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List of exhibits

12 Personnel safety

Human factors design rules that enhance the safety of FAA maintenance personnel are discussed in this section. Chapter 4, Designing equipment for maintenance; Chapter 10, Workplace design; and Chapter 13, Environment, also contain safety rules specific to their respective domains.

12.1 General

This general section discusses safety factors that are derived from human engineering and from application of military safety considerations and from FAA and OSHA health and safety considerations. The latter have precedence.

- **12.1.1 Safety factors.** As part of facility and equipment design, safety factors shall be given major consideration, including, as a minimum, the representative safety rules herein, together with the effective application of the human engineering rules in other sections of this document. Safety factors are also determined from the application of MIL-STD-822B to the acquisition program and from FAA Order 3900.19(B), OSHA 29 CFR 1910 and 1926 as they apply to the program. In the area of safety and health OSHA and FAA documents have precedence. [Source: 29 CFR 1910 and 1926; Department of Defense (MIL-STD-1472F), 1999]

12.2 Work space safety

Rules addressing general work space safety including the safety of maintainers using platforms, ramps, stairs, ladders, and handholds are given in this section.

12.2.1 General

- **12.2.1.1 Hazard alerting or alarm devices.** A hazard alerting or alarm device shall be provided to warn personnel of impending danger or existing hazards such as fire, radio frequency or X radiation, or the presence of combustible or asphyxiating gas. OSHA 29 CFR 1910.165 shall govern employee alarms for fire or other hazards that require escape (see also OSHA 29 CFR 1910.165 Appendixes A, B, and C for rules). [Source: 29 CFR 1910.165; MIL-STD-1472F, 1999; Department of Energy (DOE-HFAC1), 1992]

- **12.2.1.2 Location.** Hazard alerting or alarm devices shall be located where the people who must take corrective action can easily distinguish them. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.2.1.3 Redundant hazard alerting or alarm devices.** Redundant hazard-alerting devices of different types, for example, a light and a bell, shall be required if ambient noise could mask the audible alarm, or if the warning light could not be seen in the ambient illumination. Tactile devices may be used to alert employees who would not otherwise be able to recognize audible or visual alarms. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.2.1.4 Physical barriers.** Physical barriers (for example, safety chains, guards, shields, or walls) shall be provided in addition to safety labels, placards, and signs, to prevent contact with hazards, such as moving parts of machinery. Fixed and portable power tools shall be guarded in accordance with OSHA 29 CFR 1910.212 -247. Live electrical parts operating at 50 or more volts shall be guarded in accordance with OSHA 29 CFR 1910.303 (b)(2). Floor and wall openings shall be guarded in accordance with 29 CFR 1910.23. Power transmission apparatus shall be guarded in accordance with OSHA 29 CFR 1910.219. [Source: CFR 1910.212 –247, 29 CFR 1910.303; Department of Defense (MIL-HDBK-759B), 1992]

- **12.2.1.5 Obstruction-free.** Work spaces shall be free of obstructions that could cause injury to personnel either through accidental contact with the obstruction or because the obstruction forces the maintainer to adopt an awkward position. In accordance with OSHA 29 CFR 1910.22, all workplaces shall be kept clean and dry and shall not have obstructions where they would cause a hazard. [Source: 29 CFR 1910.22, MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.2.1.6 Emergency door and exit design and construction.** Emergency doors and exits shall be designed and constructed so that they:

  a. are simple to operate,

  b. are readily accessible,

  c. are clearly designated,

  d. are unobstructed,

  e. are simple to locate and operate in the dark,

  f. are capable of being opened in 3 sec or less,

  g. require 44 to 133 N (10 to 30 lb) of operating force to open,

  h. permit exit by one person in 5 sec or less, and

  i. do not in themselves, or in their operation, constitute a safety hazard. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

  Note. Means of egress and exit shall comply with OSHA 29 CFR 1910.35 -40.

- **12.2.1.7 Nonskid surfaces.** Stairs, ramps, platforms, and catwalks shall have skid-proof flooring, stair, and step treads. Where applicable, surfaces shall be treated with nonskid material that conforms to MIL-W-5044 and that is applied in accordance with MIL-W-5050. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.2.1.8 Illumination.** Adequate illumination shall be provided for all work spaces. Recommended and minimum levels are given in Exhibit 12.2.1.8. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

Exhibit 12.2.1.8 Specific task illumination requirements

Illumination levels

Work area or type of task	Lux* Recommended	(ft-C)	Lux* Minimum	(ft-C)
Corridors	215	(20)	110	(10)
Emergency lighting	NA**		30	(3)
Hallways	215	(20)	110	(10)
Passageways	215	(20)	110	(10)
Repair work:				
general	540	(50)	325	(30)
instrument	2155	(200)	1075	(100)
Service areas, general	215	(20)	110	(10)
Stairways	215	(20)	110	(10)

* As measured at the task object or 760 mm (30 in) above the floor.

** Recommended illumination is the level appropriate to the task.

12.2.2 Platforms, ramps, stairs, ladders, and handholds

- **12.2.2.1 Self-locking devices.** Self-locking or other fail-safe devices shall be incorporated on elevating stands, work platforms, and "draw bridges" to prevent accidental or inadvertent collapsing or falling. Safety requirements of OSHA 29 CFR 1910.21 -30 shall also apply to platforms and scaffolding. [Source: 29 CFR 1910.21 –30; MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992]

- **12.2.2.2 High centers of gravity.** Platforms that have a high center of gravity shall have anchors or outriggers for stability. [Source: MIL-HDBK-759B, 1992]

- **12.2.2.3 Safety measures.** Guardrails, safety bars, or chains shall be installed around platforms and across stair or step openings of ledges, catwalks, and the like. These guards shall be 1.1 m (42 in) above the standing surface. An additional guardrail shall also be provided between the platform and the top guardrail, safety bar, or chain. These top guardrails shall be no more than 1.1 m (42 in.) and no less than 91 cm (36 in.) from the platform. Safety chains shall only be used where it is not feasible to install guardrail or safety bars. [Source: MIL-STD-1472F, 1999]

- **12.2.2.4 Toe board or guard screen.** A toe board of 10 cm (4 in) to 15 cm (4 in) shall be used to guard floor openings or a guard screen shall extend from the floor base to the intermediate rail. [Source: MIL-STD-1472F, 1999]

  Note. OSHA 29 CFR 1910.23 (e) permits a 102 mm (4 in) toe board as a minimum.

  Discussion. The guard screen is used to prevent a person who falls on the platform from falling from the platform. It can also prevent most tools, parts, and equipment from falling from the platform. Toe boards are intended to prevent tools, parts, and equipment from falling as well as to prevent the worker's foot from slipping off the edge of the platform.

- **12.2.2.5 Safety mesh.** Screen or safety mesh shall be installed on the underside of open gratings, platforms, or flooring surfaces where there is a possibility that small tools, parts, or debris may fall through the grating onto maintainers or equipment beneath the platform. [Source: MIL-STD-1472F, 1999]

- **12.2.2.6 Telescoping ladders.** Adequate finger clearance shall be provided between the moving parts of telescoping ladders. [Source: MIL-STD-1472F, 1999]

- **12.2.2.7 De-icing ladders and steps.** Ladders and steps should be designed so they can be de-iced with hot water or steam. [Source: MIL-HDBK-759B, 1992]

- **12.2.2.8 Handholds.** Handholds shall be furnished where needed to assist maintainers in climbing onto a platform or in performing the intended maintenance tasks from the platform. [Source: MIL-STD-1472F, 1999]

- **12.2.2.9 Nonfixed handholds.** When a flat surface is desired, handholds shall fold or telescope so they are concealed or flush with the surface except when they are being used. Folding hand grips shall remain securely folded when not in use and maintainers shall not need tools to open them. [Source: MIL-HDBK-759B, 1992]

- **12.2.2.10 Fixed handholds.** Handholds should be fixed except when a flat surface is desired. [Source: MIL-HDBK-759B, 1992]

12.3 Equipment-related safety

Safety factors need to be a major part of equipment design. This section gives rules to protect from possible injury when using or working with hazardous equipment.

- **12.3.1 Hazardous operations.** The operation of switches or controls that initiate hazardous operations (for example, equipment-moving devices) shall require the prior operation of a related or locking control. When practical, the critical position of such a control shall activate a visual and auditory warning device in the affected work area. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.3.2 Accessibility.** Units of equipment shall be located and mounted so that they are accessible to the maintainer with minimal danger from electrical charge, heat, moving parts, radiation, or other hazards (see also Paragraph 12.4.1.1). [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.3.3 Test equipment stability.** Equipment, particularly portable equipment such as maintenance stands, tables, benches, platforms, and ladders, shall be designed for maximum stability and shall meet OSHA requirements. [Source: MIL-HDBK-759B, 1992]

- **12.3.4 Equipment with wheels.** Equipment with wheels shall be designed to maximize stability and safety when it is moved on ramps or inclines. [Source: MIL-HDBK-759B, 1992]

  Discussion. Ramps and inclines change the equipment's center of gravity. The lower wheels bear a majority of the weight. With heavier equipment, this may mean that weight is concentrated enough to exceed allowable ramp loads. Shifting the center of gravity also increases the risk that equipment will overturn.

- **12.3.5 Mechanically stored energy devices.** Personnel shall be protected from mechanical devices capable of storing energy, such as springs, levers, and torsion bars. A means shall be provided to release the stored energy. [Source: National Aeronautics and Space Administration (NASA-STD-3000A), 1989]

  Discussion. Protection can be achieved by shielding the stored energy devices. The release of stored energy can be achieved by a device that automatically releases the energy or by a device or procedure that permits the personnel to safely release the energy.

