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Standard on
Aircraft Maintenance

NFPA 410-1980

1980 Edition of NFPA 410

This 1980 edition of NFPA 410 was prepared by the Technical Committee on Aircraft Maintenance Operations and was adopted by the National Fire Protection Association, Inc., at its Annual Meeting in Boston, Massachusetts on May 21, 1980. It was released by the Standards Council on June 11, 1980.

This edition supersedes NFPA 410A-1975; NFPA 410B-1971; NFPA 410C-1972; NFPA 410D-1971; NFPA 410E-1975; and NFPA 410F-1975.

Origin and Development of NFPA 410

Work on an overall project to develop recommendations on fire safety safeguards for aircraft maintenance was launched in 1955. NFPA 410A, *Recommendations on Safeguarding Aircraft Electrical System Maintenance Operations*, was adopted in 1958; NFPA 410B, *Recommendations on Aircraft Breathing Oxygen Systems Maintenance Operations*, was adopted in 1958; NFPA 410C, *Recommendations on Safeguarding Aircraft Fuel System Maintenance*, was adopted in 1962; NFPA 410D, *Recommendations for Safeguarding of Aircraft Cleaning, Painting, and Paint Removal*, was adopted in 1965; NFPA 410E, *Recommended Safe Practice for Aircraft Welding Operations in Hangars*, was adopted in 1963; and NFPA 410F, *Recommendations on Safeguarding Aircraft Cabin Cleaning and Refurbishing Operations*, was adopted in 1963. The 1980 edition is a compilation of the 410 series which has been rewritten as a standard. The mandatory provisions are in the body and the explanatory material including recommendations is in Appendix A.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in membership may have occurred.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Appendix B.

Chapter 1 General Information

1-1 Scope. This standard covers the minimum requirements to be followed during aircraft maintenance. The operations include maintenance of electrical systems, maintenance of oxygen systems, fuel tank repairing, cleaning, painting and paint removal, welding operations in hangers, cabin cleaning, and refurbishing operations.

1-2 Purpose. The purpose of this standard is to provide a reasonable degree of protection for life and property from fire through requirements for aircraft maintenance based upon sound engineering principles, test data, and field experience.

1-3 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). One unit (liter), outside of but recognized by SI, is commonly used in international fire protection.

1-3.1 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value may be approximate.

NOTE: For additional information, see ASTM E380, *Standard for Metric Practice*.

1-3.2 The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

Chapter 2 Electrical Maintenance Operations

2-1 General.

2-1.1* Electrical system maintenance as used herein and references to NFPA 70, *National Electrical Code®* , apply only to aircraft maintenance.

2-1.2 The fire record indicates that a substantial number of aircraft fires occur during aircraft maintenance due to failure to de-energize electrical systems before working on them, accidental contact with live circuits while performing other maintenance work, and short circuits.

2-1.3 Electrical systems shall be de-energized during maintenance work except in those cases where a live circuit is necessary in order to accomplish the required maintenance.

2-1.4 Where more than one maintenance operation is being carried out at the same time and an electrical system is energized, steps shall be taken to inform personnel working on the aircraft that the system is energized.

2-1.5 Wherever possible, provision shall be made to effectively tag out or lock out de-energized circuits so that anyone attempting to energize them will be unmistakably alerted to the resulting hazard to other maintenance operations.

2-2 Battery Charging and Equipment.

2-2.1 Whenever possible, aircraft batteries shall be disconnected or removed during maintenance operations in order to de-energize all electrical circuits.

2-2.2 The battery switch on aircraft shall be in the "off" position before removing or installing batteries.

2-2.3 When moving batteries, including removal and replacement, precautions shall be taken to prevent the terminal prongs from contacting metal structure or objects. A "short" across these terminals can burn or weld metal, and resultant arcs can cause an explosion if the short circuit occurs in the presence of a flammable vapor.

2-2.4* When removing and replacing batteries, precautions shall be taken to prevent the electrolyte from spilling. Such a spill might result in damage to wiring insulation which, in turn, may create an exposure to a short circuit, spark, or arc. Similar precautions shall be taken when replacing or adding electrolyte solutions in batteries.

2-2.5 Batteries shall never be charged while in the aircraft, except on those aircraft where adequate on-the-ground ventilation is provided as part of the aircraft design. Most aircraft have battery compartments designed for in-flight ventilation only, and if batteries are charged in such compartments while the aircraft is on the ground, an explosive gas-air mixture may be trapped in the battery compartment.

2-2.6 Flexible cords used for charging shall be suitable for the type service used and approved for extra hard usage. Their current-carrying capacity shall be adequate for the charging current.

2-2.7 Connectors shall have a rating not less than the current-carrying capacity of the cord.

2-2.8 Connectors to the battery terminals shall be of a positive type to prevent them from coming loose from vibration, causing arcs which might ignite gas from the batteries or other flammables or combustibles.

2-2.9 Tables, racks, trays, and wiring shall conform to the provisions of Article 480, NFPA 70, *National Electrical Code*, where storage batteries use acid or alkali as the electrolyte and consist of a number of cells connected in series with a nominal voltage in excess of 16 volts.

2-2.10 Mobile chargers shall carry at least one permanently affixed warning sign to read: "Warning—Keep 5 Ft (1.5 m) (Horizontally) Clear of Aircraft Engines, Fuel Tank Areas, and Vents."

2-2.11 Batteries shall be charged at a rate (amperage and length of charge) that will not produce a dangerous concentration of gas or excessive heat.

2-2.12 Battery chargers and their control equipment, tables, racks, trays, and wiring shall not be located or operated within any of the hazardous areas defined in 513-2(b) of Article 513 of NFPA 70, *National Electrical Code*. They shall preferably be located in a separate building or in an area such as described in 513-2(d) of the *National Electrical Code*.

2-2.13 Areas wherein batteries are charged shall be well-ventilated to assure that the maximum gas-air mixture that may be generated during charging is held below the lower explosive limits. Where mechanical ventilation is required to accomplish this, it shall be of the type approved for use in Class 1, Group B, atmosphere locations (as defined in Article 500 of NFPA 70, *National Electrical Code*) and shall be so interlocked as to ensure operation when batteries are on charge. Exhaust ducts shall lead directly to the outside, above roof level, where fumes cannot accumulate.

2-2.14 While proper ventilation is a prime factor in preventing gas explosions in battery rooms, precautions shall be taken to avoid open flames, sparks, or electric arcs.

2-2.15 Access to battery rooms shall be limited to qualified personnel only.

2-2.16 Smoking shall be prohibited and open flames, sparks, arcs, and other sources of ignition shall be kept away from the immediate vicinity of batteries which are being charged. Appropriate warning signs shall be prominently displayed.

2-2.17* Finger rings, wrist watches, wrist chains, etc., shall not be worn while working near battery terminals because a short circuit may cause an arc or result in a severe burn.

2-2.18 Brushes used to clean batteries shall have neither a metal frame nor wire bristles.

2-2.19 Attention is called to the hazard of spillage of electrolyte solutions as noted in 2-2.4.

2-2.20 Good practice recommendations of the manufacturers of batteries shall be followed with regard to segregation of nickel-cadmium battery-charging operations from lead-acid battery charging to prevent contamination.

2-3 Ground Power Units.

2-3.1 Types in Common Use.

2-3.1.1 Engine-Driven Generators.

2-3.1.2 Electric converters are used to convert line voltage alternating current to the voltage and frequency (or direct current) suitable for the aircraft power system.

2-3.1.3 Rectifier units are also used to accomplish the same job as converters.

2-3.2 Location in Use. (*See Section 513-9 of Article 513 of NFPA 70, National Electrical Code, and 2-6.2 of NFPA 407, Standard for Aircraft Fuel Servicing.*)

2-3.3 The use within hangars of engine-driven generators is regarded as a material increase in the inherent hazard of aircraft servicing operations and shall be avoided.

2-3.4 Engine-driven generators shall be located as far as practical from fueling points, tank vents, tank outlet areas, and fuel line drains. This will reduce the danger of igniting flammable vapors or liquids that may be discharged. During overwing fueling or where aircraft fuel-servicing vents are located on the upper wing surface, ground power generators shall not be positioned under the trailing edge of the wing. Ground power generators shall not be positioned within a 10-ft (3-m) horizontal radius of aircraft fuel system vent openings. They shall not be used in areas wherein adequate ventilation is not available or where they may constitute a fire hazard. If used inside hangars, they shall be so designed and mounted that all electrical equipment, sparking contacts, hot surfaces, and any other possible ignition sources shall be at least 18 in. (457 mm) above floor level. At no time shall engine-driven generators be refueled within any aircraft maintenance and/or storage area within a hangar.

2-3.5 The safety precautions to be followed in locating converter and/or rectifier units are the same as outlined in 2-3.3 and 2-3.4 above for engine-driven generators. Electrical equipment in pits used to store cables shall be of the type approved for Class I, Group D, Division 1 hazardous locations (as defined by NFPA 70, *National Electrical Code*).

2-3.6 The connector shall fit snugly and securely in the aircraft receptacle and shall be so designed as to prevent the possibility of reverse polarity occurring.

2-3.7 The battery switch in the aircraft shall be turned to the "Off" or "Ground Power" position. This is extremely important for, in some aircraft, the battery switch has a mid-position, and, if the switch is in this position and the batteries have not been removed or disconnected, the batteries will be charged in the aircraft battery compartment giving off excessive heat and hydrogen gas.

2-3.8 Units shall always be operated at the prescribed voltage.

2-3.9 In the event of extensive fuel spills or whenever similar hazardous conditions exist, ground power in the vicinity which would constitute a fire hazard shall be withdrawn or left "as is" until the hazardous condition is corrected. No fixed rule can be made on this subject since firesafety will vary with individual circumstances. However, if a portable ground power unit is to be moved under such hazardous conditions, the unit shall be de-energized before disconnecting the cable, and the cable shall be disconnected before the unit is moved.

2-3.10 Cables shall be stowed properly to prevent damage.

2-3.11 Strains on cables and connectors shall be avoided.

2-3.12 The engine-driven generator shall be turned on only after the connector is installed in the aircraft receptacle. When connected, the unit shall be checked to determine that it is operating at the prescribed voltage.

2-3.13 The engine-driven generator shall be de-energized before disconnecting.

2-3.14 Portable units shall be disconnected before they are moved.

2-4 Repair of Aircraft Electrical Systems.

2-4.1 Whenever possible, the entire aircraft electrical system shall be de-energized by disconnecting or removing the batteries and/or by disconnecting any outside power source. The use of a "dummy" ground power plug shall be considered.

2-4.2 Whenever it is impractical to de-energize the entire aircraft electrical system, all personnel working on the aircraft shall be informed that the aircraft's electrical systems are energized.

2-4.3 Whenever it is impractical to de-energize the entire aircraft electrical system due to other work being accomplished, the electrical system being worked on shall be isolated by placing the circuit breaker in an "Off" position or pulling the fuse.

2-4.4 When an electrical system is to be isolated in order to work on it, the person who is going to work on the system shall place the circuit breaker in an "Off" position or pull the fuse. He shall not rely on someone else to do this for him. A positive test on the isolated circuit shall be made.

2-4.5 Where two or more people are going to work on the same system, provisions shall be made to make one person responsible for energizing or de-energizing the system.

2-4.6 Circuit breakers shall be in the "Off" position and fuses shall be pulled before removing and installing system units.

2-4.7 The use of a "tag-out" system, covering the switch with masking tape, or some other similar method of indicating positively that an electrical system is being worked on and shall not be energized except on the authorization of the supervisor shall be considered and used where practical.

Figure 2-4.7 Typical illustration of the use of a "tag-out" system.
(*Courtesy: American Airlines, Inc.*)

2-4.8 When working on energized electrical systems in areas containing flammable fluid lines, the following precautions shall be taken:

(a)* Precautions shall be taken whenever working on any part of the aircraft to prevent accidental contact of control cables, tools, metal parts, etc., with energized electrical systems, components, or both. Protect adjacent terminals, electrical components and wiring, and/or flammable fluid lines to prevent arcing and fire if accidental cross contact is made.

(b) Adequate fire-fighting equipment shall be available for immediate use.

2-4.9 When trouble shooting, all wires shall be considered "hot" until proven otherwise.

2-4.10 Nonconductive or insulated tools shall be used for working "hot" circuits.

2-4.11 The aircraft electrical circuit involved shall be de-energized whenever equipment and wiring is removed or installed.

2-4.12 Equipment that is new, repaired, or both shall be thoroughly tested and checked for "shorts" before being installed on the aircraft.

2-4.13 Aircraft wiring shall be properly secured to prevent chafing.

2-4.14 All loops provided in electrical cables to prevent flammable fluids from entering electrical connections or components shall be reformed so that they will perform their intended functions.

2-4.15 When dripshields, cables, sheaths, plug covers, or similar devices have been provided to prevent flammable fluids from contacting electrical components, care shall be taken to see that they are reinstalled so that they effectively perform their intended function.

2-5 Repairs to Communications and Navigation Equipment. Repairs to communications and navigation equipment shall be made at a bench or in a shop located away from the aircraft. Radar and radio transmitting equipment shall not be operated, tested, or checked on the aircraft whenever fueling, defueling, tank repair operations (during the time when flammable vapor-air atmospheres are present), or any other similar hazardous operation is taking place within the distance limits outlined in Section 2-9 of NFPA 407, *Standard for Aircraft Fuel Servicing*, or within the distances of the manufacturer's prescribed limitations, except that such operation, testing, or checking may be made at any time if a dummy load, which prevents the energizing of the antenna, is used. In addition, the precautions outlined in 2-4.10 through 2-4.15 above shall be followed.

2-6 Cleaning of Electrical Components Installed on the Aircraft.

2-6.1 Electrical components shall not be energized and shall be isolated from other power sources during cleaning operations.

2-6.2 Only nonflammable solvents shall be used for cleaning electrical components.

2-7 Testing of Electrical Equipment During and Following Repair Operations.

2-7.1 Testing of electrical equipment installed on aircraft shall be held to a minimum. Whenever possible, testing shall be done at a bench or in a shop away from the aircraft.

2-7.2 If practical, equipment shall be checked for continuity of circuitry and resistance before power is applied.

2-7.3 All applicable subsections of Section 2-4 above shall also apply during testing.

2-8 Energizing and De-energizing Electric Circuits During Complete Engine Change.

2-8.1 During engine change, fire hazards can result from failure to de-energize electrical systems prior to disconnecting such systems which are in close proximity to flammable vapors.

2-8.2 Standard aircraft static grounding procedures shall be followed.

2-8.3 Magneto circuits shall be grounded when disconnected at the fire wall.

2-8.4 The electrical systems involved in an engine installation shall be de-energized prior to removal of the engine and remain de-energized until any hazard of flammable vapors in the area has been removed. Such flammable vapors may accumulate during the breaking and making of flammable fluid line connections.

