AEROSPACE RECOMMENDED PRACTICE

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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, Warrrendale, 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 devise 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 $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot °F$).

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

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

For dry air this becomes:

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

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.

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

For dry air this becomes:

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

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.

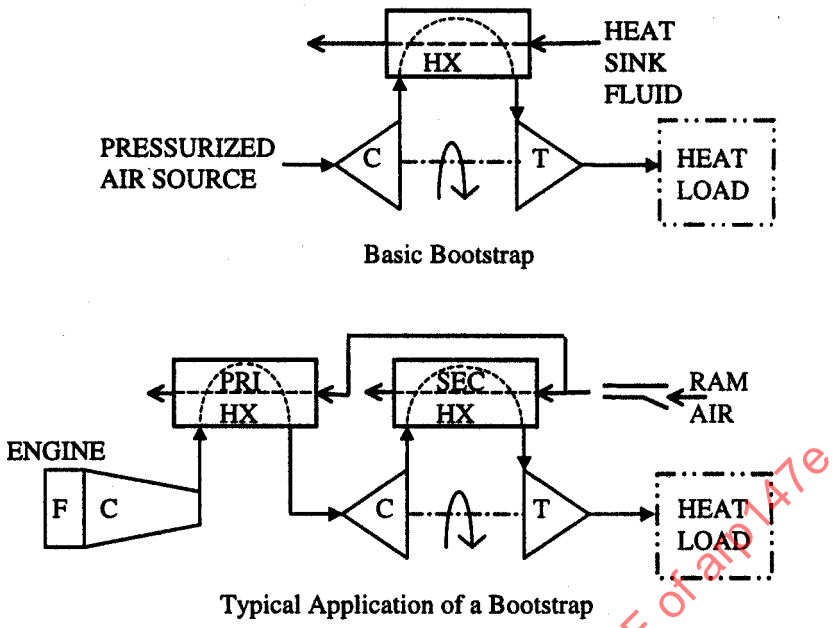
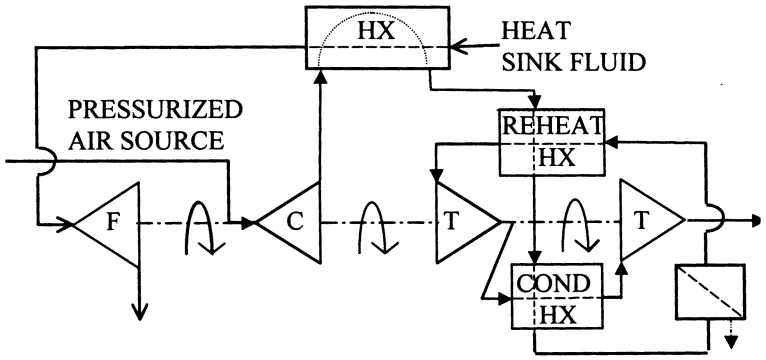


