



NASA-STD-3000 Man-Systems Integration Standards

Volume I, Section 6

6 CREW SAFETY

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This section contains the following topics:

- 6.1 [Introduction](#)
- 6.2 [General Safety](#)
- 6.3 [Mechanical Hazards](#)
- 6.4 [Electrical Hazards](#)
- 6.5 [Touch Temperature](#)
- 6.6 [Fire Protection and Control](#)
- 6.7 [Decompression Hazards](#)

6.1 INTRODUCTION

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This section is not intended to be a comprehensive guide to manned spacecraft safety. It deals only with general safety considerations and requirements and a specialized subset of the total safety problem. This specialized subset addresses only the following topics: 1) mechanical hazards; 2) electrical hazards; 3) thermal hazards; and 4) fire hazards.

Other safety topics are covered in the topical sections on human performance (Section 4.0), natural and induced environments (Section 5.0), health management (Section 7.0), architecture (Section 8.0), workstations (Section 9.0), hardware and equipment (Section 11.0), maintainability (Section 12.0), and EVA (Section 14.0).

An exhaustive treatment of general system safety is given in AFSC Design Handbook 1-6 (Reference 21). The appendices of the Space Station Crew Safety Alternatives Study (Reference 42) provide an exhaustive treatment of crewmember safety requirements.

6.2 GENERAL SAFETY

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6.2.1 Introduction

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This section briefly describes some of the principles of system design and human behavior related to safety and provides general safety requirements.

6.2.2 General Safety Design Considerations

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Two primary considerations in crew safety are prevention of the following:

- a. System failures affecting the health/safety/survival of the crew.
- b. Design-induced crew errors causing crew injury or damage to the system.

6.2.2.1 Safety Factors

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Safety factors shall be given major consideration as a part of system design. Applying adequate factors of safety in the design of systems such as unpressurized and pressurized structural subsystems, assures systems will not fail under expected operating loads.

6.2.2.2 Crew Induced Accidents

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The probability of occurrence of crew-induced accidents is directly related to some principles of human behavior that result in human errors that might be committed during operation and maintenance of equipment. Some of these human behavior principles are listed below as an aid to equipment designers (see references 15 and 21 for a more detailed discussion of these principles). These principles provide answers to why people make errors, misuse equipment, and make unsafe judgments.

- a. Equipment design that exceeds the physical and psychological limits of human capability can create situations where the likelihood of accidents is high.
- b. Any design that makes crewmembers work harder because of the physical requirements of the work situation is likely to promote fatigue and increase error.
- c. When crewmembers must perform tasks in inadequate facilities or without proper information, errors are likely to occur.
- d. When design results in tasks that are unpleasant or complex, crewmembers may not devote sufficient time and attention to attain satisfactory performance.
- e. Crewmembers are less likely to perform tasks as frequently if they are aware the task is hazardous.
- f. If equipment is insufficient or inadequate, crewmembers will modify it, or improvise, so they can get the job done.
- g. Procedures should be definitive, comprehensive, and as accurate as possible.
- h. Equipment must be designed so that it encourages safe use, allowing a minimum opportunity for the crewmembers to be exposed to hazards.
- I. If the equipment is designed so that it does not operate in accordance with the crewmember's expectancies, he will eventually make an error.

J. If hazards are designed into the equipment, warning notes in the technical manual, or warning labels on the equipment, special instructions and special training will reduce, but may not completely eliminate the possibility of human error.

In summary, the designer should remember that most safety problems are the result of the equipment not being designed properly and/or people using it improperly. The designer must, therefore, anticipate how equipment might be misused and design it so that misuse is less likely and error effects are not catastrophic.

6.2.3 General Safety Design Requirements

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The following general minimum safety requirements shall apply:

a. General Safety Design - Design shall reflect applicable system and personnel safety factors, including minimization of potential human error in the operation and maintenance of the system.

b. Fail-Safe Design - A failure tolerant design shall be provided in areas where failure can disable the system or cause a catastrophe by damaging equipment, injuring crewmembers, or causing critical equipment to be operated at undesirable times.

c. Elimination or Minimization of Hazards - Design actions to eliminate or minimize a hazard shall be conducted in the following order of precedence. This hazard reduction sequence shall apply to all nominal and contingency (e.g., planned maintenance or repair) equipment operations.

1.Design - Elimination of hazards by removal of hazardous sources and operations by appropriate design measures.

2.Safety Devices - Prevention of hazards through the use of safety devices or features.

3.Warning Systems - Control of hazards through the use of warning devices.

4.Special Procedures - Control of hazards through the use of special procedures.

6.3 MECHANICAL HAZARDS

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6.3.1 Introduction

{A}

This section provides the design considerations and design requirements for designing IVA hardware to avoid safety problems with burrs, edges, corners and protrusions.

(Refer to Paragraph 14.1.3, EVA Safety Design Requirements, for related EVA requirements.)

6.3.2 Mechanical Hazards Design Considerations

{A}

Sharp surfaces or protrusions include surfaces, edges, crevices, points, burrs, wire ends, screw heads, corners, brackets, rivets, braided cable, cable fittings, cable strands, clamps, pins, latches, lap joints, bolt ends, lock nuts, etc., which, if contacted, could injure crewmembers or damage equipment by entrapment, cutting, sawing, abrading, snagging, tearing or puncturing.

These hazards will be avoided if the above equipment is mounted/installed so that it does not interfere with crewmember movement in habitable areas, transfer corridors and tunnels, hatchways, or external surfaces of equipment within the habitable space. Items that must be grasped by the bare hands, or that could puncture a space suit, must be free from hazards.

(Comply with Surface Finish Requirements found in ANSI/ASME/B46.1-1985.)

6.3.3 Mechanical Hazards Design Requirements

{A}

Design requirements for the elimination of burrs, corners, edges, protrusions, pinching, snagging, and cutting for IVA are given in this section:

(Refer to Paragraph 14.1.3, EVA Safety Requirements, for comparable EVA requirements.)

6.3.3.1 Corner and Edge Requirements

{A}

- a. Edges with which the crew can come in contact, 6.4 mm (0.25 in.) Thick or greater shall be rounded to a minimum radius of 3.0 mm (0.12 in.) as shown in Figure 6.3.3.1-1.
- b. Edges with which the crew can come in contact, 3.0 to 6.4 mm (0.12 to 0.25 in.) Thick shall be rounded to a minimum radius of 1.5 mm (0.06 in.) as shown in Figure 6.3.3.1-2.
- c. Edges with which the crew can come in contact, 0.6 to 3.0 mm (0.02 to 0.12 in.) Thick shall be rounded to a full radius as shown in Figure 6.3.3.1-3.
- d. The edges of thin sheets less than 0.5 mm (0.02 in.) Thick shall be rolled or curled as shown in Figure 6.3.3.1-4.

6.3.3.2 Exposed Corner Requirements

{A}

- a. Exposed corners of materials which exceed 25 mm (1.0 in.) thickness shall be rounded to 13 mm (0.5 in.) spherical radius, as shown in Figure 6.3.3.2-2.
- b. Exposed corners of materials less than 25 mm (1.0 in.) Thick shall be rounded to a minimum radius of 13 mm (0.5 in.), as shown in Figure 6.3.3.2-1.

6.3.3.3 Protective Covers on Exposed Protrusions Requirements

{A}

Equipment which cannot meet corner and edge requirements of 6.3.3.1 and 6.3.3.2 shall be covered or shielded when not in use.

