NOTE: AFGS-87234A has been redesignated as a handbook, and is to be used for guidance purposes only. This document is no longer to be cited as a requirement. For administrative expediency, the only physical change from AFGS-87234A is this cover page. However, this document is no longer to be cited as a requirement. If cited as a requirement, contractors may disregard the requirements of this document and interpret its contents only as guidance.

NOT MEASUREMENT SENSITIVE

MIL-HDBK-87234
14 February 1997
SUPERSEDING
AFGS-87234A
NOTICE 1
14 February 1997

# DEPARTMENT OF DEFENSE
# HANDBOOK

# PERSONAL PROTECTIVE EQUIPMENT, AIRCREW

THIS HANDBOOK IS FOR GUIDANCE ONLY
DO NOT CITE THIS DOCUMENT AS A REQUIREMENT

AMSC N/A FSC 8475

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

# WARNING

## INFORMATION SUBJECT TO EXPORT CONTROL LAWS

This document contains information subject to the International Traffic in Arms Regulation (ITAR) and/or the Export Administration Regulation (EAR) of 1979 which may not be exported, released, or disclosed to foreign nationals inside or outside the United States without first obtaining an export license. A violation of the ITAR or EAR may be subject to a penalty of up to 10 years imprisonment and a fine of $100,000 under 22 U.S.C. 2778 or Section 2410 of the Export Administration Act of 1979. Include this notice with any reproduced portion of this document.

DESTRUCTION NOTICE - AFGS-87234A is an unclassified, limited document. Destroy unclassified, limited documents by any method that will prevent disclosure of contents or reconstruction of the document.

## FOREWORD

1. This military specification is approved for use by the Department of the Air Force and is available for use within the distribution limitations noted on the cover page.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASD/ENES, Wright-Patterson AFB OH 45433-6503 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

CONTENTS

CONTENTS - continued

CONTENTS - continued

CONTENTS - continued

# MILITARY SPECIFICATION

# PERSONAL PROTECTIVE EQUIPMENT, AIRCREW

## 1. SCOPE

**1.1 Scope.** This specification establishes the development requirements and verifications for aircrew personal protective equipment.

**1.2 Use.** This specification cannot be used for contractual purposes without tailoring it to the program under consideration and without supplemental information relating to the performance requirements of aircrew personal protective equipment. The paragraphs in sections 3 and 4 of the specification should be completed using the information in the associated handbook rationale, guidance, and lessons learned paragraphs. This document may be used to develop a contract-peculiar item development specification, or tailored for a subsystem specification or system specification.

**1.2.1 Structure.** The supplemental information required is identified by blanks within the specification. The blanks afford tailorability to different personal protective equipment performance requirements.

**1.2.2 Instructional handbook.** The instructional handbook, which is the appendix to this specification, provides rationale for the requirements and verifications, guidance to assist in determining the appropriate information to fill the blanks, and a lessons learned repository.

**1.2.3 Tailoring instructions.** When using this document to add requirements and verifications to an aircraft subsystems requirements document (SRD), address only the protection capabilities desired. When writing a detailed specification, all paragraphs apply.

**1.3 Deviation.** In the event a projected design for a given application results in improvement of system performance, reduced life cycle cost, or reduced development cost through deviation from this specification, or where the requirements of this specification result in compromise in operational capability, the issue shall be brought to the attention of the procuring activity for consideration of change.

## 2. APPLICABLE DOCUMENTS

### 2.1 Government documents

**2.1.1 Specifications, standards, and handbooks.** The following specifications, standards, and handbooks form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

SPECIFICATIONS

*MIL-P-116* *Preservation, Methods of*

*MIL-E-87235* *Emergency Escape, Aircraft*

*(Additional standards may be added to this list. Appendix section 20 may list applicable specifications.)*

STANDARDS

*MIL-STD-810* *Environmental Test Methods and Engineering Guidelines*

*MIL-STD-846* *Escape System Testing, Ground, Track, and Flight Test*

*MIL-STD-1800* *Human Engineering Design Requirements for Systems*

*MIL-STD-2073-1* *DOD Materiel Procedures for Development & Application of Packaging Requirements*

*(Additional standards may be added to this list. Appendix section 20 may list other applicable standards.)*

(Unless otherwise indicated copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

**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. Unless otherwise specified, the issues are those cited in the solicitation.

Armstrong Aerospace Medical Research Laboratory

*AAMRL-TR-88-012* *Users Guide to Accessing the Anthropometric Data Base at the Center for Anthropometric Research Data*

*(Additional documents may be added to this list. Appendix section 20 may list other applicable documents.)*

(Order unclassified, unlimited distribution technical reports from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161.)

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

**2.2 Non-Government publications.** The following document(s) form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation.

*(Appendix section 20 may list applicable publications.)*

(Application for copies should be addressed to (name and address of the source).)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

**2.3 Order of precedence.** In the event of a conflict between the text of this document and the 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.

# 3. REQUIREMENTS

**3.1 System description.** The personal protective equipment shall be designed, tested, and installed from the systems viewpoint. The personal protection system requirements shall consist of:

a. (see 3.2.2) Chemical/biological (CB) protection.
b. (see 3.2.3) G protection.
c. (see 3.2.4) Personal altitude protection.
d. (see 3.2.5) Thermal stress protection.
e. (see 3.2.6) Flame and heat protection.
f. (see 3.2.7) Smoke and toxic fumes protection.
g. (see 3.2.8) Head protection.
h. (see 3.2.9) Eye protection and augmentation devices.
i. (see 3.2.10) Hearing protection and communication devices.

The personal protective equipment interfaces and special concerns shall be considered and adequately addressed. Refer to the following sections for information to determine requirements of this type:

j. (see 3.3) Personal protective subsystem integrity.
k. (see 3.4) Logistics support and maintainability.
l. (see 3.5) Human engineering, anthropometric sizing, and utilization.
m. (see 3.6) Aircraft compatibility.
n. (see 3.7) Personal equipment compatibility.
o. (see 3.8) Escape system interface.
p. (see 3.9) Health and safety.

## 3.2 Performance requirements

### 3.2.1 Item characteristics

**3.2.1.1 Electrical characteristics.** The aircraft mounted and crew member personal protective system electrical characteristics shall be designed to interface properly with the aircraft electrical subsystem. The electrical characteristics shall consist of: ______________.

**3.2.1.2 Environmental conditions.** The personal protective equipment shall be capable of performing as required by this specification before, during, and after the following exposures.

(a) HIGH TEMPERATURE: Personal protective equipment shall not fail structurally or functionally, as defined by this specification, due to the high temperature stresses. It shall operate as necessary to meet the requirements of this specification during exposure to operational environments. Components that are to be permanently mounted in the aircraft shall be capable of withstanding exposure to the high temperatures of _________ in closed cockpits on summer days with full solar loading. Maximum design high storage temperature shall be _____°F. Maximum design high operating temperature shall be _____°F for man-mounted equipment and ______°F for aircraft mounted equipment.

(b) LOW TEMPERATURE: Personal protective equipment shall not fail structurally or functionally, as defined by this specification, due to the effects of low temperatures, and shall operate as required during operationally encountered low temperatures. The minimum design low storage temperature shall be ____°F. Minimum design low operating temperature shall be ____°F for man-mounted equipment and ____°F for aircraft mounted equipment.

(c) TEMPERATURE SHOCK: Personal protective equipment shall continue to perform as required by this specification during rapid changes in ambient operational temperatures, from ____°F high temperature to ______°F low temperature, and from ______°F low temperature to ______°F high temperature.

(d) SOLAR RADIATION: Man-mounted or aircraft mounted personal protective equipment that is exposed to the direct rays of the sun shall maintain the performance required by this specification before, during, and after exposure.

(e) BLOWING RAIN: Personal protective equipment shall continue to maintain the performance required by this specification during and after prolonged exposure to blowing rain at a rate of ____ inches per hour and a wind speed of ______ miles per hour for a duration of ______ minutes.

(f) HUMIDITY: Personal protective equipment shall be capable of storage and operation under conditions of _____ °F temperature extreme and ______ percent humidity extreme without failing, breaking, becoming inoperable or deteriorating.

(g) FUNGUS: Personal protective equipment shall continue to maintain the performance required by this specification during and after exposures to environmental fungus throughout its operational and storage lives.

(h) SALT FOG: Personal protective equipment shall continue to maintain the performance required by this specification during and after exposures to environmental salt fog throughout its operational and storage lives. The effects from salt accumulation and salt fog corrosion shall be minimized.

(i) BLOWING DUST: Personal protective equipment shall continue to maintain the performance required by this specification during and after exposure to a dust-laden environment.

(j) VIBRATION: The aircraft mounted personal protective equipment shall perform as required by this specification during exposure to vibrations encountered during any flight condition for ________ aircraft. There shall be no resonances throughout the operational environment for any aircraft mounted equipment.

(k) GUNFIRE VIBRATION: Aircraft mounted equipment shall operate and meet the performance requirements of this specification during exposures to gunfire vibrations for ________ aircraft.

(l) EXPLOSIVE ATMOSPHERE: Aircraft or man-mounted personal protective equipment shall be capable of operating as required by this specification in an ambient atmosphere without causing ignition of such an atmosphere.

(m) ACCELERATION: The personal protective equipment shall not cause discomfort or injury to the aircrew member, and shall not break or otherwise fail structurally or functionally, as defined by this specification, during or after exposure to the following acceleration environment: Operational exposure of ___ $G_z$, ___ $G_x$ and ___ $G_y$ sustained for no less than ___ seconds, and crash exposure of ___ $G_z$, ___ $G_x$ and ___ $G_y$ peak impulsive acceleration with a duration of _____ seconds and a ______ curve shape. No forces shall be imposed on the aircrew member by inertial effects of the personal protective equipment under the above accelerations that may cause a reduction in the crew member's ability to perform at peak capability.

(n) SHOCK: All personal protective equipment shall meet the requirements of this specification after exposure to shock loads associated with transport or bench handling.

(o) COMBINED ENVIRONMENTAL STRESS: All personal protective equipment shall continue to maintain the performance required by this specification during a combined environmental stress environment of temperature, altitude, vibration and __________.

(p) OTHER RESISTIVE PROPERTIES: The personal protective equipment shall also exhibit the following resistive properties.

i. Corrosion

ii. Dissimilar Metals

iii. Other __________

**3.2.1.3 Air transportability.** Certain transportability features are desired in the design of the personal protective system components. The personal protective system components are ______. The transportability features should consist of ___________.

**3.2.2 Chemical/biological protection level.** The eye/respiratory fit factor of the aircrew chemical/biological (CB) head/respiratory protection system shall not be less than _______ for _______ percent of the USAF population. The protection level is defined as the ratio of the measured airborne concentration of a test agent in ambient air surrounding the system to the concentration of test agent within the system. The protection level afforded to the crew member's skin from liquid and solid agents consisting of __________ shall be ___________. Outward leakage of the breathing and ventilation equipment shall not be less than _____ percent.

**3.2.2.1 Chemical/biological ventilation and filtration.** A ventilation and filtration system shall be provided to assure removal of chemical/biological (CB) agents from the breathing gas, to maintain _______ protection level, and to minimize lens misting or fogging during transition between collective shelter and aircraft and during flight operations. Ventilation and breathing gas delivered to the crew member shall have chemical agent concentrations less than or equal to __________.

**3.2.2.2 Chemical/biological permeation resistance.** Permeation of chemical/biological warfare agent vapors through the system materials exposed to the external environment shall be less than the breakthrough concentrations defined below for a minimum of _______ hours.

| Agent | Breakthrough Concentration |
|---|---|
| ______________ (specify agent) | ____________________________ (specify breakthrough concentration) |

**3.2.2.3 Decontamination.** The personal protective equipment shall be capable of being decontaminated using prescribed methods specified in ________. After decontamination, the personal protective equipment shall still provide the protection from chemical agents by meeting the following requirements: _________. Additionally, the personal protective equipment shall be designed to be capable of being doffed in a contamination control area (CCA) without contaminating the wearer or to clean areas of the shelter with chemical agents.

**3.2.3 G protection.** The acceleration protection (G) system shall be provided commensurate with the aircraft capabilities that are __________. The G system shall consist of the following:

a. __________ Lower body coverage.
b. __________ G valve.
c. __________ Positive pressure breathing (PPB) with upper body coverage.
d. __________ Body positioning.

**3.2.3.1 G system pressure regulation.** The pressure regulating source shall sense change in acceleration force to provide the necessary pressures to the G system as specified by the following schedule _______. The G system will be prevented from over pressurizing by __________.

**3.2.3.2 G system reliability of operation.** The G system shall be subjected to the following cyclic operational conditions _______ and shall subsequently meet all functional and environmental requirements. In the event of a G system failure the crew member(s) shall receive a warning to indicate that proper G protection is not being provided.

**3.2.4 Personal high altitude protection.** Personal high altitude protection shall be provided for aircrews on aircraft during missions at altitudes above _____ feet. The protection shall be provided by pressure suit ensembles (PSEs) properly donned and worn with other personal protective flight equipment. The PSE shall provide counterpressure to the crewmember when exposed to reduced pressures at high altitudes and shall be integrated with a pressure breathing oxygen system. The other high altitude personal protection equipment items must be compatible with the PSE. The PSE must provide a get-me-down capability.

**3.2.4.1 Aircraft pressure suit provisions.** A pressure suit ensemble shall be provided for missions above 50,000 feet and for missions above 25,000 feet if, in the event of an unplanned cabin depressurization, it would be impossible to immediately descend to an altitude at which cabin pressure altitude can be maintained at or below 25,000 feet (a). Pressure demand oxygen, ventilation, heating, communication, and (b) aircraft interfaces shall be provided in the in-flight and ground egress system. A controller shall maintain the suit system pressure at a nominal ______ feet when the cabin pressure exceeds ______ feet. A pressure relief device shall be provided, located ______ and calibrated to relieve overpressure in the range of ______. The oxygen or breathing system shall be designed to provide pressure demand regulated oxygen with the following features: ______. The system shall have the capability to provide oxygen for each crew member with varying flow rates dependent on altitudes for ______ hours. The system supply and distribution plumbing shall operate under an internal pressure range of ______ psi. Pressure suit ventilation and comfort provisions shall be provided according to ______.

**3.2.4.1.1 Pressure suit controls and displays.** Manual override control of the suit shall be provided, and test features for a preflight check of the assembly shall be provided consisting of ______. Pressure, flow, and ______ displays shall be provided for normal operations. Warning displays and alarms shall inform the ______ crew members should the cabin pressure and altitude exceed ______ feet, should the oxygen flow rate to the suit deviate from that normally expected for that cabin pressure altitude, and ______. The controls and displays provided shall be functionally compatible with the protective breathing system such that ______.

**3.2.4.2 Oxygen system for altitude protection.** The aircrew member on all mission scenarios must be provided with an oxygen system providing protection for the reduced pressures at altitude. Sufficient oxygen stores on the aircraft must supply the aircrew member with breathing oxygen at adequate flow rates and pressures to maintain physiological well-being and acceptable performance level. The oxygen system shall provide respirable gas volume of ______ lpm with oxygen partial pressures at ______ mm Hg with the gas flows at pressures of ______ psig, correlated with the altitude pressures. The oxygen system must be integrated with other personal equipment items worn by the aircrew member and present on or in the aircraft cockpit.

**3.2.4.3 Cabin environmental control system for altitude protection.** A cabin pressurizing system shall be provided for aircraft cabins with flight altitudes of ______ ft. The cabin pressure shall be at ______ psig differential at altitudes up to ______ ft. Above ______ ft, the cabin differential pressure of ______ psig must be maintained when partial and/or full pressure suit ensembles are worn.

**3.2.5 Thermal stress protection.** The personal protection system shall prevent a reduction in aircrew performance, and provide for crew member comfort, and safety when exposed to high and low thermal stresses.

a. Low temperature stress – The system shall protect the crew member during exposure to temperatures as low as ______ degrees for ______ period of time in water and ______ degrees for ______ period of time in air. Hypothermia shall be precluded.

b. High temperature stress – The system shall protect the crew member during exposures to temperatures as high as ______ degrees with a relative humidity of ______ for ______ period of time and from metabolic heat generation rates induced by physical activity as high as ______ kcal/hour for ______ period of time in ambient temperatures up to ______ degrees with a relative humidity of ______. High temperature shock and dehydration effects to the crew member shall be precluded.

**3.2.6 Flame and heat protection.** The crew member shall be protected against incapacitation by the flame and heat of a fire environment.

a. Flame protection: The system shall provide burn through protection for ________ minutes. The system shall also have the following flammability characteristics: maximum flame time shall be ________, maximum glow time shall be ________, and maximum char length shall be ________.

b. Heat protection: The system shall provide protection from thermal burns and incapacitation for temperatures as high as _____ degrees for _____ period of time. The thermal protective performance (TPP) rating shall be ________.

**3.2.7 Smoke and toxic fumes protection.**

a. Smoke and toxic fumes protection shall be provided for crew members and passengers (as applicable) during _____ mission segments at cabin altitudes up to _____ feet and for emergency escape. The protective device shall have a maximum permissible leakage of contaminant gases less than ________ for _____ levels of smoke and fumes and for _____ period of time. Eye protection shall be provided for _____ levels of smoke and fumes and for _____ period of time.

b. Special Concerns: The following performance criteria shall be considered.
(1) Maximum inspiration of carbon dioxide caused by rebreathing: ________.
(2) Malfunction indication: ________.
(3) Workload factors: ________.
(4) Other critical concerns: ________.

**3.2.8 Protective headgear.** The protective headgear shall provide the aircrew member with impact and penetration protection.

a. Impact protection. The total dynamic response of the headgear to an impact energy of _____ foot-pounds shall limit the acceleration imparted to the head to no more than _____ G's for _____ seconds.

b. Headgear penetration resistance. The headgear penetration resistance shall be ________.

**3.2.9 Eye protection and enhancement devices.**

**3.2.9.1 Nuclear flash protection.** The nuclear flash protection subsystem shall provide flash blindness protection to the aircrew member against energy emitted from single and multiple detonations of nuclear weapons. The nuclear flash protection subsystem shall attenuate direct and off angle viewing of nuclear flash energy to prevent flash blindness for the duration of the nuclear weapons flash event. For purposes of this specification, flash blindness protection shall be defined as a loss of visual function not greater than _____ seconds for a _______ viewing condition. Visual function refers to the ability of the aircrew member to read critical flight instruments. The nuclear flash protection subsystem shall provide protection against nuclear weapons threats defined in ________.

**3.2.9.2 Nuclear thermal protection.** The thermal protection subsystem shall provide protection against retinal burn resulting from energy emitted from single and multiple detonations of nuclear weapons. The thermal protection subsystem shall not transmit more than ________ calories per square centimeter total fluency when exposed to the nuclear weapons threats defined in ________.

**3.2.9.3 Laser eye protection.** The subsystem shall provide eye protection against threats/hazards including (vitreal hemorrhage, retinal burn, flash blindness, glare) resulting from exposure to laser radiation specified in the document ________.

**3.2.9.4 Sun protection.** The subsystem shall provide eye protection against sunlight glare and ultraviolet components of sunlight and shall allow ________ percent transmission of visible light.

**3.2.9.5 Night vision enhancement.** The subsystem shall provide enhanced nighttime vision under ambient lighting conditions ranging from natural starlight to moonlight. Using the subsystem, the aircrew member shall attain a visual acuity of ______ for targets of contrast for ______ ambient lighting conditions.

**3.2.10 Hearing protection and communication devices.**

**3.2.10.1 Hazardous noise attenuation.** The subsystem shall function to provide hearing protection to the aircrew member against hazardous acoustic noise of the crew station environments for the aircraft and ______ mission profiles specified. Cumulative hazardous noise, when measured at the aircrew member's ear, shall not exceed 1.0 when calculated as follows:

$$\sum_{\substack{\text{Mission}\\ \text{Segments}}} \frac{D_i}{P_i} = \sum_{\substack{\text{Mission}\\ \text{Segments}}} \left[ \frac{D_i}{\text{antilog}\left[\dfrac{dB(A)_i - 102.76}{-13.12}\right]} \right] - 1.0$$

Where: $i$ = segment of given mission.
$D_i$ = duration of mission segment.
$P_i$ = permissible duration of noise exposure to segment.
$\overline{dB(A)}_i$ = maximum overall A-scale sound pressure at the crew member ear for segment.

**3.2.10.2 Speech intelligibility.** Use of the subsystem shall enable sufficient intelligibility of speech communication to permit successful mission completion in the environment of aircraft noise.

**3.3 Personal protective subsystem integrity.** The personal protective equipment integrity shall be established as ____________.

**3.4 Logistics support and maintainability.** Logistics supportability has been established on current personal protective equipment. The goal shall be to establish logistics supportability requirements that are consistent with existing methods in use in the USAF. Areas of concern for logistics support are as follows:

a. __________ Maintenance repair levels.
b. __________ Support and test equipment.
c. __________ Support facilities.
d. __________ Packaging and shipment methods.

Areas of concern for maintainability are as follows:

e. __________ Maintenance tasks.
f. __________ Interchangeability and standardization.
g. __________ Repairability and calibration requirements.
h. __________ Fault detection and isolation.
i. __________ Built-in-test.
j. __________ Operational support equipment requirements.
k. __________ Personnel skill levels.
l. __________ Maintenance tools.

**3.5 Human engineering, anthropometric sizing, and utilization.** The following human engineering design considerations shall be addressed, as applicable, and shall be in accordance with *MIL-STD-1800*.

a. Population, Fitting and Sizes: All personal protective equipment shall be designed and sized to fit Air Force populations of officer and enlisted aircrew members associated with each weapons platform. The subpopulations shall include the representative Air Force aircrew race, sex and age subpopulations as applicable to the aircraft. Personal protective equipment shall be designed and sized to accommodate the range of body size and proportions for the central ________ percent or more of the persons in the populations specified above using multivariate accommodation of all relevant variables simultaneously. A minimum number of sizes for each type of personal equipment shall be used. Individual parts and components shall be of a single size wherever possible. The personal protective equipment shall provide maximum adjustability for individual user's personal comfort. The definitions and data contained in the on-line anthropometric data base at the Center for Anthropometric Research Data shall be applied (see operating manual, *AAMRL-TR-88-012*). Personal Equipment must be compatible with eye glasses. The _______ critical body dimension(s) shall be specified and utilized for system sizing and design.

b. Field Issuing Procedures: The personal protective equipment shall include a set of field issuing procedures for assigning the size of best fit for each user. The procedures shall emphasize a relatively simple fitting process that minimizes human error and maximizes proper user fit.

c. Comfort: The personal protective equipment shall be comfortable to wear for the required period, without inducing hot spots, irritation, scratching, pinching, itching, chafing, bruising, digging into the skin or objectionable pressure or forces. The personal protective equipment shall have no objectionable odors from the materials, and shall not retain body odors. Portions of the personal protective equipment in contact with the user's skin shall not be tacky to the touch, and shall permit the removal of perspiration. Discomfort due to heat stress, psychological stress or aircrew member workload shall not be attributable to the personal protective equipment.

d. Waste Elimination: An aircrew member, while wearing the personal protective equipment, shall be capable of using standard rest room facilities or shall have waste elimination capability integrated within the personal protective equipment.

e. Valsalva: The personal protective equipment shall not interfere with the performance of the Valsalva maneuver by the aircrew member.

f. Drinking/Eating: The personal protective equipment shall permit the aircrew member to drink/eat while wearing the equipment if drinking/eating is permitted during the mission in which the equipment will be worn/used.

g. Ingress/Egress: The personal protective equipment shall not interfere with the normal ingress/egress procedures imposed on the aircrew members.

h. Don/Doff: The personal protective equipment shall be capable of being donned in ________ (time) and doffed _______ (time), as applicable to the aircraft mission. Donning and doffing shall be _______ (with or without) assistance as defined by operational requirements.

i. Transition: The personal protective equipment shall be capable of being transitioned from the ground mode to the aircraft operational mode in _______ (time). (If applicable) the personal protective equipment must also provide the capability to transition back from the aircraft mode to ground mode without interrupting protection in ________ (time).

j. Launderability: The personal protective equipment shall be capable of being cleaned without performance degradation. Garments shall withstand ______ washing cycles in a commercial washing machine. Other equipment shall be cleaned using the methods recommended with the equipment.

k. Other: ___________.

**3.6 Aircraft compatibility.** The personal protective equipment shall effectively interface with the aircraft on which it will be used. These aircraft include __________. Of particular concern, the personal protective equipment must properly function with ________. Also, the personal protective equipment shall not interfere with the proper operation of other aircraft systems.

**3.7 Personal equipment compatibility.** The personal protective equipment shall when properly donned and worn with all other flight ensembles, be compatible and fully usable. The personal protective equipment under consideration shall be fully functional and not degrade or negate the proper operation and use of the following types of personal equipment:

a. __________ Headgear.
b. __________ Oxygen mask, hoses and connectors.
c. __________ Life preserver unit.
d. __________ Parachute.
e. __________ Parachute harness and quick release fittings.
f. __________ Seat restraint devices and disconnects.
g. __________ Survival vest and included equipment.
h. __________ Anti-exposure suit.
i. __________ Anti-g suit, hoses and disconnects.
j. __________ Partial pressure suit ensemble, hoses and disconnects.
k. __________ Survival kit and attachment straps.
l. __________ Chemical defense clothing and equipment.
m. __________ Eye protection devices.
n. __________ Vision enhancement devices.
o. __________ Flight clothing, jackets and gloves.
p. __________ Spectacles (i.e. HGU-4/P).
q. __________ Communication systems.
r. __________ (Specify other personal equipment).

**3.8 Escape system interface.** The personal protective equipment must be designed to properly interface with emergency in-flight and ground escape systems. Each aspect of the emergency escape system must be considered relative to the personal protective equipment under development or modification consisting of __________. The following escape system areas must be assessed to determine a proper design and interface:

a. __________ Weight and center-of-gravity.
b. __________ Personal services disconnects.
c. __________ Space and clearance provisions.
d. __________ Windblast effects to include any seat speed sensing system.
e. __________ Parachute deployment.
f. __________ Seat-man separation.
g. __________ Survival kit deployment.
h. __________ Restraint provisions.
i. __________ Parachute landing and release.
j. __________ Water entry.
k. __________ ____________________.
(Specify other areas of concern)

**3.9 Health and safety.** The personal protective equipment shall be designed and constructed with the user's, maintainer's and manufacturer's safety as a primary requirement. The equipment shall be airworthy and shall not create hazards when the user is in the _________ aircraft. All subsystems shall be designed to minimize the risk of any catastrophic failures. To provide effective safety control measures, the following areas of concern shall be addressed:

a. __________ Warning devices or capability.
b. __________ Dangerous materials or processes.
c. __________ Overpressure protection.
d. __________ Electrical shock protection.
e. __________ Toxic gases.
f. __________ ____________________
(Specify other areas of concern)

## 4. VERIFICATIONS

**4.1 System testing.** Testing and verification shall be accomplished from the standpoint of the overall system and installation. It shall consist of ____________.

### 4.2 Performance verifications

#### 4.2.1 Item characteristics verifications

**4.2.1.1 Electrical characteristics tests.** Verification of the electrical characteristics for the aircraft mounted and crew member personal protective system shall consist of _________.

**4.2.1.2 Verification of environmental conditions.** Each configuration of the personal protective equipment shall be subjected to the following verifications. The verification procedures shall be as required in *MIL-STD-810* and as supplemented below. Except for storage condition verifications, the personal protective equipment shall be in the operational configuration. The personal protective equipment shall meet the requirements of Section 3 before, during, and after each of the following verifications.

a. HIGH TEMPERATURE: Method 501.2, Procedure I (Storage) and/or Procedure II (Operation). Use ____ °F as the high storage temperature and ____ °F as the high operating temperature. ______ 24-hr storage cycles and ____ 24-hr operating cycles shall be used. Due to the nature of these high temperatures, the use of a simulated human interface, i.e., dummy, headform, and/or pneumatic apparatus, etc., may be used at the discretion of the procuring agency. The personal protective equipment shall perform as required.

b. LOW TEMPERATURE: Method 501.2, Procedure I (Storage) and/or Procedure II (Operation). The low storage temperature shall be _____ °F for a duration of hours, and the low operating temperature shall be _____ °F for a duration of _____ hours. The use of a simulated human interface as described above may be used at the discretion of the procuring agency. The personal protective equipment shall perform as required.

c. TEMPERATURE SHOCK: Method 503.2, Procedure I. The high temperature chamber shall be __________.

d. SOLAR RADIATION: Method 505.2, Procedure I (cycling) and/or Procedure II (steady state). The Procedure I test item shall be exposed to __________ continuous 24-hr cycles of controlled simulated solar radiation and dry bulb temperature as described in Table 505.2-I. The Procedure II test item shall be exposed to ______ continuous 24-hr cycles of controlled simulated solar radiation. Procedure II shall use a cycle of 8 hours at 1120 W/$m^2$ and a dry bulb temperature of ______ °F. The duration of the test shall be _____ minutes. The personal protective equipment shall perform as required.

e. BLOWING RAIN: Method 506.2, Procedure I. A rainfall rate of ______ inches per hour with a wind velocity of ______ miles per hour shall be used. The test item temperature shall be ______ °F, and the rain temperature shall be ____ °F. The duration of the test shall be _____ minutes. The personal protective equipment shall perform as required.

f. HUMIDITY: Method 507.2, Procedure I (natural), Procedure II (induced), and/or Procedure III (aggravated). A temperature of ______ °F and a relative humidity of ________ percent shall be used for a duration of ______ continuous 24-hr cycles. The personal protective equipment shall perform as required.

g. FUNGUS: Method 508.3. The test period shall be __________ days. The personal protective equipment shall perform as required.

h. SALT FOG: Method 509.2, Procedure I. The personal protective equipment shall be subjected to _____ continuous cyclic exposures consisting of _____ hours of salt fog exposure and ____ hours of ambient (drying) conditions. A 5 ± 1 percent salt solution shall be used. The personal protective equipment shall perform as required.

i. BLOWING DUST: Method 510.2, Procedure I. Air velocities of ______ feet per minute shall be used. The dust composition shall consist of (percent of each material). The dust concentration shall be maintained at 10.6 ±7.0 grams per cubic meter. The exposure shall consist of _____ hours at _____ °F (high storage or operating temperature). The personal protective equipment shall perform as required.

j. VIBRATION: Method 514.3, Category ___. The vibration spectrum and intensity, as well as the duration of exposure shall be determined from the information given for the category chosen. This verification applies to aircraft mounted equipment only. The personal protective equipment shall perform as required.

k. GUNFIRE VIBRATION: Method 519.3, Procedure I. This verification applies only to equipment mounted in aircraft that carry and fire on-board guns. The vibration spectrum and intensity shall be ______. The duration of the exposure shall be ______ seconds. The personal protective equipment shall perform as required.

l. EXPLOSIVE ATMOSPHERE: Method 511.2, Procedure I (operation in a flammable environment) and/or Procedure II (explosion containment). The fuel volume and/or weight shall be _______. The verification shall be conducted at a simulated altitude of _____ feet. Personal protective equipment shall be examined after completion of the Method 511.2 verification to determine that no degradation in the materials or performance has resulted from exposure to the explosive atmosphere mixture. The personal protective equipment shall perform as required.

m. ACCELERATION: Method 513.3, Procedure I (structural) and/or Procedure II (operational). The Procedure I test item shall withstand the accelerations suggested in Table 513.3-I. The Procedure II test item shall withstand the acceleration suggested in Table 513.3-II. The personal protective equipment shall perform as required.

n. SHOCK: Method 516.3, Procedure VI (bench handling). This verification shall include ______ drops from a height of ______ inches above a wooden laboratory table. Other procedures may be performed as deemed necessary by the procuring agency. The personal protective equipment shall perform as required.

o. COMBINED ENVIRONMENTAL STRESS: Method 520.0, Procedure I (engineering development test), Procedure II (flight or operational support test), and/or Procedure III (qualification test). Test profiles, cycles, and duration shall be determined as specified in each procedure. The personal protective equipment shall perform as required.

p. OTHER RESISTIVE PROPERTIES: The requirements of 3.2.1 (p) shall be verified by _______. The personal protective equipment shall perform as required.

**4.2.1.3 Air transportability verification.** The survival and flotation equipment transportability features shall be verified by _________.

**4.2.2 Chemical/biological protection level tests.** Quantitative leakage tests shall be performed with a ________ person test panel to verify that leakage and population requirements can be met. The test subjects shall wear the complete aircrew chemical/biological (CB) protection system and other applicable life support equipment. The leakage tests shall be performed in a test chamber of adequate size to permit the simulation of all aircrew movements during transition from a collective shelter to the aircraft, during flight operations, and during transition back to the shelter. A chemical test simulant ________ shall be used to challenge the protection system. Continuous measurements of the leakage into the system shall be recorded with instruments of sufficient accuracy to measure protection levels greater than ________. Skin protection capability shall be determined by ___________.

**4.2.2.1 Verification of the chemical and biological ventilation and filtration system.** The following ventilation and filtration system tests shall be performed:

a. _____ Breathing performance: ___________

b. _____ Demist and ventilation performance: ___________

c. _____ Respiratory protection level performance: ___________

d. _____ Service life: ___________

e. _____ Subjective use: ___________

f. _____ Durability: ___________

g. _____ ________________; ___________
(Specify other)

**4.2.2.2 Verification of chemical and biological permeation resistance.** The components of the system (e.g., helmet shell, lens, seals, hoses, shrouds, and other fabrics) shall be resistant to test agent penetration when subjected to the following tests ___________.

**4.2.2.3 Verifying decontamination.** The personal protective equipment shall be contaminated with _______, then decontaminated according to the applicable procedures; then it shall pass _______ tests. ________ subjects shall don the personal protective equipment and it shall be contaminated with ________ simulant. Also, _______ subjects shall don the personal protective equipment and shall be contaminated with ______ simulant. Each subject shall perform the control contamination area (CCA) ingress procedure as approved by the procuring activity.

**4.2.3 G protection testing.** The G system shall be demonstrated to provide protection commensurate with the aircraft capability through testing consisting of ____________.

**4.2.3.1 G system pressure regulation.** The G system shall be analyzed and tested to demonstrate the capability to meet the required performance schedule. It shall be proven that overpressurization of the system cannot occur.

**4.2.3.2 G system reliability of operation.** The G system shall be subjected to meet the following cyclic operational conditions ______; and shall subsequently meet the functional and environmental requirements.

**4.2.4 Verifying personal high altitude protection.** The high altitude protection for aircrew members must be analytically compared with the environmental conditions of a mission profile. The requirements for oxygen partial pressure and the atmospheric pressure exposures must be shown to be adequately fulfilled and provide protection. Simulated altitude chamber exposures must demonstrate adequate protection by the oxygen system, the pressure suit ensemble and the cabin pressurization system.

**4.2.4.1 Verification of pressure suit ensemble.** The pressure suit ensemble shall be evaluated for adequacy to fulfill the requirements of the PSEs on missions and aircrews on various selected ______ and in the specific environments ________. Test subjects shall verify fit and adequacy of PSE for protection against specific environments, natural and induced. Testing of the PSEs shall verify that the physiological requirements of the aircrew members are satisfied.

**4.2.4.1.1 Verification of pressure suit controls and displays.** The verification of the aircraft pressure suit controls and displays shall consist of ______________.

**4.2.4.2 Verification of oxygen system for altitude protection.** The oxygen system for altitude protection must be verified by analysis of _______ required for aircrew member performance under the reduced pressures of aircraft flight profiles. The oxygen supply requirement must be correlated with the aircrew member's physiological oxygen usage and the protection required against altitude reduced pressures. This protection must be verified in ground altitude chamber tests of the respiration equipment on the aircrew member and on the aircraft. Subsequent flight testing of aircrew member altitude oxygen systems must verify the protection requirements for oxygen at altitude. The oxygen system equipment must demonstrate no interference or detriment in performance by the aircrew member.

**4.2.4.3 Verification of cabin environmental control system for altitude protection.** The cabin structure with the associated mounted equipment shall be tested for integrity and show acceptable pressure retention to maintain specified cabin pressures at the reduced pressures at altitude. The ECS shall produce cabin pressures at differentials protecting aircrews at the operational altitudes.

**4.2.5 Verification of thermal stress protection.** Verification of the requirements of *3.2.5* shall be accomplished.

a. Low temperature stress protection shall be verified by ______________.

b. High temperature stress protection shall be verified by ______________.

**4.2.6 Verification of flame and heat.** Verification of the requirements of *3.2.6* shall be accomplished.

a. Protection from flame shall be verified by ____________.

b. Protection from heat shall be verified by ___________.

**4.2.7 Verification of smoke and toxic fumes protection.**

a. The capability of the system to provide smoke and toxic fumes protection shall be determined by ______________.

b. All additional performance criteria shall be verified by _____.

**4.2.8 Verification of protective headgear.** The requirements of *3.2.8* shall be verified as follows:

a. Verification of impact protection. The requirements of *3.2.8a* shall be verified by __________.

b. Verification of penetration resistance. The requirements of *3.2.8b* shall be verified by ________.

**4.2.9 Verifying eye protection and enhancement devices.**

**4.2.9.1 Verification of nuclear flash protection.** The verification of flash blindness protection shall be performed by analysis and test of the subsystem performance characteristics and their relation to providing flash blindness protection.

**4.2.9.2 Verification of nuclear thermal protection.** The verification of protection against retinal burn shall be performed by analysis and measurement of subsystem performance characteristics and their relation to providing retinal burn protection to the eye.

**4.2.9.3 Verification of laser eye protection.** Verification of laser eye protection shall be performed by the measurement and analysis of subsystem performance characteristics and their relation to providing laser eye protection.

**4.2.9.4 Verification of sun protection.** The verification of sun protection shall be performed by measurement, test, and demonstration of the subsystem performance characteristics and their effectiveness in providing sun protection.

**4.2.9.5 Verification of night vision enhancement.** The verification of night vision enhancement capability shall be performed by measurement, test, and demonstration of the subsystem performance characteristics and their relation to providing a night vision enhancement capability.

**4.2.10 Verifying hearing protection and communication devices.**

**4.2.10.1 Verification of hazardous noise attenuation.** Verification of the hazardous noise attenuation requirement shall be by analysis and measurement of subsystem performance characteristics and their relation to providing hazardous noise attenuation.

**4.2.10.2 Verification of speech intelligibility.** Verification of speech intelligibility when using the _____ subsystem shall be performed by analysis and test. Using the __________ test, the subjects shall score a minimum of __________ percent in a noise environment.

**4.3 Personal protective subsystem integrity verification.** The verification of the integrity of the personal protective equipment shall consist of __________.

**4.4 Verification of logistics support and maintainability.** Inspections, analyses, demonstrations, and tests shall be accomplished as necessary to determine that all logistics support and maintainability requirements have been met. As a minimum the following shall be accomplished __________.

**4.5 Verification of human engineering, anthropometric sizing and utilization.** The following verification procedures shall be established to ensure compliance with the requirements of section *3.5*.

a. Human test subjects anthropometrically selected in accordance with the on-line anthropometric data base at the Center for Anthropometric Research Data (see *AAMRL-TR-88-012*) shall wear the personal protective equipment to demonstrate that it is sized to fit the user population in all configurations and operating environments. The ________ critical body dimension(s) shall be specified and utilized for system sizing and subject selection.

b. Field issuing procedures shall be verified subjectively for ease of use by invoking the procedure(s) during all other verifications requiring subjects to wear, use, or handle equipment for testing or demonstration. The issuance of proper user fit/size without error shall be compared against current fitting procedures to determine minimization of error and proper user fit.

c. The personal protective equipment shall be tested by ______ aircrew members during flight testing. Objectionable odors, tackiness to the touch, hot spots, pressure points, restriction of movement, or other detrimental performance characteristics of the personal protective equipment shall be determined by subjective evaluation using an approved questionnaire. Evaluation of flight crew comments by the procuring activity shall determine whether this requirement is met. The flight crew shall be anthropometrically selected from the central ______ percent of the flying population based on the ______ critical body dimension(s), as well as any other subpopulations for the intended mission.

d. ________ human test subjects, both male and female, shall demonstrate use of standard rest room facilities or other applicable waste elimination techniques while wearing the system in both the ground and operational modes. For verification of waste elimination provisions with chemical defense systems, _______ human test subjects shall be sprayed with, chemical simulant and shall simulate use of waste elimination provisions without contamination of test subjects. Subjective evaluation as well as verification of performance requirements shall be accomplished.

e. _________ completely outfitted test subjects shall perform a Valsalva maneuver by occluding the nose as required to equalize pressure in the ears during altitude ascent and descent. Inability of any test subject to perform the Valsalva with one hand shall constitute a failure to meet the Valsalva requirement.

f. ________ completely outfitted test subjects shall demonstrate drinking/eating capabilities. Inability to perform in accordance with the requirement shall constitute a failure.

g. ________________ completely outfitted aircrew members shall perform normal ingress/egress procedures. Any failure to perform the normal ingress/egress due to interference by the personal protective equipment shall constitute failure to meet the ingress/egress requirement.

h. The time taken by each of __________ trained test subjects selected from the USAF aircrew population to don and to doff the personal protective equipment shall be measured. An average donning time or an average doffing time which exceeds the requirements for don/doff shall constitute a failure.

i. The elapsed time for each of _________ trained test subjects selected from the USAF aircrew population to make the transition from ground use to aircraft use shall be measured. The test subject shall be seated in the aircraft seat and a crew chief or assistant may aid in the transition if normally performed as such. An average elapsed time which exceeds the required transition time shall constitute a failure.

j. The personal protective equipment shall be subjected to ______ washing cycles in a commercial washing machine or shall be subjected to _______ cycles of the required cleaning method. Failure of the equipment to meet any of the performance requirements after the specified cleaning cycles shall constitute a failure.

k. ________ verifications shall be established to show compliance with any other human engineering requirements.

**4.6 Aircraft compatibility.** The personal protective equipment shall be validated for a proper aircraft installation and interface by the following methods ________.

**4.7 Personal protective equipment compatibility tests.** The personal protective equipment shall be donned along with all required life support equipment by (number and size) of aircrew member test subjects. The test subjects shall enter a ______ mock-up and ______ aircraft properly modified to accept the _____ personal protective equipment. Evaluations shall be conducted to determine any undue restrictions, interferences or other problems which are considered to be detrimental to the crew member, the mission, and emergency procedures.

**4.8 Verification of escape system interface.** Inspections, analyses, demonstrations and tests shall be conducted as necessary to determine that a satisfactory interface to personal escape system has been provided. The following demonstrations and tests shall be performed to verify that the personal protective equipment will properly interface with the escape system:

a. ____________ Windblast.
b. ____________ Adverse acceleration environments (including vertical deceleration and/or horizontal acceleration).
c. ____________ Release force.
d. ____________ Wind tunnel.
e. ____________ High speed sled.
f. ____________ Seat ejection (clearance and posture) see *MIL-STD-846* and *MIL-E-87235* as applicable.
g. ____________ Hanging harness.
h. ____________ Parachute.
i. ____________ Water survival (including flotation and life raft boarding).
j. ____________ Ejection tower.
k. ____________ ______________________________ (Specify other verification methods.)

**4.9 Health and safety verification.** Measures shall be taken to ensure that the manufacture, use and maintenance of personal protective equipment does not result in health and safety hazards. Proper precautions shall be taken to determine that all hazards have been identified, eliminated and/or effectively controlled. These measures shall consist of ____________.

## 5. PACKAGING

**5.1 Packaging.** Preservation, packing, and marking requirements in accordance with *MIL-STD-2073-1* shall be such that the ____________ is delivered suitable for use and free from damage and defects.

(Note – Further guidance is given in the packaging section of the appendix to this document.)

**5.2 Packaging verification.** Verification of packaging shall be by inspection per the quality assurance provisions of *MIL-STD-2073-1*. Packaging design validation provisions shall be performed, when required, in accordance with *MIL-STD-2073-1*.

## 6. NOTES.

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

**6.1 Intended use.** The personal protective equipment addressed in this document is intended primarily for use by aircrew personnel. Of primary concern is the design and installation of personal protective equipment systems for aircrew members of high performance aircraft, where personal protection is a most critical factor. Personal protection equipment requirements for aircrew members of other types of aircraft may also be derived from this document.

**6.2 Issue of DODISS.** When this specification is used in an acquisition, the applicable issue of the DODISS must be cited in the solicitation.

**6.3 Consideration of data requirements.** The following data requirements should be considered when this specification is applied on a contract. The applicable Data Item Descriptions (DIDs) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DIDs are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where *DOD FAR Supplement 27.475-1* exempts the requirement for a DD Form 1423.)

| Reference Paragraph | DID Number | DID Title | Suggested Tailoring |
|---|---|---|---|

(see appendix for a partial list of DIDs which may apply)

The DIDs were those cleared as of the date of this specification. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DIDs are cited on the DD Form 1423.

(The DIDs under consideration should be studied to determine whether all paragraphs of the DID are applicable to the program or project under consideration. The delivery of unnecessary data results in increased program costs for no benefit. If necessary, specify only those DID paragraphs that are applicable to the program or project.)