2-8.5 Pertinent electrical systems shall be de-energized prior to installation of the engine and remain de-energized until all flammable fluid system connections are completed and no flammable vapors exist in the area.

2-8.6 Personnel performing an engine change shall be advised when the electrical systems are de-energized and re-energized following the principles expressed in 2-1.4 and 2-4.5.

2-8.7 The de-energized circuits shall be tagged out or locked out so that anyone attempting to energize them will be definitely aware that others may be endangered by his action.

2-8.8 Electrical disconnects shall be protected against accidental contact, dirt, and moisture during the disconnect period, by tight fitting blind plugs or by tape wrapping or both.

2-9 Electrical Equipment Mounted on Fixed Work Stands.

2-9.1 Electric wiring, outlets and equipment (including lamps) on or attached to fixed docks and stands which are located or likely to be located in hazardous areas as defined in Sections 513-2 and 513-3 of Article 513, NFPA 70, *National Electrical Code*, shall conform to the requirements for Class I, Group D, Division 2 locations.

2-9.2 Where docks and workstands are not located or likely to be located in hazardous areas as defined in 2-9.1 above, wiring and equipment shall conform to Sections 513-4 and 513-5 of Article 513, NFPA 70, *National Electrical Code*. Receptacles and attachment plugs shall be of the locking type, which will not break apart readily.

2-10 Electrical Equipment Mounted on Movable Stands. Movable docks and workstands with electrical equipment conforming to 2-9.2 shall carry at least one permanently affixed warning sign to read: "Warning—Keep 5 Ft (1.5 m) (Horizontally) Clear of Aircraft Engines, Fuel Tank Areas, and Vents."

Chapter 3 Aircraft Breathing Oxygen Systems

3-1 General.

3-1.1 Application. This section describes the hazards associated with the handling of breathing oxygen aboard aircraft and describes the procedures for safe servicing, repair, and testing of aircraft breathing oxygen systems. It does not cover either gaseous or liquid oxygen when used for any purpose other than for breathing. It does not cover the storage and handling of breathing oxygen and charging equipment outside of operations directly associated with aircraft breathing oxygen systems.

NOTE: For information on bulk storage of oxygen, see NFPA 50, *Standard on Bulk Oxygen Systems at Consumer Sites*, and NFPA 53M, *Fire Hazards in Oxygen-Enriched Atmospheres*.

3-1.2 Purposes of Aircraft Breathing Oxygen Systems. Breathing oxygen is supplied aboard current types of civilian and military aircraft in the form of:

(a) Supplemental breathing oxygen equipment designed to enrich the breathed ambient air with oxygen at altitudes where the reduced partial pressure of oxygen would otherwise cause hypoxia (oxygen deficiency).

(b) Protective breathing oxygen equipment designed to supply essentially 100 percent oxygen thereby excluding ambient air to prevent the breathing of noxious gases which might be present as contaminants in the air within an aircraft during emergency situations.

3-1.3* Description of Gaseous and Liquid Oxygen.

3-1.3.1 Current aircraft breathing oxygen systems may utilize either gaseous or liquid oxygen or a chemical oxygen generator.

3-1.3.2 Gaseous oxygen is colorless, odorless, tasteless and nontoxic. It comprises about 21 percent of normal air by volume and is about 10 percent heavier than air. Above its critical temperature of −180.4°F (−82.4°C) oxygen can exist only as a gas regardless of the pressure exerted upon it.

3-1.3.3 Liquid oxygen is a light blue, transparent liquid which flows like water. It boils at −297°F (−147.2°C) at standard atmospheric pressure. The gaseous oxygen formed at room temperature [70°F (21°C)] and standard atmospheric pressure [29.92 in. (760 mm) of mercury] by vaporization of liquid oxygen will occupy a volume about 862 times that occupied by the original liquid. If a volume of liquid oxygen is confined and allowed to warm to room temperatures, the attempt of the vaporizing oxygen to expand will result in the attaining of extremely high pressures [in the order of 40,000 psi (276 MPa)]. For this reason, liquid oxygen containers shall be fitted with safety relief devices or vented to atmosphere.

3-1.4 Hazards.

3-1.4.1 Both gaseous and liquid oxygen are stable materials and are nonflammable. Combustible materials ignite more readily in an oxygen-enriched atmosphere. The intensity of a fire increases in the presence of oxygen. This makes it very important to keep concentrations of oxygen separated from combustibles and from any source of ignition. Therefore, the highest standards of housekeeping are essential in areas where oxygen is stored or serviced. Physical damage to or failure of oxygen containers, valves, or plumbing can result in an explosive rupture in oxygen system components with resultant danger to life, limb and property.

3-1.4.2 Combustible materials, particularly easily ignitable flammable liquids and lubricating oil, are especially hazardous when present inside the aircraft breathing oxygen systems where the oxygen concentrations are high. There have been several incidents where explosive rupture of system components has resulted under these circumstances.

3-1.4.3 In addition to aggravating the fire hazard, liquid oxygen will cause severe "burns" (frostbite) in contact with the skin because of its low temperature.

3-1.4.4 Since oxygen-enriched atmospheres accelerate the corrosion process, only materials approved for oxygen service shall be used.

3-2 Types of Aircraft Breathing Oxygen Systems.

3-2.1 Low-Pressure Breathing Oxygen Systems. These fixed systems utilize compressed gaseous oxygen stored in containers having a maximum service pressure of about 400 to 450 psi (2.76 to 3.10 MPa). A typical system consists of one or more containers manifolded to suitable oxygen distribution piping, check valves to isolate individual containers, relief devices to prevent container overpressure from overcharging or heating, a pressure gage to indicate quantity of oxygen available, a manual shutoff valve, valves to isolate portions of the system, a fill fitting to permit charging the system, and one or more of the types of regulators previously described.

3-2.2 High-Pressure Breathing Oxygen Systems. These fixed systems utilize compressed gaseous oxygen stored in containers having a maximum service pressure of about 1800 to 2200 psi (12.4 to 15.2 MPa). A typical system is quite similar to the low pressure systems except that fill fittings may sometimes not be provided (in such systems the entire container is replaced with a full container as needed).

3-2.3 Liquid Breathing Oxygen Converter Systems. These fixed systems utilize liquid oxygen stored in highly insulated containers which may be vented to the atmosphere or operated under low or moderate pressure. A typical system utilizes demand or continuous flow regulators and the liquid oxygen is passed through tubing where it vaporizes and then through a warm-up coil (heat exchanger) to raise the temperature of the gaseous oxygen to a comfortable breathing level. A pressure operated control valve maintains the desired delivery pressure and volume. Overpressure relief devices vent excessive pressures overboard. Other components include a cockpit oxygen quantity indicator, a fill fitting, and the necessary distribution piping and check valves. Some liquid oxygen containers are spherical in shape and are surrounded by integral vaporizer tubing. Others have the vaporizer tubing separate from the container.

3-2.4 Oxygen Generator Systems. These systems utilize a generator with a chemical core. Chemical reaction is initiated by an electrically fired squib or a firing pin. Upon initiation, the generator supplies oxygen to the masks. The generator systems are installed on some turbine aircraft to supply emergency oxygen to the passengers and cabin attendants in the event of loss of cabin pressure.

3-2.5 Portable Equipment. Portable equipment ("walk-around bottles") utilize compressed gaseous oxygen in either the low or high pressure containers. A typical system is comprised of either a demand or continuous flow regulator, a pressure reducer, a quick disconnect fill fitting equipped with a check valve for charging, a container pressure gage and a snap-in connection for mask fittings.

3-3 Types of Aircraft Breathing Oxygen Regulators. The three basic types of aircraft breathing oxygen regulators are supplied from fixed or portable oxygen systems as described in Section 3-2.

3-3.1 Continuous flow-type regulator, with or without automatic or manual, is a means for increasing the flow with altitude. With this regulator, the breathing oxygen flow is fixed for any given adjustment and does not vary automatically to suit work or rest conditions.

3-3.2 Demand-type regulator allows breathing oxygen to flow only when a suction is applied, as by inhaling through a mask or tube.

This regulator may feed only pure breathing oxygen, or the diluter-demand type may have automatic means for mixing air with the pure breathing oxygen to maintain the partial pressure of oxygen in the lungs at a preset, low altitude condition up to some predetermined altitude. An emergency valve for eliminating the dilution of pure breathing oxygen is normally provided.

3-3.3 A pressure breathing demand-type regulator, when used with the proper mask, imposes a predetermined pressure upon the lungs at certain altitudes [usually above 30,000 ft (9000 m)]. Below that altitude, the regulator functions as an ordinary diluter-demand type.

3-4 Oxygen System Charging Operations and Safeguards.

3-4.1 General Cautions Applicable to both Gaseous and Liquid Breathing Oxygen.

3-4.1.1 Because of the possibility of fire or explosion involving quantities of oxygen, the person choosing the site for oxygen charging operations shall consider such items as exposure of other aircraft, vehicles, structures, utilities, and people in the vicinity and the accessibility of the aircraft to fire-fighting equipment. Where it is necessary to conduct gaseous oxygen system recharging or filling in a hanger or building, it shall be done under controlled conditions. Liquid oxygen recharging shall not be conducted indoors under any conditions. Where possible at least a 50-ft (15.2-m) separation shall be maintained between a filling point and other aircraft structures, etc. Avoid liquid oxygen charging operations within range of any drainage system elements, such as catch basins, through which a liquid oxygen spill could enter the drainage system. Such systems always contain combustible material which could be extremely hazardous in contact with liquid oxygen in the confined space.

3-4.1.2 Good housekeeping practices are necessary in the vicinity of oxygen charging operations. This is particularly true with combustibles such as grease, lubricating oil, asphalt, etc.

3-4.1.3 Open flames (including smoking) shall be prohibited within 50 ft (15.2 m) of charging equipment.

3-4.1.4 Adequate safeguards shall be taken while performing aircraft servicing or maintenance operations which may inherently or accidentally introduce ignition sources or combustibles concurrent with oxygen charging operations. These include fueling, fuel and hydraulic system repairs, use of flammable cleaning fluids, de-icing fluids, operation of electrical equipment, etc.

3-4.1.5 Only charging equipment and containers suitable for the specific aircraft breathing oxygen system shall be used. Each container shall be identified by its marking before connecting to the aircraft system. Equipment intended or used for other gases shall not be interchanged with oxygen equipment. High-pressure commercial containers [1800 psi (12.4 MPa) or higher] shall be connected through a pressure regulator to service low-pressure aircraft systems. Failure to use a high-pressure regulator specified for oxygen service is extremely dangerous. Oxygen charging hoses shall be kept clean, capped when not in use and clearly marked or tagged "For Oxygen Use Only."

3-4.1.6 The importance of cleanliness cannot be overstressed. Oil, grease or other readily combustible substances shall not be permitted to come in contact with containers, flasks, valves, regulators, fittings or any other part of the aircraft oxygen system or charging equipment. Oxygen equipment shall not be handled with oily gloves or tools. Charging operations shall not be performed while wearing oily or greasy clothing. Protective caps shall be kept on equipment as long as possible and replaced as soon as possible. Before charging, all connections shall be inspected for cleanliness. If dust, dirt, grease, or any other contaminant is found, it shall be removed with detergent or solvent approved for oxygen service. A small amount of oxygen shall be bled through hose or valve outlets before connecting to the fill fitting to eliminate foreign material which may escape external inspection.

3-4.1.6.1 The hose or valve outlet shall be aimed away from the body and equipment. Merely crack open necessary valves. A clean, dry container shall be available to collect any liquid oxygen discharge which might accidentally escape.

3-4.1.7 Only lubricating and thread compounds specifically approved for oxygen service under the pressures and temperatures involved shall be used. Other oils or greases shall not be used.

3-4.1.8 Only valve packing and transfer hose gaskets which are suitable for oxygen service shall be used.

3-4.1.9 Damage to oxygen containers, hoses, flasks, converters, etc., shall be avoided. Equipment shall be secured so that it cannot fall or roll.

3-4.1.10 Safety devices, identifying markings, symbols, and nameplates shall not be tampered with.

3-4.1.11 Valve outlets or controls which become clogged with ice shall be thawed with warm (not boiling) water.

3-4.1.12 Gaseous oxygen shall not be directed at the body or clothing or liquid oxygen shall not be allowed to contact the body or clothing because of the possibility of both fire and personal injury.

3-4.1.13 Desiccant cartridges are sometimes required to ensure that only dry oxygen is introduced. If required, only fresh desiccant cartridges with filters shall be used.

3-4.1.14 Threaded fittings on regulators, container valve outlets, hoses, etc., shall properly mate with each other. Connectors which do not fit shall not be forced. Fittings with worn or damaged threads shall be replaced.

3-4.1.15 After connecting containers or charging hoses to the oxygen system fill fitting, the connection shall be checked for gastightness by audible and visual means. If a leak is suspected, test with a solution specifically approved for that particular oxygen service (gaseous, chemical or liquid).

3-4.1.16 Charging equipment discharge valves shall be closed when charging is completed.

3-4.2 Specific Cautions Applicable to Gaseous Breathing Oxygen.

3-4.2.1 Container charging valves shall be opened slowly. Rapid opening and subsequent sudden and fast discharge of oxygen into the aircraft oxygen system can cause dangerous heating, which could result in a fire or explosion of combustibles within the system. Container valves shall be fully opened to prevent leakage around the valve stem.

3-4.2.2 Wrenches, hammers, or other tools shall not be used to force container valves. If a container valve cannot be hand operated, it shall be considered defective and taken out of service.

3-4.2.3 The aircraft oxygen system shall be charged to the established pressure after properly setting the supply regulating valve to the proper setting.

3-4.2.4 Where the aircraft oxygen system does not have filler valves and it is necessary to remove the aircraft containers themselves for recharging (a condition found particularly where high pressure containers are employed), the container valve shall be closed and all oxygen in the lines released to atmosphere before attempting container removal. It is important that this discharge be slow because sudden release of oxygen might create a serious fire hazard. Before removing the container from the aircraft, the container valve outlet shall be disconnected and capped, and all distribution lines shall be plugged.

NOTE: Draining or bleeding of oxygen within the aircraft is not considered hazardous as long as the precautions indicated herein are followed and only residual oxygen in the lines (not container supplies) is discharged.

3-4.3* Specific Cautions Applicable to Liquid Breathing Oxygen.

3-4.3.1 Liquid oxygen shall not be permitted to contact any part of the body or clothes. It can cause severe skin injury and make clothing highly combustible. Liquid oxygen lines shall not be handled with bare hands.

3-4.3.2 Personnel shall wear protective clothing while handling liquid oxygen equipment including:

(a) Safety goggles or a clear plastic face shield.

