AIRCRAFT FIRE PROTECTION HANDBOOK

1. SCOPE

This Handbook embodies requirements and design objectives for fire protection for all types of manned Naval aircraft (including helicopters) with turbine engines.

2. REQUIREMENTS AND DESIGN OBJECTIVES

2.1 FLAMMABLE FLUID TANKS (See Figures 1, 2 and 3 on pages 9, 11 and 13)

2.1.1 GENERAL

2.1.1.1 TANK LOCATION

2.1.1.1.1 TANKS IN ENGINE COMPARTMENTS

Fuel tanks shall not be located in engine compartments.

Oil, hydraulic, and water-alcohol tanks may be located in compressor sections of engine compartments, but shall be designed to withstand a 2000°F fire for 10 minutes without leakage. Oil, hydraulic, and water-alcohol tanks in compressor sections of engines should be kept, as far as practicable, toward the front of the compressor and be located as low as practicable. These tanks shall not be located adjacent to burner, turbine and tailpipe areas. Oil tanks for auxiliary power plants may be located in their surrounding compartments but shall be designed to withstand a 2000°F fire for 10 minutes without leakage.

2.1.1.1.2 TANKS ABOVE ENGINE COMPARTMENTS

Location of fuel tanks above engine compartments should be avoided. If fuel tanks must be located above engine compartments for justifiable reasons, provisions shall be made to prevent leakage of fuel into engine compartments or onto exhaust systems. A ventilated and drained space shall be provided between fire wall and tank to afford safe disposal of any fuel leakage from the tank. Insulation shall also be provided, if necessary, to prevent ignition within the tank, or in the shrouded air space, in case of a power plant fire. Such insulation shall be nonabsorbent as a material configuration and shall be suitable for periodic inspection.

2.1.1.1.3 FUEL TANKS AND TURBINES

Fuel tanks should be located laterally as far from the plane of the propulsion engine turbine as possible. If fuel tanks must be located in the plane of the turbine for justifiable reasons, the turbine should be tested for blade containment up to a speed which produces kinetic energy of the maximum allowable overspeed of the engine, or strategic armoring around the turbine shall be provided.

2.1.1.1.4 FUEL TANKS AND PROPELLERS

Fuel tanks should be avoided in an area within ± 5° of propeller planes.

2.1.1.1.5 LIGHTNING PROTECTION

Fuel tanks with walls adjoining the free atmosphere should be avoided in protrusions and extremities of the aircraft, and in areas less than 12 inches from leading edges and trailing edges for reasons of lightning protection. If fuel tanks must be located in these areas for justifiable reasons, adequate protection against lightning shall be provided (see 2.18). Fuel should not be stored in fore or aft extremities, such as in the nose of the fuselage, or in the nose or aft cone of a wing tip tank.

2.1.1.1.6 FUEL TANK CRASH PROTECTION

Wing fuel tanks in the wing roots should be avoided, if practicable, and should be placed behind heavy spars and leading edge sections for maximum protection from direct crash impact. For the same reason, all fuel tanks should be arranged as high as possible in the aircraft. Fuel tanks should, whenever practicable, be located so that a collapsing landing gear does not result in a major fuel tank leakage.

2.1.1.2 FUEL TANK ISOLATION

Fuel tanks and fuel compartments shall be isolated from one another and from wing and fuselage compartments by liquid and vapor tight seals to the greatest practicable extent. This will serve to keep fuel and fuel vapors away from engines, crew, electric equipment, hot bleed air lines, and armament, with attendant advantages in reducing fire hazards in case of fuel leaks caused by accident or battle damage. These precautions shall also be applied, as far as practicable, to bomb bays which contain jettisonable fuel tanks.

Fuel tanks in inhabited areas should be separated by liquid and vaportight barriers from the rest of the inhabited area. The space between the tank and the barrier should be ventilated and drained (see 2.1.1.3).

2.1.1.3 FUEL TANK COMPARTMENTS

All areas surrounding fuel tanks shall be drained and ventilated to remove the fire hazard resulting from any fuel spillage or leakage (see 2.4). The drainage and ventilation openings shall remain open at all times. There shall be no trapped fluid. If a fuel tank is in or adjacent to a sealed compartment without potential ignition sources, it is acceptable to limit the ventilation to that provided by drain holes of sufficient size to prevent excessive pressure resulting from altitude changes. The minimum ventilating air flow in fuel tank compartments with potential ignition sources shall be one air change per minute.

Electric equipment in fuel tank compartments shall comply with 2.7.3

Bleed air ducts in fuel tank compartments shall comply with 2.8.1 and 2.8.2.

2.1.1.4 ELECTRIC EQUIPMENT IN FUEL TANKS

All electric equipment, and all metal lines within a fuel tank connected to electric equipment, regardless of size, shall be grounded. All electric wires and equipment in fuel tanks shall be designed with the highest degree of protection against sparking, arcing, or overheat under normal operating and emergency conditions, and during maintenance. Arc-over from electric equipment or wiring being removed from or installed into fuel tanks shall be prevented by positive means, if such arcs are a potential ignition source. In addition, metal wire conduit wall thickness, joints, and attachments shall carry maximum fault current without dangerous external heating or conduit burnthrough under conditions of an internal power fault to the wall of the conduit or between adjacent wires.

Conduits which are open to the exterior of the tank for breathing purposes, or for easy removal of the wires shall discharge safely any leakage of fuel into the conduit.

All electric equipment in fuel tanks shall be explosion-proof in accordance with MIL-E-5272, Procedure IV.

See 2.2.3 for pumps for flammable fluids and 2.2.4 for quantity gages.

2.1.1.5 FUEL TANK FITTINGS

Fittings which can be located above the fuel level, preferably on top of the tank, should be so located whenever practicable. Fuel tank shutoff valves shall be as near to fuel tank outlets as possible.

This location provid greatest protection against battle damage and fuel line leakage. If practicable, filler caps, vents, gage units, outlets, etc., should be incorporated in one inspection plate at the top of the tank. Fuel tank fittings in or close to the bottom of the aircraft shall be avoided, or provisions shall be made to minimize the hazards of tank rupture in a crash landing or due to gunfire.

2.1.1.6 TANKS IN COMBAT AIRCRAFT

Fuel lines shall be routed through fuel tanks and close to heavy structure, wherever possible, to provide the greatest possible protection against combat damage, and fire hazard resulting from line leakage. Fuel tanks shall not be located above engine compartments. Metallic tubing shall not be in contact with the walls of self-sealing tanks, and fuel tank fittings shall be so located that they are as well protected against battle damage as practicable. Fuel tank fittings should be located as high as practicable in the tank so that battle damage to a fitting causes a minimum of fuel loss. Fuel tanks shall not be located immediately adjacent to gun compartments; they shall be separated from such compartments by at least one liquid and vaportight bulkhead in addition to the tank boundary structure. Fuel tank shutoff valves shall be integral with or as close as possible to the tanks. The fuel sequencing from multiple fuel tanks should be arranged to result in lowest vulnerability to battle damage.

2.1.1.7 FUEL TANK LOADS

Prevention of major fuel leakage caused by fuel inertia loads in the tanks during a crash landing should be considered in tank design to the greatest practicable extent. Fuel tanks which withstand, without major leakage, the same crash inertia loads as the seats of the occupants are desirable for a balanced crash safety level of an aircraft.

2.1.1.8 FASTENERS

Self-locking units utilizing nonmetallic locking devices shall not be used in oil tanks because of loss of locking characteristics through oil and heat. Nonmetallic nuts shall not be used on tanks containing flammable fluids where frequent threading of the nuts is required.

2.1.1.9 FUEL TANKS IN BOMB BAYS

The requirements for fuel tank isolation of paragraph 2.1.1.2 and for fuel tank compartments of paragraph 2.1.1.3 should be applied to fuel tanks in bomb bays to the greatest practicable extent.

2.1.1.10 FUEL TANK INERTING (See 2.16)

2.1.2 INTERNAL, REMOVABLE, NON-SELF-SEALING TANKS

2.1.2.1 TANK MOUNTING

The support structure of tanks containing flammable fluids shall be such that the stresses in the tank are low. Support in padded cradles is recommended, whenever practicable. Material for padding shall be nonabsorbent, and fuel and oil resistant. Supports of tanks containing flammable fluids, which are located in engine compartments shall be designed to withstand a 2000°F fire for 10 minutes without failure. The tank support pads shall withstand a 2000°F fire for five minutes without losing the ability to retain the tank in position under normal flight loads.

2.1.2.2 BLADDER CELL CAVITY

Bladder cells shall be so supported by the tank cavity that the bladder is not required to withstand fluid loads. Negative loads on bladder cells shall be avoided by proper vent size and design. Interior surfaces of bladder cell cavities shall be smooth and free of projections which could cause wear of the bladder, unless provisions are made for protection of the bladder at such points or unless the construction of the bladder itself provides such protection. Tank fittings and accessories shall be mounted so that their loading is transmitted to the structural cavity. The bladder shall fit the cavity without clearance. The tank cavity shall be liquid and vaportight, and drained.

2.1.3 SELF-SEALING TANKS

2.1.3.1 TANK CAVITY FOR RIGID TANKS

Metal structural members such as stiffeners, hat sections etc., shall be kept to a minimum in cavities for rigid nonmetallic self-sealing tanks. The minimum clearance between metal structure and the tank should be one inch. However, it may be necessary to use the tops of stringers for tank support to maintain tank shape. The above requirements with regard to surrounding structure do not apply to the top surface of the tank. The tank cavity shall be liquid and vaportight, and drained and ventilated.

2.1.3.2 TANK CAVITY FOR FLEXIBLE TANKS

All surfaces of the tank cavity of flexible self-sealing tanks, other than the top surface, shall be lined with plastic panels conforming to MIL-P-8045. The tank cavity shall be liquid and vaportight, and shall be drained. The cavity structure and the plastic panels shall withstand the forces produced by the passage of projectiles, specified in MIL-T-55'.., paragraph 4.6.12, through the confined liquid to such a degree that no additional hazards evolve.

2.1.4 INTEGRAL TANKS

2.1.4.1 SPECIFICATIONS

These tanks shall comply with the requirements of MIL-F-17874, paragraph 3.3.3 and the following:

(1) Extrusions or one piece sections should be used instead of built-up members.

(2) Faying surface sealing should be applied so that it will not interfere with electric bonding requirements.

(3) Ample space for corners and butting parts shall be provided for the sealant to contact all surfaces.