**6.4 Reference documents tree.** The following list of documents comprises the first and second tier references of documents applicable to sections 3 and 4 of this specification. Note that only the first tier references are contractually binding; the second tier is provided for guidance only.

| 1st Tier | 2nd Tier | |
|---|---|---|
| *AFGS-87235* | *AFSC DH 1-3* | *Human Factors Engineering* |
| *MIL-STD-810* | *MIL-S-901* | *Shock Tests H. I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for* |
| | *MIL-STD-167* | *Mechanical Vibrations of Shipboard Equipment* |
| | *MIL-STD-210* | *Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment* |
| | *MIL-STD-781* | *Reliability Testing for Engineering, Development, Qualification, and Production* |
| | *MIL-STD-882* | *System Safety Program Requirements* |
| | *MIL-STD-1165* | *Glossary of Environmental Terms (Terrestrial)* |
| | *MIL-STD-1540* | *Test Requirements for Space Vehicles* |
| | *MIL-STD-1670* | *Environmental Criteria and Guidelines for Air-Launched Weapons* |
| | *MIL-STD-45662* | *Calibration Systems Requirements* |
| | *STANAG 2895* | |
| | *STANAG 3518* | |
| | *AR 70-38* | |

| 1st Tier | 2nd Tier | |
|---|---|---|
| *MIL-STD-846* | (no referenced documents in this standard) | |
| *MIL-STD-1800* | *MIL-W-5044* | *Walkway Compound, Nonslip, and Walkway Matting, Nonslip* |
| | *MIL-W-5050* | *Walkway, Coating and Matting, Nonslip, Aircraft, Application of* |
| | *MIL-M-18012* | *Design and Configuration of Markings for Aircrew Station Displays* |
| | *MIL-L-85762* | *Lighting, Aircraft, Interior, AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS) Compatible* |
| | *MIL-E-87145* | *Environmental Control, Airborne* |
| | *MIL-D-87213* | *Displays Airborne, Electronically/Optically Generated* |
| | *MIL-P-87234* | *Personal Protective Equipment, Aircrew* |
| | *FED-STD-595* | *Colors* |
| | *MIL-STD-280* | *Definitions of Item Levels, Item Exchangeability, Models, and Related Terms* |
| | *MIL-STD-415* | *Provisions for Electronic Systems and Associated Equipment, Design Criteria for* |
| | *MIL-STD-454* | *Standard General Req'ts for Electronic Equipment* |
| | *MIL-STD-721* | *Definitions of Effectiveness Terms for Reliability and Maintainability, Human Factors, and Safety* |
| | *MIL-STD-783* | *Legends for Use in Aircrew Stations and on Airborne Equipment* |
| | *MIL-STD-1472* | *Human Engineering Design Criteria for Military Systems, Equipment, and Facilities* |
| | *MIL-STD-1776* | *Aircrew Station and Passenger Accommodations* |
| | *MIL-STD-1789* | *Sound Pressure Levels in Aircraft* |
| | *A-A-1619* | *Recorder-Reproducer Sound* |
| | *MIL-HDBK-300* | *Technical Information File of Support Equipment* |
| | *AFLCR 65-2* | *Economic Considerations in Maintenance Coding* |
| | *AFLCR 171-12* | *Acutarial Program for Selected Items* |
| | *AFM 11-1* | *US Air Force Glossary of Standardized Terms* |
| | *AFM 67-1* | *USAF Supply Manual* |
| | *AFM 400-1* | *Selective Management of Propulsion Units* |
| | *AFR 66-1* | *Maintenance Management Policy* |
| | *AFR 66-14* | *The USAF Equipment Maintenance Program* |
| | *AFR 80-14* | *Test and Evaluation* |
| | *AFR 161-35* | *Hazardous Noise Exposure* |
| | *AMRL-TR-79-2* | *Guidelines for Fit Testing and Evaluation of USAF Personal-Protective Clothing and Equipment* |
| | *T.O. 00-20-1* | *Prevention Maintenance Program and General Policy Requirements and Procedures* |
| | *T.O. 00-20-3* | *Maintenance Processing of Repairable Property and the Repair Cycle Asset Control System* |

**6.5 Definitions and acronyms.** See the appendix of this document for a listing of definitions and acronyms used in this document.

**6.6 Responsible engineering office.** The responsible engineering office (REO) for this document is ASD/ENECE, Wright-Patterson AFB OH 45433-6503. The engineer responsible for the technical content of this document is Dennis W. Schroll, ASD/ENECE, Wright-Patterson AFB OH 45433-6503, AUTOVON 785-2165, commercial (513) 255-2165.

**6.7 Keyword list.**

altitude protection
anthropometric sizing
aircrew protection
decontamination
eye protection
flash protection
G protection
G suit
chemical/biological protection
nuclear protection
personal equipment
pressure suit
protective equipment
thermal protection

**6.8 Changes from previous issue.** Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodian
Air Force - 11

Preparing activity
Air Force - 11

Project No. 8475-F229

# PERSONAL PROTECTIVE EQUIPMENT, AIRCREW

# HANDBOOK FOR

## 10. SCOPE

**10.1 Scope.** This appendix contains rationale, guidance, a lessons learned repository, and information to tailor the requirements of section 3 and the verifications of section 4 into a specification for use in the development and acquisition of personal protective equipment.

**10.2 Purpose.** This appendix provides information to assist the acquiring activity in the use of *AFGS-87234A*.

**10.3 Use.** This appendix is designed to assist the project engineer or individual using this document in determining the information to use in a personal protective equipment specification. This document is oriented primarily towards the development of equipment specifications. A system specification or aircraft specification which contains a life support or personal protective equipment section may not need to be as detailed as discussed herein. In the later phases of a program, the developing activity may use this document as a guide to write critical item development specifications.

### 10.4 Format

**10.4.1 Requirement and verification identity.** Section 30 of this appendix parallels sections 3 and 4 of the basic specification; paragraph titles and numbering are in the same sequence. Section 30 provides each requirement (section 3) and associated verification (section 4) as stated in the basic specification. Both the requirement and verification have sections with rationale, guidance, and lessons learned. The specific wording used in the basic specification is not necessarily required to be used as given, but is intended as an example of wording that may be used or modified for the program or project under consideration. The rationale, guidance, and lessons learned are given as background information to assist in determining the applicable specification requirements and to fill in the blanks.

**10.4.2 Requirement and verification package.** Section 30 of this appendix has been arranged so that the requirement and associated verification are a complete package to permit the addition to, or deletion from, the criteria as a single requirement. A requirement is not specified without an associated verification.

**10.5 Responsible engineering office.** The responsible engineering office (REO) for this document is ASD/ENECE, Wright-Patterson AFB OH 45433-6503. The engineer responsible for the technical content of this document is Dennis W. Schroll, AUTOVON 785-2165, commercial (513) 255-2165.

## 20. APPLICABLE DOCUMENTS

**20.1 References.** The documents referenced in this appendix are not intended to be applied contractually. Their primary purpose is to provide background information for the engineers or individuals responsible for developing the most appropriate performance specification wording and values by filling in the blanks for the requirements and verifications contained in the specification under development.

**20.2 Avoidance of tiering.** Should it be determined that the references contained in this appendix are necessary in writing a Request for Proposal (RFP) or building a contract, excessive tiering shall be avoided by calling out only those portions of the reference which have direct applicability. It is a goal of the Department of Defense that the practice of referencing documents in their entirety be eliminated in order to reduce tiering of document requirements.

**20.3 Government documents**

SPECIFICATIONS

Federal

| | |
|---|---|
| *PPP-B-566* | *Boxes, Folding, Paperboard* |
| *PPP-B-636* | *Boxes, Shipping, Fiberboard* |
| *PPP-B-676* | *Boxes, Setup* |
| *PPP-C-795* | *Cushioning Material, Packaging (Flexible, Closed Cell, Plastic Film for Long Shipping Cycle Applications* |
| *PPP-C-1752* | *Cushioning Material, Packaging, Polyethylene Foam* |
| *PPP-C-1797* | *Cushioning Material, Resilient, Low Density Unicellular, Polypropylene Foam* |
| *PPP-C-1842* | *Cushioning Material, Plastic, Open Cell (For Packaging Applications)* |

Military

| | |
|---|---|
| *MIL-E-6051* | *Electromagnetic Compatibility Requirements, Systems* |
| *MIL-C-9177/5* | *Connector, Audio, Airborne, Jack, Switch, 4 Contact* |
| *MIL-V-9370* | *Valve, Automatic, Pressure Regulating, Anti-G Suit* |
| *MIL-S-9479* | *Seat System, Upward Ejection, Aircraft, General Specification for* |
| *MIL-C-18387* | *Cloth, Twill, Cotton, Fire Retardant Treated* |
| *MIL-S-25948* | *Sunglasses, HGU-4P (with case)* |
| *MIL-L-38169* | *Lenses, Goggle and Visor, Helmet, Optical Characteristics, General Spec for* (cancelled) |
| *MIL-V-43511* | *Visors, Flyer's Helmet, Polycarbonate* |
| *MIL-G-81188* | *Gloves, Flyers, Summer, Type GS/FRP-2* |
| *MIL-C-81393* | *Cloth, Knitted, Polyamide, High Temperature Resistant, Simplex, Jersey* |
| *MIL-C-81814* | *Cloth, Twill, Aramid, High Temperature Resistant* |
| *MIL-C-83195* | *Coverall, Flyers, Anti-Exposure CWU-21A/P* |
| *MIL-L-83197* | *Liner, Anti-Exposure, Flying Coveralls, CWU-23/P* |
| *MIL-J-83382* | *Jacket, Flyer's, Men's, Summer, Fire Resistant, CWU-36/P* |
| *MIL-J-83388* | *Jackets, Flyer's, Cold Weather* |
| *MIL-A-83406* | *Anti-G Garment, Cutaway, CSU-13B/P* |
| *MIL-C-83429* | *Cloth, Plain and Basket Weave, Aramid* |
| *MIL-E-87145* | *Environmental Control, Airborne* |
| *MIL-V-87223* | *Valves, Pressure, Anti-G Suit, MXU-804/A and MXU-805/A* |
| *AFGS-87226* | *Oxygen Systems, Aircraft* |
| *AFGS-87238* | *Survival and Flotation System, Airborne* |
| *AFGS-87240* | *Lighting Equipment, Airborne Interior and Exterior* |
| *MIL-A-87244* | *Avionic/Electronic Integrity Program Requirements* |
| *AFGS-87249* | *Mechanical Equipment and Subsystems, Requirements for the Integrity of* |

STANDARDS

Federal

| | |
|---|---|
| *FED-STD-191* | *Textile Test Methods* |
| *FED-STD-209* | *Clean Room and Work Station Requirements, Controlled Environment* |

Military

| | |
|---|---|
| *MIL-STD-125* | *Standard Guides for Preparation of Item Descriptions* |
| *MIL-STD-129* | *Marking for Shipment and Storage* |
| *MIL-STD-130* | *Identification Marking of U.S. Military Property* |
| *MIL-STD-147* | *Palletized Unit Loads* |
| *MIL-STD-210* | *Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment* |
| *MIL-STD-415* | *Test Provisions for Electronic Systems and Associated Equipment, Design Criteria for* |
| *MIL-STD-454* | *Standard General Requirements for Electronic Equipment* |
| *MIL-STD-461* | *Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference* |
| *MIL-STD-462* | *Electromagnetic Interference Characteristics, Measurement of* |
| *MIL-STD-470* | *Maintainability Program for Systems and Equipment* |
| *MIL-STD-471* | *Maintainability Verification/Demonstration/Evaluation* |
| *MIL-STD-648* | *Design Criteria for Specialized Shipping Containers* |
| *MIL-STD-882* | *System Safety Program Requirements* |
| *MIL-STD-889* | *Dissimilar Metals* |
| *MIL-STD-1189* | *Standard Department of Defense Bar Code Symbology* |
| *MIL-STD-1250* | *Corrosion Prevention and Deterioration Control in Electronic Components and Assemblies* |
| *MIL-STD-1472* | *Human Engineering Design Criteria for Military Systems, Equipment and Facilities* |
| *MIL-STD-1510* | *Container Design Retrieval System, Procedures for Use of* |
| *MIL-STD-1629* | *Procedures for Performing a Failure Mode Effects and Criticality Analysis* |
| *MIL-STD-1686* | *Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment* |
| *MIL-STD-1776* | *Aircrew Station and Passenger Accommodations* |
| *MIL-STD-1789* | *Sound Pressure Levels in Aircraft* |
| *MIL-STD-1791* | *Designing for Internal Aerial Delivery in Fixed Wing Aircraft* |
| *MIL-STD-1798* | *Mechanical Equipment and Subsystems Integrity Program* |

HANDBOOKS

| | |
|---|---|
| *AFSC DH 1-3* | *Human Factors Engineering (Personnel Subsystems)* |
| *AFSC DH 1-7* | *Aerospace Materials* |
| *AFSC DH 2-2* | *Crew Stations and Passenger Accommodations* |

*MIL-HDBK-729 Corrosion and Corrosion Prevention Metals*

*Handbook of Laser Bioeffects Assessment* - Beatrice, Penetar, Letterman Army Institute of Research, Project 3EI62777A878, Task/WU: BA/161.

(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.)

**20.4 Other Government documents, drawings, and publications.**

*AAMRL-TR-86-054 Chemical Warfare Challenge to Aircrews, Part I.* (Classified: Secret)

*AAMRL-TR-86-055 Chemical Warfare Challenge to Aircrews, Part II.* (Classified: Secret)

*AAMRL-TR-86-063 Chemical Warfare Scenario for Air Base Challenge Assessment, 7-day Scenario, October 1986.* (Classified: Secret)

*ADC 027335 Approved Test Plan for Aircraft Operations in a Toxic Environment, Subtests 1-12.* (Classified: Confidential)

*AFAMRL-TR-75-50 Bioenvironmental Noise Data Handbook*, June 1975, Volume 1-172.

*AFAMRL-TR-80-25 Voice Communication Research and Evaluation System.*

*AFAMRL-TR-85-055 Instrument Lighting Levels and AN/AVS-6 Usage.*

*AFFDL-TR-71-35* Study conducted by Grumman Aerospace Corp., 1971.

*AFFDL-TR-74-48 High Acceleration Cockpits for Advanced Fighter Aircraft*, Sinnett, J. M., Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, May 1974.

*AFFTC-TR-87-05 Qualitative Evaluation of the Tactical Life Support System in the F-15.* Harbert, M. R., 1st Lt, USAF and C. J. Precourt, Maj, USAF, Air Force Flight Test Center, Edwards Air Force Base, CA, April 1987.

*AFFTC-TR-87-07 Limited Evaluation of Three Prototype Positive Pressure Breathing Anti-G Systems in the F-16*, George, E. J. and L. D. Jollett, Maj, USAF, Air Force Test Center, Edwards Air Force Base, CA, May 1987.

*AFFTC-TR-88-15 Flight Test Evaluation of Active Noise Reduction, Final Report*, June 1988.

*AFOSH 161-10 Health Hazards Control for Laser Radiation.*

*AFP-160-5 Air Force Pamphlet: Physiological Training*, Department of the Air Force, pages 4-11 to 4-12 and 6-1 to 6-12, 23 January 1976.

*AFR 161-35 Aerospace Medicine, Hazardous Noise Exposure*, 9 April 1982.

*AFR 355-7 (also Army FM 3-9) Military Chemistry and Chemical Compounds.*

*AFWAL-TR-86-4080 Personnel Protection Program (PPP)*, Final Report, Nov 1986 (Secret).

*AFWAL-TR-87-4100 Handbook for Laser Hardening Technologies*, Feb 1988. (Secret) *

*AMRL-TR-72-117 Advanced Fighter Concepts Incorporating High Acceleration Cockpits, Vol. V - Crew Station Concepts*, Sinnett, J. M. and L. N. Edington, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base Ohio, July 1973.

*AN/AVS-6 Night Vision Goggles, Study Guide*, 1005 SG, June, 1987, 436 Strategic Training Squadron, Carswell AFB, TX 76127.

*CRDEC-SP-84010 Laboratory Methods for Evaluating Protective Clothing Systems Against Chemical Agents.*

*FAA-AM-76-5 Visual Evaluation of Smoke Protective Devices*, John A. Vaughan and Kenneth W. Welsh, May 1976.

*FAA-AM-78-41 Optical Properties of Smoke Protective Devices*, John A. Vaughan and Kenneth W. Welsh.

*FAR 25.853 Vertical Flame Test. Federal Aviation Regulation Part 25. Airworthiness Standards: Transport Category Airplanes.*

*HSD-AAMRL Human Tolerance to Unconventional Flight Maneuvering Accelerations.* Van Patten, R. E., PhD, P. E., July 1985.

*HSD-TR-87-009 Tactical Life Support System: Final Report*, Lloyd, A. J. P., Human Systems Division, Brooks Air Force Base, Texas, May 1988.

*NADC-MA-55-08 Human Tolerance to Positive G as Determined by Physiological Endpoints.* Stoll, A. M., U.S. Naval Air Development Center, Pennsylvania, August 1955.

*Prevention of Loss of Consciousness with Positive Pressure Breathing and Supinating Seat*, by Burns, J.W., USAF School of Aerospace Medicine (USAF/SAM), Brooks Air Force Base, TX 1985.

*SAM-ACHE-86-14 Man-rating of the F-16 Positive Pressure Breathing (PPB) System.* Test Plan Under Three Generic Protocols a) CEIL b) Acceleration c) Altitude, USAF/SAM, Brooks Air Force Base, Texas, September 1986.

*HEW Publication (FDA) 79-8086 Evaluation of Commercially Available Laser Protective Eyewear*, May 79

*SAM-TR-78-30 Evaluation of Laser Eye Protection Eye Wear.*

*SAM-TR-80-17 Evaluation of PLZT Goggles.*

*TFD-87-1595 Pilot Forward Leaning Support System*, by Munson, K. M., July 1987.

*USAFSAM-TR-85-3 Night Vision Manual for the Flight Surgeon.*

*qUSAFSAM-TR-88-21 Medical Management of Combat Laser Eye Injuries*, Oct 88

*DPG-TR-85-203 Aircraft Operations in a Toxic Environment*, Subtest 12: "Hazards of Ground Operations of Large, Multi-engine Aircraft in a Simulated Toxic Environment."

*NATO Document: NL Chemical Defense Gear for F-16 Pilots* by Medema, Dr. J. and van Zelm, M., Prins Maurits Laboratory TNO, National Defense Research Organization, Netherlands.

*NIOSH/OSHA Standards on Toxicology*, (National Institute for Occupational Safety and Health/Occupational Safety and Health Administration, US Department of Health and Human Services, Public Health Service and US Department of Labor).

*USAF T.O. 11C15-1-3 Technical Manual, Chemical Warfare Decontamination, Detection and Disposal of Decontaminating Agents.*

*USAF Dwg 16123G A/P22S-6A High Altitude Full Pressure Flying Outfit.*

*WRDC-TR-89-4047 Personnel Protection Implementation Program*, Sep 1989 (Secret). *

Aerospace Medical Association, Burns, J. W. and U. T. Balldin, 1983: "+ Gz Protection with Assisted Positive Pressure Breathing (PPB)," *Aerospace Medicine*. by Burton, R. R. and S. D. Leverett Jr. and E. D. Michaelson, October 1974: pp 1115-1136 "Man at High Sustained +Gz Acceleration: A Review."

*An Overview of Laser Induced Eye Effects* - Survivability/Vulnerability, Information Center (SURVIAC), DOD Information Analysis Center.

**20.5 Non-Government documents**

*ANSI S3.2-1960 Phonetically Balanced Word Intelligibility Test Method*

*ANSI S3.5-1969 Articulation Index Test*

*ANSI S12.6 Method for Measurement of Real-Ear Attenuation of Hearing Protectors at Threshold*

*ANSI Z87.1 Practice for Occupational and Educational Eye and Face Protection*

*ANSI Z90.1 Specification for Protective Headgear for Vehicular Users*

*ASTM D4108-87 Standard Test Method for Thermal Protective Performance of Materials for Clothing by Open-Flame Method*

*Aviation, Space and Environmental Medicine*, "A Conceptual Model for Predicting Pilot Group G Tolerance for Tactical Fighter Aircraft," by Burton, R. R., D.V.M., PhD, August 1986, 733-744.

*Aviation, Space, and Environmental Medicine*, Vol. 53, No. 12, "PAVELOW III: Interior Lighting Reconfiguration for Night Lighting and Night Vision Goggle Compatibility," December 1982, 1162-1165.

Bhatnagar, Vijay Mohan. *Fire Retardant Formulations Handbook*, "Progress in Fire Retardancy," Technomic Publishing Co.: Volume 1, 1972 LC: 72-80324, ISBN: 0-87762-090-3; Volume 4, 1974 (out of print); and Volume 8, 1977 LC: 72-91704, ISBN: 0-87762-217-5.

deSteiguer, D. and McFadden, E. B. *SAFE Symposium Journal*, "The Use of n-Pentane as a Tracer Gas for the Quantitative Evaluation of Aircrew Protective Breathing Equipment," 1976.

deSteiguer, D. and Pinski, M. S. *SAFE Symposium Journal*, "The Objective Evaluation of Aircrew Protective Breathing Equipment: I. Oxygen Mask/Goggles Combinations, II. Full-face Masks and Hoods, IV. Full-face Masks and Hoods Suitable for Flight Attendant Use," 1976.

*DNA001-C-0033 Product Function Specification for Passive Thermal Protection System*, PDA Engineering: Costa Mesa, CA, Sandia Reports, 22 Sept 1987.

Defense Research Establishment Ottawa Report No. 983, *A Study on the Preparation and Characterization of Charcoals used in Military Gas-Mask Canisters*, Ottawa, Canada, Feb 1988.

*Fiber, Fabrics and Flames: Instructor's Handbook with References*. US Department of Health, Education, and Welfare; US Government Printing Office, 1970.

Gillingham, K. K., and G.B. McNaughton, MD, Col, USAF. *Flying Safety*, "G Induced Loss of Consciousness," April 1983, 23-27.

Mendez, Arthur R., and Smith, Peter A. "Model for Predicting the Effects of Laser Exposures and Eye Protection on Vision," from S.P.I.E Proceedings, Los Angeles, Vol 1207, 16–18 Jan 90

Pluta, J. C., Maj, USAF, *Flying Safety*. "Loc Survey." January 1984, 25-28.

Glasstone, Samuel. *Effects of Nuclear Weapons*.

*Human Engineering Guide to Equipment Design*, Revised Edition. LC: 72-600054.

*LANL Report LA-5488 Selection of Respirator Test Panels Representative of US*, March 1974.

*NA-87-1476 B-1B Crew Compartment Thermal Hardness Study* Rockwell International, August 1987.

"PLZT Electro-optic Shutters: Applications," *Applied Optics*, Volume 14, Number 8, August 1975.

Reeves, W. A., Drake, G. L., and Perkins, R. M. *Fire Resistant Textile Handbook*. Technomic Publishing Co.: 1974, 276 pp. LC: 73-82116; ISBN: 0-87762-088-1.

Rockwell International *B–1B Crew Compartment Thermal Hardness Study*, August 1987.

*SAE AMS 1775A Fabric, Nylon Upholstery, Fire Retardant*

*SAE AMS 3841 Cloth, Cotton Twill, Fire Retardant Treated*

*SAE AS 8031 Personal Protective Devices for Toxic and Irritating Atmospheres, Air Transport - Crew Members*

*Thermal/Flash Protective Progress Reports*, Sandia National Laboratories, Albuquerque, New Mexico.

Yehaskel, Albert. *Fire and Flame Retardant Polymers*, Noyes Data Corporation, 492 pp; LC: 78-70742; ISBN: 0-8155-0733-X: Series Chemical Technology Review, 122, 1979.

## 30. REQUIREMENTS AND VERIFICATIONS

**3.1 System description.** The personal protective equipment shall be designed, tested, and installed from the systems viewpoint. The personal protection system requirements shall consist of:

- a. (see *3.2.2*) Chemical/biological (CB) protection.
- b. (see *3.2.3*) G protection.
- c. (see *3.2.4*) Personal altitude protection.
- d. (see *3.2.5*) Thermal stress protection.
- e. (see *3.2.6*) Flame and heat protection.
- f. (see *3.2.7*) Smoke and toxic fumes protection.
- g. (see *3.2.8*) Head protection.
- h. (see *3.2.9*) Eye protection and augmentation devices.
- i. (see *3.2.10*) Hearing protection and communication devices.

The personal protective equipment interfaces and special concerns shall be considered and adequately addressed. Refer to the following sections for information to determine requirements of this type:

- j. (see *3.3*) Personal protective equipment integrity.
- k. (see *3.4*) Logistics support and maintainability.
- l. (see *3.5*) Human engineering, anthropometric sizing, and utilization.
- m. (see *3.6*) Aircraft compatibility.
- n. (see *3.7*) Personal equipment compatibility.
- o. (see *3.8*) Escape system interface.
- p. (see *3.9*) Health and safety.

### REQUIREMENT RATIONALE (3.1)

In the design of crew member personal protective equipment, more than one personal protective system requirement is likely to apply to the design and development of the equipment. For example, the chemical/biological ensemble or garment may also incorporate personal altitude protection for proper breathing to preclude hypoxia at higher aircraft altitudes and, in addition, flame and heat protection to protect the crewmember from burns in an emergency. It is also quite possible that the CB garment may need to interface with other personal equipment in the most effective manner possible. For this reason, this document has approached the concept of personal protective equipment design and development from the overall systems viewpoint.

### REQUIREMENT GUIDANCE

In any new personal protective equipment program, the past approach has been to divide the individual components and establish separate programs or projects and to procure and/or develop this equipment accordingly. While this approach usually allows the acquiring agency to get what they want or think they need, often it results in oversight or overkill of one or more technical requirements in favor of another of which the responsible program management and engineering are more knowledgeable. Additionally, if coordination or effective communication fails between organizations that are responsible for interfacing systems, incompatibilities inevitably arise. This usually results in program changes, schedule slips, and increased costs.

This document addresses the design, development, and testing of the personal protective equipment from a systems viewpoint. The impact on the total system of any one component or requirement should be assessed. For example, if a G garment is to be developed, requirements such as chemical and biological defense or flame and heat protection must also be assessed for applicability and used accordingly. This also applies to other areas of concern such as the impact to the personal escape system. A list is given in the requirements to remind the person using this document of all areas that must be assessed for applicability. Only those areas that finally are determined to be applicable should be used.

### REQUIREMENT LESSONS LEARNED

No lessons learned available.

**4.1 System testing.** Testing and verification shall be accomplished from the standpoint of the overall system and installation. It shall consist of _______.

VERIFICATION RATIONALE (4.1)

When all the personal protective equipment components are integrated into a complete system and are interfaced with the aircraft escape system, the human operator, the organizational concept, and the maintenance concept, a system level assessment, in addition to the component level verification, will determine if all the requirements, including system level considerations, have been met.

VERIFICATION GUIDANCE

Many of the problem areas and deficiencies can be determined through comprehensive, well thought out test programs. Usually, the final approval of the design will be after the evaluation by the acquiring agency. In the US Air Force, this could be the Developmental Test and Evaluation including flight testing.

Refer to each individual section for complete information on suggested verification methods to use in a specification or contract. Examples and lessons learned are given to aid in the development of test methods and to prevent the reoccurrence of past mistakes.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.2 Performance requirements.**

**3.2.1 Item characteristics.**

**3.2.1.1 Electrical characteristics.** The aircraft mounted and crew member personal protective system electrical characteristics shall be designed to interface properly with the aircraft electrical subsystem. The electrical characteristics shall consist of _____________.

REQUIREMENT RATIONALE (3.2.1.1)

To ensure proper operation of all electrical components that may be included with the personal protective system, it is desirable to specify electrical characteristics.

REQUIREMENT GUIDANCE

Electrical characteristics to be considered are maximum and average power consumption, power phase, current amplitude, cycle rate, alternating versus direct current, and any electrical connections needed. Intermittent current and power interruptions should be considered in terms of the effect on the proper operation of the personal protective equipment. Another consideration is electrical power loss. All personal protective equipment must continue to operate properly in the event of an electrical power failure. To ensure this, a backup electrical power source may be accomplished by connecting to the aircraft's emergency electrical system or aircraft batteries. This introduces another consideration: that of the power allowance effectively interfacing with all other equipment and subsystems using electrical power.

Several factors that often are overlooked in the design of electronic components are electromagnetic interference (EMI) and voltage surges or spikes often encountered in the environment of military aircraft. Electrical wiring and components act as antennas that gather electromagnetic energy and convert it to low current energy. This extra electric current can disrupt the proper operation of electronic equipment unless precautions are taken. This may consist of shielding the wiring that is properly grounded and electrically sealing circuit cards in metal containers. Voltage surges and electromagnetic pulses (EMP) can damage or disrupt the proper operation of electronic equipment. One method of protection is to provide diodes at the proper circuit location. Another factor to consider is that electronic components must be mounted so that temperature effects do not result in strain cracks on the individual electronic components. Some electronic components generate heat and methods of reducing the temperature are conductive/convection cooling. This means that thermal conductive paths should be provided from the component to the cooling medium (ambient air or a cooling fluid.)

REQUIREMENT LESSONS LEARNED

When electrical components are used in the design of personal protective equipment, careful consideration should be given to the thermal, vibration and humidity environment. Investigations of the design of electrical equipment used in military aircraft has shown that most failures are caused by high thermal stresses induced by improper strain relief. One study conducted by Grumman Aerospace Corp. in 1971, *AFFDL-TR-71-35*, revealed that up to 55 percent of environment-induced failures were caused by temperature changes. In most cases, thermal expansion causes cracks to begin on electrical component leads on circuit cards. The second leading cause of failures was vibration, which accounted for 20 percent of the failures. Humidity effects caused another 19 percent of the failures, and dust contributed to the remaining 6 percent of the failures.

In the Aircrew Integrated System (AIS) personal protective equipment development program in the late 1980's the following electronic requirements were determined:

Electromagnetic interference and compatibility (EMI and EMC). The electromagnetic interference and compatibility characteristics proposed in the Government specifications for the AIS program are: it shall conform to the requirements of Parts 1 and 2 of *MIL-STD-461, Notice 2*, for Class A1b equipment and *MIL-E-6051*. Any noncommanded change or any inability to perform a required change in the equipment's control settings, modes of operation, output, or configuration shall be indication of susceptibility and/or incompatibility. This shall apply whether the change is transitory or permanent in nature. All equipment shall perform as required when subjected to the aircraft chassis electromagnetic noise for the aircraft specified. The following requirements of *MIL-STD-461* shall be met: CE03, CE07, CS01, CS06, CS12, CS13, RE02, RS02, RS03, and RS06.

**4.2.1.1 Electrical characteristics tests.** Verification of the electrical characteristics for the aircraft-mounted and crew member personal protective system shall consist of ____________.

VERIFICATION RATIONALE (4.2.1.1)

Performing analyses and functional tests of the electrical characteristics for the personal protective system will ensure that all equipment operates properly for all required flight operations and all emergency situations.

VERIFICATION GUIDANCE

In the initial design layouts of the aircraft personal protective system, complete circuit schematics and diagrams should be provided. Electrical systems should be completely analyzed to determine compliance. Acknowledging the expanding use of computers, microchips, and circuits in all types of equipment, trained computer hardware and software technicians and engineers should analyze the equipment. Breadboarding all electrical components and circuits with the survival and flotation system and functionally checking all operations is advised. Design improvements may be determined at this design stage. After installation of electrical equipment on the aircraft, inspections should be accomplished to verify that wiring has been properly installed and restrained. Perform checks to ensure the personal protective equipment and aircraft electrical subsystems are compatible. Proper operation should be demonstrated during all functional, environmental and emergency egress testing.

VERIFICATION LESSONS LEARNED

In the Government specification for the Aircrew Integrated System (AIS) personal protective equipment development program, the following verification methods were given: All subsystems of the AIS that emit electromagnetic radiation, or carry electric current when operated shall be tested as required by *MIL-STD-462* and *MIL-E-6051*. The requirements of *MIL-STD-461* as cited or modified shall be met.

**3.2.1.2 Environmental conditions.** The personal protective equipment shall be capable of performing as required by this specification before, during, and after the following exposures.

a. HIGH TEMPERATURE: Personal protective equipment shall not fail structurally or functionally, as defined by this specification, due to the high temperature stresses. It shall operate as necessary to meet the requirements of this specification during exposure to operational environments. Components that are to be permanently mounted in the aircraft shall be capable of withstanding exposure to the high temperatures of ________ in closed cockpits on summer days with full solar loading. Maximum design high storage temperature shall be ________ °F. Maximum design high operating temperature shall be ______ °F for man-mounted equipment and ________ °F for aircraft mounted equipment.

b. LOW TEMPERATURE: Personal protective equipment shall not fail structurally or functionally, as defined by this specification, due to the effects of low temperatures, and shall operate as required during operationally encountered low temperatures. The minimum design low storage temperature shall be ____ °F. Minimum design low operating temperature shall be ______ °F for man-mounted equipment and ________ °F for aircraft mounted equipment.

c. TEMPERATURE SHOCK: Personal protective equipment shall continue to perform as required by this specification during rapid changes in ambient operational temperatures, from ____ °F high temperature to _____ °F low temperature, and from ______ °F low temperature to ______ °F high temperature.

d. SOLAR RADIATION: Man-mounted or aircraft mounted personal protective equipment that is exposed to the direct rays of the sun shall maintain the performance required by this specification before, during, and after exposure.

e. BLOWING RAIN: Personal protective equipment shall continue to maintain the performance required by this specification during and after prolonged exposure to blowing rain at a rate of ______ inches per hour and a wind speed of ______ miles per hour for a duration of ________ minutes.

f. HUMIDITY: Personal protective equipment shall be capable of storage and operation under conditions of _____ °F temperature extreme and ____ percent humidity extreme without failing, breaking, becoming inoperable, or deteriorating.

g. FUNGUS: Personal protective equipment shall continue to maintain the performance required by this specification during and after exposures to environmental fungus throughout its operational and storage lives.

h. SALT FOG: Personal protective equipment shall continue to maintain the performance required by this specification during and after exposures to environmental salt fog throughout its operational and storage lives. The effects from salt accumulation and salt fog corrosion shall be minimized.

i. BLOWING DUST: Personal protective equipment shall continue to maintain the performance required by this specification during and after exposure to a dust-laden environment.

j. VIBRATION: The aircraft mounted personal protective equipment shall perform as required by this specification during exposure to vibrations encountered during any flight condition for ________ aircraft. There shall be no resonances throughout the operational environment for any aircraft mounted equipment.

k. GUNFIRE VIBRATION: Aircraft mounted equipment shall operate and meet the performance requirements of this specification during exposures to gunfire vibrations for ________ aircraft.

l. EXPLOSIVE ATMOSPHERE: Aircraft or man-mounted personal protective equipment shall be capable of operating as required by this specification in an ambient atmosphere without causing ignition of such an atmosphere.

m. ACCELERATION: The personal protective equipment shall not cause discomfort or injury to the aircrew member, and shall not break or otherwise fail structurally or functionally, as defined by this specification, during or after exposure to the following acceleration environment: Operational exposure of _______ $G_z$, ________ $G_x$ and _______ $G_y$ sustained for no less than _______ seconds, and crash exposure of _____ $G_z$, _____ $G_x$, and ______ $G_y$ peak impulsive acceleration with a duration of _______ seconds and a _______ curve shape. No forces shall be imposed on the aircrew member by inertial effects of the personal protective equipment under the above accelerations that may cause a reduction in the crew member's ability to perform at peak capability.

n. SHOCK: All personal protective equipment shall meet the requirements of this specification after exposure to shock loads associated with transport or bench handling.

o. COMBINED ENVIRONMENTAL STRESS: All personal protective equipment shall continue to maintain the performance required by this specification during a combined environmental stress environment of temperature, altitude, vibration and __________.

p. OTHER RESISTIVE PROPERTIES: The personal protective equipment shall also exhibit the following resistive properties.

i. Corrosion

ii. Dissimilar Metals

iii. Other: _____________

REQUIREMENT RATIONALE (3.2.1.2)

a. The effect of high temperature must be evaluated to determine the effects to the equipment and the capability of the equipment to perform satisfactorily when exposed to elevated temperatures that may be encountered during service life for both storage and operational conditions.

b. The effect of low temperature exposure must be evaluated to determine resistance of the equipment to low temperatures encountered during storage and operational use.

c. Exposure to temperature shock must be evaluated to determine the equipment's resistance to sudden changes of temperature.

d. The effect of solar radiation energy on personal protective equipment must be evaluated to determine the resistance of the equipment to heating and spectral energy input associated with solar radiation.

e. Personal protective equipment must be evaluated for resistance to structural or functional degradation in a blowing rain environment.

f. Personal protective equipment must exhibit resistance to corrosion or degradation induced by warm, highly humid environments, such as those encountered in tropical areas.

g. Personal protective equipment must exhibit fungus resistance to prevent structural and functional degradation.

h. Resistance of personal protective equipment to the effects of a salt atmosphere is essential to prevent corrosion, electrical problems, and structural and functional degradation which may reduce the performance of the equipment.

i. The ability of personal protective equipment to resist the effects of blowing dust without degradation of performance or structure is essential.

j. Personal protective equipment must be constructed to withstand expected dynamic vibrational stresses, including vibrational resonances, and to ensure that performance degradations or malfunctions will not be produced by the operational vibration environment.

k. Resistance of personal protective equipment, particularly that which is aircraft mounted, to the brief but intense vibration fields resulting from blast pressure fields generated by repetitive firing guns mounted in, on, or near the aircraft structure is essential.

l. Personal protective equipment must have the ability to operate in the presence of an explosive atmosphere without creating an explosion.

m. Personal protective equipment must be constructed to withstand expected steady state stresses and to ensure that performance degradation or malfunction will not be produced by the operational acceleration environment.

n. Personal protective equipment must be constructed to withstand expected dynamic shock stresses to ensure that no performance degradations or malfunctions are produced by the service shock environment expected in handling, transportation, and use.

o. The combined stresses found in the service environment must not cause structural or functional degradation of the personal protective equipment.

p. Other resistive properties of the personal equipment, such as resistance to corrosion, must be exhibited to ensure safe and proper operation of the equipment.

REQUIREMENT GUIDANCE

Personal protective equipment must be suitable for its intended operational and storage environments. Therefore, all personal protective equipment must function satisfactorily before, during, and after (as applicable) exposure to any natural or induced environments encountered during storage or operational use. Any degradation or malfunction of the equipment may not only hinder performance, but may endanger the safety of the crew member. In order to establish environmental requirements, the environment in which the equipment is intended to be used must be determined from the aircraft type, mission analysis, and crew duty responsibilities. *MIL-STD-810* and *MIL-STD-210* provide some guidance in determining the appropriate requirement levels. In the case of operational use, no requirement should exceed the limits of human tolerance. The following paragraphs are intended to provide additional information in regard to each particular environmental condition's effect on equipment.

a. High temperatures may temporarily or permanently impair the performance of the equipment by changing the physical properties or dimensions of the material(s) of which it is composed, and by promoting a chemical reaction, for example. The maximum storage temperature is typically higher than the maximum operating temperature.

b. Low temperatures have adverse effects on many basic materials. As a result, exposure of the personal protective equipment to low temperatures may either temporarily or permanently impair the operation of the equipment by changing the physical properties of the materials of which it is composed (e.g., causing brittleness). The minimum storage temperature is typically lower than the minimum operating temperature.

c. As a result of exposure to sudden temperature changes, operation of the equipment could be affected either temporarily or permanently by contraction, expansion, and delamination, for example. The temperature extremes for this requirement are typically the same operational temperatures as required for the high and low operating temperature requirements.

d. The heating effects of solar radiation differ from those of high air temperature alone in that the amount of heat absorbed or reflected depends on the roughness and color of the surface on which the radiation is incident as well as the angle of incidence. In addition to the differential expansion between dissimilar materials, changes in the intensity of solar radiation may cause components to expand or contract at different rates, which can lead to severe stresses and loss of structural integrity. Other solar radiation effects may occur as a result of exposure to ultraviolet radiation, such as bleaching, crazing, and molecular structure breakdown, for example. Solar radiation requirements are applicable to equipment which may be exposed to solar radiation during service or unsheltered storage at the Earth's surface or in the lower atmosphere. Consider the effects of all wavelengths of radiation from the tropical and arctic sun. Also, consider possible adverse effects while at altitude.

e. Blowing rain can penetrate the enclosure of the equipment and cause physical deterioration. The accompanying wind velocity can vary from almost calm to extremely high depending on the expected environment. Typical rainfall rates are 2 to 5 inches per hour alternating during a 30 minute period. A typical wind speed is 40 miles per hour.

f. Moisture can cause physical and chemical deterioration of material. Temperature changes and humidity may cause condensation inside the equipment which may lead to swelling, electrical degradation, corrosion, and other forms of deterioration which degrade the performance of the equipment. The humidity requirement is intended for equipment which will be exposed to warm, highly humid conditions such as those encountered in the tropics. Temperature and humidity extremes should be based on the anticipated environment.

g. Fungus growth impairs the functioning or use of equipment by changing its physical properties.

The detrimental effects of fungus growth may result from direct attack on nonresistant materials, which breaks down the structure of the material; from indirect attack, which supports surface deposits of grease, dust, perspiration, and other contaminants; or from physical interference with the components of the equipment. Fungus growth on equipment may also cause physiological problems, such as allergies, or may be aesthetically unpleasant causing reluctance to use the equipment. Materials used for personal protective equipment should discourage fungus growth.

Observance of the detrimental effects of fungus growth may be accomplished by facilitating direct attack on nonresistant materials, which breaks down the structure of the material; by facilitating indirect attack, which supports surface deposits of grease, dust, perspiration, and other contaminants; or by facilitating physical interference with the components of the equipment. Fungus growth on equipment can also cause physiological problems, such as allergies, or be aesthetically unpleasant causing reluctance to use the equipment. Materials used for personal protective equipment should discourage fungus growth.

h. Salt is one of the most pervasive chemical compounds in the world. In coastal regions, the exposure is intensified, and in marine environments, the exposure reaches a maximum. As a consequence, all materials will probably be exposed to some form of salt during their service life that may affect their performance. The salt fog requirement is intended primarily to evaluate the durability of coatings and finishes exposed to a corrosive salt atmosphere and to determine if the effects of corrosion will be within acceptable limits. The salt fog requirement is not intended to replace requirements for corrosion due to other media.

i. Exposure to blowing dust may cause performance degradation through surface abrasion or erosion, penetration of mechanical or electrical hardware, and/or clogging of openings and filters. This requirement is applicable to all mechanical, electronic, electrical, electrochemical, and electromechanical devices for which exposure to the effects of a dust-laden atmosphere is anticipated. These requirements are not intended to be applicable to all conditions of dust that may be encountered in all areas of the world, but are typical of the majority of dust environments.

j. Vibration and vibration resonance can cause chafing, loosening, cracking, or fatiguing of the equipment's components, optical misalignment, electrical discontinuity, and excessive noise, for example. Vibration levels are strictly related to the type of aircraft in which the equipment is to be used and the approximate location of the equipment within the aircraft.

k. The vibration resulting from repetitive gun blast pulses may be two orders of magnitude above normal flight vibration levels. As a result, gunfire vibration may cause the structure and equipment to respond in a more severe manner than encountered during normal flight vibration. This response can cause intermittent electrical contact, catastrophic electrical failures, and structural fatigue failures. For equipment located far from gunblast vibration sources, the normal vibration levels discussed in (j) above may far exceed those caused by gunfire. In this case, the normal vibration requirements take precedence as the worst case.

l. Low levels of energy discharge or electrical arc can ignite mixtures of fuel vapor and air. Even a "hot spot" on the surface of a sealed equipment case can ignite these fuel/air mixtures.

m. Acceleration generally increases the forces acting on equipment and the hardware used to mount the equipment. An exception is acceleration that induces forces in opposition to gravitation forces, in which case a state of weightlessness or excess reverse loading is attained. Acceleration forces can cause deflections, deformations and/or fractures that interfere with the required operation of the equipment. The acceleration level requirements are strictly determined from the capabilities of the aircraft in which the equipment will be used. The acceleration levels used should agree with those found under 3.2.3 if this section is applicable to the equipment being evaluated.

n. Mechanical shocks will excite equipment to respond at both forced and natural frequencies. This response can cause interference between parts, overstress deformation, and rapid fatigue of the materials of which the equipment is composed.

o. The interaction of effects caused by temperature, vibration, and altitude environments can cause increased incidence of deformation, cracking, shattering, leaking, or other degradation of performance in equipment. Humidity may also be included in the combined stress requirement if the mission requires operation or storage in an adversely humid environment.

p. Refer to *MIL-HDBK-729* for corrosion prevention guidance for metals and *MIL-STD-125* for corrosion prevention guidance for electronic components and assemblies. Information concerning dissimilar metals is in *MIL-STD-889*.

**4.2.1.2 Verification of environmental conditions.** Each configuration of the personal protective equipment shall be subjected to the following verifications. The verification procedures shall be as required in *MIL-STD-810* and as supplemented below. Except for storage condition verifications, the personal protective equipment shall be in the operational configuration. The personal protective equipment shall meet the requirements of section 3 before, during, and after each of the following verifications.

a. HIGH TEMPERATURE: Method 501.2, Procedure I (Storage) and/or Procedure II (Operation). Use _____ °F as the high storage temperature and ______ °F as the high operating temperature. _________ 24-hr storage cycles and ______ 24-hr operating cycles shall be used. Due to the nature of these high temperatures, the use of a simulated human interface, i.e., dummy, headform, and/or pneumatic apparatus, etc., may be used at the discretion of the procuring agency. The personal protective equipment shall perform as required.

b. LOW TEMPERATURE: Method 501.2, Procedure I (Storage) and/or Procedure II (Operation). The low storage temperature shall be ______ °F for a duration of ______ hours, and the low operating temperature shall be ______ °F for a duration of ________ hours. The use of a simulated human interface as described above may be used at the discretion of the procuring agency. The personal protective equipment shall perform as required.

c. TEMPERATURE SHOCK: Method 503.2, Procedure I. The high temperature chamber shall be set at ______ °F and the low temperature chamber shall be set at ______ °F. The duration of the exposure shall be _______ hours at the high temperature and ______ hours at the low temperature. The test item shall be exposed alternately between the low-temperature and high-temperature chambers ________ times. The test item shall then be stabilized and inspected under controlled ambient conditions.

d. SOLAR RADIATION: Method 505.2, Procedure I (cycling) and/or Procedure II (steady state). The Procedure I test item shall be exposed to ________ continuous 24-hr cycles of controlled simulated solar radiation and dry bulb temperature as described in Table 505.2-I. The Procedure II test item shall be exposed to ________ continuous 24-hr cycles of controlled simulated solar radiation. Procedure II shall use a cycle of 8 hours at 1120 $W/m^2$ and a dry bulb temperature of ____ °F. The duration of the test shall be _______ minutes. The personal protective equipment shall perform as required.

e. BLOWING RAIN: Method 506.2, Procedure I. A rainfall rate of ________ inches per hour with a wind velocity of _______ miles per hour shall be used. The test item temperature shall be ____ °F and the rain temperature shall be ______ °F. The duration of the test shall be ______ minutes. The personal protective equipment shall perform as required.

f. HUMIDITY: Method 507.2, Procedure I (natural), Procedure II (induced), and/or Procedure III (aggravated). A temperature of ______ °F and a relative humidity of ______ percent shall be used for a duration of ______ continuous 24-hr cycles. The personal protective equipment shall perform as required.

g. FUNGUS: Method 508.3. The test period shall be _____ days. The personal protective equipment shall perform as required.

h. SALT FOG: Method 509.2, Procedure I. The personal protective equipment shall be subjected to __________ continuous cyclic exposures consisting of ______ hours of salt fog exposure and _______ hours of ambient (drying) conditions. A 5 $\pm$1 percent salt solution shall be used. The personal protective equipment shall perform as required.

i. BLOWING DUST: Method 510.2, Procedure I. Air velocities of _____ feet per minute shall be used. The dust composition shall consist of (percent of each material). The dust concentration shall be maintained at 10.6 $\pm$7.0 grams per cubic meter. The exposure shall consist of _______ hours at _____ °F (high storage or operating temperature). The personal protective equipment shall perform as required.

j. VIBRATION: Method 514.3, Category ____. The vibration spectrum and intensity, as well as the duration of exposure shall be determined from the information given for the category chosen. This verification applies to aircraft mounted equipment only. The personal protective equipment shall perform as required.

k. GUNFIRE VIBRATION: Method 519.3, Procedure I. This verification applies only to equipment mounted in aircraft that carry and fire on-board guns. The vibration spectrum and intensity shall be ______. The duration of the exposure shall be ______ seconds. The personal protective equipment shall perform as required.

l. EXPLOSIVE ATMOSPHERE: Method 511.2, Procedure I (operation in a flammable environment) and/or Procedure II (explosion containment). The fuel volume and/or weight shall be ________. The verification shall be conducted at a simulated altitude of ____________ feet. Personal protective equipment shall be examined after completion of the Method 511.2 verification to determine that no degradation in the materials or performance has resulted from exposure to the explosive atmosphere mixture. The personal protective equipment shall perform as required.

m. ACCELERATION: Method 513.3, Procedure I (structural) and/or Procedure II (operational). The Procedure I test item shall withstand the accelerations suggested in Table 513.3-I. The Procedure II test item shall withstand the acceleration suggested in Table 513.3-II. The personal protective equipment shall perform as required.

n. SHOCK: Method 516.3, Procedure VI (bench handling). This verification shall include _____ drops from a height of ______ inches above a wooden laboratory table. Other procedures may be performed as deemed necessary by the procuring agency. The personal protective equipment shall perform as required.

o. COMBINED ENVIRONMENTAL STRESS: Method 520.0, Procedure I (engineering development test), Procedure II (flight or operational support test), and/or Procedure III (qualification test). Test profiles, cycles, and duration shall be determined as specified in each procedure. The personal protective equipment shall perform as required.

p. OTHER RESISTIVE PROPERTIES: The requirements of 3.2.1 (p) shall be verified by _______. The personal protective equipment shall perform as required.