(b) Gloves which are clean, resistant to oxygen absorption, insulating, and loose fitting, without gauntlets.

(c) Clean coveralls with long cuffless sleeves and legs and clean aprons impervious to liquid oxygen absorption.

(d) Shoes of the high-top type with cuffless trousers worn outside the shoes.

3-4.3.3 If liquid oxygen is spilled on clothing, the clothing shall be removed immediately and thoroughly aired before re-use.

3-4.3.4 Personnel who have handled liquid oxygen shall refrain from smoking for at least 15 minutes after leaving the charging area.

3-4.3.5 Exercise care so that no moisture is introduced into a liquid oxygen system and so that there is no moisture in fill fittings or nozzles where it may be entrained into the system during transfer operations. If it is necessary to remove moisture from the system, dry, oil-free air, gaseous oxygen, or nitrogen shall be used before introduction of liquid oxygen.

3-4.3.6 Because of its low temperature, liquid oxygen shall be handled in equipment constructed of materials suitable for the service. For example, ordinary rubber or plastic hoses, gaskets, seals, etc., are unsuitable.

3-4.3.7 If it is necessary to transfer liquid oxygen from one container to another, care is needed to avoid splashing. Cool the receiving container gradually to avoid breakage. Easily fracturable containers (such as glass) shall not be used. The container must be clean.

3-4.3.8 When transferring liquid oxygen, valves shall not be left open all the way; open them wide and then immediately close them about one-quarter turn; otherwise, they may freeze in the open position.

NOTE: See 3-4.2.1 for different instructions relative to gaseous oxygen.

3-4.3.9 Pressure relief devices shall be installed on all lines in which liquid oxygen may be trapped between closed valves and on closed containers.

3-4.3.10 Avoid spilling liquid oxygen on pavement. Drip pans shall be used where pavement surfaces may be combustible or contaminated with dirt, oils, or similar materials which could ignite on contact with any spilled liquid oxygen. A fire and explosion hazard can result if pavement is combustible (asphalt) or is porous and impregnated with combustibles (as concrete contaminated with oil). If a spill does occur, the flow of liquid shall be stopped where possible and the area involving the liquid spill shall be evacuated for the time necessary for liquid oxygen to evaporate. Personnel shall not walk on or move equipment through a liquid oxygen spill.

3-4.3.11* The equipment manufacturer's instructions shall be followed when transferring liquid oxygen from the supply tank to the aircraft system.

3-4.4 Specific Cautions Applicable to Oxygen Generator Systems. During maintenance operations which require the removal of the generator from its aircraft position, a safety cap shall be installed on the oxygen generator primer, since, when activated, it will generate temperatures up to 500°F (260°C). If the generator is inadvertently activated, it shall immediately be placed on a noncombustible surface. However, if the generator is inadvertently activated in its aircraft position, it shall be left in its protected location.

3-4.5 Aircraft Breathing Oxygen System Test and Repair Operations and Safeguards.

3-4.5.1 When flow testing the aircraft system, use the minimum amount of oxygen necessary to check the system. If available, breathing air may be used for this purpose rather than oxygen.

3-4.5.2 Distribution lines within the aircraft shall be inspected periodically in accordance with the aircraft manufacturer's recommendations.

3-4.5.3 Pressure shall be released before attempting to tighten or loosen fittings. This is not intended to prevent connecting or disconnecting the type of containers which incorporate self-opening and self-venting valves.

3-4.5.4 When making pressure tests of oxygen distribution lines, the valves isolating the supply containers shall be closed. The system shall be tested in accordance with the specific instruction for the particular application. Cleanliness is vitally important when checking for leaks. Oil or grease shall not be permitted to come in contact with escaping oxygen. Only leak testing solutions specifically approved for the purpose shall be used. All solutions shall be cleaned off carefully following the test.

3-4.5.5 Close check shall be kept on the vacuum available on all vacuum insulated liquid oxygen tanks and the manufacturer's instructions shall be closely followed.

3-4.5.6 When oxygen regulators or other oxygen system components on the pressure side of shutoff valves are removed for repair or replacement, the oxygen in the lines shall be released in the same manner as for container replacement (*see 3-4.2.4*) and all disconnected lines plugged or capped.

3-5 Fire Protection.

3-5.1 In case of a fire, the oxygen supply to the fire shall be shut off.

3-5.2* Fires in an oxygen-enriched atmosphere are controlled or extinguished in the same manner as fires in an air atmosphere.

3-6 Aircraft Maintenance Equipment, Use, and Facilities.

3-6.1* This section describes safeguards for storage and handling of aviators' breathing oxygen and aircraft breathing oxygen system charging equipment in locations not directly associated with the actual aircraft system charging operations (*see 3-1.1*). It does not cover either gaseous or liquid oxygen used for any purpose other than for breathing.

3-6.2* Breathing Oxygen Cylinder Storage (DOT Gaseous Oxygen Cylinders and DOT Type 4L Cylinders of Liquid Oxygen).

3-6.2.1 Cylinders shall be stored in a definitely assigned location and protected against tampering by unauthorized individuals. Oxygen cylinders shall not be stored in aircraft servicing and maintenance areas of aircraft hangers.

Exception: Cylinders scheduled to be installed on the aircraft.

3-6.2.2 Storage areas shall be reserved for liquid oxygen storage alone and shall be clearly placarded "Oxygen — No Smoking — No Open Flames" or equivalent.

3-6.2.3 Oxygen cylinders shall not be stored near flammable or combustible materials (such as petroleum products), other readily combustible substances, or in the same area as compressed combustible gases. Empty and full cylinders shall be stored separately with empty cylinders clearly marked.

3-6.2.4 Each cylinder of aviators' breathing oxygen shall be clearly marked to indicate its content. Aviators' breathing oxygen shall be separately stored from all other oxygen cylinder supplies.

3-6.2.5 Cylinders shall be stored so that they are never allowed to reach a temperature exceeding 125°F (51.7°C). When stored in the open they shall be protected against direct rays of the sun in localities where extreme temperatures prevail, from snow and ice where necessary, and from the ground beneath to prevent rusting.

3-6.2.6 Cylinders shall be protected against abnormal mechanical shock which could damage the cylinder, valve or safety devices. Valve protection caps shall also be used when cylinders are not connected in use providing cylinders are designed for protection caps.

3-6.2.7 When moving cylinders, care shall be exercised to prevent dropping, which may cause injury to the cylinder, valve or safety devices. Lifting magnets, slings of rope or chain, or any other device in which the cylinders themselves form a part of the carrier shall not be used for hoisting oxygen cylinders. On hand or power trucks or tractors, cylinders shall be secured in an upright position.

3-6.2.8 DOT Regulations regarding hydrostatic testing of DOT Specification 3A or 3AA cylinders shall be followed.

3-6.3 Liquid Breathing Oxygen Storage (in Other than DOT Type 4L Cylinders).

3-6.3.1 Liquid oxygen containers shall be stored outdoors or in a detached, noncombustible structure in accordance with NFPA 50, *Bulk Oxygen Systems at Consumer Sites*, if the oxygen quantities fall within the scope of that standard. Smaller quantities shall be located outdoors in a detached noncombustible structure or in a cutoff room provided the cutoff room has effective ventilation and necessary doorways protected by fire doors with ramps or curbs to prevent entrance of flammable liquids and exit of liquid oxygen.

3-6.3.2 Storage areas shall be reserved for liquid oxygen storage alone and shall be clearly placarded "Oxygen — No Smoking — No Open Flames" or equivalent.

3-6.3.3 The construction and occupancy of liquid oxygen storage areas shall be strictly noncombustible and have no floor drains. Wall scuppers (not connected to drainage systems) are advisable.

3-6.3.4 In outdoor areas, valves and safety devices shall be protected from ice and snow accumulations.

3-6.4 Miscellaneous Requirements.

3-6.4.1 Oxygen shall not be used as a substitute for compressed air to operate pneumatic tools, for pressurizing containers, for paint spraying, for blowing out pipelines, etc.

3-6.4.2 Gases shall not be mixed in an oxygen container.

3-6.5 Mobile Aircraft Oxygen Charging Equipment. Charging of fixed aircraft oxygen cylinder systems aboard aircraft can only be done with safety if there is rigid compliance with these operating instructions and expert guidance secured on the design of the charging equipment utilized.

3-6.5.1 Gaseous Oxygen Equipment.

3-6.5.1.1 General. The conventional equipment used for this purpose consists of a wheeled cart on which are mounted a number of high-pressure cylinders with an attached manifold. A pressure-reducing device, such as a regulator, installed on the manifold is provided with an outlet connection to which the hose used to fill the aircraft oxygen system is attached. A dehumidifier, used to dry the oxygen, is sometimes interposed between the regulator outlet and the filling hose.

3-6.5.1.2 Design Considerations.

3-6.5.1.2.1 Cylinders used to store gaseous oxygen supplies shall conform with DOT Regulations (DOT Specification 3A or 3AA); be equipped with a shut-off valve; be equipped with a frangible disc safety device (S-1.1)[1]; be connected to a common header by suitable pigtails strong enough to safely withstand full cylinder pressure; and be securely fastened to the cart.

3-6.5.1.2.2 Manifolds shall be constructed with sufficient strength to safely withstand full cylinder pressure. Manifolds shall be equipped with a valve connection for use in filling the cylinders and a valved outlet connection to which the regulator is attached.

[1]*Compressed Gas Association Safety Relief Device Standard S-1.1*, 1965, published by the Compressed Gas Association, 500 Fifth Avenue, New York, NY 10036

3-6.5.1.2.3 Regulators.

(a) Regulators and components shall be approved for oxygen service.

(b) Seats used in regulators shall be of a material chosen for maximum resistance to ignition in an oxygen atmosphere and which will have the required physical characteristics needed to maintain a gastight seal.

(c) Regulators shall be provided with a suitable filter to prevent foreign particles from entering their inlet chambers.

(d) Regulators shall be provided with a means for dissipating heat of recompression resulting from admission of high-pressure oxygen to the regulator which might otherwise cause the regulator high-pressure seat to ignite. This can be a dead-end chamber directly connected to the inlet passage of the regulator or some other heat-absorbing device.

(e) Regulators shall be equipped with gages for indicating cylinder and discharge pressures.

3-6.5.1.2.4 Orifice.

(a) Pressure reduction may also be achieved through the use of a flow-restricting orifice installed at the manifold outlet valve or in the line between the outer valve and the cylinder to be filled. This arrangement, unlike the one employing a regulator, requires the presence of an operator to shut off the gas supply from the manifold when the aircraft oxygen system comes up to specified pressure.

(b) The orifice plate shall be constructed of approved material and shall be provided with a hole small enough to restrict the flow of oxygen to the equipment being filled to prevent development of excessive temperature in this equipment.

(c) A pressure gage shall be provided downstream of the orifice as a means of indicating the pressure in the aircraft oxygen system being filled.

3-6.5.1.2.5 Overpressure Protection.

(a) An approved spring-loaded relief valve, preferably equipped with a metal seat, shall be provided to protect the hose and other equipment that may be attached to the outlet of the manifold.

(b) A frangible disc shall be provided in the system downstream of the manifold outlet to function in the event that the safety relief valve malfunctions.

3-6.5.1.2.6 Dehumidifiers or Dryers.

(a) Any drying agent used shall be approved for use with oxygen.

(b) The container housing the drying agent shall be strong enough to safely withstand the pressure to which it may be subjected. The container shall be constructed of an approved material. If steel is used, it shall be suitably corrosion-proofed.

(c) Gasket materials used shall be approved for use with oxygen.

3-6.5.1.2.7 Hose.

(a) Hose shall be approved for use with oxygen. It shall be strong enough to safely withstand any pressure to which it may be subjected.

(b) Hose connections shall be of a positive type that will not loosen in use.

(c) The outlet end of the hose shall be equipped with a shutoff valve.

(d) The valve outlet shall be attachable to the system fill receptacle by positive means which will not loosen in use.

3-6.5.1.2.8 Miscellaneous.

(a) No oil, grease, or other such combustible materials shall be allowed to come in contact with the equipment.

(b) Thread-sealing compounds, when used, shall be approved for use with oxygen.

(c) All parts of the equipment shall be thoroughly cleaned of oil, grease, etc., before being assembled.

3-6.5.1.3 Precautions.

3-6.5.1.3.1 The cart manifold outlet valve immediately upstream of the regulator shall be in the closed position before opening the cylinder valves on the cart.

3-6.5.1.3.2 Oxygen valves shall be opened slowly to avoid rapid pressure rise.

3-6.5.1.3.3 After opening cylinder valves on the cart, wait 60 seconds before opening the manifold outlet valve to permit heat of recompression to dissipate.

3-6.5.1.3.4 Before opening the manifold outlet valve to the regulator, relieve the regulator of pressure (if the regulator is not the self-relieving type).

3-6.5.1.3.5 Before disconnecting, the valve at the end of the fill hose shall be closed (to avoid whipping).

Chapter 4 Aircraft Fuel System Maintenance

4-1 General.

4-1.1 Application. This chapter deals with fire safety in the servicing, maintenance and testing of aircraft fuel systems.

4-1.2 Fuel Handling.

4-1.2.1 Requirements for fire safety for procedures, equipment installations and for the operation of ground equipment and radar during fueling and defueling are given in NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-1.2.2 Draining of residual fuel from the system is covered in 4-2.2.2.5 and 4-3.2.1.2.

4-1.2.3 Aircraft fuel transfer operations are covered in 4-4.2.

4-2 Safeguarding Tank Atmospheres.

4-2.1 General Procedures and Definitions.

4-2.1.1 This chapter outlines three possible methods of safeguarding tank atmospheres, one of which may be followed during aircraft ground handling in the interest of fire and explosion prevention when reduction of the flammable vapor hazard of aircraft fuel tank atmospheres is desired when such tanks contain or did contain a volatile fuel. The circumstances under which any one procedure may be followed are variable and subject to the discretion of the operator (*see 4-2.1.5, 4-2.1.6 and 4-2.1.7*). Airborne fuel tank inerting is not included.

4-2.1.2 The authority having jurisdiction shall determine the need for the protection of fuel tank atmospheres and the method to be used. Normally, preventive measures are taken where flammable vapors in aircraft fuel tanks present a hazard during the handling of aircraft under conditions and in locations where the release of such flammable vapors presents an unacceptable risk, either because of the life hazard involved or the potential magnitude of the property damage which might result from the ignition of such vapors.

4-2.1.3 The three basic procedures suggested herein are:

(a) Siphon inerting, covered in 4-2.3

(b) Pressure inerting, covered in 4-2.4

(c) Air ventilation, covered in 4-2.5 through 4-2.7.