6.3.3.4 Holes Requirements

{A}

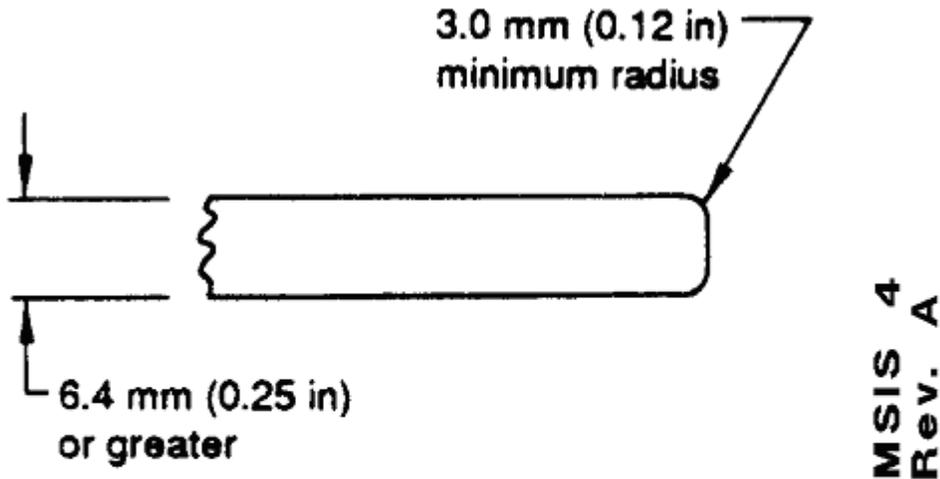
Holes that are round or slotted in the range of 10.0 to 25.0 mm (0.4 to 1.0 in) shall be covered.

6.3.3.5 Latches Requirements

{A}

Latches which pivot, retract, or flex such that a gap of less than 25 mm (1.4 in.) exists shall be designed to prevent entrapment of crewmember appendages.

Figure 6.3.3.1-1 Requirements for Rounding Exposed Edges 6.4 mm (0.25 in) Thick or Thicker



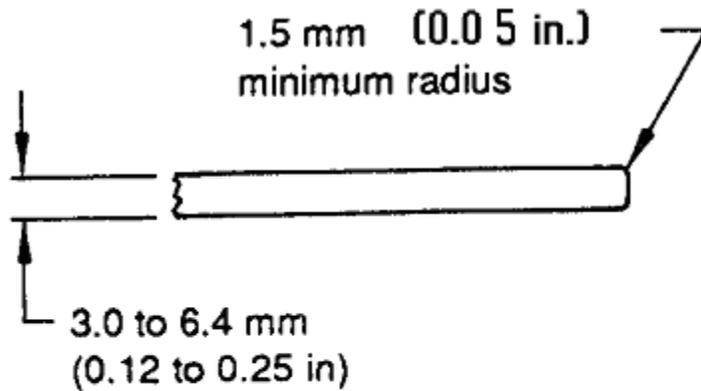
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Reference: 1, Figure 3.5-1, page 3.5-10
155, page 6-31

Figure 6.3.3.1-1 Requirements for Rounding Exposed Edges 6.4 mm (0.25 in) Thick or Thicker

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Figure 6.3.3.1-2 Requirements for Rounding Exposed Edges 3.0 to 6.4 mm (0.12 to 0.25 in) Thick



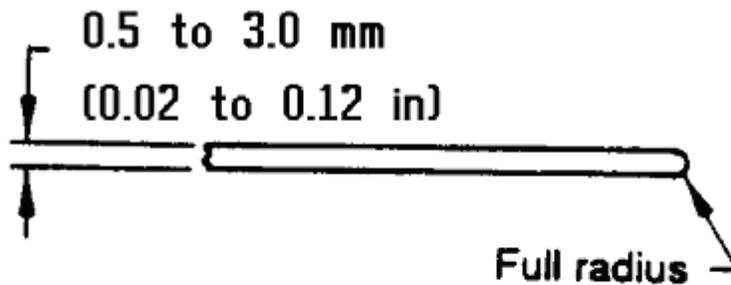
Reference: 1, Figure 3.5-2, page 3.5-11
155, page 6-31

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Figure 6.3.3.1-2 Requirements for Rounding Exposed Edges 3.0 to 6.4 mm (0.12 to 0.25 in) Thick

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Figure 6.3.3.1-3 Requirements for Rounding Exposed Edges 0.5 to 3.0mm (0.02 to 0.12 in.) Thick



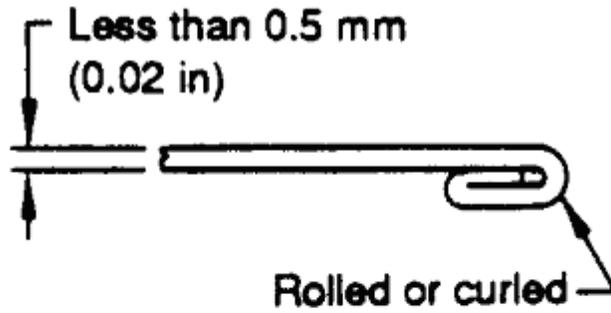
Reference: 1, Figure 3.5-3, page 3.5-11
155, page 6-31
With Updates

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Figure 6.3.3.1-3 Requirements for Rounding Exposed Edges 0.5 to 3.0mm (0.02 to 0.12 in.) Thick

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Figure 6.3.3.1-4 Requirements for Curling of Sheets Less Than 0.5 mm (0.02 in) Thick



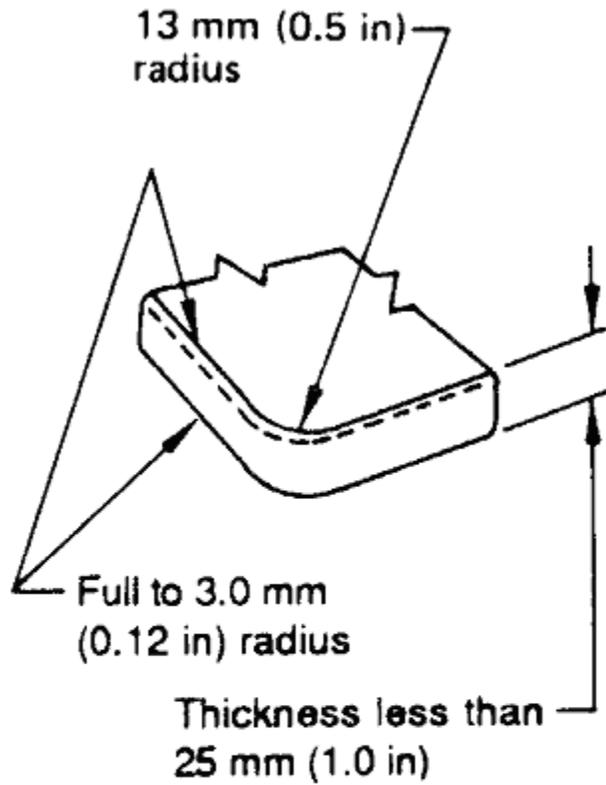
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Reference: 1, Figure 3.5-4, page 3.5-11
155, page 6-31
With Updates

***Figure 6.3.3.1.-4 Requirements for Curling
of Sheets Less Than 0.5mm
(0.02in.) Thick***

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Figure 6.3.3.2-1 Requirements for Rounding of Corners Less Than 25 mm (1.0 in) Thick



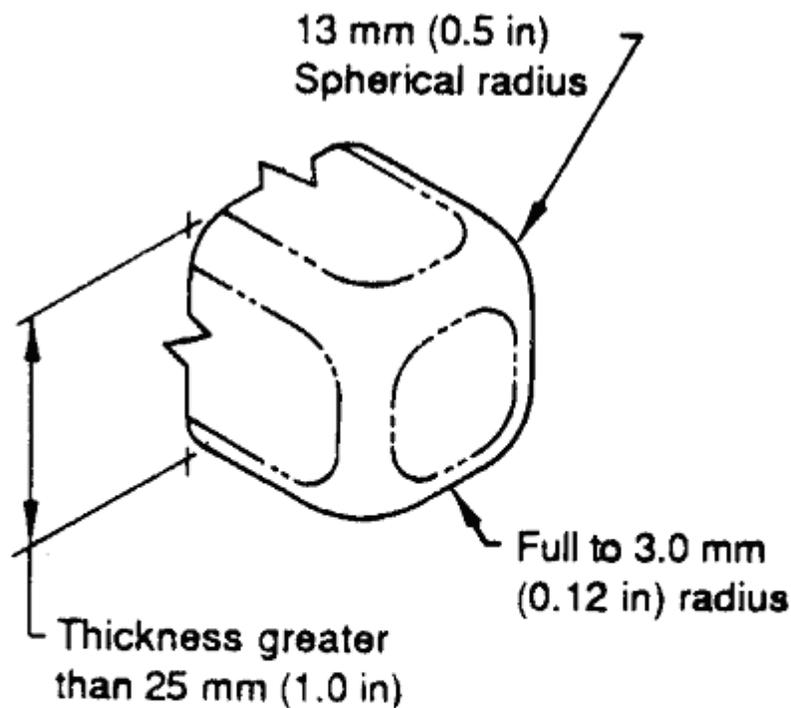
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Reference: 1, Figure 3.5-5, page 3.5-11
155, page 6-32