VERIFICATION RATIONALE (4.2.1.2)

Verification is required to assure that the personal protective equipment performs as required by this specification. *MIL-STD-810* establishes the uniform environmental test methods for determining the resistance of equipment to the effects of natural and induced environments peculiar to military operations. These test methods are used to obtain reproducible test results.

a. The high temperature tests are performed to determine if the test item will operate without degradation in, or after storage in, a climate which induces high temperatures within the test item, if the test item can be operated and handled without affecting its integrity, and if the test item is safe during and following high temperature exposure.

b. The low temperature tests are performed to determine if the test item can meet the requirements of this specification during operation and after storage in a cold environment, if the test item can be operated safely during and following low temperature exposure, and if the handling (manipulation) required to make the test item operational can be conducted without affecting its functional performance.

c. The temperature shock test is performed to determine if the test item can satisfy the requirements of this specification and be safely operated following exposure to the sudden changes in temperature of the surrounding atmosphere.

d. The solar radiation tests are performed to determine if the test item can satisfy the requirements of this specification during and after exposure to solar radiation without physical, structural, or functional degradation.

e. The blowing rain tests are performed to determine if the rain can penetrate the enclosure of the test item while it is in its operational and/or storage position, if the test item can meet the requirements of this specification, and if the rain causes physical deterioration of the test item.

f. The humidity tests are performed to determine if the test item can meet the requirements of this specification without physical, structural, or functional degradation.

g. The fungus tests are performed to determine if fungi will grow on the test item, how rapidly they will grow, and how this growth affects the test item. The fungus tests also determine if the fungi affect the mission of the test item and to what extent; if the test item can be stored effectively in a field environment; if the test item is safe for use following fungal growth; and/or if sanitizing the fungus-affected item is possible.

h. The salt fog tests are performed to determine if the test item can withstand the corrosion or electrical and physical effects of a salt fog environment, and if it meets all of the requirements of this specification.

i. The blowing dust tests are performed to determine if the test item can resist penetration by dust particles while meeting all the requirements of this specification.

j. The vibration tests are performed to determine if the test item can resist the normal vibrational stresses associated with storage, handling, and operational use while meeting all the requirements of this specification.

k. The gunfire vibration tests are performed to determine if the test item can resist the complex combination of broadband random vibration and intense narrow band random vibration, and sinusoidal peaks at specific frequencies, meet the requirements of this specification. Because the severe resonance effects are difficult to predict from a model, direct measurement is necessary.

l. The explosive atmosphere tests are performed to determine if the equipment can operate in a flammable atmosphere without causing an explosion and/or if a flame reaction occurring within encased equipment will be contained and not propagated outside the test item.

m. The acceleration tests are performed to determine if the test item performs as required by this specification during and after exposure to the acceleration environment of the aircraft in which it is designed to be used.

n. The shock tests are performed to determine if the test item meets all the requirements of this specification following exposure to the usual level of shock associated with bench or bench-type maintenance or repair and transportation handling.

o. The combined environmental stress tests are performed to determine if the test item can perform as required by this specification during and following exposure to the combined stresses of temperature, altitude, humidity, and vibration.

p. Inspections conducted after the salt spray and operations testing will reveal corrosion problems.

## VERIFICATION GUIDANCE

Verification is required to determine the resistance of equipment to the effects of natural and induced environments peculiar to military operations. When it is known that the equipment will encounter conditions more or less severe than the environmental levels stated here, the tailored equipment specification should be modified accordingly. Specific guidance for each test method is given below. The conditions chosen for each test should be determined based on the anticipated levels in the geographical deployment area, the aircraft environment, and the anticipated duration of exposure. These test conditions can be established from field measurements or can be derived from information provided in *MIL-STD-810*. Guidance in determining the appropriate test sequence may also be determined from *MIL-STD-810*.

a. For the operational testing during high temperature testing, the test item should be brought to the applicable temperature, then operated to determine performance characteristics. Since little is known about how to time-compress this test, the number of cycles is set at a minimum of seven (7) for the storage test and three (3) for the operational test. When considering extended exposure, critical test items or test items determined to be very sensitive to high temperature, the number of cycles should be increased to assure that the design requirements are met.

b. The low temperature test is not intended for testing equipment that will be installed and operated in aircraft, since this equipment is usually subjected to the combined environmental conditions of low temperature storage and operation.

c. The temperature shock test is not used to assess performance characteristics after lengthy exposure to extreme temperatures, as are the high and low temperature tests. The relative humidity during portions of this test could be a factor in the resistance of the test item to temperature shock, as equipment with a high moisture content could be affected by freezing of the moisture.

d. The solar spectrum and energy levels used in this method are those that are received at sea level. For the cycling test, the possible cooling effects of airflow over the test specimens must be considered. An airflow as minimal as 1 meter per second can cause a 20 percent reduction in temperature rise.

e. An instantaneous rainfall rate equivalent to 1.89 inches per minute occurs commonly in areas of heavy rainfall, but a minimum rate of 4 inches per hour is recommended. A wind speed of 40 miles per hour is recommended, as this is common during a storm.

f. The humidity test is potentially damaging; therefore, it is generally inappropriate to conduct this test on the same test item used for salt fog or fungus tests. The preferable number of cycles is suggested in Table 507.2-11 of *MIL-STD-810*.

g. The fungus test should not be performed after the salt fog and sand/dust test. A heavy concentration of salt may affect the germinating fungal spores, and sand/dust can provide nutrients, thus leading to a false indication of the biosusceptibility of the test item. A minimum duration of 28 days is required to allow germination, breakdown of carbon compounds, and material degradation.

h. A 5 $\pm 1$ percent salt solution is recommended for the salt fog test, since this has proven to have the most significant effect on material. A minimum exposure period of 48 hours followed by a 48-hr drying period is recommended for continuous salt fog exposure. Alternating 24 hour periods of exposure and drying for a minimum of four (4) 24-hr periods is recommended for a cyclic test.

i. The blowing dust test can produce a dust coating on, or severe abrasion of, a test item which can then influence the results of other environmental tests such as fungus, humidity, and salt fog. The minimum air velocity of 300 feet per minute and a higher desert wind velocity of 1750 feet per minute should be used for most tests. Excessively high velocities may lessen the caking/clogging caused by lower velocities. Suggested dust compositions and durations can be found in *MIL-STD-810*.

j. *MIL-STD-810* contains extensive guidance to determine the appropriate category and vibration parameters.

k. If an item is to be installed in a location where the gunfire vibration is less than normal flight vibrations, no gunfire testing is recommended. *MIL-STD-810* provides significant guidance in choosing the applicable spectra and duration.

l. The stresses caused by vibration and temperature testing may reduce the effectiveness of equipment seals, thus producing previously unobserved flammable atmosphere sensitivities. Single-component hydrocarbon n-hexane is the recommended fuel because its ignition properties for this testing are equal to or better than the similar properties of 100/130 octane aviation gasoline and JP-4 jet engine fuel.

m. Acceleration levels should be determined from aircraft mission profiles. Some information on acceleration levels and durations may also be found in *MIL-STD-810*.

n. Test experience has shown that climate-sensitive defects often show up more clearly after the application of shock and vibration forces. Therefore, the shock tests should be placed in the test sequence appropriately.

o. The combined environmental stress test is primarily intended for electronic equipment mounted inside an aircraft. Significant supplemental information is provided in *MIL-STD-810*.

p. Other resistive properties of the materials must be evaluated as appropriate for the intended use of the item.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.2.1.3 Air transportability.** Certain transportability features are desired in the design of the personal protective system components.The personal protective system components are ________. The transportability features should consist of ________.

REQUIREMENT RATIONALE (3.2.1.3)

Some personal protective system components may be used in or shipped by military air transport aircraft. The transport tie-down method and space constraints should be consistent with existing techniques.

REQUIREMENT GUIDANCE

*MIL-STD-1791*, titled *Designing for Internal Aerial Delivery in Fixed-Wing Aircraft*, provides detailed design information that should be considered. Of primary concern is the restraint of the personal protective equipment while in the cargo compartment of the aircraft. Another concern is safety while transporting personal protective equipment. It also may be desired to use the personal protective equipment while in transport such as with helmets and chemical defense ensembles.

REQUIREMENT LESSONS LEARNED

No lessons learned are available.

**4.2.1.3 Air transportability verification.** The survival and flotation equipment transportability features shall be verified by ________.

VERIFICATION RATIONALE (4.2.1.3)

It is desirable to determine that the transportability design features are adequate for the planned use of the personal protective equipment.

VERIFICATION GUIDANCE

The verification should consist of analyses, inspections, demonstrations, and tests as necessary to determine that the transportability design features will be adequate. Formal certification of air transportability of the personal protective systems as cargo must be performed by the Air Transportability Test Loading Agency (ASD/ENECA, Wright-Patterson AFB, Ohio.)

VERIFICATION LESSONS LEARNED

No lessons learned are available.

**3.2.2 Chemical/biological protection level.** The eye/respiratory fit factor of the aircrew chemical/biological (CB) head/respiratory protection system shall not be less than ______ for ______ percentiles of the USAF aircrew population. The protection level is defined as the ratio of the measured air-borne concentration of a test agent in ambient air surrounding the system to the concentration of test agent within the system. The protection level afforded to the crew member's skin from liquid and solid agents consisting of __________ shall be __________. Outward leakage of the breathing and ventilation equipment shall not be less than ______ percent.

REQUIREMENT RATIONALE (3.2.2)

A minimum protection level must be maintained within the eye/respiratory region to protect this region from injury by CB agent vapors, aerosols and particles. Some chemical agents such as mustard gas may also affect the skin so that some degree of skin protection is required.

REQUIREMENT GUIDANCE

The required protection level is determined based on threat analysis and time of exposure to the threat. The 1975 Chemical Warfare Defense Functional Analysis study, code named HAVE PLOT, provided chemical and biological threat estimations for aircrew. The protection level requirements for individual protective equipment have, in the past, been based on this study plus any current threat analysis unique to the program. Current guidance regarding the chemical warfare threat, including physiological harmful dosage levels for agents, is in the classified Aeromedical Research Laboratory reports, *AAMRL-TR-86-054*, titled, "*Chemical Warfare Challenge to Aircrews, Part I*" and *AAMRL-TR-86-055*, titled, *"Chemical Warfare Challenge to Aircrews, Part II*" (These documents are SECRET).

The current accepted protection level is $10^4$. Time of exposure must also be considered as agent effects are dependent on cumulative exposure. Since fitting 100 percent of the USAF aircrew population may not be considered practical without custom fitting because of the wide range of facial sizes, a more realistic and achievable requirement in current practice is to fit the 5th through 95th percentile of this population. Individuals not meeting the required protection level must be identified and custom fitted. The threat to USAF and NATO bases is constantly changing and expanding as new CB agents, toxins, delivery means, employment doctrine, and tactics change. Protection level requirements must be based on the latest threat estimations.

Chemical warfare agents can take the form of gases, aerosols, liquids, and/or solid substances. Liquid or solid substances may also have toxic gases depending on the volatility (evaporation) rates and concentrations. Solid substances and liquids can be dispersed into the air as aerosols. An aerosol may enter the body via the respiratory organs in the same way as a gas. Some chemical warfare agents can also invade the body through the skin.

This mainly applies to liquid agents but in certain cases also to gases and aerosols. It is certainly evident that under a number of different likely situations both respiratory and skin protection is required.

Chemical warfare agents may be classified in many ways. We may refer to highly volatile or nonpersistent substances, which contaminate the air, and also to persistent substances that are non-volatile and used to contaminate surfaces such as the ground or the aircraft. Chemical agents used mainly against human beings may be classified as either lethal or incapacitating. The border between lethal and incapacitating agents is not absolute, but this refers to the statistical probability of the effect on a large number of persons. In the case of nerve agents, the relationship between lethal and incapacitating doses is much closer as nerve agents are very lethal in small concentrations. Chemical warfare agents can also be classified in terms of their effects on the organism.

It is not easy to tailor-make a chemical warfare agent for a specific purpose. There is always a degree of uncertainty with regard to time, space and effect. For example, the time of persistence varies somewhat in relation to the method of dispersion and the prevailing weather conditions. To facilitate dispersion, prolong the time period of persistence and, if possible, obstruct decontamination, thickeners may be added to modify the physical properties of the chemical warfare agents. This may mean that many substances previously not considered a threat due to their instability and lack of persistence have now acquired significance as potential chemical warfare agents. Protective equipment must be developed to counter this threat.

The chemistry and effects of many chemical warfare agents are described in the *Army Field Manual (FM) 3-9* or *Air Force Regulation (AFR) 355-7*, (same document) titled, *Military Chemistry and Chemical Compounds*. (See *table I* for a list of some common chemical warfare agents.)

Particulate filters are required in combination with any chemical warfare agent gas and vapor filter(s) to stop any aerosols, biological and radioactive particles. Experience has shown that vapor filters are not necessarily good particulate filters.

An acceptable level of outboard leakage that has been adopted for the aircrew eye respiratory protection (AERP) program is 0.01 percent or less.

Personal equipment connectors are an area of concern. The connectors should not allow agent contaminants to enter into the breathing gas during connections, disconnections, and flexing and movement during use in a contaminated environment. In the development of the hood and ensemble, consideration must be given to compatibility with the HGU-4/P glasses and the helmet that will be used.

The effects of the crew members wearing eye glasses must be determined as many USAF pilots, navigators and other crew members wear glasses. Eye glasses may degrade the protection levels provided by breaking face seals on the ensemble.

REQUIREMENT LESSONS LEARNED

Field tests of commercial respiratory protective devices have shown that significantly lower protection levels are provided during actual industrial use than when the device is tested under laboratory conditions. A parallel can be drawn with military devices.

The selection of materials which satisfy all of the following requirements is a difficult technical problem. The materials could be required to provide a positive pressure chemical/biological barrier, be fire resistant, be flexible and lightweight so as not to restrict head movement, be structurally strong enough to withstand the windblast forces experienced during an emergency ejection, and be aerodynamically smooth so as not to disturb the airflow into the ejection seat pressure sensors. Parachutes may get entangled with the HGU-41/P chemical/biological defense hood, and removal of the hood prior to ejection, if possible, is the recommended practice. With the current aircrew eye respiratory protection (AERP) equipment, the crew member cannot remove the hood without losing chemical/biological protection because the mask seal is molded into the hood. It is not necessary to remove the ensemble prior to ejection to preclude adverse effects to the ACES II sequencing system pitot tubes at the seat headrest since testing has shown that this is not a problem; however, the crew member may still want to remove the ensemble to assist in preventing drowning if water entry is involved.

Adding weight to the helmet for CB defense can degrade crew member performance especially in a dynamic environment. Adding much weight to the forward part of the head could cause a high forward moment on the head. This could injure the neck of the crew member on ejection.

The current MBU-13/P chemical/biological protective equipment impairs peripheral vision. Therefore, exaggerated head movements are required for almost all tasks.

The MBU-13/P protective equipment incorporated an acrylic faceplate. The new faceplate used in the aircrew eye respiratory protection (AERP) program uses a polycarbonate faceplate with an

TABLE I. Some common chemical warfare agents. 1/

| Agent | Symbol | State | Rate Of Action | Physiological Action |
|---|---|---|---|---|
| Choking agent | | | | |
| Diphosgene | DP | Colorless liquid | Immediate to 3 hr | Damages and floods lungs. |
| Nerve agents | | | | |
| Tabun | GA | Colorless/ brown liquid | Very rapid | Cessation of breath, and death may follow. |
| Sarin | GB | Colorless liquid | Very rapid | Cessation of breath, and death may follow. |
| Soman | GD | Colorless liquid | Very rapid | Cessation of breath, and death may follow. |
| -- | VX | Colorless liquid | Rapid | Cessation of breath, and death may follow. |
| Blister agents | | | | |
| Distilled mustard | HD | Colorless/ yellow liquid | Delayed, hours to days | Blisters; destroys tissues injures blood vessels. |
| Nitrogen mustard | HN-1 | Dark liquid | Delayed action 12 hr or longer | Blisters; affects respiratory tract; destroys tissues; injures blood vessels. |
| Lewsite | L | Dark oily liquid | Rapid | Similar to HD; may cause systemic poisoning. |
| Blood poisons | | | | |
| Hydrogen cyanide | AC | Colorless gas/liquid | Very rapid | Respiratory irritant, unconsciousness, death. |
| Cyanogen chloride | CK | Colorless gas | Rapid | Chokes, slows breathing; Unconsciousness and death. |
| Arsine | SA | Colorless gas | Delayed action, 2 hrs to 11 days | Respiratory irritant and death. |
| Vomiting agents | | | | |
| Adamsite | DM | Yellow to green solid | Very Rapid | Like cold systems, plus headache, vomiting and nausea. |

**TABLE I. Some common chemical warfare agents 1/ (cont'd).**

| Agent | Symbol | State | Rate Of Action | Physiological Action |
|---|---|---|---|---|
| Tear agents | | | | |
| Chloroacetophenone | CN | Solid | Instantaneous | Lacrimatory; irritates respiratory tract |
| Bromobenzyl-eyanide | CA | Liquid | Rapid | Irritating; not toxic |
| o-Chloro-benzylmalononitrile | CS | Colorless solid | Instantaneous | Highly irritating, but not toxic |

1/ Reference Army Field Manual *FM 3-9* or Air Force Regulation *AFR 355-7*, titled *Military Chemistry and Chemical Compounds*,* October 1975.

* This document also contains other chemical warfare agents and much more complete information on the properties of all of these agents.

abrasion resistant coating as the plastic polycarbonate is very tough but easily scratched when used in operations. While the acrylic faceplate could have better optical properties, the polycarbonate faceplate provides better impact protection in the event an emergency seat ejection is required.

Breathing and ventilation connectors that have passed static chemical/biological simulant testing were shown to leak during flexing at the connection junction.

**4.2.2 Chemical/biological protection level tests.** Quantitative leakage tests shall be performed with a _____ person test panel to verify that leakage and population requirements can be met. The test subjects shall wear the complete aircrew chemical/biological (CB) protection system and other applicable life support equipment. The leakage tests shall be performed in a test chamber of adequate size to permit the simulation of all aircrew movements during transition from a collective shelter to the aircraft, during flight operations, and during transition back to the shelter. A chemical test simulant _____ shall be used to challenge the protection system. Continuous measurements of the leakage into the system shall be recorded with instruments of sufficient accuracy to measure protection levels greater than ________. Skin protection capability shall be determined by _______.

VERIFICATION RATIONALE (4.2.2)

Protection level can only be accurately determined through quantitative leakage measurements into the facial region. An anthropometrically selected human subject test panel is necessary to determine if the system facepiece or head covering will provide an acceptable seal for varying facial features and head sizes of the USAF aircrew population.

VERIFICATION GUIDANCE

For designs in which the aircrew CB head and respiratory protection system incorporated a peripheral facial seal, the test panel in past programs included at least 25 persons with a range of facial sizes. For designs which consisted of a head covering with a neck seal, a significantly smaller test panel, e.g., 10 persons, was considered acceptable. An in-depth study was performed by the Los Alamos National Laboratory (LANL) to determine anthropometric specifications for test subjects wearing various styles of respirators. This study is documented in LANL report number *LA-5488, Selection of Respirator Test Panels Representative of US Adult Facial Sizes*, issued March 1974. The accuracy of test instrumentation should permit measurements of greater than $10^5$ protection level. The reason for this accuracy requirement is to assure that quantifiable measurements can be acquired significantly above the minimum protection level of $10^4$ to evaluate the adequacy of the system.

Currently, the method of testing is to use at least one hundred subjects and correlate their body dimensions on anthropometric charts. Fit testing may then be conducted with some reasonable degree of correlation for the full range of anthropometric dimensions.

Simulant testing may be conducted to determine if there are any leakage problems with the ensemble. A simulant is a safe gas or vapor used for testing that is representative of the molecular weight and properties of the chemical agent under consideration. Live subjects may be tested with appropriate simulants. Probes may be put into areas of special concern in the ensemble and precise measurements taken to determine if any simulant penetrates the ensemble and if so, how much. Penetration levels should be harmless to crew members.

VERIFICATION LESSONS LEARNED

Selection of a trained test panel is a tedious process. The test subjects must be properly trained and motivated to acquire useful test data. There are a number of types of test chambers and measurement instrumentation. Of greatest importance are accuracy and repeatability in selecting the test system. Calculation of protection level from the raw test data can be accomplished using several techniques. The most widely accepted technique is based on average peak penetration. This technique uses an average of the peak simulant penetrations into the facial region recorded on a strip chart during an exercise such as moving the head from side-to-side.

Past testing has shown that the sampling probe should be positioned within the facial region at as many locations as feasible. Because facial dimensions may vary significantly between individuals, if too few sampling sites are specified the probe may miss possible infiltration of ambient contaminant through an opening in the CB barrier. A judgement will need to be made as to adequate sampling sites for each system design. It may be necessary to put a test probe in the neck area also, as certain agents can harm and penetrate the skin. Systems which use blown air and overpressure may still have leakage problems due to the generation of vortices and other flow patterns which may cause agents to be drawn into the protected areas.

**3.2.2.1 Chemical/biological ventilation and filtration.** A ventilation and filtration system shall be provided to assure removal of chemical/biological (CB) agents from the breathing gas, to maintain _____ protection level, and to minimize lens misting or fogging during transition between collective shelter and aircraft and during flight operations. Ventilation and breathing gas delivered to the crew member shall have chemical agent concentrations less than or equal to _________.

REQUIREMENT RATIONALE (3.2.2.1)

A ventilation and filtration system must be provided to preclude or remove liquid, aerosol, particulate and vapor chemical and biological agents from breathing gas and ventilation airflow. Ventilation airflow is necessary to maintain the required protection level, to prevent misting of the crew member chemical and biological protection system lens, and to reduce thermal stress on the crew member. The ventilation and filtration system may have various configurations including: modification of the aircraft environmental control system to add filtration and cooling as needed; separate ground use and aircraft mounted systems; or a common use in aircraft and on the ground which may be readily mounted inside the aircraft. A recommended safe practice is that the breathing gas should be filtered even if the aircraft oxygen supply is provided to the user. See *AFGS-87226* for additional detailed information regarding breathing gas and blower characteristics.

Both the breathing gas and the ventilation flow must be filtered as necessary to provide chemical and biological agent free gas flows continuously during transition between collective shelter and aircraft and during flight operations. Filtration upstream of the man-mounted disconnects may be necessary to assure that neither the breathing gas nor ventilation airflow will become contaminated with chemical agent vapor during transition between ground and flight modes of operation. If possible, the best approach is to avoid disconnecting filtered lines during this transition.

REQUIREMENT GUIDANCE

The ventilation system must maintain a positive pressure within the facial region to assure that a high protection level (greater than $10^4$) can be maintained. Loss of this positive pressure will result in a significantly lower protection level dependent upon the design of the head enclosure. It may be acceptable to have reduced protection ($10^3$) during emergency situations such as ground abort and ejection. A full head enclosure with neck seal or dam may be necessary to provide at least a $10^3$ protection level in the event of failure or disconnect from the ventilation supply system. Protective requirements for the face, eyes, and respiratory tract of the wearer in field concentrations of chemical and biological agents are highly recommended. The specification should require that the filter system of a protective mask be capable of withstanding a minimum of ______ attacks with nerve, choking, and blister agents under combat conditions (e.g., past programs have used up to 20 attacks) and provide at least a one-attack capability against blood agents (reference NATO document by Dr. J. Medema and M. van Zelm, titled, *NL Chemical Defence Gear for F-16 Pilots*, pg 14, Prins Maurits Laboratory TNO, National Defence Research Organization, The Netherlands, (Unclassified)). For a seven day scenario, a chemical and biological attack is defined as an exposure of _____ mg-min per cubic meter of chemical and biological agent (reference *AAMRL-TR-86-063*, titled, *Chemical Warfare Scenario for Air Base Challenge Assessment (U), 7 day Scenario*, October, 1986 (SECRET), and refer to *AAMRL-TR-86-063* to determine the exposure). For a one day scenario, a chemical and biological attack is defined as an exposure of _______ mg-min per cubic meter of chemical and biological agent (classified SECRET—refer to *AAMRL-TR-86-054* to determine the exposure). These protective requirements should be altered where threat data, mission analysis, including time duration or Statement of Operational Need (SON) for the system require other performance capabilities. The ventilation and filtration system may have various configurations including: modification of the aircraft environmental control system to add filtration and cooling as needed; separate ground use and aircraft mounted systems; or a common use on the aircraft and on the ground which may be readily mounted inside the aircraft.

REQUIREMENT LESSONS LEARNED

In developing the chemical and biological protection requirements for crew members, consider the potential air base threat during transition between the protective shelter and the aircraft as well as potential cockpit contamination throughout the mission. Performance requirements for the ventilation and filtration system must reflect the latest threat analysis for the mission of the aircraft selected for use of the aircrew chemical and biological protection system.

The ventilation airflow to the head must be properly adjusted and directed to assure not only the required protection level but also to prevent eye dryness, cold spots, and other physical discomforts.

If a survivable protection level of at least $10^3$ is required in the event of the loss of the ventilation supply, then a neck seal and full head enclosure may be necessary. Without the neck seal, the protection level could rapidly drop to immediately hazardous levels if the ventilation supply system fails.

**4.2.2.1 Verification of the chemical and biological ventilation and filtration system.** The following ventilation and filtration system tests shall be performed:

a. Breathing performance: ________

b. Demist and ventilation performance: _____

c. Respiratory protection level performance: ___________

d. Service life: ________

e. Subjective use: ________

f. Durability: ________

g. ____________: ________
(Specify other)

VERIFICATION RATIONALE (4.2.2.1)

Ventilation and filtration system tests are necessary to assure that the system will function satisfactorily and provide adequate comfort, service life, storage life, and durability throughout its required operational life. Verification testing should apply to all components of the ventilation and filtration system (e.g., filters, air mover, hoses, etc.).

VERIFICATION GUIDANCE

a. Breathing performance - Breathing performance is covered in *3.2.4* of this document. Refer to *AFGS-87226* for further information. Manned testing is necessary for the evaluation of the capability of the ventilation and filtration system to deliver desired gas flows at various ambient, altitude, and induced-load conditions pertinent to the aircraft mission. Centrifuge testing and altitude chamber testing are typical of the types of tests to simulate the workload and dynamics of the actual flight operation conditions. The test conditions and envelopes tested are dependent upon the aircraft mission.

b. Demist and ventilation performance - The protection afforded by the demist and ventilation design may be determined by testing as discussed in the previous section. Other areas of concern are comfort and heat stress. These factors may be assessed by actual use of the proposed design(s) by operational crews. Pressures and air flow rates should be determined to assist in the analyses of the protection and thermal cooling capabilities of the protective equipment.

c. Respiratory protection level performance - The level of protection afforded to the crew member may be determined by simulant testing with probes in locations of concern for safe and effective breathing. This should include a minimum of three probes spaced uniformly inside the mask and the delivery hoses for normal and emergency breathing.

d. Service life - Service life may first be determined by an analysis of the materials used. Past performance of the materials should be determined by past experience with the use of these materials in other similar or unsimilar equipment if no precedence exists. Some type of accelerated testing may also be desired to determine the service life expected.

e. Subjective use - Subjective-use testing is necessary to determine if there are any physiological detrimental performance characteristics of the ventilation and filtration system. Objectionable odors and discomfort are indications of such physiological problems. The rated airflow of the ventilation system is based on physiological response as well as the required protection level. The filter size is based on the airflow rate necessary to meet physiological needs and the required protection level.

f. Durability - Durability requirements should meet the stated goals and requirements of the aircraft mission and Statement of Operational Need (SON). Endurance testing of mechanical and electrical components of the ventilation system is necessary to assure an adequate durability. Rigorous wearing trials and ruggedness tests could also be conducted. Selected components (e.g., filters and air movers) should have performance evaluated following such trials and tests. Durability testing should complement environmental testing.

g. Other - Other analyses, inspections, demonstrations and testing should be specified as necessary to determine proper design and performance of the ventilation and filtration capability of the equipment.

VERIFICATION LESSONS LEARNED

Early evaluation of a mock-up of the CB protective system in the aircraft cockpits mock-up and/or simulator for which the system is intended will minimize cockpit integration problems.

Lack of proper and complete verification can lead to very costly modification or replacement of equipment. In Army testing of chemical defense masks, the filter canisters emitted a small amount of charcoal dust after rough handling. The charcoal dust in these canisters contains hexavalent chromium, which has been found to be a carcinogen and could be a health hazard if it is breathed into the respiratory tract of the user over a period of time. The problem was corrected by adding a thin outlet particulate filter.

In the aircrew eye respiratory protection (AERP) program during operational test and evaluation in hot and humid conditions, the C-2 canister was found to produce an ammonia-like smell. Testing is currently underway to determine what quantity of ammonia is being generated. This information can be used to determine if a health hazard exists. It was found that this has always been the characteristic of this C-2 canister, but in the AERP configuration two canisters are used, apparently worsening the smell.

The entire chemical defense ensemble must be worn along with all other items of required life support to assure a thorough and valid subjective evaluation of the system.

Selection of trained test subjects is essential for detecting any shifting and movement of the chemical and biological barrier which would degrade performance.

Breathing resistance can be affected by agent contamination and decontamination tests, rough handling, and environmental tests, so this should be evaluated after such tests.

Water can degrade blood agent capability of charcoal filters, possibly requiring more frequent filter changes if blood agent protection is of a concern.

**3.2.2.2 Chemical/biological permeation resistance.** Permeation of chemical/biological warfare agent vapors through the system materials exposed to the external environment shall be less than the breakthrough concentrations defined below for a minimum of ________ hours.

| Agent | Breakthrough Concentration |
|---|---|
| ________ | ________ |
| (specify agent) | (specify breakthrough concentration) |

REQUIREMENT RATIONALE (3.2.2.2)

All components of the system should be capable of providing skin protection if the wearer is continuously exposed to the heaviest concentration of toxic chemical agents (liquid or vapor) that can be operationally delivered.

REQUIREMENT GUIDANCE

The Statement of Operational Need should provide the time period for protection. Requirements are dependent upon the user's needs. Agent and breakthrough concentrations, if used, may be determined from the referenced documents of *3.2.2.1*.

REQUIREMENT LESSONS LEARNED

Seams and cavities can contain CB agents. The need to maintain a smooth contour of the CB barrier should be emphasized. Faceblank materials may be less resistant to chemical agent than the hood materials. The faceblank material may need to be covered by a hood material to give the total required protection. Voicemitters, hose clamps, and inlet valves may leak agents. This happened in Army testing of CB defense masks.

**4.2.2.2 Verification of chemical and biological permeation resistance.** The components of the system (e.g., helmet shell, lens, seals, hoses, shrouds, and other fabrics) shall be resistant to test agent penetration when subjected to the following tests ________.

VERIFICATION RATIONALE (4.2.2.2)

Permeation tests using chemical warfare agents provide the best testing techniques to assure that all components of the system are chemical agent resistant for the required time period specified by the user.

VERIFICATION GUIDANCE

The Army has developed material permeability test methods. These test methods are described in special publication *CRDEC-SP-84010, Laboratory Methods for Evaluating Protective Clothing Systems Against Chemical Agents*. The test methods described by the CRDEC test methods should be altered where threat data, mission analysis, or Statement of Operational Need (SON) for the system requires other performance capabilities.

A new test method under development with considerable promise is a chemical agent impact test. The Prins Mauritz Lab, TNO, Rijswijk, Netherlands, and the Chemical Defense Establishment

(CDE), Porton Down, England are two foreign laboratories that have developed laboratory test equipment to simulate a falling agent droplet onto a fabric test sample. The Battelle Institute, Columbus, Ohio, has developed an agent impact tester under USAF funding and transitioned to the US Army for evaluation. The objective of this test is to measure agent penetration in a fabric with varying droplet sizes and patterns at terminal velocity.

VERIFICATION LESSONS LEARNED

Fabric seams should be tested along with the parent material since agents may penetrate through seams faster than through the parent material.

3.2.2.3 **Decontamination.** The personal protective equipment shall be capable of being decontaminated using prescribed methods specified in __________. After decontamination, the personal protective equipment shall still provide the protection from chemical agents by meeting the following requirements: _____________. Additionally, the personal protective equipment shall be designed to be capable of being doffed in a contamination control area (CCA) without contaminating the wearer or to clean areas of the shelter with chemical agents.

REQUIREMENT RATIONALE (3.2.2.3)

Designing the crew member personal equipment to be usable after contamination in a chemical warfare environment reduces costs and increases equipment availability in the operational environment.

REQUIREMENT GUIDANCE

Methods of decontamination are based on one or more of the following procedures:

- destroy the chemical agent by bringing about a chemical reaction and resulting chemical changes.
- physically remove the chemical agent from the contaminated item.
- screen or isolate the chemical agent to a controlled area.

Most chemical warfare agents may be destroyed or neutralized with a chemical reaction by introducing suitable chemicals. The basic problem is determining the agent or combination of agents that must be neutralized. There are chemicals which work against most of the agents, but which are also corrosive or destructive to the equipment to be decontaminated. Decontaminants which act against a specific group of agents may be better than general type decontaminants as they may have a more rapid and superior effect against the particular agent to be neutralized. The main disadvantage of the use of this decontamination procedure is that the chemical agent must be detected, then identified, and there must be access to a number of different kinds of decontaminants. This process increases the time required to decontaminate in a situation in which little time is available.

Chemical warfare agents can be washed and rinsed away; dried, absorbed, or adsorbed by the proper substances such as "Fuller's Earth"; or removed by heat treatment. When decontamination is accomplished by washing or adsorption, the toxicity of the substance(s) remain(s) and is in the decontaminant substance which must be placed in a controlled area. Contaminated items of equipment may also be encapsulated in nonpermeable covering and removed to controlled areas for later decontamination or destruction. (See *table II* for a sample of toxicity estimates.)

The current philosophy for decontamination is covered by *USAF T.O. 11C15-1-3, Technical Manual, Chemical Warfare Decontamination, Detection and Disposal of Decontaminating Agents*. Other valuable sources of information for decontamination are *ADC 027335* (Confidential), *Approved Test Plan for Aircraft Operations in a Toxic Environment*, Subtests 1-12; and *DPG-TR-85-203* (Confidential), *Aircraft Operations in a Toxic Environment*, Subtest 12, "Hazards of Ground Operations of Large, Multi-Engine Aircraft in a Simulated Toxic Environment."

To ensure that the protective equipment will be designed to provide the same level of protection after decontamination, protection requirements must be called out after decontamination. The protection level shall be as specified and measured as a ratio of the airborne concentration of test agent

TABLE II. Sample of toxicity estimates.

| Percutaneous | Clothing | Response | GD | H | HL | GL | AC |
|---|---|---|---|---|---|---|---|
| Liquid | Bare | Threshold | 6 | 35 | 35 | 350 | ---- |
| (mg/man) | ---- | Medium | 70 | 350 | 350 | ---- | ---- |
| | ---- | Lethal | 350 | 7000 | 7000 | 1700 | ---- |
| | Summer | Medium | 350 | 2100 | 2100 | ---- | ---- |
| | ---- | Lethal | 1200 | ---- | ---- | ---- | ---- |
| | Winter | Medium | ---- | 3500 | 3500 | ---- | ---- |
| | ---- | Lethal | 17,500 | ---- | ---- | ---- | ---- |
| Percutaneous | Bare, | Threshold | 200 | 50 | 50 | 1000 | ---- |
| Vapor | Summer, | Medium | 1900 | 500 | 500 | ---- | ---- |
| (mg–min/$m^3$) | and Winter | Lethal | 2900 | 10,000 | 10,000 | 15,000 | 135,000 |
| Inhalation | ---- | Threshold | 2 | 50 | 50 | 2 | 500 |
| (mg–min/$m^3$) | ---- | Medium | 17 | 750 | 750 | 35 | ---- |
| | ---- | Lethal | 25 | 1500 | 1500 | 70 | 1000 |
| Eyes | ---- | Threshold | 2 | 2 | 2 | 0.5 | ---- |
| (mg–min/$m^3$) | ---- | Medium | 0.2 | 90 | 90 | 2 | ---- |

outside the system to the concentration of test agent inside the eye/skin/respiratory regions of the crew member at the specified region of measurement. Breakthrough time should also be evaluated. Currently, $10^4$ for 5th through 95th percentile part of the specified population is an accepted level of protection. Physical characteristics and performance requirements should be acceptable after decontamination so as to be able to meet operational requirements.

To remove crew members to a CCA, the protective equipment should be removable by other individuals without danger of any person being contaminated. In the event the crew member is incapacitated, part of his or her protective clothing may need to be cut away. The ensemble should be designed considering this scenario.

REQUIREMENT LESSONS LEARNED

No lessons learned available.

**4.2.2.3 Verifying decontamination.** The personal protective equipment shall be contaminated with ______, then decontaminated according to the applicable procedures, then shall pass ______ tests. ______ subjects shall don the personal protective equipment and it shall be contaminated with ______ simulant. Also, (number) of subjects shall don the personal protective equipment and shall be contaminated with ______ simulant. Each subject shall perform the control contamination area (CCA) ingress procedure as approved by the procuring activity.

VERIFICATION RATIONALE (4.2.2.3)

The performance capability of the equipment, including the protection level and permeation capability of the personal protective equipment after decontamination, is tested to ensure that the materials used in the procedure do not adversely affect the equipment.

VERIFICATION GUIDANCE

The item should be evenly contaminated with a chemical warfare agent (preferable, if feasible) or chemical simulant at the test level. (i.e., 5 $g/m^2$ of chemical simulant) and then decontaminated in accordance with the applicable decontamination procedures. The personal protective equipment should then be subjected to performance tests including leakage and permeation to ensure the same level of protection will be afforded. These performance tests have already been discussed in the preceding paragraphs of this section.

Trained subjects representative of the entire population range of crew members should don the personal protective equipment and be subjected to a chemical simulant contaminated to the test level (i.e., 2-3 $g/m^2$ or 5 $g/m^2$ on the exterior surface of the protective clothing. Subjects should then perform the control contamination area (CCA) ingress procedure and be checked for chemical contamination transfer to themselves and to the clean areas of the shelter. This demonstration should expose problems with the design of the proposed protective system related to CCA processing or indicate necessary changes to the processing procedure.

VERIFICATION LESSONS LEARNED

Recent CCA testing at Brooks AFB, Texas has shown that it is desirable to monitor the vapor concentrations in areas of the CCA where the protective clothing and equipment are being removed. Time of exposure readings should be taken so that, based on a knowledge of the time of exposure and the concentration of exposure, the potential skin and eye damage may be assessed.

Recent recommendations indicate that testing subjects in mid-population range may be unnecessary, as small and large subjects are considered the worst case for skin contaminations from liquid agents.

**3.2.3 G protection.** The acceleration protection (G) system shall be provided commensurate with the aircraft capabilities that are ________. The G system shall consist of the following:

a. ________ Lower body coverage.
b. ________ G valve.
c. ________ Positive pressure breathing (PPB) with upper body coverage.
d. ________ Body positioning.

REQUIREMENT RATIONALE (3.2.3)

The G protection system installed in an aircraft must reliably aid the crew member in combating the effects of G forces. The level of protection provided should be at least equal to or greater than the design load limits of the aircraft. Newer fighter aircraft with greatly improved thrust-to-weight ratios are capable of pulling up to +9Gz (z=vertical axis) at rates of onset that exceed 6 Gz per second. These aircraft can sustain high +Gz levels for periods exceeding the aircrew member's capability to cope with them. The aircrew member's inability to withstand high sustained +Gz is a limiting factor in the mission performance capabilities of new fighter weapon systems and has resulted in the loss of several aircraft.

REQUIREMENT GUIDANCE

The maximum Gx, Gy, Gz (as applicable) onset rate and any endurance characteristics should be specified for the particular aircraft's mission. This will ensure that the G system is designed to the proper characteristics of the aircraft. Also specify the capabilities of the crew members who will be flying the aircraft. Last, specify the preferred type or combination of types of G system(s).

The key to G protection is to provide the necessary blood pressure at the eye/brain to maintain pilot consciousness and vision. Methods for maintaining this pressure include providing a maximum volume of blood at the heart, increasing the pressure at the chest and reducing the eye-to-heart vertical distance. The increasing G loads require an increased amount of internal pressure to raise the blood level from the heart to the head. When an insufficient amount of internal pressure exists, the blood flow decreases to the eyes and brain causing grayout, blackout, and potentially loss of consciousness (LOC). In-flight LOC may not be preceded by visual warning symptoms and may last 9-21 seconds (mean = 15 seconds), as reported by Gillingham and McNaughton in *Flying Safety*, 1983. When the aircrew member regains consciousness, he may be unaware that LOC has occurred. In-flight LOC seriously jeopardizes flying safety.

Crew member tolerance to high Gz is multifactorial and varies not only from individual to individual but from day to day in a given individual. High G tolerance can be influenced by crew member physiological measures (i.e., natural tolerance level, age, motivation, overall health), by behavioral measures (diet, alcohol, dehydration, exercise, sleep/fatigue, stress, illness) by training (weight training, centrifuge training, regular high G exposures) and by equipment design (seat back angle, G-suit characteristics, breathing system characteristics), (see *AFP-160-5*, pages 4-11, 12 and 6-1 through 6-12).

Human Systems Division (HSD) has trained over 800 fighter pilots at the Brooks AFB centrifuge since 1985. The training data has been plotted on a normally distributed curve and shows a mean relaxed G tolerance of 5.2 Gz (gradual onset rate) and 4.2 Gz (rapid onset rate) with a standard deviation of 0.9 Gz, see *Figures 1 & 2*. Mean relaxed human tolerance refers to the inherent ability of an average individual without straining or artificial protection, in an upright position, to withstand 4.2 Gz acceleration loads without loss of vision and/or consciousness. It is important to note that some individuals will be unable to reach 4.2 Gz before they observe significant light loss because they are below the mean. The human's relaxed tolerance during rapid onset rate conditions, in excess of 0.5 Gz/sec, should be focused upon because aircraft loads are employed at rapid onset rates. The designer is responsible for developing methods of raising the man's G tolerance from his relaxed level to the aircraft load levels.

At this time the US Air Force physiologists believe that a maximum of 100 mm Hg internally can be generated within the typical person, (see Burton, *Aviation, Space and Environmental Medicine*, 1986). Each 25 mm Hg internal pressure generated

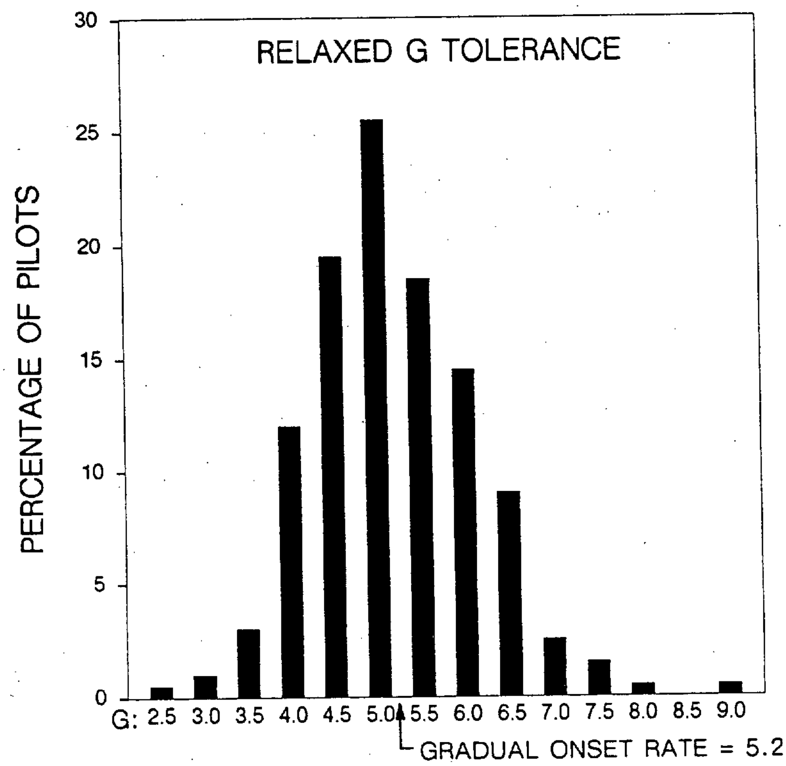


FIGURE 1. Mean relaxed human G tolerance under gradual onset conditions.