(4) The seams should be arranged so that the fluid head will aid the sealing. Access doors should be designed as inward opening doors, whenever possible.

(5) Fasteners through tank boundaries should be avoided, whenever possible. Bolt heads rather than nuts should be located in the sealed area when such a choice is available.

(6) The sealed area should be accessible for application and inspection of the sealant and for repair.

(7) All holes or gaps in the assembly should be covered by plates, caps, shims, etc.

2.1.4.2 STATIC ELECTRICITY (See 2.18)

		PARAGRAPH
(1)	LIGHTNING PROTECTION	2.1.1.1.5
(2)	FUEL TANK CRASH PROTECTION	2.1.1.1.6
(3)	FUEL TANK ISOLATION	2.1.1.2
(4)	FUEL TANK COMPARTMENTS	2.1.1.3
(5)	FUEL TANKS IN BOMB BAYS	2.1.1.9

2.1 FLAMMABLE FLUID TANKS

FIGURE 1

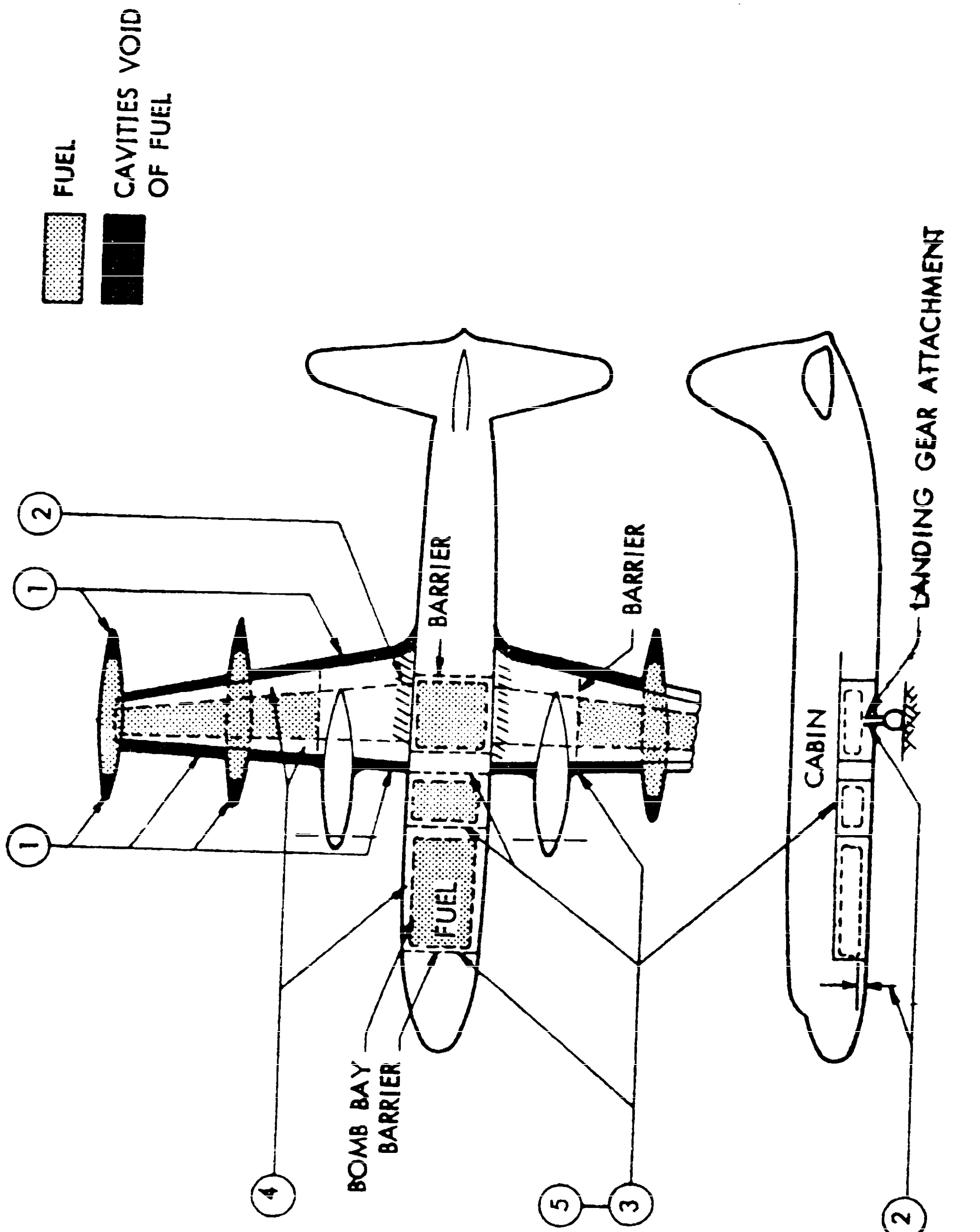


FIGURE 1 -- 2.1 FLAMMABLE FLUID TANKS

		PARAGRAPH
(1)	TANKS IN ENGINE COMPARTMENTS	2.1.1.1.1
(2)	TANKS ABOVE ENGINE COMPARTMENTS	2.1.1.1.2
(3)	FUEL TANKS AND TURBINES	2.1.1.1.3
(4)	FUEL TANKS AND PROPELLERS	2.1.1.1.4
(5)	FASTENERS	2.1.1.8
(6)	REMOVABLE RIGID TANKS	2.1.2
(7)	TANK MOUNTING	2.1.2.1

2.1 FLAMMABLE FLUID TANKS

FIGURE 2

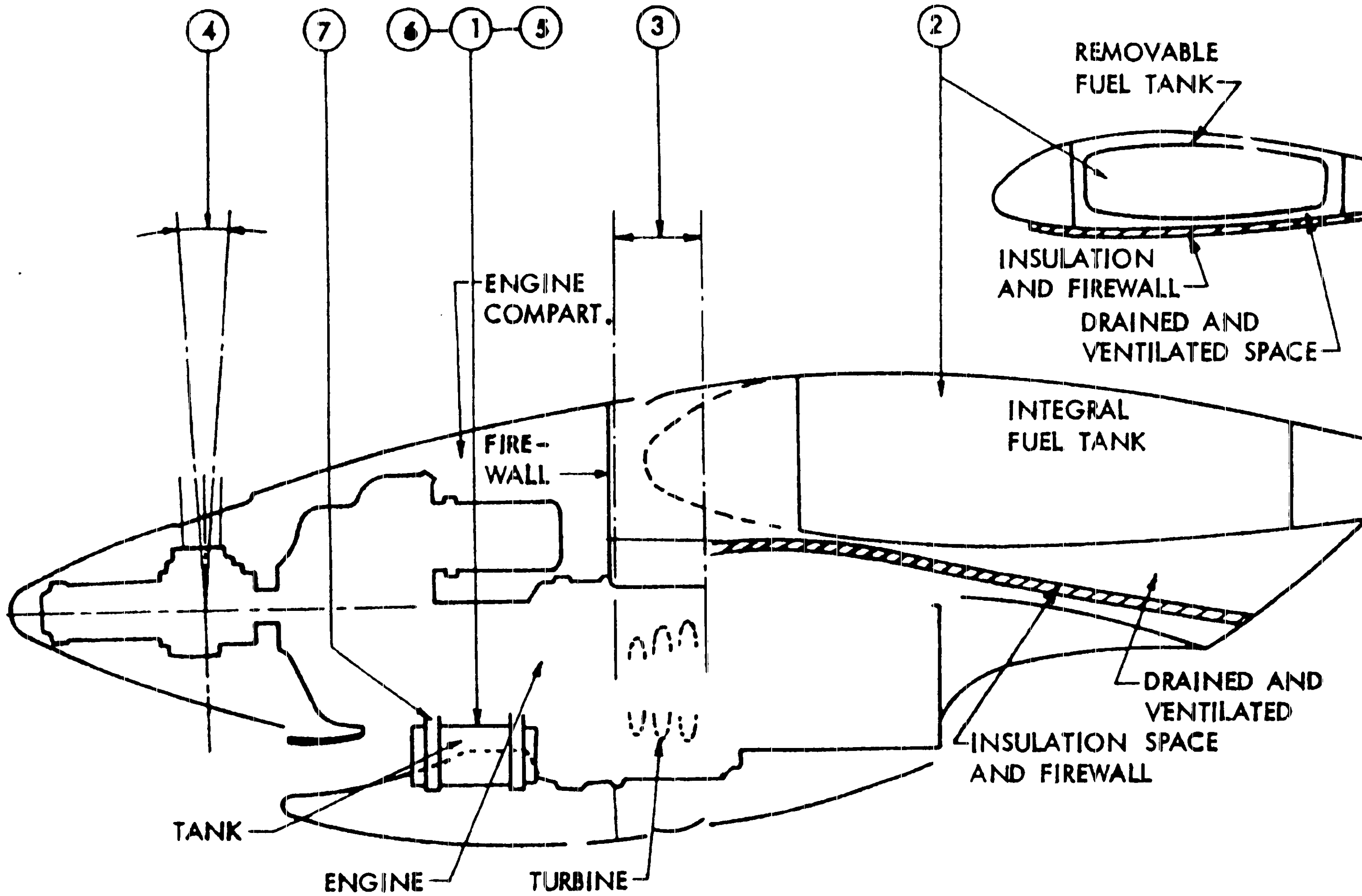


FIGURE 2 - 2.1 FLAMMABLE FLUID TANKS

		PARAGRAPH
(1)	FUEL TANK COMPARTMENT	2.1.1.3
(2)	ELECTRIC EQUIPMENT IN FUEL TANKS	2.1.1.4
(3)	FUEL TANK FITTINGS	2.1.1.5
(4)	FUEL TANK LOADS	2.1.1.7
(5)	FASTENERS	2.1.1.8
(6)	NON-SELF-SEALING TANKS	2.1.2
(7)	SELF-SEALING TANKS	2.1.3
(8)	INTEGRAL TANKS	2.1.4

