpy.

ALTITUDE, EQUIVALENT OR CABIN: The standard altitude corresponding to the ambient pressure measured within the inhabited region of the aircraft.

ALTITUDE, PRESSURE: The altitude corresponding to a given pressure in the standard atmosphere.

ALTITUDE, STANDARD: The altitude corresponding to the temperature and pressure tabulated in an accepted standard atmosphere table. (See ATMOSPHERE, STANDARD.)

4. (Continued):

ANTICIPATOR: A sensing element in a control system designed to respond to a rate of change in pressure or temperature and to provide a control signal to reset the pressure or temperature control instrument to counteract the tendency of the control system to become unstable or to hunt.

ANTI-ICE: Prevention of ice formation on a surface. See also DEICE.

ANTI-FOG: Prevention of moisture formation on a surface, usually on a transparent area. See also DEFOG.

AREA, POSITIVE PRESSURE: Any region in which the static pressure is greater than that of the static pressure of the undisturbed air stream.

AREA, NEGATIVE PRESSURE: Any region in which the static pressure is less than that of the static pressure of the undisturbed air stream.

ATMOSPHERE, STANDARD: A standard established by the National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration and United States Air Force or the ICAO. The U.S. Standard Atmosphere or International Standard Atmosphere is derived by averaging data over long periods of time in mid latitudes of the northern hemisphere. It is a hypothetical vertical distribution of atmospheric temperature, pressure and air density which, by national agreement is taken to be representative of the atmosphere for the purpose of altimeter corrections, aircraft design and performance calculations. The U.S. Standard Atmosphere agrees with the ICAO Standard Atmosphere up to 65,000 ft altitude.

AUX VENT: An auxiliary ventilation device or system usually used for emergency ventilation in the event of the failure of the primary cooling and ventilation system. May be used for occupied compartments or equipment.

BOILER: A heat exchanger, used as a part of an air conditioning system, in which a source of heat is utilized to vaporize a liquid heat transfer medium. (See EVAPORATOR.)

BULB, THERMOSTATIC: A liquid and vapor filled tube whose pressure changes with change in temperature in a predetermined manner. The device is used in a control system to provide a temperature related signal..

CABIN, NONPRESSURIZED: An airplane cabin which is not designed or equipped for pressurization.

CABIN, PRESSURIZED: An airplane cabin which is constructed, sealed, and equipped with an auxiliary system to maintain a pressure within the cabin greater than that of the surrounding atmosphere.

4. (Continued):

CAPILLARY TUBE:

- a. A small diameter tube connecting a sensor with a bellows or diaphragm in a control device.
- b. A small diameter tube used as an expansion orifice in some vapor cycle systems.

CENTRIFUGAL SEPARATOR: A device which utilizes centrifugal force to separate materials of differing densities, such as water droplets or impurities from air.

CHARGE, REFRIGERANT: The amount and type of refrigerant contained in a vapor cycle system.

CHARGE, OIL: The amount of refrigerant oil added to a vapor cycle system to lubricate the compressor and valves.

CHARGING: The process of filling a vapor cycle system with the refrigerant and oil charge.

CHILLER: A cooling system that uses a liquid to transport heat to the heat sink. A closed loop vapor cycle cooling system for food, beverage, etc.

CLOSED-LOOP FEEDBACK/LOOP CONTROL: In an AUTOMATIC CONTROL system, the comparison of system output parameter to a reference parameter. The error signal is used to automatically modify the system operation using appropriate actuators or effectors to drive the output parameter performance to a desirable value or criteria.

COEFFICIENT OF PERFORMANCE (COP): Pertaining to a refrigeration cycle, COP is the ratio of refrigeration produced to the power supplied, where refrigeration produced and power are expressed in consistent units.

COMPRESSOR: A device in which work is done on a fluid to raise its total pressure. The temperature also rises as a result of the compression.

COMPRESSOR, AXIAL: A compressor which inducts and delivers a fluid axially by one or more rotating elements.

COMPRESSOR, CABIN: A compressor that delivers air for cabin pressurization.

COMPRESSOR, CENTRIFUGAL: A compressor that inducts a fluid axially, delivers it radially outward relative to the rotating impeller.

COMPRESSOR, LYSHOLM TYPE: A positive displacement lobe-type compressor with internal compression.