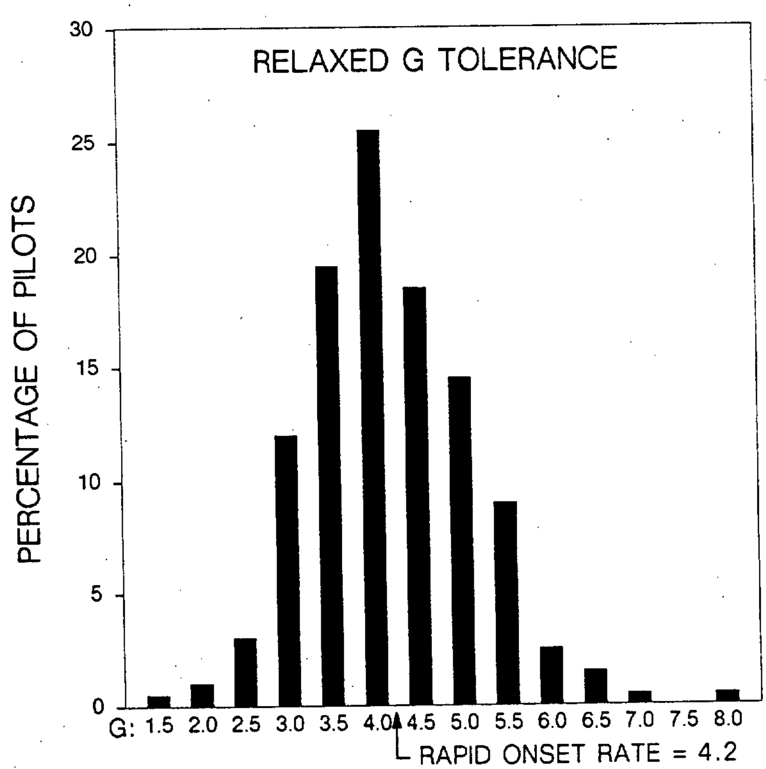


FIGURE 2. Mean relaxed human G tolerance under rapid onset conditions.

allows the man to withstand 1 Gz. A well trained pilot can for a short period of time increase his mean arterial blood pressure by as much as 100 mm Hg through the use of the M-1/L-1 anti-G straining maneuver, thus conferring an additional 4 Gz of protection over relaxed tolerance. The anti-G straining maneuver increases internal pressure by expanding the lungs and diaphragm through inhalation and simultaneously tensioning the body's muscles, focusing on the muscle groups above the waist. This maneuver is very fatiguing and the G system should attempt to alleviate some of the reliance on this maneuver. An anti-G straining maneuver which raises the blood pressure by 50 mm Hg can be maintained much longer, is a more reasonable level of performance, and enhances endurance. (See *AFP-160-5*, pages 4-11, 12 and 6-1 through 6-12 and Burns and Balldin, *Aerospace Medical Assoc.*, 1983). The ideal G protection system would afford total G protection without requiring any anti-G straining maneuver.

With conventional G protection techniques (G valve, G-suit, maximum M-1/L-1 straining maneuver) in a 15-30 degree seat back angle, the average crew member can obtain an additional 5 Gz of protection. Future aircraft should have a goal to protect a larger percentage of the pilot population and exploit the tactical advantages of reduced G induced fatigue and workload. *Figure 3* shows the anticipated protection capability which may be obtained when combining various G protective techniques, (as discussed by Burton in *Aviation, Space and Environmental Medicine*, August 1986). The techniques are discussed in greater detail below.

The G system should be designed to the capabilities of the aircraft and the aircrew to allow the full capability of the aircraft to be utilized. Using one or a combination of the approaches identified, a G system can be developed to satisfy this requirement. Because all combinations of the potential G systems have not been explored, some of the interrelationships and performances in combination are theoretical. The effects of each technique may not be additive when combined since some G protection techniques overlap in their induced physiological responses and human physiology has bounded limits.

Some discussions about the advantages of implementing anticipatory systems and/or immediate reaction G systems have been proposed. These may offer some advantages. In Stoll's study, (Van Patten, *HSD/AAMRL*, July 1985 and Stoll, *NADC-MA-55-08*, August 1955), it was shown that man has approximately a 5 second oxygen reserve in the brain during his primary G exposures, *Figure 4*. By ensuring full equipment function within the 5 seconds, instantaneous operation was unnecessary. The advantages of an anticipatory system or immediate reaction system may be in the areas of multiple Gz exposures and ensuring that the crew member never lags the protection level required. It appears that through the use of electronics and faster data collection, the equipment may be approaching this immediate reaction state. But, focus of development should be placed upon equipment protection and then potential benefits that may be derived from an anticipatory system.

The assisted methods of providing Gz protection are as follows:

a. Lower Body Coverage - Currently, the US Air Force provides each crew member of high performance aircraft with a lower body pressure garment called a G-suit, and an aircraft installed pressurized system to combat the acceleration forces encountered during flight. This suit assists the crew member during acceleration and tends to mitigate fatigue and to reduce the likelihood of loss of consciousness for a fit and well trained crew member. Numerous configurations of G-suits have existed since the 1930's. The current suit, CSU-13B/P, *MIL-A-83406*, contains bladders which inflate with air and compress portions of the lower body to decrease pooling of blood in the legs, increase peripheral arterial resistance (leading to increased arterial pressure), inhibit the internal organs from lowering in the body cavity, and provide a device to assist in performing the anti-G straining maneuver. It is estimated that the G-suit provides 1 to 1.5 Gz of protection.

The G-suit is currently produced in seven sizes and is designed to be worn over the flight coveralls. It is connected to the pressure source by means of a quick disconnect fitting. The male portion of this

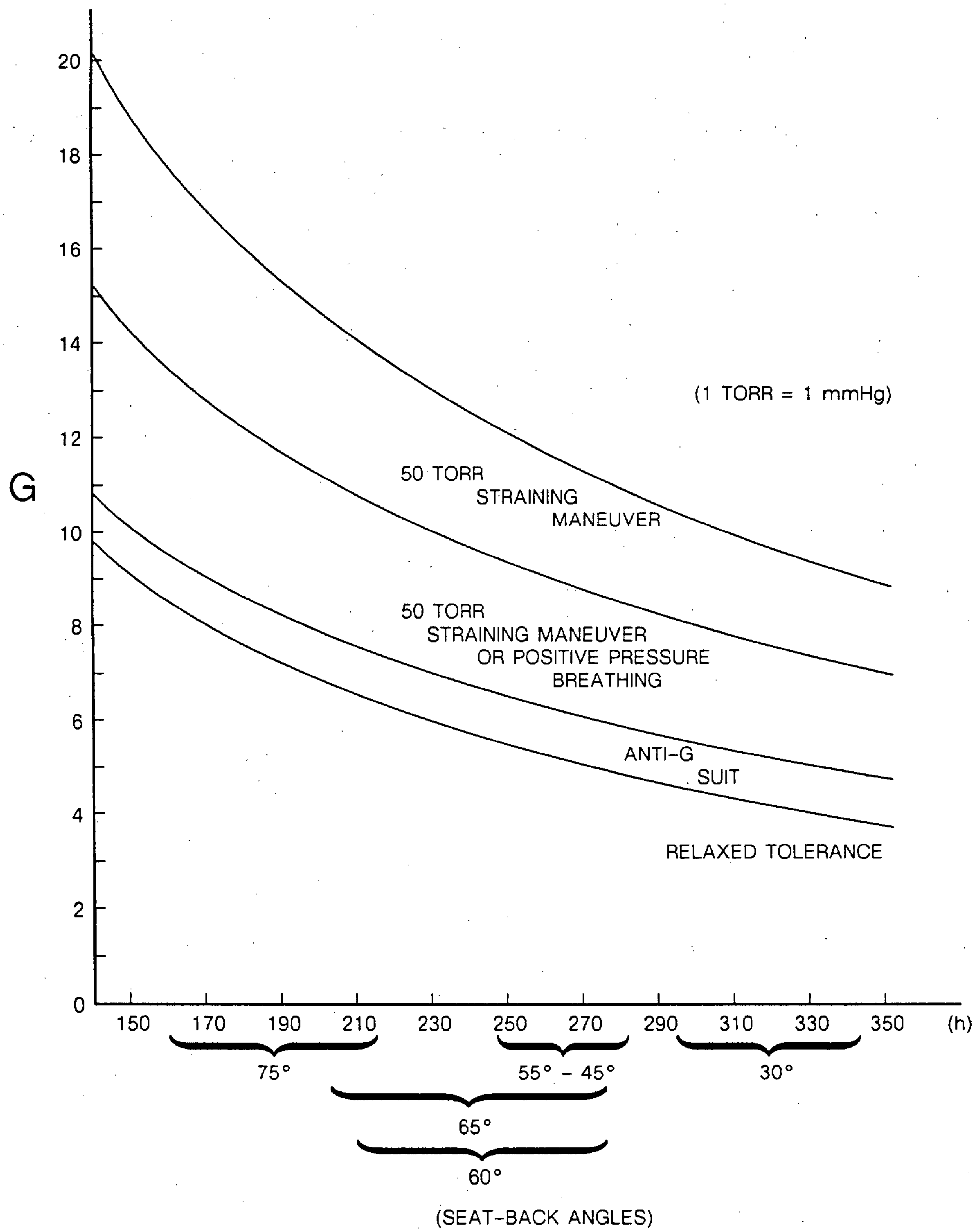


FIGURE 3. G tolerance to aircraft maneuver with G protection equipment.

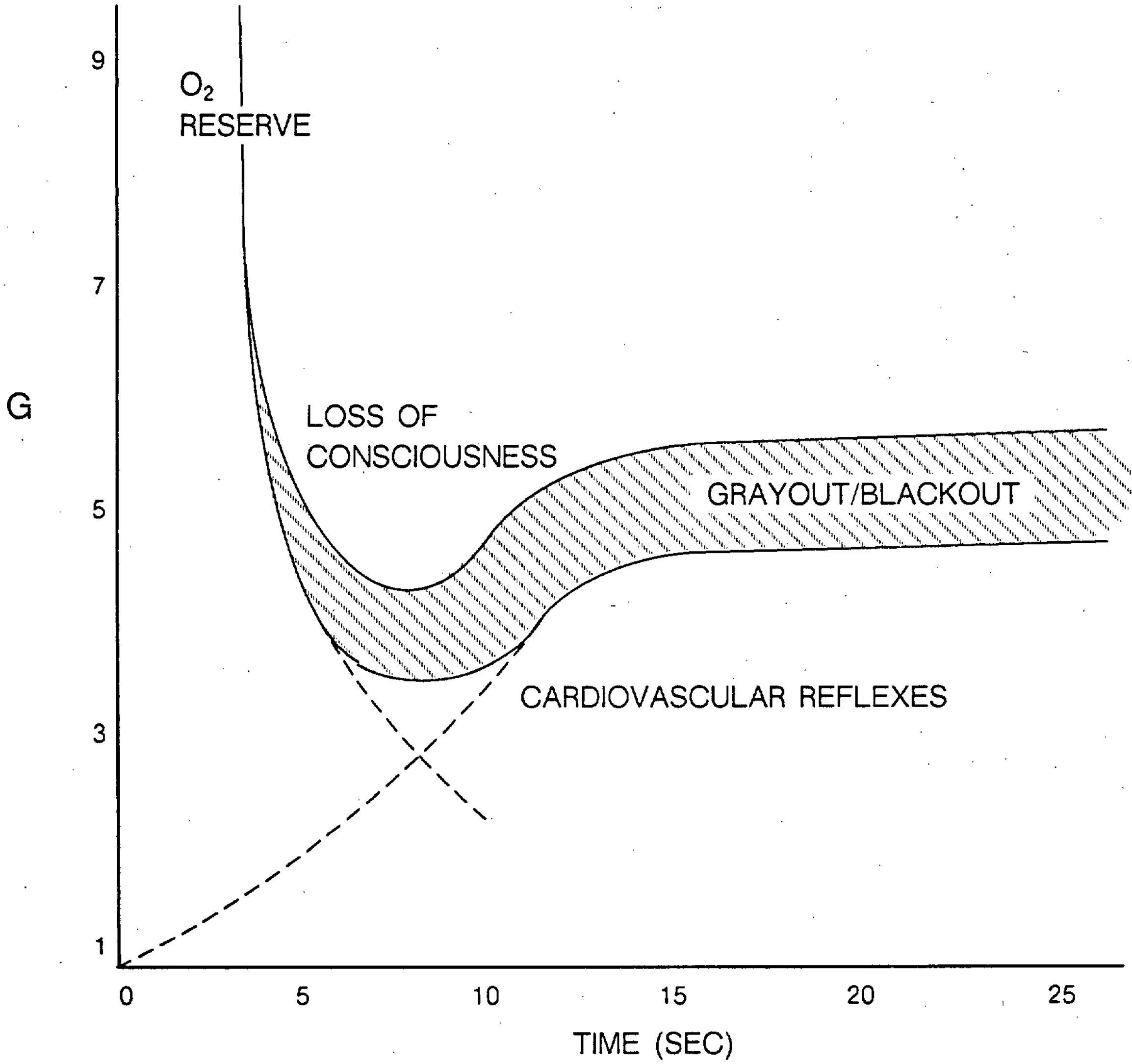


FIGURE 4. G-time tolerance curve.

fitting is carried on the pressure tube of the suit and the female portion of the fitting is attached to the aircraft pressure source. The suit operates automatically when these two connections are joined. To break the connection, 20 to 90 N (5 to 20 lbf) is necessary. In aircraft with ejection seats, the connection is broken by hand when dismounting, and automatically when the ejection seat is used. The female unit of the quick disconnect has a spring loaded dust cap which automatically seals the opening when the suit is not in use.

Additional G-suit concepts are being explored and these may offer some increased protection by reducing fatigue and pressure points and increasing the blood volume available to the heart. The concepts include extended bladder coverage, uniform lower body coverage and sequential bladder inflation.

b. G valve - G valves automatically regulate the inflation pressure to the G-suit during periods of positive acceleration. The current G valve incorporated in modern fighter aircraft (i.e., F-15, F-16), High Flow G Valve, see *MIL-V-87223*, is a modified version of the pneumatic G valve, 8000 Series ALAR G Valve, see *MIL-V-9370*, used in older fighter/attack aircraft (i.e., F-4), and provides faster inflation of the G-suit. The valve begins inflating the suit at 1.5 Gz and continues pressurizing at the rate of 1.5 psi per G up to a maximum of 12 psi.

Other valves have been explored which may provide improved response times. The high flow ready pressure valve was an enhanced high flow valve which maintained a 0.2 psi constant pressure in the G-suit to reduce the time of inflation. Test data showed a reduction in the inflation time with the high flow ready pressure valve, but this concept was not accepted by flight test pilots during an ASD/AE flight test and evaluation program. The Bang-Bang Servo Control Valve developed at HSD/AAMRL supplies maximum pressure to the garment under the following conditions: Gz level exceeds 2.0 and the rate of onset exceeds 2.0 Gz/sec, then the valve responds by remaining fully open for 1.4 seconds. After this the valve operates on a standard schedule, similar to the current valve, until it senses the condition again. The electronic valves sense and track the G level of the aircraft more rapidly and provide a faster response to the G-suit. Since it is anticipated that a fully inflated G-suit provides 1 to 1.5 Gz of protection, quicker valves may not provide a substantial increase in protection unless there is an anticipatory benefit, which has not been shown to date.

c. Positive pressure breathing with upper body coverage - Positive pressure breathing with upper body coverage, also known as assisted positive pressure breathing (APPB) is a technology being implemented into modern fighter aircraft to provide the pilot with a mechanical straining maneuver. Two concepts were successfully demonstrated by the Air Force under the Tactical Life Support System (TLSS) program at HSD on an F-15 and F-16 aircraft, and in the Life Support SPO at ASD on an F-16 aircraft, (see Harbert and Precourt, *AFFTC-TR-87-05*, April 1987 and George and Jollet, *AFFTC-TR-87-07*, May 1987). In conjunction with the demonstrated concepts, a G-suit and G valve were used.

APPB drives breathing gas into the lungs and diaphragm and inflates an external chest counter pressure garment, upper body coverage, at the same pressures. The internal and external pressures place additional force around the heart and thereby assist the heart in pumping blood to the head. In addition, the positive pressures prevent blood from pooling in the lung cavity. The chest counter pressure garment is needed to assist breathing under increased lung pressures. By maintaining equivalent pressures in the chest counter pressure garment and the lungs, the respiratory system experiences a zero net differential across the chest wall. Positive pressure breathing studies below 35 mm Hg, have been conducted without the use of an external pressure, see *AFP-160-5*, January 1976 and Burton, *Aviation, Space and Environmental Medicine*, August 1986).

TLSS uses a positive pressure schedule which initiates at 4 Gz with 12 mm Hg and the pressure increases linearly, 12 mm Hg/Gz, to a maximum of 60 mm Hg. The 60 mm Hg limit was established because tests showed 70 mm Hg to be fatiguing, thus reducing endurance. This was reported by Burns and Balldin, *Aerospace Medical Assoc.*, 1983. To hold the additional mask pressures, a high pressure mask and mask tensioning device were developed by the TLSS program. The mask tensioning device is a bladder in the back of the helmet that inflates and tightens the mask to the face as the increased pressures are delivered. Due to the importance of breathing pressures in this approach, the breathing system must be examined for interfacing and adequacy of performance, see Lloyd, *HSD-TR-87-009*, May 1988.

The positive pressure breathing varies the internal blood pressure on almost a one-to-one basis. Thus, if the maximum internal pressure which can be generated is 100 mm Hg and 60 mm Hg are supplied by PPB, then the person need only build up an additional 40 mm Hg through a straining maneuver. The reduction in the anti-G straining maneuver will decrease fatigue associated with active straining and increase endurance throughout the aircraft mission. The use of PPB with chest counter pressure at pressures of 50 mm Hg would provide about 2 G of protection, *Figure 3*.

d. Body positioning - Another approach to providing increased G protection is to reduce the height of the blood column from the brain to the heart. This can be accomplished by adjusting the seat back angle. Body positioning could occur in the forward leaning or reclined positioning. However, all of the body positioning concepts must closely examine their impact on aircraft design (i.e., interfacing with the crew station (see *MIL-STD-1776*) and ejection systems (see *AFGS-87235*), fixed vs multi-position seat back angle concepts, pilot commanded vs automated activation, crew member performance). The High Acceleration Cockpit (HAC) Program at HSD/AAMRL, reported by Sinnett, *AFFDL-TR-74-48*, May 1974 and Sinnett and Edington, *AMRL-TR-72-117, Vol V*, July 1973, demonstrated a reclined seat. During testing in the AAMRL centrifuge at reclined seat back angles of 65 degrees and beyond, significant increases in human tolerance to Gz and reduction of fatigue were demonstrated. Studies at the USAF School of Aerospace Medicine have shown seat back angles in excess of 45 degrees produce significant G tolerance improvements, see Burton, Leverett and Michaelson, Aerospace Medicine, October 1974 and Burns, USAF/SAM, 1985. The reclined seat data is represented in *Figure 3*. In addition, data has been generated to support the benefit of a forward leaning seat, by Munson, *TFD-87-1595*, July, 1987. Again improvements in G tolerance are obtained by reducing the blood column height.

The benefit of body positioning is a function of the seat design. To estimate the advantage of the seat back angle one need only use trigonometric functions to determine the effect the seat back and head rest angles are going to have on the blood column height. The Air Force has determined that the 30 degree seat back angle used in the F-16 provides little in the way of increased protection over an upright seat. This is because the column height is not reduced significantly.

REQUIREMENT LESSONS LEARNED

Recently we have found that the capabilities of our aircraft are exceeding the capabilities of the aircrew with G protection systems. It has become necessary to limit the capabilities of the aircraft to protect the crew member. If the capabilities of the aircraft and aircrew member can be designed into the G protection system from the start, these limitations may be avoided.

With the development of advanced life support systems such as TLSS, the protection for acceleration and altitude is obtained through the same equipment. In flight environments in which the crew member is exposed to both altitude and acceleration, it is essential that an appropriate equipment response be obtained. TLSS monitors altitude and acceleration conditions and selects the maximum pressure between these two conditions to supply to the equipment, reported by Lloyd, *HSD-TR-87-009*, May 1988.

In 1983, the Tactical Air Command (TAC) crew members were surveyed for personal incidents associated with the acceleration environment, see Pluta, *Flying Safety*, January 1984. The report indicated that numerous inadvertent disconnects of the CSU-13B/P anti-G garment from the pressure source had occurred. A modification of the G-suit connection was required to eliminate the inadvertent disconnects.

Problems have been encountered fitting all of the aircrew population with a limited number of sizes. Some of the problems have been due to poor quality control. However, design problems have shown that smaller individuals suffer increased discomfort when a universal bladder size is selected due to the increased relative surface area.

**4.2.3 G protection testing.** The G system shall be demonstrated to provide protection commensurate with the aircraft capability through testing consisting of __________.

VERIFICATION RATIONALE (4.2.3)

It is essential that the abilities of the G protection system are known with respect to the aircraft in which it will be utilized. Testing prior to in-flight usage will prevent individuals from exceeding their capabilities and those of the equipment.

VERIFICATION GUIDANCE

Several different combinations of techniques can be employed to resolve the G protection problem. It is necessary to conduct studies to determine the optimum combination of techniques for the aircraft and then demonstrate and validate this solution. The G protection or G tolerance system and issues should be analyzed, tested, and traded against weapon system performance, crew member effectiveness, and life cycle cost (LCC). Areas which must be addressed are: level of G protection required, crew system integration, aircrew performance, human factors evaluations, escape system interfacing, reliability, maintainability, weight, and cost.

In addition to performing qualification tests on the G protection system hardware, it is appropriate to test the system in a centrifuge environment to obtain simulated operational data. The system should be tested under manned and unmanned conditions to assess functional operation and crew tolerance and endurance. A centrifuge program might include unmanned and manned testing of the equipment to include gradual onset rate, endurance, simulated air combat and rapid onset runs, the test plan was documented by USAF SAM, Brooks AFB, TX, *SAM ACHE 86-14*, September 1986.

Following centrifuge testing, a flight test program is beneficial to assess environmental and operational issues which cannot adequately be addressed in a laboratory environment. One such issue is acceleration onset rates: current US Air Force facilities can test only up to 6 Gz/sec, while aircraft are capable of exceeding that level.

VERIFICATION LESSONS LEARNED

The high occurrence of inadvertent disconnects between the anti-G garment and pressure source, prior to 1983, shows the need for a thorough evaluation of the system to consider human factors issues. Each potential cockpit installation must be thoroughly evaluated to assess disconnect problems associated with hose length, aircrew movement, high G maneuvers, equipment interfaces, and fit and function.

**3.2.3.1 G system pressure regulation.** The pressure regulating source shall sense change in acceleration force to provide the necessary pressures to the G system as specified by the following schedule __________. The G system shall be prevented from overpressurizing by __________.

REQUIREMENT RATIONALE (3.2.3.1)

To ensure that the aircrew is receiving adequate protection the pressure must be supplied at the proper level and overpressurization must be prevented. With the proper pressurization, grayout, blackout, and loss of consciousness during high G maneuvers may be prevented.

REQUIREMENT GUIDANCE

The currently used G valve design has remained unchanged since the early 1950s. The valve automatically regulates the inflation pressure to the G-suit during periods of positive acceleration. The air used in this process is from aircraft engine bleed air which has been cooled and filtered and enters the valve inlet fittings at pressures from 10 to 300 psig. The valve contains a relief system which limits suit pressure to 12 psig. The current high flow G valve begins inflating the suit at about 1.5 Gz and continues pressurizing at the rate of 1.5 psi per Gz up to a maximum of 10 to 12 psig.

*MIL-V-9370* provides a performance schedule for the 8000 Series ALAR G valve. *MIL-V-87223* provides the high flow G valve performance schedule. Newer valves or G protection systems may require new schedules depending on new centrifuge data and aircraft performance. Also, the inflation rates and pressures are strongly dependent on the type of G-suit that is used.

REQUIREMENT LESSONS LEARNED

In interfacing the upper and lower pressure coverage of the TLSS equipment, it was determined that pressure needed to be supplied to the lower coverage garment first. This ensures the availability of the blood supply and prevents loss of consciousness due to upper body pressure forcing the blood supply to the extremities. Testing to ensure proper activation and pressures is critical.

**4.2.3.1 G system pressure regulation.** The G system shall be analyzed and tested to demonstrate the capability to meet the required performance schedule. It shall be proven that overpressurization of the system cannot occur.

VERIFICATION RATIONALE (4.2.3.1)

The system or its components, as applicable, must be tested and analyzed under all the induced acceleration stresses that will be encountered during operational use to determine if the system will meet the performance schedule.

VERIFICATION GUIDANCE

Tests are developed to evaluate current G protection system components. *MIL-A-83406* describes the test procedure to measure inflation time of the CSU-13B/P anti-G garment. *MIL-V-9370* and *MIL-V-87223* describe test procedures to measure minimum operating accelerating outlet pressure regulation, and response times for automatic pressure regulating valves. *MIL-V-87223* also describes manned and unmanned centrifuge tests. Acceleration through a simulated air combat maneuver with test subjects in the centrifuge will provide a subjective evaluation of the system performance prior to a flight test evaluation, reported in the test plan by USAF *SAM ACHE 86-14*, September 1986.

VERIFICATION LESSONS LEARNED

**3.2.3.2 G system reliability of operation.** The G system shall be subjected to the following cyclic operational conditions: ____________; and shall subsequently meet all functional and environmental requirements. In the event of a G system failure the crew member(s) shall receive a warning to indicate that proper G protection is not being provided.

REQUIREMENT RATIONALE (3.2.3.2)

Reliability of the G protection system must be defined to assure that the system will perform satisfactorily throughout its required service life. Cyclic stress requirements are necessary to assure the structural integrity of the system over its desired service life.

REQUIREMENT GUIDANCE

Selection of appropriate cyclic operational conditions is dependent upon the mission requirements for the system; i.e., the acceleration stress requirement and the service life requirement. *MIL-A-83406* provides endurance requirements for the current anti-G garment, CSU-13B/P. The endurance test in *MIL-A-83406* is to inflate the garment 1000 times to a pressure of 15 psig. The pressure designated in this specification is approximately 50 percent above the maximum use pressure and thus adequately stresses the garment during an endurance test. The number of cycles selected should likewise exceed the anticipated cycles for normal use of the garment. *MIL-V-87223* provides endurance requirements for the high flow valve and *MIL-V-9370* provides information for the 8000 series ALAR G valve. The requirements in these specifications vary the inlet pressure, inlet air temperature, and applied force at selected numbers of cycles of operation. Since the design of the pressure source as well as the garment will vary for future aircraft, cyclic operational conditions should reflect the acceleration stresses imposed by the mission requirements for advanced aircraft.

REQUIREMENT LESSONS LEARNED

No lessons learned available.

**4.2.3.2 G system reliability of operation.** The G system shall be subjected to meet the following cyclic operational conditions: ________; and shall subsequently meet the functional and environmental requirements.

VERIFICATION RATIONALE (4.2.3.2)

The system or its components, as applicable, must be endurance tested to assure that it will perform reliably throughout the required service life.

VERIFICATION GUIDANCE

Current specifications for the G garment and the high flow G valve, *MIL-A-83406* and *MIL-V-87223*, respectively, provide endurance test requirements that may be used as a guide in developing new system component endurance test methods. Cyclic operational test conditions should represent the mission requirement and stress the system beyond its required service life.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.2.4 Personal high altitude protection.** Personal high altitude protection shall be provided for aircrews on aircraft during missions at altitudes above _____ feet. The protection shall be provided by pressure suit ensembles (PSEs) properly donned and worn with other personal protective flight equipment. The PSE shall provide counterpressure to the crewmember when exposed to reduced pressures at high altitudes and shall be integrated with a pressure breathing oxygen system. The other high altitude personal protection equipment items must be compatible and integratable with the PSE. The PSE must provide a get-me-down capability.

REQUIREMENTS RATIONALE (3.2.4)

Aircrew members on high altitude missions must be protected from low pressures of altitude and the existing physical environments of the aircraft. The PSE must provide protection in the event of an unplanned cabin depressurization by integrating with other aircraft subsystems, providing 100 percent oxygen and counter chest pressure for positive pressure breathing. A partial pressure or full pressure suit must protect the aircrew member at altitude pressures of 30,000 feet and above. Protection can also be provided by a pressurized cabin system maintaining a pressure higher than the ambient, and by providing a breathing gas system with oxygen-enhanced respirable gas mixture with up to 100 percent oxygen in the event of a cabin decompression. At altitudes above 30,000 feet, 100 percent oxygen at positive pressures in the face mask must provide breathing gas at increased pressures to fulfill the physiological alveolar oxygen tension in the aircrew member's lung.

REQUIREMENT GUIDANCE

Altitude protection for the aircrew member is fundamentally a system for providing a breathing atmosphere at pressures sustaining the physiological well being of the crew member. Atmospheric gases in the cabin at the lower pressures at altitude will equalize with the gases in the body causing decompression sickness, also called the bends. Oxygen gas in solution in body cavities and tissues equalizes rapidly, but nitrogen gas in solution does not equalize as rapidly and thus causes neurological and physiological problems. The nitrogen content in breathing gas is significant. To avoid decompression sickness, prebreathing 100 percent oxygen for various time periods will eliminate the nitrogen from the body, depending on several factors such as ventilation rate and volume, and on activity such as exercise. On a sudden cabin or pressure suit decompression, the higher partial pressure of oxygen in the body fluids and tissues resulting from the prebreathing 100 percent oxygen allows the aircrew member more time physiologically to react and institute corrective action to the decompression. Eventually the lower oxygen partial pressure in the cabin would produce hypoxia in the aircrew member since the oxygen partial pressure would be significantly reduced.

The pressure suit ensemble for high altitude protection can be either a partial pressure suit or a full pressure suit. Either suit is provided to fulfill a specific mission requirement. The PSE must be integratable with the G-suit, the thermal control suit, the helmet and helmet-mounted components (including the oxygen system) and the counter pressure garment for altitude compensation and for providing counter pressure during positive pressure breathing. The PSE must be compatible with personal flight items specified for personal protection. The pressure suit must be compatible with the ejection seat parameters, the oxygen system components, (bottle, tubing, hose, and connectors), and the survival kit. The pressure suit ensemble shall be readily donned and doffed, and provide unimpeded maneuverability for the aircrew member in performance of flight duties.

**4.2.4 Verifying personal high altitude protection.** The high altitude protection for aircrew members must be analytically compared with the environmental conditions of a mission profile. The requirements for oxygen partial pressure and the atmospheric pressure exposures must be shown to be adequately fulfilled and provide protection. Simulated altitude chamber exposures must demonstrate adequate protection by the oxygen system, the pressure suit ensemble and the cabin pressurization system.

VERIFICATION RATIONALE (4.2.4)

The high altitude protection system must meet the physiological requirements imposed on the aircrew member during high altitude missions. Altitude chamber simulation must ascertain the adequacy of the designs proposed for altitude protection. Actual flight test and evaluation must verify the protection provided for aircrew members.

VERIFICATION GUIDANCE

The altitude protection systems are based on the aircrew member's physiological requirements that will be present during a flight profile. The altitude low pressures determine the pressures (mmHg) of oxygen and the counterpressures needed to provide adequate breathing gas and pressure protection. Analytically comparing the aircrew member physiological requirements with the conditions in the flight profile altitudes will guide the equipment design and establish the criteria for testing and evaluating the protection system on actual missions.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.2.4.1 Aircraft pressure suit provisions.** A pressure suit ensemble shall be provided for missions above 50,000 feet and for missions above 25,000 feet if, in the event of an unplanned cabin depressurization, it would be impossible to immediately descend to an altitude at which cabin pressure altitude can be maintained at or below 25,000 feet (a). Pressure demand oxygen, ventilation, heating, communication, and (b) aircraft interfaces shall be provided in the in-flight and ground egress system. A controller shall maintain the suit system pressure at a nominal (c) feet when the cabin pressure exceeds (c) feet. A pressure relief device shall be provided, located (d) and calibrated to relieve overpressure in the range of (d) . The oxygen or breathing system shall be designed to provide pressure demand regulated oxygen with the following features: (e) . The system shall have the capability to provide oxygen for each crew member with varying flow rates dependent on altitudes for (e) hours. The system supply and distribution plumbing shall operate under an internal pressure range of (f) psi. Pressure suit ventilation and comfort provisions shall be provided according to (g) .

REQUIREMENT RATIONALE (3.2.4.1)

a. In aircraft required to fly missions in excess of a few minutes above 50,000 feet pressure altitude, a means of providing counterpressure to crew members' lungs is necessary. This is essential for several reasons. As the flight altitude is increased beyond 43,000 feet pressure altitude, the necessity for breathing 100 percent oxygen at increasingly higher pressures becomes critical. The crew member cannot tolerate the elevated breathing pressures for an extended period of time, as the normal function of respiration and circulation become seriously impaired. The requirement for high breathing pressures in excess of 30 mmHg, and the application of external counterpressure to offset the resultant undesirable effects, are discussed in Chapter 4 of *AFP 160-5* on hypoxia and hyperventilation. Additionally, prolonged exposure to these altitudes in the aircraft cabin in excess of 25,000 feet can cause the bends and decompression sickness.

b. Pressure demand oxygen, ventilation, and heating capability are essential functions to provide in the full pressure garment system to keep the crew member within physiological stress limits. There may or may not be a need for ventilation and heating in a partial pressure suit or garment. Communication equipment is always required so crew members may satisfactorily accomplish their flight duties. For an existing pressure garment, aircraft interfaces are connected to the suit and must be compatible. Even if the pressure garment is developed for this application, the required interfaces will be very similar. Quick disconnects are required to enable crew members to egress during either airborne or ground emergencies.

c. The cabin pressure altitude within the suit is normally at the same as the altitude in the cockpit until this altitude begins to exceed the physiological limits of the crew member within the suit.

d. The pressure relief device is required as a safety measure for the crew member to preclude overpressurizing his suit. The operational requirements or suit design may necessitate a specific location for the device.

e. In the design of the aircraft oxygen supply, the oxygen delivery characteristics needed for the oxygen subsystem with pressure suits. The number of crew members must be specified to determine quantity and flow rates required of the oxygen subsystem.

f. To be compatible with an existing pressure suit design, the delivery pressure range should be specified.

g. Since the suit must cover part or all of the crew member's body, adequate cooling and ventilation to the body is not available via ambient air. The environmental control system cooling and ventilating air may be provided to the suit interior. Other methods of cooling the body may be applied, such as liquid cooling. The suit should be designed to provide comfort to the crew member within his expected operational environment and flight durations.

REQUIREMENT GUIDANCE

a. Pressure garments may be partial pressure assemblies or full pressure suits. The entire system includes the coveralls, helmet, boots, gloves, survival kits, integrated clothing, air conditioning, air conditioning units, test equipment, and support equipment. Pressure garments provide excellent aircrew protection, and under the concept of the system, this equipment is tailor-made for each mission profile. Comfort and mobility are prime factors, and the assemblies are adaptable to missions of short or prolonged duration. The partial and full pressure suit systems are discussed as follows in terms of past design considerations.

(1) Partial pressure system. The partial pressure coveralls are form-fitting garments covering the entire body with the exception of the hands, feet, head, and neck. Special items are integrated with the coveralls to provide mechanical counterpressure in the event of decompression. The associated equipment needed to provide the wearer with physiological protection at any altitude includes helmet, pressure gloves, footwear, and the kit-provided oxygen regulator. An important part of the altitude suit assembly is the pressure oxygen helmet (MA-2) designed to deliver oxygen to the lungs at pressures up to 150 mmHg (approximately 0.02 MPa or 3 psi). The cloth neck piece of the helmet extends down inside the suit to provide a continuous pressure layer. Attached to the bladder neck piece is an in-turned cuff which effects the pressure seal. The bladder-type helmet consists of an inner layer of pressure-retaining, neoprene-coated nylon bladder cloth with a removable hard shell to provide head protection during buffeting. The removable visor contains the breathing valves as well as an electric grid laminated between two layers of plexiglas. The breathing valves are identical in operation with those of the standard pressure demand oxygen mask. There is one inlet check valve and one pressure-compensated exhalation valve. The suits are used with the seat kit regulator (cushion, seat, oxygen, oxygen regulator, and survival equipment, 0.03 $m^3$ (1800 $in.^3$)). This special regulator must be used because the small diameter of the hoses on the helmet necessitates the inclusion of an injection stage in the regulator. In use, the regulator provides 100 percent oxygen at 6 to 8 mm of mercury pressure from ground level to

approximately 38,000 feet. Above 38,000 feet, an appropriately balanced capstan, helmet, and torso bladder pressure is required. The regulator also automatically reduces the various pressures as descent occurs; thus, no dump or bleed valves are needed in the suit. When the suited user is ejected from the aircraft, the seat kit remains attached to him and the assembly automatically provides properly balanced capstan, torso bladder, and helmet pressures from an emergency oxygen supply in the seat kit. The only occasion when the assembly must be manually activated is when the aircraft oxygen supply has been depleted. When the emergency oxygen is activated ("green apple" is pulled), the assembly provides properly balanced suit and helmet pressures if the cabin altitude is above 40,000 feet, and 100 percent oxygen at the proper pressure altitude if the cabin altitude is below 40,000 feet. The seat kit also has a press-to-test button which supplies moderately balanced capstan, torso bladder, and helmet pressures as a preflight check of the assembly. Partial pressure systems are in limited operational use.

(2) Full pressure system. The A/P22S-6A outfit (*Dwg 16123G*) is designed to provide aircrew members with adequate physiological protection at altitudes exceeding 50,000 feet. It can be used on missions of short or prolonged duration. The wearer is provided with protection against low barometric pressure with ventilation and exposure factors in a single unit. The assembly consists of full pressure coveralls, gloves, helmet, full pressure controller, and a helmet-mounted pressure demand oxygen regulator. The helmet consists of a hard shell of reinforced plastic, an electrically heated plexiglas visor and a sunshade on front of the hard shell (both of which can be raised on top of the shell when not needed), a seal on the outer front edge of the face opening in the shell, an oxygen regulator, and communication devices. A quick-disconnect oxygen inlet hose from the survival kit is routed through the rear of the hard shell to an oxygen regulator which provides the required breathing oxygen when the visor is closed. This visor is automatically sealed to the helmet shell by a compression seal which remains effective as long as the visor is in the closed position. The helmet breathing pressure regulator monitors suit pressure and is preset to deliver oxygen to the helmet face area at a pressure slightly greater than suit pressure. This precludes entry of suit gas into the helmet face area. Oxygen from the regulator enters the helmet through small holes in the spray bar, washing over the inner surface of the visor to prevent fogging. The oxygen regulator used in the helmet is a pressure demand style. The controller maintains the suit system pressure at a nominal 35,000 feet when the cabin altitude exceeds 35,000 feet. Manual control of suit pressure is also provided by a dial-to-test device. The type A/P22S-6A is the operational pressure suit which is currently used.

b. Experience and physiological tests have shown that pressure demand oxygen regulation is essential to support crew members subject to pressure altitudes in excess of 25,000 feet for prolonged periods. Since pressure garments will be the only protection the crew member has in a high altitude decompressed aircraft cockpit, ventilation and heating are needed for the suit to keep within physiological thermal stress limits. Ventilation is usually provided from the aircraft engine bleed air to a vent adapter hose which plugs into the suit. A quick disconnect can be provided at the aircraft interface and/or the suit connector. Using oxygen for ventilation will rapidly deplete the available supply. Using oxygen as the primary means of ventilation is not considered desirable. However, use of the unlimited oxygen supply from an on-board oxygen generating system might be an exception. Heating can be provided from the engine bleed air also or from electrical heating elements. On the suit side of the communication plug, a typical communication connector is U-93A/U and *MIL-C-9177*.

For emergency ground egress from the aircraft cockpit, all services must release automatically if the aircrew member stands erect in the crew station or cockpit preparatory to abandonment. Additionally, the crew member should be able to manually pull free all his personal leads and services from a seated and a standing position.

For ejection seat emergency egress, all services, with the exception of bailout oxygen, should be designed to disconnect automatically during the initial portion of the seat ejection. The bailout oxygen service must disconnect automatically, prior to seat/man separation as specified in *MIL-S-9479*.

c. The altitude to activate pressure into the suit assembly is a function of the minimally acceptable lower limit of partial pressure of oxygen in the lungs, alveolar, and trachea before symptoms of hypoxia begin to occur. Because the helmet assembly incorporates the oxygen breathing gas which also mixes with expelled carbon dioxide and moisture, it is essential that the vent valves be designed such that inhalation of carbon dioxide be within tolerable physiological limits. All these factors must be considered in the choice of the altitude at which the pressure garment begins inflation.

d. The aircraft should supply pressure within a range compatible with the suit. But an adverse situation may occur in which the pressure supplied to the suit may exceed what is safe. The pressure delivered to the helmet area with the breathing air is slightly greater than that in the suit area. On the High Altitude Full Pressure Flying Outfit, A/P22S-6A, the pressure relief valve is located on the lower left leg and is calibrated to open between 3.5 to 4.0 psi to prevent overpressurization.

e. The need for a pressure suit exists when the aircraft must fly above 50,000 feet pressure altitude for periods in excess of a minute. To maintain the minimum alveolar partial pressure of oxygen in the lungs at these high altitudes, it is necessary to apply counter pressure to the outside of the body, especially around the lungs. At altitudes in excess of 50,000 ft, counter pressure must be applied to the major extremities of the body.

f. Should the currently available USAF pressure suit be used, then the aircraft must be compatible with the suit throughout the operational environment of the aircraft. Should a new pressure suit be developed, all details for delivery of the oxygen supply should be physiologically compatible to the crew member. The oxygen supply pressure range shall be 50-120 psig (70 psig normally), 300-450 psig (350 psig normally) or 1800-2200 psig pressure reduced to 300-450 psig in supply distribution. These are the normal pressure supply ranges used in most aircraft. Deviation from these pressure ranges might require the design and development of new components.

g. On aircraft in which pressure suits are used, air ventilation may be provided to the pressure suits by conditioned air from the cabin supply system or from a separate source. Ensure that the conditioned air has a dew point below 4°C (+40°F). Ensure that the airflow for ventilation to the pressure suit is 0.0061 $m^3$/sec (13 cfm) maximum. Install a manually operated flow control valve in the cabin to permit each suit wearer to shut off the air being supplied to the suit or to regulate the flow at intermediate values up to the design flow. Also, configure this valve to admit and control the pressure suit air that is delivered to the aircraft by a ground cooling unit. Ensure that the air temperature, as measured at the suit inlet, is adjustable between 12.7°C (55°F) and 32°C (90°F). Ensure that the pressure drop through the pressure suit and inlet tubing is no more than 6.9 kPa (1.0 psi) at the design flow rate of 0.0061 $m^3$/sec (13 cfm). During normal use of the pressure suit when the cabin is pressurized, ensure that the control system regulates the suit inlet flow at the pressure of 6.9 $\pm$1.4 kPa (1.0 $\pm$0.2 psi) above cabin pressure. During use of the pressure suit, when the cabin is unpressurized and the cabin altitude is below 10,668 m (35,000 feet), ensure that the differential pressure is at a gage pressure of 6.9 $\pm$1.4 kPa (1.0 $\pm$0.2 psi). During emergency use of the pressure suit when the cabin altitude exceeds 10,668 m (35,000 feet), ensure that the inlet pressure to the pressure suit can be regulated at an absolute pressure of 31 $\pm$1.4 kPa (4.5 $\pm$0.2 psi). This is based on the absolute pressure of 24.1 kPa (3.5 psi) within the pressure suit. The pressure suit system may be designed with an integral liquid cooling system to reduce thermal loads on the crew member. It may even be desirable to provide heating to the crew member through the liquid system. This technique is presently under research but is not in production pressure suit systems. The cooling tubes may be used throughout the partial pressure suit system to simplify the suit design. For air cooling and heating, some inflation of the entire suit is needed. It is most difficult, time consuming, and awkward to put one of these suits on. Usually, another person is needed to help put on the suit.

A liquid cooling system may minimize these problems.

The pressure suit system is an interlayered fabric and harness that has adequate strength to apply counterpressure. Comfort may be difficult to incorporate into the suit design, but comfort of the crew member is essential to his ability to properly operate the aircraft.

High altitude protection garments designed and evaluated as part of the tactical life support system (TLSS) have included an option with counter pressure to the torso by the upper pressure garment (UPG) or jerkin, lower G garment (LGG), body cooling liquid transport equipment assembly (LTE), survival vest and flight coverall, and a personal equipment connector (PEC). An integrated garment provides chemical defense protection and fire protection with G protection but not at high altitude. The UPG had bladders front, back, and over the shoulders and was integrated with positive pressure breathing up to 40 inches of water in the oxygen mask. The LGG had bladders at the abdomen, thighs and lower legs with pressures up to 12 psig within 1 second at +9 Gz onset.

For aircraft without ejection seats, the escape sequence is modified with a parachute and harness adapted for partial pressure suit wear and thermal control, and ECS air for pressurization and thermal control.

The helmet and helmet mounted systems (H&HMS) in the TLSS have specific requirements for high altitude protection up to 60,000 ft. The mask provides up to 40 inches water positive pressure breathing (PPB) with a face seal up to 70 mmHg and stability at 9 Gz. The mask and helmet characteristics are specifically discussed in the section on the H&HMS.

A personal equipment connector (PEC) of the TLSS provides the connection of the aircraft side to the human side of the personal protection systems. The various connections provide upper and lower oxygen hoses, demist hoses, UPG pressure hoses, LGG pressure hose, and body cooling hoses.

A specially modified breathing regulator with G sensing and valving (BRAG) valve provides for positive pressure breathing integrated with G protection. The BRAG valve senses G and by an electronic actuator, provides LGG pressurization from the engine bleed air source at a rate of 1.5 psi/G, starting with 3.5 psig at 2 G up to 11.0 psig at +9 Gz. A pressure safety relief is at 13.5 psig.

The UPG or jerkin is never used without a G-suit. Positive pressure breathing beginning at 42,000 ft requires the use of the UPG and must be integrated with the oxygen regulator and helmet mounted systems, specifically the tensioning bladder and demist bar. In the chemical defense mode, a breathing gas filter in the oxygen hose path to the mask protects from cabin or atmospheric contaminants.

The cold water immersion and cold weather protection presents some design and wear difficulties.

In the Combat Edge program, a concept provides for a sleeveless shirt tail jerkin mechanically joined to and with an anti G-garment with air cooling and provides the highest personal comfort and mobility, and cockpit compatibility for operational effectiveness.

Integration of the personal high altitude protection components with the aircraft system is exemplified by the BRAG valve. A specific terminal block attaches to the CRU-60/P to supply the jerkin supply pressure. The mask tensioning bladder in the helmet is pressurized from the PPB oxygen source through the BRAG valve.

The tactical aircrew eye respiratory system (TAERS) and the aircrew eye respiratory protection system (AERPS) provide for chemical defense but do not provide high altitude protection; G protection can be provided.

REQUIREMENT LESSONS LEARNED

The PSE used in normal pressurized flight conditions imposes some restriction on crew mobility and on performance.