4-2.1.4 Generally, siphon inerting is suitable in cases where it is not necessary to open the tanks to conduct inspection or work therein and where it has been found particularly desirable for a series of tanks (metal, integral or bladder) mounted in an aircraft. Siphon inerting requires the draining of the fuel within the tanks to be inerted. There may be cases where siphon inerting would be desirable for safeguarding a tank or tanks adjacent to (but not adjoining) another tank which is to undergo inspection or work. Under such conditions, a combination of procedures might be employed on a single aircraft at the same time.

4-2.1.5 Pressure inerting is also used in cases where it is not necessary to open tanks to conduct inspection or work therein. Pressure inerting does not necessarily require the draining of the fuel within the tanks to be inerted. The effectiveness of the method can only be assured when it is possible to sample the fuel tank atmosphere in all void portions of each tank to be treated to determine that a satisfactory concentration of inert gas is secured. Siphon inerting (*see 4-2.1.4*) is considered the most efficient procedure for inerting interconnected tanks in that this method assures even distribution of the inert gases throughout such a fuel tank system. Pressure inerting will find its greatest usefulness for inerting individual tanks, but, where interconnected tanks are inerted by this method, it is important that each individual interconnected tank be probed to determine that efficient distribution of the inert gas has been secured in all portions of such a fuel tank system.

4-2.1.6 Generally, air ventilation is suitable in cases where the tank or an interconnected tank must be opened to conduct inspection or work therein. Air ventilation requires the draining of the fuel within the tanks to be ventilated prior to start of the ventilation. In many cases, the health hazards resulting from the presence of fuel vapors, particularly leaded grades of aviation fuel, determine the extent of ventilation required when human occupancy is necessary for the inspection or work and fresh air breathing masks are not available or are impractical. An atmosphere that is safe from the health viewpoint will automatically result in an atmosphere containing a "too lean" mixture of fuel vapors to present a fire or explosion hazard. (*See 4-2.5.2.1 and 4-2.5.2.2*).

4-2.1.7 Definitions.

Air Ventilation. Air ventilation, as used herein, means to pass undiluted air (air not containing flammable vapors or inert gases) through an aircraft tank to render the atmosphere of the tank more suitable for human occupancy and to reduce the amount of flammable vapors in the tank to below the lower explosive limit of the fuel vapors involved. It is recognized that, at sometime during and possibly after air ventilation, the tank may contain a flammable vapor-air mixture. During such periods, a fire and explosion hazard exists which requires the elimination of ignition sources within the vapor-hazardous areas.

Inert Atmosphere. An inert atmosphere is an atmosphere where combustion cannot occur.

Inert Gas. Inert gas is any gas which is nonflammable, chemically inactive, noncontaminating for the use intended, and oxygen-deficient to the extent required.

Inerting. Inerting[1], as used herein, means the use of an inert gas to render the atmosphere of an enclosure nonexplosive or nonflammable. Inerting, in effect, reduces the oxygen content (*see 4-2.1.9.1 and Table 4-2.1.9*) of the air in the tank vapor space below the lowest point at which combustion can occur by replacing the oxygen in air with an inert gas.

Purging. Procedures to accomplish purging[2] are not covered herein, but it is important to establish the technical difference between inerting (as used herein) and purging to avoid confusion of terminologies, procedures, and results. For the above purposes, purging an aircraft fuel tank means to remove the flammable vapor atmospheres or any residue capable of producing flammable vapors in the tank and connected distribution lines so that subsequent natural ventilation will not result in the reinstatement of a flammable atmosphere unless or until a flammable liquid is again introduced into the tank or its connected distribution lines.

4-2.1.8* Inert Gases. Nitrogen is a satisfactory medium and is also normally available at locations where work of this type is conducted. Greater quantities of nitrogen are required than of carbon dioxide to secure the desired inerting effect (*see 4-2.1.9.1 and Table 4-2.1.9*), but, generally, nitrogen can be retained more easily in a sealed tank than can carbon dioxide because of its lighter weight. Periodic checks (not to exceed 48 hours) shall be conducted to assure the maintenance of an inert atmosphere, particularly in nonmetallic fuel cells, or, in lieu of this, a positive pressure (within the safe working pressure of the tank) shall be maintained on the inerted tank from the inert gas supply.

[1] The term "inerting" is used to avoid the more awkward use of the adjective "inert" throughout the text. "Inerting" is identical in meaning to the phrase, "to render inert."

[2] Dictionary definition: To cleanse or purify by separating and carrying off whatever is impure, heterogeneous, or superfluous.

4-2.1.9 Inert Gas Concentrations.

4-2.1.9.1 Table 4-2.1.9 is included as a guide to the maximum permissible oxygen percentages in atmospheres containing various typical aviation fuel vapors with nitrogen as the inert gas. The quantity of inert gas provided should reduce oxygen concentrations to at least the 20 percent factor of safety (20 percent below the lower explosive limit at which combustion can occur). (*For exceptions, see 4-2.3.1.3 and 4-2.4.1.3.*)

4-2.1.9.2 Prior to certifying that a tank has been inerted, a check should be made to determine that the maximum permissible oxygen content of the tank with the inert gas used does not exceed that specified in Table 4-2.1.9 with the 20 percent factor of safety (*see 4-2.1.9.1*), assuming that the fuel involved is one of those listed in Table 4-2.1.9 as typical. (For other fuels, consult the appropriate laboratory.) The instrument used to secure this measurement must be of a type specifically designed to measure the oxygen content of the inerted atmosphere or the inert gas concentration.

4-2.1.10 Personnel Skills and Procedures.

4-2.1.10.1 Personnel selected to supervise inerting work shall have considerable knowledge and experience in handling flammable liquids and inert gases. They shall be fully informed about the chemistry of combustion and trained in the handling of explosion hazards.

4-2.1.10.2 Special caution is required to avoid asphyxiation in concentrations of inert gases and to avoid the toxic effects of gasoline vapors. Air supply breathing masks shall be required where tank entry is made into an inerted tank.

4-2.1.10.3 Warning! The inerting of aircraft fuel tanks containing other fuels than those listed in Table 4-2.1.9 may involve hazards not yet fully understood. Consult a qualified laboratory for data on fuels not listed.

Table 4-2.1.9
Maximum Permissible Oxygen Percentages and Minimum Inert Gas Concentrations with Various Factors of Safety for Inerting of Aircraft Fuel Tanks Containing Various Typical Aviation Fuels*

Typical Fuels and Factors of Safety	Using Carbon Dioxide as Inerting Medium		Using Nitrogen as Inerting Medium	
	Maximum O_2%	Minimum CO_2%	Maximum O_2%	Minimum N_2%
Aviation Gasoline[1]				
0% Factor of Safety	14.6	27.9	11.9	41.2
10% " " "	13.1	30.7	10.7	45.3
20% " " "	11.6	33.5	9.5	49.4
Aviation Gasoline[2]				
0% Factor of Safety	14.8	27.0	11.9	40.6
10% " " "	13.3	29.7	10.7	44.7
20% " " "	11.8	32.4	9.5	48.7
Type B Turbine Fuel (JP-4)[3]				
0% Factor of Safety	14.3	29.0	11.5	43.0
10% " " "	12.8	31.9	10.3	47.3
20% " " "	11.4	34.8	9.1	51.6

[1] Figures based on Aviation Gasoline grade 115/145 at atmospheric pressure and 80° ± 2°F (27° ± 1°C).
[2] Figures based on Aviation Gasoline grade 100/130 at atmospheric pressure and 80° ± 2°F (27° ± 1°C).
[3] Figures at atmospheric pressure and about 75°F (24°C).

Data on other aviation fuels are not currently available. See 4-2.1.10.3.

* Based on information supplied by the Bureau of Mines, U.S. Department of the Interior, Report No. 3460 (July 7, 1955) "Research on the Flammability Characteristics of Aircraft Fuels."

4-2.2 Inerting Procedures, General.

4-2.2.1 Location of Work. The aircraft, wing section, or tank to be inerted shall be located out-of-doors in an established area or in an approved structure clearly segregated and indicated as a hazardous area.

4-2.2.2 Precautions Against Exterior Ignition Sources.

4-2.2.2.1 All open flame- and spark-producing equipment or devices within the vapor hazard area shall be shut down and not operated during the inerting procedures.

4-2.2.2.2 Procedures to guard against the accumulation of static electrical charges on the aircraft, wing section, or tank shall utilize equipment as described in Chapter 13 of NFPA 409, *Standard on Aircraft Hangars*.

4-2.2.2.3 Electrical equipment used in the vapor hazard areas shall be approved for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-2.2.2.4 All mechanics and other persons, except those engaged in the inerting procedures, shall remain clear of the aircraft, and no other maintenance activities shall be conducted on the aircraft, the wing section, or tank until after the inerting has been accomplished.

4-2.2.2.5 Aircraft fueling and defueling shall conform to the requirements of *Standard for Aircraft Fuel Servicing*, NFPA 407. (*See also 4-1.2.*) Draining of residual fuel from aircraft tanks and system components presents special fire hazards. Variations between different types of aircraft preclude the establishment of standard procedures but the following principles apply:

(a) After defueling the residual fuel is normally drained from the fuel piping system through sump drain valves into a covered, vented container or drum using temporary pipe or hose.

(b) The aircraft and the container shall be grounded and bonded in accordance with the requirements of *Standard for Aircraft Fuel Servicing*, NFPA 407. It is important to provide bonds across points of possible spark gap even though relatively small amounts of fuel and slow flow rates are involved. (*See also 4-3.2.1.2.*)

4-2.2.2.6 Warning! These procedures are designed to accomplish satisfactory inerting of aircraft fuel tanks under the conditions discussed in 4-2.1.4 and 4-2.1.5. When aircraft wing or fuselage sections (other than fuel tank areas) contain flammable vapors (as a result of spillage of fuel, leakage in the fuel system, or penetration and entrapment of flammable vapors during fueling or defueling), it is important that such flammable vapors be cleared from such areas out-of-doors by either natural or forced ventilation of such spaces.

4-2.2.2.7 A suitable warning sign shall be placed in a conspicuous location on the aircraft to indicate that the fuel system has been inerted.

4-2.2.3* Fire Protection.

4-2.2.3.1 Aircraft hangars in which work of this type is conducted shall be provided with automatic fire protection equipment in accordance with the requirements contained in NFPA 409, *Standard on Aircraft Hangars.*

4-2.2.3.2 Adequate portable fire extinguishing equipment shall be provided for the hazards involved. Portable or mobile equipment shall include extinguishing agents such as carbon dioxide, Halon 1211 or dry chemical. A permanent, smothering-type extinguishing agent such as foam shall also be available. The amount and nature of such equipment depends on the size of the tank being inerted, the size of the aircraft, and the life and exposure hazards involved. An extinguisher having a rating of not less than 20B and a minimum capacity of 15 lb (6.8 kg) of agent shall be located within 50 ft (15 m) of the aircraft undergoing inerting.[1]

4-2.3* Siphon Inerting.

4-2.3.1 Evaluation of Method, General.

4-2.3.1.1 This is a recommended method of inerting an aircraft fuel tank or tanks; it is particularly desirable for a series of tanks (metal, integral or bladder) mounted in an aircraft.

4-2.3.1.2 The aircraft fuel tank shall first be filled to capacity with fuel (less outage space). Then this fuel shall be drained while the inert gas is siphoned into the tank void spaces through the tank vent line(s). This involves, in some cases, the handling of considerable quantities of fuel.

4-2.3.1.3 If "hot work" is to be performed on a tank which has been inerted by this method, the oxygen content in the tank vapor space

[1]See NFPA 403, *Recommended Practice for Aircraft Rescue and Fire Fighting Services at Airports and Heliports*, for airport mobile fire equipment; NFPA 407, *Standard for Aircraft Fuel Servicing*, for fire extinguisher requirements during fueling and defueling; and NFPA 409, *Standard on Aircraft Hangars*, for hangar and adjacent ramp protection. NFPA 10, *Standard for the Installation of Portable Fire Extinguishers*, is also a useful reference.

shall be maintained at substantially zero during the entire period when the work is in progress. (Processes included in the category of "hot work" are welding, cutting, soldering, explosive riveting, or any similar process involving an open flame, the application of heat, or a spark-producing tool.)

4-2.3.2 Apparatus Required.

4-2.3.2.1 The following equipment is required to accomplish the siphon inerting of an aircraft fuel tank:

(a) An inert gas supply. The gas must be delivered to the fuel tank atmosphere in the gaseous state. If the gas is stored in cylinders at high pressure, special precautions shall be taken to avoid liquid discharge [*see 4-2.3.2.1(d)*].

(b) If a pressurized gas supply is used, a pressure-reducing or regulator valve to accommodate the cylinder or other source of inert gas. This valve shall be suitable for the gas being used.

(c) A needle-type flow control valve to regulate the flow of inert gas.

(d) When a pressurized gas supply is used, a surge tank (this may be an airtight oil drum) equipped with adequate pressure and vacuum relief devices.

(e) A calibrated differential pressure gage.

(f) Tubing, equipped with airtight connectors, to transmit the inert gas to the aircraft tank vent.

(g) Equipment to defuel the aircraft in a safe manner (normally an aircraft fuel servicing vehicle).

4-2.3.2.2 An oxygen or an appropriate inert gas analyzer or a combustibles detector will be needed for subsequent testing for the maintenance of an inerted atmosphere in a tank.

4-2.4* Pressure Inerting.

4-2.4.1 Evaluation of Method, General.

4-2.4.1.1 This method of inerting the vapor space of an aircraft fuel tank or tanks requires careful analysis to assure that all vapor portions of the tank or tanks are reached by the inert gas in sufficient volume to render the nonliquid portions of the tank inert. To assure that such tank atmosphere is inert, it is necessary to thoroughly probe the vapor spaces of the tank with an appropriate instrument (an oxygen analyzer, the appropriate inert gas analyzer, or a combustibles detector). This method may be used with greatest satisfaction on single tanks, whether mounted in aircraft or not. Interconnected tanks tend to dissipate the inert gas unevenly when introduced by this rather than the siphon method, and, accordingly, a larger volume of gas is needed (*see 4-2.1.4 and 4-2.1.5*).

4-2.4.1.2 An advantage of this method is that the tank vapor space can be inerted without a change of level of fuel in the tank assuming that drainage of the fuel is not necessary or desirable for other purposes or that work is not to be performed in the tank.

4-2.4.1.3 If "hot work" is to be performed on a tank which has been inerted by this method, the oxygen content in the tank vapor space shall be maintained at substantially zero during the entire period when the work is in progress. (Processes included in the category of "hot work" are welding, cutting, soldering, explosive riveting, or any similar process involving an open flame, the applicaton of heat, or a spark-producing tool.)

4-2.4.2 Apparatus Required.

4-2.4.2.1 The following equipment is required to accomplish pressure inerting of an aircraft fuel tank.