COMPRESSOR, POSITIVE DISPLACEMENT: A compressor that takes in a finite mass of fluid and reduces its geometrical volume so increasing its pressure before exhausting it.

4. (Continued):

COMPRESSOR, RECIPROCATING: A positive displacement piston-type compressor.

COMPRESSOR, ROOTS-TYPE: A positive displacement lobe-type compressor without internal compression.

COMPRESSOR, SCREW: A positive displacement compressor that compresses with two linear screws or with one linear screw and two satellite rotors.

COMPRESSOR, SCROLL: A rotary motion, positive displacement compressor that compresses with two interfitting, spiral-shaped scroll members.

COMPRESSOR, VANE: A positive displacement compressor in which the initial and final volumes of the mass of fluid being processed is determined by static or rotary vanes sliding on an eccentrically rotating surface.

CONDENSER: A heat exchanger in which the state of a fluid is changed from a vapor to a liquid by removing heat. In a vapor cycle refrigeration system, it is used to condense the refrigerant following compression. In an air cycle refrigeration system, it is used to condense water in a high pressure water separator system.

CONDITIONING, AIR: The simultaneous control of some or all of the factors affecting both the physical and chemical conditions of the atmosphere within an enclosure such as temperature, humidity, airflow, distribution, pressure, dust, ozone and bacteria.

CONDITIONING, PREFLIGHT AIR: The process of air conditioning aircraft compartment(s) while the aircraft is on the ground.

CONDUCTANCE, AIR SPACE: The overall heat transfer coefficient of an air space which includes the combined influence of conduction, convection, and radiation for a specified air space width. The units are usually expressed in $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot ^\circ F$).

CONDUCTIVITY, THERMAL: The property of a substance that permits heat to flow through the substance usually expressed in units of $W/m \cdot K$ ($Btu/h \cdot ft \cdot ^\circ F$). ($1 W/m \cdot K = 0.578 Btu/h \cdot ft \cdot ^\circ F$)

CONTROL, AUTOMATIC: A device or system of devices which autonomously regulates some parameter or output to a reference parameter. Used to automatically modify system operation to drive output performance to a desired value or criteria.

CONTROL, BAROMETRIC: A method of control that depends on the pressure of the atmosphere.

CONTROL, DIFFERENTIAL PRESSURE: A method of control that regulates the maximum pressure differential between two points. When used for cabin pressure control, the differential pressure control limits the maximum pressure differential between cabin pressure and atmospheric pressure and maintains this differential at all altitudes above those of the isobaric control.

4. (Continued):

CONTROL, ISOBARIC: A method of control which maintains essentially constant pressure. The isobaric control in a cabin pressure control system maintains the cabin at a selected pressure.

CONTROL, MANUAL: A control device regulated by hand directly or through a mechanism or an electrical interface.

CONTROL, MODULATING: A continuous automatic regulating type of control.

CONTROL, PRESSURE RATIO: A control that operates to maintain a specific pressure ratio between two points in a system.

COOLANT: A fluid used to absorb heat from a heat source. A coolant may also be used to add heat to the source when required.

COOL DOWN TIME (PULL-DOWN TIME): The time required after cooling system start-up to cool (or pull-down) the interior air of a heat-soaked aircraft to a required operating temperature.

COOLING EFFECT DETECTOR (SENSOR): A sensor that generates a signal proportional to heat lost by the sensor. When used in fluid stream its output relates to the cooling capacity (velocity, density, temperature) of the stream flowing across the detector.

COOLING CAPACITY:

- a. The heat transfer rate from the coolant supply as measured by the difference between the total enthalpy of the coolant entering the cooling device or devices and the total enthalpy of the coolant leaving the cooling devices under steady-state conditions. This is the classic definition used for commercial air conditioning systems.

$$q = m(h_{\text{outlet}} - h_{\text{inlet}})$$

For dry air this becomes:

$$q = mc_p(T_{\text{outlet}} - T_{\text{inlet}})$$

where:

q = cooling capacity (heat transfer rate)

m = mass flow of cooling supply

h = enthalpy

c_p = specific heat capacity, constant pressure

T = dry air rated temperature

subscripts:

inlet = related to coolant entering cooling device

outlet = related to coolant leaving cooling device

4. (Continued):

- b. The maximum heat transfer rate achievable from the heat load to the coolant supply as measured by the difference between the total enthalpy of the coolant entering the heat load and the total enthalpy of the coolant leaving the heat load under steady-state conditions. It is dependent on the temperature to which the heat load is required to be cooled. This is the definition usually used in the aerospace industry where the concern is how much heat can be removed by a cooling system.

$$q = m(h_{\text{load}} - h_{\text{supply}})$$

For dry air this becomes:

$$q = mc_p(T_{\text{load}} - T_{\text{supply}})$$

where:

subscripts:

load = related to coolant leaving heat load

supply = related to coolant supply to heat load

COOLING LOAD, CABIN: See HEAT LOAD, CABIN.