2.1 FLAMMABLE FLUID TANKS

FIGURE 3

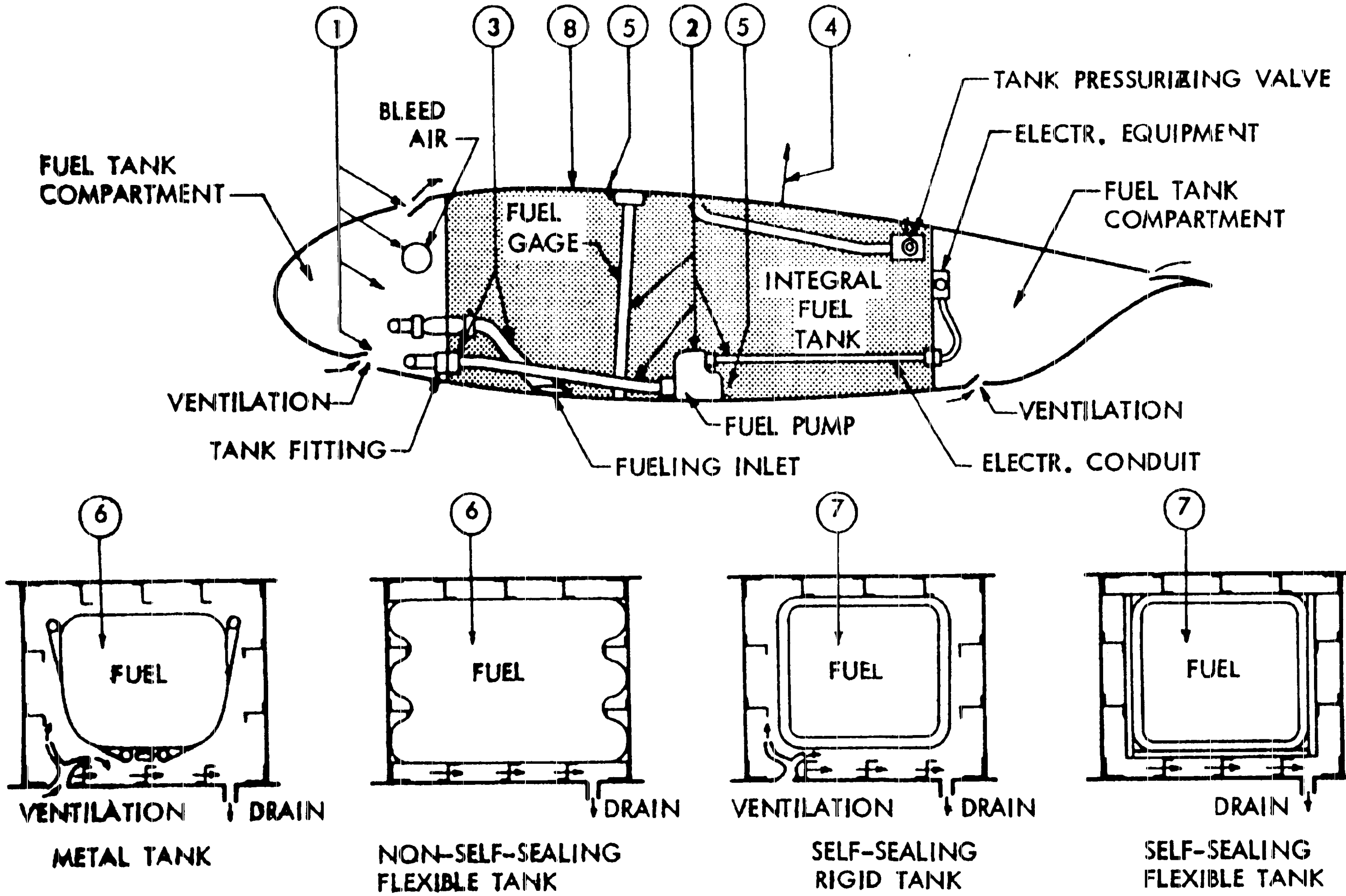


FIGURE 3 - 2.1 FLAMMABLE FLUID TANKS

2.2 FLAMMABLE FLUID SYSTEMS (See Figures 4, 5, 6, and 7 on pages 23, 25, 27 and 29).

2.2.1 GENERAL

2.2.1.1 SPECIFICATIONS

Flammable fluid systems and components shall comply with the fire protection requirements of the following specifications:

FUEL SYSTEMS, AIRCRAFT, INSTALLATION AND TEST OF, MIL-F-17874;
FUEL SYSTEM COMPONENTS, GENERAL SPECIFICATION FOR, MIL-F-8615;
FUEL AND OIL LINES, AIRCRAFT, INSTALLATION OF, MIL-I-18802;
HYDRAULIC SYSTEM, AIRCRAFT, REQUIREMENTS FOR, MIL-H-5440.

2.2.1.2 COMPONENT LOCATION

Components carrying flammable fluid, such as fuel, oil, water-alcohol, and hydraulic fluid shall not be located in compartments where a "single failure," such as leakage, can cause ignition. They shall not be located, if practicable, in compartments where a dual failure, such as leakage plus electrical overheating or arcing, can cause ignition. If this cannot be accomplished for justifiable reasons, components carrying flammable fluid shall be located so that leaking fluid will not come in contact with electric equipment and wiring, bleed air ducts, or other potential ignition sources by the effect of gravity, airflow, or battle damage. This shall be accomplished by locating components carrying flammable fluid below and away from ignition sources. If compliance with above requirements cannot be accomplished for justifiable reasons, the compartment shall be treated as potential fire zone (see 2.11).

Components carrying fuel should not be located in inhabited areas (see 2.2.1.7.7) and in cargo compartments (see 2.2.1.7.8).

Fuel lines should be routed within fuel tanks to the greatest possible extent to minimize fire and explosion hazards resulting from leakage.

Where duplicated flammable fluid systems are provided, these systems should be separated by location or compartmentation.

For location of components carrying flammable fluid with regard to oxygen components see 2.9.

2.2.1.3 DRAINAGE AND .ENTILATION (See 2.4)

Al_ compartments containing flammable fluid components with potential leakage, and compartments adjacent to fuel tanks, shall be drained and ventilated. Compartments into which leakage of flammable vapor from other compartments is likely shall be ventilated. Where mixtures too rich to burn can be maintained in these compartments throughout all flight regimes, prevention of air circulation rather than ventilation may be employed.

2.2.1.4 ELECTRIC EQUIPMENT

Electronic equipment shall comply with the fire protection requirements of MIL-E-5400, and electric wiring shall comply with the fire protection requirements of MIL-W-5088. Also see 2.7.

Electric equipment which can be an ignition source in a normal operating or failed condition should not be located in compartments containing flammable fluid components, or in compartments adjacent to fuel tanks, or in compartments into which leakage of flammable vapor from other compartments is likely due to lack of adequate sealing. Such lack of adequate sealing is normal in many cases after extended maintenance and service. Leakage of flammable vapors into electrical compartments should be avoided, when practicable, by providing a positive pressure head in the electrical compartment relative to any adjacent compartment containing flammable fluid components. If, for justifiable reasons, electric equipment which can be an ignition source must be located in a compartment containing flammable fluid components or tanks, or in a compartment into which leakage of flammable vapor from other compartments cannot be prevented, the equipment shall comply with 2.7.2 and 2.7.3.

2.2.1.5 HOT GAS DUCTS

Hot bleed air ducts and other hot gas ducts and components which can be an ignition source due to high surface temperatures or to leaking hot air or gas should not be located in compartments containing flammable fluid components with potential leakage, or in compartments adjacent to fuel tanks, or in compartments into which leakage of flammable vapor from other compartments is likely. If, for justifiable reasons, hot air or gas ducts must be located in compartments with potential flammable fluid or vapor leakage, they shall comply with 2.8.1 and 2.8.2.

2.2.1.6 ACCESSORY SUPPORT

All accessory units such as filters, valves, etc., the weight or operation of which impose adverse stresses or vibration on tubing carrying flammable fluid, shall be supported by means other than the tubing. If rigid connections are used between accessories, then all accessories so connected shall be rigidly mounted on the same base.

2.2.1.7 FLAMMABLE FLUID LINES

Installation of fuel and oil lines shall comply with the fire protection requirements of MIL-I-18802.

2.2.1.7.1 LINE LOCATION (See 2.2.1.2)

2.2.1.7.2 LINE SUPPORT

Unsupported sections of lines carrying flammable fluids whose natural frequency would be such that dangerous amplitudes of vibration might occur in operation shall be avoided. Rubberlined clamps, such as MS21919, shall be used to support metal tubing and hoses. Chafing of lines shall be prevented by clamping, or in bulkheads or other structure by grommets. Grommets, however, shall not be used for support of rigid lines. Grommets in firewalls shall withstand a flame of 2000°F for 15 minutes without flame penetration in installed condition. Lines shall not be supported from each other.

2.2.1.7.3 HOSES

Cut hose and hose clamps shall not be used in any part of a flammable fluid system. Hose assemblies shall be protected by shielding or other means against temperatures in excess of the maximum specified allowable temperature for the particular hose.

2.2.1.7.4 TUBES

Tubes, carrying flammable fluid, with below standard radii shall not be used. Tubes shall be provided with bends or other expansion means to avoid rupture during normal service, or during a fire if located in or close to a fire zone.

2.2.1.7.5 FITTINGS

Lines shall have as few joints as possible, consistent with economical installation requirements. Fittings for hoses and tubes 3/8 inch I.D. and smaller shall be made of steel.

2.2.1.7.6 LINES IN POTENTIAL FIRE ZONES

Tubes carrying flammable fluids in or close to a potential fire zone shall be made of stainless steel, or equivalent. Hoses carrying flammable fluids in or close to a potential fire zone shall withstand a flame of 2000°F for at least 5 minutes without leakage, at the lowest fluid flow rate and the highest fluid temperature, and under vibration of operation. Fittings shall have an equal resistance to fire. Also see 2.11.1.16.

2.2.1.7.7 LINES IN INHABITED AREAS

See 2.2.1.2. If fuel lines must be routed through inhabited areas for justifiable reasons, they should not incorporate fittings and shall be sufficiently well protected against damage. If fittings must be provided within the inhabited area, the lines shall be enclosed in a fluid and vaportight drained shroud.

2.2.1.7.8 LINES IN CARGO COMPARTMENTS

See 2.2.1.2. If fuel lines must be routed through cargo compartments for justifiable reasons, they shall be protected by rugged, fire resistant conduits and covers, so that they cannot be damaged by movement of cargo. The conduits or covers for lines which have connectors within the cargo area shall be drained overboard.

2.2.1.7.9 LINES IN WHEEL WELLS

Flammable fluid lines in wheel wells shall be installed to have the maximum protection against rocks, frozen mud or exploding tires.

2.2.1.8 INTERNAL PRESSURE

Excessive internal pressure in components carrying flammable fluids, during normal service, or during exposure to a fire, if located in a potential fire zone, shall be prevented by positive means.