***Figure 6.3.3.2-1. Requirements for Rounding of
Corners Less Than 25 mm
(1.0 in) Thick***

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Figure 6.3.3.2-2 Requirements for Rounding of Corners Greater Than 25 mm (1.0 in) Thick



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Rev. A**

Reference: 1, Figure 3.5-6, page 3.5-11
155, page 6-32

Figure 6.3.3.2-2. Requirements For Rounding of Corners Greater Than 25 mm (1.0 in) Thick

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6.3.3.6 Screws and Bolts Requirements

{A}

Screws or bolts with more than two exposed threads shall be capped to protect against the sharp threads.

6.3.3.7 Securing Pins Requirements

{A}

Securing pins in handrails shall be designed to prevent their inadvertently backing out above the handhold surface.

6.3.3.8 Levers, Cranks, Hooks, and Controls Requirements

{A}

Levers, cranks, hooks, and controls shall not be located where they can pinch, snag, or cut the crewmember or clothing.

6.3.3.9 Burrs Requirements

{A}

Exposed surfaces shall be free of burrs.

6.3.3.10 Mechanically Stored Energy Requirements

{A}

Mechanical devices capable of storing energy (such as springs, levers, and torsion bars) shall be avoided in spacecraft design. Bungee cords are acceptable.

a. Safety Features - Where stored energy devices are necessary, safety features such as removal tabs, locks, protective devices, and warning placards shall be provided.

b. Stored Energy Release - Spring-loaded devices (i.e., bungee restraints) shall provide means for releasing stored energy forces.

c. Backlash - Stored energy devices shall not generate a backlash.

d. Locking Wires - Refer to 11.9.3.2 h and 11.9.3.3.i.

6.3.3.11 Loose Equipment

{A}

See Figure 6.3.3.11-1 for data regarding loose equipment edge and corner radiusing requirements.

Figure 6.3.3.11-1 Loose Equipment Edge and Corner Radiusing Requirements

Mass (Kg)	Edge radius (mm)	Corner radius (mm)
0.0 to 0.25	0.3	0.5
0.25 to 0.5	0.8	1.5
0.5 to 3.0	1.5	3.5
3.0 to 15.0	3.5	7.0
15.0 to 50.0	3.5	13.0

Mass (lb)	Edge radius (in)	Corner radius (in)
0.0 to 0.5	0.01	0.02
0.5 to 1.1	0.03	0.06
1.1 to 6.6	0.06	0.14
6.6 to 33.0	0.14	0.3
33.0 to 110.0	0.14	0.5

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Reference: 381

Figure 6.3.3.11-1 Loose Equipment Edge and Corner Radiusing Requirements

6.3.4 Non-Exposed Edges and Corners

{A}

All edges and corners of hardware exposed to crew contact during maintenance or servicing shall be rounded to a minimum radius of 0.003 inch.

6.4 ELECTRICAL HAZARDS

{A}

6.4.1 Introduction

{A}

This section contains the design considerations and design requirements for protection of crewmembers from electrical hazards. This section does not include considerations or requirements that pertain to protection of hardware from electrical hazards.

6.4.2 Electrical Hazards Design Considerations

{A}

Controls must be in place such that no single failure can allow a critical hazardous event (e.g., nondisabling injury to personnel), and no two failures can allow a catastrophic hazardous event (e.g., disabling or permanent injury to personnel). Implied is that two failures can allow a critical hazardous event to occur.

For electrical hazards, a crew/machine interface critical hazardous event is an event which can subject the crew to an electric shock.

If, however, the failure can result in a hazardous event causing other than a nondisabling injury (e.g., inability to let go of the electrically energized surface, stoppage of breathing, ventricular fibrillation of the heart, electric burns, or paralysis), the hazard is classified as catastrophic.

6.4.2.1 Hazard Controls For Crew/Machine Interface

{A}

The design should consider the effects of a worst case, credible, hazardous scenario including the highest internal voltage applied to or generated within the equipment under analysis. The scenario should take into account the potential for a smart short to an accessible conductive surface (or a surface likely to become electrically energized upon encountering a fault) such that the fault current supplied to the conductive surface is internally limited to be below the trip point of the overcurrent protector. It also should take into account the worst case physiological effect of frequency and wave form associated with the smart short.

Once the worst case scenario is identified, an electrical shock hazard classification of critical versus catastrophic is made and appropriate controls are utilized. If the classification is marginal or unclear, a conservative position is taken with the hazard classified as catastrophic until proven otherwise. Avionics equipped with three electrical shock hazard controls need only be assessed for the independence of these controls.

6.4.2.1.1 Hazard Control Selection

{A}

Hazard controls for electric shock at the crew/machine interface must be independent controls (i.e., no single equipment failure or event can eliminate a control, and no single control failure, event, or environment can eliminate more than one control).

Typical methods of implementing these hazard controls include the use of:

1. safety (green) wire.
2. bonding,
3. insulation around electrically energized surfaces and conductive surfaces likely to become electrically energized upon experiencing a fault within the equipment,
4. barriers to electrically energized surfaces and conductive surfaces likely to become electrically energized upon experiencing a fault within the equipment, and
5. a ground fault interrupter (i.e., a device through which power is applied to the equipment wherein the device continuously monitors the difference between the current applied power applied upon detecting a difference in current beyond a preset threshold, the difference in current presumed to have been undesirably returned through ground).

As long as controls remain independent, two similar methods of hazard control may be utilized. For example, double insulation in which an insulation system comprised of basic insulation and supplementary insulation with the two insulations physically separated and so arranged that they are not subjected to the same deteriorating influences (i.e., failure, event, or environment) could represent two controls.

It should be noted that terrestrially, three (3) controls are frequently used. For example, hair blowers are typically fabricated with double insulated enclosures and derive power through fixed ground fault interrupters; many power tools are double insulated and frequently derive power through fixed or portable ground fault interrupters; and many power tools are double insulated, have a safety (green) wire, and frequently derive power through fixed or portable ground fault interrupters (4 controls).

6.4.2.2 Hazard Classification - Physiological Considerations

{A}

In order to classify a hazard as critical versus catastrophic, the physiological effects of electric current must be known. Included within these effects is the body impedance which appears to change non-linearly with varying voltages. In addition, a physiological effect of current through the skin is that the hands will not remain dry; skin will perspire at the point of contact with an electrically energized surface. Test reports from several independent investigators indicate that minute cuts or punctures that may be difficult to visually locate can greatly reduce the resistance of the skin by acting as short circuits through the skin. Therefore, conservative analysis should assume that the body contact areas are wet (i.e., skin resistance is negligible).

Most of the internal body resistance is attributed to the joints (wrist: 250 ohms; elbow: 150 ohms; shoulder: 100 ohms; knee: 100 ohms; ankle: 250 ohms; neck: 50 ohms; torso length: 100 ohms). Also reported is that people with long body parts appear to have higher body impedance than those with shorter body parts, and people with strong musculature generally have less body impedance than those who have weak musculature. Figure 6.4.2.2-1 shows the approximate value of internal body resistance with contact through the torso with different parts of the body.