- **12.3.6 Safety features.** Where stored energy devices are necessary, safety features such as removal tabs, lockouts, and warning placards shall be provided (see also Section 12.16). [Source: NASA-STD-3000A, 1989]

- **12.3.7 Equipment coloring.** Equipment designed for safety, protective, or emergency functions should be colored in accordance with MIL-STD-1473. [Source: MIL-HDBK-759B, 1992]

12.4 Electrical hazards

The principal electrical hazard is shock. The effects of electric shock depend on the body's resistance, the current path through the body, the duration of the shock, the amount of current and voltage, the frequency of the alternating current, and the individual's physical condition. The most critical determinant of injuries is the amount of current conducted through the body. Besides the obvious risk of burns and injuries to the nervous system, electric shock can produce involuntary muscular reactions that injure people. Exhibit 12.4 gives the typical effects of various current intensities. All electrical systems of 30 volts or more are potential shock hazards. Research reveals that most shock deaths result from contacts with electrical systems ranging from 70 to 500 volts. Under extraordinary circumstances, even voltages below 30 volts can cause injury. [Source: MIL-HDBK-759B, 1992;NASA-STD-3000A, 1989]

Exhibit 12.4 Shock current intensities and their effects

Current (mA)	Effects
Less than 1	Usually not felt (no sensation)
1-2	There is a sensation of shock.
3-15	Painful shock occurs, but the individual can still let go.
16-20	Painful shock occurs and the individual may not be able to let go because control of the immediately adjacent muscles is affected.
21-50	Very painful shock occurs plus severe muscular contractions. Breathing typically becomes difficult.
51-100	Ventricular fibrillation (a heart condition that may result in death).
101-200	Same as above except that the results are certain.
201 and up	Severe burns occur as well as muscle contractions so severe that the other muscles stop the heart during the duration of the shock.

12.4.1 General

The two basic types of safety switches for preventing electric shock are interlocks and main-power switches. [Source: MIL-HDBK-759B, 1992]

Definitions. Interlocks are devices (for example, switches) connected with a cover, shield, or case that disable the associated internal hazard (usually electrical) when the cover, shield, or case is opened. OSHA regulations discuss lockout and tagout procedures to be used in the workplace during maintenance or operations to protect from electrical hazards. A **lockout** uses a mechanical mean to disable a control or switch in its safe position (for example, electricity disconnected) and to prevent its activation without the use of undue force or tools. **Tagouts** are tags that are attached to a control or place of hazard associated with an ongoing mode of operation or maintenance.

- **12.4.1.1 Protection from electric shock.** Personnel shall be protected from accidental contact with voltages in excess of 30 volts AC or DC by interlocks, grounding, and other protective devices. [Source: MIL-HDBK-759B, 1992; Department of Defense (MIL-STD-454M), 1989]

  Discussion. Human protection from hazardous conditions with unexpected energy or release of stored energy is treated in OSHA 29 CFR 1910.301 -308, 331 -335, and 399. OSHA 29 CFR 1910.333 (b)(2)(iii)(A) requires the simultaneous use of both tagout and lockout in the workplace; OSHA 29 CFR 1910.333 (b)(2)(ii)(B) states that interlocks shall not be the sole mean of de-energizing circuits of equipment and are not substitutes for lockout and tagout procedures and practice. [Source: 29 CFR 1910.301 -308, 331 -335, and 399]

- **12.4.1.2 Rubber insulating equipment.** To help ensure the safety of personnel, insulated rubber gloves and live line tools shall be provided for personnel working on or near energized power circuits and equipment rated over 600 volts. [Source: Department of Transportation (FAA Order 3900.19A), 1982]

- **12.4.1.3 Selection of rubber insulating equipment.** Rubber protective equipment shall be selected in accordance with the voltages and equipment maintained. Exhibit 12.4.1.3 provides proof test for various classes of protective gloves. OSHA 29 CFR 1910.137 specifies that the rubber protective equipment for electrical workers conform to ANSI standards. (See 29 CFR 1910.137 for testing of applicable ANSI standards). FAA Order 3900.19B 145B specifies that new rubber gloves shall be tested before used and at a minimum each 12 months. Reissued rubber glove shall be retested within 9 months of issue. [Source: 29 CFR 1910.137; FAA Order 3900.19A, 1982]

Exhibit 12.4.1.3 Proof test values for protective gloves

		Maximum proof test current (mA)			
Class of glove	**3 min. proof test voltage RMS (Volts)**	**10.5" glove**	**14" glove**	**16" glove**	**18" glove**
Class 0	5,000	8	12	14	16
Class I	10,000	-	14	16	18
Class II	20,000	-	16	18	20
Class III	30,000	-	18	20	22
Class IV	40,000	-	-	22	24

- **12.4.1.4 Static charge buildup.** Equipment design shall prevent static charge buildup or provide a method to discharge it. [Source: NASA-STD-3000A, 1989]

  Discussion. The effects of electrostatic buildup can range from minor discomfort (the shock from walking across a new carpet and touching a metal object) to physical injury.

- **12.4.1.5 Fail-safe.** The design and development of all electronic equipment shall provide fail-safe features for safety of personnel during installation, operation, maintenance, and repair or interchanging of a complete equipment assembly or component parts. [Source: 29 CFR 1910.7; MIL-STD-454M, 1989]

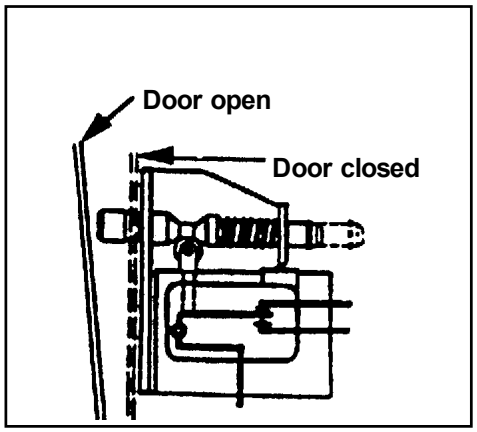
- **12.4.1.6 Electrical conductors.** Electrical conductors with which personnel might come into contact during maintenance activities shall be insulated. [Source: NASA-STD-3000A, 1989]

- **12.4.1.7 Power.** Personnel shall be provided a means for removing power while they are installing, replacing, or repairing components or equipment. [Source: MIL-STD-454M, 1989]

- **12.4.1.8 Covers.** Grounded or nonconductive protective covers shall be provided for all electrical equipment. [Source: NASA-STD-3000A, 1989]

- **12.4.1.9 Bypassable interlocks.** Doors, covers, or lids that provide access to voltage in the range of 70 to 500 volts shall have a bypassable interlock. Equipment that has been bypassed shall conform to OSHA 29 CFR 1910.333 (c)(10). Exhibit 12.4.1.9 shows an example of such an interlock. [Source: 29 CFR 1910.333; MIL-HDBK-759B, 1992; NASA-STD-3000A, 1989; MIL-STD-454M, 1989]

Exhibit 12.4.1.9 An interlock switch



- **12.4.1.10 Non-bypassable interlocks.** Doors, covers or lids that provide access to voltages in excess of 500 volts or allow exposure to microwave and radio frequency radiation in excess of 300 KHz shall have non-bypassable interlocks. [Source: MIL-STD-454M, 1989]

- **12.4.1.11 Interlock override.** If a task requires that a maintainer work on hazardous equipment that is equipped with a disabling interlock, the equipment shall have an interlock override that permits manual bypassing or overriding of the interlock when the case or cover is open. This override shall automatically reset to the safety-protection position when the cover or case is replaced. OSHA 29 CFR 1910.333 requires that only qualified personnel shall be allowed to disable an interlock. [Source: 29 CFR 1910.333; Department of the Air Force (AFSC DH 1-3), 1980; Department of Energy (UCRL-15673), 1985; MIL-HDBK-759B, 1992]

- **12.4.1.12 Medium voltage guarding.** If contacts, terminals, or other similar devices having voltages between 70 and 500 volts ac or dc with respect to ground are exposed, they shall be guarded from accidental contact by maintainers (see Paragraph 12.16.6 concerning wording for medium voltage labels and placards). [Source: MIL-STD-454M, 1989]

- **12.4.1.13 High voltage guarding.** Systems or equipment operating in excess of 500 volts ac or dc shall be completely enclosed (see Paragraph 12.16.7 concerning wording for high voltage labels and placards). [Source: MIL-STD-454M, 1989]

- **12.4.1.14 Guarding radio frequency (rf) voltages.** Transmitter output terminals, antennas, and other devices that carry sufficient rf voltage to burn or injure personnel shall be guarded from accidental contact. [Source: MIL-STD-454M, 1989]

- **12.4.1.15 Explosion-proof equipment.** All electrical equipment that will be used near flammable gases or vapors shall be explosion-proof. This equipment shall also be certified or listed by a nationally recognized testing laboratory recognized by OSHA (for example, Underwriters Laboratory). [Source: MIL-HDBK-759B, 1992]

- **12.4.1.16 Plugs and receptacles.** Plugs and receptacles shall be designed so that a plug of one voltage rating cannot be inserted into a receptacle of another rating. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- **12.4.1.17 "Hot" leads.** Wiring shall be routed through plugs and receptacles so that "hot" leads are not exposed in either the plug or the receptacle when they are disconnected. [Source: MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992]

- **12.4.1.18 Design and location of electrical installations and electrical utilization equipment.** The design and location of electrical installations and electrical utilization equipment shall conform with OSHA 29 CFR 1910.302 through 308 which includes rules for workspace clearances around such equipment dependent upon its nominal voltage to ground and nominal voltage between phases for elevated energized parts. These rules apply to the protection of qualified electrical or electronic repair people, unqualified electrical or electronic repair people, and other unqualified personnel who could be exposed to electrical hazards or to electrical equipment in classified hazardous electrical locations. OSHA 29 CFR 1910.331 -335 address safety related work practices. [Source: 29 CFR 1910.302]

12.4.2 Switches

- **12.4.2.1 Main-power switches.** A unit of equipment shall have a clearly labeled main-power switch that turns off all power by opening leads from the main-power service connection. [Source: MIL-HDBK-759B, 1992]

- **12.4.2.2 Main-power switch location.** Main-power switches shall be located so that accidental contact by maintainers will not place the equipment in operation. A lockout shall be provided as specified in OSHA 29 CFR 1910.335 (b)(2). [Source: 29 CFR1910.333(b)(2); MIL-STD-454M, 1989]

- **12.4.2.3 Physical protection at main-power switches.** The "hot" side of the main-power switch and the incoming power line connections shall be physically protected against accidental contact by maintainers. [Source: MIL-STD-454M, 1989]

- **12.4.2.4 Arc prevention.** Main-power switches shall be safeguarded to prevent heavy arcing. [Source: MIL-HDBK-759B, 1992]

- **12.4.2.5 Safety switches.** Safety switches that will deactivate associated mechanical drive components shall be provided for the purpose of disconnecting these components without disconnecting other parts of the equipment. [Source: MIL-STD-454M, 1989]

- **12.4.2.6 Switch box safety.** The switch box should be designed so the box cannot be opened when the switch is turned on. [Source: MIL-HDBK-759B, 1992]

12.4.3 Discharging devices

Circuits that contain capacitors can store lethal charges for relatively long periods of time therefore all medium- and high-voltage power supplies need devices that discharge the capacitors when they are turned off.