(a) An inert gas supply. The gas must be delivered to the fuel tank atmosphere in the gaseous state. If the gas is stored in cylinders at high pressure, special precautions shall be taken to avoid liquid discharge. The supplier of the gas may be consulted as to the proper manner of avoiding liquid discharge from cylinder supplies.

(b) A pressure-reducing or pressure-regulating valve to accommodate the cylinders or other sources of inert gas. This valve shall be suitable for the gas being used.

(c) A needle-type flow control valve to regulate the flow of inert gas.

(d) A length of flexible steel, equivalent metallic or conductive rubber tubing with an electrostatic bonding wire at each end. This tubing shall be of sufficient length to locate the inerting equipment at a distance from the aircraft being inerted to permit observation of the entire operation from the pressure regulator position.

(e) A pressure relief valve set to operate at the maximum safe working pressure of the tanks being inerted. The exhaust from this valve shall be directed away from the aircraft. [*See A-4-2.4.2.1(f).*]

(f)* A fitting to accommodate the filler neck of the tank being inerted, arranged as to form a gastight seal between the fuel tank opening and the inert gas delivery tube. This fitting must be made of conducting material to form a bond between the tank filler line and the inert gas delivery line. This is in addition to the electrostatic bonding wire and clip on the end of the inert gas delivery line.

In addition, the fitting shall have a length of copper tubing not less than 1 in. in diameter and 12 in. (.3 m) in length, closed at its far end and containing many holes or discharge ports along the last 3 in. (76 mm) of its length to discharge the inert gas.

(g) An oxygen or appropriate inert gas analyzer or a combustibles detector.

4-2.5 Air Ventilation — General.

4-2.5.1 Basic Considerations.

4-2.5.1.1 Under these procedures, air ventilation of aircraft fuel tanks is recommended for the sole purpose of rendering the atmosphere in an aircraft fuel tank more suitable for personnel to enter the tank area for inspection or work purposes. This requires, basically, reducing the fuel tank vapors to below a predetermined toxic threshold (unless respiratory protection is provided) and below the predetermined lower flammability limits of the flammable vapors and, then, maintaining this condition throughout the period of inspection or work. Air ventilation is not a method of inerting an aircraft fuel tank and this distinction must be clearly understood (*see 4-2.1.4 through 4-2.1.6*).

4-2.5.1.2 Air ventilation may be accomplished by exhausting the fuel tank atmosphere of toxic and flammable concentrations of fuel vapors through a specified vapor exhaust system with or without a blower designed to augment the "sweeping" of the fuel vapors from the tank. As explained later, the design of the air ventilation system used on any particular aircraft shall be "tailor-engineered" to satisfy the requirements of the aircraft in question, and detailed specifications will be required for each fuel tank configuration to properly achieve these objectives.

4-2.5.1.3* Under some conditions (particularly in integral-type fuel tanks having sealing compounds at tank joints and in baffled tanks where drainage through baffles may not be efficient) it is possible to reinstate a flammable fuel vapor-air concentration after initial ventilation has secured a satisfactory condition. Where flammable solvents are used to remove or replace sealant or where fuel vapors are released by the breaking of sealing compound blisters, a localized toxic and/or flammable vapor atmosphere may be created. When such conditions exist, extreme caution shall be exercised to eliminate all possible ignition sources. To minimize this type of hazard, nonflammable solvents shall be used wherever possible and air ventilation shall be continued during all work periods. Periodic checks shall be made with a combustibles detector or other appropriate instrument in the area of work to assure the maintenance of a safe tank atmosphere.

4-2.5.1.4 Personnel working in fuel tanks shall wear approved respirators when tests show the tank atmosphere exceeds the threshold limit values (TLV) of the toxic vapors present or the oxygen content is below 19½ percent.

4-2.5.1.5 Air mover equipment used to secure air ventilation shall not create fire hazards. Air movers designed to operate by expansion of compressed air or steam are recommended. Where electrical equipment is used, the appliances shall conform to the types specified by Article 513 of NFPA 70, *National Electrical Code*. Compressed air shall not be introduced directly into aircraft fuel tanks for air ventilation purposes.

4-2.5.2 Lower Flammability Limits.

4-2.5.2.1 Table 4-2.5.2 is included as a guide to the lower flammability limits of the various aircraft fuels in current usage based on technical information presently available. (*See Appendix A of NFPA 407, Standard for Aircraft Fuel Servicing.*)

4-2.5.2.2 The determining factor of threshold limit values (TLV) may be influenced predominantly, as mentioned previously, by the maximum allowable concentration of vapors permitted from an industrial hygiene viewpoint where respiratory protection for workers is not provided. For leaded gasoline of all grades, the limit established is 500 parts per million based on exposures for an eight-hour workday. For gas turbine fuels (such as Type A and B), the limits are 400 to 500 parts per million. Solvent vapors may be even lower (e.g., methyl ethyl ketone has a limit of 250 parts per million).

Table 4-2.5.2
Lower Flammability Limits of Aviation Fuels

Fuel	Lower Flammability Limit	
	Percent by Volume	Parts per Million
Aviation Gasoline (all grades)	1.4	14,000
Type A (kerosene) Turbine Fuel	0.6	6,000
Type B (gasoline-kerosene blend)	0.8	8,000

4-2.5.2.3 A factor of safety shall be included where the lower flammability limit is the criterion and that 20 percent of the limits shown in Table 4-2.5.2 shall be considered the maximum allowable concentration of fuel vapor.

4-2.5.2.4 Instruments used to measure the lower flammability limit (or maximum allowable toxic limit) shall be calibrated accurately for the type of vapors present and checked periodically against standard samples to assure maintenance of calibration. (*See 4-2.7.2.1(c).*] Sampling tubes shall be of a type which will be impervious to absorption of the vapors. Instruments depending upon electrical power, if not designed for use in Class I, Group D atmospheres (as defined in NFPA 70, *National Electrical Code*) or certified as instrinsically safe because of their low energy design, shall be operated only in nonhazardous locations.

4-2.5.3 Personnel Skills and Procedures.

4-2.5.3.1 Personnel selected to conduct air ventilation work shall have considerable knowledge of and experience in handling flammable liquids. Since a health hazard is also involved in many cases, knowledge of industrial hygiene requirements is important.

4-2.5.3.2 Thorough knowledge of the fuel system of the aircraft is essential.

4-2.6 Preparations for Air Ventilation.

4-2.6.1 Location of Work.

4-2.6.1.1 Prior to conducting work on tanks, it is necessary to defuel the tank or tanks to be inspected or maintained. Such defueling operations shall be done in accordance with NFPA 407, *Standard for Aircraft Fuel Servicing*. Residual fuel which cannot be withdrawn by normal defueling procedures is drained from the tanks by removal of bottom tank plates. With the opening of the tank, air ventilation procedures shall be immediately instituted (*see 4-2.7*). Preferably, this operation shall be done outdoors when weather conditions permit. This operation is inherently very hazardous as there can be little control over the vapors released and frequently liquid fuel escapes as bottom plates are removed. Such fuel shall be retrieved in the safest possible manner and the fuel prevented from excessively wetting the underside of the wing or dripping to the ground or ramp to form pools. Furthermore, some of the residual fuel shall be siphoned out of the tank or be manually sponged or "mopped up" from tank low points or where trapped by baffles [*see 4-2.7.1.2(a)*]. Prior to entry into the tank to conduct any manual operation, tests shall be conducted to determine that the flammable air vapor mixture and/or oxygen levels below 19 percent do not exist or that toxic quantities of vapors are not present unless approved respiratory protection is provided and worn.

4-2.6.1.2 Where such facilities are available and practical, hangar docks (open-faced structures) are preferable to enclosed hangars for the balance of the air ventilation procedure. Aircraft undergoing fuel tank ventilation procedures shall be segregated or isolated from other aircraft when the flash point of the fuel is less than 100°F (37.8°C) or until a 20 percent lower flammable limit (LFL) of the flammable vapor concentration is maintained.

4-2.6.1.3 When air ventilation is done in an enclosed hangar and where a closed ventilating system to discharge vapors from tanks to outside the hangar is not used and tank vapors are discharged into the hangar, tests shall be conducted to determine that the presence of such fuel vapor laden air in the enclosed hangar does not consitute a hazard under the worst conditions that can normally be anticipated. Any flammable vapor concentration over 20 percent of the lower flammability limit within or beyond a distance of 5 ft (1.5 m) downwind from any discharge point of a tank shall result in emergency revisions of procedures.

4-2.6.2 Precautions Against Exterior Ignition Sources.

4-2.6.2.1 All open flame- and spark-producing equipment or devices within the vapor hazard area shall be shut down and not operated during the ventilation procedures.

4-2.6.2.2 Electrical equipment used in the vapor hazard areas shall be approved for use in Class I, Group D, Division 1 hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-2.6.2.3 Procedures to guard against the accumulation of static electrical charges on the aircraft, wing section, or tank shall utilize equipment as described in Chapter 13 of NFPA 409, *Standard on Aircraft Hangars*.

4-2.6.2.4 Aircraft electrical circuits which are in vapor hazardous areas shall be de-energized.

4-2.6.2.5 Aircraft radar operations shall be controlled as required in Section 2-9 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-2.6.2.6 Suitable warning signs shall be placed in conspicuous locations around the aircraft to indicate that tank ventilation is in progress until a flammable vapor concentration less than 20 percent of the lower flammable limit (LFL) is maintained.

4-2.6.3 Fire Protection.

4-2.6.3.1 Aircraft hangars, in which work of this type is conducted, shall be provided with automatic fire protection equipment in accordance with the requirements contained in NFPA 409, *Standard on Aircraft Hangars*.

4-2.6.3.2 Adequate portable fire extinguishing equipment shall be provided for the hazards involved. Portable or mobile equipment shall include extinguishing agents such as carbon dioxide, Halon 1211, or dry chemical. A permanent smothering-type extinguishing agent such as foam shall also be available. The amount and nature of such equipment depends on the size of the tank being inerted, the size of the aircraft and the life and exposure hazards involved. An extinguisher having a rating of not less than 20B and a minimum capacity of 15 lb (6.8 kg) of agent shall be located within 50 ft (15 m) of the aircraft undergoing inerting.

4-2.7* Air Ventilation Procedures.

4-2.7.1 Evaluation of Method, General.

4-2.7.1.1 When using air ventilation procedures, there will be times when the fuel-vapor air mixture in the tank will be within the flammability range. (*See also 4-2.1.7, Air Ventilation.*) During such periods, a fire and explosion hazard exists. It is thus vitally important that there are no ignition sources within the tank or within reach of the vapors being discharged from the tank.

4-2.7.1.2 Successful use of air ventilation depends heavily on three basic factors:

(a) Complete drainage of the fuel tank to be treated, including siphoning, sponging, or "mopping up" of fuel residues which may be trapped in the tank. During the latter operations extreme caution is necessary to prevent accidental ignition of the vapors which will be present. Fuel vapor concentrations shall be maintained below 20 percent of lower flammable limit (LFL) and approved respirators shall be used until an approved health safe condition is maintained.

(b) Establishment of adequate air circulation through the tank to be treated to assure that the air movement rids the entire tank volume of hazardous quantities of fuel vapors. This requires exhaustive tests on each tank configuration to establish the correct tank openings required, the rate of air movement, and the time needed. Such tests must include combustible vapor measurements of all the tank volume to assure that no hazardous vapor pockets remain, especially in tank corners which may not be properly air ventilated if the air currents established by the exhaust and/or blower systems are ineffective.

(c) Continuation of air ventilation during the entire period that the tanks are open and any work is being done. If additional quantities of flammable vapors are introduced into the tank volume (as during internal cleaning of tank surfaces or resealing of tank seams) adjustments may be required to maintain the proper amount of ventilation required.

4-2.7.1.3 Air ventilation shall not be relied upon to safeguard fuel tank atmospheres if "hot work" is to be performed on the tank. (Processes included in the category of "hot work" are welding, cutting, soldering, explosive riveting or any similar process involving an open flame, the application of heat, or a spark-producing tool.)

4-2.7.1.4 When air exhaust only is used, precautions shall be taken to prevent building up a negative pressure which might result in tank collapse. Where a blower is used, the volume and pressure of air introduced and discharged shall be so balanced that no pressure differential arises which might have an adverse effect on the tank structure.

4-2.7.2 Apparatus Required.

4-2.7.2.1 The following equipment is required to accomplish air ventilation of aircraft fuel tanks:

(a) An air mover (exhaust) and, if circumstances dictate, a blower (*see 4-2.5.1.5*).

(b) When air ventilation is conducted in an enclosed hangar and conditions warrant, an exhaust system designed to discharge the vapors to the outside of the hangar.

(c)* Properly calibrated instruments designed to take readings of fuel and solvent vapor and oxygen concentrations within the tank volume being treated and appropriate gas sampling tubing.

4-3 Tank Repairs.

4-3.1 General and Definitions.

4-3.1.1 Fire records indicate mishandling of fuel as the main contributor of the three principle factors responsible for aircraft ground fires.

4-3.1.2 These procedures outline safeguards for the repair of the three basic types of aircraft fuel tanks presently in use:

(a) *Integral.* The designation integral fuel tank shall be confined to fuel containers whose boundaries are made up of as nearly 100 percent primary structure as possible, primary structure being the elements of the aircraft which carry the major stresses of flight, such as, stressed skin, spar caps, spar webs, etc. Integral fuel tanks may be either part of the wing or the fuselage. Integral fuel tanks discussed here shall be confined to the types which are basically without gasket materials installed in the seams, the structural cavities being made fueltight by the installation of a sealing material after the completion of fabrication of the unit where the tank is located.

(b) *Bladder.* The designation bladder tank includes both collapsible and self-sealing tanks. The bladders themselves are of a special synthetic rubber and fabric material. Normally these cells have a fairly low melting point and change pliability with relatively small changes in temperature. Pliability is a critical quality in the fuel cell material. A plasticizing agent is compounded into the synthetic rubber to keep it pliable. Fuel tends to extract the plasticizing agent, however, this is not detrimental since fuel itself keeps the material pliable.

(c) *Metal Tanks.* The term metal tanks applies to all types of metal fuel containers, including surge and vent tanks that may be removed from the aircraft for shop or bench repair, but does not include metal fuel containers that are an integral part of the aircraft, that may, under certain major overhaul conditions, be removed from the primary portion of the airframe.

4-3.2* Repair of Integral Fuel Tanks.

4-3.2.1 Procedure for Repairing.