The full pressure suit with gloves has reduced dexterity and tactile sense in the hand.

Air cooled garments have been generally unreliable in cooling subjects, whereas the liquid cooled vest was better but heavier.

Also, the press-to-test function of the torso jerkin and the G-suit produced uncomfortably high suit pressures, which were vented when the press-to-test function was stopped.

The air cooled garments do not provide sufficient cooling under certain mission scenarios. The liquid cooled vest provides more cooling but with an additional weight penalty of about 10 pounds per crew member.

**4.2.4.1 Verification of pressure suit ensemble.** The pressure suit ensemble shall be evaluated for adequacy to fulfill the requirements of the PSEs on missions and aircrews on various selected ______ and in the specific environments. ________. Test subjects shall verify fit and adequacy of PSE for protection against specific environments, natural and induced. Testing of the PSEs shall verify that the physiological requirements of the aircrew members are satisfied.

VERIFICATION RATIONALE (4.2.4.1)

The verification of the adequacy of the PSEs to meet the requirements of personal protection at high altitudes will be accomplished by testing and analysis of the aircrew member's physiological needs in relation to the natural and physical environment at the various mission altitudes. Maintenance of counter pressures during oxygen pressure breathing and G-protection, and of thermal adequacy are demonstrated by simulated chamber altitude exposures and then by actual flight. Performance of mission duties and safety for the aircrew and the aircraft set the limits for testing and evaluation.

VERIFICATION GUIDANCE

The PSE for high altitude protection must protect the aircrew member in all phases of flight from 25,000 ft when oxygen is added to the breathing gas to high altitudes of 50,000 ft and above. The PSE is an integration of several systems: the oxygen system with the counter pressure garment, the jerkins and the anti-G suit with pressurized bladders to prevent blood pooling in the lower body parts. Pressurized oxygen for pressurized breathing along with torso counterpressure must be present. Each system must be adequate and evaluated separately and integrated as a whole in altitude chambers and in actual flight.

VERIFICATION LESSONS LEARNED

The pressure suit ensemble designed for the tactical life support system (TLSS) provides personal protection systems at high altitude, during sustained high acceleration, from chemical agents and laser and flash blindness environments. The TLSS hose routing configurations prevented a quick scramble alert capability due to interference with the pilot's lap belt. The TLSS G-suit hose connector interfered with the parachute leg strap connector. The personal equipment connector (PEC) which connected oxygen, thermal protection lines, G-suit lines and the jerker line was prone to inadvertent disconnects. The hose routing and the interfaces between the hoses should be re-evaluated. The personal thermal control system of the TLSS pressure suit ensemble could not be evaluated because of exposure to low ambient temperatures. Over cooling of the aircrew member by the TLSS PSE is possible.

**3.2.4.1.1 Pressure suit controls and displays.** Manual override control of the suit shall be provided, and test features for a preflight check of the assembly shall be provided consisting of __(a)__. Pressure, flow, and __(b)__ displays shall be provided for normal operations. Warning displays and alarms shall inform the __(c)__ crew members should the cabin pressure and altitude exceed __(c)__ feet, should the oxygen flow rate to the suit deviate from that normally expected for that cabin pressure altitude, and __(c)__. The controls and displays provided shall be functionally compatible with the protective breathing system such that __(d)__.

REQUIREMENT RATIONALE (3.2.4.1.1)

a. The suit controller contains a valve which is automatically controlled by an altitude-sensing aneroid to retain the required pressure within the outfit by utilizing vent air or oxygen from the make-up valve incorporated in the controller. Should a malfunction of the controller assembly occur, manual override provides a safety device. A test control indicates to the crew member that the suit pressurization equipment is performing satisfactorily.

b. A suit pressurization display is provided to assure the crew members that the altitude pressure inside the suit is within safe physiological limits. Flow indication tells the crew member that oxygen is being delivered to the suit and not just ventilation air. Other displays may be needed depending on the pressure suit design.

c. All crew members must be immediately aware of an impending hazardous situation so that they may check their pressure suits for proper inflation and functioning and, if necessary, take corrective actions to obtain suit inflation.

d. Many interrelated factors are involved in the control and display design that must be compatible throughout. The information that must be displayed to alert personnel to emergency or impending dangerous conditions will be a function of the system and type of component provided.

REQUIREMENT GUIDANCE

a. It is not necessary to specify the exact description of these control features, but a successful design is used in the existing Type A/P22S-6A high altitude full pressure suit. It incorporates a red press-to-test button that is located on the controller to provide for pressurization (2.0 to 2.5 psig) of the suit and helmet to test the suit assembly preflight. This device may also be used at any altitude to obtain suit pressure.

b. The existing high altitude full pressure flying outfit, Type A/P22S-6A, has an altimeter display located on the upper left leg of the coverall which registers absolute pressure inside the coverall in graduated thousands of feet. Ideally, the oxygen flow device should be located on the aircraft interface at the panel from which the oxygen comes. Should the plumbing arrangements make this impossible, locate the flow display at a readily viewable position. The most reliable type of flow display is a mechanical device that actuates by pressure differences. Flow blinkers provide the crew members with information that air/oxygen is delivered as expected through all plumbing. Status indicator lights may be desired. Liquid cooling displays will be needed if such a design is used.

c. Usually the crew of high altitude aircraft consists of only one pilot, but some have more crew members. Certain bomber-type aircraft carry up to six crew members. The warning system should activate at 38,000 feet pressure altitude or higher. The normal range at which the garment begins inflation is 35,000 to 36,500 feet pressure altitude. As long as cabin pressure is maintained below 35,000 to 36,500 feet, the existing pressure garment allows gas to escape to the aircraft cabin without appreciable pressure build-up in the flying outfit. Should the cabin pressure increase above 35,000 to 36,500 feet, either by gradual leakage or explosive decompression, gas venting is stopped and a safe pressure is maintained inside the suit. In the event of a failure of the gas supply or a vent valve, the crew member should take appropriate action when a warning is received. Another option would be for the pilot to initiate aircraft descent to a safe altitude.

d. Should existing control and display components be selected in the design, the electrical and physical characteristics of these parts can be determined from specification details. Sensing devices on other components, such as on the LOX converter or plumbing for pressure readings, must be compatible.

REQUIREMENT LESSONS LEARNED

No lessons learned available.

**4.2.4.1.1 Verification of pressure suit controls and displays.** The verification of the aircraft pressure suit controls and displays shall consist of ________.

VERIFICATION RATIONALE (4.2.4.1.1)

Verification of the aircraft pressure suit controls and displays is necessary to ensure that they function properly in the expected operational environment and meet the needs of the crew members who use them. Crew members must be able to detect and understand all displays.

VERIFICATION GUIDANCE

The verification of the aircraft pressure suit controls and displays should consist of analyses, inspections, demonstrations, and tests as necessary to ensure that all requirements have been met. Some past methods of verification that may be applicable are discussed in crew oxygen controls in *AFGS-87226*.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.2.4.2 Oxygen system for altitude protection.** The aircrew member on all mission scenarios must be provided with an oxygen system providing protection for the reduced pressures at altitude. Sufficient oxygen stores on the aircraft must supply the aircrew member with breathing oxygen at adequate flow rates and pressures to maintain physiological well-being and acceptable performance level. The oxygen system shall provide respirable gas volume of _____ lpm with oxygen partial pressures at _____ mmHg with the gas flows at pressures of _____ psig, correlated with the altitude pressures. The oxygen system must be integrated with other personal equipment items worn by the aircrew member and present on or in the aircraft cockpit.

REQUIREMENT RATIONALE (3.2.4.2)

An oxygen system is provided for an aircrew member to assure that the inspired gases contain sufficient oxygen to maintain adequate levels of oxygen in the blood and tissues and that the physiological well-being of the aircrew member is maintained. In the various aircraft environment scenarios, oxygen in the breathing gases must be assured to protect against contamination and the reduced oxygen content at altitude conditions and possible decompression of the cabin atmosphere. Hypoxia results when insufficient oxygen partial pressure occurs in the lungs after inspiring gas deficient in oxygen.

The environmental control system for transport type aircraft maintains a breathable gaseous atmosphere in the cabin, usually at 8000 ft altitude, so that the oxygen requirement is fulfilled. As the aircraft altitude increases, the cabin pressure altitude is maintained at 8000 ft altitude. Fighter aircraft typically maintain a 5 psi differential cabin altitude range between 25,000 ft and 50,000 ft aircraft altitude. However, upon a decompression or loss of cabin pressure, emergency procedures must provide for administration of 100 percent oxygen at sufficient pressure to maintain 100 mmHg partial pressure in the lungs. This is attained by the use of pressure suit ensembles with positive pressure breathing equipment, by emergency oxygen system masks, by quick don oxygen masks, or by drop-down passenger masks. The aircraft altitude or the decompressed cabin altitude governs the method of oxygen administration.

REQUIREMENT GUIDANCE

The protection provided for an aircrew member at the reduced pressures of altitude is maintained by enhancing the oxygen content in the inspired air. The physiology of respiration for military aircraft crewmembers is discussed in *AFGS-87226* (Appendix B) with data on partial pressure oxygen requirements correlated with cabin altitudes and altitude pressures. The normal oxygen partial pressure of 100 to 103 mmHg must be maintained to avoid hypoxia symptoms.

At altitudes above 25,000 ft to 28,000 ft, oxygen is delivered to the aircrew member under pressure by pressure demand regulators and with the use of pressure breathing masks. The masks are equipped with an inhalation-exhalation valve(s) and can be used up to altitudes of 42,000 ft and short excursions up to 50,000 ft. Pressure breathing with 30 mmHg in the mask is required at altitudes above 45,000 ft. With the use of counter pressure garments, various compromises are allowed. At 47,000 ft, oxygen from aviators breathing oxygen at 22.5 mmHg results in an absolute mask cavity pressure of 123.5 mmHg.

Positive pressure breathing (PPB) with the use of thoracic counter pressure vests and G trouser inflation with breathing oxygen at 100 mmHg protects a subject up to 80,000 ft and above. PPB and counter pressure garments with pure oxygen breathing protects the aircrew member during decompressions and limited stays at altitudes above 8000 feet. and are required when flights exceed 50,000 feet. The full pressure suit provides considerable protection but with the disadvantages of discomfort and limits on mobility. The full pressure suit becomes the major crew support element for flights in which altitudes exceed 50,000 ft.

REQUIREMENT LESSONS LEARNED

The standby 100 percent oxygen bottle provided an insufficient quantity of oxygen and was difficult to maintain. Several false failure indications were shown. The servicing of the oxygen bottle at room temperature when filled to 1900 psig subsequently dropped to 1750 psig following exposure to cold, overnight temperatures. This indicated that the bottle required refilling, since the proper procedure is to service when below 1800 psig.

The press-to-test function for the standby oxygen system, when actuated, produced uncomfortably high mask pressures. The high mask oxygen pressures were vented blow-by from the mask.

The Molecular Sieve Oxygen Generating System (MSOGS) produces a 93 to 94.5 percent oxygen product. At altitudes above 48,000 feet, 100 percent oxygen is required. The MSOGS oxygen product is not sufficient and symptoms of hypoxia could be initiated. Backup oxygen maintained by the MSOGS is insufficient as its supply lasts for only minutes. To maintain the required 30 mmHg partial pressure of oxygen in the blood, the 94 percent oxygen breathing gas must be provided at pressure in the oronasal mask.

**4.2.4.2 Verification of oxygen system for altitude protection.** The oxygen system for altitude protection must be verified by analysis of ______ required for aircrew member performance under the reduced pressures of aircraft flight profiles. The oxygen supply requirement must be correlated with the aircrew member's physiological oxygen usage and the protection required against altitude reduced pressures. This protection must be verified in ground altitude chamber tests of the respiration equipment on the aircrew member and on the aircraft. Subsequent flight testing of aircrew member altitude oxygen systems must verify the protection requirements for oxygen at altitude. The oxygen system equipment must demonstrate no interference or detriment in performance by the aircrew member.

VERIFICATION RATIONALE (4.2.4.2)

The oxygen system components on the aircrew member and on the aircraft should be evaluated in altitude chamber tests to verify adequate operational performance. Testing under simulated flight altitude profiles must ascertain that the partial pressures of oxygen and the flow rates satisfy the physiological oxygen requirements for protection at the reduced pressures at altitude. Integration of the oxygen system equipment with other personal protective systems shall be evaluated to show no interference of the protection requirement of all the personal protective systems. Positive pressure breathing of oxygen must show positive integration with the other protection systems.

VERIFICATION GUIDANCE

The requirement for 100 percent oxygen breathing and the pressure breathing of oxygen at less than 100 percent content is significant in the design for altitude protection. As the altitude increases, the oxygen content in the atmosphere decreases. To maintain breathing gas in the lungs at an adequate physiological partial pressure of oxygen at 100 mmHg, oxygen must be added under pressure to the oxygen mask or helmet. *AFGS-87226* discusses in detail the oxygen physiological needs and the equipment necessary to supply the aircrew member with oxygen to the breathing gas at the pressures and flow rates required for various altitude profiles. The helmet with associated protective equipment, the mask and the breathing valve, the hoses and oxygen supply lines must be integrated with other protective systems. The limitations of excessive mask pressures at 40 mmHg oxygen must not be exceeded in pressure breathing and in positive pressure breathing in association with pressure suit ensemble components and in sealed helmet breathing.

**3.2.4.3 Cabin environmental control system for altitude protection.** A cabin pressurizing system shall be provided for aircraft cabins with flight altitudes of _____ ft. The cabin pressure shall be at _____ psig differential at altitudes up to ______ ft. Above ______ ft, the cabin differential pressure of _____ psig must be maintained when partial and/or full pressure suit ensembles are worn.

REQUIREMENTS RATIONALE (3.2.4.3)

A cabin pressurizing system must provide a pressurized air supply for maintaining the cabin environment at a pressure which supports the aircrew member's physiological well being. The oxygen system, the thermal control system and G system must be integrated with the cabin pressurization system. Aircraft at altitudes from 8000 ft to 50,000 ft have altitude protection with the pressurized cabin system and provide air dilution oxygen to the aircrew member. *MIL-E-87145* recommends an 8000 ft altitude in aircraft operating at 20,000 ft and above. At 24,000 ft and above, a 5 psi differential cabin pressure provides adequate pressure to prevent decompression sickness but the aircrew member must use 100 percent oxygen or pressure breathing oxygen equipment for adequate partial pressures of oxygen in the lungs. At 70,000 ft altitude, a cabin differential pressure of 5 psi produces a cabin altitude above 24,200 feet which can potentially induce decompression sickness. At higher aircraft altitudes, higher differential pressure between the cabin and the aircraft altitude will be required with positive pressure oxygen breathing with full pressure suits for aircrew protection.

REQUIREMENT GUIDANCE

Altitude protection for an aircrew member in unpressurized aircraft or in depressurized cabins is provided by pressure suit ensembles with other personal wear items integrated with the oxygen system. The oxygen requirements are discussed in *AFGS-87226*. The pressure suit ensembles are discussed in the previous paragraphs.

Altitude protection in aircraft pressurized cabins is provided by the cabin pressurization system consisting of a source of pressurized air regulators, safety valves, air conditioners and other equipment. Bleed air from the engines provides the compressed air. For aircraft with isobaric control, the cabin altitude can be maintained at sea level, 22,000 to 25,000 ft, and then cabin pressures are typically controlled within pressure ranges of 5-14.7 psi increased up to 8000 ft depending on the aircraft and its mission. For fighter aircraft, a cabin pressure altitude of up to 25,000 ft can occur at the operational altitude. A 5 psi pressure differential is typically maintained between the cockpit pressure altitude and the aircraft altitude on fighter aircraft. A differential pressure of 2.5 psi will permit flight to any altitude. The premise here is that the pressure demand oxygen equipment is used most of the time since the cabin altitude will be 25,000 ft or less.

The physiological effects of exposure of the aircrew member to high altitude are incapacitating and mission limiting. The low pressures at altitudes cause the expansion of trapped gases in body cavities such as the sinuses, lungs and gastrointestinal tract, cavities, and an associated evaporative cooling. These effects are discomforting enough to degrade performance and may eventually be fatal. The reduced oxygen levels associated with altitude exposure and during a decompression, will initiate hypoxic conditions which adversely affect performance and may be fatal. The altitude hypoxia results when the alveolar oxygen partial pressure is reduced below 100 mmHg partial pressure/sea level.

Protection on flights above 80,000 ft for extended duration requires full pressure suits of special design that can maintain internal pressures up to 8 psia.

Decompression effects are physical as well as physiological due to loss of oxygen partial pressure. The physical effects are related to changes of pressure of gases in body cavities. On reduction of pressure, the enclosed gases must escape to equalize the pressures. Any blockages, as in the middle ear, the lungs, and sinuses, will cause excessive gas expansion and result in rupture of tissues. Dissolved gases in body fluids will bubble out and occlude blood flow in critical body organs such as the brain, heart or eyes. Decompression causes "chokes," chest pain, dyspnea and cough. The skin can be discolored with itching. The nervous system symptom evokes stagger, a motor neural lesion. Decompression sickness usually develops after a few minutes of exposure and is correlated with nitrogen bubbling out of body tissue and fluids.

REQUIREMENT LESSONS LEARNED

No lessons learned available.

**4.2.4.3 Verification of cabin environmental control system for altitude protection.** The cabin structure with the associated mounted equipment shall be tested for integrity and show acceptable pressure retention to maintain specified cabin pressures at the reduced pressures at altitude. The ECS shall produce cabin pressures at differentials protecting aircrews at the operational altitudes.

VERIFICATION RATIONALE (4.2.4.3)

The aircraft cabin structure and support systems must be evaluated to show that the cabin pressures are produced by the ECS with the differential pressures adequate for aircrew protection. Engine bleed air pressures and supply shall provide for most pressurization functions whereas positive pressure breathing of oxygen also provides pressurization of the helmet and pressure suit. Cabin pressurization and pressure suit ensemble pressurization must realistically provide the counter pressures for altitude protection.

VERIFICATION GUIDANCE

The high altitude protection for an aircrew member shall be based on the physiological requirements for maintaining the aircrew member's well-being at the altitude pressures expected during a mission profile or during a decompression. The physical parameters of low pressure, temperature, and decompression times set the limits within which the protection measures must serve. Chamber tests provide the conditions against which the protection procedures and equipment must respond so that protection for the aircrew member can be assured. Flight tests are not adequate, since the aircrew member responses are not timely enough to correct or adjust equipment and follow procedures for protection against altitude exposure effects.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.2.5 Thermal stress protection.** The personal protection system shall prevent a reduction in aircrew performance, and provide for crew member comfort and safety when exposed to high and low thermal stresses.

a. Low temperature stress – The system shall protect the crew member during exposure to temperatures as low as _____ degrees F for ______ minutes in water and _____ degrees F for ______ minutes in air. Hypothermia shall be precluded.

b. High temperature stress – The system shall protect the crew member during exposures to temperatures as high as ______ degrees F with a relative humidity of _______ for ________ period of time and from metabolic heat generation rates induced by physical activity as high as _________ kcal/hour for ________ period of time in ambient temperatures up to ______ degrees F with a relative humidity of _______. High temperature shock and dehydration effects to the crew member shall be precluded.

REQUIREMENT RATIONALE (3.2.5)

a. Both normal and emergency environments may cause the crew member to be exposed to extremely low temperatures. It is important that protection against these low temperature environments be provided so that the crew member may perform normal or emergency tasks without degradation of performance, comfort, or safety. Possible effects of inadequate protection are frostbite, hypothermia, and performance degradation.

b. The crew member may be exposed to high temperature environments or generate high metabolic heat rates in both normal and emergency situations. Protection against these heat exposures is necessary so that the crew member may perform normal or emergency tasks without degradation of performance, comfort, or safety.

REQUIREMENT GUIDANCE

For comfort to be maintained while performing duties which demand a moderate to high level of concentration or dexterity, the environment surrounding the crew member must be maintained between 66°F (18.9°C) and 85.6°F (29.8°C). The actual degree of task interference depends on many factors, including individual characteristics as well as the nature and the difficulty of the task.

a. Worst case low temperature stress is often associated with hypothermia following ejection and entry into water. Currently, protection against extreme low temperatures is being provided by a number of existing USAF anti-exposure garments, including the CWU-16/P quick donning coverall; CWU-10/P outer coverall with the CWU-9/P liner, rubber socks and overshoes; CWU-12/P wet assembly coverall; CWU-21/P flying coverall with the CWU-22/P underwear, CWU-23/P liner, SRU-25/P socks. Additional information on existing anti-exposure garments may be found in *AFGS-87238, Survival and Flotation Systems*, paragraph titled "Anti-exposure garments." Extreme low temperature information may be found in *MIL-STD-210, Climatic Extremes for Military Systems and Equipment*, under the paragraphs titled "Low temperature" in the "Regional surface environment" and "Worldwide air environment" sections, respectively. Also, *AFGS-87238* paragraph on "Winter clothing" provides information for low temperature exposure including trousers, parka, underwear, and gloves. If new low temperature exposure garments are being designed, the information on existing garments should be used as a baseline. One problem encountered with low temperature protective garments is the increased bulkiness which adversely affects performance and comfort. Alternate methods of providing low temperature protection, such as integrating the protection with existing garments, should also be sought. One possible solution may include the use of a thermal electric heating module to circulate warm vapor or liquid through a modified existing garment. In determining the length and degree of protection, environments encountered during both normal and emergency operations should be considered, as well as the insulating characteristics of the clothing worn by the crew member.

*Figure 5* gives specific tolerance times in cold air environments, assuming no radiation with fixed clothing insulation values.

For example, a person wearing a heavy pile, quilted and shearling suit (3 clo), engaging in a task lasting 6 hours, should not be exposed to temperatures below -5°C.

The low temperature environment requirements should also be reflected by the requirements of *3.2.1.3.b*.

b. High temperature stress may be a result of a high temperature environment and/or prolonged physical activity. Both areas need to be evaluated for any particular aircraft and mission to determine the protection required for the aircrew. Extreme high temperature information may be found in *MIL-STD-210*, paragraphs under the "Worldwide Surface Environment" section titled "High Temperature" and "High Temperature With High Humidity"; paragraphs under the "Coastal/Ocean Regional Type" section titled "High Temperature" and "High Relative Humidity With High Temperature"; and paragraphs under the "Worldwide Air Environment" section titled "High Temperature" in each of the respective subsections "Atmospheric Envelopes" and "Atmospheric Profiles." Information on existing "summer weight clothing" may be found in *AFGS-87238* paragraph on this topic. In determining the length and degree of protection, environments encountered during both normal and emergency operation as well as activity levels should be considered. The special case of heat generated in a fire environment is addressed in section *3.2.6* herein. The aircraft mission statement or Statement of Requirements Document should provide necessary information to establish the requirement.

The high temperature environment requirements should also be reflected by the requirements of *3.2.1.2 a* herein, regarding environmental conditions: "high temperature."

Metabolic heat generation rates may be estimated by tailoring data from *table 3*.

Actual thermal limits have been identified by determining how long it would take an average person of good health to achieve a maximum allowable internal temperature (38°C).

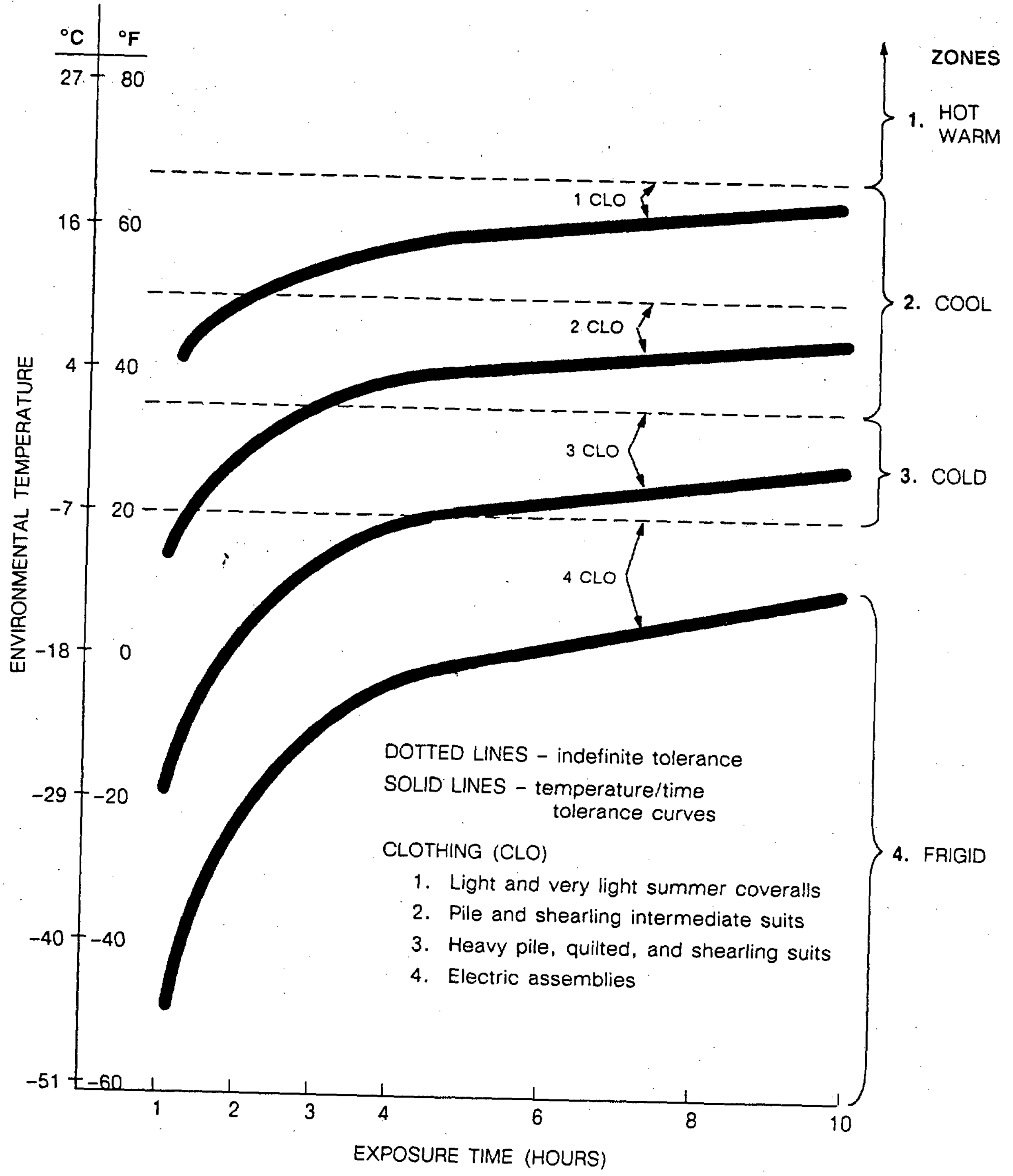


FIGURE 5. Human tolerance in cold air exposure.

TABLE III. Typical metabolic heat generation rates.

| ACTIVITY | METABOLIC HEAT GENERATION (BTU/HR) | (WATTS) |
|---|---|---|
| Standing, relaxed | 430 | 126 |
| Slow walking | 900 | 264 |
| Creeping, crawling prone maneuvers | 1360 | 398 |
| Marching at double | 3160 | 926 |
| Pilot DC-3 level | 400 | 117 |
| Piloting bomber in combat | 700 | 205 |
| Workload of 77 Kg person in an emergency | | |
| Anxiety of seated personnel 15-30 minutes | 171 | 50 |
| High workload in an emergency evacuation 5 minutes | 234 | 80 |
| Increased activity and average time it may be sustained | | |
| 2 minutes | 341 | 100 |
| 1 minute | 512 | 150 |
| 30 seconds | 615 | 180 |
| 15 seconds | 683 | 200 |

To determine the maximum allowable ambient temperature, one must first estimate the duration of exposure personnel will be expected to endure (if no estimation can be made, an upper thermal limit of 29.4°C, the maximum temperature which the average person can endure indefinitely, should be used). Once the duration has been established, use *figure 6* to identify specific thermal limits. For a task duration time of two hours, the maximum thermal limit is 35°C.

Body cooling may be provided by integrating protection with existing garments or by using additional garments. However, the use of additional garments may increase weight and bulkiness and ultimately result in decreased performance and comfort. Integrating the protection with existing garments should be considered.

Whole body cooling results in maximum reduction of heat strain; however, cooling of just the head or torso can also be effective. Various technologies have become available in the area of cooling. Solutions to body cooling may include circulating a cold liquid or vapor through new or existing garments with new or existing refrigeration units and/or pumps. These include liquid cooled undergarments, head coolers, and thermoelectric refrigeration pumps.

REQUIREMENT LESSONS LEARNED

a. Much design and associated expense may go into the proper selection of an emergency egress

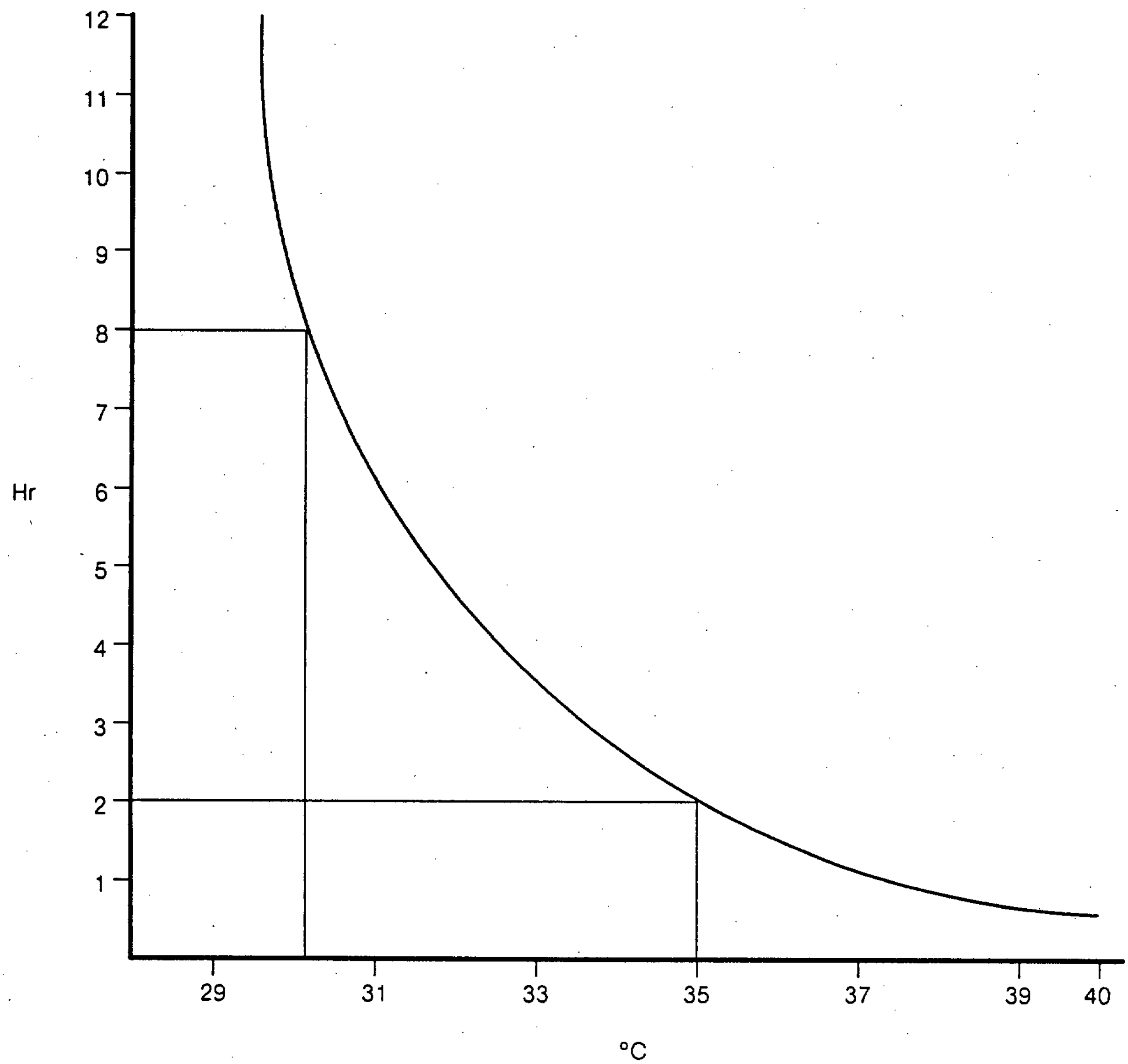


**FIGURE 6. Maximum permissible temperature as a function of duration of exposure.**

system, but this is not useful to the egressing crew members unless they can survive exposure to the environment after a safe escape. The possibility of thermal stress after egress is an important element to consider in selecting the proper garment(s) and/or equipment. More than one thermal protective system may be required to accommodate the range of low temperatures which may be encountered.

b. Several factors affecting heat stress include air temperature, humidity, air movement, heat radiation, and level of activity. Some work in the area of body cooling has been accomplished at USAF School of Aerospace Medicine, Brooks Air Force Base, Texas, as well as other military research facilities. Some of the lessons learned included from this study are noted:

(1) Liquid cooled undergarments tend to cause overcooling in the beginning.

(2) Testing suggests that the maximum metabolic rate at which a thermal balance between the surface and inner core of the body can be maintained is about 500 kcal/hr. Beyond the maximum metabolic rate, an uncomfortable sensation of being internally hot but externally cool becomes apparent.

(3) Thermoelectric devices have a number of advantages including no toxic contamination, no moving machinery, no contaminating refrigerants, and no noise. However, several disadvantages also exist, including use of additional aircraft electrical power consumption if not designed for maximum efficiency.

(4) Systems in which a cooled liquid or vapor circulates through a number of tubes in a garment have a number of drawbacks, including a) only line contact with the skin, b) raised profile of the garment to an unnecessary height above the skin, c) thick walled tubing which retards mobility and efficient heat transfer, and d) inefficient disconnect seals.

(5) The use of cooling alone can produce condensation on the outer surface of the system depending on the humidity/temperature conditions within the system's use envelope.

(6) The potential for heat transfer through the head is amplified by a) rich scalp vasculature remaining dilated at low temperatures, b) possible counter current heat exchange between the jugular veins and carotid arteries, and c) the subjective importance of head cooling in determining overall thermal comfort. However, head cooling is not an effective means of reducing core temperature.

More than one thermal protective system may be required to accommodate the range of temperatures and metabolic generation rates which may be encountered.

**4.2.5 Verification of thermal stress protection.** Verification of the requirements of *3.2.5* shall be accomplished.

a. Low temperature stress protection shall be verified by ______________.

b. High temperature stress protection shall be verified by ______________.

VERIFICATION RATIONALE (4.2.5)

a. Verification of low temperature protection is imperative to ensure aircrew performance, comfort, and safety especially in emergency situations.

b. Verification of high temperature protection is necessary to ensure aircrew performance, comfort, and safety during exposure to high temperature environments and/or increased levels of physical activity.

VERIFICATION GUIDANCE

Direct measurement is the only means of obtaining quantitative objective data with the needed accuracy. Demonstrations are essential to ensure that the tasks conducted by the crew members are properly compensated. Often a demonstration reveals aspects of a task or the environment that would not otherwise be considered.

a. Analyses, inspections, demonstrations, and tests should be accomplished as necessary to ensure that the low temperature protection system provides the required level of protection. As a minimum, verification should include testing of the system's protective capability by immersion of test subjects in a cold water tank of the required temperature and for the required length of time. Parameters such as efficiency of task performance and core temperature should be measured and evaluated. Verification may also be performed on areas such as selection of materials and workmanship. Evaluation of subjective data from realistic verifications will be an important aspect of verification.

b. Analyses, inspections, demonstrations, and tests should be accomplished as necessary to ensure that the high temperature protection system provides the required level of protection.

Verification may be accomplished by task simulation in the required environment to assess heat stress protective capability. Equipment such as a treadmill may be used to acquire the estimated metabolic generation rates as required. Parameters such as core temperature, sweat rate, and efficiency of task performance should be measured and evaluated. Evaluation of subjective data from realistic verifications will be an important aspect of verification.

VERIFICATION LESSONS LEARNED

Continuous monitoring of human test subjects is essential to prevent excessive health hazards caused by the unacceptable decrease or elevation of body core temperature.

**3.2.6 Flame and heat protection.** The crew member shall be protected against incapacitation by the flame and heat of a fire environment.

(a) Flame protection: The system shall provide burn through protection for _______ minutes. The system shall also have the following flammability characteristics: maximum flame time shall be _______, maximum glow time shall be ________, and maximum char length shall be __________.

(b) Heat protection: The system shall provide protection from thermal burns and incapacitation for temperatures as high as ________ degrees for _________ period of time. The thermal protective performance (TPP) rating shall be ___________.

REQUIREMENT RATIONALE (3.2.6)

The crew members and passengers (if applicable) must operate in aircraft which carry exceptionally flammable aviation or jet fuel, as well as a 100 percent (or near 100 percent) oxygen supply. In an emergency situation requiring corrective action and possible escape, the likelihood of a fire is quite high. As such, some degree of flame and heat protection must be provided in all personal protective equipment and clothing, regardless of its primary function (i.e., anti-g suit, climatic protection, chemical protection, etc.), unless the flame and heat protection is to be a separate system (suit) worn with other necessary protective equipment.

REQUIREMENT GUIDANCE

Although fires may occur in flight, most fires occur on crash landings. Aircraft fires from aviation or jet fuels can occur at any location on the aircraft in an emergency situation, but often they occur on a crash landing when fuel tanks and lines are ruptured, spraying fuel all about the crashed aircraft environment. Metal sparks, electrical arcs and/or the exhaust manifold of the engine(s) may ignite the combustible fuels. The latter case is the mechanism that is most likely to ignite a fire in a post-crash scenario. Usually, the on-board personnel will have only a short amount of time in which they may escape a crashed aircraft (or land and emergency egress, in the case of an in-flight fire), and this is likely to be in a fire environment.

For fires caused by aviation and jet fuel, the temperatures inside the aircraft typically reach 1500°F to 1850°F. This is considered a cool fire in an oxygen deprived environment. In a post-crash environment, where the fuel burns exterior to the aircraft and is fed by continuous fresh air from convective air flows, new oxygen is available for burning. In these situations, the flame temperatures can exceed 2000°F.

This thermal environment may be significantly more severe than the high temperature environment discussed in *3.2.5*. However, the crew member may not need to be protected for as long a period of time. Also in the case of thermal stress induced by a fire environment, the importance of body cooling for comfort is secondary to protection against incapacitating heat stress and burns. Materials with reflective coatings and ample insulation appear to be effective in protecting against this extreme thermal environment.

Heat energy can be transmitted to the evacuee by several mechanisms: convection, radiation, and conduction.

Convection - This heat energy and possible temperature rise is associated with the movement of air currents through the fire environment. This not only brings new oxygen into the fire, allowing more effective combustion, but enhances circulation and mixing of the oxygen and combustible fuel. Convection may cause a small fire to rapidly increase in intensity and size. The main concern from the standpoint of the design of protective clothing is increased effects of heat energy on the clothing and equipment. Also of concern is the possible effects of breathing hot air and the fact that preventive measures could be taken to not only reduce the fire, but preclude breathing this hot air.

Radiation - The radiation effect or, of most concern, the infrared energy from an aircraft fire are most intense. Only recently has much research been accomplished to determine the amount of radiation energy from these fires. Radiant heat at 1.7 watts per $cm^2$ of not less than 30 seconds has been proposed by the Civil Aviation Authority on 9 May 1988 as a guide for passenger protective breathing equipment or smoke hoods. One method to deal with radiation energy is to use clothing which more efficiently reflects the energy. Fabrics can be light colors or aluminized to reflect the heat, but this process may reduce the comfort and wearability of the garment. Also of concern would be the impact of such garments on flight operations. Crew members could be more easily detected by the enemy, or this may adversely impact cockpit night lighting.

Conduction - Conduction is a major concern in the design of protective clothing since the energy impinges on the fibers. The fibers, in turn, conduct heat towards the next layer of fabric or the body as the case may be. The index of conductivity is very similar for different types of fabrics and is more directly related to the number of fabric layers or the associated thickness. Air is the primary factor involved to obtain efficient insulating properties. Layers of fabrics or material which include dead air space will improve the insulating properties of the fabric or equipment.

The flame and heat protection system may be either integrated into existing personal equipment or may consist of additional personal equipment. If the system is an addition to existing personal equipment, it may be worn throughout the mission or donned only in an emergency situation.

A total personal protection system in a 2000°F environment is not a practical solution, as this would result in bulky and cumbersome personal protective equipment and clothing that would compromise comfort and mobility in an aircraft operational environment. This, of course, necessitates a compromise between flame and heat protection capability and other factors such as comfort and mobility. When Nomex® (registered trademark of E.I. duPont de Nemours and Co., Inc.) was developed years ago, it was the most fire resistant fiber available from which affordable, wearable and comfortable fabrics could be woven. Nomex is now in widespread use today for flight clothing and gloves, but new fabrics in research, development and testing may prove to be superior to Nomex.

Information regarding flame protection provided by current military aircrew and commercial flight clothing may be found in *table IV*. Additional information regarding the military clothing may be found in *table V*.

Currently accepted flammability requirements are maximum flame time of 2 seconds, maximum glow time of 25 seconds, and maximum char length of 3.5 inches. Materials do exist which have flame times, glow times, and char lengths significantly less than these maximum values. These materials may also be evaluated for suitability with the flame and heat protection system before the requirements are established. The following discussion examines the most critical properties to consider when choosing an appropriate fabric:

a. Flame or Burn Resistance - Flame resistance has previously been determined by a Bunsen burner test where a small patch of the fabric is exposed to a flame and then removed. If the fabric or material extinguishes itself after the flame is removed, then it is said to exhibit some degree of burn resistance. If it continues to burn, it has no burn resistance. The length of the char effect and the time of after glow can be measured as a yardstick to the degree of burn resistance.

One method of increasing a material's flame or burn resistance is to treat the material with a fire retardant finish. A fire retardant finish is a chemical or mixture containing a high proportion of phosphorus, nitrogen, chlorine, antimony, or bromine. For example, the combination of tetrakishydroxymethyl phosphonium chloride (THPC) with trimethyl melamine (TMM) is effective in producing fire retardant fabrics. Various theories have

**TABLE IV. Flame resistant requirements for aviator's clothing. 1/**

| GARMENT | TYPE | CHAR TEMP (minimum) | CHAR LENGTH | FLAME TIME | GLOW TIME |
|---|---|---|---|---|---|
| USAF Military Clothing | | | | | |
| Summer Coveralls | CWU-27/P CWU-28/P | 675°F | 3.5 in. avg. single test 4.0 in. | 2 sec. | 25 sec. |
| Summer Jacket | CWU-36/P | 675°F | 3.5 in. avg. single test 4.0 in. | 1 sec. | 14 sec. |
| Flying Coveralls, Anti-Exposure Liner | CWU-23/P | Not Given | 5.5 in. avg. single test 6.5 in. | 2 sec. | 2 sec. |
| Anti-Exposure Coveralls | CWU-21A/P | Not Given | none | none | none |
| Cold Weather Jacket | CWU-17/P | 675°F | 3.5 in. avg. single test 4.0 in. | 2 sec. | 14 sec. |
| Summer Gloves | GS/FRP-2 | 675°F | 5.5 in avg. | 2 sec. | 2 sec. |
| Commercial Flight Clothing | | | | | |
| Cotton Twill Cloth | ----- | Not Given | 5.5 in. avg. single test 6.5 in. | 2 sec. | 2 sec. |

1/ All fabrics are tested per *FED-STD-191*, Test Method 5903.

been proposed to explain flameproofing action, including a theory regarding two types of combustion. In one, the volatile decomposition products burn with a flame; in the other, the solid material undergoes flameless combustion, or afterglow. In general, the alkaline types control afterglow. A few, such as ammonium phosphates and halogenated products, reduce both flame and afterglow. The best supported theory for prevention of afterflame regards the use of chemical flame retardants which direct the decomposition of the cellulose when heated so as to minimize the formation of volatile flammable products and increase the amount of water and solid char formed. The prevention of afterglow is usually attributed to a modification of the flameless combustion to make it less

TABLE V. Military garment specifications.

| GARMENT | TYPE | GARMENT DOCUMENT | FABRIC | FABRIC DOCUMENT |
|---|---|---|---|---|
| Summer Coveralls | CWU-27/P CWU-28/P | *MIL-C-83429* | Aramid Plain and Basket Weave Cloth | *MIL-C-83429* |
| Summer Jacket | CWU-36/P | *MIL-J-83382* | Aramid Twill Cloth High Temp, Resistant | *MIL-C-81814* |
| Flying Coveralls Anti-Exposure Liner | CWU-23/P | *MIL-L-83197* | Cotton Twill Cloth Fire Retardant Treatment | *MIL-C-18387* |
| Anti-Exposure Coveralls | CWU-21A/P | *MIL-C-83195* | Cotton Ventile | Not Given |
| Cold Weather Jacket | CWU-17/P | *MIL-J-83388* | Aramid Twill Cotton High Temp. Resistant | *MIL-C-81814* |
| Summer Gloves | GS-FRP-2 | *MIL-G-81188* | Polyamide Knitted Cloth, High Temp. Resistant | *MIL-C-81393* |

exothermic and therefore incapable of maintaining itself, for example, by formation of carbon monoxide instead of carbon dioxide. Other theories include the formation of a coating or froth which excludes oxygen and smothers the combustion, the formation of nonflammable gases which dilute the flammable products and exclude oxygen, and the thermal theories which hold that heat is dissipated by endothermic reactions or by conduction.

Many fabrics, including dacron, melt, shrink or char around 300°F. Nylon melts when exposed to intense heat or flames. This is unacceptable for flight clothingbecause the molten material may cause severe burns to the wearer's skin. The char resistance of Nomex is better, as it withstands temperatures up to 700°F. Today, two chemical treatments, FRT Cotton and ARNOX, can improve the tolerance of fabrics against ignition. Three permanent fire-resistant fibers, PRE-OX, PBI® (Polybenzimidazole, a registered trademark of Hoechst Celanese Corp.), and Kynol can withstand temperatures of 1500°F and more for a short time without melting, igniting, or charring. With FRT Cotton and ARNOX, chemical reactivity problems with chlorine laundry products may reduce or destroy the fire resistivity.

Blending fire resistant fibers introduces several advantages, such as improved comfort and durability and reduced cost. Blends of PBI and Nomex have been proven as successful flame resistant clothing; possibly an improvement over existing Nomex-only flight garments. Fiber blending is used in the existing emergency escape breathing device hoods, which are a blend of 70 percent Kynol and 30 percent Nomex fibers.