Figure 6.4.2.2-1 Internal Body Resistance, OHMS

	HAND	ARM	TORSO	LEG	FOOT
HAND	1000	700	600	750	1100
ARM	700	400	300	450	800
TORSO	600	300	100	250	600
LEG	750	450	250	300	650
FOOT	1100	800	600	650	1000

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Rev. B

Reference: 403

Figure 6.4.2.2-1 Internal Body Resistance, OHMS

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6.4.2.2.1 Catastrophic Hazard Classification

{A}

The injurious physiological effects of the passage of electric current through the human body include the inability to let go of the electrically energized surface, stoppage of breathing, ventricular fibrillation of the heart, electric burns, and paralysis. The stoppage of breathing and paralysis are not the critical physiological effects if the limits for let-go and ventricular fibrillation, is totally disabling, and, if allowed to continue, can result in a fatal injury, let-go is the current threshold used to classify hazards as catastrophic.

The let-go current threshold is the current above which a person will be unable to release his/her grip on the electrically energized surface because of involuntary muscle contractions. The threshold current for let-go is affected by the physical characteristics of the body, and the frequency and wave shape of the current.

The 99.5 percentile rank recommended limits for direct current are 60 milliamperes (mA) for a man, 40 mA for a woman, and 30 mA for a child. For sinusoidal current at power line frequencies, the recommended limits are 9 mA root-mean-square (rms) for a man, 6 mA rms for a woman, and 4.5 mA rms for a child. Complex wave forms significantly decrease these recommended limits. As the frequency of the current is increased, the recommended current is increased.

If the exposure is expected to be limited to adults, the recommended limits for a woman is used. If the exposure might include children, the recommended limits for a child is used.

For many nonsinusoidal waveforms, the parameter of the current that is used for establishing limits is the peak value of the waveform instead of the rms value or the average of the rectified waveform. For waveforms consisting of both alternating current and direct current components, the recommended limit becomes more complex, and as either component approaches zero, the limit of the other component approaches the limit of the component alone.

In addition to using the let-go current threshold as a means of determining the number of hazard controls required to control the identified hazard, it is also used in the design of hazard controls that are current sensitive.

As an illustration, assume that a ground fault interrupter was designed to trip in 25 milliseconds with a 60 mA direct current trip threshold. Assume that the current conducted through the crewperson as the result of the open safety (green) wire was 58 mA direct current. The ground fault interrupter would not trip since the current was below its threshold. If the crewperson was a man, he would probably be able to let go, but if the crew person was a woman, there is a significant risk (p~75%) that she would not be able to let go, and barring intervention by another crewperson, might be in serious jeopardy.

Clearly, this ground fault interrupter should be designed to trip on a current threshold as low as possible without introducing false tripping due to leakage currents or transients. In addition, the selection of let-go current threshold must take into account the power frequency, frequencies superimposed on the power form the power system itself,

and frequencies that might be superimposed on the power system form the load attached to the ground fault interrupter both normally and as the result of a fault.

System response time, including the period from detection through power removal, must be evaluated so as to ensure rapid power removal (perhaps, within 25 milliseconds) upon encountering the fault current which might be exceeding the let-go threshold. Even at a level slightly above the let-go threshold, the crewperson is at risk for prolonged exposure.

Figure 6.4.2.2.1-1 is a compiled chart of let-go current thresholds and includes the results of composite waveform test. Figure 6.4.2.2.1-2 graphically describes the composite waveforms.

6.4.2.3 Bioinstrumentation

{A}

Bioinstrumentation should be designed to consider the interactions among several bioinstruments when multiple equipment are simultaneously connected to the same crewperson.

For invasive bioinstrumentation, the design should consider the effects of fluids contacting energized electrical surfaces (e.g., blood or saline leakage to an intravenous pressure transducer). It has been demonstrated that a current gradient, precipitated particles, and gas bubbles can be rapidly generated within the fluid when the fluid is exposed to voltages (i.e., test used just 5 volts direct current). The concern with the particles and gas bubbles is the possibility of migration to the crewmember's circulatory system, and the concern with the current gradient is the possibility of inducing ventricular fibrillation.

6.4.2.4 Leakage Current Verification

{A}

Hazard analysis for avionics which exhibit leakage currents below the threshold of perception may consider leakage current design control as an electrical hazard control for critical hazards.

The physiological response to the perception of current is frequency sensitive. A relatively precise method of verifying that leakage currents are below the threshold of perception entails the use of spectrum analysis to determine the root-mean-square (rms) current for each frequency component of the leakage current. An analysis is then performed to assure that these components are below the threshold of perception individually and in combination.

An alternate technique utilizes a simple, GO/NO-GO method to verify the leakage current levels. Utilizing a true rms voltmeter in conjunction with a resistor/capacitor network which synthesizes the human threshold of perception characteristics, the analysis reduces to determining if the total avionics leakage current as evidenced by the true rms voltmeter indication exceeds the maximum permissible level.

6.4.3 Electrical Hazards Design Requirements

{A}

Equipment design shall protect the crewmembers from electrical hazards.

In designing to minimize electrical shock hazards, controls shall be incorporated such that if the worst case credible failure can result in a crewmember exposure that:

a. is below the threshold for shock (i.e., below maximum leakage current and voltage requirements as defined within this Section), no control shall be required;

b. exceeds the threshold for shock and is below the threshold of let-go (critical hazard) as defined in Figure 6.4.3-1, two independent controls (e.g., a safety green) wire, bonding, insulation, leakage current levels below maximum requirements (shall be required such that no single failure, event, or environment can eliminate more than one control.; or, c. exceeds the threshold of let-go (catastrophic hazardous event), three independent controls shall be required.

If two independent controls are provided the, physiological electrical shock effect of the combination of the highest internal voltage applied to or generated within the equipment and the frequency and wave form associated with a worst case credible failure that can be applied to the crewmember shall be below that threshold of let-go.

Non-patient equipment with internal voltages not exceeding 30 volts rms (root-mean-squared) shall be considered as containing potentials below the threshold for electrical shock.

If the classification of the hazard is marginal or unclear, three independent hazard controls shall be required.

Figure 6.4.2.1-1 Let-Go Current Thresholds

LET-GO CURRENTS (mA) (99.5 Percentile Rank)						
WAVE FORM	MEN			WOMEN		
	AC (rms)	DC	AC crest (Im)	AC (rms)	DC	AC crest (Im)
DC		60.0			40.0	
Sinusoid:						
5 Hz	14.5			9.6		
10 Hz	9.8			6.5		
15-70 Hz	9.0			6.0		
180 Hz	10.4			6.9		
500 Hz	11.0			7.3		
1 kHz	13.7			9.1		
2.5 kHz	20.0			13.3		
5 kHz	29.3			19.5		
10 kHz	55.3			36.9		
COMPLEX³ (60 Hz sine with DC):						
Sine		0	12.7		0	8.4
25% offset		15.5	3.9		10.2	2.6
50% offset		10.9	5.4		7.2	3.6
141% offset		5.8	8.2		3.8	5.4
Rectified :						
Half wave		3.9	8.2		2.5	5.5
Full wave		9.8	5.6		6.5	3.7

Reference: 403

NOTES:

1. For adults, let-go current limits are those shown for women.
2. If children might be exposed to the hazard, let-go current limits are 1/2 those shown for men.
3. Refer to Figure 6.4.2.2.1-2 for graphical descriptions.