4-3.2.1.1 Prior to conducting work on tanks, it is usually necessary to defuel the tank or tanks to be repaired or inspected. Such defueling operation shall be done outdoors in accordance with the requirements contained in NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-3.2.1.2 Residual fuel which cannot be withdrawn by normal defueling procedures shall usually be drained from the tanks by removal of tank access plates. With the opening of the tanks, air ventilation procedures, as outlined, shall be immediately instituted (*see 4-2.7*). Preferably this operation shall be done outdoors when weather conditions permit. This operation is inherently very hazardous as there can be little control over the vapors released, and, frequently, liquid fuel escapes as bottom plates are removed. Such fuel shall be retrieved in the safest possible manner and the fuel prevented from excessively wetting the undersurface of the wing or dripping to the ground or ramp to form pools. Furthermore, some of the residual fuel shall be siphoned out of the tank to be manually sponged or "mopped up" from tank low points or where trapped by baffles or other internal structural members [*see 4-2-7.1.2(a)*].

4-3.2.1.3 Prior to entry into the tank to conduct any manual operation therein, tests shall be conducted to determine that a flammable vapor air mixture does not exist, or that toxic quantities of vapors are not present (unless adequate respiratory protection is provided and worn). Obviously, as much of this operation as is possible shall be conducted outdoors to gain the maximum advantages of free air circulation and the elimination of ignition sources.

4-3.2.2 Safeguarding Fuel Tank Atmospheres. Prior to the start of any repairs to the integral tanks, it is necessary to rid the entire tank volume of hazardous quantities of fuel vapors. This operation shall be conducted in accordance with the requirements contained in 4-2.7 of this standard.

4-3.2.3 Personnel Skills and Procedures.

4-3.2.3.1 Personnel selected to perform fuel tank repair shall have considerable knowledge of and experience in handling flammable liquids. Since a health hazard is also involved in many cases, knowledge of industrial hygiene requirements is important.

4-3.2.3.2 The supervisor in charge of the operation shall have a thorough knowledge of the operation.

4-3.2.4 Location of Work.

4-3.2.4.1 Hangar docks (open-faced structures), where they are available and practical, are preferable to enclosed hangars for tank maintenance work.

4-3.2.4.2 When tank repair work is done in an enclosed hangar, and tank vapors are discharged into the hangar, tests shall be conducted to determine that the presence of such fuel vapor laden air does not constitute a hazard under the worst conditions that can normally be anticipated. Any flammable vapor concentration over 20 percent of the lower flammability limit within or beyond a distance of 5 ft (1.5 m) from any discharge point of a tank shall result in emergency revision of procedures.

4-3.2.4.3 Consideration shall be given to the toxic characteristics of the material being used.

4-3.2.5 Precautions Against Exterior Ignition Sources.

4-3.2.5.1 All open flame- and spark-producing equipment or devices within the vapor hazard area shall be shut down and not operated during the ventilation procedure.

4-3.2.5.2 Electrical equipment used in the vapor hazard area shall be approved for use in Class I, Group D, Division 1, hazardous locations as defined by NFPA 70, *National Electrical Code.*

4-3.2.5.3 Procedures to guard against the accumulation of static electrical charges on the aircraft, wing section, or tank shall utilize equipment as described in Chapter 13 of NFPA 409, *Standard on*

Aircraft Hangars. Personnel wearing apparel shall be made of material which will not accumulate static charges. (Cotton is presently the material most commonly used.)

4-3.2.5.4 Aircraft electrical circuits which are in vapor hazardous areas shall be de-energized.

4-3.2.6 Fire Protection.

4-3.2.6.1 Aircraft hangars and docks in which tank repair work is being conducted shall be provided with automatic fire protection equipment in accordance with the requirements contained in NFPA 409, *Standard for Aircraft Hangars.*

4-3.2.6.2 Adequate portable fire extinguishing equipment shall be provided for the hazards involved. Portable or mobile equipment shall include extinguishing agents such as carbon dioxide, Halon 1211, or dry chemical. A permanent smothering-type extinguishing agent such as foam shall also be available. The amount and nature of such equipment depends on the size of the tank being inerted, the size of the aircraft and the life and exposure hazards involved. An extinguisher having a rating not less than 20B and a minimum capacity of 15 lb (6.8 kg) of agent shall be located within 15 ft (15 m) of the aircraft undergoing inerting.

4-3.2.7 Additional Requirements.

4-3.2.7.1 Aircraft docks or workstands shall conform with the requirements in Chapter 2.

4-3.2.7.2 Portable electrical lights used in tank repair operations shall be approved for use in Class I, Group D, Division 1, hazardous locations as defined by NFPA 70, *National Electrical Code.*

4-3.2.7.3 If flashlights are used within integral fuel cells, they shall be approved for use in Class I, Group D, Division 1, hazardous locations as defined by NFPA 70, *National Electrical Code.*

4-3.2.7.4 Containers used to transport flammable solvents used in effecting compound removal within the fuel tanks shall be equipped with positive closing or antispill lids to prevent spills while entering the fuel tank.

4-3.2.7.5 Removal of sealant and cleanup of area to be resealed often requires considerable agitation of the solvent or stripper. When flammable solvents or strippers are used for this operation, it becomes imperative that extreme caution be exercised to eliminate all possible ignition sources. To minimize this type of hazard, nonflammable solvents shall be used whenever possible, recognizing, however, that nonflammable solvents may be more toxic.

4-3.2.7.6 Removal of existing sealant should be accomplished with nonsparking metallic or hardwood scrapers. Plastic scrapers, which tend to accumulate a static electric charge, shall not be used.

4-3.2.7.7 Repairs necessitating structural rework shall be accomplished with compressed air driven tools, i.e., drill motors, rivet gun, etc.

4-3.2.7.8 No hot work shall be permitted within the boundaries of integral fuel tanks. (Processes included in the category of hot work are welding, cutting, soldering, explosive riveting, or any similar process involving an open flame, the application of heat, or a spark-producing tool.)

4-3.2.7.9 Blowers having electrical components used to accelerate cure time of sealant or to warm tank interiors shall be approved for use in Class I, Group D, Division 1, hazardous locations as defined by NFPA 70, *National Electrical Code*.

4-3.2.7.10 Top coating of fuel tank sealant base materials is normally accomplished by brushing one or more coats of sealer over the base material. This operation is inherently very hazardous as these sealers generally have a flash point in the 25° to 50°F (4° to 10°C) range. During such operation, extreme caution shall be taken to eliminate all possible ignition sources. Adequate respiratory equipment shall be provided and worn. Application of top coating by spray method is not recommended.

4-3.2.7.11 Air ventilation shall be continued during tank-closing operations and discontinued only after all tank doors are installed.

4-3.2.8 Nonroutine Tank Repairs.

4-3.2.8.1 Requirements specified in 4-3.2.7 shall be observed. Additionally, when individual tanks are to be repaired, sufficient access doors must be removed to ensure adequate ventilation during such repair work.

4-3.2.8.2 When repairs are to be made to integral tanks which are interconnected to other integral or bladder tanks which do not require rework, steps shall be taken to prevent fumes from entering the tank or the section undergoing repairs, e.g., plugging or taping interconnector openings, vent openings, or vent manifolds.

4-3.2.8.3 When repairs are necessary at other than regular repair stations, portable fire extinguishers (capacity to be determined by exposure hazard) and standby personnel shall be provided. (*See 4-3.2.6.2 for additional guidance.*)

4-3.2.8.4 When tank repairs are in progress, steps shall be taken to prevent all electrical and manual controls to the affected tank from being activated or energized.

4-3.3* Repair of Bladder Tanks.

4-3.3.1 Procedure for Repairing.

4-3.3.1.1 Prior to working on bladder-type fuel cells, it is necessary to defuel the cell or cells to be repaired or inspected.

4-3.3.1.2 Because of the necessity of working inside of cells which may contain fuel, extreme caution shall be taken to prevent an ignition source inside the cell. Defueling operations shall be done outdoors in accordance with the requirements contained in NFPA 407, *Standard on Aircraft Fuel Servicing*.

4-3.3.1.3 Tank removal is inherently very hazardous as there can be little control over the vapors released and fuel spillage. Such fuel shall be retrieved in the safest possible manner, as quickly as possible. Preferably this operation shall be done outdoors when weather conditions permit.

4-3.3.2 Safeguarding Fuel Tank Atmospheres.

4-3.3.2.1 With the opening of the cell, air ventilation procedures shall be immediately instituted. Residual fuel, where possible, shall be removed from the cells to prevent unnecessary fuel spills.

4-3.3.2.2 Prior to entry into the cell to conduct any manual operation, tests shall be conducted to determine that a flammable vapor-air mixture does not exist or that toxic quantities of vapors are not present (unless adequate respiratory protection is provided and worn).

4-3.3.2.3 When repairs are to be made to a cell which is interconnected with other fuel tanks, steps shall be taken to completely seal the adjacent sections of the system to prevent additional vapors from entering the working section. Obviously as much of this operation as is possible shall be conducted outdoors to gain the maximum advantage of free air circulation and the elimination of ignition sources.

4-3.3.3 Personnel Skills and Procedures. (*See 4-3.2.3.1 and 4-3.2.3.2.*)

4-3.3.4 Location of Work.

4-3.3.4.1 Hangar Docks (open-faced structures) are preferable to enclosed hangars for fuel system maintenance work where such facilities are available and practical. It is recommended that aircraft be segregated or isolated during the time fuel cells are being removed.

4-3.3.4.2 Fuel cell repair areas shall be well ventilated and segregated from other maintenance or assembly areas.

4-3.3.5 Precautions Against External Ignition Sources. (*See 4-3.2.5.1 through 4-3.2.5.4.*)

4-3.3.6 Fire Protection. (*See 4-3.2.6.1 and 4-3.2.6.2.*)

4-3.3.7 Additional Requirements.

4-3.3.7.1 Portable electric lights used in cell repair operations must be approved for use in Class I, Group D, Division 1, hazardous locations, as defined by NFPA 70, *National Electrical Code*.

4-3.3.7.2 If flashlights are used in the cells they shall be of the type approved for use in Class I, Group D, Division 1, hazardous locations, as defined by NFPA 70, *National Electrical Code*.

4-3.3.7.3 Containers used to transport flammable solvents should be equipped with positive closing or antispill lids to prevent spilling.

4-3.3.7.4 Electrical heating units used in tank repair operations shall be approved for use in Class I, Group D, Division 1, hazardous locations, as defined by NFPA 70, *National Electrical Code*.

4-3.3.7.5 Blowers having electrical components used to accelerate the cure time of sealants shall be approved for use in Class I, Group D, Division 1, hazardous locations, as defined by NFPA 70, *National Electrical Code*.

4-3.3.7.6 Fuel cell repairs are normally accomplished by alternately applying several coats of solvent and sealer over and under the patch. This operation is inherently very hazardous as the sealers generally have a flash point in the 25° to 50°F (−3.9° to 10°C) range. During such operation, extreme caution must be taken to eliminate all possible ignition sources. Approved respiratory equipment shall be provided and worn if necessary.

4-3.3.7.7 Upon reinstallation of the cell, air ventilation procedures shall be started again and maintained until the fuel cell is closed.

4-3.4 Repair of Metal Tanks.

4-3.4.1 Prior to conducting work on metal tanks, the recommendations outlined in 4-3.2.1 through 4-3.2.6 shall apply.

4-3.4.2 Procedures for the safe removal of flammable vapors from metal tanks are given in NFPA 327, *Standard Procedures for Cleaning or Safeguarding Small Tanks and Containers.*

4-3.5 Special Precautions. In addition to the precautions contained in NFPA 327 (*see 4-3.4.2*) the following special precautions are required:

(a) Treat each compartment in a container having two or more compartments in the same manner regardless of which compartment is to be repaired.

(b) Stencil or tag all tanks that have been cleaned and tested. The stencil or tag shall include a phrase such as "Safe for Welding or Cutting," the signature of the person so certifying, and the date.

4-4 Fuel Transfer Equipment and Operations and Pressure Testing of Aircraft Fuel Systems.

4-4.1 Application. The general firesafety requirements outlined in this section are applicable for aircraft fuel transfer operations and testing aircraft fuel systems during aircraft maintenance and overhaul operations, not for routine fueling and defueling. (*See NFPA 407, Standard for Aircraft Fuel Servicing.*) The type of operation considered here may be one of the following:

(a) Transferring fuel from one tank to another within an aircraft while on the ground preparatory to maintenance;

(b) Transferring fuel from a tank in an aircraft to a tank in ground equipment or vice versa in order to achieve a maintenance objective;

(c) Transferring fuel for the purpose of performing tank repairs, replacement of tank accessories, or for balancing of fuel loads; and

(d) Pressure testing of an aircraft fuel system with a test fluid or fuel to assure the integrity of the system.

4-4.2 General. The maintenance procedure manuals for each aircraft shall be consulted to determine the procedures to be followed. The requirements herein provide basic firesafety precautions.

4-4.2.1 Aircraft fuel transfer operations shall be done outdoors whenever possible and shall be done outdoors where the fuels used are flammable [flash point under 100 °F (37.8 °C)], except where the system described in 4-4.2.2.8(b) is employed. Routine fueling and defueling shall be done outdoors following the requirements of NFPA 407, *Standard for Aircraft Fuel Servicing*. Dump valve tests involving fuel discharge shall also be done outdoors.

4-4.2.2 Fuel transfer operations and pressure testing of aircraft fuel systems may be conducted indoors using high flash point test fluids or JET A fuels (kerosene grade) where the fill requirements specified in 4-4.2.2.1 through 4-4.2.2.12 are followed. Such operations shall not be permitted, however, if the aircraft tanks contained JET B fuels (gasoline-kerosene blends) during the preceding 20 flying hours.

4-4.2.2.1 Such operations shall preferably be conducted in open dock-type hangars rather than enclosed hangars because of the normally more adequate natural ventilation available to dissipate any flammable vapors which might be released during the operations in the enclosed structure. All hangars used for these operations shall meet the construction requirements of NFPA 409, *Standard on Aircraft Hangars*, and shall be provided with automatic protection in accordance with the provisions of Chapters 15 and 16 thereof.

4-4.2.2.2 Each such operation shall be tailored to the fuel system design features of each type aircraft and shall be performed only after the detailed procedures have been approved by the authority having jurisdiction.

4-4.2.2.3 An aircraft undergoing this type of fuel system maintenance shall be located in the hangar so that it or adjacent aircraft, unless on jacks or otherwise immobilized, may be rapidly withdrawn from the structure in an emergency (provision having been made to tow aircraft using preplanned techniques) so that emergency fire control procedures can be undertaken.

4-4.2.2.4 Hangar doors shall be open when weather conditions permit and, if closed, unlatched and in such condition so that in an emergency the doors can be opened fully.

4-4.2.2.5 The amount of test fluid or fuel transferred shall be the minimum considered essential to each operation.

4-4.2.2.6 The area used for such operations shall be placarded with suitably worded warning signs.

4-4.2.2.7 During each operation, a trained and qualified person shall be assigned to specifically oversee the firesafety of the procedures used, including the handling of the fire protection equipment provided, spill emergency precautions, and ventilation techniques.

