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MILITARY SPECIFICATION

ENVIRONMENTAL CONTROL SYSTEMS, AIRCRAFT, GENERAL REQUIREMENTS FOR

This specification is approved for use by the Naval Air Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification establishes the general requirements for design and performance of aircraft Environmental Control Systems (ECS) required for occupied spaces and equipment. It includes pressurization, heating, cooling, ventilating, mositure control, bleed air system, ram air supply, pressure and anti-G suit systems, defogging, defrosting, anti-icing, rain removal, electronic/electrical equipment environment, boundary layer control and related systems.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commanding Officer, Naval Air Engineering Center, Engineering Specifications and Standards Department (ESSD), (Code 93), Lakehurst, NJ 08733 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 1660

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified. the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

QQ-C-320	Chromium Plating (Electrodeposited)
QQ-P-416	Plating, Cadmium (Electrodeposited)
QQ-Z-325	Zinc Coating, Electrodeposited, Requirements for

Military

MIL-S-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces.
MIL-I-5099	Indicator; Cabin Air Pressure, 1-7/8 Inch Dial, Type MA-1
MIL-V-5379	Valves, Safety, Cabin Air, General Specifications for
MIL-E-5400	Electronic Equipment, Aerospace, General Specifications for
MIL-H-5484	Heater, Aircraft, Combustion Type
MIL-T-5842	Transparent Areas, Anti-Icing, Defrosting, and Defogging Systems, General Specification for
MIL-E-6051	Electromagnetic Compatibility Requirements, Systems
MIL-S-6144	Sound and Thermal Insulation for Aircraft; General Specifications for Installation of
MIL-R-6855	Rubber; Synthetic, Sheet, Strips, Molded or Extruded Shapes
MIL-P-6992	Pump Assembly; Fuel, Electrically Driven, Aircraft Heater
MIL-E-7080	Electrical Equipment; Aircraft, Selection and Installation of
MIL-I-7171	Insulation Blanket; Thermal Acoustical
MIL-F-7179	Finishes and Coatings: Protection of Aerospace Weapons Systems, Structures, and Parts, General Specifications for
MIL-G-7734	Gages, Pressure, Engine and Utility, Aircraft
MIL-D-7890	Design and Installation of Anit-G Suit Pressure Systems in Jet Propelled Aircraft
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles

MIL-A-8625	Anodic Coatings, for Aluminum and Aluminum Alloys
MIL-I-8670	Installation of Fixed Guns and Associated Equipment in Naval Aircraft
MIL-I-8673	Installation and Test of Aircraft Flexible Weapons Systems
MIL-D-8706	Data and Test, Engineering: Contract Requirements for Aircraft Weapons Systems
MIL-H-8796	Hose, Air Duct, Flexible, Aircraft
MIL-D-8804	De-Icing System, Pneumatic Boots, Aircraft, General Specification for
MIL-D-8806	Acoustical Noise Level in Aircraft, General Specification for
MIL-T-8879	Screw Threads, Controlled Radius Root with Increased Minor Diameter; General Specification for
MIL-R-9345	Regulator, Air Pressure, Aircraft Cabin, General Specification for
MIL-T-18606	Test Procedures for Aircraft Environmental Systems
MIL-T-18607	Thermal Anti-icing Equipment, Wing and Empennage
MIL-T-23103	Thermal Performance Evaluation, Airborne Electronic Equipment and Systems, General Requirement for
MIL-A-23121	Aircrew Environmental, Escape and Survival Cockpit Capsule System; General Specification for
MIL-O-27210	Oxygen, Aviators Breathing, Liquid and Gas
MIL-C-38999	Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect Environment Resistant, Removable Crimp Contacts, General Specification for
MIL-B-81365	Bleed Air Systems, General Specification for
MIL-R-81367	Rain Removal System, Aircraft Windshield, Jet Air Blast
MIL-B-81592	Bleed Air Systems, Load Analysis of, Method for
MIL-C-83488	Coating, Aluminum, ION Vapor Deposited.

STANDARDS

Military

MIL-STD-143	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-210	Climatic Extremes for Military Equipment
MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-461	Electromagnetic Emission Susceptibility Requirements for the Control of electro magnetic Interface

MIL-STD-470	Maintainability Program Requirements (for Systems and Equipments)
MIL-STD-704	Aircraft, Electric Power, Characteristics
MIL-STD-785	Reliability Program for Systems and Equipment Development and Production
MIL-STD-800	Procedure for Carbon Monoxide Detection and Control in Aircraft
MIL-STD-810	Environmental Test Methods
MIL-STD-882	System Safety Program Requirements
MIL-STD-889	Dissimilar Metals
MIL-STD-1247	Marking, Functions and Hazard Designations of Hose, Pipe and Tube Lines for Aircraft, Space and Missile Systems
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-STD-2072	Survivability, Aircraft, Establishment and Conduct of Programs for
MS-16051	Coupling, Ground Cooling, Combat Type Aircraft
MS-16052	Air Inlet, Combat Aircraft, Ground Cooling
MS-33561	Connection, Aircraft Ground Air Conditioning, 5 Inch, Minimum Requirements
MS-33562	Connection, Aircraft Ground Air Conditioning, 8 Inch, Minimum Requirements
MS-33565	Connections Ground Leakage Test, Pressurized Cabin, Aircrafts
MS-33656	Fitting End, Standard Dimensions for Flared Tube Connection and Gasket Seal
MS-33740	Nipple, Pneumatic Starting, 3 inch ID, outline dimensions of

HANDBOOKS

Military

MIL-HDBK-221	Fire Protection Design Handbook for U.S. Navy Aircraft Powered by Turbine Engines

(Copies of specifications, standards, handbooks, drawings, and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.1.2 Other Government documents, drawings and publications. The following other Government documents, drawings, and publications form a part of this specification to the extent specified herein.

Air Force-Navy Aeronautical

AN-929	Cap Assembly, Pressure Seal, Flared Tube Fitting

Air Force

AFOSH Standard 161-8 Permissible Exposure Limits for Chemical Substances

PUBLICATIONS

Military

MIL-BUL-544 List of Specifications and Standards (Book Form)

2.2 Other publications. The following document(s) form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DOD adopted shall be the issue listed in the current DODISS and the supplement thereto, if applicable.

Society of Automotive Engineers (SAE), Inc. Aerospace Recommended Practice

ARP699C-High Temperature Pneumatic Duct Systems for Aircraft

(Application for copies should be addressed to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.

3. REQUIREMENTS

3.1 System components. The environmental control system shall include all instruments, controls, valves, ducting, filters, water separators, dehydrators, compressors, refrigeration units, heaters, dust separators, heat exchangers, pumps, fluid lines. and such other equipment necessary to provide the required environmental control system performance for all operating conditions of the aircraft.

3.2 Design conditions.

3.2.1 Design atmospheric conditions.

3.2.1.1 Operations. The design ambient conditions of the atmopsphere under which equipment shall remain operational shall be in accordance with the operations criteria of MIL-STD-210, Ground and World-Wide Air Environments.

3.2.1.2 Performance. The design ambient conditions of the atmosphere for meeting the performance requirements of this specification shall be in accordance with the 10 percent risk criteria of MIL-STD-210, Ground and World-Wide Air Environments. If a 10 percent risk criteria is not available for a given parameter, the highest risk factor provided shall be used.

3.2.1.3 Ground operation humidity. For joint occurence of high temperature and high humidity, the 1 percent curve of figure 1 shall be used in conjunction with 3.2.1.1 and the 10 percent curve of figure 1 shall be used in conjunction with 3.2.1.2.

3.2.2 Electrical equipment. Electrical equipment environment factors are specified in MIL-E-7080.

3.2.3 Electronic equipment. The environment factors for electronic equipment used in the design of environmental control systems shall be in accordance with MIL-E-5400.

3.2.4 Transparencies. The atmospheric conditions specified in MIL-T-5842 shall govern the design of defogging and defrosting systems for all transparencies.

3.2.5 Icing conditions for wings and empennage. The atmospheric conditions specified in MIL-T-18607 shall govern the design of the thermal anti-icing systems and MIL-D-8804 for pneumatic boot de-icing systems.

3.2.6 Transient operating conditions. The ECS shall be capable of continuous operations and meet performance requirements during all transient conditions such as rapidly changing altitudes, extremes of temperature, accelerations, or other conditions which could be encountered during take-off, flight, landing the aircraft, and during ground conditions when engines are running.

3.2.7 System sizing. The ECS shall be sized to provide the required heating and cooling capacity during all anticipated ground and flight operations. The cooling provisions for electronic equipment shall provide for an electronic heat dissipation load 25 percent greater than the equipment heat load of the first production aircraft. Enough clearance in the aircraft shall be provided to allow the ECS to enlarge to accomodate an additional 25 percent growth in electronic heat load (50 percent greater than that of the first production aircraft).

3.3 Selection of materials, parts, and processes. The materials, parts and processes used shall be selected primarily to accomplish the designated performance requirements. Specifications and standards for all materials, parts and processes shall be selected in accordance with MIL-STD-143 and MIL-BUL-544. These specifications and standards shall be presented for review and acceptance by the procuring activity (see 6.2.2).

3.3.1 Materials. All parts of the systems shall be made of corrosion resisting material or shall be suitably protected against corrosion internally and externally. The use of dissimilar metals in contact with each other shall be suitably protected against galvanic corrosion. Dissimilar metals are defined in MIL-STD-889.