Figure 6.4.2.2.1-1 Let-Go Current Thresholds

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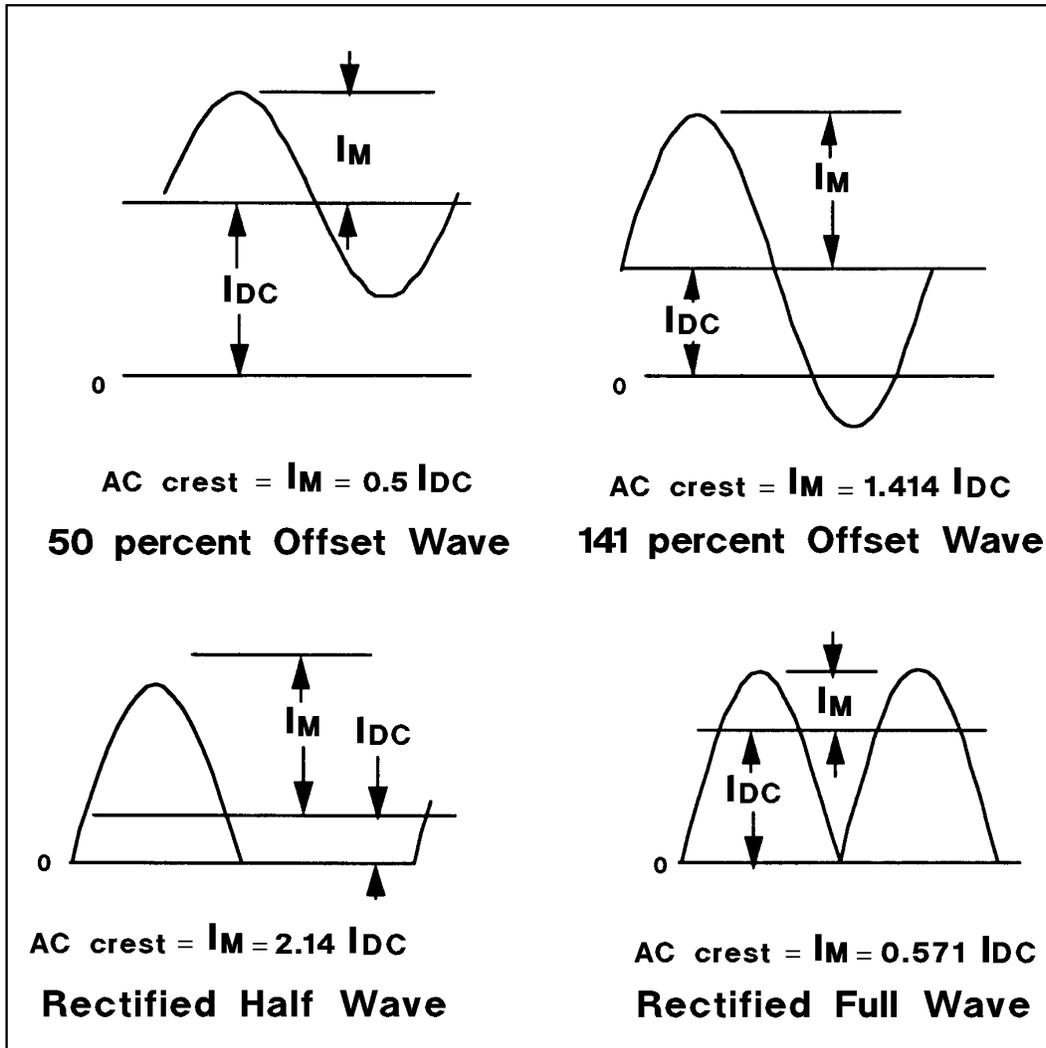
NASA-STD-3000 504

NOTES:

1. For adults, let-go current limits are those shown for women.
2. If children might be exposed to the hazard, let-go current limits are those shown for men.

3. Refer to Figure 6.4.2.2.1-2 for graphical descriptions.

Figure 6.4.2.2.1-2 Complex Waveforms With DC Components



Reference: 403

MSIS505
Rev. B

Figure 6.4.2.2.1-2 Complex Waveforms With DC Components

Figure 6.4.3-1 Let-Go Current Profile, Threshold Versus Frequency

(Based on 99.5 Percentile Rank of Adults)	
Frequency (Hertz)	Max Total Peak Current (ac + dc components combined) milliamperes
DC	40.0
15	8.5
2000	8.5
3000	13.5
4000	15.0
5000	16.5
6000	17.9
7000	19.4
8000	20.9
9000	22.5
>10000	24.3

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Reference: 404

Figure 6.4.3-1 Let-Go Current Profile, Threshold Versus Frequency

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6.4.3.1 Grounding

{A}

All electrical powered equipment external, non-isolated metal parts subject to user contact shall be at ground potential. A permanent bonding means shall be provided to facilitate the connection of metal parts to ground prior to the connection of any electrical signals or power. A permanent bonding means shall be provided to facilitate the removal of all electrical signals and power prior to the removal of metal parts from ground.

Grounding conductors internal to an ORU shall be secured internally to the Ores metal enclosure by means of a fastening technique unlikely to be removed during any servicing operation. Solder alone shall not be used for securing the grounding conductor.

Each grounding or bonding means shall be capable of conducting the maximum ground fault current amplitude and duration which might occur as the result of discharges (static, plasma, etc.), induced RF voltages, internal power-faulted equipment and accidental short circuits.

All grounding shall conform to the vehicle's grounding requirements.

6.4.3.1.1 Hinged or Slide Mounted Panels and Doors Grounding

{A}

Hinges or slides shall not be used for grounding paths. A ground shall be considered satisfactory if the electrical connection between the conductive door or panel, in both the open and closed position, and the equipment tie point exhibits a resistance of less than 0.1 ohms and has sufficient ampacity to insure the reliable and immediate tripping of associated equipment over-current protection devices.

6.4.3.2 Electrical Bonding

{A}

On-orbit electrical bonding shall meet the vehicle's requirements for electrical bonding to prevent damage to the vehicle or injury to crewmembers due to discharges (static, plasma, etc.), induced RF voltages, internal power-faulted equipment, and accidental short circuits. Each independent bonding path is considered a hazard control for electrical shock.

6.4.3.3 Protective Covers

{A}

Equipment shall provide grounded or nonconductive protective covering for all electrical hardware. These coverings shall protect against inadvertent contact from foreign object entering electrical junctions, and moisture accumulation.

6.4.3.4 Interlocks

{A}

Equipment access doors or covers shall incorporate interlocks to remove all potentials in excess of 150 V when open.

6.4.3.5 Warning Labels

{A}

Warning labels shall be provided where inadvertent contact with electrical potentials are hazardous to crewmembers. Warning labels shall comply with the requirements in Section 9.5.3 Labeling and Coding Design Requirements

6.4.3.6 Warning Labels Plus Recessed Connectors

{A}

Provide warning labels and recessed connectors or other protective measures where potentials exceed 150 V.

6.4.3.7 Plugs and Receptacles

{A}

Plugs and receptacles shall meet the requirements of Section 11.10 Connectors. In addition:

- a. Plugs and receptacles (connectors) shall be selected and applied such that they cannot be mismated or cross-connected in the intended system as well as adjacent systems. Although required, the use of identification alone is not sufficient.
- b. Connectors shall be selected and applied such that they have sufficient mechanical protection to mitigate inadvertent crewmember contact with exposed electrical contacts.
- c. Connectors shall be specifically designed and approved for mating and demating in the existing environment under the loads being carried, or connectors shall not be mated or demated until voltages have been removed (dead-faced) from the powered side(s) of the connectors.

6.4.3.8 Insulation

{A}

All materials shall meet the vehicle's requirements for materials and processes. In addition:

- a. All exposed electrical conductors and terminations shall be insulated.
- b. The crew shall be protected from electrical hazards when utilizing tools within 24 inches of exposed electrical potentials.

6.4.3.9 Portable Equipment/Power Cords

{A}

A ground fault circuit interrupter (GFCI) used in conjunction with a portable equipment shall be considered as one hazard control. Non-battery powered portable equipment shall incorporate a three-wire power cord with one wire at ground potential. A system of double insulation or its equivalent, when approved by the procuring agency, may be used without a ground wire.

6.4.3.10 Moisture Protection

{A}

Equipment shall be designed so that moisture collection will not present a safety hazard to the crew.

6.4.3.11 Static Discharge Protection

{A}

Equipment shall be designed so that the crewmembers are protected from static charge buildup.