- **12.4.3.1 Bleeders.** Bleeders shall be incorporated in all power supplies unless they can discharge 30 volts or less within 2 sec after power removal. When a resistive bleeder network is used to discharge capacitors, the bleeder network shall consist of at least two equal valued resistors in parallel. [Source: MIL-HDBK-759B, 1992; MIL-STD-454M, 1989]

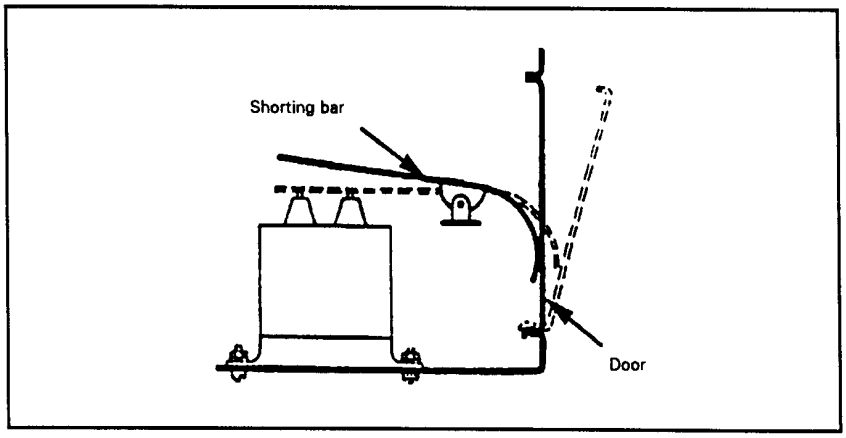
  Discussion. It is better to discharge capacitors gradually, rather than shorting them. High-power resistors are often used in place of a grounding rod with several thousand ohms of resistance being a typical value. DC power supplies may be discharged when switched off by having a permanently connected bleeder resistor across the output terminals. The bleeder resistor needs to be of low enough resistance so that it is able to discharge the capacitors quickly after the power is turned off but not so low that it overloads the circuit.

- **12.4.3.2 Shorting rods.** Shorting rods shall be provided (in addition to bleeder resistors) with all equipment having voltages in excess of 70 volts ac or dc. [Source: MIL-STD-454M, 1989]

  Discussion. Some circuits with large, high-voltage capacitors (such as high-voltage radar equipment) cannot use bleeder resistors; other methods need to be used to discharge the capacitors before doing maintenance. Often capacitors are discharged with a shorting or grounding rod that has a well-insulated handle.

- **12.4.3.3 Removing power.** Interlocks shall remove power by mechanical releases or electrical solenoids, before automatic shorting bars (see Exhibit 12.4.3.3) discharge the power supply. These bars shall operate automatically whenever the enclosure is opened and function quickly, with high reliability. [Source: MIL-HDBK-759B, 1992]

Exhibit 12.4.3.3 Automatic shorting bar



- **12.4.3.4 Shorting rod storage.** Where size permits, shorting rods shall be stored within the transmitting equipment, permanently attached, and readily accessible to maintainers. The permanently attached rod shall be connected through a flexible stranded copper wire (covered with a transparent sleeve) to the stud provided at the transmitter main frame. Where size does not permit internal storage of a shorting rod, a grounding stud shall be provided to permit attachment of a portable shorting rod. The connection to the stud shall be such that accidental loosening or high resistance to the ground is prevented. [Source: MIL-STD-454M, 1989]

12.4.4 Grounding

Various grounding techniques are used to protect maintainers from dangerous voltages in equipment. A terminal that is spot-welded to the chassis provides a reliable ground connection. Rules for other methods are also given in this section. [Source: MIL-HDBK-759B, 1992]

- **12.4.4.1 Same common ground.** All enclosures, exposed parts, and the chassis shall be kept at ground potential by a common ground. [Source: MIL-STD-454M, 1989; MIL-HDBK-759B, 1992; NASA-STD-3000A, 1989]

- **12.4.4.2 Path to ground.** The path from the ground connection to ground shall:

  a. be continuous and permanent,

  b. have ample carrying capacity to conduct safely any currents that may be imposed on it,

  c. have impedance sufficiently low to limit the voltage above ground and to facilitate the operation of the over-current devices in the circuits, and

  d. have sufficient strength to minimize the possibility of ground disconnection. [Source: MIL-STD-454M, 1989]

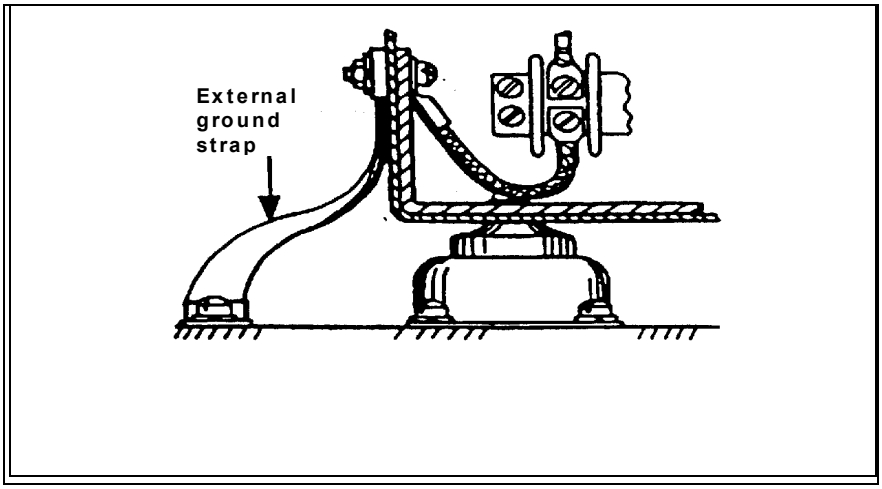
- **12.4.4.3 Grounding techniques.** If welding is not feasible, for example with aluminum chassis, the ground connection of equipment shall be attached with a machine bolt, lock washer, and nut. [Source: MIL-HDBK-759B, 1992]

- **12.4.4.4 Nonconductive finishes.** Any nonconductive finish on a unit of equipment shall be removed before attaching the ground connection. [Source: MIL-HDBK-759B, 1992]

- **12.4.4.5 Rivet connections.** Ground connections shall not be attached with rivets because rivets do not give reliable electrical connections. [Source: MIL-HDBK-759B, 1992]

- **12.4.4.6 Equipment grounding.** The common ground of equipment should connect to a bolt that goes through the enclosure and that is clearly marked "ENCLOSURE GROUND". An external safety ground strap should, in turn, be connected to this bolt. The external safety ground strap should be a plated flexible copper strap with a current-carrying capacity at least twice as large as the equipment requires (see Exhibit 12.4.4.6). [Source: MIL-HDBK-759B, 1992]

Exhibit 12.4.4.6 Equipment grounding



- **12.4.4.7 Ground connections.** Ground connections to shields, hinges, slides, or other mechanical components shall not be used to complete electrical circuits. [Source: MIL-STD-454M, 1989]

- **12.4.4.8 Hinges and slides.** Hinges and slides shall not be used for grounding paths. [Source: MIL-STD-454M, 1989]

- **12.4.4.9 Panels and doors.** Panels and doors that contain meters, switches, and test points shall be attached or hinged so that they are at the same voltage as the equipment in which they are mounted, whether opened or closed. [Source: MIL-STD-454M, 1989]

  Discussion. A ground is considered satisfactory if the electrical connection between the door or panel and the ground connection exhibits a resistance of 0.1 ohm or less. A satisfactory ground also has sufficient current-carrying capacity to ensure the reliable and immediate tripping of equipment over-current protection devices.

- **12.4.4.10 Ground wire in the cable.** Any external or interconnecting cable in which a ground is part of the circuit shall include a ground wire in the cable. This ground wire shall be terminated at both ends in the same way as the other conductors. [Source: MIL-STD-454M, 1989]

- **12.4.4.11 Cable shields as grounds.** Cable shields shall not be used as current-carrying ground connections except with coaxial cables. [Source: MIL-STD-454M, 1989]

- **12.4.4.12 Test equipment.** Test equipment (signal generators, amplifiers, and oscilloscopes) that is connected by a plug shall have an integral ground prong. [Source: MIL-HDBK-759B, 1992]

12.4.5 Electrical tools and self-powered equipment

- **12.4.5.1 Insulation of tools.** Tools used near high voltages shall be insulated. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- **12.4.5.2 Electrical cords.** Electrical hand-held power tools shall be designed with three-wire power cords with one wire grounded. Portable tools protected by an approved system of double insulation or its equivalent may be used without a ground wire when approved by the acquisition program office. [Source: MIL-STD-1472F, 1999; NASA-STD-3000A, 1989]

- **12.4.5.3 Exposed surfaces of tools.** Electrical hand-held power tools shall have exposed surfaces that are either nonconducting or are electrically connected to the ground wire. [Source: MIL-STD-1472F, 1999]

  Discussion. Exposed surfaces include cases, grips, handles, switches, triggers, chucks, and other surfaces with which maintainers might come into contact with during operation.

- **12.4.5.4 Same voltage.** All external surfaces of self-powered equipment shall be at the same voltage. [Source: MIL-STD-454M, 1989]

12.5 Physical hazards

General safety rules for physical hazards are given in this section. This section focuses on making equipment free of potential physical hazards to maintainers. Guards, caps, and shields are addressed specifically.