2.2.1.9 INSULATION

Insulation used in compartments carrying flammable fluid components shall be nonabsorbent as a material configuration and so installed that fluids will not be retained on or under it.

Sandwich type insulation blankets shall be vented, and drained at their lowest points. The vent and drain holes shall be shielded if required to prevent entrance of fluid. The insulation shall be "nonpacking" under service conditions.

2.2.2 TANK FILLER UNITS

Tank filler caps and adapters shall comply with the fire protection requirements of MIL-C-7244.

All filler units for tanks containing flammable fluids, both gravity and pressure fueling type, which are recessed behind access doors, shall incorporate positive provisions whereby the access doors physically may not be secured unless the filler cap or safety cap is properly installed. Unless specifically authorized, all filler units shall be sealed to the exterior of the aircraft against the entrance of flammable fluids or vapors to the interior of the aircraft. If necessary, filler basins (scuppers) shall be provided with drains of at least 3/8 inch I.D. The scupper shall be adequately sealed to the surrounding structure to prevent spilled fluid from entering the fuselage, engine compartment, or wing. The cap shall incorporate provisions for positive locking. Filler caps shall be so designed that visual inspection of the installed cap from a distance of at least 10 feet in daylight gives positive indication that the cap is properly and positively locked in the closed position. An electric ground receptacle for grounding pressure and gravity fueling nozzles, conforming to MS 33645, shall be installed, with the exception that the receptacle shall be located: (a) not more than 20 inches or less than 5 inches from the adapter, and (b) not near fuel vents or openings. For lightning protecting design of filler caps, see 2.18.

Pressure fueling adapters shall comply with the requirements of MIL-A-6425. Fueling adapters shall be properly grounded to the airframe in accordance with MIL-B-5087.

See fueling and defueling 2.5.

2.2.3 PUMPS FOR FLAMMABLE FLUIDS

Fuel booster pumps shall comply with the fire protection requirements of MIL-P-5238.

Electric motor driven pumps for flammable fluids shall have shaft seals and suitable drain chambers and overboard drains to allow any fluid, which leaks past the main seal, to drain to the outside before entering the motor. The drain shall terminate on the outside of the pump in a boss in accordance with AND 10049-4 or AND 10050-4. The only possibility of seal leakage shall be from between the rubbing members of the seal. In the event that an electric motor is utilized, wherein its rotating element operates immersed in the fluid, this requirement does not apply. On electric motor driven pumps, unless the motor operates immersed in fluid, the motor shall be vented overboard. The vent line should be integral with the pump without connectors. Motor cases of electric motor driven pumps with immersed motor shall have a vent hole to the tank cavity, which incorporates a proven flame arrestor. The electric motors shall be explosion-proof in accordance with MIL-E-5272, Procedure IV.

Electric motor driven pumps which, in case of a failure, can reach case temperatures higher than the autogenous ignition temperature of the fluid shall incorporate thermal protection. The thermal protection shall cut off the current to the motor so that no point of the motor case exceeds at any time a temperature which is 50°F below the autogenous temperature of the fluid. The thermal protection shall not be resettable in flight. (Also see 2.7.3.2.)

Electric motor driven pumps shall be such that current cannot be carried from the motor section into the pump under any failure condition. The electric wires shall enter the motor through potted inlets, if the wire inlet is submerged, in normal condition or in case of a failure.

For electric wiring, connectors and conduits, and for metal tubes attached to electric motor driven fuel pumps in fuel tanks, see 2.1.1.4.

Centrifugal pumps should be used rather than positive displacement pumps if necessary to preclude high pressure buildup in case of line blockage. High speed positive displacement pumps shall not be used when the pump element may run emersed.

2.2.4 QUANTITY GAGES

Capacitor type fuel quantity gages shall comply with the fire protection requirements of MIL-G-8998.

Quantity indicators in tanks containing flammable fluids shall be designed so that no "single electrical failure" in any part of the circuit, inside or outside the tank, shall cause a spark or arc, with an energy greater than 0.2 millijoules, within the tank. Liquid level switches shall be in accordance with the fire protection requirements of MIL-S-21277. If transformers are used for power supply to the gages in the tank, electrostatic grounded shields should be applied between the two windings, if a short between the primary and secondary winding could cause a spark or arc, with an energy greater than 0.2 millijoules in the tank.

For routing of fuel gage electrical wiring with regard to lightning protection, see 2.18.

2.2.5 ELECTRIC VALVES

Drain openings shall be provided and arranged to prevent any potential leakage of flammable fluid from passing through the shaft seal and entering an electrical actuator in the position of installation. Such leakage shall not impinge on or otherwise contact an ignition source. Electrical actuators shall be explosion-proof in accordance with MIL-E-5272, Procedure IV.

2.2.6 VALVES IN FUEL TANK VENT LINES

Valves in fuel tank vent systems should be avoided, when possible. If they cannot be avoided for justifiable reasons, they shall be designed and installed so that no flammable fluid will be released into an existing fire within the first five minutes of the fire. Dual valves for inflow and outflow control shall be incorporated so that a "single failure" cannot cause excessive positive or negative tank pressures. The valves should preferably incorporate a "self-exercising" feature to prevent sticking from inactivity.

2.2.7 FUEL DIPSTICKS

If dipsticks are used in fuel tanks which have provisions for pressure fueling, they shall either be made of material which is electrically nonconductive and does not retain an electrostatic surface charge, or they shall be contained in an electrically conductive sheath, made of metal screen or perforated tube, or any other suitable design, which is electrically bonded to the metal filler adapter and carries away static charges rapidly from the fuel surface in the vicinity of the dipstick.

2.2.8 ACCESSORIES IN POTENTIAL FIRE ZONES

Accessories containing flammable fluids which are located in a potential fire zone shall be so designed that not more than 0.5 gallons of flammable fluid are likely to be released into an existing fire, as a consequence of an existing fire, within the first five minutes of a fire. If necessary to accomplish this, accessories shall be made to withstand a 2000°F flame for five minutes, or flow restrictions shall be provided, where feasible. Simultaneous leakage from multiple accessories or tanks is not likely to be released into an existing fire, if accessories or tanks are located remote from each other and so that spread of fire to both accessories and tanks is unlikely.

2.2.9 FUEL TRANSFER SYSTEMS

The fuel transfer system shall be designed so that a "single failure" in the system cannot cause failure of the level control in the tank to shut off the transfer flow, if such failure can cause fuel discharge through the vent line or pressurization of a fuel tank with resulting tank leakage. Vent lines for fuel tanks receiving fuel from a transfer tank, normally or due to a failure of a level control, shall be sized to accommodate the maximum fuel transfer rate, in addition to the venting flow rate, without imposing pressures on the tank which could cause fuel leakage.

		PARAGRAPH
(1)	DRAINAGE AND VENTILATION	2.2.1.3
(2)	LINE SUPPORT	2.2.1.7.2
(3)	HOSES	2.2.1.7.3
(4)	TUBES	2.2.1.7.4
(5)	FITTINGS	2.2.1.7.5
(6)	LINES IN POTENTIAL FIRE ZONES	2.2.1.7.6
(7)	INTERNAL PRESSURE	2.2.1.8
(8)	INSULATION	2.2.1.9
(9)	ACCESSORIES IN POTENTIAL FIRE ZONES	2.2.8