6.4.3.12 Overload Protection

{A}

- a. The functioning of an overload protective device shall not result in a fire, electric shock, or crewmember injury.
- b. An overload protective device shall not be accessible without opening a door or cover. Exception: The operating handle or operating button of a circuit breaker, the cap of an extractor-type fuseholder, and similar parts may project outside the enclosure.
- c. The arrangement of extractor-type fuseholders shall be such that no energized parts are exposed at any time during fuse replacement.
- d. Overload protection (fuses and circuit breakers) intended to be manually replaced or physically reset on-orbit shall be located where they can be seen and replaced or reset.
- e. Each overload protector (fuses and circuit breakers) intended to be manually replaced or physically reset on-orbit shall be readily identified or keyed for its proper value.
- f. Overload protection shall be designed and rated for on-orbit use including the maximum environmental range expected as the result of contingencies.

6.4.3.13 Batteries

{A}

Unless intentionally designed for the purpose, batteries shall not be connected to or disconnected from a current drawing load. Batteries and their utilization will conform to the requirements of JSC 20793, Manned Space Vehicle Battery Safety Handbook, and JPL 86-14, The NASA Aerospace Battery Safety Handbook.

Batteries/battery packs with potentials above 30 volts dc (direct current) shall provide hazard controls as specified in Section 6.4.3.

6.4.3.13.1 Non-ORU Batteries

{A}

Non-ORU batteries shall be disconnectable and removable without special equipment. Mounting provisions shall ensure retention for all service conditions. Polarity of the battery terminals shall be prominently marked or battery terminal connections shall be polarized to mitigate erroneous installation.

6.4.3.14 Mechanical Assembly

{A}

A switch, fuseholder, lampholder, attachment plug receptacle, or other energized component that is handled by a crewmember shall be mechanically held (not relying on friction alone) to prevent turning in its mounting panel.

The mounting of components to a printed wiring board and the mounting of the printed wiring board itself shall be such that any forces that might be exerted on the components or board will not displace the components or deflect the board so as to produce an electric shock or fire.

6.4.3.15 Switches/Controls

{A}

Switches/controls shall be designed such as to prevent unplanned hazardous manual or automatic operation. Switches/controls which provide automatic starting after an overload initiated shutdown shall not be employed.

6.4.3.15.1 Power Switches/Controls

{A}

Switches/controls performing ON/OFF power functions shall open or dead-face all supply circuit conductors except the power return and the equipment grounding conductor while in the power OFF position.

Power OFF markings and/or indications shall only be used if all parts, with the exception of overcurrent devices and associated EMI filters, are disconnected from the supply circuit. STANDBY, CHARGING, or other appropriate nomenclature shall be used to indicate that the supply circuit is not completely disconnected for this power condition.

6.4.3.16 Power Driven Equipment Control Requirements

{A}

If a risk of injury to a crewmember or damage to equipment can result from the motion of power driven equipment:

- a. the controls for that mechanism shall be of a reversible type and shall not continue operation of the moving part in the same direction when a switch readily accessible to that crewmember is activated to initiate operation in the other direction, or
- b. the power driven equipment shall be mechanically constructed such that the injurious forces are immediately removed by activation of a switch readily accessible to that crewmember.

6.4.3.17 Ground Fault Circuit Interrupters (GFCI)

{A}

A non-portable utility outlet intended to supply power to portable equipment shall include a GFCI, as an electrical hazard control, in the power path to the portable equipment. GFCI trip current detection shall be independent of the portable equipment's safety (green) wire.

GFCI will be designed to trip below the threshold of let-go based upon the 99.5 percentile rank of adults. Non-portable utility outlets supplying power to portable equipment shall include a GFCI with trip point characteristics such that tripping will not exceed the currents specified in the profile shown in Figure 6.4.3-1.

Ground fault circuit interrupters that depend upon the analysis of current shall remove power within 25 milliseconds upon encountering the fault current.

GFCI shall provide an on-orbit method for testing trip current detection threshold at a frequency within the maximum human sensitivity range of 15 to 70 Hertz.

6.4.3.18 Leakage Current Design Requirements

{A}

Non-patient equipment with internal voltages not exceeding 30 volts rms (root-mean-squared) and non-patient equipment incorporating three independent hazard controls (excluding non-patient equipment incorporating leakage current as a control) shall not be required to verify leakage current design requirements.

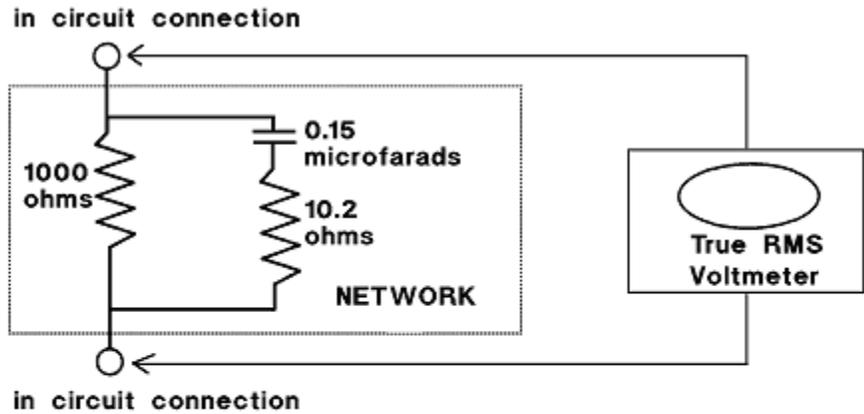
For designs using leakage current as a control, verification of leakage current design requirements shall be accomplished using the network shown in Figure 6.4.3.18-1. The leakage current (milliamperes) shall be computed as the voltage (volts) measured across the network in series with the grounding conductor (for chassis leakage current), or in series with the crewmember connection lead (for ordinary patient connection leakage current), divided by 1000. For isolated patient connection lead leakage current, a non-inductive, 1000 ohm resistor shall replace the network shown in Figure 6.4.3.18-1 for this measurement.

6.4.3.18.1 Chassis Leakage Current

{A}

Crewmembers shall not be exposed to excessive levels of leakage current from direct or indirect contact with electrically powered equipment. Equipment qualification shall include verification of acceptable chassis leakage currents as defined within Section 6.4.3.18. Leakage current test procedures for DC powered equipment shall not include reversed polarity input power tests.

Figure 6.4.3.18-1 Leakage Current Verification Network



Reference: 394

Notes:

1. Resistors are non-inductive.
2. Voltmeter is a true RMS (root-mean-squared) type with frequency bandwidth appropriate for the frequencies of the voltages being measured. Voltmeter frequency bandwidth may be limited to 20 megaHertz (MHz) for equipment-under-test frequencies above 20 MHz.

Figure 6.4.3.18-1 Leakage Current Verification Network

MSIS503
Rev. B

NASA-STD-3000 503

6.4.3.18.1.1 Chassis Leakage Current - Nonpatient Equipment

{A}

The chassis leakage currents for nonpatient equipment shall not exceed the values shown in Figure 6.4.3.18.1.1-1. Leakage current shall not exceed 0.700 milliamperes (ma) DC for grounded nonpatient Equipment, and leakage current shall not exceed 0.350 ma DC for double insulated nonpatient Equipment.

Figure 6.4.3.18.1.1-1 Non-Patient Equipment Maximum Chassis Leakage Current

ENCLOSURE OR CHASSIS				
GROUNDED		DOUBLE INSULATED		
DC ma	AC ma RMS	DC ma	AC ma RMS	
0.700	0.500	0.350	0.250	

MSIS 502
Rev. B

Reference: 394, 399

Figure 6.4.3.18.1.1-1 Non-Patient Equipment Maximum Chassis Leakage Current

NASA-STD-3000 502

6.4.3.18.1.2 Chassis Leakage Current - Patient Care Equipment

{A}

The chassis leakage currents for patient care equipment shall not exceed the values shown in Figure 6.4.3.18.1.2-1. Leakage current shall not exceed 0.140 ma DC for grounded patient care Equipment, and leakage current shall not exceed 0.070 ma DC for double-insulated patient care Equipment.