COOLING LOAD, TOTAL: See HEAT LOAD, TOTAL.

COOLING SYSTEM, BOOTSTRAP: An air cycle refrigeration system in which air from a pressure source flows successively through a compressor, a heat exchanger and a turbine. Heat is rejected in the heat exchanger to a heat sink. The power necessary to drive the compressor is obtained from the turbine. See also COOLING SYSTEM, FOUR WHEEL BOOTSTRAP and COOLING SYSTEM, THREE WHEEL BOOTSTRAP.

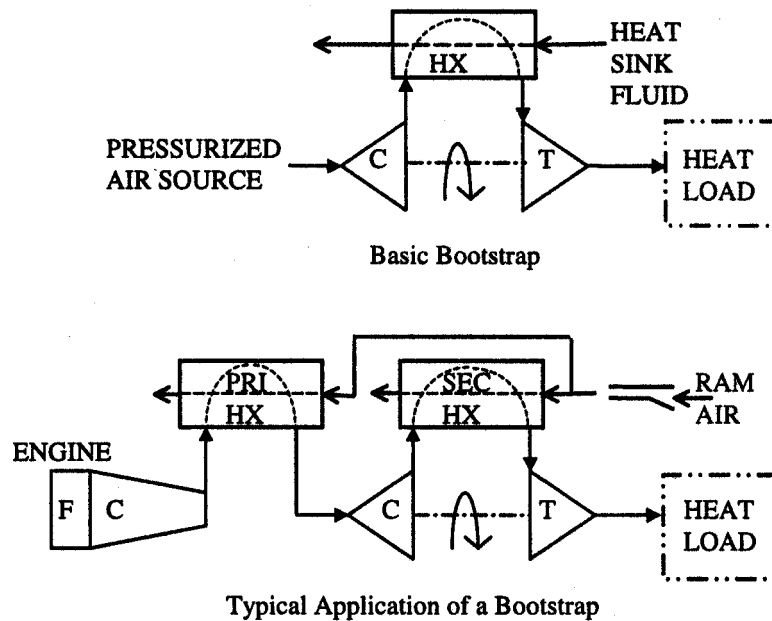
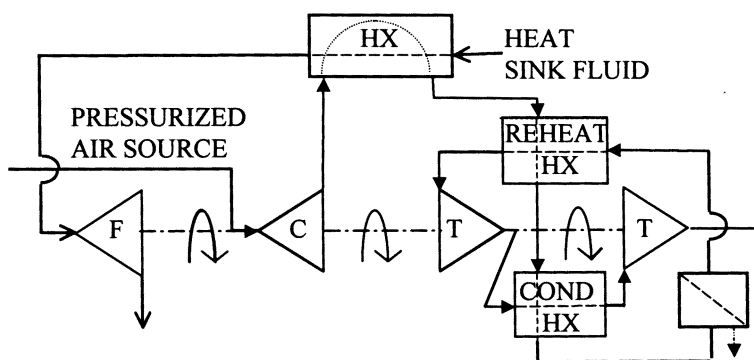