3.3.1.1 Magnesium. Magnesium and Magnesium alloys shall not be used.

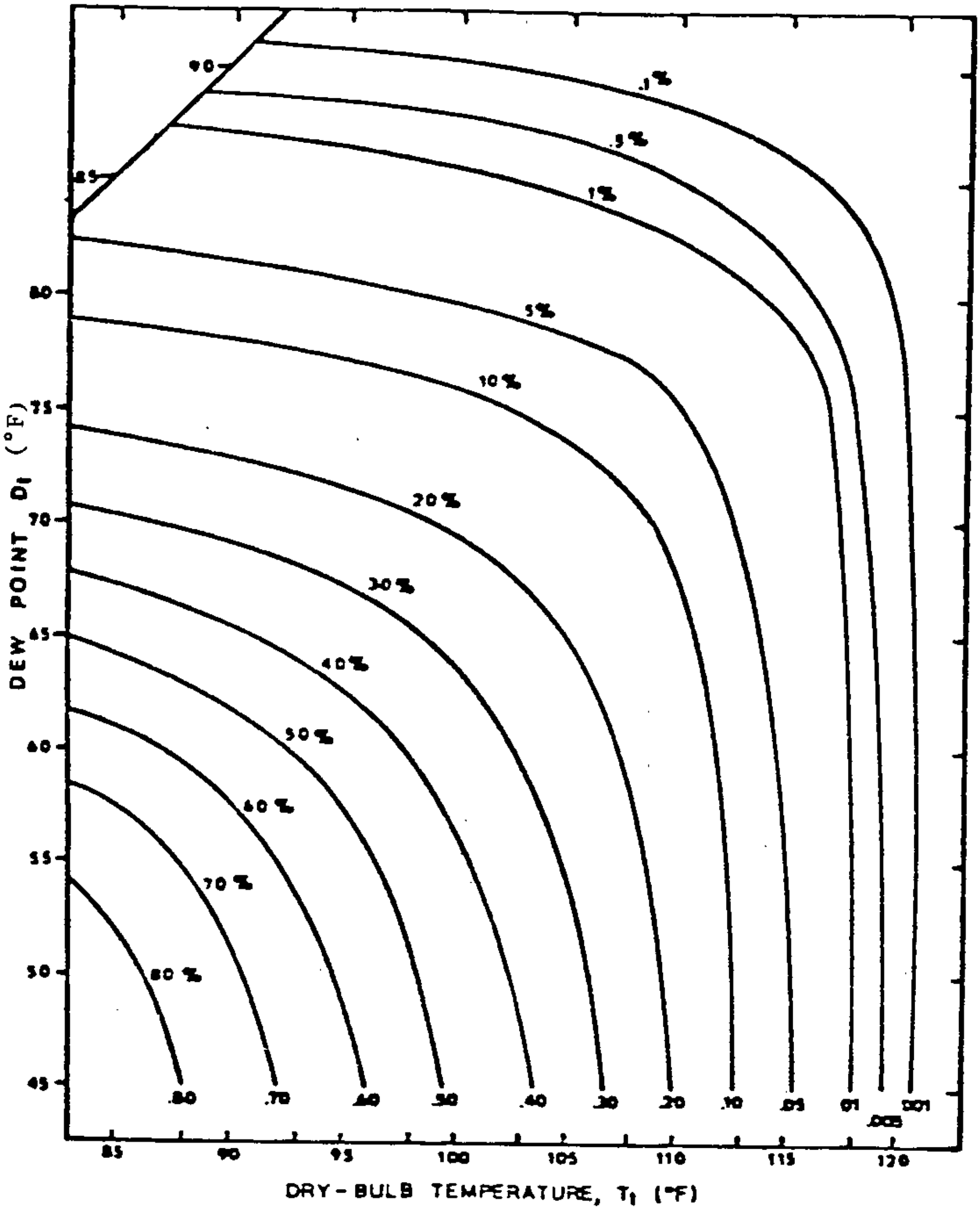

FIGURE 1 Percent risk for joint occurrence of high temperature and high humidity (see MIL-STD-210 for definition of percent risk)

3.3.1.2 19-9 DL steel. 19-9 DL stainless steel shall not be used.

3.3.1.3 Non-specification material. Materials for which no federal, military, or industry specification exists, the contractor shall develop specifications covering technical requirements and test methods thereof and acceptance criteria for review and acceptance by the procuring activity (see 6.2.2).

3.3.2 Parts.

3.3.2.1 Standard parts. Standard parts (MS, AN or JAN) shall be used whenever they are suitable for the purpose and shall be identified on the drawings by their part numbers.

3.3.2.2 Interchangeability. All parts having the same manufacturer's part number shall be functionally and dimensionally interchangeable as defined in MIL-I-8500.

3.3.3 Processes.

3.3.3.1 Protective treatment.

3.3.3.1.1 Painting. Exposed corrosion and heat resisting steel parts need not be painted. Finishes and coatings for all other exposed metal surfaces shall be Type I in accordance with MIL-F-7179.

3.3.3.1.2 Aluminum anodizing. All aluminum and aluminum-alloy parts shall be anodized in accordance with MIL-A-8625, Type II. Parts which cannot be anodized shall receive chemical conversion treatment in accordance with MIL-S-5002.

3.3.3.1.3 Steel plating. All steel parts shall be plated. The parts which reach temperature detrimental to plating shall not be plated.

3.3.3.1.4 Chromium plating. Chromium plating shall be in accordance with QQ-C-320. Plating shall be applied directly on steel and at a rate not greater than 0.0005 inches per hour.

3.3.3.1.5 Zinc plating. Zinc plating shall be in accordance with QQ-Z-325. Zinc plating shall not be used on parts the temperature of which may exceed 600°F (315°C) in service.

3.3.3.1.6 Cadmium plating. Cadmium plating shall be electro-deposited in accordance with QQ-P-416, Type II, class 2, except cadmium plating shall not be used on parts the temperature of which exceeds 450°F (232°C) in service.

3.3.3.1.7 Corrosion-Resistant Steel (CRS). Corrosion resistant parts need not be plated unless required for dissimilar metal interface or functional reasons. They shall be passivated in accordance with MIL-S-5002.

3.3.3.1.8 Aluminum plating. Aluminum plating on steel by ION Vapor Deposit (IVD) shall be in accordance with MIL-C-83488.

3.3.3.2 Threads. Machine screw threads shall be in accordance with MIL-T-8879.

3.4 Performance requirements.

3.4.1 Pressurization. The pressurization systems for occupied and designated equipment compartments shall automatically maintain the nominal pressure schedules detailed herein. Aircraft with operating ceiling greater than 20,000 feet shall be pressurized.

3.4.1.1 Fighter and attack aircraft. The cabins of fighter and attack aircraft shall be pressurized as shown in figure 2.

3.4.1.1.1 Pressure change rate. The rate of pressure change during normal operations shall be not greater than 0.2 psi/sec for decreasing pressure and 0.2 psi/sec for increasing pressure under all operating conditions including transients. For emergency pressure release and repressurization, the maximum rate of pressure change shall be 1.0 psi/sec for decreasing pressure and 0.5 psi/sec for increasing pressure.

3.4.1.2 Other aircraft. The occupied compartments of aircraft other than fighter and attack aircraft shall be pressurized so that any cabin altitude between -1,000 and +10,000 feet may be selected by the crew members and may be maintained up to a maximum pressure differential equivalent to that between an 8,000-foot cabin altitude and the maximum operating cruise altitude of the aircraft. In addition, the cabin altitude for ASW and AEW aircraft shall be not greater than 5,000 feet during mission performance. Pressure regulation tolerance shall be ±0.15 psi in the pressurized range and +.25 psi, -0.0 psi in the unpressurized range. The cabin pressure selection tolerance shall be ±300 feet.

3.4.1.2.1 Pressure change rate. The maximum rate of pressure change during normal operation shall be 0.08 psi/sec for decreasing pressure and 0.04 psi/sec for increasing pressure under all operating conditions including transients. The capability to select and automatically control a pressure change rate anywhere in the range of 100 to 2000 feet/min shall be provided. For emergency pressure release and repressurization, the maximum rate of pressure change shall be 1.0 psi/sec for decreasing pressure and 0.5 psi/sec for increasing pressure.

3.4.1.3 Equipment. The pressurization of equipment and equipment compartments and bays shall be in accordance with applicable equipment specification.

3.4.1.4 Decompression. In the event of an emergency loss of pressure means shall be provided to protect the occupants as follows:

a. The occupants wearing diluter demand oxygen equipment shall not be exposed to pressure altitudes higher than 40,000 ft under any condition.

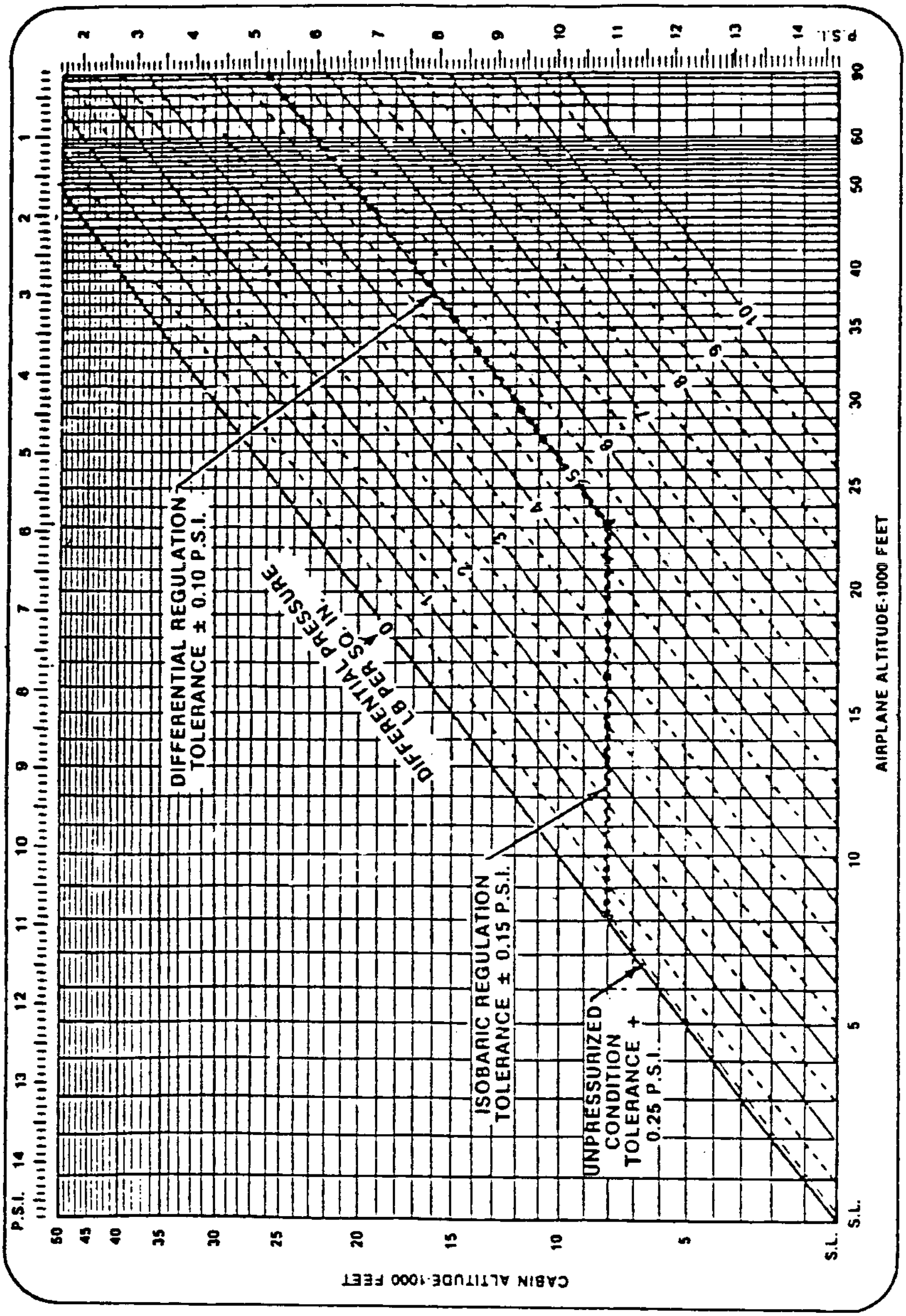

FIGURE 2 Cabin pressure for fighter and attack aircraft

b. Occupants wearing pressure demand oxygen equipment shall not be exposed to pressure altitudes higher than 50,000 ft under any condition.