Figure 6.4.3.18.1.2-1 Patient Care Equipment Maximum Leakage Current

PATIENT CONNECTION				
Patient Interface	ISOLATED¹		ORDINARY	
	DC ma	AC ma RMS	DC ma	AC ma RMS
Invasive	0.014	0.010	Not Permitted	
Non-invasive	0.070¹	0.050¹	0.070	0.050

ENCLOSURE OR CHASSIS				
Patient Interface	GROUNDING		DOUBLE INSULATED	
	DC ma	AC ma RMS	DC ma	AC ma RMS
Invasive	0.140	0.100	0.070	0.050
Non-invasive	0.140	0.100	0.070	0.050

MSIS 501
Rev. B

Reference: 394, 399

NOTES:

1. If equipment labeling indicates "isolated," the maximum current is 0.014 ma dc/0.010 ma rms.

Figure 6.4.3.18.1.2-1 Patient Care Equipment Maximum Leakage Current

NOTES:

1. If equipment labeling indicates isolated, the maximum current is 0.014 ma dc/0.010 ma rms.

6.4.3.18.2 Crewmember Applied Current

{A}

Crewmembers shall not be exposed to excessive levels of leakage current from direct or indirect contact with electrically powered equipment. Equipment qualification shall include verification of acceptable patient connection leakage currents as defined within Section 6.4.3.18. Leakage current test procedures for DC powered equipment shall not include reversed polarity input power test.

The leakage currents for patient care equipment as seen from the patient end of cables or terminals shall not exceed the values shown in Figure 6.4.3.18.1.2-1.

Leakage currents shall be tested:

a. lead to ground

1. between each patient lead and ground, and
2. between combined patient leads and ground; and,

b. between leads

1. between any pair of patient leads, and
2. between any single patient lead and all other patient leads.

6.4.3.18.2.1 Leakage Current - Patient Care Equipment - Patient Connection - Isolated

{A}

a. Invasive Patient Interface - Isolated, patient connected, patient care equipment leakage current shall not exceed 0.014 ma DC for isolated, patient connected, patient care, Equipment such as intra-aortic pressure monitors.

b. Non-Invasive Patient Interface - Isolated, patient connected, patient care equipment leakage current shall not exceed 0.070 ma DC for isolated, patient connected, patient care, Equipment such as muscle stimulators utilizing attached body surface electrodes provided that equipment labeling does not indicate the equipment is isolated.

6.4.3.18.2.2 Leakage Current - Patient Care Equipment - Patient Connection - Ordinary

{A}

Ordinary, patient connected, patient care equipment leakage current shall not exceed 0.070 ma DC for ordinary, patient connected, patient care, Equipment such as blood pressure cuffs, thermometers, and limb muscle stimulators.

6.4.3.18.2.3 Health Maintenance System Instrumentation Grounding

{A}

Any two exposed conductive surfaces in the instrumented crewmember's vicinity shall not exceed a 40.0 millivolt potential difference at frequencies up to 1000 Hertz or less measured across a 1000 ohm resistor. conductive surfaces which can be contacted by an attending crewmember while the attending crewmember is in contact with the instrumented crewmember shall be considered as within the crewmember's vicinity.

6.4.3.18.2.4 Countermeasure System

{A}

Any two exposed conductive surfaces in the instrumented crewmember's vicinity shall not exceed a 40.0 millivolt potential difference at frequencies up to 1000 Hertz or less measured across a 1000 ohm resistor. conductive surfaces which can be contacted by an attending crewmember while the attending crewmember is in contact with the instrumented crewmember shall be considered as within the crewmember's vicinity.

6.4.3.18.2.5 Portable Medical Instrumentation

{A}

While attached to a crewmember, electrically powered medical instrumentation shall be:

- a. battery powered,
- b. double insulated,
- c. electrically isolated from ground, and
- d. not connected to vehicle power (e.g., charging).

6.4.3.19 Bioinstrumentation System Microshock Protection

{A}

All bioinstrumentation systems shall be designed with sufficient series resistance/isolation to limit to safe levels electrical shock currents that could flow through an instrumented crewmember including as the result of:

- a. contact with available electric sources, including those sources applied by an attending crewmember's simultaneous contact with the instrumented crewmember and other equipment or ground, and
- b. transients that may occur when the bioinstrumentation is either energized (turned ON) or deenergized (turned OFF).

Bioinstrumentation shall be designed with fault tolerant protection to prevent exceeding the current limit requirements defined within Figure 6.4.3.19-1.

Figure 6.4.3.19-1 Maximum Permissible Bioinstrumentation Fault Current

CLASSIFICATION	NUMBER OF FAULTS	MAXIMUM CURRENT (milliamperes dc/rms)
INVASIVE (ref. paragraph 6.4.3.18.2.1)	0	0.014/0.010
	1	0.014/0.010
	2	0.020/0.020
NON-INVASIVE (ref. paragraph 6.4.3.18.2.2)	0	0.070/0.050
	1	0.140/0.100
	2	0.500/0.500

Reference: 405

Figure 6.4.3.19-1 Maximum Permissible Bioinstrumentation Fault Current

NASA-STD-3000 500

6.5 TOUCH TEMPERATURE

{A}

6.5.1 Introduction

{A}

This section provides the design considerations and design requirements for surface touch temperature limits, both the upper and lower temperature limits, for IVA applications.

(Refer to Paragraph 14.2.3.11, EVA Touch Temperature and Pressure Design Requirements, for EVA-unique touch temperature limitations.)

6.5.2 Touch Temperature Design Considerations

{A}

Definition of surface touch temperature limits depends on several factors:

- a. Temperature of the surface to be touched
- b. Duration of touch
- c. Degree of thermal control
 1. Finish on surface
 2. Force of contact
 3. Size of contact area
- d. Diffusivity of the surface touched. Diffusivity is determined by the thermal conductivity divided by the product of the density of the material times its specific heat.

Tissue burns can occur when skin temperature reaches 45°C (113°F). Objects at temperatures in excess of this can be touched safely, depending on the variables listed above, as long as skin temperature is not raised to this level during the period of contact.

The lower temperature limits for surfaces continuously touched by the bare skin are controlled by the dew point and the variables listed above.

6.5.3 Touch Temperature Design Requirements

{A}

Surface touch temperature design requirements for minimizing crewmember discomfort and injury are as follows:

- a. The design goal for the maximum surface temperatures which can come into contact with bare skin shall be 40°C (104°F).
- b. The maximum allowable surface temperature for continuous contact with bare skin shall be 45°C (113°F).
- c. Incidental or momentary bare skin contact with surface temperatures from 46° - 49°C (114° - 120°F) is permissible. Warning labels shall be provided to alert crewmembers to these excessive temperature levels. Guards or insulation shall be provided to prevent crewmember contact with surface temperatures in excess of 49°C (120°F). Where contact with surfaces above this limit is required, adequate warning labels and protective equipment are required.
- d. For surfaces that must be touched with bare skin, the minimum temperature shall not be below 4°C (39°F). Where contact with surfaces below this limit is required, adequate warning labels and protective equipment are required.

(Refer to Paragraph 14.2.3.11, EVA Touch Temperature and Pressure Design Requirements, for EVA-unique touch temperature requirements.)

6.6 FIRE PROTECTION AND CONTROL

{A}

6.6.1 Introduction

{A}

This section provides fire hazard design considerations and requirements that pertain to the man/system interface. This includes fire detection and warning, crew interfaces with fire extinguishing systems, and crew emergency procedures. Materials selection, sensors, extinguishing systems are outside the scope of this document. Users interested in these topics should refer to Reference 1, Section 3.5.2, and Reference 21, DN3N2.