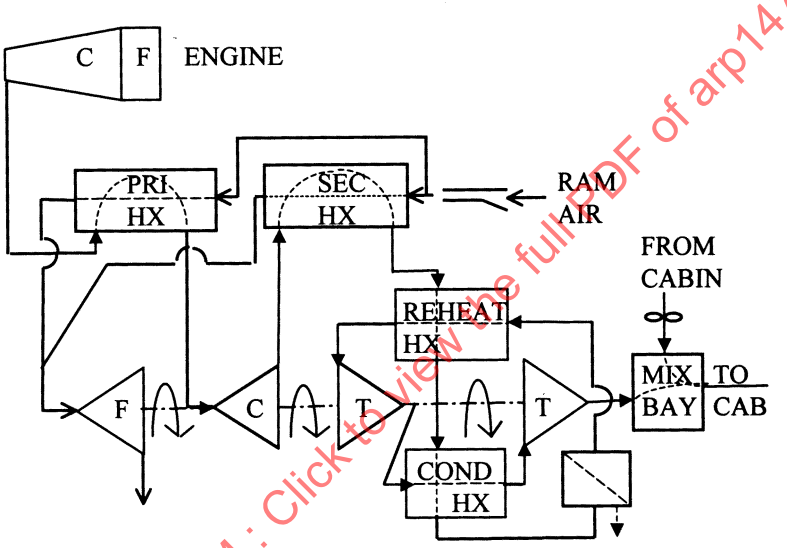
FIGURE 1

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



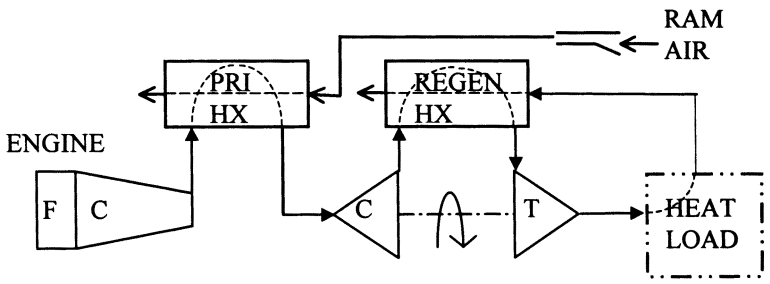
Typical Four Wheel Bootstrap Cooling System Application

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 SYTEM, 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.

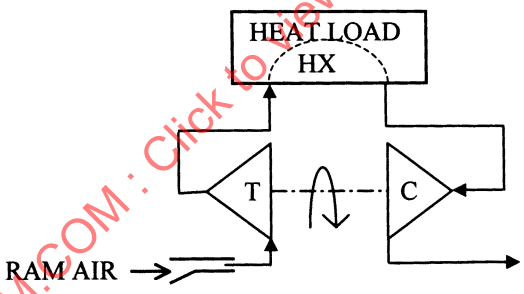


FIGURE 4

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.

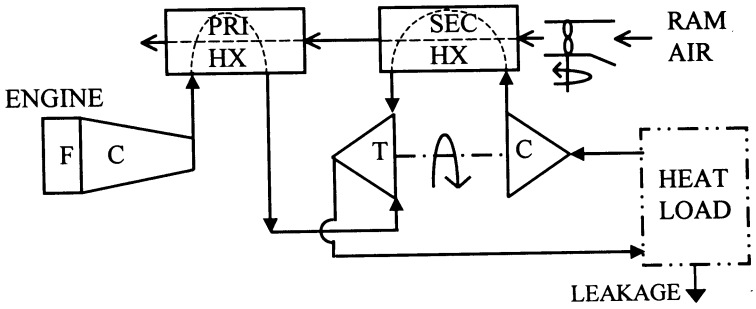
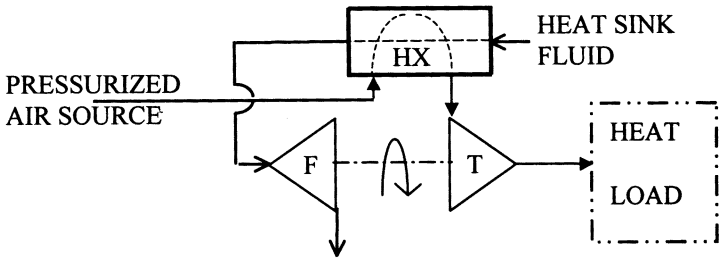


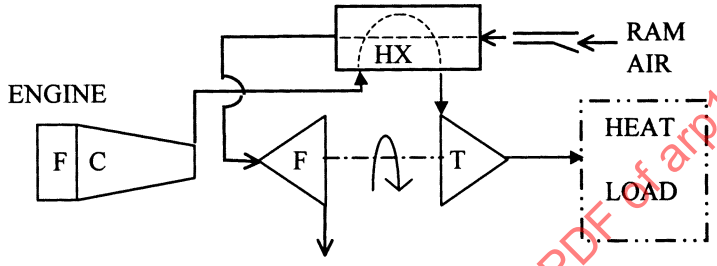
FIGURE 5

4. (Continued):

COOLING SYSTEM, SIMPLE: An air cycle refrigeration system in which air from a pressure source flows successively through a heat exchanger followed by a turbine in the supply air stream. The heat exchanger cooling air is provided by a fan or compressor which is driven by power from the cooling turbine. Another variation is with the compressor supplying an outside source with some of its air used by an ejector to induce flow through the heat exchanger. (See EJECTOR.)