c. The occupants without oxygen equipment which are not crew members shall be brought to pressure altitudes below 23,000 feet as soon as practical and shall not be exposed to an altitude of 23,000 feet, or above, for more than 10 minutes.

3.4.1.5 Engine speed effect. The cabin differential pressure change shall be minimized when any main propulsion engine power is changed at maximum rate of any ground or flight operating condition as follows: ground idle to 100 percent, flight idle to 100 percent, 100 percent to flight idle. The tolerances listed on figure 1 shall not be exceeded by more than 0.1 psi. If necessary, special cabin air inflow controls shall be included to control the rate of airflow increase and limit the change to 0.1 psi greater than the tolerances shown in Figure 2.

3.4.1.6 Positive and negative pressure relief. Provisions shall be incorporated to prevent structural damage or personnel injury due to sudden compression or decompression. For multi-compartment pressurized aircraft, provisions shall be incorporated to prevent structural damage due to excessive positive or negative pressure within and between pressurized compartments.

3.4.1.7 Pressure lock. Pressurized aircraft which have areas of different pressure from the cabin shall be provided with pressure locks. The lock shall permit passage of crew members from the cabin to other areas of the aircraft without decompressing the cabin. Controls for the lock pressurization system shall be located both within the lock and on both outside surfaces of the lock bulkhead. These controls shall permit adjustment of the rate of change of pressure within the lock as follows:

a. Minimum time for lock pressure to conform with either cabin pressure, or with ambient atmospheric pressure - one minute.

b. Maximum time for lock pressure to conform with either cabin pressure, or with ambient atmospheric pressure - five minutes.The adjustment shall be of the infinitely variable type to enable the selection of a rate of change of pressure to conform with the needs of the individual crew member.

3.4.2 Ventilation.

3.4.2.1 Air supply. Air to occupied spaces shall be suitable for breathing purposes for extended periods and shall not contain noxious odors, toxic compounds or any contaminants which have an adverse effect on visibility or operator performance. Contaminant levels shall be in accordance with paragraph 3.4.7. Particular attention shall be given to the design of the cabin air supply to prevent contamination by the aircraft engine fuel or lubrication system (see 3.4.7.5).

3.4.2.1.1 Storage systems. A storage system used as a source of supply for the occupied spaces atmosphere shall be designed to insure that the partial pressure of oxygen within the cabin shall not fall below 2.1 psi at any flight altitude. The system shall include means for automatically preventing carbon dioxide contamination from exceeding 0.5 per cent under any operating condition. Complete design, engineering and performance data of the system selected shall be acceptable to the procuring activity prior to any procurement or parts fabrication for the first airplane (see 6.2.2).

3.4.2.2 Airflow. Ventilation airflow of the occupied spaces and equipment compartments during normal system operations shall be adequate to remove contaminants and moisture added to the air by occupants and by equipment. Minimum airflow shall be in accordance with figure 3. 100 percent of the airflow to the cockpit shall be fresh air. A minimum of 50 percent of the airflow to other occupied compartments shall be fresh air. Galley and toilet area shall be vented with fresh air and provided with direct overboard exhaust outlets sufficient to eliminate odors. In addition to the above requirements, the minimum airflow rate into occupied spaces of pressurized aircraft shall be 1.8 times the production leakage rate.

3.4.2.2.1 Emergency ventilation. An emergency ventilation system shall be provided to supply clean ventilating air to the occupied compartments during interims when the primary environmental control system is inoperative.

3.4.2.2.2 Equipment compartments. Airflow for specific equipment shall be as required by the detail specifications covering the equipment involved.

3.4.2.3 Air distribution. Air systems shall be designed to give specified environment without causing discomfort of occupants. The ventilators shall be manually operated by controls convenient to the cabin occupants and shall be water tight in the closed position only. Provision shall be made at the outlet at each crew station for individual control of the volume and flow direction of air delivered.

3.4.2.3.1 Cabin air distribution. Cabin air distribution shall improve crew comfort and minimize occupant heat stress. Cabin airflow shall be directed in such manner that the crew's exhalation is prevented from coming in contact with transparencies. If an air blast type defogging and defrosting system is used, controls shall be installed to permit incoming air for the cockpit to be directed to the windshield front panel and side panels. The velocity of air at head level in crew stations shall be capable of being maintained below 200 feet per minute (1 meter per second) in combat aircraft and 100 feet per minute (0.5 meter per second) in non-combat aircraft. Particular attention shall be given to preventing the flow of air directly into occupant's eyes.

3.4.2.3.2 Equipment air distribution. Air introduced into electronic, electrical, armament, or other equipment shall be distributed as specified in the equipment detail specification.

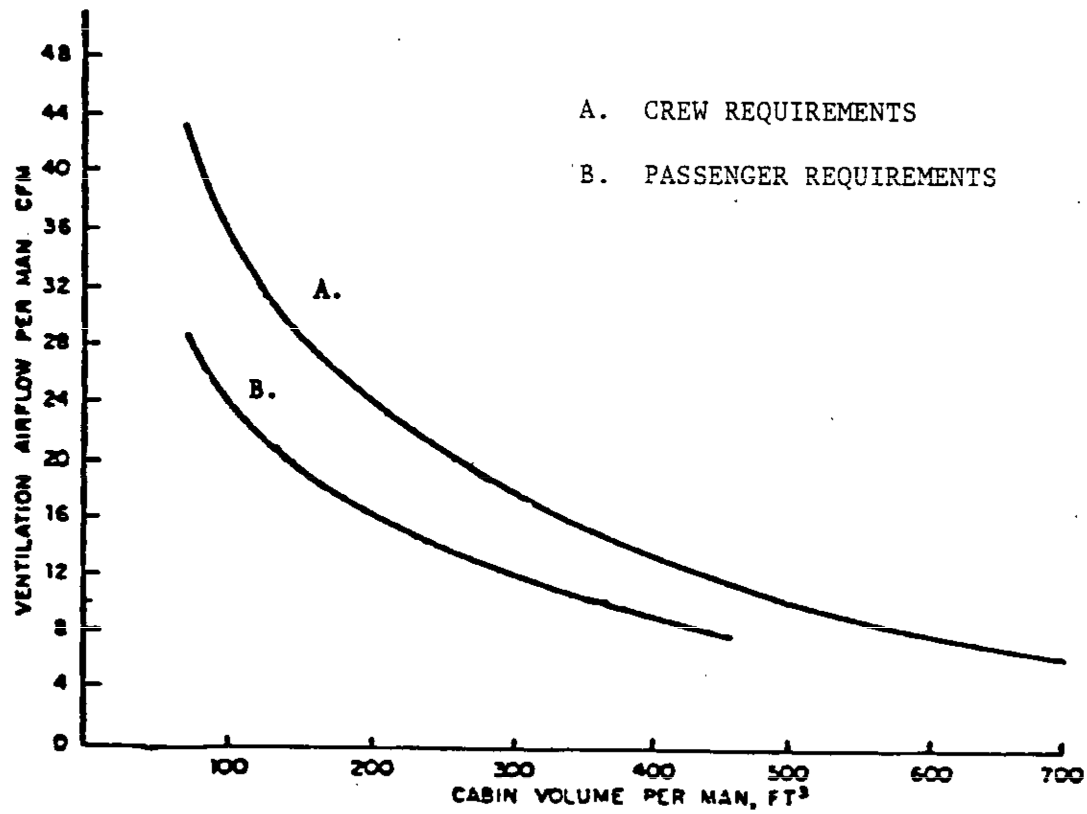

FIGURE 3 Ventilation flow rate as a function of cabin volume

3.4.2.4 Gun gas elimination. Adequate ventilation shall be provided to prevent excessive accumulations of gun gases, and suitable sealing provisions shall be made to prevent contamination of adjacent compartments in excess of the limits given in this specification. For fixed gun installations, see MIL-I-8670(Aer) and for flexible weapons systems, see MIL-I-8673.

3.4.3 Leakage from occupied compartments. All pressurized aircraft shall meet the following requirements.

3.4.3.1 Production leakage rate. The production leakage rate is defined to be the leakage rate of the aircraft following completion of the acceptance flight tests just prior to delivery of the using command. The maximum allowable production leakage rate of the occupied compartments shall be the lesser rate that will result from the following:

a. The maximum allowable production leakage rate for fighter and attack aircraft shall be not greater than one-half the rate that assures the compartment pressure altitude will not exceed 30,000 feet during a maximum rate of descent from maximum operating ceiling with the compartment initially pressurized at 10 pounds per square inch absolute (psia). The maximum allowable production leakage rate for other aircraft shall be not greater than one-half the rate that assures the compartment pressure altitude will not exceed 42,000 feet during a maximum rate of descent from maximum operating ceiling with the compartment initially pressurized at a 35,000 foot pressure altitude.

b. The maximum allowable production leakage rate under the most adverse flight condition of pressure and temperature shall be not greater than $0.07V^{0.667} + 0.5$ pounds per minute, where V is the volume of the pressurized enclosure in cubic feet. This value for leakage includes the leakage from outflow valve and air conditioning units.

c. The maximum allowable production leakage rate shall be not greater than one-half the rate that assures the required pressure schedule can be maintained during descent with engines at idle speed.

d. The maximum allowable production leakage rate for aircraft that have more than one air conditioning unit supplying air to the pressurized compartment shall be not greater than one-half the rate that assures that the required pressure schedule can be maintained with one air conditioning unit inoperative.