6.6.2 Fire Protection and Control Design Considerations

{A}

Fire is one of the most difficult hazards with which to cope in the aerospace environment. From the first statement of mission concept, the interactions between fire hazards and vehicle configuration must be analyzed and corrective action initiated during the initial design phases when cost is at a minimum.

a. Fire Hazard - Any cabin atmosphere where oxygen concentration is greater than 30% by volume is considered hazardous and special considerations must be made. Although the fire hazard is reduced significantly by the use of a two-gas system, it cannot be completely eliminated. The ignition temperature of most materials is decreased as much as 50% when exposed to this type of atmosphere. Spacecraft atmospheres of 100% oxygen amplify the dangers of fire once ignition occurs. This increased potential fire hazard places special emphasis on material selection and system design. Only materials with high ignition temperatures, slow combustion rates, and low explosion potentials should be used inside the pressurized cabin. Atmosphere movement by ventilation, cabin venting, or even crew movement can resupply the fire with oxygen, allowing flame propagation in the absence of convection.

First response during a fire emergency in a shirtsleeve environment should be to don an oxygen mask and turn off cabin ventilation. The oxygen mask is necessary because rapid oxygen consumption and toxic products of combustion allow little time for corrective action once the fire starts.

Careful design and proper choice of atmosphere and materials, in conjunction with a design hazard study to reduce flame propagation, can ensure that the three conditions of combustion (fuel, oxygen, and ignition source) are not encountered.

b Toxic Hazards - Within the confines of a space module, toxic products of combustion may pose a serious threat to the crew since the oxygen supply is limited and large amounts of carbon monoxide can be generated.

c. Fire Extinguishing - The fire potential within a spacecraft cabin cannot be totally eliminated. Spacecraft atmospheres make the cabin a fire zone and so require fire detection and extinguishing systems. Materials should be selected which minimize the likelihood of ignition, limit the spread of fire, and are self-extinguishing. Housekeeping also affects this potential because pure, nonflammable waste does not exist. Toxic and flammable gases from waste can evolve and the interaction of various items can cause spontaneous combustion. Therefore it is necessary to consider an integrated spacecraft fire extinguishing system. Selection of a fire extinguishing system for a spacecraft presents a unique problem. It must be usable in a microgravity environment and be completely compatible with an enriched oxygen atmosphere. In addition, the extinguishing agent must not support combustion in an oxygen enriched environment, emit toxic or anesthetic products when applied to a fire, interfere with visual observation, or

result in liquid or solid residue that will contaminate the spacecraft. Information available indicates three agents which best satisfy these basic requirements: carbon dioxide, Halon 1301, and water or water based agents.

d. Venting - Venting or cabin depressurization may be useful in dealing with accidental fires or cleanups. Venting action may initially accelerate flame propagation, depending on vent location and other considerations. Venting may be impractical for the following reasons: crewmembers are normally not in space suits, time to don space suits, ability to don a suit without assistance, and ability to don a suit in poor lighting (electrical equipment damage), and other stress factors should point out the inability of using this as an operational technique. The quantity of oxygen onboard is a governing factor in determining the use of venting. Therefore, if the loss of oxygen in an unmanned area or compartment can be tolerated, then the possible use of venting for fire control or cleanup should be considered.

e. Detection Systems - The ability to detect an inflight fire is difficult to predict. Open fire may be seen, although the heat load may not be sensed. Convection is provided in manned areas and this could make smoke visible or cause its odor to be detected. The enclosed out-of-sight regions around electrical equipment may not produce convection. Incipient overheated conditions may exist for extended periods before a fire occurs. These are not easy to detect unless sensors are provided. Also, the effect of microgravity, without convection or reduced convection, may cause no initial flame flicker.

(Refer to Reference 21, DN3N2, for more detailed discussion of manned spacecraft fire protection and control.)

6.6.3 Fire Protection and Control Design Requirements

{A }

Fire protection and control design requirements are given below.

6.6.3.1 General Requirements

{A}

6.6.3.1.1 Fire Protection System

{A}

A fire protection system comprising detection, warning, and extinguishing devices shall be provided during all mission phases.

6.6.3.1.2 Material Selection

{A}

Only approved fire-retardant materials shall be used.

6.6.3.2 Detection Requirements

{A}

6.6.3.2.1 Detection System Signals

{A}

The fire detection system shall provide signals to the vehicle warning system.

6.6.3.2.2 Reset and Self-test

{A}

The fire detection system shall have reset and self-test capabilities.

6.6.3.2.3 Sensor Replacement

{A}

All sensors shall be replaceable and accessible.

6.6.3.3 Warning System Requirements

{A}

Warning - General requirements for the fire warning system are as follows:

(Refer to Paragraph 9.4, Caution and Warnings, for complete description of design considerations and requirements.)

- a. The caution and warning system shall include a fire warning system to alert the crew in case of a fire.
- b. The fire warning system shall be capable of operating independently.
- c. Warnings shall be both visual and auditory to provide maximum information to the crew for timely action.
- d. The visual fire warning display shall be aviation red in accordance with MIL-STD-25050.

6.6.3.4 Extinguishing Requirements

{A}

- a. Automatic extinguishing equipment shall be provided to aid the crewmember in containing and extinguishing fires.
- b. Design of the vehicle and its components shall provide for rapid access with fire fighting equipment.
- c. Chemical agents used for fire extinguishing shall be compatible with the toxicity requirements of the spacecraft.
- d. Portable fire extinguishers shall be provided for open areas and a fixed fire extinguishing system shall be provided for enclosed inaccessible areas.
- e. Capability for removal of expended fire extinguishing material during post-fire cleanup shall be provided.
- f. Automatic extinguishing systems shall incorporate a disabling feature to prevent inadvertent activation during servicing.

6.7 DECOMPRESSION HAZARDS

{A}

The major effects of failure of a pressurized cabin or a space suite arises from;

- a. hypoxia due to the reduction in the partial pressure of oxygen in the lungs,
- b. decompression sickness due to the evolution of nitrogen bubbles in the blood and tissues,
- c. expansion of gas within various body cavities,
- d. cold injury and hypothermia due to exposure to low ambient temperatures and connective cooling of the individual,
- e. and vaporization of tissue fluids.

The physiological constraints imposed by these potential hazards requires judicious tradeoffs in order to meet engineering limitations and operational objectives so that performance, comfort, and protection of crewmembers are not compromised.

6.7.1 Hypoxia

{A}

Hypoxia is the most serious hazard following decompression. Although the degree of hypoxia is primarily related to the pressure to which the crewmember is exposed, the pressure differential and rate as well as the time elapsing before an adequate pulmonary partial pressure of oxygen is restored also influences the degree of the hypoxia in the period immediately following the decompression.

6.7.2 Decompression Sickness

{A}

The incidence of symptoms of decompression sickness depends on the absolute pressure and the duration of exposure. There are wide differences between individuals in their susceptibility to decompression sickness. Several factors seem to predispose individuals to decompression sickness, such as age, obesity and physical activity.

6.7.3 Gas Expansion

{A}

Gas expansion is generally not a significant problem during rapid decompression. Gas containing body cavities include the lungs, middle ear, sinuses, and gastrointestinal tract. Although the lung contains the largest volume of gas, rarely does pulmonary barotrauma occur; an overpressure of approximately 80 mm Hg is required. If pulmonary barotrauma occurs, a secondary hazard, that of arterial gas embolism can occur.

6.7.4 Short Duration Exposure

{A}

A short duration exposure to low temperatures will not cause serious impairment of performance or serious injury to individuals wearing lightweight clothing which encompasses the whole body. However, if exposure to low temperature lasts for more than a few minutes, uncovered skin will be damaged and general hypothermia may occur.

6.7.5 Vaporization of Tissue Fluids

{A}

Vaporization of tissue fluids will occur on exposure to pressures less than 47 mm Hg if portions of the body remain unpressurized. The need to maintain adequate oxygen pressure in the respiratory tract, and hence throughout the cardiovascular system to prevent hypoxia, also prevents vaporization of tissue fluids, except in the skin and subcutaneous tissues of unpressurized regions of the body.