4-4.2.2.8 Precautions.

(a) Where this type operation is conducted routinely, a specifically designed fixed fuel transfer piping system shall be used, designed, and maintained in accordance with the requirements of Chapter 5 of NFPA 407, *Standard for Aircraft Fuel Servicing*, for airport fixed fueling systems.

(b) For some maintenance operations, a limited capacity, self-contained trailer having a closed liquid transfer system may be employed.

(c) Where these practices are not utilized, self-propelled fuel servicing vehicles may be employed with the following limitations:

1. The fuel servicing vehicle shall not be permitted inside the hangar and shall be so positioned outside as to be readily movable.

2. Where it is necessary to drive the fuel servicing vehicle into the hangar, the following minimum additional precautions shall be taken:

(i) The fuel servicing vehicle shall be parked in such a position as to be readily driven out of the hangar without having to maneuver around parked or immobile aircraft.

(ii) The fuel servicing vehicle driver-operator shall be in constant attendance at the vehicle during operations.

(iii) A foam hose line capable of discharging foam for a period of 20 minutes at a minimum foam-solution discharge rate of 60 gpm (227 L/min) (nominal) shall be provided and ready for instant service.

(iv) At least two wheeled dry chemical extinguishers shall be provided having at least a minimum rating of 80B:C and a minimum capacity of 125 lb (57 kg) of agent each within a 50-ft (15-m) distance.

4-4.2.2.9 Any fueling hose used shall be continuous (without intermediate couplings), if practical and/or available from manufacturers, and shall conform and be maintained in accordance with Chapter 3 of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-4.2.2.10 Nozzles shall comply with the requirements of NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-4.2.2.11 Only one aircraft shall undergo fuel system testing or be subjected to fuel transfer operations at any one time in a single maintenance and servicing area not separated by fire walls.

4-4.2.2.12 Any other simultaneous maintenance operation on that aircraft or within 25 ft (7.6 m) of the aircraft fuel system vents, fuel tank openings, or fuel servicing vehicle (if used) which can constitute a source of ignition of vapors that may be released during an operation shall not be permitted.

4-4.3 Personnel Skills. Personnel selected for fuel transfer operations shall have a thorough knowledge of the fuel system of the aircraft involved, the handling of combustible liquids, and shall be familiar with the operation and limitations of the fire-extinguishing equipment available (*see also 4-4.2.2.7*).

4-4.4 Fire Protection. Adequate portable or mobile fire extinguishing equipment shall be provided to safeguard the work involved during aircraft fuel transfer operations and pressure testing of aircraft fuel systems. Portable or mobile equipment shall include extinguishing agent for Class B fires (such as carbon dioxide, Halon 1211, or dry chemical). A permanent smothering-type extinguishing agent for Class B fires (such as foam) shall also be available. The amount and nature of such equipment depend on the size and type of the aircraft undergoing service and the fire exposure hazards involved. In no event, however, shall there be less than two extinguishers, each with a minimum rating of at least 80-B:C and a minimum capacity of 125 lb (57 kg) of agent, located within a 50-ft (15 m) distance, one on each side of the aircraft undergoing maintenance.

4-4.5 Precautions Against Exterior Ignition Sources.

4-4.5.1 Precautions against exterior ignition sources shall be taken in accordance with 4-3.2.5.1 through 4-3.2.5.3.

4-4.5.2 Internal combustion engine-powered equipment shall not be operated within 25 ft (7.6 m) of the aircraft fuel system vents or fuel tank openings prior to the start of aircraft fuel transfer operations or pressure testing of aircraft fuel systems.

NOTE: Industrial trucks suitable for use in such locations are available. See NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance and Operation.*

4-4.5.3 Ground power generators that are essential when employing the aircraft fuel booster pump for the transfer or pressure-testing work shall not be located within 25 ft (7.6 m) of the aircraft fuel system vents or fuel tank openings.

4-4.6 Personnel Requirements.

4-4.6.1 When transferring fuel from one aircraft tank to another by means of aircraft fuel booster pump, sufficient personnel shall be assigned to accomplish the operation, to prevent overfilling and overpressurizing, and to detect possible leakage. Where such fuel transfer operations cannot be done utilizing the internal aircraft fuel system plumbing, there shall be sufficient personnel to perform the functions outlined in the previous sentence with particular attention given to the integrity of the external plumbing arrangement.

4-4.6.2 When transferring fuel from an aircraft tank by suction using an external pump or fuel servicing truck, sufficient personnel shall be assigned to accomplish the operation, to prevent overfilling, and to guard against hose slippage and any combustible liquid spillage.

4-4.7 Additional Requirements.

4-4.7.1 During fuel transfer operations, signs reading "Caution — Transferring Fuel" shall be placed either on or under each wing of the aircraft and at the fuel selector panel in the cockpit.

4-4.7.2 Aircraft radio, radar, strobe lights, and electronic transmitting equipment shall not be operated during aircraft fuel transfer operations or pressure testing of aircraft fuel systems. (*See NFPA 407, Standard for Aircraft Fuel Servicing, Chapter 2.*)

4-4.7.3 Any fuel transfer hose nozzle used during these operations shall be electrically bonded as may be required to prevent a difference of electrostatic potential developing between any of the component equipment being used and to equalize over adjacent conductive surfaces any electrostatic charges developed by the flow of fuel. These bonding connections shall be made prior to the start of operations and maintained until after the operations have been completed.

4-4.7.4 When removing fuel from an aircraft tank by gravity, free fall of the fuel should be avoided and a positive electrical bond shall be provided between the fuel tank and the receiving container.

4-4.7.5 Any spillage of fuel shall be handled in accordance with the requirements given in NFPA 407, *Standard for Aircraft Fuel Servicing*.

4-4.7.6 When transferring aircraft fuels or flammable fluids by hose into a tank or drum, the hose should be extended and fixed below the liquid level of the receiving tank to reduce the hazard of liquid surface electrostatic generation.

4-4.7.7 When transferring fuel from an aircraft tank by any of the means described herein, it is normally not possible to completely defuel or drain a tank. This means that residual fuel will remain in the tank creating fuel vapor hazards therein which must be reckoned with in the event subsequent tank maintenance or repair operations are to be conducted. (*See Section 4-2 for further information.*)

4-4.7.8 Be sure that in transferring fuel from one tank to another, attention is given to the relative capacities of the tanks to prevent accidental overfilling.

4-4.7.9 Caution shall be exercised to prevent intermixing of test fluids or different grades of fuel.

Chapter 5 Aircraft Cleaning, Coating, Painting and Paint Removal

5-1 General.

5-1.1 Application. This chapter deals with firesafety practices and precautions for aircraft cleaning, coating, painting, and paint removal.

5-1.2* This chapter applies to all types and sizes of aircraft in all phases of private, commercial transport and military service.

It does not apply to military aircraft where contact with propellants may require extreme caution in applying protective finishes to parts and equipment.

5-1.3 Spray cleaning, painting, and paint removal of components and subassemblies which are small enough to be removed from the aircraft for work and which require a total application rate of more than 1 qt (1 L) of material in one hour, or the cumulative use of more than 4 qt (4 L) of material in eight hours shall be conducted in accordance with NFPA 33, *Standard for Spray Application Using Flammable and Combustible Materials*, and will not be discussed in this chapter.

5-2 Definitions.

Coating. Application of special purpose materials such as anticorrosion and walkway paints.

External Cleaning.* The removal of soil from the complete aircraft exterior or from only localized areas. When surface icing occurs, de-icing procedures must be implemented.

Interior Cleaning. The removal of soil from cockpit and cabin areas (this subject is covered in Chapter 7).

Major Painting. Complete or virtually complete surface finishing of either the exterior or interior, or both.

Overhaul. The major aircraft disassembly, inspection, repair, and reassembly of aircraft.

Paint Removal. The process of softening existing paint by application of appropriate solvents and spraying or brushing away the residue.

Repair. The "out of flying" status due to need for modification of aircraft, rebuilding structural damage, correcting system malfunction, or replacing a major component or subassembly.

Service Operation. Routine service checks, correction of flight crew complaints, and minor repair and maintenance performed while the aircraft is routinely "out of flying" status.

Touch-up Painting. The refinishing of only localized areas, exterior or interior, involving no more than 1 qt (1 L) of material by spray or 1 gal (4 L) by brush or roller.

5-3 Materials.

5-3.1* In selecting materials for cleaning and paint removal purposes, nonflammable materials shall be specified and used.

Exception: When nonflammable materials are not available, combustible materials shall be specified and used in preference to flammable materials.

5-3.2 Liquids. Flammable liquid shall mean any liquid having a flash point under 100°F (38°C) closed cup and having a vapor pressure not exceeding 40 psia (2068.6 mm) at 100°F (38°C). Combustible liquid shall mean any liquid having a flash point at or above 100°F (38°C). For further classification, see NFPA 321, *Basic Classification of Flammable and Combustible Liquids*.

5-3.3* Toxicity of Solvents. This standard deals with firesafety requirements of all operations concerning aircraft cleaning, coating, painting, and paint removal and would not normally deal with health hazards. However, proper ventilation to maintain flammable vapor concentrations below the lower explosive limit will not only reduce the fire hazard but will materially reduce human respiratory hazard.

5-3.4 Wherever practicable in selecting methods of painting, the "hot" or "airless" method, the roller application method, or the electro-static paint method shall be chosen in preference to ordinary pressure spray painting because the three first-named methods discharge less flammable solvent vapor into the atmosphere.

5-4 Operational Sites and Precautions.

5-4.1 When nonflammable materials are used for cleaning and paint removal purposes, the major consideration in choosing a location shall be that of good general ventilation, ease of cleanup, and convenience.

5-4.2 Cleaning and painting major aircraft assemblies and subassemblies which are not removable as specified in 5-1.3 may be done at any hangar that meets the requirements of NFPA 409, *Standard on Aircraft Hangars*, and those outlined in 5-4.4 through 5-4.9.

5-4.3 Ramp areas used for these maintenance procedures shall be servicing ramps not subject to public access. Sufficient clearance shall be maintained to avoid creating a hazard to adjacent aircraft or structures and to assure access by fire-fighting equipment, and the aircraft being worked upon shall not be in the path of other normal aircraft movements on the ramp. See NFPA 415, *Standard on Aircraft Fueling Ramp Drainage*, for applicable data.

5-4.4 Where major cleaning, painting, or paint removal operations are being conducted, no concurrent, potentially hazardous operations shall be conducted within 50 ft (15.2 m) of the working area. Even for touch-up operations, the area shall be inspected prior to the start of operations for any ignition sources within the working area and these sources shall be eliminated. Such conditions shall be maintained hazard-free during the entire work period.

5-4.5 A hangar's general ventilation, supplemented by slight opening of hangar doors, if necessary, shall be capable of sufficient air movement to prevent flammable vapor concentrations at floor level, in floor pits and drains, and in aircraft compartments from reaching 25 percent of the lower explosive limit. (This shall be spot checked periodically with a flammable gas analyzer, with concentrations recorded.) If general and natural ventilation does not achieve this, additional means of forced ventilation shall be used.

5-4.6 Fixed electrical equipment shall conform to Article 513 of NFPA 70, *National Electrical Code*. Temporary lighting used for general illumination during these operations shall be so located as not to be in direct range of any flammable sprays or liquids or in any "overspray" areas. Such equipment, if not approved for use in Class I, Group D, hazardous locations shall be of the enclosed and gasketed type to minimize the danger of breakage and reduce entrance of hazardous vapors within the fixtures.

5-4.7 The use of heat lamps to accelerate the drying of painted surfaces shall be prohibited unless used as part of an approved drying booth or enclosure. See NFPA 33, *Standard for Spray Finishing Using Flammable Materials*, and NFPA 86A, *Standard on Ovens and Furnaces*, for further information on drying apparatus.

5-4.8 When cleaning or paint removal agents are applied through spray nozzles under pressure, the nozzle shall be of the self-closing type so that, when the hand of the operator is removed, the nozzle will automatically close.

5-4.9 Aircraft electrical systems shall be de-energized during cleaning, painting, and paint removal operations.

Exception: When aircraft power is required for concurrent operations, then all electrical equipment exposed to flammable or combustible liquids or vapors shall be de-energized to avoid any chance of ignition from arcs, faults, or hot surfaces.

5-5 Control of Flammable and Combustible Materials. Consumable materials used in the painting of aircraft and aircraft equipment are normally flammable and sometimes toxic. Therefore, the requirements detailed in 6-5.1 to 6-5.5 are specifically designed to reduce potential explosion, fire, and health hazards in the painting areas.

5-5.1 Supply stores of paints and flammable thinners and solvents shall be located in a separate building or segregated from the aircraft maintenance and servicing areas of hangars by a fire partition with openings which shall be protected by an approved fire door. See also NFPA 30, *Flammable and Combustible Liquids Code*, for further guidelines on indoor and outdoor tank and container storage.

5-5.2 Only an operational supply of paints and flammable solvents, limited to one day's or one shift's needs, may be maintained in a hangar. These shall be in approved, marked containers located remotely from other operations. Dispensing drums, when essential to the operation, shall be equipped with positive acting pumps and pressure relief fittings and shall be provided with drip pans and static bonding clamps and cables. No pneumatic devices which pressurize the drum shall be used for dispensing the liquid.

5-5.3 Paints and solvents at the aircraft in the working area shall be limited to only those necessary for the job.

5-5.4 Epoxy or polyester resins shall not be stored close to ketone-type thinners.

5-5.5 Petroleum distillate suitable for use as a dry cleaning solvent and other solvent cleaners such as mineral spirits, aliphatic naphtha, aromatic naphtha, trichlorethylene, xylene, methyl ethyl ketone, and other ketone-type thinners shall not be used in areas of aircraft oxygen systems. These materials are not compatible with oxygen.

5-6 Fire Extinguishing Equipment Requirements. Regardless of how small, all aircraft on which cleaning, paint removal, or painting operations are performed shall have portable dry chemical, carbon dioxide, or halogenated agent Halon 1211 fire extinguishing equipment placed close to the painting area. There shall be a minimum of one hand-portable fire extinguisher having a 20 B:C rating (minimum capacity 15 lb (6.8 kg) of agent) and one 80 B:C rated (minimum capacity 125 lb (58 kg) of agent) nonsparking wheeled fire extinguisher or the nearest equivalent, located within 50 ft (15.2 m) of the operation, available for immediate use.

5-7 Housekeeping and General Safeguards.