3.4.3.2 In-service leakage rate. The maximum allowable in-service leakage rate of occupied compartments shall be 1.6 times the maximum allowable production leakage rate corrected to sea level standard conditions. The in-sevice leakage rate shall be the leakage rate included in field maintenance manuals.

3.4.4 Air conditioning. Unless otherwise specified in the aircraft detail specification, all aircraft shall have an air conditioning system which shall adequately maintain temperatures in all compartments, pressurized or unpressurized, within the prescribed limits under all possible flight and ground conditions. Air conditioning may be accomplished by use of air cycle refrigeration, vapor cycle refrigeration, ram air, compartment air, thermo electric refrigeration, or other means as approved by the procuring activity with the design data (see 3.12).

3.4.4.1 Heating. A heating system shall be provided for all aircraft. Sufficient heating capacity shall be provided for occupied compartments and for compartments housing cold sensitive equipment. The source of heat may be engine bleed air, combustion heater, engine exhaust heater, electric heater, auxiliary power unit, or auxiliary compressor.

3.4.4.2 Occupied compartments.

3.4.4.2.1 Fighter and attack aircraft. The pilot envelope temperature of the crew shall be maintained within the limits of curves #3 and #2 of figure 4. The pilot envelope temperature is defined as the arithmetical average of temperature measurements taken about the envelope occupied by the crew member and should include measurements taken at the ankle, knees, hips, chest, shoulders, and head. The Wet Bulb Globe Temperature (WBGT) in the vicinity of crew member's head and shoulder shall not exceed 90°F (32°C) during flight operations and 95°F (35°C) during ground operations.

$$WBGT = .7T_{wb} + .2T_{bg} + .1T_{db},$$

Where T_{wb} = wet bulb temperature
T_{bg} = black globe temperature from a 5cm sphere, and
T_{db} = dry bulb temperature,

For ambient environments which exceed the performance limits (see 3.2.1.2) but are within the operations limits (see 3.2.1.1), pilot envelope temperatures shall be maintained within the thermal tolerances provided in MIL-STD-1472.

3.4.4.2.2 Other aircraft. The average compartment temperature of occupied compartments of other air-conditioned aircraft shall be maintained within the limits of curves #1 and #2 of figure 4. The WBGT in the vicinity of the head and shoulder levels of crew stations shall be not greater than 90°F (32°C). For ambient environments which exceed the performance limits (see 3.2.1.2) but are within the operations limits (see 3.2.1.1), the pilot envelope temperatures of crew stations shall be maintained within the thermal tolerances specified in MIL-STD-1472.

3.4.4.2.3 Nonair-conditioned aircraft. Adequate ventilation shall be provided under all possible flight conditions to prevent a rise in temperature exceeding 10°F (5°C) above ambient temperatures within occupied compartments. Aircraft heating systems shall be capable of maintaining a temperature of +60°F (15°C) in occupied spaces, during flight in atmospheric conditions where

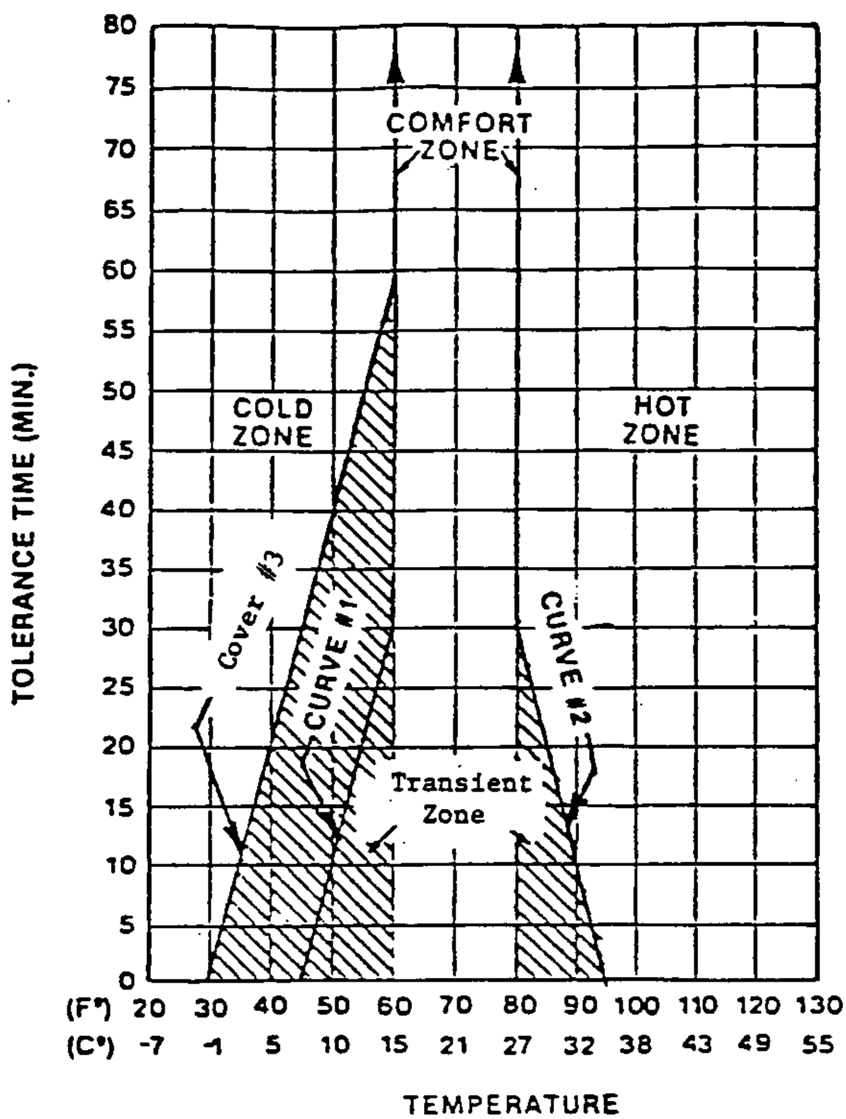

FIGURE 4 Thermal requirements for occupied compartments

the outside air temperature is -65°F (-53°C) or above. At lower outside air temperature, the heating system shall be capable of maintaining a temperature rise of 125°F (51°C) above outside air temperature. At outside air temperatures above -55°F (-48°C) the heating and ventilating system shall automatically regulate the air temperature to 70°F plus or minus 5°F (21°C ±3°C) in occupied spaces.

3.4.4.3 Electronic equipment and equipment compartments. The ECS shall, as a minimum, maintain equipment installed in the aircraft within the temperature ranges specified in the equipment specification.

3.4.4.3.1 Electronic equipment. The cooling and heating of electronic equipment both on the ground and in flight, shall be in accordance with MIL-STD-454 and the individual equipment specifications. Conditioned air for avionic equipment shall be provided as free flow ambient or direct forced flow. Other advanced cooling designs used shall be in accordance with the equipment specifications. The avionics equipment, both ambient cooled and external source cooled, shall be maintained within the Steady State Thermal Performance Limit, as defined by MIL-T-23103, for all flight and ground steady state conditions. Steady state for this purpose shall be defined as any ground or flight condition which can exist for more than 15 minutes. If the steady state thermal performance limit is not available, the equipment shall be maintained within the environment specified in the individual equipment specification. Cooling of Contractor Furnished Equipment (CFE) shall be sufficient to meet aircraft reliability goals. For transient conditions (less than 15 minutes), the electronic equipment shall be maintained within maximum intermittent operating temperature as defined in the equipment specification. For ambient environments which exceed the performance conditions (see 3.2.1.2) but are within operations conditions (see 3.2.1.1), the electronic equipment shall be maintained within the maximum intermittent operating temperature as defined in the equipment specifications.

3.4.4.3.2 Electrical equipment. Compartments which contain electrical equipment shall have cooling designed to meet the requirements of MIL-E-7080.

3.4.4.3.3 Other equipment. Equipment not included above such as weapons, gun systems, armament, photographic and other miscellaneous items shall have compartment or bay cooling as required to meet the equipment specifications.

3.4.4.4 Ground operations requirements. All performance requirements contained herein shall be met while the aircraft is on the ground without aircraft engines operating, the ECS requirements shall be provided by internal or external sources. When external sources are used, the ECS shall be compatible with existing Navy mobile cooling units and carrier deck facilities.

3.4.4.4.1 Ground cool down and heat up. With or without the engines operating, the ECS shall be able to provide the requirements of 3.4.4.2 and subparagraphs and 3.4.4.3 and subparagraphs starting from a cold soak of -60°F (-50°C) and a hot soak of 120°F (49°C) with the cockpit at 160°F (72°C) within the time limits required to meet mission requirements.

3.4.4.5 Temperature limits.

3.4.4.5.1 Surface temperature limits. Preselection of thermally safe construction materials or component insulation shall be used in the heating system to ensure that inadvertent contact of bare skin or voluntary contact (such as in adjusting controls) will not result in injury or in an abrupt, disruptive pain reaction on the part of the crew. The temperature of those portions of the outside surface of the heating installation or ducts within reach of operating and maintenance personnel shall be not greater than the Equipment Thermal Hazard Temperatures of MIL-STD-1472.

3.4.4.5.2 Heated air limits. The design and construction of the heating system shall be such that the temperature of the air delivered from the heat exhanger or combustion heater under any conditions of flight shall be not greater than 450°F (232°C) exiting the heat exchanger or combustion heater or 200°F (93°C) entering an occupied compartment being heated.

3.4.4.5.3 Structural member limits. The installation of the heating system shall be such that the temperature of no structural member of the airplane is raised above the maximum allowable temperature of the affected material under any condition of operation of the heating system.