Basic Simple Cooling System

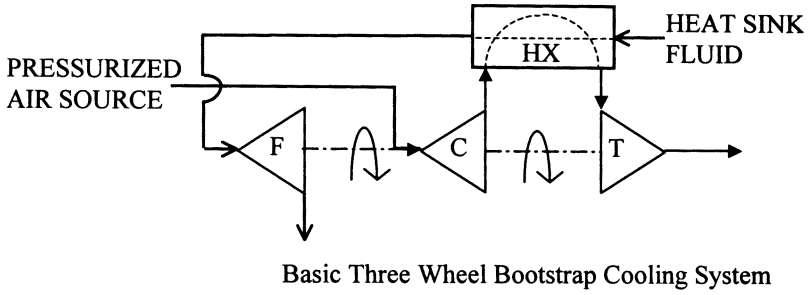


Typical Application of a Simple Cooling System

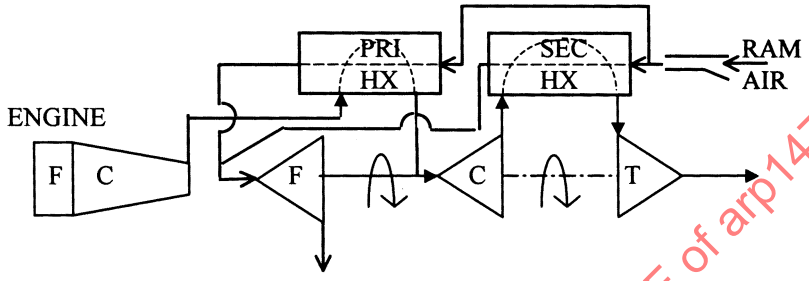
FIGURE 6

4. (Continued):

COOLING SYSTEM, THREE WHEEL BOOTSTRAP: This system combines both the Bootstrap Cooling System and the Simple Cooling System. Air from a pressure source flows successively through a compressor, a heat exchanger, and a turbine. The turbine drives the compressor as well as a fan. The fan which absorbs a percentage of the shaft power is used to pull cooling air through the heat exchanger.



Basic Three Wheel Bootstrap Cooling System



Typical Three Wheel Bootstrap Cooling System Application

FIGURE 7

4. (Continued):

COOLING SYSTEM, THREE WHEEL RECIRCULATING (THREE WHEEL SHOESTRING): A recirculating or shoestring cooling system which utilizes a three wheel air cycle machine. The third wheel is a fan which consumes a fraction of the shaft power and provides heat exchanger cooling air.

COOLING TURBINE: The air expansion turbine in an AIR CYCLE MACHINE. It is the basic component of an air cycle cooling system. Sometimes this term is used synonymously with AIR CYCLE MACHINE.

CYCLE, CLOSED LOOP: A closed loop cycle is one where the working substance is neither added to or deducted from and is returned regularly to a particular state or condition at each point in the cycle during steady operation. Where leakage is inevitable, such as closed air cycle loops that include aircraft compartments, the working substance will need to be constantly recharged to maintain the system pressure.

CYCLE, OPEN LOOP: An open loop cycle is one where the working substance is continually added at the beginning of the cycle and discharged at the end of the cycle.

DAMPER: A device for controlling air flow.

4. (Continued):

DECIBEL: The decibel is a logarithmic scale unit of sound intensity measurement and is described as: the sound intensity I_1 is N decibels higher in "intensity level" than the reference sound intensity I_o if $N = 10 \log_{10} I_1/I_o$. The reference intensity level is usually taken as 1.0×10^{-16} W/cm^2.

DEFOG: Removal of moisture after it is condensed, usually on a transparent area. This term may, in common usage, also include the prevention of moisture formation or be used to designate both functions, but this is not technically correct. Prevention of moisture would be antifog. See also ANTIFOG.

DEICE: Removal of ice after it has formed on a surface. See also ANTI-ICE.

DEMISTER: A term with the same meaning as DEFOG that is used in Europe.

DEW POINT: See TEMPERATURE, DEW POINT.

DIFFUSER: A device for converting the velocity pressure of a fluid stream into pressure head, usually accomplished by efficiently reducing the velocity.

DISTRIBUTION SYSTEM: The combination of ducts, outlets, valves and orifices to distribute fluids to satisfy cabin and equipment cooling and heating demands.

DRAINAGE: Fluid collected in a cooling system which is drained overboard. In an air-conditioning system the term refers to the water removed from the water separator.

DRYER: A device used to remove water or water vapor from a refrigerant or other fluid.

ECONOMIZER: See FLASH SUBCOOLER.

4. (Continued):

EFFECTIVENESS, HEAT EXCHANGER:

a. It is a measure of the performance of the heat exchanger. In the aircraft industry, the terms ‘hot side effectiveness’ and ‘cold side effectiveness’ are used to define hot and cold side heat exchanger performance when same fluids are used on both sides and there is no condensation. They are defined as follows.