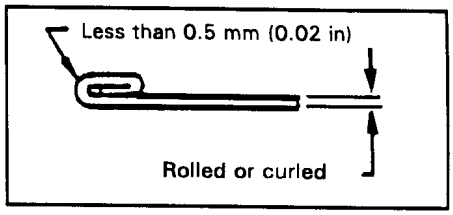
12.5.1 General

- **12.5.1.1 Protective devices.** Protective covers, cases, or padding shall be used on protrusions or other objects that cannot be made completely hazard free. [Source: NASA-STD-3000A, 1989]
- **12.5.1.2 Carried units.** Components and equipment shall be designed so maintainers can carry them without risk of cutting their hands on sharp edges. [Source: MIL-HDBK-759B, 1992]
- **12.5.1.3 Countersunk screws.** Screws shall be countersunk if a smooth surface is required. [Source: UCRL-15673, 1985; MIL-HDBK-759B, 1992]

■ **12.5.1.4 Exposed edges.** Exposed edges shall be either protected by rubber, fiber, or plastic or rounded as follows:

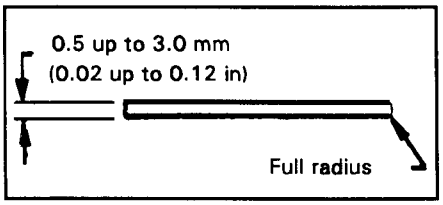
a. The edges of thin sheets less than 0.5 mm (0.02 in) thick shall be rolled or curled as shown in Exhibit 12.5.1.4 (a).

Exhibit 12.5.1.4 (a)
Rolling edges of sheets less than 0.5 mm (0.02 in) thick.



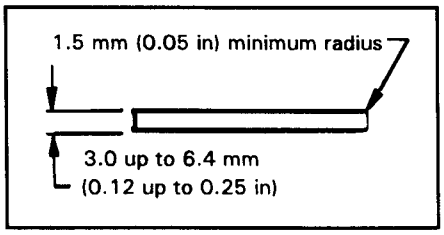
b. Exposed edges 0.5 to 3.0 mm (0.02 up to 0.12 in) thick shall be rounded to a full radius as shown in Exhibit 12.5.1.4 (b).

Exhibit 12.5.1.4 (b)
Rounding exposed edges 0.5 up to 3.0 mm (0.02 up to 0.12 in) thick.



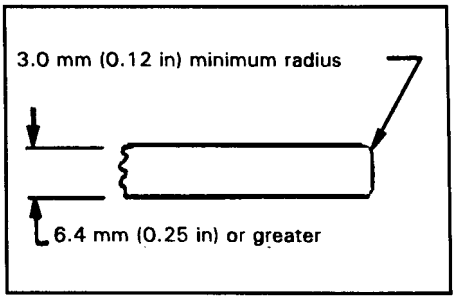
c. Exposed edges 3.0 up to 6.4 mm (0.12 up to 0.25 in) thick shall be rounded to a minimum radius of 1.5 mm (0.05 in) as shown in Exhibit 12.5.1.4 (c).

Exhibit 12.5.1.4 (c)
Rounding exposed edges 3.0 to 6.4 mm (0.12 up to 0.25 in) thick.



d. Exposed edges 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 Exhibit 12.5.1.4 (d). [Source: NASA-STD-3000A, 1989]

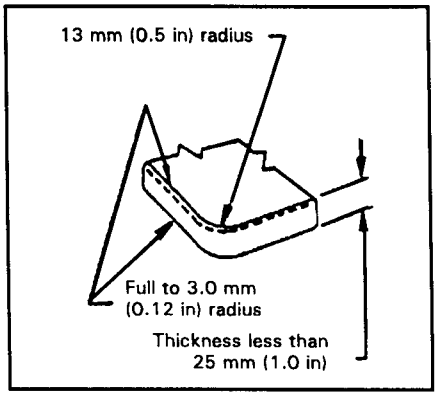
Exhibit 12.5.1.4 (d)
Rounding of exposed edges 6.4 mm (0.25 in) thick or greater



■ **12.5.1.5 Exposed corners.** Exposed corners shall be rounded as follows:

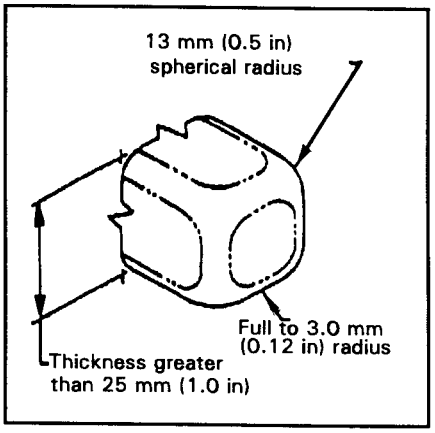
a. Exposed corners less than 25 mm (1.0 in) thick shall be rounded to a minimum radius of 13 mm (0.5 in) as shown in Exhibit 12.5.1.5 (a).

Exhibit 12.5.1.5 (a) Requirements for rounding of corners less than 25 mm (1.0 in) thick.



b. Exposed corners 25 mm (1.0 in) thick or greater shall be rounded to 13 mm (0.5 in) spherical radius, as shown in Exhibit 12.5.1.5 (b). [Source: NASA-STD-3000A, 1989]

Exhibit 12.5.1.5 (b) Requirements for rounding of corners greater than 25 mm (1.0 in) thick.



▫ **12.5.1.6 Projecting components.** In areas where maintainers must make rapid movements, small projecting components should be avoided or covered. [Source: MIL-HDBK-759B, 1992]

Discussion. If small projecting parts (such as toggle switches or small knobs) must be mounted on a front panel, recessed mountings of these projecting parts are desirable.

■ **12.5.1.7 Latches.** Latches or similar devices that can pinch fingers shall not be used. [Source: NASA-STD-3000A, 1989]

- **12.5.1.8 Levers, cranks, hooks, and controls.** Levers, cranks, hooks, and controls shall not be located where they can pinch, snag, or cut the maintainer or his or her clothing. [Source: NASA-STD-3000A, 1989]

- **12.5.1.9 Burr free.** Exposed surfaces that can be grasped by the bare hand shall be free of burrs. [Source: NASA-STD-3000A, 1989]

- **12.5.1.10 Capped bolt threads.** Bolts with more than two exposed threads shall be capped to protect the maintainer from the sharp threads. [Source: NASA-STD-3000A, 1989]

- **12.5.1.11 Air-exhaust openings.** Air-exhaust openings used to cool equipment should be located so that maintainers are not exposed to moving parts or direct drafts. [Source: MIL-HDBK-759B, 1992]

12.5.2 Guards, caps, and shields

- **12.5.2.1 Avoiding accidental contact.** Equipment shall have shields and guards to prevent maintainers from accidentally touching rotating or oscillating parts such as gears, couplings, levers, cams, and large solenoids. [Source: MIL-HDBK-759B, 1992]

- **12.5.2.2 Enclosure of hazardous components.** Any component that rotates, oscillates, or carries high voltage shall be enclosed so that maintainers cannot accidentally come in contact with the component. [Source: MIL-HDBK-759B, 1992]

- **12.5.2.3 Ventilation holes.** If a cover or shield requires ventilation holes, the holes shall be small enough to prevent inadvertent insertion of objects that might touch high voltage sources or moving parts. [Source: AFSC DH 1-3, 1980]

- **12.5.2.4 High-temperature units of equipment.** High-temperature units of equipment shall be located, guarded, or shielded so that maintainers will not accidentally touch them. [Source: MIL-HDBK-759B, 1992]

- **12.5.2.5 Guard design.** Guards should be designed and mounted so that maintainers do not have to remove them in order to inspect components. Guard design and applications should comply, as applicable with provisions of OSHA 29 CFR 1910.211 -222 which addresses guarding for various industries. [Source: 29 CFR 1910.211 – 222; MIL-HDBK-759B, 1992]

12.6 Liquid and gas hazards

This section gives rules for maintaining safety near liquid and gas lines. OSHA 29 CFR 1910.101 -111 address handling of hazardous gases and liquids including those that are flammable and combustible. Electrical requirements associated with such hazards are treated.

- **12.6.1 Releasing gases.** Equipment shall not release gases that combine with the atmosphere to form an acid or corrosive alkali that would be detrimental to the health of the maintainer. [Source: Department of Transportation (FAA-G-2100F), 1993; MIL-STD-454M, 1989]

- **12.6.2 Distinctive types.** Connectors for lines serving different functions, for example, fuel lines and water lines, or electrical power lines and radio-frequency signal lines, shall be distinctively different and physically incompatible. [Source: UCRL-15673, 1985]

- **12.6.3 Automatic shutoffs.** Automatic shutoff devices shall be provided on fluid and fuel service equipment to prevent overflow and spillage. [Source: MIL-STD-1472F, 1999]

- **12.6.4 Avoid spraying fluids.** Lines shall be kept from spraying or draining fluid on personnel or equipment during disconnection by: (1) locating connections away from work areas and sensitive components, (2) shielding sensitive components where required, and (3) providing drains and bleed fittings so lines can be drained or depressurized before they are disconnected. [Source: MIL-HDBK-759B, 1992; UCRL-15673, 1985]

- **12.6.5 Mercury.** Components and equipment containing mercury shall not be used unless use of mercury is specifically required or approved by the acquisition program office. [Source: FAA-G-2100F, 1993; MIL-STD-454M, 1989]

- **12.6.6 OSHA safety criteria for hazardous gases and liquids.** Design and handling for hazardous liquids and gases shall be governed by OSHA 29 CFR 1910.101 -111. [Source: 29 CFR 1910.101 -111]

12.7 Toxic hazards

All reasonable precautions need to be taken to eliminate hazards from toxic fumes, for example, those from the exhausts of internal combustion engines. From the standpoint of health hazards, the most widespread toxic hazards are carbon monoxide from gasoline engines, and aldehydes and nitrogen oxides from diesel engines. This section gives rules for keeping toxic hazards within safe limits in the maintainer's environment. OSHA 29 CFR 1910 addresses toxic chemical hazards and their control. OSHA 29 CFR 1910.1450 addresses controls and exposures in laboratories. Exposures to cleaning materials is addressed in OSHA 29 CFR 1910.107 and 252. Specific chemical agents, air contaminants and fibers, and processing operations are covered in OSHA 29 CFR 1910.