3.4.4.5.4 Auto ignition. Operating temperatures shall not raise the temperture of any material to its auto ignition temperature except where necessary for operation such as combustion heater combustion chamber.

3.4.4.5.5 Temperature variation. The temperature between the head and foot levels of crew stations shall not vary more than 10°F (5°C). The temperature variation between any two points in the occupied compartment of other than fighter and attack aircraft shall not deviate more than ±10°F from the average compartment temperature. The minimum average floor temperature during all heating conditions shall be 60°F (15°C) and the maximum shall be not greater than the Equipment Thermal Hazard Temperatures of MIL-STD-1472.

3.4.4.5.6 Combustion heater. If a combustion type heater is employed as the primary or auxiliary source of heat, it shall conform to MIL-H-5484.

3.4.4.5.7 Aircraft equipment. Temperature limits of all aircraft equipment, such as weapon systems, electronic equipment, electrical equipment, instruments, and photographic equipment shall be in accordance with the individual equipment specification.

3.4.5 Humidity control. The system shall be designed to prevent discharging air with entrained moisture onto windshields or into pressure suits, occupied compartments, electronic equipment compartments, or forced cooled electronic equipment. Air forced directly over the surfaces of miniaturized or basic parts in electronic equipment shall, in addition, have a dew point of 40°F (4.4°C) or less. All air delivered to the compartments or equipment by any means, including ram air shall meet these requirements, except where ram air is used as an emergency backup or where air is being supplied from a ground cart.

3.4.6 Accoustical noise level. Acoustical noise of the ECS when combined with acoustical noise from all other sources shall be not greater than the maximum acceptable levels of MIL-A-8806.

3.4.6.1 Heater noise. In flight, the noise produced by the combustion heating system, when installed, shall not increase, at any frequency within the audible airplane sound spectrum, the total sound level within the enclosed and heated spaces by more than two decibels.

3.4.6.2 Ventilation noise. The design and location of air outlets and ducts shall be such that, in flight, the total sound level in the enclosed spaces will not be increased more than three decibels when the ventilation system is operating.

3.4.6.3 Vibration isolators. Any ECS components, whose operation is of such nature that noise or vibration would be transmitted to the airplane structure, shall be mounted on vibration damping supports of an approved type.

3.4.7 Contamination. Adequate control of the contamination levels in the occupied compartment atmosphere and the occupant's breathing atmosphere shall be provided by the environmental control system. The system shall prevent the concentration of harmful or irritating substances in the occupied compartment atmosphere from exceeding the maximum allowable concentration, as listed in AFOSH Standard 161-8.

3.4.7.1 Carbon monoxide. The concentration of Carbon Monoxide (CO) in the occupant's breathing atmosphere shall be not greater than the limits specified in MIL-STD-800.

3.4.7.2 Fluid systems. Fluid systems design shall preclude the possibility of contaminating the environment of occupied spaces due to leakage of the fluid.

3.4.7.3 Oxygen. The oxygen supplied to the occupant's breathing atmosphere shall be in accordance with MIL-O-27210.

3.4.7.4 Exhaust heaters. Engine exhaust heating systems shall have provisions for extracting heat so that no single failure will result in contamination of the cabin air supply by exhaust gases.

3.4.7.5 Fuel vapors and flammable gases. Concentration of fuel vapors and other flammable gases in any part of the airplane shall be not greater than the following percentages of the Lower Explosive Limit (LEL) of the mixture, except that there shall be no conflict with the requirements of MIL-STD-800 for gases contaminated with carbon monoxide.

Location	% LEL (Av.)
Any compartment occupied by personnel (Extended periods)	2-1/2
Any compartment intended for occupancy for periods up to five minutes in duration	7-1/2
Any part of the airplane (outside of the fuel system)	20

3.4.7.6 Filtration. Satisfactory air filtration of radioactive particles and chemical and biological warfare agents shall be provided in accordance with the aircraft detail specification requirements.

3.4.7.7 Fuel transfer. Aircraft fuel systems which utilize compressed air derived from the same source as the cabin air supply and used for pressurization for fuel transfer of fuel tank pressurization shall be isolated from compartment air supply.

3.4.8 Controls.

3.4.8.1 Temperature. Automatic temperature control systems shall be provided.

3.4.8.1.1 Occupied compartments. The automatic cabin temperature control system shall be provided with a manual override. Each compartment shall have independent temperature controls. The controls shall be readily accessible to the crew. For any system condition causing flow disturbances, flow overshoot or undershoot shall be not greater than ten percent of the valve existing immediately before the disturbance and the flow shall be within five percent of the final control level within two cycles or 10 seconds, whichever is less, following completion of the condition causing the disturbance. The temperature within each compartment shall be maintained within ±3°F (±1.7°C) of its selected value. The temperature selector for automatic cabin temperature control shall be designed for the range of 10°F (5°C) above and below the comfort zone of figure 4. The effect of solar radiation upon occupant comfort shall be minimized by providing suitable adjustable sunshield or cooling air outlets.

3.4.8.1.1.1 Combustion heater system. The controls for starting the combustion heater system in operation shall be simple and the shut off control on the heating system shall consist of a single control for shutting off all the component parts of the system. An indicator shall be provided to operate automatically whenever the temperature of the heated ventilating air exceeds 350°F (176°C) at the heater outlet and when air temperature at compartment outlet exceeds 200°F (93°C). (See 3.4.3.3.2)

3.4.8.1.1.2 Engine exhaust heater. If an engine exhaust heater is installed, there shall be a single control for stopping all flow of heated air into the occupied spaces.

3.4.8.1.1.3 Bleed air heating. A bleed air heating system shall have a single control to completely shut off the flow of bleed air to the heating system. During steady state conditions and with single component failure, the air temperature entering occupied compartments shall be not greater than 200°F (93°C). An indication of overtemperature conditions shall be provided.

3.4.8.1.1.4 Electrical heat. Electrical resistance heaters shall incorporate an over-heat protection device. A control shall be used to prevent operation of the heater below a predetermined minimum airflow rate.

3.4.8.1.2 Equipment and equipment compartments. Temperature control for equipment and equipment compartments when utilized shall be automatic and in accordance with the equipment detail specifications. Avionics requirements are specified in 3.4.4.2.1. An indication of overtemperature conditions shall be provided to the crewmembers.

3.4.8.2 Pressure. Control of pressurized compartments shall be automatic with pressure regulators and safety valves. A control shall be provided for releasing pressure manually. The capacity of safety valves installed in combat type aircraft shall permit the differential pressure of occupied compartments to be reduced to two psi within the period of 4 ± 2 seconds. The dump time of six seconds shall be fulfilled under the most critical combination of flight altitude and inlet air flow from the pressurizing system.

3.4.8.3 Subsystems. Controls, instrumentation and indicators for various subsystems are specified under the section applicable.

3.4.9 Related systems.

3.4.9.1 Transparency clearing. Defogging, anti-icing, defrosting, and rain removal shall be in accordance with MIL-T-5842. If an air blast type system is used, consideration shall be given to ducting this air separately from a point upstream of the final stage of cooling in order to reduce the overheating effect in the cabin. Air blast rain removal system shall be in accordance with MIL-R-81367. Where both defogging and thermal anti-icing are specified, the heating system shall be capable of simultaneously preventing the formation of ice on the exterior of the windshield, and fog and frost on the interior surfaces. Where two systems are used the operational performance requirements of each system shall apply.

3.4.9.2 Sun shields. Sun shields shall be readily removable, shall be of the visibly transparent infrared reflecting type and shall reduce the transmission of incident infrared radiant energy by at least 60 percent.

3.4.9.3 Bleed air system. When bleed air is used as a source for the ECS, the bleed air system shall be in accordance with MIL-B-81365 and MIL-B-81592. Bleed air, as used herein, includes all compressed air sources for the ECS. On multi-engine aircraft, the ECS shall be able to maintain operation within design limits with loss of air supply from one of the engines. In the case of a duct or component failure bleed air shall not be extracted from the engine at a flow rate greater than allowed by the engine manufacturer. The bleed air system shall have provisions to permit the use of APU or ground pneumatic carts for ground functional checkout without main engine operation.

3.4.9.4 Wing and empennage anti-icing and de-icing systems. Anti-icing systems shall be in accordance with MIL-T-18607. Pneumatic boot de-icing system shall be installed in accordance with MIL-D-8804.

3.4.9.5 Pressure, anti-exposure and anti-G suit provisions. Ventilation and pressurization of pressure suits and ventilation of anti-exposure suits and G-suits shall be accomplished by conditioned air obtained from the cabin supply system or from separate source.

3.4.9.5.1 Air flow control. Design air flow for ventilation of either the exposure suit or pressure suit shall be 14.0 cfm. A manually-operated flow control valve shall be installed in the cabin to permit each suit wearer to shut off the air being supplied to the suit or to regulate the flow at several intermediate valves up to the design flow. This valve shall also be configured to admit and control air delivered to the airplane by a ground cooling unit.

3.4.9.5.2 Air temperature control. Inlet air temperture, as measured at the suit, shall be adjustable between +50°F (10°C) and +100°F (37°C). The Controller shall regulate the selected temperature within plus or minus 3°F (2°C) of the control point setting during steady state conditons of airplane operation. During transient conditions of airplane or system operation, the ventilating air temperature at the suit inlet must be maintained within ±5°F (3°C) of the control point setting. The temperature selector panel shall be marked cold and hot for the control.

3.4.9.5.3 Air pressure control. The pressure drop through anti-exposure and pressure suits shall be in accordance with the individual suit specifications. During emergency use of the pressure suit when the cabin altitude exceeds 35,000 feet, the inlet pressure to the pressure suit shall be regulated to maintain a pressure of 3.5 psia within the pressure suit.

3.4.9.5.4 Anti-G suit air. When an anti-G suit is used in the aircraft, air shall be supplied from the ECS for the anti-G suit in accordance with MIL-D-7890.

3.4.9.5.5 Related requirements. Use of either the pressure suit or anti-exposure suit shall not adversely affect performance of the defogging - defrosting system for the windshield. Under all operating conditions, if a restrictor or throttling device is used down stream of an air cycle refrigeration turbine to produce sufficient pressure for the suit, the thrust loads and speed surges induced shall be specified in the detail specification for this equipment.