1. Hot Side

$$\varepsilon = \frac{(T_{hi} - T_{ho})}{(T_{hi} - T_{ci})} \quad \text{only if } C_h = C_{min}$$

2. Cold Side

$$\varepsilon = \frac{(T_{co} - T_{ci})}{(T_{hi} - T_{ci})} \quad \text{only if } C_c = C_{min}$$

b. Heat exchanger effectiveness can also be described by heat transfer effectiveness, which is defined as the actual heat transfer rate divided by the maximum possible rate and is calculated as follows:

$$\varepsilon = \frac{C_h(T_{hi} - T_{ho})}{C_{min}(T_{hi} - T_{ci})} = \frac{C_c(T_{co} - T_{ci})}{C_{min}(T_{hi} - T_{ci})}$$

where:

T = temperature
C = heat capacity, Wc_p
W = mass flow
c_p = specific heat capacity, constant pressure
C_{min} = smaller of C_h and C_c magnitudes
subscripts:
c = cold flow
h = hot flow
I = inlet
o = outlet

4. (Continued):

EFFICIENCY, ISENTROPIC:

a. Turbines: The ratio of the actual dry gas, usually air, enthalpy drop through a turbine to the enthalpy drop for a reversible adiabatic expansion.

b. Compressors: The ratio of enthalpy rise of dry gas, usually air, in a compressor for a reversible adiabatic compression to the actual gas enthalpy rise.

EJECTOR: A device that uses a high velocity fluid stream (called primary jet) to induce ambient fluid (secondary) flow. The dynamic pressure of the mixed flow is converted to a total pressure in a diffuser.

An ejector designed to optimize secondary/primary flow ratio is called an aspirator.

An ejector designed to optimize output/secondary fluid pressure is called a jet pump.

Although sometimes used for flow mixing in pneumatic systems, the primary use of an ejector in aircraft ECS is to supply cooling air for heat exchangers on the ground or in low speed or vertical flight. Normally ECS heat exchangers use ram air in flight as a cooling air source heat sink. (Military aircraft may also use fuel or an intermediate heat transport fluid.) When ram air is no longer available or is inadequate, an ejector is used to “pump” outside ambient airflow through the cooling side of the heat exchanger. Although there are a number of different ejector designs, the simplest form is to supply a high pressure bleed source through nozzle(s) located downstream of a heat exchanger. The high velocity airflow through the nozzle(s) draws (pumps) ambient airflow from upstream of the nozzle(s) and through the heat exchanger, where it is used as the heat sink.

ENTHALPY: Property of substance in an energy term defined as follows:

$$h = u + Pv$$

where:

h = enthalpy (usually expressed in J/kg or Btu/lb)
u = specific internal energy
P = pressure
v = specific volume

If the fluid can be regarded as a perfect gas, its enthalpy can alternately be expressed as the product of its constant pressure specific heat and its absolute temperature.

Enthalpy represents the value between two states. For computational convenience a reference state is chosen in order that an enthalpy value can be assigned to any state and the difference from any other state can easily be determined from tables or charts. The value at the reference state is arbitrarily assigned to be zero. For example the enthalpy of saturated liquid water is assigned to be zero at 0 °C (32 °F).

4. (Continued):

ENVIRONMENTAL CONTROL SYSTEM: A set of components that controls pressure, temperature, humidity and contaminants to maintain crew comfort and equipment integrity within an aerospace vehicle.

EVAPORATOR: A device in which a liquid changes phase from liquid to gas.

As pertains to a refrigeration system, that part of the system in which heat is transferred to the refrigerant resulting in its change of phase from a liquid to a vapor. (See BOILER.)

As pertains to an air cycle system, that part of the system in which heat is transferred to the air stream in order to raise its temperature above the dew point of the air stream before delivering it to cabin, avionics or other users. This is to prevent the delivery of free moisture to those areas. Hot incoming compressed air is often the source for the heat.

EXHAUST SYSTEM (VENTILATING): As relates to compartment ventilation, that combination of air discharge ducts, vents and outlet grills utilized for the discharge of air from the compartment to the outside.

EXPLOSIVE DECOMPRESSION: The sudden loss of pressurization usually in an occupied compartment. It is normally caused by the loss of some part of the pressure containment structure, such as a door or access panel. The pressure rapidly decreases to that of the outside ambient.