Another alternative is to modify the susceptibility of the textile to combustion by the introduction of noncombustible and otherwise inert materials. Metal and/or mineral threads may be combined with the textile fabric to improve fire resistance.

b. Flame shrinkage - Most fabrics when exposed to intense heat and/or flame have a tendency to carbonize and shrink. This is unacceptable for protective equipment and clothing. The material may also lose its insulating properties, thus reducing the level of protection to the crew member and passengers. While the material will degrade to some extent, the goal is to minimize this flame shrinkage so that fire protection will be as effective as possible.

c. Fabric or material embrittlement - When fabrics such as aluminized skin are added to protective clothing for heat and flame resistance, the suppleness or flexibility of the clothing may be compromised.Stiff fibers tend to crease in the same place each time they bend, causing cracks in that area. Insulating layers of fabric or material may tend to tear when flexed. New fabrics should not degrade or reduce the flexibility of the garments as compared to the flexibility of currently used garments. Requirements for fabric strength and flexibility may be found in *FED-STD-191* and *SAE AMS 3841*.

Another phenomenon that could degrade the ability of the clothing to provide protection is material embrittlement from intense flames or heat. If these types of fabrics and materials are used, the garment may easily tear away from the person after exposure and reduce the protection.

d. Protection capability - Some fabrics may have protection capability defined by standards other than the *FAR 25.853* Vertical Flame Test. An example is the Thermal Protective Performance (TPP) as adopted and used by the National Fire Protection Association (NFPA). When adopting this requirement, refer to the applicable National Fire Protection Association (NFPA) standard. Another standard for TPP has been developed by the American Society for Testing and Materials (ASTM). If this standard is desired for use, refer to *ASTM D4108-87, Standard Test Method for Thermal Protective Performance of Materials for Clothing by Open-Flame Method.*

e. Thermal insulation properties - As discussed previously in this section, thermal insulation properties of protective garments and equipment can provide significant protection to the wearer against intense heat and/or flame. Trade-offs need to be considered when providing wearer comfort as the insulation may not allow cooling and ventilation of the wearer. For operation in the cold environment and emergency egress in the cold environment or cold water immersion, such insulation could provide the wearer cold weather protection. In the warmer environments, insulation against intense heat or flames may be best provided by layers of fabric garments that breathe to some extent, allowing ventilation of warm humid air from the body to the ambient environment. The insulating layer(s) between the garments provide some degree of fire protection.

f. Durability and tear strength - The protective garment(s) and equipment must, in addition to fire protection, exhibit durability and tear strength properties comparable to existing fabrics. Often measures taken to enhance fire protection will significantly reduce the durability of the fabric. Durability and tear strength requirements, depending on the types of fabric and fire resistant treatment, may be found in the applicable test method of *FED-STD-191*. Further information on the best commercial practices for fire resistant fabrics in aircraft may be found in *SAE AMS 3841* (refers primarily to flight clothing) and/or *SAE AMS 1775A* (refers primarily to aircraft seat upholstery).

g. Comfort and mobility considerations - As a reminder to the designer, this section has been added to ensure that flame and heat protection is not provided at the sacrifice of comfort and mobility. Other sections of this document also provide useful information to consider when designing the flame and heat protection garment. A requirement may be included to ensure that the flame and heat protection provide an acceptable level of comfort and mobility for the entire population range for which the garment and equipment is designed.

h. Other - Consider requirements which prevent the flame and heat protection capability from being degraded. For example, some flame resistant treatments may degrade when the fabric is laundered. Also, the fabric may shrink when laundered. Launderability requirements are desirable and are discussed further in section *3.5*.

The following references are provided as additional sources of guidance for the design engineer:

*Fiber, Fabrics, and Flames: Instructor's Handbook with References*; US Department of Health, Education, and Welfare; US Government Printing Office; 1970.

*Fire and Flame Retardant Polymers*; by Albert Yehaskel, Noyes Data Corporation; 1979, 492 pp.; LC: 78-70742; ISBN: 0-81 55-0733-X; Series: Chemical Technology Review, 122.

*Fire Resistant Textile Handbook*; by W.A. Reeves, G.L. Drake, R.M. Perkins; Technomic Publishing Co.; 1974; 276 pp.; LC: 73-82116; ISBN: 0-87762-088-1.

*Fire Retardant Coated Fabrics Formulations Handbook*; by Vijay Mohan Bhatnagar; Technomic Publishing Co.; 1974 Series: Progress in Fire Retardancy; Volume 4; 1974; (out of print).

*Fire Retardant Formulations Handbook*; by Vijay Mohan Bhatnagar; Technomic Publishing Co.; 1972; 245 pp.; LC: 72-80324; ISBN: 0-87762-090-3; Series: Progress in Fire Retardancy: Volume 1.

*Fire Retardant Polyurethanes: Formulations Handbook*; by Vijay Mohan Bhatnagar; Technomic Publishing Co.; 1977; 300 pp.; LC: 72-91704; ISBN: 0-87762-217-5; Series: Progress in Fire Retardancy; Volume 8.

REQUIREMENT LESSONS LEARNED

The use of fire retardant coatings may slow the spread of fire; however, they may generate unacceptable levels of smoke or emit unacceptable levels of toxic gases.

Some insulations, although protecting from extreme heat, actually speed burn-through since they do not allow heat to dissipate.

Trade studies will have to be performed to determine which materials meet the flammability requirement, while also meeting requirements for smoke and toxic fumes generation, as well as any requirements for comfort and durability.

**4.2.6 Verification of flame and heat.** Verification of the requirements of *3.2.6* shall be accomplished.

a. Protection from flame shall be verified by __________.

b. Protection from heat shall be verified by __________.

VERIFICATION RATIONALE (4.2.6)

Verification of fire protection is essential to ensure that the crew member is capable of performing mission essential and emergency tasks in the event of exposure to a fire environment. Verification is necessary to establish that these tasks are accomplished without performance degradation, while maintaining maximum safety and reasonable comfort.

VERIFICATION GUIDANCE

Analyses, demonstrations, inspections, and tests shall be accomplished as necessary to verify that the flame and heat protection system(s) meets the established requirements. The complex interactions between requirements limiting flammability, smoke generation, and toxic gas emission suggest that system testing using mock-ups or full-scale test measures be used as much as possible. Materials need not be tested if the suppliers provide sufficient information which proves that the materials have been tested in the past and meet the established requirements. Due to the synergistic effects of flame, smoke, and toxic gases, testing with instrumented mannequins is desirable before human testing.

a. When conducting the standard Bunsen burner tests for fabric flame resistance, use the methods established by *FED-STD-191*, Test Method 5903. A small patch of fabric should be burned by the Bunsen burner and after glow will be determined after the fabric is removed from the flame. Use *ASTM D4108-87* to determine the Thermal Protective Performance of the fabric by open-flame method. It may be desirable to launder the fabric several times before conducting any flame tests, as flame retardant properties may be degraded by laundering. It may also be desirable to reestablish material strength and insulating properties so the tests from *FED-STD-191* and/or for the *SAE AMS 3841* properties may be retested after the flame testing.

b. Burn insulating, flame resistance, and material embrittlement properties can be determined using an open pit fire test. A dummy may be clothed and swung into an open pit in which fuel such as JP-4 is burning. The time of exposure should be representative of a scenario which an evacuee would experience when attempting to escape a burning aircraft. This test will also show if any fabric shrinkage occurs during exposure to flame or heat.

VERIFICATION LESSONS LEARNED

A number of lessons learned can be obtained from the broad field of flammability testing. In the area of ease of ignition testing, some materials which shrink or melt upon heating can often pass a Bunsen burner test by retreating from the fire, yet they can show serious ignition propensities in actual fire experience due to the total effect of material surroundings in the extensive flames. This phenomenon may limit the usefulness of the Bunsen burner test in ease-of-ignition testing. The flame spread rate is influenced by the superimposed radiant heat flux, oxygen concentration, density of the material being tested, and the orientation of the material and the burning. Therefore, the combination of these factors must be evaluated when using the flame spread rate as a means of comparison between different materials. An example of the importance of burning orientation is: the flame spread rate of cotton sheeting in air (1 atm) was observed to be about 40 times greater for upward burning than for downward burning when specimens are in a vertical position. In fact, any ratings based only on downward or horizontal burning should not be used, as these ratings will not be as indicative of the worst case of those based upon upward burning. When fire was permitted to burn to the point of extensive damage in two full scale tests, the levels of temperature, smoke, oxygen depletion, and carbon monoxide until flashover occurred were low relative to human survival limits. Therefore, it is important that the flashover/ flashfire potential of materials be evaluated. Test results of materials in commercial aircraft fires showed that some materials, such as synthetic polymers, yielded products of combustion substantially different from those produced by the same materials in controlled laboratory settings. These products of combustion are often flammable hydrocarbons; therefore it should be kept in mind that melting materials have a greater concentration of highly flammable hydrocarbons than those which intumesce (swell) or char (scorch).

**3.2.7 Smoke and toxic fumes protection.**

a. Smoke and toxic fumes protection shall be provided for crew members and passengers (as applicable) during _____ mission segments at cabin altitudes up to ____ feet and for emergency escape. The protective device shall have a maximum permissible leakage of contaminant gases less than _____ for _____ levels of smoke and fumes and for ________ period of time. Eye protection shall be provided for _________ levels of smoke and fumes and for __________ period of time.

b. Special concerns: The following performance criteria shall be considered.

(1) Maximum inspiration of carbon dioxide caused by rebreathing: _______.
(2) Malfunction indication: _________.
(3) Workload factors: ____________.
(4) Other critical concerns: _________.

REQUIREMENT RATIONALE (3.2.7)

a. Equipment and/or procedures are required to ensure that crew members and passengers have the respiratory and eye protection necessary to successfully survive a smoke and toxic fumes environment. Since aircraft fires may occur in flight, the device may also have to provide some altitude protection. Minimum time periods of protection are required to allow for performance of essential tasks in-flight as well as emergency egress.

Threshold contamination levels do exist for the time period in which adverse effects to the body may occur. These levels of contamination could seriously affect or hinder the capability of the crew members and passengers to survive and successfully egress the aircraft. Since some by-products of combustion may also cause permanent physiological damage to the aircrew members or passengers, these harmful effects should be avoided where possible.

b. Experience has shown that the listed performance parameters are necessary to ensure that the personal protective devices will provide satisfactory operation without harming or hindering the crew member or passenger.

REQUIREMENT GUIDANCE

a. In many military aircraft, the oxygen regulators will deliver breathing gas at 100 percent oxygen concentration. If the breathing mask does not allow smoke and toxic fumes to enter in hazardous concentrations, additional special breathing equipment for respiratory protection in flight may not be required. While respiratory protection allows the crew members to breathe, certain crew members, primarily the flight crew, will require eye protection to satisfactorily continue their duties. Smoke and toxic fumes will obscure the surrounding environment rapidly. The primary concern, however, will be the effect of severely degraded vision from such airborne contaminants upon the crew members' eyes.

Altitude protection is required in the aircraft along with smoke and toxic fumes protection, as the crew members and passengers can only breathe on one device at a time, and smoke and toxic fumes may occur at higher altitudes. The means of providing breathing gas or oxygen to the crew member usually determines the degree of altitude protection. For example, continuous flow equipment affords altitude protection up to 25,000 feet for several hours, or higher altitudes for shorter periods of time, without danger of hypoxia. Any time that the crew member is above 25,000 feet for more than a few minutes, however, potential for the bends and chokes exists.

A crew member in a fighter aircraft will most likely need protection while in flight with a cabin altitude range of ground level to 25,000 feet. Should cabin pressure be lost, protection up to 50,000 feet for current aircraft and 60,000 to 70,000 feet for some newer aircraft will be required for a short time. This scenario might also occur in transport aircraft, but the cabin pressure altitude is normally 8000 feet unless cabin pressure is lost. Further information on breathing requirements for altitude protection is given in *3.2.4*.

No specific requirements have been established addressing the length of time altitude protection plus smoke and fumes protection should be provided. In a transport aircraft, a conservative estimate of 15 minutes is allowed for emergency descent to a safe breathing altitude of 10,000 ft or lower. When the cabin is filling with smoke and fumes in addition to the pressure loss, the problem is compounded. Additional time must be allowed to purge the smoke-filled cabin or to find a landing field and evacuate the aircraft. The current approach is to provide at least 15 minutes for altitude plus smoke and toxic fumes protection; an additional 15 minutes for smoke and toxic fumes protection; and another 5 minutes for smoke and toxic fumes protection during emergency evacuation. Therefore, a total of 35 minutes of full capability is necessary.

If the protective equipment is designed only for emergency evacuation of an aircraft during smoke and fumes conditions, then a minimum of five minutes is thought to be adequate. This device should enable the evacuee to get up from his seat, move down the aisleways, locate an exit and successfully egress.

Smoke is incapaciting to both vision and breathing. Smoke generated in such great volumes that vision becomes obscured will hinder emergency task performance and/or escape. The use of infrared devices to "see" heat is being investigated as a means of locating fires and incapacitated people in dense smoke environments. However, this may not be practical for aircrew smoke protection. A less effective approach is to choose materials for the fire protection system which minimize smoke generation, thus eliminating one source of smoke and thereby allowing the crew member or passenger more time to perform emergency tasks before vision becomes obscured. Because smoke is incapacitating when inhaled in excess, provisions must be provided to either filter the ambient air from smoke particles or provide a secondary source of acceptable breathing gas. *AFGS-87226* discusses these design approaches in Appendix A, paragraphs regarding the aircraft firefighter portable assembly.

Smoke is commonly measured in terms of optical density. The extent of smoke generation depends on the thickness and density of the materials involved, and the optical density depends on the volume of the cabin or cockpit and the light path length. The FAA's most lenient requirement for optical density is that materials may not exceed 100 within 90 seconds nor 200 within 4 minutes. Therefore, these are the most severe levels of smoke against which the crew member must be protected.

Toxic gases emitted in smoke which should be considered include carbon dioxide ($CO_2$), carbon monoxide (CO), hydrogen cyanide (HCN), hydrogen chloride (HCl), sulfur dioxide ($SO_2$), and nitrogen dioxide, ($NO_2$), as well as any other potentially toxic gases which may form. When measuring toxic gas levels and their generation rates, evaluate the gases both individually and in combination for physiological effects. The amount of any particular gas produced and the generation rate strongly depend on the temperature and oxygen concentrations in the smoke and fumes environment, as well as the amount of material being consumed and the air ventilation rate. Protection may be provided by appropriately filtering the ambient air or providing a secondary source of acceptable breathing gas.

Increases in the partial pressure of carbon dioxide in the breathing air will result in the blood becoming more acidic. This condition will worsen with increases in breathing temperature, which are likely to occur when donning a respiratory protective device. The additional carbon dioxide will affect the respiratory center of the brain. The combined effects of more acidic blood and the increased diffusion of carbon dioxide into the respiratory center and the chemoreceptors (groups of sensing cells found outside the central nervous system) will tend to increase respiratory activity. This will increase physiological stress, which in turn will impair the capability for increased physical activity and good judgement.

Regarding the origin of the smoke and fumes environment, the combustion of many materials produces noxious gases and airborne contaminants. The plastics used in walls, headliners and seat cushion materials have all proven to produce exceptionally toxic substances when combusted. While the allowable threshold for contaminants varies widely from one person to another, standards in commercial aviation have been developed and proposed. In addition to the toxic substances produced by the burning of these plastic materials, thick arid black sooty smoke that coats the eyes and respiratory passages quickly incapacitates an evacuee.

*Table VI* provides an estimate of the threat environment and proposed protection levels. Leakage and/or filtration capability not to exceed 5 percent of the total inspired volume is a goal for respiratory protection, while leakage/filtration not to exceed 10 percent is a goal for eye protection.

The following references are also provided for a more complete evaluation of smoke and toxic fume design efforts:

*SAE AS 8031 Personal Protective Devices for Toxic and Irritating Atmospheres, Air Transport—Crew Members*

*FAA-AM-78-41 Optical Properties of Smoke Protective Devices*, John A. Vaughan and Kenneth W. Welsh.

*FAA-AM-76-5 Visual Evaluation of Smoke Protective Devices*, John A. Vaughan and Kenneth W. Welsh, May 1976.

*ANSI Z87.1 Practice for Occupational and Educational Eye and Face Protection*

*SAFE Symposium Journal: The Objective Evaluation of Aircrew Protective Breathing Equipment* (by D. de Steiguer and M.S. Pinski, 1976.):

I. "Oxygen Mask/Goggles Combinations"
II. "Full Face Masks and Hoods"
IV. "Full Face Masks and Hoods Suitable for Flight Attendant Use"

TABLE VI. Threat environment and proposed protection levels.

| SPECIFIED GAS | THREAT ENVIRONMENT | PROTECTION LEVEL |
|---|---|---|
| Carbon Dioxide ($CO_2$) | 35,000 ppm | 1,225 ppm |
| Carbon Monoxide (CO) | 10,000 ppm | 100 ppm |
| Hydrogen Chloride (HCl) | 1,000 ppm | 50 ppm |
| Hydrogen Fluoride (HF) | 1,000 ppm | 50 ppm |
| Hydrogen Cyanide (HCN) | 400 ppm | 20 ppm |
| Oxides of Nitrogen ($N_xO_x$) | 200 ppm | 10 ppm |
| Acrolein ($C_3H_4O$) | 50 ppm | 2.5 ppm |
| Ammonia ($NH_3$) | 1,000 ppm | 50 ppm |
| Hydrogen Bromide (HBr) | 1,000 ppm | 50 ppm |
| Total Hydrocarbons (as Hexane) | 5,000 ppm | 250 ppm |
| Sulfur Dioxide ($SO_2$) | 100 ppm | 5 ppm |
| OTHER | | |
| Particulates (0.5 - 10 micron) | 3.5 mg/l | 0 mg/l |
| Water Vapor | 10-95% R.H. | ?? |
| Oxygen | 17-21% or less | function of altitude |

b. (1) Several factors tend to increase the level of carbon dioxide in the blood. One of the primary products of combustion is a large increase in the level of carbon dioxide in the surrounding environment. The carbon dioxide which is allowed to enter the protective breathing device through leakage or filters will contribute to an increase in physiological stress. Additionally, an increase of carbon dioxide in the breathing air results from exhaled carbon dioxide that is not allowed to leave the enclosure of the breathing device or that is not saturated/ scrubbed by any included adsorbant material. The current maximum inspiration level of carbon dioxide is 3.5 to 4 percent concentration of the breathing air and 5 percent concentration of the the breathing air for not more than 2 minutes. These levels may be refined by additional research or disagreement of acceptable physiological standards. Rebreathing is primarily a problem when the protective breathing device is a protective hood.

b. (2) Should a failure of the breathing gas supply or any filtration occur, the crew members/ passengers may want to doff the respiratory protective device and find another or tolerate the contaminated environment. Any failure or malfunction of the equipment should be readily apparent to the user so that he or she may take the appropriate action. Failure to doff the protective device could result in incapacitation due to contaminants or insufficient oxygen. On the other hand, it may be more beneficial to provide indication that the device does not function properly prior to donning it. For example, if the device includes a pressurized oxygen supply which has nearly dissipated due to leakage, the person would not want to doff the device except for a short time or as a last resort for smoke protection. Altitude protection would be expended and carbon dioxide levels would become toxic in a few minutes.

b. (3) The design of a protective device must accommodate increased workload activity to be realistic. In an emergency situation, the respiration rate will increase due to stress. Also, the duties of the crew member will cause an increase in physical activity. Consideration must be given to the increased physical activity encountered during emergency egress. The population range should also be considered. For example, a larger crew member (high percentile) will breathe larger tidal volumes of air through a filter or from an oxygen supply. A larger crew member may also generate a greater amount of carbon dioxide, body heat and moisture. *Table 3* found in provides workload rates for various emergency activities.

b. (4) Other performance factors that must be considered are discussed in other sections of this document. These include, but are not limited to *3.5* on human engineering, anthropometric sizing and utilization as well as *3.2.10* on hearing protection and communication devices.

REQUIREMENT LESSONS LEARNED

Smoke generated by smoldering or flaming materials presents both physical and physiological hazards by reducing visibility and irritating the eyes, nose, throat, lungs and skin. Excessive amounts of smoke may cause severe smoke inhalation, depriving the body of oxygen and eventually leading to death. Many survivors of aircraft fires have confirmed that smoke rapidly obscures vision. This loss of visual reference in a short amount of time slows task performance and escape, and induces panic. Therefore, adequate smoke protection has a major impact on survival.

The relative toxicity of any component in an aircraft must be determined in a manner that assesses the total effect of the toxic gases given off when smoldering or burning. The importance of this can be seen in FAA testing in which one material (76 percent wool, 24 percent PVC) showed a much higher than expected toxicity. A possible explanation for the observed toxicity was the interaction of the zirconium fluoride flame-retardant treatment that the material had received and the material itself. The importance of protection from these synergistic effects of toxic gases is seen in a number of commercial aircraft crashes. For example, a DC-9 crash involved 23 fatalities caused by the synergistic effect of toxic gases. All 23 fatalities showed carbon monoxide (CO) levels between 20 and 63 percent hemoglobin saturation. However, the lethal level of CO in humans is 67.5 percent hemoglobin saturation. Also, the lethal level of hydrogen cyanide (HCN) in humans is 3.5 micrograms per milliliter of blood; however, all but 5 of the 23 fatalities showed HCN levels below the lethal level. This indicates that fractionally effective doses of CO and HCN had the additive effect of a lethal dose on the victims.

The combination of below-lethal levels of blood toxins such as HCN and an oxygen-depleted environment can also be fatal. Blood agents affect body functions by acting on the enzyme, cytochrome oxidase, thus preventing the cells' normal oxygen utilization and causing rapid damage to body tissue. In other words, any blood agents present will prevent the use of an already limited supply of oxygen, thereby causing the victims to become partially incapacitated and hindering timely emergency task performance or egress.

**4.2.7 Verification of smoke and toxic fumes protection.**

a. The capability of the system to provide smoke and toxic fumes protection shall be determined by __________.

b. All additional performance criteria shall be verified by __________.

VERIFICATION RATIONALE (4.2.7)

To ensure that the protective device properly functions for all expected environments and that it will allow the crew member wearing the device to perform all necessary operations, verification of the use of this device by trained test subjects in the expected environments is necessary.

VERIFICATION GUIDANCE

a. To determine the altitude protection afforded by the protective device, subjective evaluation in the altitude chamber is suggested. The time period that the device provides complete protection may also be determined from this type of testing. Sections *3.2.4* and *4.2.4*, requirements for personal altitude protection, provide additional discussion on methods to verify the altitude protection capability of the protective device.

The best approach to check the protective device for smoke and toxic fumes protection is to test for any leakage that may penetrate the seals of the equipment while in actual use. Subjects which represent the full range of the full range of the population for which the equipment is designed should be used for the test. Past testing has been accomplished by inserting probes (i.e., small stainless steel needles 21 gauge by 25 mm long) through the respiratory and eye protection devices. The location of the probes should be selected to provide sampling from both the lowest and highest level of contaminant. A simulant should be selected that adequately represents the range of molecular weights of the toxic substances expected to be encountered. Past tests have been conducted using an exposure chamber of sufficient size to accommodate a subject and the equipment to be tested. A challenge atmosphere of Di-(2-Ethyhexyl1)-Sebacate (DEHI) is also used. *SAE AS 8031* contains additional information for conducting such tests. Other simulants such as Freon, dioctyl phthalate (DOP), and n-pentane are discussed in the paper by D. deSteiger, E.B. McFadden, *The Use of n-Pentane as a tracer Gas for the Quantitative Evaluation of Aircrew Protective Breathing Equipment*," SAFE Symposium Proceedings, 1976.

Temperature exposure effects on the properties of the material used for smoke and toxic fumes protection should be considered. Another important consideration is the effect on leakage when the crew member is wearing glasses. Subjective evaluation by actual persons in the intended operational environment should be extensively determined.

b. Malfunction indication may be determined by actually operating a prototype of the protective device and inspecting it to determine that its malfunction indication is suitable for use. Proper human factors guidelines should be followed to ensure that the indication is not misinterpreted.

Combined workload and contaminant leakage tests should be conducted on subjects representative of the intended population range. During these tests, contaminant levels should be measured. Also, other factors such as the possible fogging of the lens or viewing area should be evaluated.

VERIFICATION LESSONS LEARNED

The FAA has proposed that the optical density (a measure of smoke generation) of aircraft interior materials must not exceed 100 in 4 minutes for textiles, air ducting, thermal insulation, and insulation covering, and all other materials shall not exceed 100 within 90 seconds nor 200 within 4 minutes. However, *AFSC Design Handbook 1-7* presents only a general rating system from "light smoke," which is 80-100 percent transmission, to "dense smoke," which is less than 16 percent transmission. These ratings are also based on a 4 minute test. These standards may be used to determine the appropriate limits against which the crew member must be protected.

**3.2.8 Protective headgear.** The protective headgear shall provide the aircrew member with impact and penetration protection.

a. Impact protection. The total dynamic response of the headgear to an impact energy of ________ foot-pounds shall limit the acceleration imparted to the head to no more than _______ G's for ________ seconds.

b. Headgear penetration resistance. The headgear penetration resistance shall be ________.

REQUIREMENT RATIONALE (3.2.8)

The primary purpose of protective headgear is to provide protection for the aircrew member's head. Secondary considerations, which under field circumstances may also be of great importance, include use of the headgear for protection against thermal effects and hearing damage, use of the helmet as a communications platform and oxygen mask carrier, and even as a platform for part of a weapon system. Trade-offs may be necessary to accomplish multipurpose use and, therefore, such trade-offs should be dictated by field-usage experience.

Headgear must be able to provide some measure of protection against impact and penetration by sharp objects. Impact with the cockpit structures may occur during both normal and emergency procedures. Although the very sharp box corner surface is not prevalent in undamaged cockpits, accident analysis indicates that aircraft structure does sometimes break or bend into the cockpit area, causing jagged sharp sections of stiff metal which may present a very severe penetration surface.

REQUIREMENT GUIDANCE

*American National Standards Institute (ANSI) Z90.1* is currently used to establish the requirements for determining the extent of protection provided by aircrew headgear. Air Force exceptions to the standard include: one impact only at each of five sites—the crown, left, right, front, and aft section—and at ambient temperatures only. The impact protection requirements for current Air Force helmets are that the total dynamic response of the helmet assembly to an impact energy of 35 foot-pounds shall limit the acceleration imparted to the head to not more than 400 G, not more than 200 G for not more than 3 milliseconds, and not more than 150 G for not more than 6 milliseconds.

Because the threat of penetration by sharp objects is not well defined in any aircraft, the current requirements are extracted from *ANSI Z90.1* Current Air Force helmets must prevent penetrations by pointed objects greater than 0.25 inches.

REQUIREMENT LESSONS LEARNED

*ANSI Z90.1* states that a minimum impact energy of 50 foot-pounds shall limit the acceleration impacted to a test headform to the values stated in the standard. However, the Air Force has used requirements based on an impact energy of 35 foot-pounds. This reduced level of impact protection results, however, in a lighter and more stable headgear, both highly desirable characteristics in today's high performance aircraft.

A penetration of greater than 0.25 inches, when tested in accordance with *ANSI Z90.1*, is currently considered unacceptable by the Air Force.

**4.2.8 Verification of protective headgear.** The requirements of *3.2.8* shall be verified as follows:

a. Verification of impact protection. The requirements of *3.2.8 a* shall be verified by ____________.

b. Verification of penetration resistance. The requirements of *3.2.8 b* shall be verified by ____________.

VERIFICATION RATIONALE (4.2.8)

Verification must be accomplished to assure the flight safety of the headgear without significant aircrew performance degradation. *ANSI Z90.1* is currently the standard recognized by the Air Force regarding impact and penetration protection for headgear.

VERIFICATION GUIDANCE

*ANSI Z90.1* establishes techniques to determine the impact protection of the headgear. As noted, the Air Force has taken exceptions to this standard in regard to the specific impact energy requirements. The current test method, modeled after the test method in *ANSI Z90.1*, is as follows: The headgear assembly is properly fit to the test headform. The rigid anvil method, using the hemispherical impactor, is performed. The helmet is subjected to single impacts only at the front, back, crown, and each side location. The helmet/headform offset distance is measured at each impact site, and the weight of the drop system is obtained prior to the test. Based on the drop weight, the height of the drop is determined so that 35 foot-pounds impact energy is delivered. The following information is recorded for each test location on the headgear:

a. drop weight
b. helmet weight
c. helmet/headform offset distance
d. drop height
e. impact velocity
f. impact energy
g. acceleration time data
   (1) peak acceleration
   (2) total time of pulse at 200 G
   (3) total time of pulse at 150 G

*ANSI Z90.1* establishes techniques for determining the penetration protection capability of the headgear. A current test method modeled after the test method in *ANSI Z90.1* is as follows: The headgear system is fit on a rigid headform to assure firm support around the target area when properly positioned for tests. The headgear system is subjected to impacts by a 16-ounce steel bob, having a 60 degree included angle pointed tip with a radius not greater than 0.015 inch and a minimum Rockwell hardness of C-60. The bob is dropped (free fall) from a height of ten feet onto the outside surface of the headgear shell in a direction perpendicular to the surface. The points of impact are one in a facial goggle and aircraft mounted port hole window. The PLZT lens operates as an electro-optical shutter. Normally in a see-through or transparent state, the lens responds to the onset of a nuclear detonation by rapidly switching to an opaque state. In this way, the intense light energy is blocked from the aircrew member's view. Typical open state transmission of PLZT devices is approximately 19 percent. Closed state transmission is one hundredth of one percent, or an optical density (OD) of 4. (Optical density describes, in metric increments, the ability of the device to reject light of a given wavelength from passing through it. An OD of 1 means 10 percent of the light at the wavelength passes through the device; an OD of 2 means 1 percent passes through; and an OD of 3 means 0.1 percent passes through.) The time required for the lens to switch to an off state, following the onset of the nuclear detonation, is of critical importance for providing flashblindness protection. For PLZT devices, it is typical for an optical density of 3 to be achieved within a time period of 150 micro-seconds following the initial triggering of the device. The complete closed state optical density of 4 is achieved within a time period of 0.26 second. A more detailed description of the principle of operation of the PLZT devices is found in *Applied Optics*, volume 14, number 8, August 1975, "PLZT Electro-optic Shutters: Applications."

Although the PLZT technology presently offers the most promise for providing flashblindness protection, it also presents several limitations which must be considered. First, because the PLZT devices have an open state transmittance of approximately 19 percent, they are not optimum for use in nighttime operations. Using PLZT goggles at night is similar to wearing sunglasses at night. A second limitation concerns the viewing angle through the device. As the aircrew member viewing angle (with respect to the perpendicular to the lens surface) increases, the flashblindness protection provided as a light blocking device decreases. Geometry of the PLZT lens with respect to the aircrew member is therefore always an important consideration. In addition to these limitations, data collected pertaining to switching speed indicates that existing PLZT devices are less than optimum for providing flashblindness protection for certain nighttime conditions. PLZT performance is also severely affected by cold temperature. As the temperature of the PLZT lens decreases below 55 degrees Fahrenheit, switching speed of PLZT slows. To overcome or otherwise address these technology limitations, consideration must be given within the context of a system level design. A great deal of technical data concerning development of PLZT materials technology and associated devices is summarized in a series of progress reports titled: *PLZT Thermal/Flash Protective Progress Reports*, published by Sandia National Laboratories, Albuquerque, New Mexico.

REQUIREMENT LESSONS LEARNED

Early operational aircrew protective devices consisted of monocular eye patches for use at night and gold-coated fixed filters in goggle lens and helmet visor lens configurations for daytime use. Although these items possess many drawbacks, they have been utilized by Strategic Air Command and other nuclear strike forces since nothing better was available. Drawbacks of the eye patch are decrement of visual field, loss of binocular vision, and degraded depth perception. The major drawback of the fixed filter devices is their unsuitability for use at night and in other low light level conditions. Fixed filter devices employing a thin gold coating on an absorptive plastic substrate have been found to be susceptible to abrasion damage in operational use. An absorptive fixed-filter configuration has been developed to alleviate this problem. A number of eye protective device concepts have resulted from research and development efforts sponsored by the Army, Navy, and Air Force. These efforts involved directly activated photochemical filter devices, indirectly activated filter devices employing photochromic (reversible) materials, mechanical shutter techniques, and explosively deployed opaque media. Although several of these concepts progressed to the point of fabrication of hardware for operational test and evaluation by major air commands, none were considered completely acceptable for service use. Reasons for rejection by the operational commands included inadequate visual capabilities, aircraft weight and volume penalties, high aircraft modification cost, and expressed preference for protective equipment which does not encumber the crew member or present other problems during emergency situations.

each 60 degree sector at a radial distance of 4.5 ±0.5 inches from the apex and at the apex (total of seven impacts). After each impact, the test bob is reinserted into the depression with approximately a ten pound force, and the total depth of its penetration into the headgear is measured. Penetration in excess of 0.25 inch at any test point constitutes failure to pass the test.

VERIFICATION LESSONS LEARNED

In a recent USAF program which incorporated a module in the helmet liner, impact testing did not reveal a problem area in terms of impact energy. The main concern, however, was that the module protruded slightly beyond the helmet liner and it was thought that this protrusion could impact the head enough to cause bruises and/or concussion to the crew member. It was decided to keep the module within the envelope of the helmet liner even though the impact test was successfully passed. Future requirements should also consider the geometry of any installations within or on the helmet.

**3.2.9 Eye protection and enhancement devices.**

**3.2.9.1 Nuclear flash protection.** The nuclear flash protection subsystem shall provide flashblindness protection to the aircrew member against energy emitted from single and multiple detonations of nuclear weapons. The nuclear flash protection subsystem shall attenuate direct and off angle viewing of nuclear flash energy to prevent flashblindness for the duration of the nuclear weapons flash event. For purposes of this specification, flashblindness protection shall be defined as a loss of visual function not greater than ______ seconds for a ________ viewing condition. Visual function refers to the ability of the aircrew member to read critical flight instruments. The nuclear flash protection subsystem shall provide protection against nuclear weapons threats defined in __________.

REQUIREMENT RATIONALE (3.2.9.1)

The detonation of a nuclear weapon results in the emission of intense, blinding light energy. A temporary loss of vision termed "flashblindness" may occur as a result of viewing the blast. The visual effect of flashblindness is the appearance of an afterimage. In most circumstances, the afterimage is seen by the aircrew member as a dense dark spot corresponding in size and shape to the light source viewed. The effect is similar to the temporary blindness experienced when viewing a photographic flash. The duration of flashblindness may range in time from a period of a few seconds to many hours. The function of flashblindness protection, therefore, is to prevent the exposure of the aircrew member's eyes to the intense light emitted in a nuclear blast. Past studies have revealed that the flashblindness hazard occurs at greater distances from a nuclear blast than any other weapons effect. The book titled *Effects of Nuclear War*, by Samuel Glasstone, provides an overview of nuclear weapons effects.

REQUIREMENT GUIDANCE

The requirement for flashblindness protection should be specified using threat/hazard data for the intended aircraft. Other equipment requirements (e.g., electromagnetic pulse, transient radiation emission effects, and thermal pulse, etc.) should also be included in the specification to ensure proper equipment function. To specify flashblindness protection in terms of aircrew performance, it is necessary to first determine the maximum allowable flashblindness recovery time, or more specifically, the maximum time that can be tolerated for a loss of visual function. For the aircrew member, this refers to a time period for which visual tasks such as instrument and display reading, visual navigation, etc. cannot be performed. The requirement should be based upon mission scenarios and operational requirements. In addition, it is necessary to specify a daytime or nighttime viewing condition. The flashblindness hazard is much greater for a nighttime viewing condition due to increased pupil size of the eye. It is notable that available technologies for flashblindness protection are not always sufficient to meet operational requirements. For this reason, the flashblindness requirement may be "technology driven," that is, limited to what is achievable for a given technology.

"PLZT devices," using the lead (Pb), lanthanum (La), zirconate (Zi), titanate (Ti) materials technology, are considered to be state-of-the-art in nuclear flashblindness protection. The Air Force has fielded PLZT devices configured in the form of

**4.2.9 Verifying eye protection and enhancement devices.**

**4.2.9.1 Verification of nuclear flash protection.** The verification of flashblindness protection shall be performed by analysis and test of the subsystem performance characteristics and their relation to providing flashblindness protection.

VERIFICATION RATIONALE (4.2.9.1)

Verification of flashblindness protection is of sufficient complexity to merit a contractor proposed verification by analysis and test. The method of verification is dependent upon the protection concept and associated technology (i.e., electro-optic switch, fixed filter) used in the design.

VERIFICATION GUIDANCE

The contractor proposed verification should address the following general areas: nuclear weapons threat/hazard data, physiological data pertaining to flashblindness, and attenuation characteristics of the flashblindness protection device. Threat/hazard data should be realistic for the intended aircraft. Verification of the flashblindness protection function should be addressed in the context of actual use. Complex factors such as detonation yield, detonation altitude, viewing distance, atmospheric conditions, day/night condition, etc., should be addressed in the analysis. Other data pertaining to the human physiology of the eye and flashblindness thresholds should also be addressed in the analysis. Flashblindness recovery time should be based on data pertaining to instruments and displays for aircraft of intended use.

VERIFICATION LESSONS LEARNED

*SAM-TR-80-17*, on evaluation of PLZT goggles, provides a valid approach to the verification of the flashblindness protection function when the design consists of an electro-optic switch.

**3.2.9.2 Nuclear thermal protection.** The thermal protection subsystem shall provide protection against retinal burn resulting from energy emitted from single and multiple detonations of nuclear weapons. The thermal protection subsystem shall not transmit more than ______ calories per square centimeter total fluency when exposed to the nuclear weapons threats defined in __________.

REQUIREMENT RATIONALE (3.2.9.2)

The mission of many Air Force aircraft is to operate in a nuclear weapons environment. The detonation of single or multiple nuclear weapons results in the emission of very intense heat energy capable of causing permanent blindness in the form of retinal burn. Eye protection is therefore required to prevent loss of aircrew member visual function. It is notable that the thermal effects of a nuclear weapon occur at a range from the blast where the basic aircraft structure is expected to survive the blast effect.

REQUIREMENT GUIDANCE

Determination of a requirement for the thermal hardness level for protection of the aircrew member's eyes should be initiated by studying threat/hazard data relevant to operational use. The requirement for thermal protection provided by personal equipment may vary greatly depending on the overall thermal hardness requirement of the aircraft crew station. Aircraft designated specifically for a nuclear weapons mission typically have some form of thermal protection such as thermal curtains, aluminum shields, etc. integrated into the aircraft crew station. There are, however, instances where protection must be provided for an aircraft containing no thermal protection features. For this situation the aircrew member may also be vulnerable to skin burns and smoke inhalation, as well as debilitating eye effects. A discussion of heat stressing of traditional cockpit materials is provided in the report titled: *B-1B Crew Compartment Thermal Hardness Study*, performed by Rockwell International, contract NA-87-1476, August 1987.

REQUIREMENT LESSONS LEARNED

Early nuclear mission role aircraft depended heavily on flexible fabric materials for construction of thermal barriers over transparent areas, even for applications where flexibility was not a design constraint and more durable and maintainable rigid materials were available. One such substance was the early use of white cotton duck material. This material soiled easily and was difficult to maintain. Another substance was an aluminized fiberglass with silicone rubber backing. This material could withstand a high thermal flux level when new, but was not sufficiently resistant to every day wear and tear. Consequently, it was not practical for military applications. Design of aircraft thermal shields such as those developed for the B-1 aircraft included rigid aluminum panels with a port hole window style PLZT device integrated within them. This design concept could be improved by an expenditure of effort to decrease time required for installation and storage. The port hole window concept has also proven undesirable due to a limited field of view provided to the aircrew member.

State-of-the-art in nuclear thermal protection is the passive thermal protective system (PTPS). PTPS consists of flat panel window inserts that are installed on the inboard side of cockpit wing screens. PTPS functions by use of photochromic materials that block the transmission of infrared heat energy. Normally in transmissive state, PTPS responds to intense levels of thermal radiation by switching to an opaque state. The panel returns back to a transmissive state as the incident level of radiation returns to a safe level. PTPS requires no mechanical, electrical, or human interaction for operation. The advantage of PTPS is that thermal protection is provided to the entire crew station and that PTPS has a large field of view. The disadvantage of PTPS is that it does not provide flashblindness protection; a flashblindness goggle must be used in conjunction with the PTPS. As a consequence, the overall transmissivity of the combination of PLZT goggle, PTPS window panel, and windscreen is approximately 9 percent. This is less than optimum for nighttime use. Reference the product function specification for passive thermal protection, contract number *DNA001-C-0033*, September 1987.

**4.2.9.2 Verification of nuclear thermal protection.** The verification of protection against retinal burn shall be performed by analysis and measurement of subsystem performance characteristics and their relation to providing retinal burn protection to the eye.

VERIFICATION RATIONALE (4.2.9.2)

The method of verification of the nuclear thermal protection requirement is dependent on the technology used in the design. Compliance with the required optical characteristics must be performed by measurement and analysis.

VERIFICATION GUIDANCE

The verification of thermal protection should always involve discussion of the following: threat/hazard data describing heat emissions from nuclear weapons, heat attenuating performance parameters of the personal protective equipment and any other related aircraft system, and bioeffects data describing thresholds for damage to the eye.

In the past, the evaluation of thermal protection and the evaluation of equipment integrity have been performed by simulation. A solar test facility, such as that available at the White Sands Missile Range or Sandia National Laboratories is recommended for use in the verification of thermal protection. The challenge of the verification is to design a test that accurately emulates a nuclear thermal pulse.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.2.9.3 Laser eye protection.** The subsystem shall provide eye protection against threats/hazards including (vitreal hemorrhage, retinal burn, flashblindness, glare) resulting from exposure to laser radiation specified in the document __________.

REQUIREMENT RATIONALE (3.2.9.3)

The purpose of the requirement is to provide protection against threats and hazards associated with the use of military lasers. Current military lasers (i.e., target designators, range finders) as well as specially designed anti-personnel weapons have the potential to cause temporary or permanent impairment of aircrew member visual function. Adverse effects of exposure to laser light energy are varied. Those considered relevant to the aircrew member as a threat or hazard include vitreal hemorrhage, retinal burn, flashblindness, and glare. The closer the range or the higher the power of the device, the more hazardous the exposure. The most severe exposures can cause retinal hemorrhages. These hemorrhages will be associated with an immediate and permanent blind spot at the site of the exposure (size depending on intensity) as well as a gradual filling of the eye with blood which within minutes could totally block vision in the affected eye. At lower levels, retinal burns or lesions occur. These lesions will cause immediate and permanent blind spots and, depending on how close the burn or burns are to the central vision, they can have a dramatic effect on a person's ability to see targets and read instruments. At still lower levels of exposure, flashblindness and glare occur. These effects can be generated with very low laser powers (or energies). Flashblindness is a lingering effect after the exposure is over and has the same effect as looking at a flashbulb. The higher the laser power the larger the affected area and the longer the effect lasts. Glare is associated with continuous wave (CW) or high repetition lasers. This effect only lasts while the laser is on and recovery is generally immediate when the laser is gone. The exception to this is at night. If glare occurs at night, dark adaptation is lost, and it could take several minutes for the eye to readapt to the dark. Glare and flashblindness are associated with visible light exposures and do not occur with near infrared laser exposures. Vitreal hemorrhage and retinal burn may occur with visible or near IR exposures.

## REQUIREMENT GUIDANCE

Formulation of requirements for laser eye protection should begin with a complete characterization of the threat or hazard. Specification should include laser wavelength or wavelengths, beam divergence, beam diameter, and laser power/energy. In addition, other mission related information such as distance and angle of laser from aircrew personnel, atmospheric attenuation, windscreen attenuation, day/night operation, duration of exposure, or opportunity where an exposure can occur, etc., should be specified or considered in the formulation of the laser eye protection requirement. Actual requirements for protection against hemorrhage, retinal burn, flashblindness, or glare must be specified. As a minimum protection against lasers, retinal burn protection should be specified. If possible, protection down to the "glare" level should be provided. This level may require protection that is too dark to adequately perform the mission. Trade-offs between performance and protection must be made. The classified technical reports titled: *An Overview of Laser-Induced Eye Effects* (secret), and *Handbook of Laser Bioeffects Assessment*, (secret), provide useful information pertaining to laser bioeffects.

## REQUIREMENT LESSONS LEARNED

Lasers currently used for military applications within foreign military forces include the neodymium glass (1060 nanometer wavelength), the ruby laser (694.3 nanometer wavelength), and the neodymium YAG laser (1064 nanometer wavelength). Because it is possible to convert the 1060 and 1064 nanometer wavelengths to 530 and 532 nanometers wavelengths respectively, these are also considered potentially threatening wavelengths. Formulation of requirements for protection against specially developed anti-personnel lasers must be formulated from a study of the classified data.

All lasers presently used for military applications such as target designators, range finders, etc., emit light energy of discrete wavelength; however, advances in laser technology development are expected to result in future deployment of "frequency agile lasers." The frequency agile laser works by shifting the wavelength of light emitted as a function of time. Technologies to support the protection against frequency agile lasers are being worked on as conceptual and exploratory development efforts. There is, however, no equipment presently available for fielding against the agile laser threat.

**4.2.9.3 Verification of laser eye protection.** Verification of laser eye protection shall be performed by the measurement and analysis of subsystem performance characteristics and their relation to providing laser eye protection.

VERIFICATION RATIONALE (4.2.9.3)

Verification of a given design's ability to provide protection to the desired level should be accomplished by analysis of bioeffects data, threat/hazard data, and actual mission use, as well as performance characteristics of the device. Air Force adopted standards regarding lasers may be found in *AFOSH Standard 161-10*.

VERIFICATION GUIDANCE

Two important design parameters related to determination of the effectiveness of the laser eye protection device are optical density and luminous transmittance. (See *3.2.9.1* Requirement Guidance for a definition of optical density.) The parameter termed luminous transmittance is defined as the ratio of the apparent brightness of a white diffusing surface as seen through the device to that apparent brightness of that same surface as seen with the unprotected eye. Additional information pertaining to evaluations of laser eye protection is contained in the report titled: *Evaluation of Laser Eye Protection Eye Wear, SAM-TR-78-30.*

VERIFICATION LESSONS LEARNED

The development of technologies for aircrew discrete wavelength laser eye protection are described in the *Personnel Protection Program (PPP) Final Report, AFWAL-TR-86-4080*. The absorption dye technology is presently used for laser eye protection applications. Some considerations in the use of this technology are as follows: For any filter having absorption bands in the visible spectrum, increasing the OD of these absorption bands will decrease the luminous transmission of the filter. Conversely, the need for a high luminous transmission in the eye protectors for some laser system applications has necessitated a corresponding decrease in the OD at the laser wavelength in these devices. This need to balance luminous transmission against OD has become a major difficulty in the design of suitable eye protection, particularly for nighttime applications.