2.2 FLAMMABLE FLUID SYSTEMS

FIGURE 4

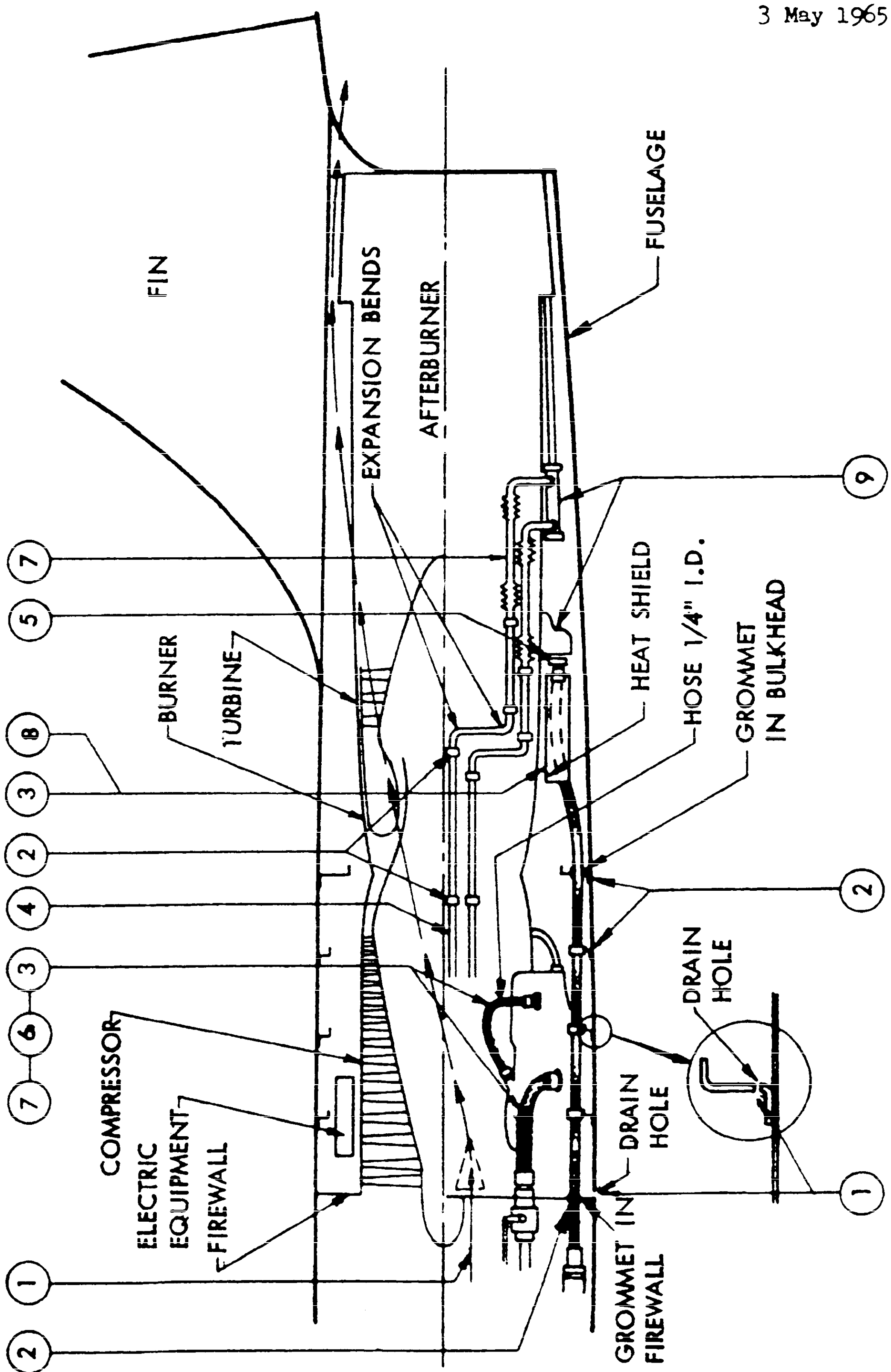


FIGURE 4 - 2.2 FLAMMABLE FLUID SYSTEMS

		PARAGRAPH
(1)	COMPONENT LOCATION	2.2.1.2
(2)	DRAINAGE AND VENTILATION	2.2.1.3
(3)	LINES IN INHABITED AREAS	2.2.1.7.7
(4)	LINES IN CARGO COMPARTMENTS	2.2.1.7.8
(5)	LINES IN WHEEL WELLS	2.2.1.7.9
(6)	TANK FILLER UNITS	2.2.2
(7)	PUMPS FOR FLAMMABLE FLUIDS	2.2.3
(8)	QUANTITY GAGES	2.2.4
(9)	VALVES IN FUEL TANK VENT LINES	2.2.6
(10)	FUEL DIPSTICKS	2.2.7
(11)	FUEL TRANSFER SYSTEMS	2.2.9

2.2 FLAMMABLE FLUID SYSTEMS

FIGURE 5

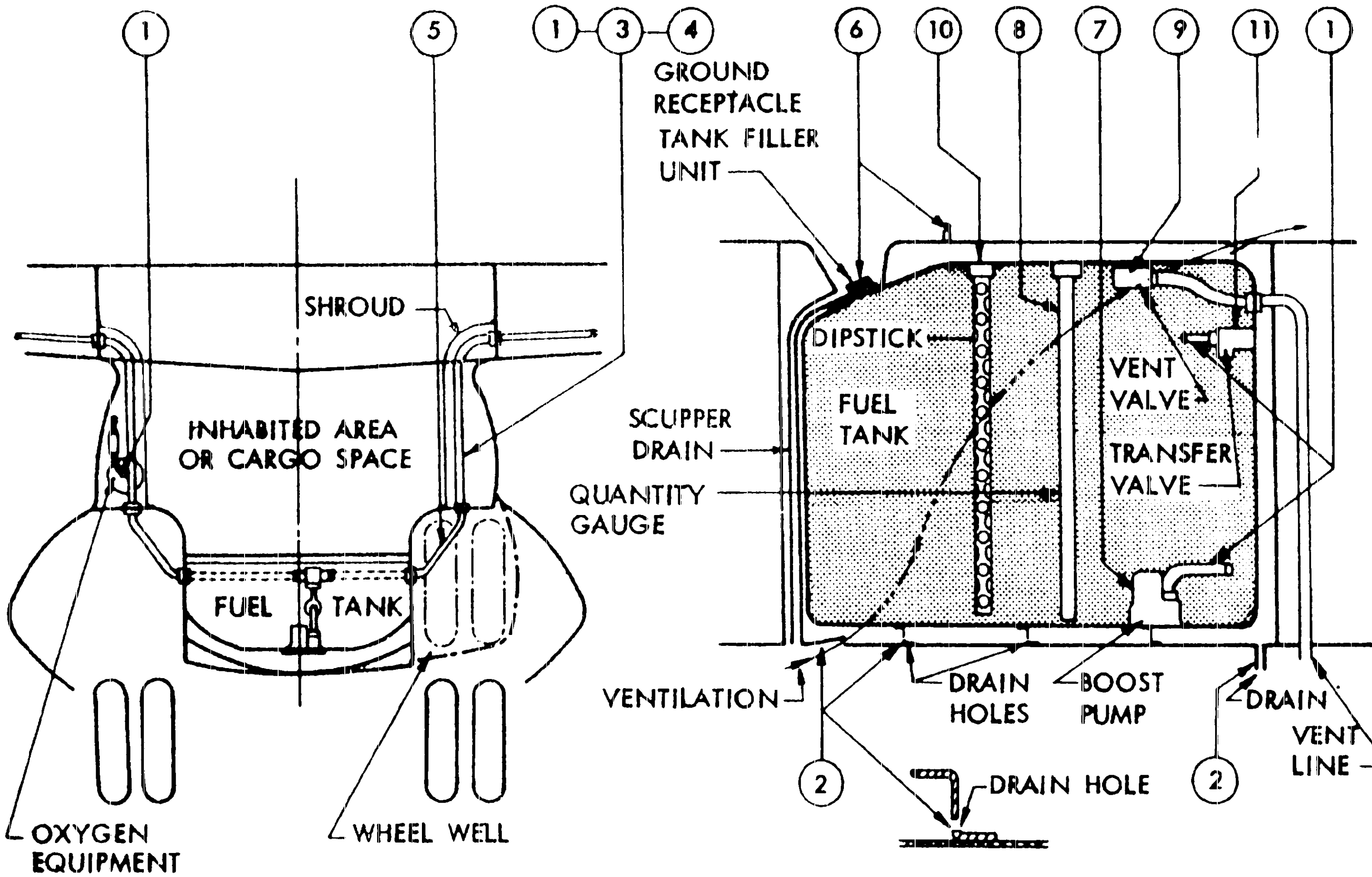


FIGURE 5 - 2.2 FLAMMABLE FLUID SYSTEMS

		PARAGRAPH
(1)	COMPONENT LOCATION	2.2.1.2
(2)	DRAINAGE AND VENTILATION	2.2.1.3
(3)	ELECTRIC EQUIPMENT	2.2.1.4
(4)	HOT GAS DUCTS	2.2.1.5
(5)	ACCESSORY SUPPORT	2.2.1.6
(6)	LINE SUPPORT	2.2.1.7.2
(7)	HOSES	2.2.1.7.3
(8)	TUBES	2.2.1.7.4
(9)	FITTINGS	2.2.1.7.5