- **12.7.1 Exposure.** Maintainers shall not be exposed to concentrations of toxic substances in excess of the limits specified in either OSHA 29 CFR 1910 or the American Conference of Governmental Industrial Hygienists Threshold Limit Values. If a discrepancy exists between these documents, OSHA 29 CFR 1910 shall take precedence. [Source: 29 CFR 1910; MIL-STD-1472F, 1999; Department of Defense (MIL-STD-1800A), 1990; MIL-HDBK-759B, 1992]

- **12.7.2 Carbon monoxide.** Maintainers shall not be exposed to concentrations of carbon monoxide (CO) in excess of 50 parts per million (ppm) or 55 mg/m^3. [Source: 29CFR 1910.100; MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992]

  Discussion. Carbon monoxide is particularly dangerous in that it is odorless, colorless, and tasteless. Its effects are cumulative; doses that may be tolerable by individuals over brief periods may prove to be dangerous to them when repeated or prolonged over several hours.

  Carbon monoxide combines with the blood to form carboxyhemoglobin (COHb). CO accumulates rapidly in the blood, however, the body is extremely slow in reducing the COHb level which may account for its toxic action. Maximum COHb levels have been set at 5% for all system design objectives and aviation system performance limits and at 10% for all other system performance.

- **12.7.3 Cadmium oxide fumes.** Maintainers shall not be exposed to more than 0.1 milligrams of cadmium oxide per cubic meter of air. If possible, adequate ventilation shall be provided whenever any silver solder is used. If adequate ventilation cannot be supplied, maintainers shall be provided with respirators to prevent serious exposure to the cadmium oxide fumes. [Source: Department of Transportation (FAA Order 6000.15), 1991]

  Discussion. When a cadmium alloy containing a silver brazing is heated appreciably above its melting point, acutely poisonous brown or yellow cadmium oxide fumes are released. Inhalation of cadmium oxide fumes can result in serious and sometimes fatal damage to maintainers.

- **12.7.4 Fumes from batteries.** Adequate ventilation shall be provided in all battery service facilities. Fumes from batteries can be harmful to maintainers both because of the hazards of breathing the fumes themselves and because the fumes may displace oxygen. [Source: FAA Order 6000.15B, 1991]

- **12.7.5 Safety for toxic chemicals and materials.** Safety design and operation for toxic materials shall be governed by OSHA 29 CFR 1910.1200 and its appendix A. [Source: 29 CFR 1910.1200]

- **12.7.6 Asbestos.** Components and equipment containing asbestos shall not be used. [Source: FAA-G-2100F, 1993]

12.8 Radiation hazards

Radiation emitting systems and equipment require special consideration to minimize hazards to maintainers. Potential hazards arising from nuclear and electromagnetic radiation need to be evaluated by specialized personnel trained in investigating and controlling such hazards. OSHA 29 CFR 1910.96 and .97 address the effects of ionizing and non-ionizing radiation respectively. This section includes the rules for radiation hazards. [Source: 29 CFR 1910.96 and .97; MIL-HDBK-759B, 1992]

- **12.8.1 Radioactive materials.** Use of radioactive materials shall conform to Nuclear Regulatory Commission regulations and shall require approval of the acquisition program office. [Source: FAA-G-2100F, 1993; MIL-STD-454M, 1989]

- **12.8.2 Radium.** Radium shall not be used for luminosity (for example, making components visible in the dark). [Source: FAA-G-2100F, 1993; MIL-STD-454M, 1989]

- **12.8.3 Ionizing radiation exposure.** The radiation measured at any external surface of a unit of equipment producing ionizing radiation shall not exceed 0.5 milliroentgens per hour (rem) at a distance of 50 mm (2 in). Cumulative whole body exposure to maintainers shall not exceed 3 rem for any calendar quarter and 5 rem for any calendar year. The cumulative occupational exposure to an employee shall not exceed 5(n-18) rems where n equals the individual's age at the last birthday. Employees under 18 years of age shall not be exposed to over 10 percent of the allowable calendar quarter dose. OSHA 29 CFR 1910.96 and 97 shall govern protection from and exposure to ionizing and non-ionizing radiation respectively. [Source: 29 CFR 1910.96 and 97; MIL-STD-1472F, 1999; MIL-STD-1800A, 1990]

- **12.8.4 Microwave and radio frequency radiation.** Electronic equipment or electrical equipment capable of emitting microwave or radio frequency radiation between 300 KHz and 100 GHz shall be designed, fabricated, shielded, and operated to avoid overexposure of maintainers. According to OSHA 29 CFR 1910.97, partial or whole body electromagnetic radiation between 10 MHZ and 100GHz shall be restricted a maximum of 10mW/cm2 over any 0.1-hour period. Equipment design and installation in any unrestricted area accessible to maintainers shall meet the requirements of IEEE C95.1. [Source: 29 CFR 1910.97]

12.9 Protection from special chemicals

Protection from special chemicals (such as battery electrolyte) cleaning solvents, Polychlorinated Byphenyls, and carcinogens is addressed in this section.

- **12.9.1 Protection against battery acid.** Maintainers shall be provided acid resistant gloves, aprons and face shields that offer side as well as frontal protection for protection against the splattering of battery acid when they measure storage battery specific gravity or when they handle electrolyte. [Source: 29 CFR 1926.441; Department of Transportation (FAA Order 3900.19A), 1982]

- **12.9.2 Battery handling area.** Quick drenching facilities shall be provided within 25 feet of a battery handling area. [Source: 29 CFR 1926.441; FAA Order 3900.19A, 1982]

- **12.9.3 Large-sized service facilities.** If large quantities of electrolyte are handled or a large number of batteries are maintained, facilities shall be provided for quick drenching or flushing of the eyes and body. [Source: FAA Order 3900.19A, 1982]

  Exception. If the storage batteries are of the enclosed type and the facility is equipped with explosion proof or resistant vents, sealed water rinse or neutralizing packs may be used.

- **12.9.4 Small-sized service facilities.** If small quantities of electrolyte are handled and a small number of batteries are maintained, water rinse for flushing of the eyes and body shall be provided in place of drenching or flushing facilities. [Source: FAA Order 3900.19A, 1982]

- **12.9.5 Cleaning solvents.** Adequate ventilation shall be provided whenever any solvents or cleaners are used. Solvents that produce fumes (such as carbon tetrachloride) shall not be used and all permissible cleaning solvents shall be stored in safety cans. [Source: FAA Order 6000.15B, 1991]

  Discussion. Inhaled fumes from carbon tetrachloride are extremely hazardous to the respiratory system and some may have a caustic effect on the skin.

- **12.9.6 Polychlorinated Biphenyls (PCBs).** Maintainers shall be provided protective clothing when handling PCBs. All PCB items (such as transformers, capacitors, hydraulic machinery, and circuit breakers) with PCB concentrations of 500 parts per million shall be marked, inspected, and disposed of according to FAA Order 1050.14. PCBs shall not be used when suitable substitutes are available. [Source: FAA Order 6000.15B, 1991; Department of Transportation (FAA Order 1050.14), 1991]

- **12.9.7 Carcinogens.** The use of chemicals that have been identified by the Occupational Safety and Health Act (OSHA) as cancer producing substances (carcinogens) shall be evaluated and conform to OSHA 29 CFR 1910. [Source: 29 CFR 1910; MIL-STD-454M, 1989]

12.10 Temperature hazards

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: (1) duration of touch, (2) finish and diffusivity of the surfaced touched, (3) force of contact, and (4) size of contact area. Rules for equipment related temperature are given in this section.

- **12.10.1 "Touch temperature" contact.** Equipment that in normal operation exposes maintainers to surface temperatures outside the range of temperatures shown in Exhibit 12.10.1, shall be shielded. Cryogenic systems shall also be shielded. [Source: DOE-HFAC1, 1992; MIL-STD-1472F, 1999; MIL-STD-454M, 1989]

Exhibit 12.10.1 Upper and lower temperature limit range

	Temperature limits °C (°F)		
Exposure	**Metal**	**Glass**	**Plastic or wood**
Momentary contact	0-60 (32-140)	0-68 (32-154)	0-85 (32-185)
Prolonged contact or handling	0-49 (32-120)	0-59 (32-138)	0-69 (32-156)

- **12.10.2 Perforation size.** Cases, covers, and shields that are perforated to permit ventilation shall be no larger than 13 mm (.050 in) in diameter to prevent inadvertent insertion of objects that might touch high voltage sources or moving parts. Many smaller perforations are preferable to a few large ones. [Source: MIL-HDBK-759B, 1992]

12.11 Fire Protection

The avoidance and minimization of fire hazards begins with good housekeeping, which needs to be a personal goal of all maintainers. This section gives rules for reducing fire hazards. Fire protection provisions which affect design of facilities and equipment as well as operations and maintenance are governed by OSHA 29 CFR 1910 Subpart Fire Protection L (155 -167) Subpart H Hazardous materials (101 -119) and Associated national consensus standard sponsored by the National Fire Protection Association and the American National Standard Institute. OSHA 29 CFR 1910.307 and 308 address electrical installations in hazardous locations and environments.

- **12.11.1 Nonflammable enclosures.** If capacitors, inductors, and motors are potential fire hazards, they shall have nonflammable enclosures with a minimum number of openings. [Source: MIL-HDBK-759B, 1992]

- **12.11.2 Flammable materials.** If possible, designers should avoid specifying the use of flammable materials in equipment. [Source: MIL-HDBK-759B, 1992]

- **12.11.3 Flammable gases.** If possible, equipment shall be designed so that it will not emit flammable gases during storage or operation. If this is not possible, automatic cutoffs and suitable warnings shall be provided. OSHA 29 CFR 1910.101 -119 governs handling of hazardous materials including those that are flammable, combustible, and explosive. [Source: 29 CFR 1910.101 – 119; MIL-HDBK-759B, 1992]

- **12.11.4 Fire extinguishers.** Where fire hazards exist, portable, hand-operated fire extinguishers shall be located where fires will not block their access. [Source: MIL-HDBK-759B, 1992]

- **12.11.5 Selection of fire extinguishers.** Fire extinguishers shall be selected for suitability by the class of fires most likely to occur in an area. OSHA 29 CFR 1910.157 governs the selection and use of fire extinguishers. [Source: 29 CFR 1910.157; MIL-HDBK-759B, 1992]

  Discussion. Class A fires involve ordinary flammable materials such as wood, paper, and rags that can be extinguished with water or aqueous solutions. Class B fires involve flammable liquids such as gasoline, solvents, and greases that can be extinguished by dilution, elimination of air, or blanketing. Class C fires involve electrical equipment such as motors, transformers, and switches that need to be extinguished by a substance that does not conduct electricity.