FAN: A fan is a compressor with a compression ratio below approximately 1.05. A fan, therefore, provides large flow volume at relatively low pressures differentials.

FILTER, AIR: A device for removing and entrapping dust or other contaminants from air.

FILTER, ODOR: A device for removing odor from air.

FIREPROOF:

a. With respect to materials and parts used to confine fire in a designated fire zone, means the capacity to withstand at least as well as steel in dimensions appropriate for the purpose for which they are used, the heat produced when there is a severe fire of extended duration in that zone.

b. With respect to other materials and parts, means the capacity to withstand the heat associated with fire at least as well as steel in dimensions appropriate for the purpose for which they are used.

4. (Continued):

FIRE RESISTANT:

a. With respect to sheet or structural members, fire resistant means the capacity to withstand the heat associated with fire at least as well as aluminum alloy in dimensions appropriate for the purpose for which they are used.

b. With respect to fluid-carrying lines, fluid system parts, wiring, air ducts, fittings, and powerplant controls, fire resistant means the capacity to perform the intended functions under the heat and other conditions likely to occur when there is a fire at the place concerned.

FLAMMABLE: With respect to a fluid or gas, flammable means susceptible to igniting readily or to exploding.

FLAME RESISTANT: "Flame resistant" means not susceptible to combustion to the point of propagating a flame, beyond safe limits, after the ignition source is removed.

FLASH RESISTANT: "Flash resistant" means not susceptible to burning violently when ignited.

FLASH SUBCOOLER: This is a term used in vapor cycle systems, with multiple stages of compression, for a heat exchanger which has evaporating on one side and subcooling of the liquid from the condenser on the other side. By using the interstage pressure of the compressor as the evaporating pressure in the flash subcooler the liquid from the condenser can usually be subcooled by 5 to 15 °C (10 to 30 °F) below that from the condenser itself. This type device can improve cycle efficiency from 10 to 20%. This device is also called an economizer.

FLOW SHARING: In multi-engine bleed air systems, it is desirable to extract equal quantities of airflow from each engine, such that they flow share. For example, on a wing mounted two engine aircraft with both engines feeding a single air cycle system, if flow sharing techniques are not employed, one of the engines will supply all or a majority of the system airflow. This results in a slight asymmetric thrust. Also, the engine dominating the flow will have a higher turbine inlet temperature, which will reduce the life of this engine. The term is also used to describe a control system for dividing the flow among all air sources.

FLOW, VOLUMETRIC: The volume rate of fluid flow at a specified temperature and pressure, usually expressed in units of m^3/s (ft^3/min).

FLOW, MASS (WEIGHT): The mass rate of fluid flow, usually expressed in units of kg/s (lbm/min). Historically this was referred to as weight flow where English customary units were used.

GASPER AIR OUTLET (INDIVIDUAL): Also know as velocity outlet. This is a supplementary (conditioned or unconditioned) air outlet, adjustable in flow quantity and direction, which is usually provided at each passenger seat and crew station to create additional air motion as required by the individual.

4. (Continued):

HEAD PRESSURE CONTROL VALVE: A valve that regulates the high side head pressure in a refrigeration or air conditioning system in order to assure a minimum pressure differential across the expansion device, even at the lowest condenser cold side temperatures. This is accomplished through the back flooding of the condenser with liquid refrigerant to reduce the condenser's effectiveness.

HEAT EXCHANGER: An apparatus in which the heat is transferred from one medium to another without mixing of the media.

HEAT EXCHANGER, CABIN PRESSURIZING PRIMARY (AFTERCOOLER): A heat exchanger designed to reduce the temperature of air discharged by a cabin air compressor.

HEAT EXCHANGER, CONDENSER: See CONDENSER

HEAT EXCHANGER, PRECOOLER: A heat exchanger which is used to cool engine bleed air before it enters the air conditioning compartment or unit. It may serve the function of a primary heat exchanger in a refrigeration system.

HEAT EXCHANGER, PRIMARY: The first heat exchanger in a multiple heat exchanger air conditioning pack. It is generally located downstream of the pack flow control and shut off valve. In a bootstrap cooling system a primary heat exchanger is often used to cool the air from the pressure source before it enters the compressor. Ram air is usually used as the cooling medium in the heat exchanger, especially in commercial aircraft. Military aircraft may also use fuel or an intermediate heat transport fluid.