2.2 FLAMMABLE FLUID SYSTEMS

FIGURE 6

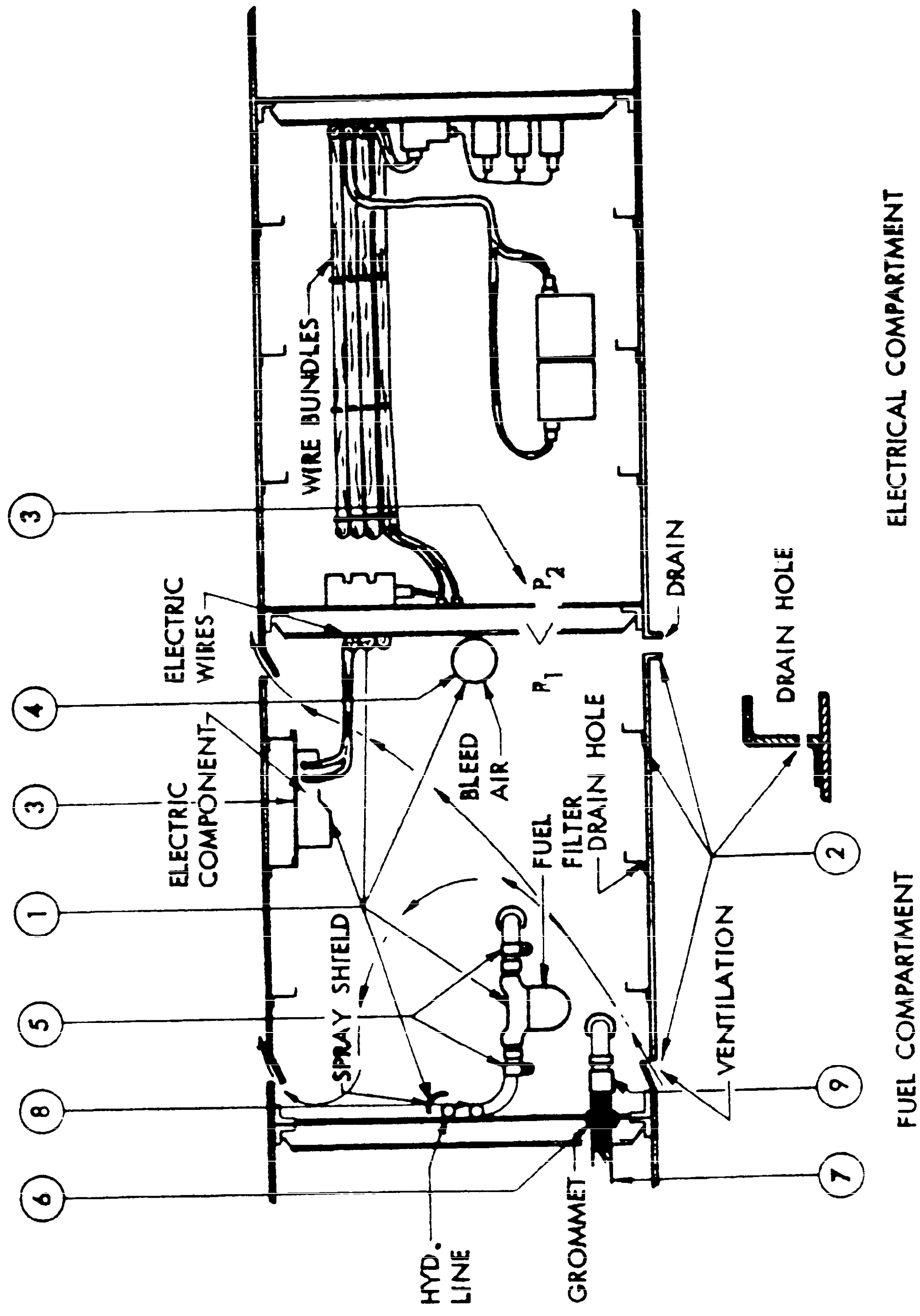


FIGURE 6 - 2.2 FLAMMABLE FLUID SYSTEMS

		PARAGRAPH
(1)	HOSES	2.2.1.7.3
(2)	PUMPS FOR FLAMMABLE FLUIDS	2.2.3
(3)	ELECTRIC VALVES	2.2.5

2.2 FLAMMABLE FLUID SYSTEMS

FIGURE 7

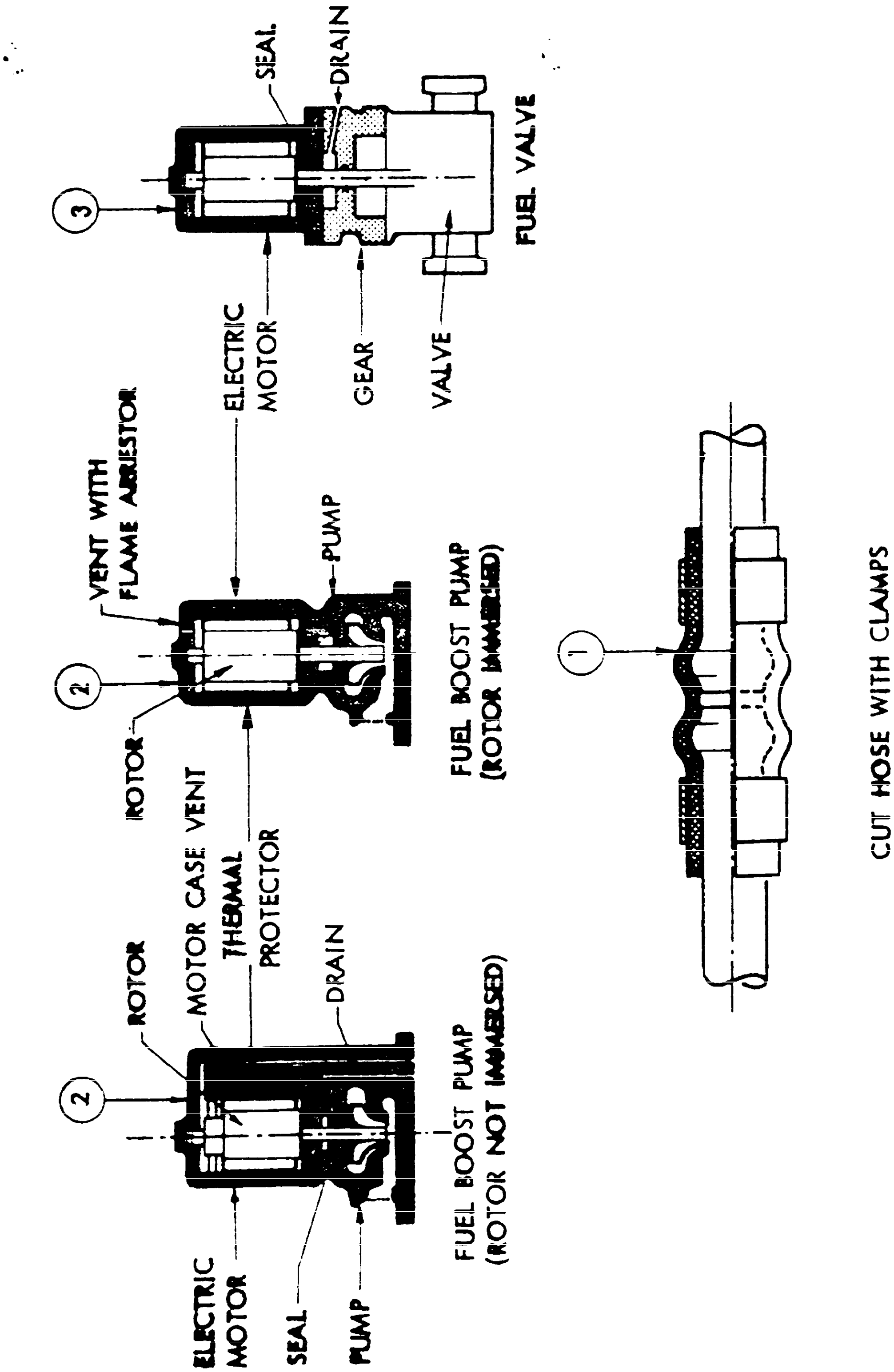


FIGURE 7 - 2.2 FLAMMABLE FLUID SYSTEMS

2.3 FLAMMABLE FLUIDS

Reserved for future text.

2.4 DRAINAGE, VENTILATION AND VENTS (See Figures 8, 9 and 10 on pages 37, 39 and 41).

2.4.1 DRAINED AREAS

All compartments containing flammable fluid components shall be drained, unless leakage from these components is extremely unlikely. All areas surrounding fuel tanks shall be drained. All drains shall be so arranged that no trapped fluid can accumulate at any place in the compartment. Cavities in flammable fluid components shall be drained if leakage into these cavities is possible and leakage can cause an ignition hazard. In this category are components in which separation of flammable fluids from electric equipment is accomplished by seals or bellows. All filler unit scuppers which can collect spilled fuel during filling, shall be provided with drains (see 2.2.2).

2.4.2 VENTILATED AREAS

All compartments containing flammable fluid components with potential leakage, compartments adjacent to fuel tanks, and compartments into which flammable vapor can enter from other compartments, shall be ventilated if these compartments also contain potential ignition sources such as electric equipment, etc., unless such leakage is extremely unlikely. The ventilation should be designed to lean out flammable mixtures below the lower limits of flammability, minimize dwell time of flammable fluid and vapor on hot surfaces and reduce environmental temperatures. One to three air changes per minute have proven to be adequate, whereby the lower value applies to compartments where only low leakage rates are expected and the higher values apply to compartments with potential high leakage rates, which can be the case in power plant accessory sections.

Where mixtures too rich to burn can be maintained in these compartments throughout the flight regimes, prevention of air circulation rather than ventilation may be employed.

Ventilation flow paths through large portions of the aircraft shall be prevented, by vapor barriers, when necessary, to restrict fuel vapor, fire, heat and smoke from spreading over wide areas at a rapid rate. This, in case of fire, gives time to the crew to consider possible countermeasures, and also gives the fire a better chance to burn itself out locally. Such vapor barriers may be made of aluminum alloy or equally fire resistant material.

2.4.3 VENT LINES

Vent lines for flammable fluid tanks shall be so designed that they safely dispose of flammable vapors which are emitted from the tanks during fueling, during climb and due to thermal expansion in the tank vapor space. The vent lines shall be sized so that the inflow and outflow through the lines is accomplished in all instances without causing an excessive pressure differential between the interior and exterior of the tank which could result in tank leakage. Obstruction or blockage of the vent lines by ice shall be prevented by avoiding trapped fluid in the lines and by proper design of the vent line exit. Icing at the vent exit can be critical in a long descent, when cold air with a high liquid water content is ingested. Vent exits shall be tested for icing if a possibility for icing is suspected. The vent lines shall be designed so that fluid will not spill out during normal maneuvering in flight and on the ground. If valves are provided in the vent lines for the purpose of tank pressurization, tank inerting or prevention of fluid loss through the vent line in transient flight attitudes or during taxiing, these valves shall comply with 2.2.6. Malfunction or misuse of fuel transfer systems should not cause a high rate of fuel flow to be pumped out the vent. Wing fuel tank installations equipped with vent valves having pressure relief provisions shall be checked for spanwise acceleration to ensure against spillage during high speed taxi turns.

Vent lines shall be provided for flammable fluid components, if excessive pressure differentials can cause a fire or explosion hazard.

2.4.4 VENT AND DRAIN DISCHARGE

All vent and drain exits which carry flammable fluids and vapors overboard shall be arranged in such a manner that there is no impingement on the aircraft under any normal condition of aircraft operation. Vent discharge, drain discharge, fueling and defueling nozzles shall not be located in close proximity to fittings for aircrew oxygen replenishment, engine start and electric power cable connections. Where the prevention of impingement is impractical, there shall be no re-entry of the flammable fluid or vapor into aircraft spaces where a possible source of ignition may exist, considering seams which might "open" during normal operation of the aircraft, throughout the service life of the aircraft. Further, fuel tank vents shall be installed so that fluids discharged will not contact ground equipment normally parked about the aircraft, when servicing the aircraft. Fuel tank vent exit configurations should be such that they do not protrude from the surface of the aircraft whenever there is a possibility of a lightning clinging on to the exit and causing flame propagation to the tank, or adequate protection against lightning shall be provided. (See 2.18.) Vent and drain exits should permit free drainage of fluid from the lines without wetting the skin when the aircraft is standing on the ground. The line exits shall be sealed at the aircraft surface around the periphery of the line to prevent entrance of fluid or vapor into the aircraft. Vent and drain discharge shall be away from engine and rocket exhaust, to the extent necessary to prevent flame propagation into drained and vented compartments. Fuel tank vent exits shall be so located that fuel vapors are not likely to enter areas in the fuselage, wing and power plant during fueling. Vent line exits for fuel tanks which have provisions for pressure fueling should be designed so that inadvertent blocking of the vent exit by masking tape or by stoppers used for system leakage checks, is eliminated to the greatest practical extent. Lightning protection of fuel tank vent exits shall be provided in accordance with 2.18.

2.4.5 DRAIN CONFIGURATIONS

Minimum drain angles should be greater than five degrees throughout the normal range of flight and ground attitudes. All drain lines shall be free of traps. Drainage provisions shall be designed so that pressure differentials and correlative airflows across the drainage paths do not alter the gravity flow and prevent proper function of the drainage provisions. No drain lines should be manifolded together except at the point of overboard discharge. In cases where manifolding is necessary, pressure differentials in drained compartments or equipment cavities and their possible cause of a fire or explosion, and the ability to identify drained fluids shall be carefully considered. Drained fluids which are manifolded must be compatible. Manifolded drains must be approved by the Bureau of Naval Weapons. Minimum diameter of drain lines and drain holes should be 3/8 inch I.D. for gravity flow, but all drain line sizes shall be such that accumulation of flammable fluid is prevented at the highest leakage rate caused by any "single failure."

2.4.6 DRAINAGE IN POTENTIAL FIRE ZONES

Vent and drain lines and fittings in potential fire zones carrying flammable fluids or vapors shall be made of material that resists a flame of 2000°F for at least five minutes without leakage, unless a failure of such lines and fittings will not result in or add to a fire hazard.

2.4.7 DRAINAGE IN CARRIER BASED AIRCRAFT

A container shall be provided for collecting fuel drainage in fixed wing aircraft as described in General Specification SD-24, Volume I, paragraph 3.12.9.10.1(2). The container shall be designed and located so that flammable vapors from the container cannot enter an engine compartment or any other compartment which contains potential ignition sources, and that the fluid in the container cannot be ignited.