- **12.11.6 Fire protection criteria.** OSHA 29 CFR 1910 Subpart L Fire protection (155 -165); Subpart H Hazardous materials (101 - 119) and associated national consensus standards sponsored by the National Fire Protection Association and the American National Standards Institute shall govern the fire protection aspects for maintenance of facilities and equipment. OSHA 29 CFR 1910.307 -308 governs electrical installations in hazardous locations and environments. [Source: 29 CFR 1910.307 -308]

12.12 Noise hazards

Noise can be hazardous to maintainers in two general ways: it can cause hearing loss, both temporary and permanent, and it can prevent maintainers from hearing audible warning signals. Rules are given in this section to protect maintainers from these hazards. Rules concerning administrative and engineering controls to reduce noise and a hearing conservation program are given in Chapter 13.5.

- **12.12.1 General noise levels.** Workplace noise shall be maintained at levels that will not (1) interfere with necessary voice, telephone, and radio communication, (2) cause fatigue or injury, or (3) degrade overall system effectiveness. [Source: MIL-STD-1800A, 1990]

- **12.12.2 Noise criteria.** Noise criteria are defined by either the A-weighted sound level, dB(A), or the speech interference level (SIL). The A-weighted sound level is the desired requirement. Where it is not possible to meet the specified A-weighted sound level, the corresponding SIL requirement shall be met. [Source: MIL-STD-1800A, 1990]

  Definitions. Preferred speech interference level (PSIL-4) is a measure of the effectiveness of noise in masking speech. **Speech interference level (SIL or SIL-4)** is the arithmetic mean, in dB (or 20μPa), of sound pressure levels in the four octave bands with center frequencies of 500, 1000, 2000, and 4000 Hz. **A-weighted sound level (dB(A))** is a sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually decreases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of A-weighting filter characteristics.

- **12.12.3 Extreme quiet areas.** Ambient noise in areas requiring extreme quiet shall not exceed 35 dB(A) or 27 dB PSIL-4. [Source: MIL-HDBK-759B, 1992]

- **12.12.4 Small office spaces and special areas.** Ambient noise in areas requiring no difficulty with speech communication (for example, libraries and classrooms) shall not exceed 45 dB(A) or 37 dB PSIL-4; conference rooms and offices shall not exceed 38 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- **12.12.5 Operational areas.** Ambient noise in areas requiring frequent phone use or requiring occasional speech communication (for example, operations centers, control rooms, tower cabs, and dynamic simulation rooms) at distances up to 4.6 m (15 ft) shall not exceed 55 dB(A) or 47 dB PSIL-4; shop offices and laboratories shall not exceed 48 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- **12.12.6 Equipment areas.** Ambient noise in areas requiring frequent telephone use or frequent speech communication (for example, computer rooms, engineering areas, equipment rooms, and telephone switching centers) at distances up to 1.5 m (5 ft) shall not exceed 65 dB(A) or 57 dB PSIL-4. [Source: FAA-G-2100F, 1993; MIL-HDBK-759B, 1992]

- **12.12.7 High noise, remote areas.** High noise, remote areas that are normally unmanned shall not exceed 85 dB(A). [Source: FAA-G-2100F, 1993]

- **12.12.8 Occupational noise exposure and control.** Administrative or engineering controls shall be used to reduce the sound levels to within permissible noise exposure levels listed in Exhibit 12.12.8. OSHA 29 CFR 1910.95 shall be used in determining equivalent A-weighted sound levels for daily exposure. A hearing conservation program shall be administered any time an employee's noise exposure equals or exceeds an 8-hour time weighted average of 85 db measure on the A scale (slow response) or equivalent without regard to attenuation that may be provided by personal protective equipment. OSHA 29 CFR 1910.95 shall govern the hearing protection program. [Source: 29 CFR 1910.95]

Exhibit 12.12.8 Permissible noise exposure

Maximum hours per day	Sound level dBA (slow response) equivalent A-weighted sound level
8.0	90
6.0	92
4.0	95
3.0	97
2.0	100
1.5	102
1.0	105
0.5	110
0.25	115
Maximum impulse noise	140 (peak sound pressure level)

If daily exposure involves two or more periods at differing levels, the combined effect is used. C_j/T_j is the total time of exposure at a specified level over the time of permissible exposure for that typical level, j. When the sum, $\sum(C_j/T_j)$ of the fractions, $C_1/T_1 + C_2/T_2 + ... + C_j/T_j + ... + C_n/T_n$ is greater than one, the combined exposure exceeds the permissible noise limit value.

12.13 Explosion and implosion hazards

Maintainers are sometimes exposed to risks of explosion (for example, the presence of explosive gases), or of implosion (for example, a scratched cathode ray tube (CRT). Rules are given in this section to protect the maintainer from such hazards.

- **12.13.1 CRT conformance.** CRTs shall conform to the requirements of UL 1418. [Source: MIL-HDBK-759B, 1992; MIL-STD-454M, 1989]

- **12.13.2 Terminal end of CRT.** Whenever possible, the terminal end of CRTs shall be located within the equipment housing. If the terminal end extends outside the equipment housing, it shall have a cover strong enough to protect the tube. This cover shall be anchored to the main housing structure firmly enough to withstand shipping and rough handling so that external pressures will not be transmitted to the tube and its wiring. There shall also be a warning inside the equipment informing maintainers that the neck of the tube is fragile and must be handled with caution. [Source: MIL-HDBK-759B, 1992]

- **12.13.3 Explosion.** Equipment that may be operated, maintained, or stored in an explosive atmosphere shall be designed to eliminate the possibility of an explosion. [Source: MIL-HDBK-759B, 1992]

- **12.13.4 Minimizing risk of explosion.** Risk of explosion shall be minimized by isolating hazardous substances from heat sources and by using spark arrestors, vents, drains, or other safety techniques. [Source: MIL-HDBK-759B, 1992]

- **12.13.5 Explosion causing gases.** Materials shall not liberate gases that will produce an explosive atmosphere. [Source: MIL-STD-454M, 1989]

12.14 Radiant energy hazards

This section gives rules for radiant energy (200 nm to 1 m) hazards. This range covers ultraviolet through microwave radiant energy.

12.14.1 Ultraviolet radiant energy (200-315 nm)

- **12.14.1.1 Exposure limit.** The maximum daily radiant energy exposure to ultraviolet light (200-315 nm) shall not exceed an effective value of 0.003 J/cm^2. [Source: Farrell & Booth, 1975]

  Discussion. The equations and tables shown in Exhibit 12.14.1.1 can be used to convert irradiance measured in each part of the spectrum to total effective irradiance.

  Definition. Irradiance is the radiant flux density on a given surface.

Exhibit 12.14.1.1 Exposure limit for ultraviolet radiant energy (200 to 315 mm)

$E_{eff} = \sum E_\lambda S_\lambda \Delta_\lambda$, where:

E_{eff} = Effective irradiance in the 200 nm to 315 nm
E_λ = Measured spectral irradiance in mW/cm^2 nm
S_λ = Relative spectral effectiveness (dimensionless) (see below)
Δ_λ = Bandwidth in nanometers (nm)

Wavelength (nm)	Relative spectral effectiveness (S_λ)	Daily exposure limit (mJ/cm^2)	Effective irradiance E_{eff} (mW/cm^2)	Maximum exposure per day*
200	0.03	100	0.0001	8 hr
210	0.0075	40	0.0002	4 hr
220	0.12	25	0.0004	2 hr
230	0.19	16	0.0008	1 hr
240	0.3	10	0.0017	30 min
250	0.43	7	0.0033	15 min
254	0.5	6	0.005	10 min
260	0.65	4.6	0.01	5 min
270	1.0	3.0	0.05	1 min
280	0.88	3.4	0.10	30 sec
290	0.64	4.7	0.30	10 sec
300	0.30	10.0	3.00	1 sec
305	0.06	50.0	6.00	0.5 sec
310	0.015	200	30.00	0.1 sec
315	0.003	1000		

* These values assume that no other occupational exposure occurs

12.14.2 Near-ultraviolet radiant energy (315-400 nm)

- **12.14.2.1 Exposure duration greater than 1000 seconds.** The maximum radiant energy exposure to near ultraviolet light (315-400 nm) shall not exceed 0.001 W/cm^2 for exposure durations longer than 1000 sec. [Source: Farrell & Booth, 1975]

- **12.14.2.2 Exposure duration less than 1000 seconds.** The maximum radiant energy exposure limit to near ultraviolet light (315-400 nm) shall not exceed 1 J/cm^2 in any 1000-second period. [Source: Farrell & Booth, 1975]

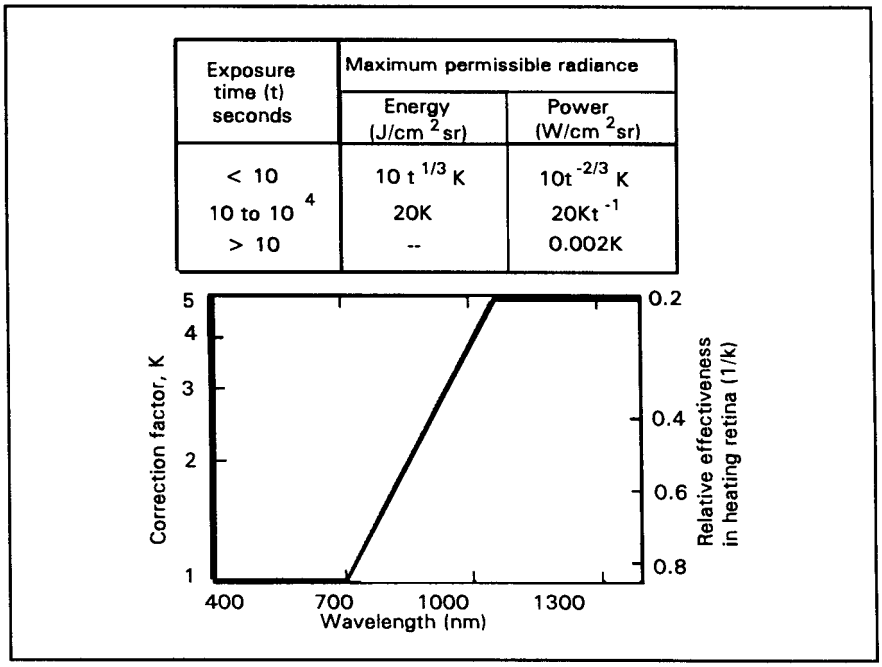
12.14.3 Visible and near-infrared radiant energy (400-1400 nm)

Visible and near-infrared radiant energy, with a wavelength of 400 to approximately 1400 nm, is largely transmitted by the ocular media of the eye and absorbed at the retina. Unlike corneal injury from ultraviolet energy, injury to the retina is generally permanent. As a result, special care must be taken to avoid retinal damage. [Source: Farrell & Booth, 1975]

If appropriate image spectral radiance data are not immediately available, it may be helpful to estimate whether a particular image luminance exceeds permissible exposure limits. The relationship between luminance and radiance has been published for typical lamps, but these values cannot be used directly because radiant energy with a wavelength greater than 700 nm is less effective in heating the retina.