5-7.1 The effects of good housekeeping cannot be overemphasized in the reduction of injuries, accidents, and, particularly, fire hazards. Upon completion of each cleaning, paint removal, or painting operation, and at least once each day during the progress of the operation, all waste solvents, wiping waste, used masking tape, and waste paper shall be collected and safely disposed of. Under no circumstances may flammable liquids or painting materials be dumped into sanitary or storm drains. Industrial waste disposal shall be made. Particular attention shall be paid to removing waste regularly from floor pits and trenches and from aircraft holds and recesses. While remaining in the painting area, waste is to be kept in covered metal containers. Rags soaked with finishing materials (solvents, thinners, diluents) shall be kept in a separate container and not in those used to keep other waste materials.

5-7.2 The aircraft, unless immobilized, shall be parked in the painting area so that it can be readily removed in an emergency, with no obstacles between the aircraft and the doors.

5-7.3 When doing touch-up painting in a hangar where other types of aircraft maintenance are being carried out at the same time, a towing vehicle shall be attached to the aircraft, so that in the event of an emergency the aircraft can be quickly removed.

5-7.4* Aircraft Electrical Grounding. To reduce the hazards associated with static electricity, aircraft shall be electrically grounded when parked in aircraft hangars. The appropriate manufacturer's description and maintenance instructions shall be consulted regarding the location of grounding points on the aircraft and the number of grounding cables required.

5-7.5* Spills shall be cleaned up as they occur.

5.7-6* Smoking shall be prohibited in hangars or aircraft servicing ramps used for cleaning, paint removal, or painting operations.

Exception: Designated safe smoking areas are exempt.

5-7.7 Boots with metal cleats or tacks shall not be worn as they may cause sparks when scuffed along the floor.

5-7.8 Scrapers for cleaning floors shall be of a nonsparking material, such as brass or bronze. Tools used to open containers shall be of a nonsparking material.

5-7.9 No open flame shall be permitted in the vicinity of the working area.

5-7.10 Flammable and combustible liquids on the job shall be kept in approved safety cans, marked with the product name. Premixed paints shall be kept in their original metal containers, covered when not in use. Maximum solvent or paint container size on the job shall be 5 gal (76 L).

5-7.11 Painters' benches and cabinets shall be kept orderly and free of trash and dust.

5-7.12 Gasoline or solvents shall not be used for personal cleaning.

5-8 Inspection and Preventive Maintenance.

5-8.1 Electrical equipment shall be regularly inspected to ensure that it is being maintained in first class condition and that it will not cause shorts or sparks.

5-8.2 Grounding or bonding equipment shall be regularly inspected, properly maintained, and properly used.

5-8.3 Pumps, faucets, and pressure relief vents of containers used for flammable liquids or solvents shall be kept leak-free and functioning.

5-8.4 Any damage to safety can structure, seals, or flame arrestors shall be promptly and properly repaired.

5-8.5 Cleaning solution spray equipment, paint removal equipment, paint spray equipment, and other applicators shall be maintained in a safe condition.

5-8.6 Stands, docks, floors, filters, scaffolds, staging, and drop curtains shall be maintained on a regular basis to keep them sound and free from combustible accumulations.

5-8.7 Floors, roof trusses, light fixtures, and overhead equipment shall be regularly inspected for paint overspray and dust accumulation and cleaned when necessary.

Chapter 6 Welding Operations in Hangars

6-1 General.

6-1.1* Application. This chapter considers only gas shielded arc welding. For other types of welding, see Appendix A.

6-2 Arc Weldings. Only gas shielded arc welding shall be performed on aircraft.

6-3* Welding Operations. Aircraft welding operations performed in hangars shall conform to the requirements of this standard. Aircraft welding operations shall be done outdoors wherever possible.

6-4 General Requirements.

6-4.1 Only qualified welders, trained in the technique and familiar with the hazards involved, shall be permitted to do this work.

6-4.1.1* A written, special welding permit shall be obtained for each welding operation conducted on an aircraft from an individual designated by management as responsible for authorizing welding operations. A welding firesafety checklist shall also be "tailor-made" and used to cover the individual hazards of each type of operation. If a hazard is encountered that is not covered on the checklist, work shall be stopped until the individual designated by management as responsible for authorizing welding operations provides any needed additional guidance. See Figure A-6-4.1.1 for a typical welding permit and aircraft welding firesafety checklist.

6-4.1.2 No welding shall be conducted, or welding equipment brought to the work area, until a permit has been issued.

6-4.1.3 No other work shall be permitted within a 20-ft (6.1-m) radius of the location of any gas shielded arc welding operation, or within a 36-ft (10.7-m) radius of the location of any other type of welding operation. All other work may be conducted routinely provided flammable vapors are not present.

6-4.1.4 If other aircraft are located in any adjacent work bays of a hangar, the person responsible for each aircraft shall be notified in advance that welding is to be conducted.

6-5 Flammable Vapors.

6-5.1 Welding shall not be done on an aircraft in a hangar while work is in progress on any system or component of an aircraft which contains, or did contain, fuel or other flammable or combustible liquids.

6-5.2 Welding shall not be done on an aircraft in a hangar while work is in progress on the fuel systems on any other aircraft within 100 ft (30.5 m) from the point of welding.

6-5.3 Fuel tank access plates and any fuel tank openings shall be closed on all aircraft within 100 ft (30.5 m) from the point of any welding. All fuel lines, valves, manifolds, and other fuel components on the aircraft on which welding is being done shall be in place, secured, or capped prior to the start of welding operations and during such welding operations.

6-5.4* All fuel tank vents on the aircraft being worked upon and the vents of other aircraft within a 20-ft (6.1-m) radius of the location of any gas shielded arc welding, or within a 36-ft (10.7-m) radius of the location of any other type of welding operation, shall be covered prior to the start of welding operations and during such welding operations. Aircraft which are brought into a heated hangar from a cold outdoor atmosphere shall be carefully watched for fuel expansion.

6-5.5 Prior to the start of welding and at least every 15 minutes during the welding operation, a qualified person shall check with a combustible gas analyzer whenever welding is being done in the vicinity of sources of flammable vapors.

6-6 Equipment.

6-6.1 Welding generating equipment shall be placarded as follows: "Warning — Keep 5 Ft (1.5 m) (Horizontally) Clear of Aircraft Engines, Fuel Tank Areas and Vents."

6-6.2 Welding equipment shall have no electrical components (other than flexible lead cables) within 48 in. (457 mm) of the floor. The ground leads shall be as close to the area to be welded as possible, and clamps used on such ground leads shall be of the "C" clamp type, not the clip type. Components which could produce arcs, sparks, or hot metal under any condition of operations shall be of the totally enclosed type or shall have suitable guards or spacing in compliance with the requirements of Article 518 of NFPA 70, *National Electrical Code*. The inert gas cylinder shall be securely fastened to prevent tipping and the regulator and gage shall be in proper working condition.

6-7 Fire Protection.

6-7.1 Aircraft hangars in which welding is performed shall be equipped with the fixed fire protection equipment specified in Chapters 12 and 13 of NFPA 409, *Standard on Aircraft Hangars*. No welding shall be permitted if such fixed fire protection equipment is inoperative for any reason. Any welding performed shall take into consideration the type of automatic fire detection equipment installed in the hangar to avoid false alarms or accidental actuation of the fire protection equipment provided.

6-7.2 The specific location where the welding is being done shall be roped off or otherwise segregated by physical barrier to prevent unintended entry into the welding area. A placard reading: "Welding Operations in Progress" shall be prominently displayed.

6-7.3 Screens shall be placed around the welding operation.

6-7.4 Good housekeeping shall prevail in the welding area. Floor drains in the area of a welding operation shall be checked periodically to determine that no flammable or combustible liquids or vapors are present.

6-7.5* A fire extinguisher having a minimum rating of 20-B [minimum capacity 15 lb (6.8 kg) of agent] shall be positioned in the immediate area of the welding operation ready for instant use. As a backup for the portable extinguisher, a wheeled extinguisher having a minimum rating of 80-B [minimum capacity 125 lb (58 kg) of agent] shall be readily available. A qualified fire watcher (*see NFPA 51B, Standard for Fire Prevention in Use of Cutting and Welding Processes, for training of fire watcher*) shall be assigned to operate this equipment and shall monitor the entire welding operation. In the event a hazardous condition develops, he shall have the authority to stop the welding operation.

Chapter 7 Cabin Cleaning and Refurbishing Operations

7-1 General.

7-1.1 Application. This chapter describes methods of safeguarding aircraft cabin cleaning and refurbishing operations. A number of serious fires have occurred during these operations where flammable cleaning agents or solvents have been used, necessitating these requirements to prevent such losses in future.

7-1.2 Basic to an understanding of the problem is the fact that aircraft cabin compartments constitute relatively small enclosures as measured by their cubic footage. This presents the possibility of restricted ventilation and the quick buildup of flammable vapor-air mixtures where there is any indiscriminate use of flammable cleaning agents or solvents. Within the same volume there may also exist the possibility of an ignition source in the form of an electrical fault, a friction or static spark, an open flame device, or some other potential introduced by concurrent maintenance work.

7-1.3* Wherever possible, nonflammable agents shall be used in these operations to reduce the fire and explosion hazards.

7-2 Types of Operations.

7-2.1 Cleaning. The principal areas of aircraft cabins which may need periodic cleaning are:

(a) Aircraft passenger cabin areas (seats, carpets, side panels, headliners, overhead racks, curtains, ashtrays, windows, doors, and decorative panels of plastic, wood, or similar materials).

(b) Aircraft flight station areas (similar materials to those found in passenger cabin areas plus instrument panels, control pedestals, glare shields, flooring materials, metallic surfaces of instruments and flight control equipment, electrical cables and contacts, etc.).

(c) Lavatories and buffets (similar materials to those found in passenger cabin areas plus toilet facilities, metal fixtures and trim, trash containers, cabinets, wash and sink basins, mirrors, ovens, etc.).

7-2.2 Refurbishing. The types of refurbishing operations considered herein are the replacement of aircraft cabin fabrics, plastic headliners, rugs or synthetic flooring, sound-insulating materials, windows, decor, or paneling.

7-3 Types of Cleaning Agents and Solvents.

7-3.1* High Flash Point Solvents. Specially refined petroleum products, first developed as "Stoddard Solvent" but now sold under a variety of trade names by different companies, have solvent properties approximating gasoline but have fire hazard properties similar to those of kerosene as commonly used (not heated). Most of these are stable products having a flash point from 100° to 140°F (37.8° to 60°C) with a comparatively low degree of toxicity.

7-3.2* Low Flash Point Solvents. Class I [flash point at below 100°F (37.8°C)] flammable liquids shall not be used for aircraft cabin cleaning or refurbishing. Common materials falling into this class are acetone, aviation gasoline, methyl ethyl ketone, naphtha, and toluol.

When it is necessary to use a combustible liquid, high flash point liquids [those having a flash point of 100°F (37.8°C) or more] shall be used and the special precautions outlined in Sections 7-4 and 7-5 shall be followed.

7-3.3 Mixed Liquids. Some commercial solvents are mixtures of liquids with differing rates of evaporation, such as a mixture of one of the various naphthas and a chlorinated material. The different rates of evaporation may present problems from both the toxicity and fire hazard viewpoints and such mixtures shall not be used unless they are stored and handled with full knowledge of these hazards and with appropriate precautions taken.

7-4 Fire Prevention.

7-4.1 Storage Practices. Combustible liquids should be stored in accordance with the provisions of NFPA 30, *Flammable and Combustible Liquids Code*. Container storage areas shall be segregated from the aircraft maintenance and servicing area of hangars by a fire partition with openings protected by an approved fire door or located in a separate building.

7-4.2 Stock Controls. Combustible solvents shall not be available in "open stock." Maintenance of a combustible liquids storage area under strict management dispensing control is essential for firesafety.

7-4.3 Quantity Controls. For authorized purposes, combustible solvents shall be dispensed only in minimal quantities for each specific operation. Dispensing of the needed quantity shall be by an approved device.

7-4.4 Container Controls. Combustible liquids shall be handled only in approved containers or safety cans appropriately marked.

7-4.5 Precautions. During aircraft cleaning or refurbishing operations where combustible liquids are used, the provisions of 7-4.5.1 through 7-4.5.6 shall be followed.

7-4.5.1 Aircraft cabins shall be provided with ventilation sufficient at all times to prevent the accumulation of flammable vapors. To accomplish this, doors to cabins shall be open to secure maximum advantage of natural ventilation. Where such natural ventilation is insufficient under all conditions to prevent the accumulation of flammable vapors, approved mechanical ventilation equipment shall be provided and used. The accumulation of flammable vapors above 25 percent of the lower flammability limit of the particular vapor being used, measured at a point 5 ft (1.5 m) horizontally from the location of use shall result in emergency revision of operations in progress.

7-4.5.2 All open flame- and spark-producing equipment or devices that might be brought within the vapor hazard area shall be shut down and not operated during the period when combustible vapors may exist.

7-4.5.3 Electrical equipment of a hand portable nature used within an aircraft cabin shall be of the type approved for use in Class I, Group D, hazardous locations as defined by NFPA 70, *National Electrical Code*.

7-4.5.4 Temporary lighting used for general illumination within a cabin during cleaning and refurbishing operations, which is not approved for use in Class I, Group D, hazardous locations, shall be enclosed and gasketed to reduce entrance of hazardous vapors within the fixtures, attached and located so as to minimize danger of breakage, and installed so as not to be in direct contact with any flammable liquids or "overspray."

7-4.5.5 Switches to aircraft cabin lighting and to the aircraft electrical system components within the cabin area should not be worked on or switched on or off during cleaning operations.

7-4.5.6 Suitable warning signs shall be placed in conspicuous locations at aircraft doors to indicate that combustible liquids are being or have been used in the cleaning or refurbishing operation in progress.

7-5 Fire Protection. During aircraft cleaning or refurbishing operations where combustible liquids are used, 7-5.1 and 7-5.2 shall be followed.

7-5.1* During such cleaning or refurbishing operations in an aircraft outside of the hangar, portable fire extinguishers having a minimum rating of 20-B [minimum capacity 15 lb (6.8 kg) of agent] (*see NFPA 10, Standard for the Installation, Maintenance, and Use of Portable Fire Extinguishers*) shall be provided at cabin entrances, and, at minimum, a booster hoseline with an adjustable water spray nozzle capable of reaching the cabin area shall be available for employee use pending the arrival of airport fire equipment.

Exception: A Class A fire extinguisher having a minimum rating of 4-A plus a Class B fire extinguisher having a minimum rating of 20-B may be placed at aircraft doors for immediate use by employees if required.

7-5.2 Aircraft undergoing such cleaning or refurbishing where the work must be done under cover shall be done in hangars equipped with automatic fire protection equipment installed in accordance with the requirements contained in NFPA 409, *Standard on Aircraft Hangars*. It cannot be anticipated that such hangar protection will provide fire control within the fuselage, so the requirements contained in 7-5.1 shall also be followed.