If the possibility of ignition in the container cannot be eliminated, the drainage system shall be designed to contain a fire without causing a hazard to drained components.

2.4.8 VENTILATION CONFIGURATIONS

Ventilation inlets shall be so located that flames cannot enter from other zones. Ventilation inlets to potential fire zones and to other compartments containing potential ignition sources shall be located so that flammable fluids and vapors cannot enter. The inlet air to these compartments shall not pass over or through any device containing flammable fluid, such as heat exchangers. The inlet air, under condition of failure, shall not contain flammable fluid or vapor. Ventilation air inlets to a potential fire zone shall have fire shutoff valves, if the airflow from a single inlet is higher than 5 cu.ft./min., and if fire extinguishing is provided for the zone.

Ventilation discharge from potential fire zones shall not impinge on surfaces of integral tanks, on vital structure, or on equipment, if such impingement can cause an additional hazard in case of fire. Ventilation discharge from potential fire zones shall not enter any other compartment or re-enter the aircraft through openings downstream of the discharge. Ventilation discharge from compartments containing flammable fluid components and from compartments adjacent to fuel tanks shall not discharge or re-enter into compartments with potential ignition sources.

The ventilating airflow shall be distributed as evenly as practicable throughout the compartment with emphasis on high airflows at areas of potential flammable fluid leakage.

Openings should be provided in engine compartments which provide natural convection ventilation during ground operation.

In rotary wing aircraft, ventilation by ram air cannot be accomplished for all flight conditions. Ventilation by artificial means such as exhaust or bleed air ejectors, or engine or electric motor driven fans should be applied. Ventilation airflow through two or more compartments, which can carry a hazard from one compartment to another, should be avoided. Such interconnection is prohibited from passing through fire barriers which isolate potential fire zones from the rest of the airplane.

		PARAGRAPH
(1)	DRAINED AREAS	2.4.1
(2)	VENTILATED AREAS	2.4.2
(3)	VENT LINES	2.4.3
(4)	VENT AND DRAIN DISCHARGE	2.4.4

2.4 DRAINAGE, VENTILATION AND VENTS

FIGURE 8

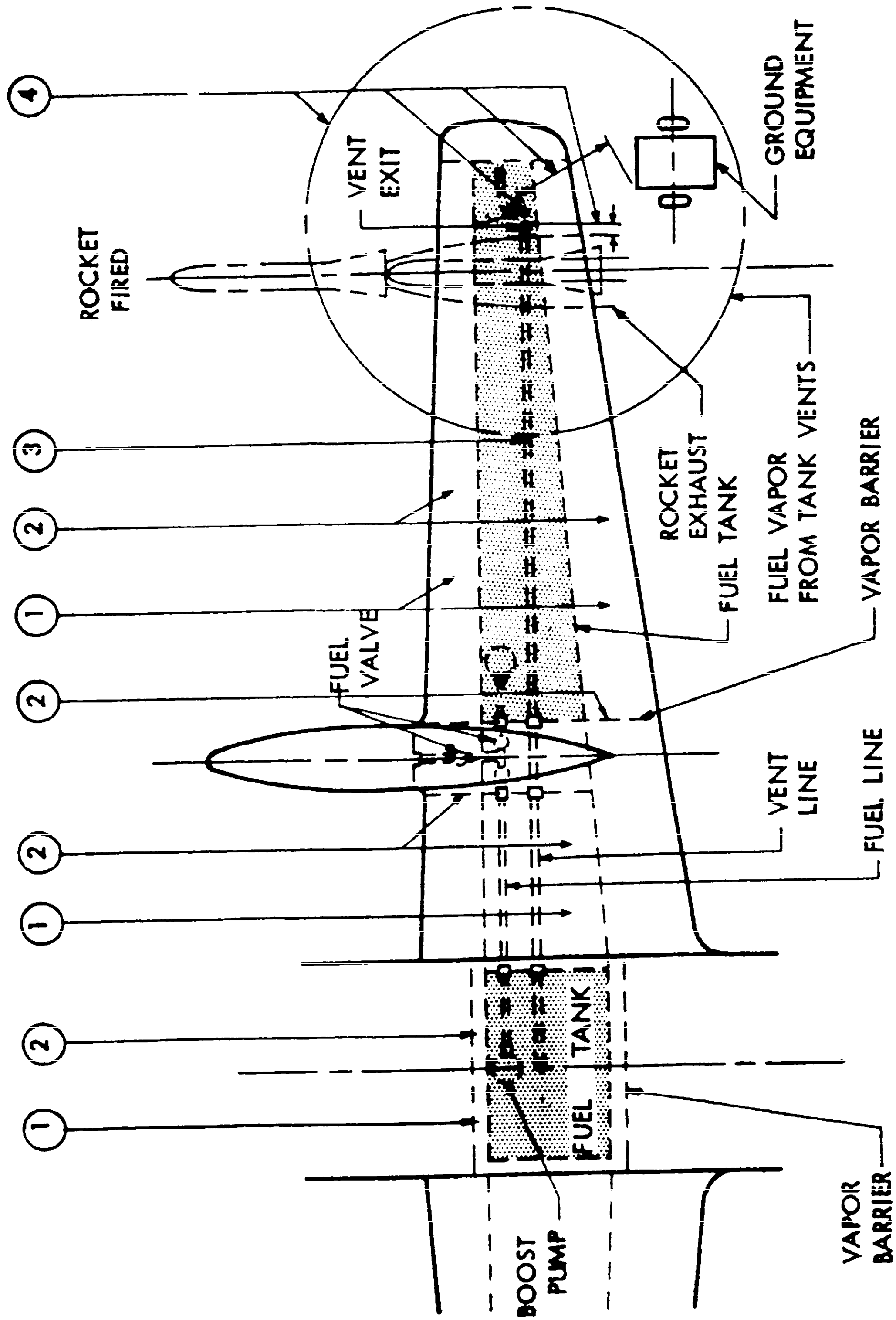


FIGURE 8 – 2.4 DRAINAGE, VENTILATION AND VENTS

		PARAGRAPH
(1)	VENT AND DRAIN DISCHARGE	2.4.4
(2)	DRAIN CONFIGURATION	2.4.5
(3)	DRAINAGE IN POTENTIAL FIRE ZONES	2.4.6
(4)	VENTILATION CONFIGURATION	2.4.8

2.4 DRAINAGE, VENTILATION AND VENTS

FIGURE 9

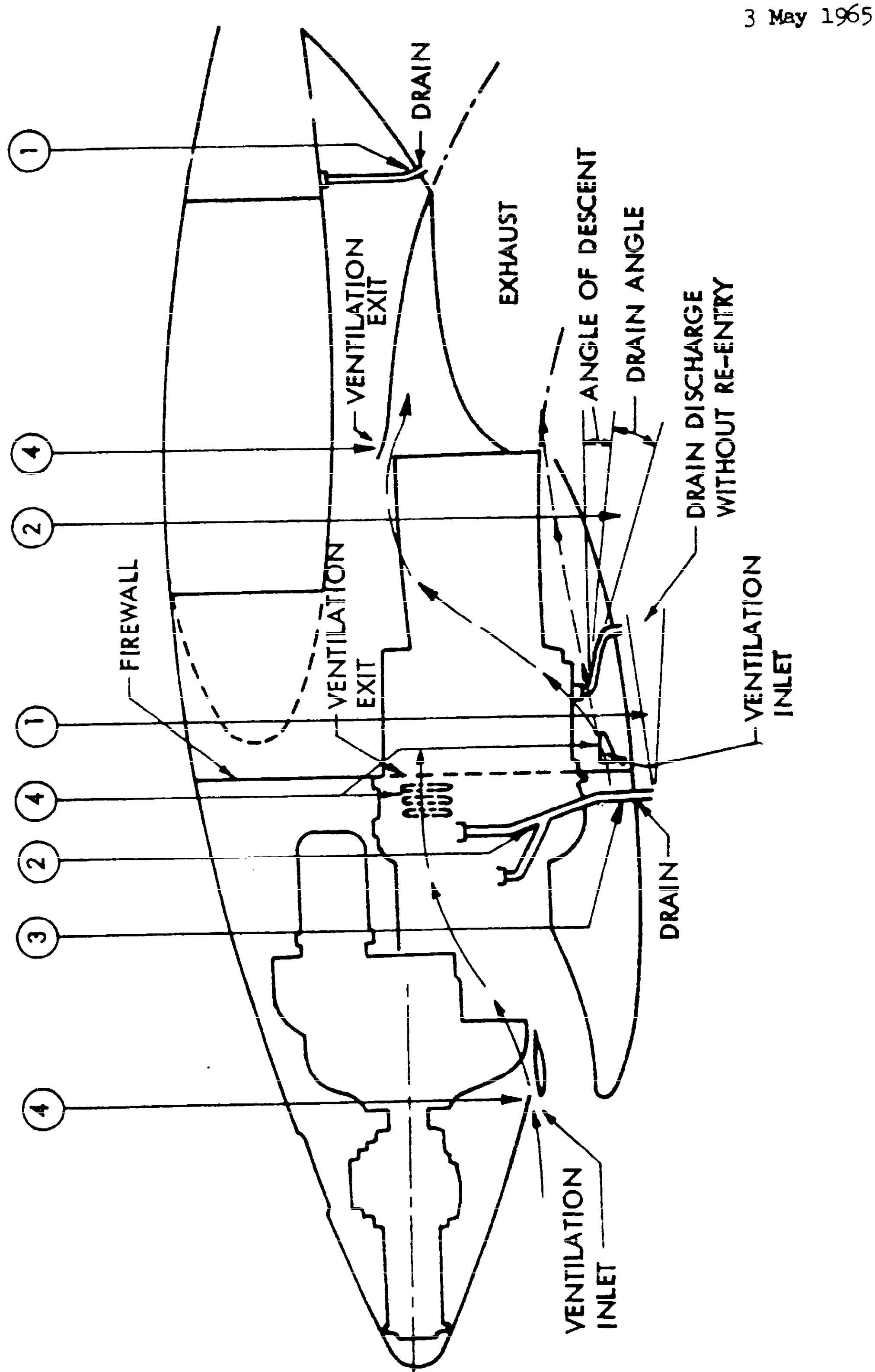


FIGURE 9 - 2.4 DRAINAGE, VENTILATION AND VENTS

		PARAGRAPH
1	DRAINED AREAS	2.4.1
2	VENTILATED AREAS	2.4.2
3	VENT AND DRAIN DISCHARGE	2.4.4
4	DRAIN CONFIGURATIONS	2.4.5
5	DRAINAGE IN CARRIER BASED AIRCRAFT	2.4.7
6	VENTILATION CONFIGURATION	2.4.8