If the spectral distribution of radiant energy in the displayed image is known, the luminosity function for the eye (see Exhibit 12.14.3) can be used to calculate the ratio between luminance and effective radiance, and hence, the permissible luminance. This process is illustrated here for three hypothetical equal-energy-per-wavelength sources that differ in wavelength range.

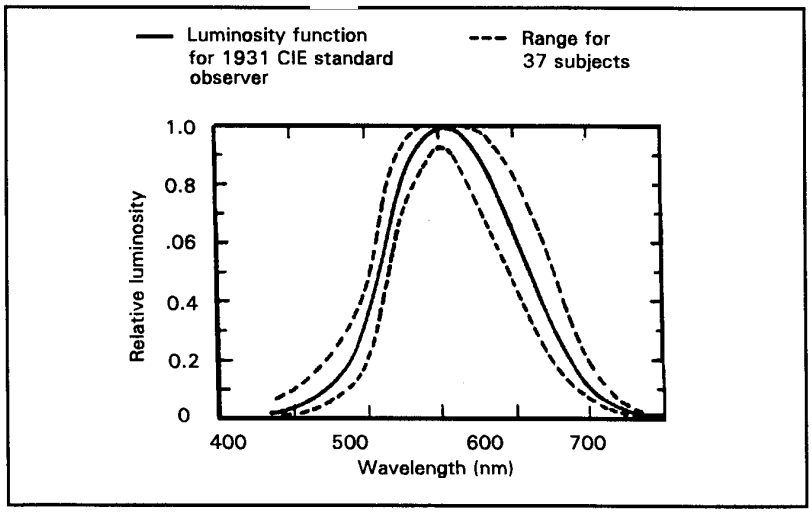
Exhibit 12.14.3 Relative contribution of different wavelengths to luminance –the luminosity function



- **12.14.3.1 Exposure of the eye.** The maximum radiant energy exposure to visible and near-infrared light (400-1400 nm) shall not exceed the limits given in Exhibit 12.14.3.1. These limits apply to any source larger than 1°. [Source: Farrell & Booth, 1975]

  Note. For wavelengths longer than 700 nm, a correction factor, K, is required to compensate for the increase in absorption in the ocular media and the decrease in absorption by the retina.

Exhibit 12.14.3.1 Maximum safe exposure to 400-1400 nm radiant energy.



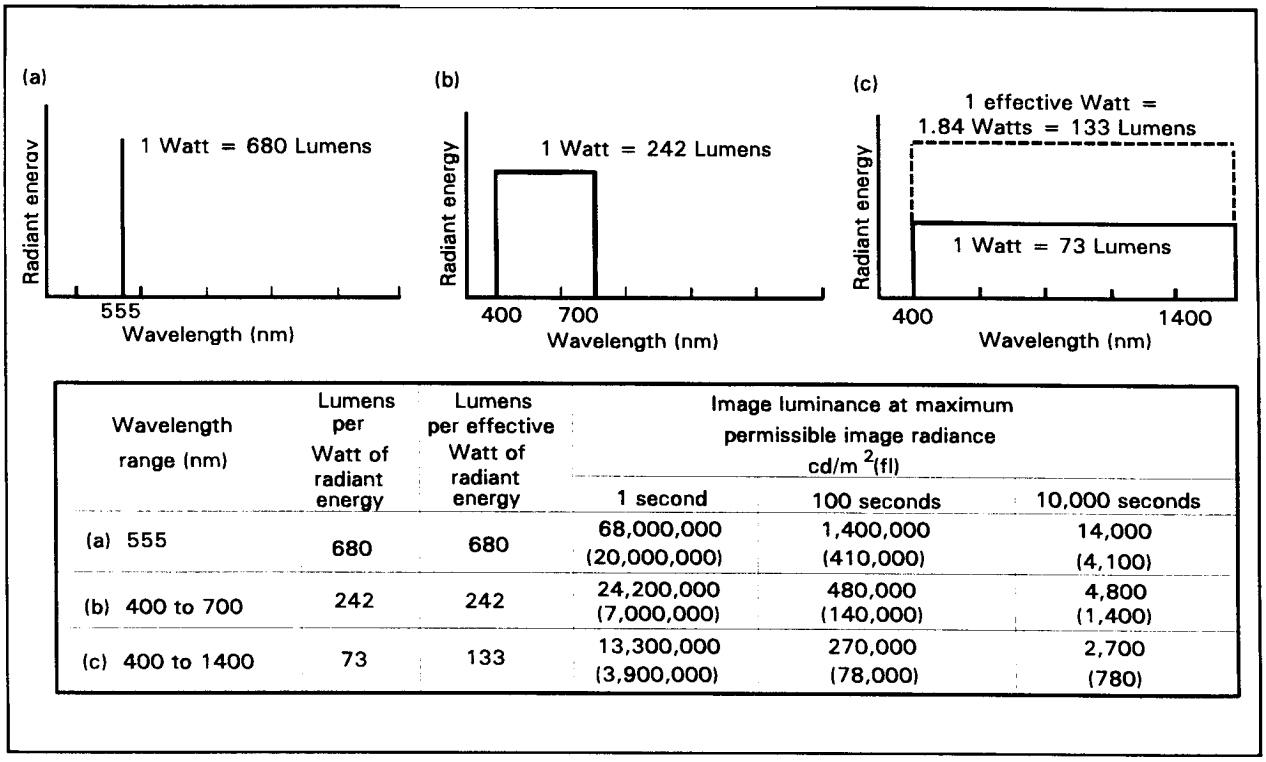
- **12.14.3.2 Exposure of skin.** The maximum radiant energy exposure of a maintainer's skin to visible and near-infrared light (400-1400 nm) shall not exceed 0.2 W/cm^2. [Source: Farrell & Booth, 1975]

- **12.14.3.3 Removing infrared.** If infrared radiant energy exceeds the allowable limit, filters shall be provided to protect the maintainer's eyes from unnecessary heat. [Source: Farrell & Booth, 1975]

- **12.14.3.4 Maximum display.** High-luminance displays should not exceed 242 lumens per effective watt of the 400 to 700 nm source (see Exhibit 12.14.3.4). [Source: Farrell & Booth, 1975]

Definition. An **effective watt** is equal to 1.84 watts.

Exhibit 12.14.3.4 Estimation of permissible image luminance



Wavelength range (nm)	Lumens per Watt of radiant energy	Lumens per effective Watt of radiant energy	Image luminance at maximum permissible image radiance cd/m^2(fl)		
			1 second	100 seconds	10,000 seconds
(a) 555	680	680	68,000,000 (20,000,000)	1,400,000 (410,000)	14,000 (4,100)
(b) 400 to 700	242	242	24,200,000 (7,000,000)	480,000 (140,000)	4,800 (1,400)
(c) 400 to 1400	73	133	13,300,000 (3,900,000)	270,000 (78,000)	2,700 (780)

12.14.4 Far-infrared radiant energy (1400-10^6 nm)

- **12.14.4.1 Short term exposure.** The maximum radiant energy exposure to far-infrared light (1400-10^6 nm) for 60-120 seconds shall not exceed 0.1 W/cm^2. A measurement aperture of 1 mm (0.04 in) shall be used for wavelengths shorter than 10^5 nm, and an aperture of 11 mm (0.43 in) shall be used for longer wavelengths. [Source: Farrell & Booth, 1975]

- **12.14.4.2 Chronic exposure.** The maximum chronic radiant energy exposure to far-infrared light (1400-10^6 nm) shall not exceed 0.01 W/cm^2. A measurement aperture of 1 mm (0.04 in) shall be used for wavelengths shorter than 10^5 nm, and an aperture of 11 mm (0.43 in) shall be used for longer wavelengths. [Source: Farrell & Booth, 1975]

12.14.5 Microwave radiant energy (10^7-10^{11} Hz)

- **12.14.5.1 Exposure limit.** The maximum radiant energy exposure to microwave radiation (10^7-10^{11} Hz, which corresponds to wavelengths of 1 mm (0.04 in) to 1 m (39.37 in)) shall be no more than 0.01 W/cm^2 averaged over a 0.1-hour period. [Source: Farrell & Booth, 1975]

12.15 Laser hazards

This section gives rules for protecting the maintainer from laser hazards.

- **12.15.1 Laser radiation.** Laser equipment and system design, installation, and operational and maintenance procedures shall conform to OSHA 21 CFR 1040. [Source: 21 CFR 1040; Farrell & Booth, 1975]

- **12.15.2 Laser exposure limits.** In accordance with OSHA 29 CFR 1926.54 (j), employees shall not be exposed to laser light intensities above:

  a. Direct staring: 1 microwatt per square centimeter.

  b. Incidental observing: 1 milliwatt per square centimeter.

  c. Diffuse reflected light: 2 1/2 watts per square centimeter.