3.4.9.6 Escape capsule. When an aircrew escape and survival capsule system is designed into the aircraft, the environmental control systems shall provide the atmosphere and pressurization to the capsule during all normal aircraft flight and operations. The ECS shall be compatible with the requirements of MIL-A-23121.

3.4.9.7 Fluid systems. Closed loop or recirculating fluid systems for cooling of electonics equipment, optical units, power supplies, weapons, etc., shall be in accordance with individual equipment specifications. If an inflammable fluid is used, fire protection shall be provided in accordance with MIL-HDBK-221. Consideration shall be given to overtemperature and also to fluid corrosive properties, freezing and boiling, expansion and contraction, heat transfer properties, consequences of leakage including loss of fluid, system capacity, control, and also alarm information to aircrew. Automatic temperture control to provide required cooling of component gear, and overtemperature indication to aircrew shall be provided as a minimum. The system shall meet the performance requirements of the specification and provision for checking of flow, temperature, and pressure shall be provided to determine system performance.

3.4.9.8 Auxiliary pressure.

3.4.9.8.1 Inflatable seal pressurization. Inflatable seals shall be sufficiently pressurized to provide effective sealing of closures when the compartment pressure is at a maximum, the aircraft is at maximum operational ceiling, and pressurizing source is at a minimum pressure. The pressurization medium shall be supplied at pressure, temperature, moisture, and contamination levels compatible with each inflatable seal requirement.

3.4.9.8.2 Subsystem reservoir pressurization. When the reservoirs of subsystems such as fuel, oil, hydraulic fluid, coolant fluid, and water are pressurized with air, the pressurization airflows shall be provided at pressure temperature, moisture, and contamination levels compatible with the applicable subsystem specification requirements. Fail-safe provisions to prevent the entrance of hazardous fumes and fluids into environmental control, the environmental protection, and the engine bleed air systems shall be provided. The supply air flow rate and temperature shall be controlled to prevent autoignition.

3.4.9.9 Ground coolant air mover. Where sufficient airflow is not available during ground and low speed flight operations, a fan or bleed air ejector, which is automatically shut off when not required, shall be used for inducing airflow through the coolant circuit. If a fan is used, it shall not windmill. The device which controls operation of the ground coolant air mover shall be designed to normally fail in the open or on position. The fan shall not be damaged or caused to malfunction due to a failure of the fan control device in the open or on position.

3.5 Design and construction.

3.5.1 Failure concept. The subsystem shall be designed in accordance with the "single failure" concept; that is, any failure within a given component shall not result in failure of another component. The normal and failure mode position (open or closed) of all ECS valves shall be that which is determined best from a failure mode and effect analysis.

3.5.2 Ground connections.

3.5.2.1 Fighter and attack aircraft cooling. Air inlet provisions, in accordance with MS 16052, shall be installed for ground cooling of electronic equipment. The same provisions shall be utilized to condition the cabin of fighter type aircraft which are required to stand a combat readiness condition where adverse cockpit environmental conditions would be generated, i.e., above +100°F (38°C) or below +40°F (5°C). In this instance, cooling air inlet(s) shall be located as close as possible to the lower-surface center line of the fuselage in such a manner that the MS 16051 coupling is accessible to deck personnel when the airplane is on the port or starboard catapult. Any door or cover required for the inlet shall automatically close and lock at the instant the coupling is removed from the airplane. The quantity and location of ground cooling inlets for combat type aircraft not required to stand a combat readiness condition shall be determined on the basis of using one ground unit which is equipped with two discharge ducts 30 feet long. In this connection, consideration shall be given to the quantity of installed electronic equipment which must be operating at any one time during maintenance and pre-flight procedures. In the event that these procedures will be such that one ground unit will not be sufficient, the simultaneous use of two units will be permitted.

3.5.2.2 Other aircraft cooling. Ground cooling provisions for the cabins of other than fighter and attack aircraft shall be in accordance with either MS 33561 or MS 33562, depending upon the airflow requirements for the particular airplane model involved.

3.5.2.3 Suit cooling. A coupling socket, complete with cap, shall be installed in the exterior of the airplane fuselage adjacent to the ground conditioning air inlet to permit cooling air from a ground unit to be supplied to the pressure suit or anti-exposure suit air flow control valve. The coupling socket shall be designed to receive a 7/8 inch hose end plug, Federal Stock Number 4730-00-392-2974.

3.5.2.4 Pneumatic pressure. Environmental control systems using compressed air as a power source shall have a ground pneumatic cart connection in accordance with MS 33740.

3.5.2.5 Leakage test fittings. Fittings in accordance with one of the sizes shown in MS 33565 shall be installed to permit ground tests of the cabin seals for leakage. Fittings in accordance with MS 33656 shall be installed to permit testing of inflatable seals for leakage, to permit testing of the high pressure ducting system and for test pressure gage connections. Flared tube fittings shall be equipped with an airtight cap, conforming to AN 929, and attached to the aircraft with a flexible chain. Fittings shall be accessible and sufficient clearance area provided to allow attachment of the ground unit hose with standard tools. Each fitting shall be plainly marked to indicate its function.

3.5.3 Components.

3.5.3.1 Shut off valves. A valve, embodying the highest degree of reliability achievable, shall be installed to permit the crew to shut off the flow of compressed air entering the occupied compartments. The incorporation of any other function into the valve, shall not compromise its operation as a shut-off valve. Closing of the valve from any degree of opening, including the fully-open position, shall be accomplished within two seconds. Each subsystem deriving air from the engine bleed air shall have an individual shutoff valve so that the subsystem can be deactivaated without deactivating the engine bleed air system. A shutoff valve for each independent source of bleed air shall be provided at the bleed air port and remotely controlled from the crew station. Provisions shall be made to provide closure of the valve during engine starting. Where multiple sources are manifolded, isolation and crossover means shall be provided to isolate each main supply duct and crossfeed to subsystems from any source. Isolation valves shall be normally closed. A readily accessible means for manually opening the crossover valve shall be provided. The isolation shutof valve in each side shall be upstream of any supply line takeoff for compartment cooling or pressurization. Means for ground testing each valve of the bleed air system for proper operation shall be incorporated.

3.5.3.2 Cabin pressure regulators. The cabin pressure regulators shall be in accordance with MIL-R-9345. Means shall be provided for locking the cabin pressure regulator out-flow valve in the closed position for cabin pressure and leakage tests. The cabin pressure regulator diaphragm shall be of molded material in accordance with MIL-R-6855 Type II.

3.5.3.3 Cabin safety valves. Protection of occupied compartments from excessive positive and negative pressure and means for emergency pressure dumping shall be provided. Safety valves shall be installed on all pressurized compartments of the airplane, and shall be in accordance with MIL-V-5379. The valves shall be adequately protected against damage and shall be sealed to prevent tampering. Discharge ports shall not be located in an area subject to exposure to adverse weather conditions such as icing or rain or to physical interference from structures, insulation or other installed items. The capacity of safety valves shall be adequate to meet the negative pressure relief requirements of MIL-V-5379.

3.5.3.4 Duct design. All flexible non-metallic air ducting shall conform to MIL-H-8796. Duct flexible connectors shall be designed to withstand axial compression or extension, radial deflection or offset movement as may be required to prevent failure of the ducting system due to vibration or stresses caused by variations in loading or temperature of the structure. The amount of deflection (compression, extension, or bending) for which the flexible connectors should be designed is that resulting from imposition of loads and temperatures applied for all operations of the aircraft. The recommended duct design and installation practices of ARP 699 shall be followed for high pressure ducting.

3.5.3.5 Check valves. A check valve shall be installed in the compressor bleed line of single engine aircraft to prevent rapid loss of pressurization in the event of engine failure. In aircraft equipped with more than one source of compressed air for pressurization a check valve shall be installed in the line from each source to preclude loss of air through an inoperative compressor or as a result of duct failure.

3.5.3.6 Air cycle. When used, air cycle refrigeration units shall be designed and installed in such a manner that the turbine assembly can be removed and reinstalled without disturbing the heat exchangers. The system design shall be such that the maximum safe rotational speed of the air cycle cooling units is not exceeded during any operating condition of the airplane. Adequate protection shall be provided to prevent injury to the crew resulting from structural failure of air cycle cooling units. The lubrication system of the cooling unit shall not require attention at intervals of less than 500 aircraft operating hours. The minimum service life of the units before overhaul is required shall be equivalent to 2000 aircraft operating hours.

3.5.3.7 Heat exchangers. Heat exchangers shall be constructed of corrosion-resistant materials suitable for the temperatures and pressures encountered and shall be designed to minimize the gross take-off weight and performance penalties on the aircraft. Heat exchangers which are exposed to direct impact of rain shall be so designed that they will not be damaged by rainfall of four inches per hour at the maximum low level speed of the air vehicle. Heat exchangers which dissipate heat from the bleed air or compressed ram air into fuel or coolants other than water shall be so designed that a single structural failure will not result in leakage of fuel or coolant fluid into the supply air if leakage could create the possibility of fire or explosion or result in excessive toxicity levels or noxious odors in occupied compartments. All heat exchangers shall be designed to satisfactorily pass the pressure and temperature cycling test of 4.3.1.

3.5.3.8 Water boilers and water storage tanks. Water boilers and water storage tanks, if used for providing a supplemental heat sink for the subsystem during high-speed flight conditions, shall be constructed of corrosion-resistant materials. The design shall be such as to require a minimum water consumption consistent with other design parameters. Water boilers and storage tanks shall be capable of operating under all conditions and shall withstand repeated freeze and thaw cycles without use of an anti-freeze. The water storage tanks shall be provided with a readily accessible fill port and overboard drain. Pressurized water storage tanks shall be protected against excessive pressure. Water storage tanks using airframe structural members shall be avoided, and no damage to the aircraft shall be possible under any conditions of flight, landing or other normal operation when the water is completely frozen. The steam shall be exhausted overboard, and these exhaust provisions shall be designed to minimize water "carry over" and water loss due to attitudes other than level flight. Water boilers shall be designed for use of potable water. The use of water boilers and storage tanks shall be avoided and procuring activity approval for their use shall be obtained before initiating a detail design of the ECS.