HEAT EXCHANGER, REGENERATIVE: A heat exchanger used to recover energy from a fluid whose cooling (or heating) potential was developed in another part of the system. Often it is used to recover cooling (or heating) potential of a fluid that would normally be wasted. (See COOLING SYSTEM, REGENERATIVE.)

HEAT EXCHANGER, REHEATER: A heat exchanger, used in the high pressure water separation loop, to reheat and evaporate any moisture present in the cold airstream, prior to it entering the turbine.

HEAT EXCHANGER, SECONDARY: The second heat exchanger in a multiple heat exchanger air conditioning pack. In a bootstrap cooling system, where a primary heat exchanger is used upstream of the compressor, the secondary heat exchanger is used to cool the air which passes from the compressor to the cooling turbine. Ram air is usually used as the cooling medium in the heat exchanger, especially in commercial aircraft. Military aircraft may use fuel or an intermediate heat transport fluid.

HEAT LOAD: Quantity of heat generation in an aircraft compartment or quantity of heat transfer into an aircraft compartment.

4. (Continued):

HEAT LOAD, CABIN: The cabin heat load is the total of solar radiation through transparent areas; convection between the interior surfaces (structure, etc.) and the aircrew/occupant heat rejection to the air; infiltration heat load (when unpressurized) and the heat dissipation of equipment in the cabin.

HEAT LOAD, CONDUCTIVE: It is the heat that enters the cabin from the outside through the structure of the airplane.

HEAT LOAD, EQUIPMENT: Heat load associated with the heat generation of equipment within an aircraft compartment, usually results from the conversion of electrical energy into heat. Heat rejected by fluid lines (hydraulic, fuel, coolant) also form a part of the equipment heat load.

HEAT LOAD, INFILTRATION: Heat load associated with a fluid which infiltrates into an aircraft compartment at a different temperature than that of the compartment.

HEAT LOAD, LATENT: Heat load associated with the change of state of a substance at a constant temperature. Usually refers to evaporative moisture (perspiration) produced by occupants. Latent heat load does not contribute to cabin heat load in a open system; i.e., no cabin air recirculation. When cabin air is recirculated a fraction of the latent heat appears in the cabin heat load. The fraction depends on the ratio of recirculated air/outside air mass flow ratio.

HEAT LOAD, SENSIBLE: Heat load associated with the change in temperature of a substance. Usually refers to the heat produced by occupants.

HEAT LOAD, SOLAR: Heat load associated with solar radiation through transparent areas directly upon flight personnel and equipment and upon the cabin interior surfaces.

HEAT LOAD, TOTAL: The total heat load results from the sum of all individual heat loads on the aircraft including cabin, equipment and any miscellaneous heat loads.

HEAT SINK: Any medium which is the ultimate receiver of energy being transferred as heat.

HEAT TRANSFER COEFFICIENT, OVERALL: The single coefficient which describes the heat transfer rate through the section under consideration. It is the combination of all the individual heat transfer paths through the section and is usually expressed in units of $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot °F$).

HEAT TRANSFER COEFFICIENT, SURFACE OR FILM: The thermal convective conductance of the thin layer of fluid immediately adjacent to the surface, usually expressed in units of $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot °F$).

HEATER, CABIN/COMPARTMENT: A device, usually employing combustion gases, compressed air, or electrical energy, from which heat is transferred to the cabin/compartment air supply.

4. (Continued):

HEATER, EXHAUST HOT AIR TYPE: An exhaust hot air type heater, as used for airplane heating, is one that utilizes, by means of a heat exchanger, the heat of the exhaust gases from the engine for the purpose of directly heating the air supplied to the airplane.

HEATER, INTERNAL COMBUSTION TYPE: An internal combustion type heater is one that utilizes the heat produced by combustion of a fuel within the heater itself.

HEATER, MUFF TYPE: A heater designed to surround the duct or pipe carrying hot gases. Heat will in this way, be transferred to air passed through the annular space between the hot pipe and the muff.

HEATER, RADIANT: A device which accomplishes heating by means of direct radiation.

HEATER, SHROUD: Synonymous with HEATER, MUFF TYPE.

HEATING CAPACITY:

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

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

For dry air this becomes:

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

where:

q = heating capacity (heat transfer rate)
m = mass flow of heating fluid
h = enthalpy
c_p = specific heat capacity, constant pressure
T = temperature
subscripts:
intlet = related to fluid entering heating device
outlet = related to fluid leaving heating device

4. (Continued):

   b. The maximum heat transfer rate achievable from the heating supply as measured by the difference between the total enthalpy of the fluid entering the heat load and the total enthalpy of the fluid leaving the heat load under steady-state conditions and where no phase change occurs in the fluid. It is dependent on the temperature to which the heat load is required to be heated. This definition is the definition usually used in the aerospace industry where the concern is how much heat can be supplied to the heating load by the heating system.