In addition, for any filter containing absorption bands in the visible spectrum, some color distortion will result. Severity of distortion is dependent upon factors such as location of absorption band(s) in the visible spectrum, band width(s), and number of absorption bands. Color distortion may adversely affect readability of cockpit displays and/or viewing outside the aircraft.

**3.2.9.4 Sun protection.** The subsystem shall provide eye protection against sunlight glare and ultraviolet components of sunlight and shall allow ______ percent transmission of visible light.

REQUIREMENT RATIONALE (3.2.9.4)

Flying personnel are exposed to extreme and varying brightness conditions, necessitating the use of filters or sunshades. Sunlight reflecting from water, clouds, or direct sunlight are sources of glare that may be extremely irritating. Prolonged exposure to brilliant light may cause watering of the eyes or even temporary blindness.

REQUIREMENT GUIDANCE

For maximum effectiveness, a sunshade should absorb enough visible light to eliminate glare without materially decreasing visual acuity. In addition, the sunshade should absorb all colors of light equally, so that the user does not perceive color shifting. Finally, the sunshade should block the transmission of ultraviolet and infrared energy.

REQUIREMENT LESSONS LEARNED

Although the desired sunlight attenuation of the sunshade is dependent upon a wide range of ambient lighting conditions, the most effective compromise seems to be a filter with an overall visible transmission of approximately 15 percent. Other optical requirements (i.e., haze, distortion, color, prismatic deviation, refractive power, etc.) that have been adopted as standards for existing aircrew helmet visors and spectacles are found in *MIL-V-43511* and *MIL-S-25948*, respectively.

Additional optical characteristics for goggles and helmet aircrew visor lens may be found in *MIL-L-38169* (cancelled document). The intent of the above specifications is to ensure that use of the sunshade does not result in significant degradation of visual performance.

**4.2.9.4 Verification of sun protection.** The verification of sun protection shall be performed by measurement, test, and demonstration of the subsystem performance characteristics and their effectiveness in providing sun protection.

VERIFICATION RATIONALE (4.2.9.4)

Verification of compliance with configuration and integration requirements is best determined by examination and demonstration. Compliance with required optical characteristics can be verified only by measurement.

VERIFICATION GUIDANCE

The tests used in the verification should ensure that no significant loss of aircrew member visual function results from use of the sunshade. In addition, the compatibility of the sunshade with other items of personal equipment must be considered.

VERIFICATION LESSONS LEARNED

Maintenance of high optical quality aircrew devices is of significant importance to preserve aircrew visual capabilities. Plastic visor lenses, in particular, have been criticized by user activities for deficiencies in optical property aspects such as distorted vision and observed point defects. Since service use of lenses can be expected to degrade optical quality, it is very important that manufacturing defects and optical imperfections in new items not be permitted.

**3.2.9.5 Night vision enhancement.** The subsystem shall provide enhanced nighttime vision under ambient lighting conditions ranging from natural starlight to moonlight. Using the subsystem, the aircrew member shall attain a visual acuity of _____ for targets of contrast for _______ ambient lighting conditions.

REQUIREMENT RATIONALE (3.2.9.5)

In daytime, human vision plays an important role in the aviator's ability to navigate an aircraft. By use of visual cues external to the aircraft, the pilot is able to determine the orientation of the aircraft in space. For the majority of nighttime illumination conditions, however, night vision enhancement capability is required to provide a visual navigation capability. Night vision enhancement devices such as night vision goggles (NVGs) are used by the Air Force as an aid to the aviator while flying in low altitude environments at night. A pilot uses NVGs in conjunction with aircraft navigation systems as an aid for terrain avoidance, terrain identification, landings, and take-offs.

REQUIREMENT GUIDANCE

To specify a night vision enhancement capability, it is necessary to first translate general "user" requirements provided by the operational commands into performance requirements. Requirements for a capability to view targets/terrain features such as bridges, airstrips, trees, mountains, water, rolling hills, etc., must be converted to a performance requirement describing a minimum resolving capability of the subsystem. Performance of a night vision enhancement device is dependent upon several factors: target size, viewing range, moonlight/starlight illumination, moon elevation, lunar phase, atmospheric conditions, and target/terrain contrasts. All must be considered in the specification.

The AN/AVS-6 Aviators Night Vision Imaging System (ANVIS) is an NVG currently being used by the Air Force. This electro-optic device weighs approximately 16 ounces and is mounted on the front of the pilot's flight helmet. A battery power supply is mounted on the back of the helmet. ANVIS functions as an image intensifier by amplification of red and near-infrared components of moonlight and starlight. Looking through the eyepieces, the user views a binocular image of the real world on green monochrome displays. The "look under" design feature of ANVIS allows the pilot to view cockpit instruments with the unaided eye and to obtain an intensified nighttime image of the world external to the aircraft without a mechanical adjustment of focus. The ANVIS which is sometimes referred to as the "Generation III" goggle was designed for use by Army helicopter pilots. More information on the ANVIS may be found in the *AN/AVS-6 Night Vision Goggles Study Guide*, June 87, 1005 SG.

Another night vision device currently used by the Air Force is the AN/PVS-5 NVG. The AN/PVS-5 or "Generation II" goggle was designed prior to the ANVIS and was intended for use by Army ground troops. Although the AN/PVS-5 goggle has the same basic principle of operation as ANVIS, it is not an optimum design for aircrew use. Problems include inadequate low light level performance, short battery life, and a cumbersome weight of approximately 30 ounces. In addition, the AN/PVS-5 does not allow simultaneous viewing of aircraft instruments and NVG display without a mechanical adjustment of focus. More information on the AN/PVS-5 and the human physiology of night vision, may be found in the document titled, *Night Vision Manual for the Flight Surgeon, USAFSAM-SR-85-3*, August 1985.

REQUIREMENT LESSONS LEARNED

There are several limitations associated with use of existing AN/PVS-5 and AN/AVS-6 model NVGs on-board Air Force aircraft. One such limitation is related to NVG weight. The mounting of the NVG on the aircrew member's head/helmet poses ejection hazards, crash safety hazards, and also contributes to aircrew member fatigue. NVGs are not certified as safe for use in aircraft equipped with ejection seats, and in general, NVGs are not suitable for use in high acceleration environments.

In addition, basic changes to the design of aircraft interior lighting are required to accommodate the use of night vision enhancement devices in the aircraft cockpit. Aircraft lighting traditionally consists of multicolor incandescent sources with spectral emissions in the infrared and visible wavelength region. Because night vision enhancement devices are extremely sensitive to the near-infrared and visible-red components of these lights, traditional aircraft lighting causes severe interference with the operation of night vision enhancement devices; therefore, all interior lighting must be redesigned. The white incandescent sources located throughout the cockpit must be replaced with "cold" blue-green lighting that contains very little or no red or infrared. Additional changes in warning, caution, and advisory lighting are also required. These changes restrict the use of color coding. Geometrical considerations also play an important role in the design of night vision compatible lighting. Location of light sources, with respect to the night vision device and the aircraft windscreen, must minimize interference with the night vision device. Reference *AFGS-87240* for requirements pertaining to NVG-compatible lighting. Also refer to "PAVE-LOW III: Interior Lighting Reconfiguration for Night Lighting and Night Vision Goggle Compatibility," *Aviation, Space and Environmental Medicine*, for information pertaining to NVG-compatible lighting.

As previously stated, ambient lighting conditions play an important role in the effectiveness of NVGs. Conditions of reduced ambient illumination due to clouds, haze, or smoke diminish their performance. NVGs operate best when used in a condition of clear sky with moonlight; there are additional limitations when the moon is at low elevation or low on the horizon. When the moon is directly in the NVG field of view, the image formed is "washed out" due to its extreme brightness relative to ground terrain features. Also, long shadows created behind objects such as mountains, hills, and trees result in diminished viewing performance.

**4.2.9.5 Verification of night vision enhancement.** The verification of night vision enhancement capability shall be performed by measurement, test, and demonstration of the subsystem performance characteristics and their relation to providing a night vision enhancement capability.

VERIFICATION RATIONALE (4.2.9.5)

Verification of a given design's ability to provide the required night vision enhancement should in part be performed by a simulation of actual usage conditions. It is expected that measurement, test, and demonstration are all necessary for the verification process.

VERIFICATION GUIDANCE

Design of a night vision enhancement device should contain provisions for compatibility with standard military night vision goggle lighting. Compatibility should be verified using actual aircraft or crew station mock-up, with lighting levels adjusted for adequate instrument readability. Reference the report "Instrument Lighting Levels and AN/AVS-6 Usage" for information pertaining to instrument lighting levels. The AN/AVS-6 goggle contains a "minus blue" rejection filter that functions by blocking NVG cockpit lighting from entering the NVG lens.

Quantifiable parameters, such as ambient illumination, target contrasts, target size, etc., should all be addressed within the verification. Certification of equipment and techniques used for lighting measurements are of critical importance to verification. It is notable that physical measurement of low light level conditions such as starlight/moonlight illumination are difficult. Sensitivity of available "off-the-shelf" equipment may not be sufficient for required accuracy of measurements.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.2.10 Hearing protection and communication devices.**

**3.2.10.1 Hazardous noise attenuation.** The subsystem shall function to provide hearing protection to the aircrew member against hazardous acoustic noise of the crew station environments for the aircraft and _______ mission profiles specified. Cumulative hazardous noise, when measured at the aircrew member's ear, shall not exceed 1.0 when calculated as follows:

$$\sum_{\substack{\text{Mission}\\\text{Segments}}} \frac{D_i}{P_i} = \sum_{\substack{\text{Mission}\\\text{Segments}}} \left[ \frac{D_i}{\text{antilog}\left[\dfrac{\overline{dB(A)}_i - 102.76}{-13.12}\right]} \right] - 1.0$$

Where: i – segment of given mission.
$D_i$ – duration of mission segment.
$P_i$ – permissible duration of noise exposure to segment.
$\overline{dB(A)}_i$ – maximum overall A scale sound pressure at the crew member ear for segment.

REQUIREMENT RATIONALE (3.2.10.1)

Acoustic noise environments on-board many military aircraft are such that hearing protection is required for the aircrew member. The purpose of this requirement is to provide protection to the aircrew member against hazardous acoustic noise environments of individual aircraft crew stations. The equipment mounted on the person should function to reduce noise at the aircrew member's ear for noise exposure caused by aircraft engines, airflow, air friction, airborne equipment, ground support equipment, and other sources of mission related steady-state noise.

REQUIREMENT GUIDANCE

The requirement is stated to reduce ambient noise levels sufficiently to prevent permanent hearing damage to the aircrew member. Formulation of this requirement is based on *AFR-161-35.* It is known that the potential for hearing damage due to hazardous noise is dependent upon both intensity and duration. For this reason, the total daily exposure must be determined. To use the requirement the aircraft and mission profile information must be provided. In addition, acoustic noise data related to the mission profile must be obtained. Hazardous noise that may be encountered during a typical aircraft mission is dependent upon the type of aircraft for which the noise reduction function is intended. In addition, hazardous noise levels are dependent upon the particular crew station (i.e., pilot, copilot, weapons operator, loadmaster, etc.) and the mission phase (i.e., taxi, takeoff, cruise, landing, etc.). Other human engineering requirements, such as speech intelligibility and comfort also play an important role in the specification of hazardous noise attenuation.

REQUIREMENT LESSONS LEARNED

A variety of ear protectors are currently used in the military services. These include ear plugs, ear muffs, communication head sets, and helmets. Refer to *AFR 161-35* on hazardous noise exposure, and *AFP 160-5* on physiological training for descriptions of ear protectors and their characteristic noise attenuations.

**4.2.10 Verifying hearing protection and communication devices.**

**4.2.10.1 Verification of hazardous noise attenuation.** Verification of the hazardous noise attenuation requirement shall be by analysis and measurement of subsystem performance characteristics and their relation to providing hazardous noise attenuation.

VERIFICATION RATIONALE (4.2.10.1)

To determine compliance with the requirement, it is necessary to use acoustic noise data describing noise levels on-board aircraft(s). In addition, it is necessary to utilize mission profile information to determine exposure duration to a given noise level for a given mission phase.

VERIFICATION GUIDANCE

*AFAMRL-TR-75-50*, volumes 1-172, on bioenvironmental noise data provides detailed information pertaining to acoustic noise environments measured on-board various military aircraft. This data or comparable data provided by the aircraft developer/manufacturer should be used to verify conformance to the design requirements for aircrew hearing protection. By analysis of aircraft acoustic noise data, the attenuation required for protection against hazardous noise is verified. Measurement of noise attenuation for a given design should be performed by use of *ANSI S12.6* or comparable method.

VERIFICATION LESSONS LEARNED

Active noise reduction is a technology using electronic means to reduce ambient noise levels at the aircrew member's ears. Active noise reduction works by electronic cancellation of noise within the aircrew member earcup. The ambient noise is sampled by a microphone in the earcup, phase shifted, and then reproduced by a speaker in the earcup. Active noise reduction when used in conjunction with traditional passive attenuation methods produces higher noise attenuation than achievable by the use of passive means alone. Although this technology offers great promise to provide the future personal equipment noise attenuation function, ongoing full scale development efforts must address comfort, reliability, and spurious noise problem areas as identified in report titled: *Flight Test Evaluation of Active Noise Reduction*, *AFFTC-TR-88-15*, June 88.

**3.2.10.2 Speech intelligibility.** Use of the subsystem shall enable sufficient intelligibility of speech communication to permit successful mission completion in the environment of aircraft noise.

REQUIREMENT RATIONALE (3.2.10.2)

Voice communication is an essential function performed by the aircrew member for virtually all mission tasks. Equipment related to, or potentially affecting hearing and voice communication, such as headsets, chemical defense ensembles, noise protectors, oxygen masks, microphones, etc., must be designed to permit clear and audible voice communication. It is therefore necessary to specify a requirement for speech intelligibility when using voice related equipment.

REQUIREMENT GUIDANCE

Speech intelligibility is dependent upon many factors. These include the electrical/acoustical characteristics of microphones, speakers, and intercommunication systems, as well as ambient noise level, and actual word content of communications. In addition, speech intelligibility becomes an important requirement in situations involving the use of a gas mask. Masks alter the acoustics of communication by introducing distortion and attenuation to speech. Applicable factors must be addressed in the formulation of a requirement. More requirement guidance may be found in the *Human Engineering Guide to Equipment Design*.

REQUIREMENT LESSONS LEARNED

No lessons learned available.

**4.2.10.2 Verification of speech intelligibility.** Verification of speech intelligibility when using the ________ subsystem shall be performed by analysis and test. Using the ___________ test, the subjects shall score a minimum of ______ percent in a noise environment.

VERIFICATION RATIONALE (4.2.10.2)

Verification of speech intelligibility requires the use of trained human test subjects to quantify speech intelligibility. The verification is a measure of human performance when using the related personal equipment.

VERIFICATION GUIDANCE

Three standard methods are available for verification of speech intelligibility. The appropriate method is dependent upon the specific data needed. When a high degree of test sensitivity and accuracy is required, the phonetically balanced (PB) monosyllabic word intelligibility test, using the *ANSI S3.2-1960* test method, is recommended. If the test requirements are not stringent or if time and training do not permit use of this method, the modified rhyme test (MRT) should be used (see *Human Engineering Guide to Equipment Design* for method). A third test referred to as the articulation index test should be used for estimations, comparisons, and predictions of system intelligibility. It uses *ANSI S3.5-1969*.

The verification should be performed under conditions that are representative of actual use. Intercommunication systems that are considered typical for the majority of Air Force aircraft are the AIC-18 and the AIC-25. One of these is recommended for test purposes. Unless the ambient noise contains special characteristics, a 105 dB steady state noise is recommended for test purposes.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.3 Personal protective subsystem integrity.** The personal protective equipment subsystem integrity shall be established as ______________.

REQUIREMENT RATIONALE (3.3)

The effectiveness of any military force depends on the operational readiness of its weapon systems. Major factors which affect the readiness of the aircraft are the reliability, maintainability and availability of its various subsystems. The personal protective equipment subsystem is an essential life support subsystem. As such, the R & M factors are important to the integrity of this equipment. To improve the R & M, increase readiness and minimize life cycle costs, the capabilities, conditions and operational limitations of this equipment must be established. Potential problems must be identified early in the life cycle to minimize their impact on the operational force. A preventive maintenance program provides for the orderly scheduling of inspections and replacement or repair of life limited components of the personal protective equipment subsystem. On the other hand, for a small development effort this may be considered excessive relative to the cost of the program. Development cost for an integrity program may be high, but life cycle cost studies have confirmed the advantages over a period of ten years or more. Trade-offs need to be considered. Demonstrations and tests as discussed in *4.3* must also be established to verify integrity.

REQUIREMENT GUIDANCE

The contractor must compile information required to design, develop, and verify specific personal protective equipment subsystems and components based on the intended use and application. Initially, however, the government engineer must establish the design requirements and associated verification in the model contract in the request for proposals. A personal protective equipment subsystem integrity plan may be proposed as part of contractor design requirements. It is anticipated that the contractor will establish refined integrity requirements for each subsystem and establish an integrity program. Integrity requirements and milestones should be derived from past experience and lessons learned integrated into a well-planned program. An integrity program should include or consider service life, usage, functional performance, environments, loads, durability, damage tolerance, strength, vibration/dynamic response, thermal-induced fatigue, flight and ground-load-induced fatigue, reliability, maintenance, and integrity scheduling and management. Also, consideration must be given to proper interfacing with the airframe, the crew and passenger escape system, the crew stations, avionics, propulsion and environmental control subsystems as applicable. The contractor must translate integrity into design criteria to be used for material selection, performance criteria, component packaging and the overall design and qualification of the equipment (aircraft mounted and personnell mounted).

Design criteria must also include producibility in the sense of fully preserving the design integrity and reliability of the personal protective subsystem. No manufacturing process, pre-fabrication or assembly procedure, part selection criteria or acceptance process, or any other factory operation due in part or in whole to equipment or human error should degrade the "designed in" integrity of the product.

The objective is to ensure that criteria which reflects the planned usage of the personal protective equipment subsystem are applied to the design so that specific functional performance, manufacturing, operational and maintenance/support requirements will be met. The task of developing criteria must begin in the earliest stages of the program, such as concept exploration phase (if applicable), and finalized in the early part of full-scale development (FSD). Requirements for a failure free operating period (FFOP) must be established relative to the design service life. Under ideal situations, they would be equal. Early criteria of a general arbitrary nature may be required in some cases, particularly when it is difficult or too early in the development phase to understand and predict specific requirements. Milestones must be established by the contractor and reviewed and approved by the Air Force for an integrity program that is consistent with the Systems Engineering Master Schedule (SEMS). All final selected design criteria shall be reviewed at predetermined events on the schedule and shall be subject to Air Force approval. It is essential that Air Force engineering be involved in the review process of the establishment of integrity design criteria. Consideration should be given to having the contractor prepare a design criteria report for each milestone which is updated as the program progresses and also a final report at the critical design review or later validation control events.

Air Force engineering may identify the desired FFOP, the service life and the expected usage of the personal protective equipment for individual subsystems and components. The contractor may chose to use this data in his integrity program

Trade Studies – A realistic service life of many components must be achieved through a designed–in–FFOP followed by a scheduled preventive maintenance program, if applicable. In the beginning phases of a personal protective subsystem program, the contractor shall conduct trade studies to determine FFOP for individual components and evaluate the impact of alternate maintenance operating periods on cost, weight, performance, and logistics. The results of the trade studies must be used to define preferred design service lives for specific components as well as to define the required in–service maintenance to achieve schedule milestones and integrity requirements agreed upon between the Air Force and the contractor.

Integrity concepts for the preferred design service life of each component should preferably be required as early as possible in the development program so this may be incorporated into subcontractor and vendor specifications. Establishing designed–in periodic scheduled preventive maintenance at intervals less than the specified subsystem service life must be evaluated against the Air Force logistics organization's capability to support this concept. Trade–offs should be accomplished since support equipment may need development and/or the cost, manpower and training requirements may prove to be excessive. In any case, the Air Force's capability to support the planned preventive maintenance concept must be realistic and feasible.

Those trade study results agreed upon between the Air Force and the contractor must be reflected in the final design criteria and the overall integrity Master Plan. Air Force guidance is available in *MIL-STD-1798*, *AFGS-87249*, and *MIL-A-87244*.

Critical Parts Analysis and Classification - The personal protective equipment subsystem is a critical piece of equipment; the crew member and passengers (as applicable) require protection and physiological support under normal and emergency flight situations. As such, the contractor must identify and classify essential equipment required as safety-of-flight, mission essential, etc. This classification should be accomplished by conducting a failure modes, effects, and criticality analysis for the personal protective equipment subsystem design. As a part of this evaluation, the contractor shall consider the effects of a failure of other aircraft subsystems that interface with or have impact to the personal protective subsystem. This should also include a crash safety analysis. The contractor must also evaluate the effect of software/firmware in other subsystems that interface with the personal protective subsystem such as built-in-test. The objective of this assessment is to identify potential hazards to the personal protective subsystems and interfacing subsystems such that risks to the on-board personnel are minimized. The critical parts evaluation must be updated periodically throughout the program by the contractor to account for changes from design and software/firmware validation.

REQUIREMENT LESSONS LEARNED

Background on critical parts and R & M of the equipment is not always easy to obtain. In many cases, this information may be obtained from the detailed military specifications of existing personal protective equipment which is similar to proposed new designs.

Reliability performance criteria was determined in Aircrew Integrated System (AIS) personal protective equipment program and this is given in *table VII*.

**4.3 Personal protective subsystem integrity verification.** The verification of the integrity of the personal protective equipment subsystem shall consist of _____________.

VERIFICATION RATIONALE (4.3)

Verification of the personal protective subsystem integrity is essential in providing a reliable and dependable operational capability under all operational and environmental envelopes.

VERIFICATION GUIDANCE

The development and establishment of an integrity program must be verified by inspection, analyses, demonstrations and tests and approved by the appropriate Air Force personnel. Certain tasks which should be established include design criteria, design service life and usage, trade studies, critical parts and classification, material and process selection and characterization, durability and damage tolerance control plans, corrosion prevention and control, load analyses, design stress and environmental specter development, performance and functional sizing analyses, thermal and environmental analyses, stress and strength analyses, durability analyses, damage tolerance analyses, vibration and dynamics and acoustics analyses, materials characterization tests, functional qualification tests, strength tests, durability tests, vibration dynamics, acoustics tests, damage tolerance tests, maintainability and repairability demonstrations, quality assurance during production, and any other verification deemed necessary to validate the integrity of the oxygen subsystem. See the appropriate integrity Mil-Prime specification for further guidance. (See section 3.3 herein).

VERIFICATION LESSONS LEARNED

Past experience has shown that R & M values determined by testing are nearly always much less than calculated values determined analytically during design. Many theories and articles have been written about this subject and its resolution is still pending. Therefore, it is almost always desirable to validate R & M values for personal protective equipment by laboratory and flight testing.

TABLE VII. Reliability performance criteria.

| | Aircraft Mounted | | | Crew Member Mounted | | |
|---|---|---|---|---|---|---|
| | Reliability * (percent) | Shelf Life (years) | Service Life (years) | Reliability * (percent) | Shelf Life (years) | Service Life (years) |
| Safety of Flight/ Survival | 0.999 | 5 | 15 | 0.999 | 5 | 5 |
| Mission Performance | 0.99 | 5 | 15 | 0.99 | 5 | 5 |
| Other Support | 0.98 | 5 | 15 | 0.98 | 5 | 5 |

* Assumes a 90 percent confidence level.

Maintainability requirements that were established in the Aircrew Integrated System (AIS) personal protective equipment program were:

| Requirement | Organizational Level | Depot Level |
|---|---|---|
| Reconfiguration Time 1/ | 0.167 | N/A |
| Mean Time To Repair (MTTR) 2/ | 0.25 | 1.75 |
| Maximum Corrective Maintenance Time 3/ (MCTMAX) (95% of all failure caused) | 0.40 | 3.00 |

1/ Reconfiguration Time – Time to alter the configuration of the system or subsystem to provide additional capabilities or to eliminate unneeded capabilities.

2/ MTTR – A basic measure of maintainability. The sum of corrective maintenance times at any specific level of repair that is divided by the total number of failures within a subsystem repaired at that level.

3/ MCTMAX – The time within which 95 percent of all the corrective maintenance actions are required to be accomplished at the various levels of maintenance.

**3.4 Logistics support and maintainability.** Logistics supportability has been established on current personal protective equipment. The goal shall be to establish logistics supportability requirements that are consistent with existing methods in use in the USAF. Areas of concern for logistics support are as follows:

a. ________ Maintenance repair levels.
b. ________ Support and test equipment.
c. ________ Support facilities.
d. ________ Packaging and shipment methods.

Areas of concern for maintainability are as follows:

e. ________ Maintenance tasks.
f. ________ Interchangeability and standardization.
g. ________ Repairability and calibration requirements.
h. ________ Fault detection and isolation.
i. ________ Built-in-test.
j. ________ Operational support equipment requirements.
k. ________ Personnel skill levels.
l. ________ Maintenance tools.

REQUIREMENT RATIONALE (3.4)

USAF life support shops have been established world-wide. Personal protective equipment is stored, maintained, and replaced as necessary to support the operational unit for which the shops are established. Logistics supportability and maintainability requirements need to be established to ensure that the new equipment will be integrated effectively into the existing methods of maintenance and support.

REQUIREMENT GUIDANCE

Logistics supportability

a. Maintenance repair levels - The three primary supportability areas of concern are organizational (O-level), intermediate (I-level) and depot (depot level). O-level refers to those tasks that are accomplished on the aircraft or at the flight line. An example might be the performance checks on an oxygen regulator or the inspection of an oxygen mask for flaws. I-level primarily refers to a flight line support facility such as a life support shop which is usually manned by military personnel. An example of a task performed at this level would be the replacement of a breathing valve in an oxygen mask and the check and replacement, if necessary, of a battery or connector. Depot level refers to a military or contractor facility that does repair and overhaul on items which require special facilities, tools and instrumentation. An example might be the overhauling of a more complicated mechanical device such as an oxygen regulator.

In the Aircrew Integrated System (AIS) program in 1987, a mean time to repair (MTTR) of 0.25 hours was established for the O-level and 1.75 hours was established for the depot level. A maximum corrective maintenance time (MCTMAX) for 95 percent of all failure causes was established as 0.40 hours for the O-level and 3.00 hours for the depot level.

b. Support and test equipment - Test equipment is required to ensure that items of personal protective equipment will properly function prior to any flight. Some flight critical items, such as the G valve, should incorporate a means of built-in-test. For example, simply pushing a button on top of the G valve allows the crew member to check for valve operation and proper inflation of the G garment bladders. It is highly desirable that test ports and built-in connections be provided to simplify testability and avoid disassembly of the component.

c. Support facilities - Special support facilities other than those already established for current personal protective equipment should not be required. In the case of a high altitude pressure suit, a piece of specialized protective equipment, unique support facilities may be required for donning, doffing and functionally checking out the suit for preflight.

d. Packaging and shipment methods - Existing methods of packaging and handling of personal protective equipment should be used to the maximum extent possible. Should the method of packaging and shipment be in question, refer to the documentation (such as a specification) currently in effect for the type of equipment under consideration. Oxygen delivery equipment is packaged with special precautions to preclude contamination. Crew member equipment such as masks and hoses is usually cleaned by the life support shop on receipt of shipment. See appendix section *50* for further information on packaging.

Maintainability

e. Maintenance tasks - Maintenance tasks include the time required to detect the fault, isolate the fault, gain access, remove, replace, checkout, inspect and return the component to flight worthy status. Often it may be desirable to request task analysis to ensure a detailed evaluation of maintenance workload requirements is properly conducted.

f. Interchangeability and standardization - Often when personal protective equipment is developed, it will be used in more than one aircraft application. To properly interface with each aircraft type, some different components may be required. For that equipment which is mounted on the crew member, there should be commonality of components. Except where different sizes of garments are required to accommodate various dimensions and weights of crew members, equipment commonality and interchangeability should be incorporated.

Some items of equipment may be standardized so that they are the same on all or several aircraft applications. An example might be a breathing valve in the mask or the G valve installed on the console. This standardization is desirable because it reduces the number of parts in the Federal system, simplifies item management by the logistics agency, and should reduce supportability costs. Standardization should not, however, compromise or reduce desired performance for a critical piece of life support equipment.

g. Repairability and calibration requirements - Consideration must be given to configurations which allow ease of replacement, repair and calibration. For example, a set screw or the like may be accessible by a screwdriver from the outside of a component without the need to disassemble the item to recalibrate it. This especially applies to components requiring calibration frequently at the O-Level and I-Level.

h. Fault detection and isolation - An indication must be provided to the crew member of the failure of a part of the system or an inappropriate mode of operation that exists. For example, if the breathing regulator is turned off, the crew member should sense a resistance to breathing or if a hose is disconnected or has a leak, the crew member will not see his or her flow blinker operate or a garment would not inflate properly. Often a failure effects and modes analysis as described by *MIL-STD-1629* will identify if a discrepancy exists in the personal protective equipment that could allow a serious concern for life support or physiological support. Assemblies and subassemblies should contain adequate test points for trouble shooting and checks. Refer to *MIL-STD-415* for further guidance.

i. Built-in-test - The use of built-in-test capability should be considered. This could take the repair to the removable component level. Also, consider that for any built-in-test functions provided, this should not cause a failure of the equipment with which it is associated. This capability should not require power external to the aircraft and should be resettable for retest.

j. Operational support equipment requirements - Any support equipment or technical orders required for the proper use of the personal protective equipment should be developed concurrently with it so that its use and employment may be properly supported in flight test operations and eventual deployment. It is highly desirable to survey the existing operations to ensure that a piece of field test or support equipment already in use may or may not be used. This could considerably reduce costs, minimize support equipment requirements in the field, and reduce the need for training a person on new support equipment.

k. Personal skill levels - It is desirable that current methods of personnel support for maintenance be used. Those shops which must support personal protective equipment can be life support, egress systems, parachute, environmental systems, and/or communications. Currently, the skill of the ninth grade level by skill level 5 airmen is in practice throughout the USAF.

l. Maintenance tools - The maintenance of the personal protective equipment should require no special fixtures for repair or replacement. In addition, special tools that are not currently in use in the USAF shops should not be required. This is not always possible, however; for example, the current MBU-12/P oxygen mask requires a special wrench to install the breathing valve into the mask.

Should the integrity process be used to develop mechanical equipment for logistics supportability and maintenance, refer to *MIL-STD-1791* to determine how to tailor requirements for the personal protective equipment program under consideration. This tailored information should be added to the Statement of Work, the specification, and other sections as necessary to define the desired system.

REQUIREMENT LESSONS LEARNED

No lessons learned available.

**4.4 Verification of logistics support and maintainability.** Inspections, analyses, demonstrations, and tests shall be accomplished as necessary to determine that all logistics support and maintainability requirements have been met. As a minimum the following shall be accomplished __________.

VERIFICATION RATIONALE (4.4)

There really is no satisfactory way to determine whether the supportability and maintainability requirements have been met satisfactorily other than proving the concepts. While analyses are important tools to determine the most effective methods of support and maintenance, demonstrations and tests are essential in determining more specific problem areas.

Consider also that support and maintenance equipment must be qualified to environmental extremes and pass functional testing just as aircraft and personal equipment must.

VERIFICATION GUIDANCE

Durability life verifications should be conducted with at least one personal protective ensemble for each planned mission scenario as defined by the equipment requirements to demonstrate the qualitative and quantitative requirements. This should include at least chemical, electrical, temperature, mechanical (including vibration, shock, storage, wear and maintenance effects), transportation and stresses with durations and magnitudes determined by the operational installation and use. The maintenance concepts developed for use with the equipment, the draft technical orders written to support the equipment and the support equipment developed for the equipment should be utilized. The durability life verifications should evaluate the performance of the equipment for two (2) life times of the environmental and operational stresses.

Maintainability and/or built-in-test verifications should be conducted to demonstrate the qualitative and quantitative requirements of the specification. The maintenance concepts, the draft technical order(s), and the support equipment developed for the personal equipment should be used throughout this evaluation. The verifications should demonstrate compliance with the requirements for reconfiguration time, maintenance personnel, tools, storage, scheduled maintenance, mean time to repair (MTTR), maximum corrective maintenance time, parts interchangeability, fault detection/isolation, calibration, built-in-test, maintainability and compatibility requirements.

Demonstration tests should be conducted close to or in an airfield environment using the level of trained technicians expected to maintain the equipment. Common standards usually referenced in the contract are *MIL-STD-470, Maintainability Program Requirements* and *MIL-STD-471, Maintainability Verification, Demonstration and Evaluation*. The first standard provides requirements for establishing a maintainability program and guidelines for the preparation of a maintainability program plan. The second standard provides procedures and test methods for verification, demonstration, and evaluation of qualitative and quantitative maintainability requirements. The project engineer should consult the maintainability engineer or manager when establishing test requirements.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.5 Human engineering, anthropometric sizing, and utilization.** The following human engineering design considerations shall be addressed, as applicable, and shall be in accordance with *MIL-STD-1800*.

a. Population, fitting and sizes: All personal protective equipment shall be designed and sized to fit Air Force populations of officer and enlisted aircrew members associated with each weapons platform. The subpopulations shall include the representative Air Force aircrew race, sex, and age subpopulations as applicable to the aircraft. Personal protective equipment shall be designed and sized to accommodate the range of body size and proportions for the central ______ percent or more of the persons in the populations specified above using multivariate accommodation of all relevant variables simultaneously. A minimum number of sizes for each type of personal equipment shall be used. Individual parts and components shall be of a single size wherever possible. The personal protective equipment shall provide maximum adjustability for individual user's personal comfort. The definitions and data contained in the on-line anthropometric data base at the Center for Anthropometric Research Data shall be applied (see operating manual, *AAMRL-TR-88-012*). Personal equipment must be compatible with eye glasses. The _________ critical body dimension(s) shall be specified and utilized for system sizing and design.

b. Field issuing procedures: The personal protective equipment shall include a set of field issuing procedures for assigning the size which best fits each user. The procedures shall emphasize a relatively simple fitting process that minimizes human error and maximizes proper user fit.

c. Comfort: The personal protective equipment shall be comfortable to wear for the required period, without inducing hot spots, irritation, scratching, pinching, itching, chafing, bruising, digging into the skin or objectionable pressure or forces. The personal protective equipment shall have no objectionable odors from the materials, and shall not retain body odors. Portions of the personal protective equipment in contact with the user's skin shall not be tacky to the touch and shall permit the removal of perspiration. Discomfort due to heat stress, psychological stress or aircrew member workload shall not be attributable to the personal protective equipment.

d. Waste elimination: An aircrew member, while wearing the personal protective equipment, shall be capable of using standard rest room facilities or shall have waste elimination capability integrated within the personal protective equipment.

e. Valsalva: The personal protective equipment shall not interfere with the performance of the Valsalva maneuver by the aircrew member.

f. Drinking/eating: The personal protective equipment shall permit the aircrew member to drink/eat while wearing the equipment if drinking/eating is permitted during the mission in which the equipment will be worn/used.

g. Ingress/egress: The personal protective equipment shall not interfere with the normal ingress/egress procedures imposed on the aircrew members.

h. Don/doff: The personal protective equipment shall be capable of being donned in _________ (time) and doffed _________ (time), as applicable to the aircraft mission. Donning and doffing shall be ______ (with or without) assistance as defined by operational requirements.

i. Transition: The personal protective equipment shall be capable of being transitioned from the ground mode to the aircraft operational mode in __________ (time). (If applicable) the personal protective equipment must also provide the capability to transition back from the aircraft mode to ground mode without interrupting protection in _________ (time).

j. Launderability: The personal protective equipment shall be capable of being cleaned without performance degradation. Garments shall withstand ____ washing cycles in a commercial washing machine. Other equipment shall be cleaned using the methods recommended with the equipment.

k. Other: __________

REQUIREMENT RATIONALE (3.5)

a. Incorporation of the appropriate population for the personal protective equipment application is necessary to ensure that the maximum number of users is accommodated.

b. Field issuing procedures are necessary to ensure that the correct size is assigned to each of the users to afford maximum protection. Incorrect fitting will be detrimental to performance, may result in misuse of equipment, and may jeopardize protection.

c. Maximization of user comfort may result in less fatigue than if wearing an uncomfortable system. Since flying multiple missions per day is a very real requirement of the operational environment, cumulative stress may affect performance. A comfortable system may alleviate some of this stress, and will probably be worn more frequently without objection. Dexterity and tactile sensitivity are necessary to avoid errors in using controls and switches.

d. Waste elimination is a necessary capability in all environments to ensure safety and the ability to perform lengthy missions. If this requirement is not met, mission duration will be severely limited.

e. Valsalva is required to ensure user comfort and safety during the aircraft mission.

f. Drinking and eating considerations are necessary so as not to restrict mission duration or user safety and comfort.

g. Unhindered ingress and egress are essential to mission performance and aircrew safety.

h. Donning and doffing requirements ensure wearability of the personal protective equipment without compromising protection. Additionally, ease of use, quick utility, fatigue, and autonomy are all areas of concern when providing donning and doffing capability.

i. Transition requirements ensure aircrew readiness and minimize mission start delays.

j. Launderability requirements are essential to ensure that the maximum life of the equipment is attained without specialized cleaning equipment or elaborate procedures.

k. Any other human engineering issues associated with the personal protective equipment must be addressed to ensure adequate protection for the aircrew members.

REQUIREMENT GUIDANCE

The sections of *MIL-STD-1800* which are associated with these human engineering requirements, as well as human engineering reference materials *AFSC DH 2-2* and *AFSC DH 1-3*, may be used for guidance in fulfilling the above requirements.

a. Since fitting 100 percent of the USAF aircrew population is not considered possible because of the wide range of body sizes, a more realistic and achievable requirement is the central 95 percent of each subpopulation. For critical equipment, such as chemical defense equipment, G-protection equipment, etc., the central 98 percent of each subpopulation should be accommodated. Specific critical body dimensions, such as height, weight, sitting height, reach, etc., as applicable to the personal protective equipment configuration and use, must be considered. It has been estimated that at least 25 percent of the USAF pilots and at least 50 percent of the navigators wear eye glasses and therefore personal equipment designs must accommodate eyeglasses. The critical body dimensions shall be identified and effectively accommodated in the human factors program. These body dimensions are associated with the item of personal equipment under consideration. For example, head sizes would be critical for helmet design and the lower torso and waist for G-suit design.

b. Field issuing procedures should be simple, should minimize human error, and should ensure proper user fit. The procedures should be established and updated throughout the design and use of the personal protective equipment. A well-fitting system is especially important in a chemically contaminated environment where maximum CB protection with ease of use is essential. For example, if the CB gloves are too large, manual dexterity is degraded. Similarly, items which are too small will restrict movement and may not afford an appropriate seal.

c. Comfort is subjective and therefore difficult to quantify. Qualitative criteria, such as subject identification and evaluation of potential objectionable performance characteristics (hot spots, skin irritations, hindrance of anticipated mission duties, etc.) are best for establishing comfort requirements. Although some discomfort is inherent in wearing a G garment, the user should not experience undue high pressure areas when the garment is inflated nor discomfort when uninflated.

d. Waste elimination must be accomplished without compromising protection and with ease and comfort for the user. The requirement for waste elimination capability without degradation or protection is especially important in a chemical-biological (CB) environment. Waste elimination may include constant wear devices or garments which allow ease of access and use in all mission scenarios.

e. Valsalva is especially important if the aircrew member is performing the Valsalva maneuver while wearing bulky gloves, which limit dexterity and tactile response. The Valsalva requirement should consider the use of forefinger and thumb, as well as the use of mechanical and pneumatic devices. The aircrew respirator (AR-5) has a mechanical Valsalva device which consists of a pair of arms, each with a small nylon roller which can be swept down the external surface of the oronasal mask within the respirator. The arms are operated by raising a bar which lies on the external surface of the respirator. For the mechanical device described above, several different sizes and shapes of arms are required so that the device is compatible with all aircrew members.

f. Systems developed to meet drinking and eating requirements should allow stowing of the system and should not present a safety hazard. Drinking and eating without compromising protection is especially important in a chemically contaminated environment.

g. Ingress and egress requirements are intended to ensure that the personal protective equipment is compatible with the ingress and egress procedures of the intended mission. Any conflicts between ingress and egress procedures and personal protective equipment use must be resolved, with the safety of the aircrew member taking priority.

h. A donning time of 5 minutes, measured from the beginning of the donning sequence to the end, will normally satisfy user requirements and should be attainable with a well-designed system. A similar doffing time may be required for most personal protective equipment. However, the donning and doffing times should be based on mission performance goals. For instance, doffing of a chemically contaminated system will require timely processing through the contamination control area to prevent user contamination. The use of assistants for donning and doffing should also be considered when determining don and doff requirements.

Some personal equipment such as chemical defense ensembles or oxygen masks must be donned much more quickly. The pilot's quick-don oxygen mask on transport aircraft must be donned in 5 seconds. Smoke protection equipment must also be donned within seconds.

i. The time required for transition from ground mode to aircraft operational mode should be kept as low as possible to minimize delay in the start of a mission. For chemical defense equipment, the transition should take place within 15 seconds, including, for example, connecting to the aircraft oxygen supply and mounting a blower in the cockpit. The same comment also applies to transition back to the ground mode.

j. The number of washing cycles should be based on the anticipated length of use between washings and the associated degree of soiling.

k. All requirements for personal protective equipment should be carefully evaluated for human engineering implications which, if not considered, may degrade performance or jeopardize aircrew safety. *MIL-STD-1800* may be of help in determining relevant human engineering requirements.

REQUIREMENT LESSONS LEARNED

Difficulty has been encountered in attempting to fit a specific size of anti-G garments to all aircrew members for which the garment was designed. Frequently the problem was due to poor workmanship. Also, one bladder size for all individuals causes increased discomfort for the smaller individual because of the larger relative surface area coverage.

Aircrew CB mask straps often cause excessive hot spots since they are worn tighter than normal masks. The use of more padding, such as in the ground crew CB masks, would provide additional comfort.

The outer glove used in the aircrew chemical defense ensemble is made of thick black rubber. A thinner glove would improve the pilot's dexterity and tactile response. Since the pilot cannot rely on his sense of touch while wearing the current glove, exaggerated head movements are required to visually locate and use the switches.

The present chemical defense ensemble is reported by users to be so restricting that performing combat maneuvers is very difficult, thereby making them easy targets for enemy aircraft.

During the removal, opening, and closing of chemically contaminated outer garments or while squatting over the latrine in a contaminated area, the possibility of transferring contamination to the underclothing or exposed skin requires special precautions. For this reason, individuals dust with the cloth pad of the M13 decontamination kit, those parts of the contaminated outer garment which may contact the skin when the outer garment is partially removed or opened. After the contaminated outer garments have been opened or partially removed, individuals remove the protective gloves before handling the undergarments or the bare skin. Safer provisions must be made for the elimination of body waste in the present chemical defense ensemble.

Lack of advance provisions for waste elimination have required other measures, such as diapers worn under pressure suits, which have been met with negative reactions by the wearers. Provisioning in anticipation of waste elimination requirements will prevent such objectionable measures.

Inability to perform the Valsalva maneuver may result in severe ear pain during aircraft descent.

Valsalva performed with the forefinger and thumb is preferred over a mechanical device. If the forefinger and thumb are used, allowance must be made for the thickness of all gloves to be worn.

The current chemical defense system makes no provisions for Valsalva.

If assistance with donning is not provided, extended donning may tire the wearer and degrade subsequent performance. Similarly, lengthy doffing times can create anxiety for the wearer, particularly following an extended duration mission.

Lengthy transition times delay mission start and increase user time in the equipment, which results in wearer fatigue and performance degradation.

When the existing charcoal liners for the chemical defense ensemble are washed, carbon particles are lost, which then degrade chemical protection.

**4.5 Verification of human engineering, anthropometric sizing and utilization.** The following verification procedures shall be established to ensure compliance with the requirements of *3.5*.

a. Human test subjects anthropometrically selected in accordance with the on-line anthropometric data base at the Center for Anthropometric Research Data (see *AAMRL-TR-88-012*) shall wear the personal protective equipment to demonstrate that it is sized to fit the user population in all configurations and operating environments. The ____________ critical body dimension(s) shall be specified and utilized for system sizing and subject selection.

b. Field issuing procedures shall be verified subjectively for ease of use by invoking the procedure(s) during all other verifications requiring subjects to wear, use, or handle equipment for testing or demonstration. The issuance of proper user fit/size without error shall be compared against current fitting procedures to determine minimization of error and proper user fit.

c. The personal protective equipment shall be tested by ____________ aircrew members during flight testing. Objectionable odors, tackiness to the touch, hot spots, pressure points, restriction of movement, or other detrimental performance characteristics of the personal protective equipment shall be determined by subjective evaluation using an approved questionnaire. Evaluation of flight crew comments by the procuring activity shall determine whether this requirement is met. The flight crew shall be anthropometrically selected from the central ________ percent of the flying population based on the ________ critical body dimension(s), as well as any other subpopulations for the intended mission.

d. ________ human test subjects, both male and female, shall demonstrate use of standard rest room facilities or other applicable waste elimination techniques while wearing the system in both the ground and operational modes. For verification of waste elimination provisions with chemical defense systems, ________ human test subjects shall be sprayed with chemical simulant and shall simulate use of waste elimination provisions without contamination of test subjects. Subjective evaluation as well as verification of performance requirements shall be accomplished.

e. ________ completely outfitted test subjects shall perform a Valsalva maneuver by occluding the nose as required to equalize pressure in the ears during altitude ascent and descent. Inability of any test subject to perform the Valsalva with one hand shall constitute a failure to meet the Valsalva requirement.

f. ________ completely outfitted test subjects shall demonstrate drinking/eating capabilities. Inability to perform in accordance with the requirement shall constitute a failure.

g. ________ completely outfitted aircrew members shall perform normal ingress/egress procedures. Any failure to perform the normal ingress/egress due to interference by the personal protective equipment shall constitute failure to meet the ingress/egress requirement.

h. The time taken by each of ________ trained test subjects selected from the USAF aircrew population to don and to doff the personal protective equipment shall be measured. An average donning time or an average doffing time which exceeds the requirements for don/doff shall constitute a failure.

i. The elapsed time for each of ________ trained test subjects selected from the USAF aircrew population to make the transition from ground use to aircraft use shall be measured. The test subject shall be seated in the aircraft seat and a crew chief or assistant may aid in the transition if normally performed as such. An average elapsed time which exceeds the required transition time shall constitute a failure.

j. The personal protective equipment shall be subjected to ________ washing cycles in a commercial washing machine or shall be subjected to ________ cycles of the required cleaning method. Failure of the equipment to meet any of the performance requirements after the specified cleaning cycles shall constitute a failure.

k. ________ verifications shall be established to show compliance with any other human engineering requirements.