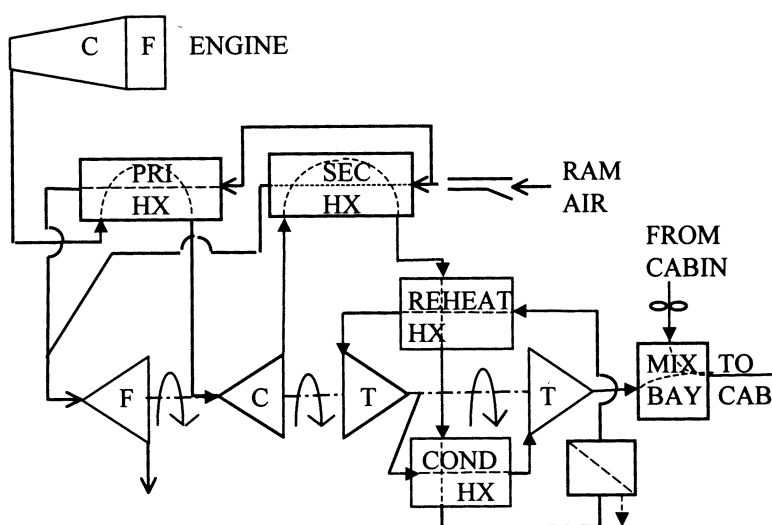
FIGURE 1

4. (Continued):

COOLING SYSTEM, FOUR WHEEL BOOTSTRAP: This system, also called a Condensing Cycle, adds a second turbine stage to the THREE WHEEL BOOTSTRAP COOLING SYSTEM. It also utilizes a high pressure water separator. Air from a pressure source flows successively through a compressor, the main heat exchanger, the hot side of a reheater heat exchanger, the hot side of a condensing heat exchanger, a water collector, the cold side of the reheater, the first stage of the turbine, the cold side of the condenser, the second stage of the turbine and finally to the heat load. The turbine drives the compressor as well as the fan. The fan which absorbs a percentage of the shaft power is used to pull cooling air through the main heat exchanger. This cycle allows the recovery of the heat of condensation which improves overall cycle efficiency and, in turn, results in a significant reduction in system weight. It also allows high pressure water separation at above freezing temperatures.



Basic Four Wheel Bootstrap Cooling System



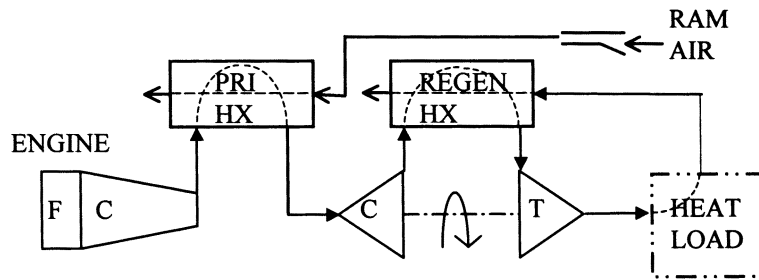
Typical Four Wheel Bootstrap Cooling System Application

FIGURE 2

4. (Continued):

COOLING SYSTEM, REDUCED AMBIENT: See COOLING SYSTEM, REVERSE BOOTSTRAP.

COOLING SYSTEM, REGENERATIVE: A refrigeration system in which cooling capacity that normally would have been wasted is recovered in the cycle. This typically is accomplished with a regenerative heat exchanger.(See **HEAT EXCHANGER, REGENERATIVE.**)



Typical Application of a Regenerative Cycle (Bootstrap)

FIGURE 3

4. (Continued):

COOLING SYSTEM, REVERSE BOOTSTRAP: An air cycle refrigeration system in which ram air from a ram air scoop is expanded in a turbine to low pressure, causing the air temperature to drop. The cold air is used as a heat sink in a heat exchanger, compressed by a compressor, and then exhausted overboard. The compressor absorbs the power produced by the turbine. Such a system requires high ram air pressure and is typically used in high speed aircraft; however, if there is insufficient pressure, a motor may be used to drive the system.

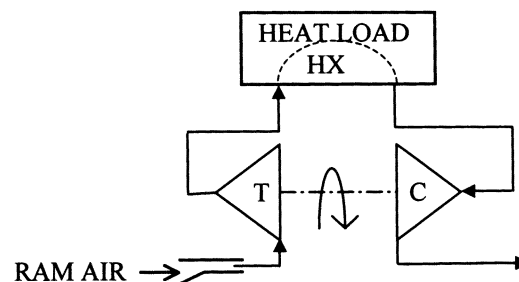


FIGURE 4

COOLING SYSTEM, SHOESTRING: Air from a pressure source flows successively through a heat exchanger and a turbine, or section of a turbine. The turbine work powers a compressor which draws exhaust air from the conditioned compartment and compresses it. The air is then cooled in a heat exchanger and flows through the turbine or a section of the turbine shared with the main bleed air. The bleed air source makes up the difference between the air going into the heat load and the exhaust air from the conditioned compartment.