  Discussion. For safety reasons, laser units need to be set up to operate above head level of employees, when possible. [Source: 29 CFR 1926.54 (j)]

- **12.15.3 Eye protection from laser light.** OSHA 29 CFR 1926.54 shall govern potential exposure areas to direct or reflected laser light. Employees shall be provided with antilaser eye protection devices if any such exposure to laser light greater than 5 milliwatts exists. OSHA 29 CFR 1926.102 (b)(2) shall govern optical density of the eye protection based upon the maximum power density and specific wavelength of the laser. [Source: 29 CFR 1926.54]

- **12.15.4 Labeling of laser protective goggles.** OSHA 29 CFR 1926.102 (b)(2)(ii) shall govern the labeling laser optical protection devices. Labels shall include the following:

  a. Laser wavelengths for intended use.

  b. Optical density of those wavelengths.

  c. The visible light transmission. [Source: 29 CFR 1926.102 (b)(2)(ii)]

- **12.15.5 Laser alignment.** In accordance with OSHA 29 CFR 1926.54 (f) only mechanical or electronic means shall be used as a detector for guiding the internal alignment of a laser. [Source: 29 CFR 1926.54]

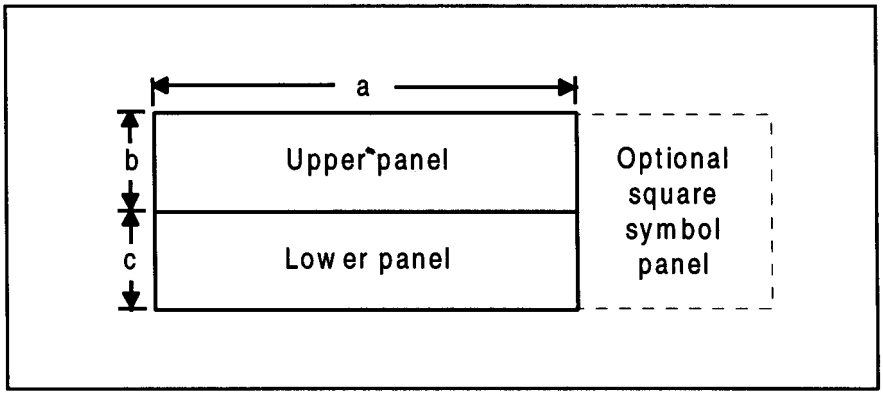
12.16 Safety labels and placards

This section contains rules for the labeling and placing of placards on hazardous components, equipment, and systems. Use of these rules will help to ensure the safety of maintainers and equipment.

- **12.16.1 Warning labels and placards.** Labels or placards shall be placed on or adjacent to any equipment that presents a hazard (for example, high voltage, heat, toxic vapors, explosion, and radiation) to maintainers. These labels or placards shall describe the hazard and state precautions the maintainer can take. [Source: MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992; DOE-HFAC1, 1992; NASA-STD-3000A, 1989; MIL-STD-454M, 1989]

- **12.16.2 Label and placard design.** Labels and placards shall consist of three panels as shown in Exhibit 12.16.2. The ratio of width to height of the upper panel (a:b) shall fall within the range of 2:1 to 5:1 inclusive. The lower panel width shall be equal to the upper panel width (both equal to a). The lower panel height shall be equal to or greater than the upper panel height, but less than twice the width of the sign (b ó c < 2a). The optional symbol panel shall be square with its edge equal to the sum of the upper and lower panel (b + c) and placed to the right of the upper and lower panels. The upper panel shall contain the signal or key work. the lower panel shall contain additional direction or explanation. Wording of this panel shall be brief, provide positive direction (if possible), and be limited to a single hazard. [Source: MIL-STD-1472F, 1999]

Exhibit 12.16.2 Label and placard layout –two panel sign with optional symbol panel



12.16.3 Label and placard design classifications and specifics. Signs shall have one of four classifications:

a. Class I (Danger). Danger labels and placards indicate immediate and grave danger or peril, a hazard capable of producing irreversible damage or injury, and prohibitions against harmful activities. These signs shall have the word "DANGER" in white within a red oval outline with a white on black rectangle in the upper panel. The lower panel, for additional wording, shall be in black or red on a white background.

b. Class II (Caution). Caution labels and placards are used to call attention to potential danger or hazard, or a hazard capable of, or resulting in severe but not irreversible injury or damage. These signs shall have the signal word "CAUTION" in yellow on a black rectangle in the upper panel. The lower panel, for additional wording, shall be in black on a yellow background.

c. Class III (General safety). General safety labels and placards include notice of general practice and rules relating to health, first aid, housekeeping, and general safety other than the two cases above. These signs shall have the appropriate key word in white on a green rectangle in the upper panel. The lower panel, for additional wording, shall be in black or green on a white background.

d. Class IV (Fire and emergency). Fire and emergency labels and placards shall be used only to label or point the way to fire extinguishing equipment, shutoffs, emergency switches, and emergency procedures. These signs shall have the key word in white on a red rectangle in the upper panel. The lower panel, for additional wording, shall be in red on a white background. [Source: MIL-STD-454M, 1989]

- **12.16.4 Label and placard placement.** Labels and placards shall be placed so as to alert and inform in sufficient time to avoid the hazard or to take appropriate action. They shall be: (1) readable from a distance, (2) create no additional distractions, or (3) be hazardous themselves. [Source: MIL-HDBK-759B, 1992; MIL-STD-454M, 1989]

- **12.16.5 Illumination for warning labels and placards.** Warning labels and placards shall be visible under the conditions in which the maintainer needs to see them. Special illumination may be needed to meet this criterion. [Source: MIL-STD-454M, 1989]

- **12.16.6 Wording for medium voltage labels and placards.** If a voltage between 70 and 500 volts is present, a caution label or placard shall be provided that includes the following statement or its equivalent: "CAUTION (insert maximum voltage) VOLTS." The label or placard shall be in accordance with ANSI Z535.2. [Source: MIL-STD-454M, 1989]

- **12.16.7 Wording for high voltage labels and placards.** If a voltage in excess of 500 volts is present, a warning label or placard shall be provided that includes the following statement or its equivalent: "DANGER -- HIGH VOLTAGE (insert maximum voltage) VOLTS." The label or placard shall be in accordance with ANSI Z535.2. [Source: MIL-STD-454M, 1989]

- **12.16.8 Microwave or rf radiation warning labels and placards.** Each unit of equipment that can emit microwave or rf radiation levels between 300 KHz and 100 GHz shall have a warning label or placard. This warning label or placard shall be in accordance with ANSI Z535.2 and ANSI C95.2. Labels shall be provided on all radiation shields and covers to warn maintainers of the radiation hazards involved upon removal. [Source: MIL-STD-454M, 1989]

- **12.16.9 X radiation shield labels or placards.** Shields that protect maintainers from X radiation shall have labels or placards in accordance with OSHA 10 CFR 20. [Source: 10 CFR 20; DOE-HFAC1, 1992; MIL-STD-1472F, 1999]

- **12.16.10 Ionizing radiation symbols.** Ionizing radiation hazard symbols shall be in accordance with ANSI N2.1. [Source: DOE-HFAC1, 1992; MIL-STD-1472F, 1999]

- **12.16.11 Laser warning labels and placards.** Laser warning labels and placards shall be in accordance with OSHA 21 CFR 1040 unless a unit of equipment has been certified as exempt. In accordance with OSHA 29 CFR 1926.54 (d) all areas on which lasers are used shall be posted with standard laser warning placards. [Source: 21 CFR 1040; MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

  Discussion. If a piece of equipment is exempt, the unit of equipment shall have a label or placard that states: CAUTION--This electronic product has been exempted from FDA radiation safety performance standards, as prescribed in the Code of Federal Regulations, Title 21, Chapter I, Subchapter J, pursuant to Exemption No. 76 EL-01 DOD issued on 26 July 1976. This product shall not be used without adequate protective devices or procedures.

- **12.16.12 Line identification.** Liquid and gas lines shall be clearly and unambiguously labeled or coded as to contents, pressure, heat, cold, or other hazardous properties in accordance with MIL-STD-1247. [Source: MIL-HDBK-759B, 1992; MIL-STD-1800A, 1990]

- **12.16.13 Electrical labels and placards.** If appropriate, all receptacles shall be marked with their voltage, phase, and frequency characteristics. [Source: MIL-STD-1472F, 1999; MIL-HDBK-759B, 1992; DOE-HFAC1, 1992]

- **12.16.14 Center of gravity.** If the unit has a high center of gravity or if the weight of a unit of equipment is not evenly distributed, the center of gravity shall be clearly marked. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.16.15 Weight labels.** Weight and center of gravity caution placards shall be placed on any unit of equipment to be moved for maintenance if its weight exceeds 13.6 kg (30 lbs.). If it is designed to be lifted or carried by more than one person, the label shall include the number of people recommended to lift or carry it. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

- **12.16.16 Weight lifting capacity.** Weight lifting capacity shall be indicated on stands, hoists, lifts, jacks, and similar weight-bearing equipment, to prevent possible overloading. [Source: MIL-STD-1472F, 1999; DOE-HFAC1, 1992]

Glossary

Effective watt - Equal to 1.84 watts.

Interlocks - Devices (for example, switches) connected with a cover, shield, or case that disable the associated internal hazard (usually electrical) when the cover, shield, or case is opened. OSHA regulations discuss lockout and tagout procedures to be used in the workplace during maintenance or operations to protect from electrical hazards.

Irradiance - The radiant flux density on a given surface.

Lockout - Uses a mechanical mean to disable a control or switch in its safe position (for example, electricity disconnected) and to prevent its activation without the use of undue force or tools.

N - Is a metric term for the force measure called a Newton. One pound force in the English measurement system is equal to 4.4482 Newton (1 lbf = 4.4482 N).

Preferred speech interference level (PSIL-4) - A measure of the effectiveness of noise in masking speech.

Speech interference level (SIL or SIL-4) - The arithmetic mean, in dB (or 20μPa), of sound pressure levels in the four octave bands with center frequencies of 500, 1000, 2000, and 4000 Hz.

Tagouts - Tags that are attached to a control or place of hazard associated with an ongoing mode of operation or maintenance.

Weighted sound level (dB(A)) - A sound pressure level (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz, drops rapidly as frequency decreases below 1000 Hz, and gradually decreases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels. ANSI S1.4 gives the definition of a-weighting filter characteristics.

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