3.5.3.9 Ram air inlet and valve. A ram air scoop or inlet shall be installed to provide clean ventilating air to the occupied compartments during intervals when the air conditioning system has to be turned off. A ram air valve, suitable for use as an emergency ventilation valve and incorporating means for controlling its degree of opening in at least four increments, shall be installed to regulate the quantity of air admitted to the cabin. Actuation of the ram valve shall not be inter-connected with the system main shut-off or other valve. Design of the ram air system shall be such that a minimum of 90 percent of the impact pressure is developed in the cabin at all altitudes above 23,000 feet up to a speed of MACH .9 when the ram air valve is fully open and all other air conditioning system valves are closed.

3.5.3.10 Vapor cycle. The system shall not require servicing at intervals of less than 500 hours of operation or replacement of components for a minimum of 1000 hours of operation. Suction pressure shall be greater than 14.7 psia (10.1 kpa) for charging. Compressors shall be hermetically sealed. Fittings shall be of the quick disconnect type.

3.5.3.11 Indicators and gauges.

3.5.3.11.1 Cabin altitude. An indicator shall be installed to indicate the cabin altitude. In the event a gauge is installed, an altimeter in accordance with MIL-I-5099 shall be near the pressurization controls. A caution indicator to show loss of compartment pressure below 10 psia shall be provided in the crew station of all aircraft having occupied pressurized compartment, except for aircraft that are designed to operate a five psig pressure schedule. A warning that compartment pressure has dropped below three psia for fighter and attack aircraft and eight psia for all other aircraft shall be provided in the crew station of fighter and attack aircraft that operate above 42,000 feet and all other aircraft that fly above 25,000 feet, respectively. When the full pressure suit is worn by the pilot and connected with the ECS, the cabin pressure altitude indicator shall indicate the pressure altitude within the full pressure suit.

3.5.3.11.2 Differential pressure. An indicator or a gage with graduations from 0 to 10 psi and in accordance with the general requirements of MIL-G-7734 shall be installed on the pressurization control panel to indicate the difference between the cabin pressure and the total pressure (static pressure plus impact or velocity pressure).

3.5.3.11.3 Instrumentation. Indicators, gauges and warning signals for various related systems and components shall be in accordance with the aircraft and equipment specification.

3.5.3.12 Water separators. Water separators, when installed for mositure control, shall have adequate drainage. If a coalescer material is used, provisions for bypass during blockage of flow for any reason shall be incorporated, and the material shall be removable from separator without disconnecting ducting.

3.5.3.13 Combustion heater. The combustion heaters, when installed, shall be in accordance with MIL-H-5484.

3.5.3.13.1 Starting. The combustion heater system shall ignite and operate continuously under any conditions of flight from sea level to the service ceiling of the airplane. The temperature of the exhaust gases from the heater shall not be greater than 1000°F measured under any condition of operation of the heating system.

3.5.3.13.2 Vapor prevention. Provision shall be made to ventilate adequately and continously the compartments in which combustion-type heaters are installed in order to prevent the accumulation of fuel vapors in the event of fuel leakage. Ventilation rate shall be greater than five pounds of air per minute per 100,000 BTU per hour rated thermal capacity of the heater. Maximum concentrations of fuel vapor shall be not greater than limits specified in 3.4.7.5.

3.5.3.13.3 Fuel pump. The heater fuel pump shall conform to MIL-P-6992 (Aer).

3.5.3.13.4 Ground operations. In multi-engine seaplanes, airships and amphibious airplanes the heating system shall be designed to operate while the aircraft is on the ground or on water when the engines are not operating.

3.5.3.13.5 Marking. Fuel lines to the heater shall be marked in accordance with MIL-STD-1247.

3.5.3.13.6 Fuel. The combustion heater system shall incorporate a suitable automatic control located in the fuel line as near the fuel takeoff from the main fuel system as possible, to stop the flow of fuel if the pressure in the fuel line downstream of this point is reduced by leakage or by being broken. In carrier type airplanes it is permissible to incorporate a limit switch in the landing gear mechanism in such manner as to cut off the flow of fuel when the landing gear is lowered as an alternate method of fuel control to that specified in MIL-H-5484.

3.5.3.13.7 Weight. The combustion heaters or heat exchangers and as much of the duct work as practical shall be readily removable from the airplane so that the weight of the heating system may be reduced as much as possible on those airplanes operating in theatres where heating is not required.

3.5.3.14 Engine exhaust heater. When the source of heat is the engine exhaust, the heat shall be extracted from the exhaust gases by a secondary heat exchanger or by a muff around the exhaust pipe.

3.5.3.14.1 Air supply. Suitable means shall be provided to permit the flow of sufficient air through the heat interchanger at all times to prevent premature failure due to overheating. The valves used to control the flow of heated air shall not warp or leak during the life of the heating system.

3.5.3.14.2 Heat exchanger. If a secondary air-to-air heat exchanger is used, means shall be provided for regulating the flow of the air being heated in the secondary exchanger. The design and construction of exhaust-to-air heat exchanger shall be such that vibration or expansion and contraction due to rapid heating and cooling shall not cause cracking of the heat exchanger or the exhaust stack. Heat exchanger design shall not adversely affect engine operation.

3.5.3.14.3 Failure. The exhaust heating system shall be designed to assure no single failure will result in contamination of occupants air supply beyond limits of 3.4.7.

3.5.4 Thermal-acoustical insulation. Thermal-acoustical insulation shall be installed as required for personnel protection, attenuation of noise (see 3.4.6), prevention of excessive heat transfer, and to preclude development of excessive temperatures in any structural member of the aircraft. Insulation shall be in accordance with MIL-I-7171 and installation in accordance with MIL-S-6144. Insulation shall be provided as required to maintain surface temperatures from exceeding safe limits for combustible fluids, liquid cooling lines, wiring and components subject to heat degradation.

3.5.5 Electrical systems. The selection and installation of electric equipment shall be in accordance with MIL-E-7080. Electric power characteristics shall be in accordance with MIL-STD-704. All electric motors shall be explosion proof and self-ventilated. Electrical connectors shall be in accordance with MIL-C-38999, Series III or IV.

3.5.6 Electromagnetic requirements. Requirements for electromagnetic compatibility shall be in accordance with MIL-E-6051. Design requirements for the control of electromagnetic emission and susceptibility characteristics shall be in accordance with MIL-STD-461.

3.5.7 Electric cables. The electric cables shall not be run inside the ECS ducts or lines and shall not be in contact with any part of the system which may cause damage to the cable insulation by high temperatures.

3.5.8 Electronic equipment. Electronic equipment used in the design of environmental control systems shall be in accordance with MIL-E-5400.

3.5.9 Containment. The housing and scrolls of all rotating machinery shall completely contain the fragments from rotating blades and wheel bursts (tri-hub failure) at the greater speed condition either of the maximum speed resulting from any failure inducing condition or of 135 percent of the maximum normal operating speed with the unit at the pressure and temperature associated with these speeds. Fragments may penetrate the containing housing but shall not pass throught the housing. Particles or parts resulting from a failure and passing through inlet or outlet ports of the assembly shall be contained by the adjoining ducting. Rotating equipment such as electrical motor operated fans or compressor wheels of bootstrap cooling turbines, which cannot exceed a certain design maximum speed, shall contain all fragments from blade and wheel burst (tri-hub failure) at the maximum possible operating speed.

3.6 Reliability. Reliability shall be a basic consideration in the design of all ECS components. A reliability program shall be established in accordance with MIL-STD-785. The inherent reliability expressed quantitatively in MTBF shall be prepared for procuring activity acceptance (see 6.2.2).

3.7 Survivability. The survivability and vulnerability of the system shall be in accordance with MIL-STD-2072.

3.8 Maintainability. The equipment shall be designed in accordance with the qualitative and quantitative maintainability requirements utilizing MIL-STD-470 as a design guide.

3.9 Safety. The ECS shall be designed to preclude the incorporation of features which result in critical or catastrophic hazards as classfied in MIL-STD-882.

3.10 Human engineering. The design of the system shall conform to the requirements of MIL-STD-1472.

3.11 Design data. Drawings and substantiating engineering data in accordance with MIL-D-8706 shall show the location, capacity, identity (including manufacturer and part number) and function of all component and equipments used in the ECS. Schematic type drawings, depicting and explaining airflow circuits and operation of controls shall be included. Engineering data shall include the system design analysis, all equipment procurement specifications, equipment test requirements, and a weight breakdown for the complete system. The system design analysis shall include the system requirements and performance analyses for the environmental control, environmental protection and engine bleed air systems (see 6.2.2).

3.11.1 System requirements analysis. The objective of the system requirements analysis is to establish the total requirements for the environmental control, environmental protection and engine bleed air systems (see 6.2.2). The report shall include the following:

a. Physiological requirements
b. Avionics cooling requirements
c. Thermal loads - aerodynamic, solar, personnel and equipment
d. Interface requirements
e. Pressurization requirements
f. Environmental protection requirements
g. Engine bleed air requirements
h. Total system requirements - summary of total requirements as required for the performance analyses.

3.11.2 Performance analysis. The objective of the performance analysis is to demonstrate that the environmental control, environmental protection and engine bleed air systems, operating with the loads generated by the system requirements analysis, meet the specified performance requirements during both steady state and transient conditions (see 6.2.2). The report shall include the following:

a. System description - detailed description of the environmental control, environmental protection and engine bleed air subsystems.

b. Steady state performance - steady state performance data shall be presented for conditions encompassing the entire ground and flight operational envelope for hot, standard, and cold day condition.

c. Dynamic performance - dynamic analysis performance data shall be presented for transient flight conditions (aircraft maneuvers, throttle changes, etc.) and for varying operating conditions (control setting changes). This includes pressurization system dynamic performance, environmental control system response and performance during transient flight or operating conditions, controls performance and stability, and compartment transient thermal analyses.

d. Failure modes and effects analysis - the failure modes and resulting effect for the various components of the environmental control, environmental protection and engine bleed air subsystems shall be presented.

e. Component and system performance data - as an appendix, the component performance data, pressure drops, and other data required for steady state and dynamic system performance analyses shall be included. These data shall be complete and in formats compatible with the following computer programs:

(1) Advanced Environmental Control System (AECS) Computer Program

(2) Environmental Control Analysis System (EASY) Computer Program.