VERIFICATION RATIONALE (4.5)

a. Verification of population, fit, and sizing is necessary to ensure that the system will perform as required by this specification when worn by all members of the aircrew population for the specified mission.

b. Verification of field issuing procedures is necessary to ensure that all aircrew members are issued the appropriate size personal protective equipment to afford them the required protection.

c. Verification of comfort requirements must be performed to assure the wearability and flight safety of the personal protective equipment without significant performance degradation. Testing is subjective and requires trained test subjects and aircrew to provide a thorough assessment of the comfort and wearability of the personal protective equipment.

d. Verification of waste elimination capability is necessary to ensure that the aircraft mission can be accomplished without delay or restriction.

e. Verification of the Valsalva requirement is necessary to ensure that the Valsalva maneuver can be performed adequately and safely.

f. Verification of drinking/eating capabilities is necessary to ensure that the mission is not compromised by such activity.

g. Verification of ingress/egress while wearing the personal protective equipment is necessary to ensure that ingress/egress procedures can be accomplished as required.

h. Verification of don/doff requirements ensure that donning/doffing of the equipment from the ground mode to the aircraft mode can be accomplished in a timely manner without compromising protection or the mission.

i. Verification of transition requirements ensure that transition of the equipment from the ground mode to the aircraft mode can be accomplished in a timely manner without compromising protection or the mission.

j. Verification of the launderability requirements ensure that the equipment can withstand the recommended laundering methods without performance degradation to prolong the life of the equipment.

k. Verification of all human engineering requirements is required to ensure that aircrew safety and performance are not degraded.

VERIFICATION GUIDANCE

The number of test subjects should be selected to ensure statistically valid data is obtained. Where anthropometric differences could affect test results, critical dimensions should be specified and used to select test subjects from the aircrew population.

Where extensive learning through repetitive tasks ("learning curve") may affect test results, the use of trained test subjects is recommended.

a. Analysis should be performed to determine the appropriate sizing criteria for the aircrew population. The data obtained should be from a representative aircrew population for the intended aircraft mission. The critical dimensions to be measured should be based on the application of the equipment. For example, possible critical dimensions for head protective equipment would include head circumference, facial breadth, etc. Human tolerance levels may also be used as a measure of the population. For example, when determining the representative population to be used to design G-protection equipment, G tolerance levels may be an important measurement. A demonstration may be performed to verify that the required range of aircrew population is fit by the system.

b. Field issuing procedures should be established and updated throughout the design process and equipment use. Use of the procedures for the selection and use of human test subjects (trained and untrained) during all human engineering verifications will aid in establishing the best procedure(s) for properly issuing the personal protective equipment. Field issuing procedures should be performed by trained subjects representative of those performing the procedure in the field.

c. The personal protective equipment should be worn by the test subjects for a specified length of time. All subjective evaluations should be recorded. Since compatibility with 100 percent of the population is impractical due to the inherent variability of human features, a more realistic and achievable goal is the central 95 percent based on specified critical dimensions and/or human tolerance measurements. For critical equipment, such as chemical defense equipment, the central 98 percent based on specific critical dimensions and/or human tolerance measurements should be accommodated. Consider also that many test subjects should wear eye glasses to ensure this compatibility is provided. Determining comfort is a very subjective issue and all subjects may not agree. Questionnaires designed by a human factors specialist may be used to gather more useful information.

d. Demonstration of actual waste elimination procedures should be performed. Subjective evaluations should be recorded and analyzed to determine compliance with all waste elimination requirements without compromising protection.

e. Actual demonstration of the Valsalva maneuver should be performed while wearing all protective equipment (especially any protective equipment which covers the hands or the face).

f. Actual demonstration of drinking/eating capability should be performed while wearing all protective equipment.

g. Demonstration of normal ingress/egress procedures should be performed while wearing all protective equipment.

h. Demonstration of don/doff capability should be performed as required.

For chemical defense equipment, doffing verifications may include a determination of self-contamination.

i. Demonstrations of transition from ground to air mode should be performed while wearing normal ground mode equipment.

j. The number of cleaning cycles required for the launderability verification should be determined based on the expected number of cleaning cycles in the field throughout the life of the equipment. Several systems should be subject to ensure valid test data. All types of washing machines used in the field should be used in this verification.

k. See *MIL-STD-1800*.

VERIFICATION LESSONS LEARNED

Flight testing evaluation often uncovers performance problems not discovered during simulated ground testing.

In the testing of the current aircrew chemical defense ensemble, Valsalva could not be performed with one hand. The current aircrew MBU-13 mask does not have built in Valsalva capability.

**3.6 Aircraft compatibility.** The personal protective equipment shall effectively interface with the aircraft on which it will be used. These aircraft include _____________. Of particular concern, the personal protective equipment must properly function with _____________. Also, the personal protective equipment shall not interfere with the proper operation of other aircraft systems.

REQUIREMENT RATIONALE (3.6)

Much personal protective equipment must use and effectively interface with the aircraft and other subsystems such as engine bleed air, electrical power, space and weight provisions and the oxygen supply and dispensing equipment. Requirements must ensure that the equipment will be properly installed and interfaced into the aircraft under consideration.

REQUIREMENT GUIDANCE

The provisions for an effective installation and interface will differ for each aircraft under consideration. For example, the vibration environment in a fighter aircraft is expected to be more severe than in a transport aircraft. Additionally, installation space will be somewhat more limited in a fighter aircraft than a larger aircraft. If the personal protective equipment is to be installed in a variety of aircraft, usually it is more prudent to establish the environmental extremes and design requirements such that all requirements will satisfy all aircraft. There will, of course, be exceptions as it may be too compromising to specify one requirement which is necessary for one aircraft, but not for any others. That one requirement may increase cost too much to be effective for all designs. These requirements and possible designs must all be evaluated prior to production to ensure the most effective cost and performance trade-offs receive due consideration and use.

Another area of concern will be the bleed air supply necessary for inflation of the G-suit and possible ventilation within a pressure suit. A partial pressure suit may use bleed air or the oxygen supply for proper inflation. Use of the oxygen supply means the suit will not necessarily inflate to any more pressure than the pressurized breathing air. Bleed air may be more difficult to regulate to preclude too low or too high garment inflation. Additionally, measures must be taken to cool or heat the bleed air as necessary to preclude thermal stress on the crew member.

The breathing system must interface with the on-board oxygen supply and dispensing equipment. The oxygen supply may be liquid oxygen, gaseous oxygen, a molecular sieve oxygen generating system or a chemically generated oxygen supply system. In most USAF aircraft the breathing regulator and G valve will be console mounted.

Some components of the personal protective equipment, such as chemical and biological blowers and nuclear flashblindness goggles, require a source of electrical power. Usually, this will be a low current and voltage source such as 28 volts DC, and the aircraft must be evaluated for available power sources and electrical wire lead-ins. A note of caution is that loss of electrical power should not preclude the effective operation of essential personal protective equipment in such a way as to harm or incapacitate the crew member(s). If this could happen, ensure that the electrical power source is backed up by the emergency BUS or consider the use of battery operation.

The lengths of equipment that tie in between the crew member and his seat and/or aircraft should be minimized as they can cause snagging during emergency egress or possibly interfere with the crew members' access to controls in the aircraft cockpit.

REQUIREMENT LESSONS LEARNED

No lessons learned available.

**4.6 Aircraft compatibility.** The personal protective equipment shall be validated for proper aircraft installation and interface by the following methods _____________.

VERIFICATION RATIONALE (4.6)

Full compatibility with installation and the use of personal protective equipment must be checked to ensure no incompatibilities are designed into the system which may harm the crew member or compromise safety-of-flight.

VERIFICATION GUIDANCE

When the qualification program for the personal protective equipment is established, the environmental extremes in which the crew member must operate must be determined. Additionally, aircraft mounted equipment usually will have to operate in differing environments depending on the aircraft. For example, the vibration environment varies considerably from a transport to a bomber to a fighter aircraft. These environments must be established. Refer to the section in this document on environmental requirements and tests.

Compatibility with space and weight provisions may best be determined by the use of aircraft mock-ups or actual aircraft. Ensure that the mock-up and/or aircraft are accurately representative of the aircraft for which the installation is intended. Routing of hoses, connections, space and clearance provisions may all be checked in this way.

Bleed air and electrical provisions may be determined by analyses and then demonstrations and tests. Bleed air pressures, temperatures and flow rates must be evaluated to ensure all personal protective equipment will properly function.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.7 Personal equipment compatibility.** The personal protective equipment shall, when properly donned and worn with all other flight ensembles, be compatible and fully usable. The personal protective equipment under consideration shall be fully functional and not degrade or negate the proper operation and use of the following types of personal equipment:

a. ______ Headgear.
b. ______ Oxygen mask, hoses, and connectors.
c ______ Life preserver unit.
d. ______ Parachute.
e. ______ Parachute harness and quick release fittings.
f. ______ Seat restraint devices and disconnects.
g. ______ Survival vest and included equipment.
h. ______ Anti-exposure suit.
i. ______ Anti-g suit, hoses and disconnects.
j. ______ Partial pressure suit ensemble, hoses and disconnects.
k. ______ Survival kit and attachment straps.
l. ______ Chemical defense clothing and equipment.
m. ______ Eye protection devices.
n. ______ Vision enhancement devices.
o. ______ Flight clothing, jackets, and gloves.
p. ______ Spectacles (i.e., HGU-4/P).
q. ______ Communication systems.
r. ______ ______________________________.
(Specify other personal equipment.)

REQUIREMENT RATIONALE (3.7)

The crew member wears many types of personal equipment depending on the aircraft type and mission. Not only must the personal equipment under consideration be compatible with the crew member, but also with a multitude of other personal equipment and interface equipment including straps, hoses, disconnects, etc. This will provide the crew member with optimum comfort and safety.

REQUIREMENT GUIDANCE

Each relevant item of personal equipment and interface equipment should be identified by model number or equivalent designation (if and when known—otherwise use the tailored list as given above for the requirement) so the activity that is developing the item will be able to determine all proper interfaces. Without this information, it will not be easy for the procuring activity to determine a final design and configuration, since all this equipment varies. For example, the HGU-55/P helmet and MBU-12/P oxygen mask could be called out if they were to be used in a development program.

Compatibility may be defined as the capability of the specified equipment to provide its function as defined in the equipment's technical orders (TOs) when used in conjunction with other items. Further, the aircrew member's mission can be accomplished with the item interfaced with the crew member's personal equipment.

It has been estimated that at least 25 percent of the USAF pilots and at least 50 percent of the navigators wear eye glasses. Therefore, personal equipment must be designed to be compatible with eye glasses.

A requirement for a combination of vision related protective and enhancement functions may present integration difficulties. As an example, consider a requirement for simultaneous nuclear flashblindness protection, laser eye protection, and night vision enhancement. Technologies to produce the equipment are specific to the function provided. Each technology used contains design penalties, such as weight, optical quality, luminous transmission, etc. associated with it. If this equipment is simply cascaded together, the combined design penalties become unacceptable. The design approach therefore must involve more basic technology developments that intend to integrate these multiple vision protective and enhancement functions.

REQUIREMENT LESSONS LEARNED

Experience has shown that the omission of any pertinent feature can lead to later costly modifications of the personal protective equipment under development. Program schedule delays also may result.

**4.7 Personal protective equipment compatibility tests.** The personal protective equipment shall be donned along with all required life support equipment by _______ number and size of aircrew member test subjects. The test subjects shall enter a _______ mock-up and _______ aircraft properly modified to accept the _______ personal protective equipment. Evaluations shall be conducted to determine any undue restrictions, interferences or other problems which are considered to be detrimental to the crew member, the mission, and emergency procedures.

VERIFICATION RATIONALE (4.7)

Use of the personal protective equipment under development with other personal and life support equipment is essential to determine all proper interfaces and identify all problem areas. Since subjective evaluations do not provide predictable results, and people are different sizes and weights, a panel of test subjects is necessary to get as complete results as possible. Problem areas with personal equipment are not always easy to determine without actually donning it on subjects and conducting a range of tests.

VERIFICATION GUIDANCE

It is not always easy to determine that a proper personal equipment interface will be satisfactory overall to the crew member. Subjective evaluation and use of all anticipated personal equipment in simulated environments has proven to be the most effective tool to determine problem areas in the design and use of this equipment. The actual donning of the personal protective equipment and associated life support equipment by the crew member and use of it throughout intended normal missions and emergency scenarios is the best method to evaluate the equipment under development. The size of the panel of test subjects will need to be determined. This can be determined using a chart and measuring potential test subjects. The variance of dimensions included in the chart will assist in establishing some degree of statistical significance and the amount of test subjects needed to conduct personal equipment compatibility testing and evaluation. Some testing will be a stronger function of certain anthropometric dimensions than others. For example, G-suit adjustments and body coverage can best be determined from leg, thigh and abdomen dimensions. Sections *3.5(a)* and *4.5(a)* provide additional information regarding population, fitting, and sizes.

Evaluations, compatibility issues, and problem areas should also be conducted during other testing such as windblast, emergency egress, flight operations, respiration, environmental testing, etc. This will ensure that all personal equipment compatibility problem areas and issues are surfaced and, if possible, eliminated. The sooner the problem areas are determined, the better for the development program as design changes may be required. Sometimes these incompatibilities cannot be reduced to an acceptable level, so that the program may have to be discontinued.

VERIFICATION LESSONS LEARNED

No lessons learned available.

**3.8 Escape system interface.** The personal protective equipment must be designed to properly interface with emergency in-flight and ground escape systems. Each aspect of the emergency escape system must be considered relative to the personal protective equipment under development or modification consisting of ____________. The following escape system areas must be assessed to determine a proper design and interface:

a. _____ Weight and center-of-gravity.
b. _____ Personal services disconnects.
c. _____ Space and clearance provisions.
d. _____ Windblast effects to include any seat speed sensing system.
e. _____ Parachute deployment.
f. _____ Seat-man separation.
g. _____ Survival kit deployment.
h. _____ Restraint provisions.
i. _____ Parachute landing and release.
j. _____ Water entry.
k. _____ ____________________________
(Specify other areas of concern.)

REQUIREMENT RATIONALE (3.8)

Because the personal protective ensemble is on the crew member or passenger (as applicable), and these persons sit on the ejection seat or they egress from the seat to the ground through an exit, proper consideration must be given to the design and donning/doffing of personal protective equipment. For example, the personal protective equipment should interface with the ejection seat system to prevent bodily injury from the dynamic forces of ejection from the aircraft, seat-man separation, parachute opening shock, parachute descent, and impact with the ground or water.

REQUIREMENT GUIDANCE

a. Weight and center-of-gravity - Since the ejection seat is an aerodynamic system which must independently escape the aircraft via a method of propulsion, the effects on weight and center-of-gravity of personal protective equipment must be assessed. This is especially true if any hardware components, such as a breathing regulator, are mounted to the seat. In most cases, however, proper consideration for the weight and center-of-gravity of nearly all personal protective and survival equipment has been taken into full consideration in the design of the ejection system. The envelope of allowable center-of-gravity excursion as well as the maximum amount of weight allowed for the crew member and any associated equipment also must be assessed.

Equipment that is added to head or helmets can cause center-of-gravity problems on seat ejection. When equipment is added to the head or helmet such that it moves the head/helmet center-of-gravity forward, it can result in a higher probability of neck injury on seat or capsule ejection.

b. Personal services disconnects - An area that receives too little concern in the beginning of the design process is the personal services disconnects. Some examples of these services and disconnects are the oxygen system breathing hose, the intercommunication lines, and the G-suit inflation hose. The services must all be properly routed so that minimum interference is afforded to the crew member for his normal operations as well as seat ejection. The disconnects should be in-line as much as possible as the seat moves up the rails (guide rails attached to the aircraft cockpit bulkhead) so that the disconnect will be executed properly. Past criteria have established disconnect limits so that the break-apart force is acceptable for each type of connector. This is necessary so that the connections will break apart on ejection, but not inadvertently break apart during crew member duties in normal (nonemergency) flight operations.

c. Space and clearance provisions - The allowable space for the personal protective equipment should be evaluated relative to what will be afforded by the ejection system. The crew member's personal protective equipment must properly clear all mechanisms that must activate and deploy as the seat ejects from the aircraft. Additionally, the crew member must be able to comfortably sit in the ejection seat and perform his/her duties for normal missions.

d. Windblast effects - Another area of special concern when interfacing personal protective equipment with the ejection system is the windblast effects on the crew member and personal protective equipment. Presently, ejection seats are designed to enable the crew member to eject at airspeeds up to approximately 600 knots. While it is in the best interest of the crew member to eject at slower airspeeds to minimize the risks and injury potential, the ejection system is designed to accommodate ejections up to these higher airspeeds for high performance aircraft. With existing ejection seats, the crew member faces the full effects of the windblast as he/she exits the aircraft. The personal protective equipment must be sufficiently secure to preclude its tearing loose or encumbering the crew member. Also, the equipment will consist of hoses and such that must not slap the crew member or become entangled in other equipment. Of special concern is the windblast effects on equipment mounted on the head, such as the helmet and oxygen mask.

e. Parachute deployment - The crew member will be attached to a parachute via restraint straps and connections. This may be either at his/her seat back or in the seat headrest, as in current configurations. Modern ejection seats have a parachute in the headrest so that seat-man separation may be delayed and minimize limb flailing injuries. If the personal protective equipment is not properly designed, the equipment could be an incompatible with proper parachute deployment. For example, the personal equipment may become entangled in the parachute risers or the equipment may loosen or come off during the parachute opening shock.

f. Seat-man separation - During the ejection sequence, the crew member with parachute and survival kit must separate from the ejection seat, as the current parachute is designed to hold only the crew member. On some earlier ejection seats the man, parachute, and survival kit would separate from the seat, then parachute deployment would occur at a lower altitude around 14,000 feet. In more modern ejection seats, the parachute deploys from the headrest at the lower altitudes after the seat is stabilized and slowed down by a drogue chute system. Often the personal protective equipment must properly operate for both types of ejection systems. The personal equipment should be designed to minimize the potential to "hang-up" during separation as this can cause crew injury or prevent successful completion of the ejection sequence.

g. Survival kit deployment - When the crew member does eject, a survival kit is attached to the harness assembly. Nearly all escape system designs incorporate the survival kit into the seat bottom. When the crew member separates from the ejection seat the kit should automatically deploy such that it falls below him or her on a lanyard. If the kit does not deploy for some reason, a manual release handle is provided so that the crew member may release it. This is important to reduce the weight on the crew member so that he or she will not be injured when hitting the ground. The primary area of concern with the personal protective equipment is that this equipment should not interfere with the proper deployment of the survival kit. Additionally, if this is a transport aircraft where the survival kit is carried away from the aircraft on abandoning it, then some emergency survival or personal protective equipment may be carried in the kit.

h. Restraint provisions - Most crew members and passengers will have some form of restraint provided to preclude their leaving the seat during take-off, landing, adverse flight conditions and emergency egress. Personal protective equipment including clothing, hoses, connectors and such must all interface properly with restraint provisions. The restraint straps can pinch hoses or cause areas of discomfort on the crew member if not properly designed and sized. There will usually be a shoulder harness, lap belt and anti-G or negative straps to contend with on a restraint system.

i. Parachute landing and release - The personal protective equipment should not interfere with a parachute landing on land or in water. The crew member must be able to release the parachute riser fittings after landing (or just prior to landing in water) to prevent being dragged by the parachute. Currently there is an Air Force program which provides a sea water activated release system (AFSEAWARS) of the parachute risers.

j. Water entry - Of particular concern now is water entry after parachuting during emergency escape. The personal protective equipment must not allow water to enter the crew member's mouth and nose, possibly drowning him or her. Currently, there is a program to develop a device which releases the oxygen mask from the crew member's face on water entry even if he or she is unconscious (the program is called WAMRS).

k. Other areas of concern - Areas of concern that may be unique to the program or project under consideration should be addressed herein.

REQUIREMENT LESSONS LEARNED

For aircraft which have ACES II ejection seats installed, consideration must be given to the aerodynamic design of the chemical-biological barrier around the head to prevent airflow distortion into the seat pitot tubes. Such flow distortion would prevent appropriate seat mode selection which is a function of altitude and airspeed.

The selection of materials which satisfy all of the criteria listed below has proven to be a difficult technical problem in the evolution of past design concepts for crew member chemical defense.

- positive pressure chemical-biological barrier;
- fire resistance;
- flexibility and light weight so as not to restrict head movement;
- structural strength to withstand the windblast forces experienced during an emergency ejection;
- aerodynamic smoothness to avoid disturbing the airflow into the ACES II ejection seat pitot tubes.

The quick disconnect provides the primary interface between the crew member and the aircraft (e.g., garment bladder and gaseous system). This disconnect separates from the aircraft due to the force of the ejection. Past experience has shown that the disconnect should separate within a range of angles of pull apart to assure against possible binding or failure to release. If this has not been possible, then careful analysis and testing is necessary to ensure of a safe and proper disconnect. The disconnect should release with an applied force not less than 8 pounds force nor more than 24 pounds force. This range will avoid inadvertent disconnects which have been problems in fighter and trainer aircraft and will also minimize the induced load on the aircrew during an ejection.

Additionally, all disconnects with the aircraft should release prior to the ejection seat clearing the ejection rails. This will prevent the disconnecting force from inducing instability into the seat.

Flailing of the G garment hose following ejection separation from the aircraft and/or failure of the disconnect to properly separate are two major concerns which must be addressed in the design of the garment to assure safe parachute opening and descent. Of major concern is the capability to assure bleed-off of the G garment bladder pressure prior to water entry. Flotation should not be provided by the G garment as this would orient the crew member with his or her legs upward rather than his or her head.

Windblast forces selected should be typical of ejection velocities anticipated for the aircraft. Ejection can occur at 600 KEAS or the aircraft design requirements velocity, but past surveys have shown high velocity ejections to be rare. Past experience has shown that imposing high velocity windblast requirements on headgear such as helmets and oxygen masks may result in a considerably heavier construction of this equipment than desired. For example, some past helmet designs have been somewhat too heavy for effective performance in high G maneuvers. This has represented a trade-off in assuring head protection at lower ejection velocities while at the same time providing a lightweight stable headgear assembly for optimum aircrew performance during the crew member's mission. With the use of new lighter, stronger materials, however, windblast requirements that are now being used for high performance aircraft helmets is approximately 600 knots equivalent airspeed (KEAS).

**4.8 Verification of escape system interface.** Inspections, analyses, demonstrations and tests shall be conducted as necessary to determine that a satisfactory interface with personal escape system has been provided. The following demonstrations and tests shall be performed to verify that the personal protective equipment will properly interface with the escape system:

a. ______ Windblast.
b. ______ Adverse acceleration environments (including vertical deceleration and/or horizontal acceleration).
c. ______ Release force.
d. ______ Wind tunnel.
e. ______ High speed sled.
f. ______ Seat ejection (clearance and posture), see *MIL-STD-846* and *MIL-E-87235* as applicable.
g. ______ Hanging harness.
h. ______ Parachute.
i. ______ Water survival (including flotation and life raft boarding).
j. Ejection tower.
k. ______ ______________________
(Specify other verification methods.)

VERIFICATION RATIONALE (4.8)

The capability of the aircrew to survive and not be injured during an emergency ejection or bailout at various airspeeds, a parachute descent, survivable crash, and landing on the ground or in the water must be verified through simulated and actual environmental demonstrations and tests. Test procedures and equipment have been developed to perform such tests. Test procedures must be modified and new procedures added as necessary to account for each type of personal protective equipment and the interface to the escape system for which it is designed.

VERIFICATION GUIDANCE

Test limits for the variety of tests required are determined by the type of aircraft, mission, operational needs, and good judgement which weighs the severity and number of tests needed to assure that the personal protective equipment is flight worthy. Past programs have used the following testing to determine flight worthiness:

a. Windblast – Windblast tests are normally performed by dressing an appropriately instrumented test dummy properly restrained for ejection in an ejection seat with the personal protective equipment. The dummy is exposed to wind blasts up to or even higher than 500 to 600 KEAS (knots equivalent airspeed) or the aircraft design requirement velocity which may be as great as 600 KEAS to assure that the personal protective equipment will not fail. A typical velocity profile is a rise time to peak velocity of 0.12 to 0.18 second with no dwell at maximum velocity and decay to 200 knots in 3 seconds. Although this velocity profile does not match an actual ejection, it is within the capability of available test facilities and provides a good structural test of the personal protective equipment. Seat attitudes should be varied in both pitch and yaw directions to simulate possible ejection positions and assure a thorough structural test.

b. Adverse acceleration environments – The acceleration test can be performed by dressing a dummy properly restrained in an ejection seat, with the personal protective equipment that is under consideration in an ejection tower (or deceleration tower) test facility. Where an ejection tower is used, separation forces can be measured with appropriate instrumentation. High speed photography is used to provide evidence of any slippage, loosening, or other failure which could result in bodily injury.

c. Release forces – In addition to the quick disconnect release forces measured at an ejection tower test facility, a test rig capable of simulating and measuring release forces may be used. Possible angles of seat–man separation should be simulated.

d. Wind tunnel – Prior to high speed sled tests, wind tunnel tests should be performed to carefully assess the compatibility of the ejection seat and aircrew worn equipment. These tests should be accomplished at varying ejection seat pitch and yaw angles as well as at varying airspeeds to cover the aircraft operational envelope.

e. High speed sled – High speed sled tests are accomplished by dressing a dummy appropriately restrained in an ejection seat with the appropriate personal protective equipment. The seat is mounted on a sled with the appropriate aircraft fore–body or a sting device in a position to simulate the initial stages of an ejection. The sled is accelerated to a pre–determined velocity (approximately 500 to 600 KEAS or the aircraft design requirement velocity). High speed photography provides the sequence of any failure. If an ejection seat is used (which includes pressure sensors) sensor pressures and mode switching are recorded to determine any interference with normal seat mode switching.

f. Seat ejection (clearance and posture) – Ejection clearance tests are usually conducted by placing a representative size range of subjects and personal protective equipment into a mock–up, simulator or actual aircraft. The suited subject is raised up and down the ejection seat rails with a crane while the personal protective equipment is pressurized and unpressurized. Canopy rail and instrument panel clearances during test and ability of the subject to assume the correct posture for ejection should be noted.

An ejection seat test requires a test set–up similar to the high speed sled test except that the sled has a closed canopy. Failure of the ejection seat to operate in the proper mode because of pressure sensor interference (i.e., ACES II seat pitot tubes) from the personal protective equipment, failure of aircrew and/or cockpit disconnects, or failure of the dummy to separate from the seat would constitute a test failure.

g. Hanging harness – In preparation for flight test evaluation, parachute ground training test should be accomplished as follows (by human test subjects experienced at parachute jump testing):

(1) The subject wearing the personal protective equipment, a parachute harness, and any other appropriate life support gear should stand with his body in a typical parachute landing attitude and should fall to the ground with the corresponding typical landing fall. Any evidence of injury to subject or hindrance to the fall test procedure should be recorded.

(2) After this test is successfully completed, the suited subject should stand on a platform 60-inches above the ground and step off of it in a manner to simulate a typical parachute landing and fall attitude onto the ground, thus adding vertical and horizontal velocity components to the fall. Any evidence of potential injury to the subject or hindrance to his or her fall should be recorded.

(3) A parachute harness drop test will be performed by a suited subject who will step quickly from an adjustable (ranging from 1 foot to 2.5 feet in 0.5 feet increments above the parachute harness resting hang position) platform into space and must be supported by the harness in a hanging position to simulate a nominal parachute opening. Tests are performed from each height increment, beginning at 1 foot. Subjective comments should be recorded. The subject should then remove the personal protective equipment and all other life support gear and be examined by a physician. One test series should be run with the helmet visor open and one with it closed and personal protective equipment pressurized if applicable. Any evidence of potential injury to the subject or hindrance to the test procedure should be recorded.

(4) The suited subject should be suspended in the parachute harness and required to look upward at where the actual parachute canopy area would be and downward at where the actual parachute landing area would be. The subject shall determine (based on experience and judgement) that vision in these areas would not be unduly obstructed in an actual parachute jump. Any vision restrictions should be recorded.

(5) The suited subject with the personal protective equipment visor open and the flotation device actuated should be suspended in a parachute harness with feet approximately 10 feet above the surface of the water and should be dropped (or by canopy release actuation) into the water using the standard "wet ditch" training procedure. The subject should float and become stabilized in the water in the standard flotation posture. The subject should then proceed to release the parachute and to board a one person life raft, or equal, using the standard procedures. Inadequate flotation posture or inability of the subject to board the raft constitutes failure.

h. Parachute - An actual parachute jump from an aircraft by a trained test subject is normally performed prior to flight test evaluation. The test subject jumps from the aircraft onto dry land and into water. The personal protective equipment must not interfere with parachute opening or inhibit any descent functions. Good visibility and unrestricted arm movement are essential during descent. The test subject must be able to easily release his or her parachute canopy after ground landing and prior to or after water landing (operation of the releases should be possible either individually or simultaneously).

i. Water survival - Water drag tests should be performed prior to jumping or flight testing over water. This can be accomplished from the aft end or side of an appropriately rigged boat. The test subject is dragged in the water at various speeds simulating possible wind velocities. The test subject must demonstrate the capability of rolling over, releasing the canopy quick releases, and performing the required water survival procedures (including flotation and life raft boarding without undue problems).

j. Other - Other tests shall be accomplished as determined necessary by any special program needs.

VERIFICATION LESSONS LEARNED

The use of instrumented dummies to assess the performance of the personal protective equipment during the more severe testing and human subjects for the less severe testing has provided a reasonable means to predict performance during operational use. Continued use of these evaluation techniques can serve as a basis for comparison of old and new systems.

Due to the expense of seat ejection tests, "piggy-back" tests are usually preferred. Many personal protective equipment compatibility testing can be accomplished with other escape system testing with no compromise to this testing, thus providing a considerable savings over running all separate tests.

**3.9 Health and safety.** The personal protective equipment shall be designed and constructed with the user's, maintainer's and manufacturer's safety as a primary requirement. The equipment shall be airworthy and shall not create hazards when the user is in the ___________ aircraft. All subsystems shall be designed to minimize the risk of any catastrophic failures. To provide effective safety control measures, the following areas of concern shall be addressed:

a. _____ Warning devices or capability.
b. _____ Dangerous materials or processes.
c. _____ Overpressure protection.
d. _____ Electrical shock protection.
e. _____ Toxic gases.
f. _____ ______________________ (Specify other areas of concern.)

REQUIREMENT RATIONALE (3.9)

While safety is of general concern in all aspects of development, this is not considered adequate without a systematic procedure to identify and control hazards. The health and safety process should compliment the personal protective equipment program in such a way that hazards are eliminated or effectively controlled.

REQUIREMENT GUIDANCE

A system safety program is identified in *MIL-STD-882* and this, if properly implemented, should identify and provide recommended actions to control all hazards. Past experience has shown that it is up to the responsible engineer on the program to see that all recommendations from safety are properly addressed, closed out, and included in the equipment design where appropriate.

The following specific areas of concern should be properly addressed:

a. Warning devices or capabilities – Any device or connection, whose failure may cause the loss of a function or may reduce the aircrew member's protection, should have a warning device or capability. Warnings should be clear, legible, operable, accessible and/or within view at all times when the personal protective equipment is being worn, donned or doffed. This applies to the maintenance of the system as well. Test equipment should incorporate warnings and built-in safety features where needed. Warnings may be visual, audio, tactile or kinesthetic, but they should provide immediate notification of the loss of the protection capabilities without the users direct attention at the time of loss and without false warnings.

b. Dangerous materials or processes – Materials or processes which may be a hazard to the fabrication, use, maintenance or other personnel, should not be used unless no other method is available. Proper precautions must be implemented and exercised if hazardous materials or processes are necessary. No requirement herein should be interpreted as permitting the use of any materials or processes that are forbidden by law.

c. Overpressurization protection – There should be at least one high pressure relief device for the oronasal mask, for each bladder and for any other pressurized device on the user to prevent pressures from injuring the user. When no upper torso counter pressure garment is used, pressures in the oronasal mask should not be permitted to exceed 18 inches water gauge (Wg) above ambient. If an upper torso counter pressure garment is used, the pressure in the oronasal mask should not be permitted to exceed 42 inches Wg. The pressure differential between the upper torso counter pressure garment and the oronasal mask should not exceed 3.0 inches Wg during steady state (no flow) conditions, and should not exceed 6.0 inches Wg during required flow conditions. Additionally, there should be no upper torso pressurization without lower torso and leg pressurization.

d. Electrical shock protection – All personal mounted equipment, components or parts with 5 volts AC or 20 volts DC or more should have provisions for grounding to preclude crew member electrical shock or static discharge. Additionally, any aircraft mounted equipment which may be touched by a crew member should have grounding provided. Electrical and electronic equipment should be designed and installed in compliance with *MIL-STD-454*.

e. Toxic gases – Any substance or components which may be subjected to an expected environment such that they would emit toxic gases should be precluded. While all materials can break down chemically and produce toxic gases under conditions such as extreme heat, it is necessary to examine the expected environment of all substances used to ensure that no toxic gases will be produced. For example, some materials used in oxygen service may oxidize and produce noxious or toxic gases, therefore special considerations must be given to any material used within an oxygen enriched environment. Refer to *NIOSH/OSHA Standards on Toxicology* (National Institute for Occupational Safety and Health/Occupational Safety and Health Administration, US Department of Health and Human Services, Public Health Service and US Department of Labor) for standards on toxicology and exposures. Other standards on toxicology are established, but those cited above are the most universally accepted.

f. Other – Any other areas of special concern should be included herein.

REQUIREMENT LESSONS LEARNED

The designers have provided an overpressurization safety pressure relief device, but have not really considered the worst case maximum flow rates that can be expected or that the ambient pressure is reduced at higher altitudes and the corresponding pressure difference is greater. If the pressure relief device does not allow sufficient volumetric flow rates, the corresponding pressure can rise and exceed safe limits.

**4.9 Health and safety verification.** Measures shall be taken to ensure that the manufacture, use, and maintenance of personal protective equipment does not result in health and safety hazards. Proper precautions shall be taken to determine that all hazards have been identified, eliminated, and/or effectively controlled. These measures shall consist of ____________.

VERIFICATION RATIONALE (4.9)

To ensure that adequate health and safety precautions have been taken, it is essential to check into all measures that have been taken.

VERIFICATION GUIDANCE

Many hazards will be identified by *MIL-STD-882*, but this does not necessarily ensure that all proper measures have been taken to eliminate or effectively control any health hazards or safety concerns. Past experience has shown that it is usually more effective to have independent experts evaluate health and safety concerns. The responsible engineer can, however, minimize the concerns of independent reviews by working health and safety concerns throughout the development program.

Inspections, analyses, demonstrations, and tests may be called out to address all areas of concern. Often areas of concern for flight safety may be found during developmental test and evaluation (DT & E), but to preclude flight safety problems during this testing, flight safety reviews should be conducted prior to the DT & E. To determine that maintenance and manufacturing health and safety concerns have been properly identified and eliminated or effectively controlled, analyses and inspections are often necessary throughout the program.

VERIFICATION LESSONS LEARNED

No lessons learned available.

## 50. PACKAGING

**50.1 Packaging.** Preservation, packing, and marking requirements in accordance with *MIL-STD-2073-1* shall be such that the __________ is delivered suitable for use and free from damage and defects.

REQUIREMENT RATIONALE (50.1)

*MIL-STD-2073-1* outlines the procedures established by DoD packaging agencies which ensure proper delivery of Government procured equipment. These procedures include *MIL-P-116* and *MIL-STD-129*. The packaging standard describes levels that should be required in the system/item specifications to ensure equipment will be free from damage and defects.

REQUIREMENT GUIDANCE

Appendix C of *MIL-STD-2073-1* contains guidance in item categorization, selecting preservation methods, development of predetermined packaging codes, formatting coded data, computation of weight and cube data, computation of the bill of materials, use of container selection table, and use of cushioning chart.

**50.1.1 Preservation.** Preservation shall be level A or C of *MIL-STD-2073-1*.

a. Level A. Items shall be cleaned, dried, and preserved in accordance with *MIL-P-116*.

b. Level C. Items shall be cleaned and dried in accordance with *MIL-P-116*. Preservation shall be applied in accordance with *MIL-P-116*, when required.

c. Unit pack. Unless otherwise specified by the contracting activity, units shall be individually wrapped and packaged in accordance with *MIL-P-116*, ensuring compliance with the applicable requirements of that specification. The items shall be sufficiently cushioned with material to prevent movement within the container and to protect the items from damage during shipment.

d. Intermediate packs. Each unit pack of identical items shall be placed in a wrap, box, or bundle as applicable.

REQUIREMENT RATIONALE (50.1.1)

The requirement for preservation includes the application or use of protective measures including appropriate cleaning, drying, preserving, unit packs (e.g., unit protection methods per *MIL-P-116*), wrapping, cushioning, blocking, bracing, intermediate containers, and identification marking up to but not including the exterior packs, to adequately prevent deterioration or misidentification of the items.

REQUIREMENT GUIDANCE

This section specifies both level A and level C requirements. The contract, AFLC Form 872, should specify which level applies depending on the situation and should be completed by the packaging office. The packaging methods in *MIL-P-116* could be required in item specifications, if determined; otherwise, the contractor should determine the specific method in accordance with *MIL-STD-2073-1* and *MIL-P-116*. Life support equipment, if requiring Method IC1 of *MIL-P-116*, should be addressed in subparagraph 50.1.1 a., level A.

The contractor should determine the following preservation requirements based on the characteristics of the item: Cleaning shall be in accordance with the "Cleaning" paragraph of *MIL-P-116*; drying shall be in accordance with the "Drying procedures" paragraph of *MIL-P-116*; preservation selection and application shall be in accordance with the "Preservatives" paragraph of *MIL-P-116*; and methods with submethods of preservation are covered in the "Methods" paragraph of *MIL-P-116*. Level C usually does not require a preservative.

Unit packs and unit pack quantity are defined in the paragraph entitled "Unit pack quantity" of *MIL-P-116* and the paragraphs entitled "Quantity per unit pack" and "Unit pack" of *MIL-STD-2073-1*. Guidance on "Unit pack requirements" is also contained in Appendix F of *MIL-STD-2073-1*. Any disassembly of the item should be addressed in this paragraph.

Appendix F of *MIL-STD-2073-1*, paragraph titled "Intermediate pack requirements" contains guidance on conditions of use, quantities, and limitations for this type of pack.

**50.1.2 Packing.** Packing shall be level A, B, or C per *MIL-STD-2073-1*. The requirements for packing shall cover the exterior shipping container, the assembly of items or packs therein, necessary blocking/bracing/cushioning and closing. Container selection for packing shall provide for the use of containers of minimum weight and cube consistent with anticipated storage and shipment hazards.

a. Level A. Unless otherwise specified by the contracting activity, units preserved as specified above shall be packed in shipping containers to level A requirements of *MIL-STD-2073-1*.

b. Level B. Unless otherwise specified by the contracting activity, units preserved as specified above shall be packed in shipping containers to level B requirements of *MIL-STD-2073-1*.

c. Level C. Unless otherwise specified by the contracting activity, units preserved as specified above shall be packed in shipping containers to level C requirements of *MIL-STD-2073-1*.

REQUIREMENT RATIONALE (50.1.2)

The requirement specifies packing items as appropriate to the different levels specified in the appropriate packing standard. It concerns the arrangement of interior packages as well as exterior containers to afford appropriate protection of the items.

REQUIREMENT GUIDANCE

The requirements for levels of packing should be included in the item specification. The contract AFLC form 872 should specify which level applies depending on the situation and should be completed by the packaging office. The type of container could be specified, if determined; otherwise the contractor should utilize *MIL-STD-2073-1*, Appendix C, table VII or Appendix E for container selection/evaluation.

**50.1.3 Marking.** Interior and exterior containers and palletized unit loads shall be marked in accordance with *MIL-STD-129* and as contractually stipulated. Unit and intermediate packages and shipping containers shall be marked with bar codes in accordance with *MIL-STD-1189*. All reusable containers shall be marked "REUSABLE—DO NOT DESTROY." All specialized containers as defined in *MIL-STD-1510* shall be marked in accordance with *MIL-STD-130* and *MIL-STD-648*. In addition, items determined to be electrostatic discharge sensitive shall be marked in accordance with *MIL-STD-1686*. Bar code markings are required and shall be in accordance with *MIL-STD-1189* and *MIL-STD-129*, except as noted on AFLC Form 53.

REQUIREMENT RATIONALE (50.1.3)

The requirement specifies the marking of both intermediate packages and shipping containers in accordance with appropriate standards to ensure efficiency in package use and handling.

REQUIREMENT GUIDANCE

Normally, marking requirements are established by reference to *MIL-STD-129*. Markings essential to safety and to the protection or identification of the configuration item which are not required by *MIL-STD-129*, or if required on an "as specified" basis by that standard, shall be specified in detail under this heading. In any instance where reference to *MIL-STD-129* is not applicable, requirements in detail or by reference to recognized documents shall include: appropriate identification of the product, both on packages and shipping containers; all markings necessary for delivery and for storage, if applicable; all markings required by regulations, statutes, and common carriers; and all markings necessary for safety and safe delivery.

The following precautionary marking should appear on each package:

| |
|---|
| LIFE SUPPORT SYSTEM<br>All oil, grease, shop residue,<br>or other contaminants<br>have been removed.<br>DO NOT OPEN UNTIL READY FOR USE. |

**50.1.4 Utilization.** Unitized loads shall be assembled in such a manner that the load can be handled as a unit through the distribution system on the 463L pallet system.

REQUIREMENT RATIONALE (50.1.4)

Unitization is any combination of unit, intermediate, or exterior packs of one or more line items of supply into a single load in such a manner that the load can be handled as a unit through the distribution system. Unitization (unitized loads - unit loads) encompasses consolidation in a container, placement on a pallet or load base, or securely binding together.

REQUIREMENT GUIDANCE

*MIL-STD-2073-1* Appendix F paragraph entitled "Unitization consolidation" provides guidance on unitization.

**50.2 Packaging verification.** Verification of packaging shall be by inspection per the quality assurance provisions of *MIL-STD-2073-1*. Packaging design validation provisions shall be performed, when required, in accordance with *MIL-STD-2073-1*.

## 60. NOTES

### 6.1 Acronyms.

AAMRL – Aerospace Aeromedical Research Laboratory

ACES – advanced concept escape system

AERP – aircrew eye respiratory protection system

AFP – Air Force Pamphlet

AIS – aircrew integrated system

ANSI – American National Standards Institute

ANVIS – aviator's night vision imaging system

ASTM – American Society for Testing and Materials

BRAG – breathing regulator with anti–G sensing and valving

CB – chemical–biological

CD – chemical defense

ECS – environmental control system

EMI – electromagnetic interference

EMP – electromagnetic pulses

FFOP – failure free operating period

FSD – Full Scale Development

G – acceleration force

Hg – mercury, i.e., mmHg

HHMS – helmet and helmet mounted systems

HSD – Human Systems Division, Brooks AFB, Texas

KEAS – knots equivalent air speed

LGG – lower G garment

LOC – loss of consciousness

LTE – liquid transport equipment

MRT – modified rhyme test

MSOGS – molecular sieve oxygen generating system

NFPA – National Fire Protection Association

NVG – night vision goggles

OD – optical density

OSU – Ohio State University

PB – phonetically balanced

PEC – personal equipment connector

PLZT – lead, lanthanum, zirconate, titanate

PPB – positive pressure breathing

PSE – pressure suit ensembles

PTPS – passive thermal protective system

RM – reliability and maintainability

SEMS – system engineering master schedule

TAC – Tactical Air Command

TEARS – Tactical Aircrew Eye Respiratory System

TLSS – Tactical Life Support System

TPP – thermal protective performance

UPG – upper pressure garment

Wg – water gauge, i.e., inches Wg

### 6.2 Definitions.

Acceleration force – A force resulting from acceleration that acts upon an aircraft or person in the aircraft.

G's or G force – A force on an object resulting from an applied acceleration due to gravity or reaction to a change of direction in unit of gravitational acceleration.

$+G_x$ – A positive acceleration acting along the axis of the aircraft from the nose to the tail. This force of acceleration will pull the crew member into the seat back cushion.

$+G_y$ – Acceleration acting across a body perpendicular to its long axis in a side–to–side direction. Examples are a pilot in a high performance aircraft executing an uncoordinated turn and exposure to lateral buffeting.

$+G_z$ – A positive acceleration acting along the z–axis of a body. Examples are aircraft recovery from a dive and turning maneuvers. It is this force of acceleration from which the G valve and suit are intended to protect the pilot.

**6.3 Data item descriptions.** The following is a partial list of data item description (DID) that may be associated with the requirements of this specification:

| DID Number | Title |
|---|---|
| *DI-A-3007* | *Program Schedule, Progress Report* |
| *DI-E-3029* | *Agenda Design Reviews, Configuration Audits and Demo* |
| *DI-E-3118* | *Minutes; Formal Reviews, Inspections and Audits* |
| *DI-S-3581* | *Subsystem Design Analysis Report, Preliminary Design Study* |
| *DI-H-7048* | *System Safety Hazard Analysis Report, Preliminary Hazard Analysis* |
| *DI-M-3413M* | *Technical Publications for Development Programs* |
| *DI-T-3718A* | *Test Reports - General, Qualification Test Report* |
| *DI-T-3721A* | *Acceptance Test Reports* |
| *DI-S-3581* | *Subsystem Design Analysis Report, Final Design Study* |
| *DI-T-3714A* | *Acceptance Test Procedures Test Plan DT and E* |
| *DI-E-3128* | *Engineering Change Proposals (ECPs)* |
| *DI-A-3028B* | *Abstract of New Technology* |
| *DI-R-3548B* | *Suspect Material Deficiency Notice, (ALERT) and Response* |
| *DI-E-7028A* | *Nonstandard Part Approval Requests/Proposed Additions to an Approved PPSL* |
| *DI-E-7031* | *Drawings, Engineering and Lists, Conceptual and Developmental Design Drawings, Level 1* |
| *DI-E-7031* | *Drawings, Engineering and Lists, Production Prototype and Limited* |

*Production Drawings*

| | |
|---|---|
| *DI-A-5026A* | *Contractor Developed Specification* |

THIS PAGE INTENTIONALLY LEFT BLANK

INDEX

## A



## B



## C



## D



## E

INDEX

# T



# W