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

      For dry air this becomes:

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

      where:

      subscripts:
      load = related to fluid leaving heating load
      supply = related to fluid supply to heating load

HEATING LOAD, CABIN: The heating load results from radiation loss through transparent areas; convection and conduction heat loss from the cabin through the interior surfaces (structure, etc.) and exterior surfaces to the external ambient air; and infiltration cooling (when unpressurized). It is off set by crew/occupant heat rejection to the air and electronic equipment heat dissipation. This should not be confused with HEAT LOAD, CABIN.

HEATING LOAD, TOTAL: The total heating load results from the sum of all individual heating loads on the aircraft including cabin, equipment compartments and any miscellaneous heating loads. This should not be confused with HEAT LOAD, TOTAL.

HOT GAS BYPASS VALVE: A valve that allows high-pressure, hot refrigerant gas into the cooler low-pressure side of a refrigeration system usually for system capacity control.

HUMIDITY, RELATIVE: The ratio of the partial pressure of water vapor in the air to the partial pressure which saturated water vapor exerts at the same dry bulb temperature. Usually expressed as a percentage.

HUMIDITY, SPECIFIC (HUMIDITY RATIO): The mass of water vapor in air expressed in grams of water vapor per kilogram of dry air (pounds or grains of water vapor per pound of dry air).

HUNTING: A term applied to the undesirable oscillation of a control system or device resulting in a poor state of control.

INDUCTION SYSTEM (VENTILATING): That combination of scoops and ducts that introduces outside air to the air distribution equipment of the airplane.

4. (Continued):

INLET, AIR: Inlets through which air is supplied to the space to be conditioned.

INTENSIFIER TUBE: An intensifier tube, as commonly applied to heating, refers to a tube which passes within the ducts or pipes carrying engine exhaust gases. Such a tube is designed to transfer heat from the exhaust gas to the air flowing within the tube.

INTERCOOLER, CABIN PRESSURIZING: A heat exchanger designed to reduce the temperature between two stages of air compression to enhance overall compression efficiency.

ISOTHERMAL REGION: A region of homogeneous temperature.

JET PUMP: See EJECTOR.

LIQUID RECEIVER, VAPOR CYCLE: A vessel permanently connected to a vapor cycle system used for the storage of liquid refrigerant. It collects or delivers refrigerant as Required to assure no flooding nor starving of the evaporator(s) under changing heat loads.

LIQUID TRANSPORT SYSTEM: A system for extracting heat at one location and rejecting it at another location. Such a system usually consists of a coolant, a coolant reservoir, a recirculation pump, and heat exchangers.

MANUAL CONTROL: See CONTROL, MANUAL.

NBC: Abbreviation for “nuclear, biological, and chemical.” Sometimes referred to as CBR (chemical, biological and radiological). NBC agents are harmful and potentially fatal airborne agents that require the addition of special filtering equipment to aircraft air conditioning systems.

NOZZLE AREA, EFFECTIVE: A resultant effective nozzle throat area which is the product of its geometric area and a dimensionless nozzle discharge coefficient that is dependent upon the pressure ratio across the nozzle.

NOZZLE AREA, GEOMETRIC: The flow area in the throat of a nozzle determined by its physical measurements.

OUTLET, AIR: Openings through which air is removed from the space being conditioned.

PHASE CHANGE: The process of changing from one physical state to another physical state. In ECS, phase change is usually in reference to materials selected that will change phase at a specific operating point or range. Significant heat storage or rejection occurs at constant temperature when most materials change phase. This provides a significant thermodynamic advantage over absorbing or desorbing heat through the process of raising or lowering the temperature of a substance that does not change phase. Phase change materials can be used a passive heat sink, such as in a dash mode of a high performance aircraft or missile. In a thermodynamic cycle, such as a vapor cycle refrigeration system, the phase change refers to a state change from liquid to vapor or vice versa of the working refrigerant.

4. (Continued):

PRESSURE, DYNAMIC: The pressure increase developed by the momentum of a fluid stream.