3.11.3 System design analysis reports. Reports shall be made available to the procuring activity according to the following schedule (see 6.2.2).

a. 30 days prior to the Preliminary Design Review (PDR) for ECS - shall contain systems requirements analysis, system description, and preliminary thermal and steady state performance analyses.

b. 30 days prior to Critical Design Review (CDR) for ECS - updated and revised to include both steady state and dynamic performance analyses.

c. 30 days prior to First Flight - updated and revised to include latest performance based on component qualification test results and sytems testing.

d. Final report 90 days after completion of flight testing - revised to reflect system performance based on flight testing. The computer programs shall be revised as necessary to correlate with the flight test results and performance predictions shall be extrapolated to the design conditions.

3.12 Workmanship. The manufacture and assembly of all systems, sub-systems and components shall be uniform and have sufficient quality and be free from irregularities, defects or foreign matter which could affect performance, reliability, durability, maintainability, safety and serviceability. All details of workmanship shall be of sufficiently high grade to ensure satisfactory operation and service life and shall be subject to visual inspection for approval. Workmanship shall meet the conditions specified in requirement 9 of MIL-STD-454.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of tests. The inspection and testing of the environmental system and components thereof shall be classified as follows:

a. Qualification tests (see 4.3)
b. System performance tests (see 4.4)
c. Acceptance tests (see 4.5)
d. Demonstration tests (see 4.6)

4.3 Qualification tests.

4.3.1 Components and high pressure ducting. Production samples of all components and high pressure ducting shall be subjected to qualification tests to prove compliance with requirements of this specification. Qualification tests shall be conducted in accordance with the airframe contractor's procurement specifications and shall include the following individual tests, where applicable:

a. Acceptance tests (see 4.5)
b. Burst test
c. Pressure cycling
d. Thermal cycling
e. Valve "close-open-close" cycling
f. Flow resonance
g. Performance at design points
h. Containment

4.3.2 Environmental tests of components. Qualification tests shall include the environmental tests specified in the applicable specifications listed in 2.1. Where no applicable specification is listed in 2.1, the following environmental tests shall be conducted (as specified in MIL-STD-810 by method and page shown).

Method No.	Test	Page
500.1	Low Pressure (Altitude)	500.1-1 - 500.1-2
501.1	High Temperature	501.1-1 - 501.1-3
502.1	Low Temperature	502.1-1 - 502.1-2
503.1	Temperature Shock	503.1-1 - 503.1-2
504.1	Temperature-Altitude	504.1-1 - 504.1-13
505.1	Solar Radiation (Sunshine)	505.1-1 - 505.1-4
506.1	Rain	506.1-1 - 506.1-3
507.1	Humidity	507.1-1 - 507.1-11
508.1	Fungus	508.1-1 - 508.1-5
509.1	Salt Fog	509.1-1 - 509.1-8
510.1	Dust (Fine Sand)	510.1-1 - 510.1-3
511.1	Explosive Atmosphere	511.1-1 - 511.1-11
512.1	Leakage (Immersion)	512.1-1 - 512.1-3
513.2	Acceleration	513.2-1 - 513.2-8
514.2	Vibration	514.2-1 - 514.2-41
515.2	Acoustical Noise	515.2-1 - 515.2-11
516.2	Shock	516.2-1 - 516.2-11
517.2	Space Simulation (Unmanned Test)	517.2-1 - 517.2-13
518.1	Temperature-Humidity-Altitude	518.1-1 - 518.1-3
519.2	Gunfire Vibration, Aircraft	519.2-1 - 519.2-63

4.3.3 Pneumatically operated components. Production configurations of all pneumatically operated components shall be subjected to the following tests in addition to the above tests.

4.3.3.1 Accelerated internal corrosion and humidity.

a. Components shall be oriented in the same attitude as they will be installed in the air vehicle during all phases of testing.

b. All internal surfaces which are exposed to pneumatic air shall be thoroughly wetted by supplying a solution of five percent (by weight) of sodium chloride in water to the component. Valves shall be cycled five times from closed to open during the wetting operation.

c. The components shall then be purged by use of factory air and all valves shall be cycled as in item (b) above.

d. The components shall then be placed in 130° ±5°F, 100 percent relative humidity environment, and baked for one hour. At the conclusion of each bake period, the internal surfaces shall be flushed with clear water and valves shall be simultaneously cycled as in item (b) above. A functional check shall then be conducted to determine if a malfunction or degradation has occurred.

e. Items (b) through (d) consititute one cycle. All components shall be cycled as follows:

(1) Ten cycles with a one-hour bake period.
(2) Ten cycles with a two-hour bake period.
(3) Ten cycles with a five-hour bake period.

Each component shall be disassembled and inspected at completion of each ten cycles. Any evidence of corrosion, damage, malfunction shall be considered failure of the test.

4.3.3.2 Freezing condensate.

a. Components shall be oriented in the same attitude as they will be installed in the air vehicle.

b. The pneumatic components shall be connected to an air source with a specific humidity of 154 grains of water/pound of dry air, and all valves shall be cycled five times from closed to open to closed.

c. Immediately after conclusion of step (b), the components shall be depressurized and de-engerized and placed in a cold chamber for one hour at 0°F or lower until the entire unit is stabilized at the low temperature.

d. At conclusion of step (c) and with components still in the cold chamber at 0°F, the components shall be subjected to a functional test to determine that all components perform satisfactorily.

4.3.4 Reliability tests. Qualification (demonstration) reliability tests will be specified in the contract.

4.4 System performance tests. Specified performance of the ECS shall be demonstrated prior to installation in the airplane. System performance tests shall be conducted in conjunction with a mock-up of the pressure cabin with all distribution ducting and flow control devices installed. Air flows, pressures and temperatures shall be recorded under similuated flight conditions. The system test data shall be compared to the system design analysis (see 3.12). All discrepancies must be resolved to the extent that the analytical system performance and laboratory test data are in reasonable agreement and demonstrate the performance requirements have been achieved. The report conditions of 3.12 apply.

4.5 Acceptance tests of components. Acceptance tests of components shall be conducted in accordance with the applicable specifications listed in 2.1. Where no applicable specification is listed in 2.1, the acceptance tests shall include the following tests:

a. Examination of product
b. Performance
c. Proof pressure
d. Pressure drop
e. Leakage
f. Rotational overspeed
g. Dielectric
h. Insulation resistance
i. Burn-in

4.5.1 Reliability tests. Production acceptance (sampling) reliability tests will be specified in the contract.

4.6 Demonstration tests. Demonstration tests of the complete system shall be performed in accordance with MIL-T-18606 to assure compliance with this specification and the limits specified herein.

5. PACKAGING. This section is not applicable to this specification.

6. NOTES.

6.1 Intended use. The requirements of this specification are intended for use in designing environmental control systems for pressurized and unpressurized aircraft for the occupied spaces, electronic and electrical equipment compartments, and various related systems installed in military aircraft. These requirements apply to the ducting, thermal controls, ventilation controls, pressure regulators, and ancillary items of equipment required for related systems such as pressure/exposure suit ventilating systems, external bleed air rain removal, boundary layer control, fuel transfer, photographic systems, etc., using compressor bleed air supply.

6.2 Ordering data.

6.2.1 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this specification.
b. A reliability assurance program (see 3.6).
c. Reliability MTBF demonstration, if other than specified in 4.1.
d. Responsibility for inspection, if other than specified in 4.1.
e. Test plans, if required (see 4.2.1.3 and 6.2.2).
f. Test reports and distribution if required (see 4.2 and 6.2.2).
g. Test station certification, if requred (see 4.3.1).
h. Environmental tests, if other than specified in 4.3.2.

6.2.2 Data requirements. When this specification is used in an acquisition which incorporates a DD Form 1423, Contract Data Requirements List (CDRL), the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved CDRL incorporated into the contract. When the provisions of DAR 7-104.9 (n) (2) are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this specification are cited in the following paragraphs.

Paragraph no.	Data requirement title	Applicable DID no.	Option
3.3.1.3	Material Specification	DI-E-3131/C-144	-
3.4.2.1.1	Storage System Design	UDI-S-23272C	-
3.6	Reliability MTBF	DI-R-7079	-
3.3, 3.5.3.8	Request for procurement activity approval of deviation, waiver or change	DI-E-3129/C-142	-
3.11	Subsystem design analysis report	DI-S-3581	-
3.11.1	Systems requirements analysis data	DI-S-30602B	-
3.11.2	Systems performance analysis report	DI-S-30609	-
3.11.3	Systems engineering analysis report	DI-S-21433B	-
3.11	Design Proposal Drawings	DI-E-7031	-
3.11	Design Report	DI-R-24039A	-

(Data item descriptions related to this specification, and identified in section 6 will be approved and listed as such in DoD 5000.19L., Vol. II, AMSDL. Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

6.3 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue, due to the extensiveness of the changes.

6.4 International standardization agreements. Certain provisions of this specification are the subject of the following International Standardization Agreements:

Paragraph	STANAG	ACSS	Description
3.5.2.2	3208	17/33	Air Conditioning Connections
3.5.2.5	3315	17/33	Air Cabin Pressurizing Test Connections
3.5.2.4	3372	17/22	Pneumatic Starting Nipple
3.4.2.1	3610	-	Characteristics of Conditioned Breathable Air Supplied to Aircraft on the Ground

When amendment, revision, or cancellation of this specification is proposed which will affect or violate the International Agreement concerned, the preparing activity will take appropriate reconciliation action through International Standardization channels including departmental standardization offices to change the agreement or make other appropriate accomodations.

Preparing Activity
Navy-AS
(Project 1660-N385)

INDEX

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-E-18927E	General Requirements for Aircraft Environmental Control Systems

3a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS (Street, City, State, ZIP Code)

4. TYPE OF ORGANIZATION (Mark one)

☐ VENDOR

☐ USER

☐ MANUFACTURER

☐ OTHER (Specify): ______

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER (Last, First, MI) – Optional

b. WORK TELEPHONE NUMBER (Include Area Code) – Optional

c. MAILING ADDRESS (Street, City, State, ZIP Code) – Optional

8. DATE OF SUBMISSION (YYMMDD)

DD FORM 1426 PREVIOUS EDITION IS OBSOLETE.