PRESSURE, PARTIAL: That portion of the static absolute pressure of a mixture of gases, attributable to one gaseous component. It is the gas molar fraction times the mixture's total pressure (Dalton's law of Partial Pressures).

PRESSURE, (DIFFERENTIAL) RAM AIR STATIC (INLET): The differential between the static pressure within the inlet and the static pressure of the undisturbed air stream.

PRESSURE, (DIFFERENTIAL) RAM AIR TOTAL (INLET): The maximum differential between the total pressure within the inlet and the static pressure of the undisturbed air stream (ambient atmosphere).

PRESSURE, STATIC: The pressure that would be measured by a probe having zero velocity relative to the fluid. Pressure measurement taken by the probe normal to the direction of motion of the fluid closely approximates this pressure.

PRESSURE, TOTAL: For incompressible fluids or as an approximation for low Mach numbers, the sum of the static pressure and the dynamic pressure at a given point in a fluid stream. For compressible flow, the pressure a flowing fluid would have if decelerated isentropically to zero velocity.

PRESSURE DIFFERENTIAL, STATIC: The difference between the static pressures at two points in a fluid stream.

PRESSURE DIFFERENTIAL, TOTAL: The difference between the total pressures at two points in a fluid stream.

PRESSURE DROOP: Pressure droop is used to describe the pressure regulation performance of pressure regulators as the inlet pressure to them is varied. Generally, pressure regulators have a constant reference pressure in an actuator opening chamber that the downstream is compared with, causing the valve to modulate to provide a desired constant pressure. However, the reference pressure regulator may have a small pressure unbalanced poppet area that sees the inlet pressure variation. This causes a force unbalance in the reference regulator resulting in a slightly reduced reference, with increasing inlet pressure, being supplied to the valve's actuator opening chamber. The resulting valve's regulated downstream pressure will then decrease slightly with the inlet pressure, and is called pressure droop. Note that pressure regulators can be designed to have not only negative droop, but also positive droop, and with additional complexity, no droop.

PRESSURE DROP (LOSS), TOTAL NONRECOVERABLE: The loss of total pressure between two points in a fluid stream. (Equal to the total pressure differential).

4. (Continued):

PRESSURE RATIO: The ratio of the absolute pressures of a fluid entering and leaving a device. The order of the pressures is customarily chosen so that the value of the pressure ratio is greater than one. For turbines, inlet total to outlet static pressure is commonly used. For compressors, outlet total to inlet total pressure is commonly used.

PRESSURE RECOVERY: The percentage of dynamic pressure that is converted to static pressure and usable for downstream functions. It depends, among other factors, on air velocity at the scoop entrance.

PRESSURIZING, CABIN: Increasing the pressure in a compartment above that of ambient pressure and controlling the pressure in said compartment.

PROBE, DOWNSTREAM FACING: Servo supply pressure sense ports for pneumatic actuated valves, either remotely located or within a valve flow housing, are often of the downstream facing probe type. This sense port type is like a total probe facing in the reverse direction, so the pressure sensed at the port is slightly lower than the free stream static pressure. The advantage of this type of port is that particles of contamination in the flow stream have too much momentum to allow them to turn and enter the downstream facing probe. In this manner, the probe is as effective as a filter, and never needs maintenance. However, valves that consume some servo air and spend most of their time closed should have their supply pressure sense port protected by a filter.

PUMP, JET: See EJECTOR

QUENCH VALVE: A refrigeration system valve used in conjunction with a HOT GAS BYPASS VALVE that is designed to control the superheat into the compressor suction line. This valve functions very much like a Thermostatic Expansion Valve and controls by metering the flow of liquid refrigerant. It is used to limit the inlet temperature where a suction gas cooled motor is utilized.

RECOVERY FACTOR: The fraction of the theoretical stagnant temperature or pressure that is recovered in a ram air scoop or similar devise. Typically the factor is 50 to 85%.

RECUPERATOR: Very similar if not the same as a reheater, but the term is more commonly used for engines where the exhaust gas is used to preheat the inlet air stream to increase cycle efficiency. Typically a heat exchanger type of hardware.

REFRIGERANT: The medium of heat transfer in a refrigeration system which picks up heat by evaporating at a low temperature and pressure and gives up heat by condensing at a higher temperature and pressure.

REFRIGERATION CYCLE: The complete course of operation of a refrigerant back to a starting point, evidenced by: a repeated series of thermodynamic processes, or flow through a series of apparatus, or a repeated series of mechanical operations.