2.4 DRAINAGE, VENTILATION AND VENTS

FIGURE 10

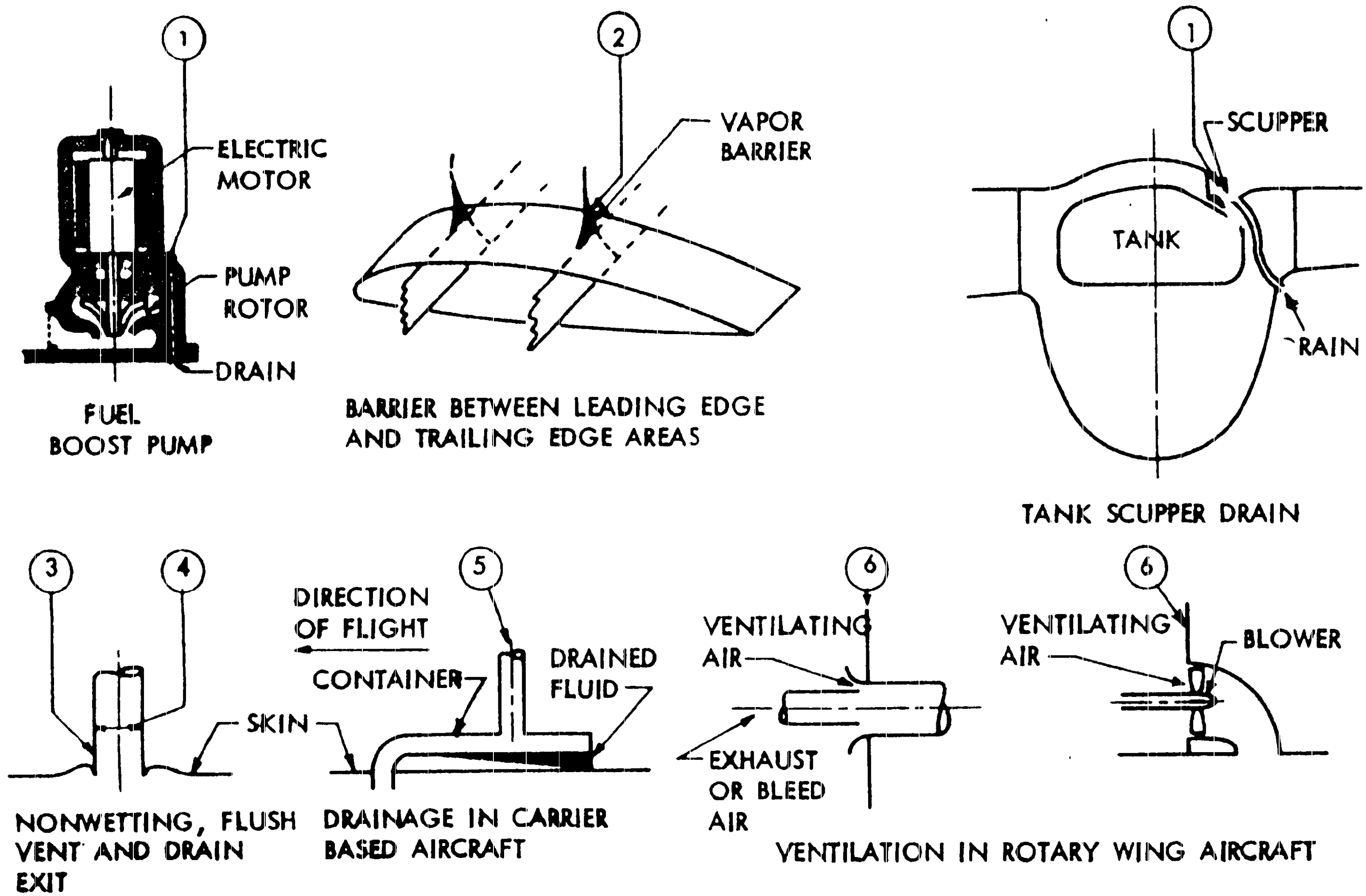


FIGURE 10 - 2.4 DRAINAGE, VENTILATION AND VENTS

2.5 FUELING AND DEFUELING (See figure 11 on page 45).

2.5.1 TANK FILLER UNITS

For the design of filler units for fuel tanks, both gravity and pressure fueling type, see 2.2.2.

2.5.2 ELECTRIC CURRENT

The electric system of the aircraft shall be so designed that supply power can selectively be provided to only those electric components which are needed during fueling and defueling.

2.5.3 DEFUELING CONNECTION

Where the defueling connection is not also a pressure fueling point and the tank can be damaged by pressure fueling at the defueling point, means shall be provided to prevent pressure fueling through this point.

2.5.4 PRESSURE FUELING

The pressure fueling system in the aircraft shall be designed so that a "single failure" in the system cannot cause failure of the level control in the tank to shut off the fueling flow. Provisions shall be incorporated in the fueling system which allow checking of all components of the fueling system for proper function prior to fueling. Vent lines for fuel tanks incorporating pressure fueling provisions should be sized to accommodate the maximum fueling rate which can occur when the level control fails, in addition to the venting flow rate, without imposing pressures on the tank which could cause fuel leakage. Fueling inlets to tanks shall be sized and designed to minimize fuel splashing.

		PARAGRAPH
1	TANK FILLER UNITS	2.2.2
2	ELECTRIC CURRENT	2.5.2
3	DEFUELING CONNECTIONS	2.5.3
4	PRESSURE FUELING	2.5.4

2.5 FUELING AND DEFUELING

FIGURE 11

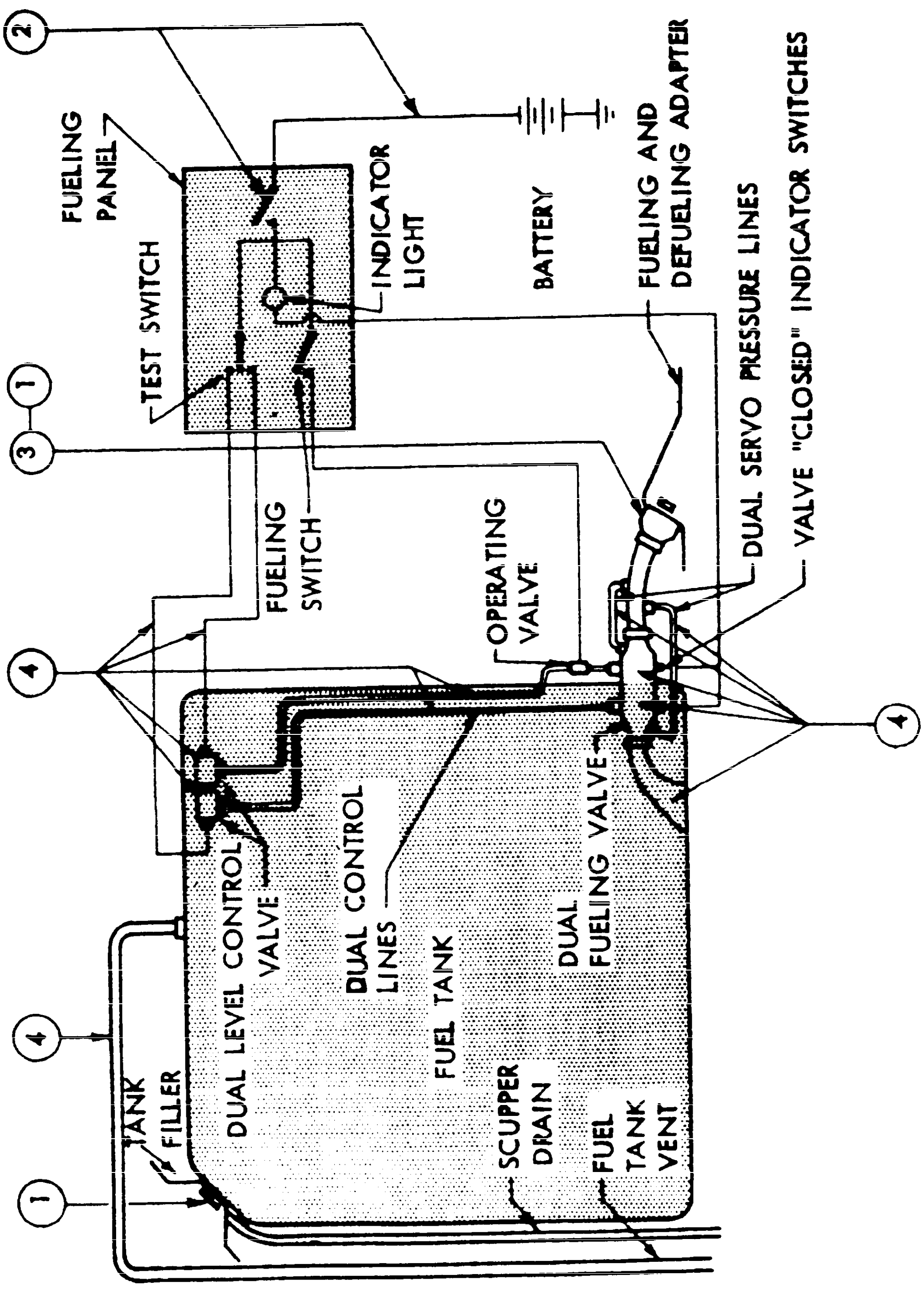


FIGURE 11 - 2.5 FUELING AND DEFUELING

2.6 FUEL JETTISONING (See figure 12 on page 49).

2.6.1 JETTISON DISCHARGE

Jettison discharge openings shall be designed and arranged in such a manner that there shall be no impingement on the aircraft under any normal condition of aircraft operation.

2.6.2 LEAKAGE

Jettison lines and controls shall be so designed that they are easily installed without the possibility of misrigging, easy to inspect and maintain. Ground inspections should be made frequently, to prove that controls are operating, and that lines are intact and will not leak in the event they are used in flight.

	PARAGRAPH
(1) JETTISON DISCHARGE	2.6.1
(2) LEAKAGE	2.6.2

2.6 FUEL JETTISONING

FIGURE 12

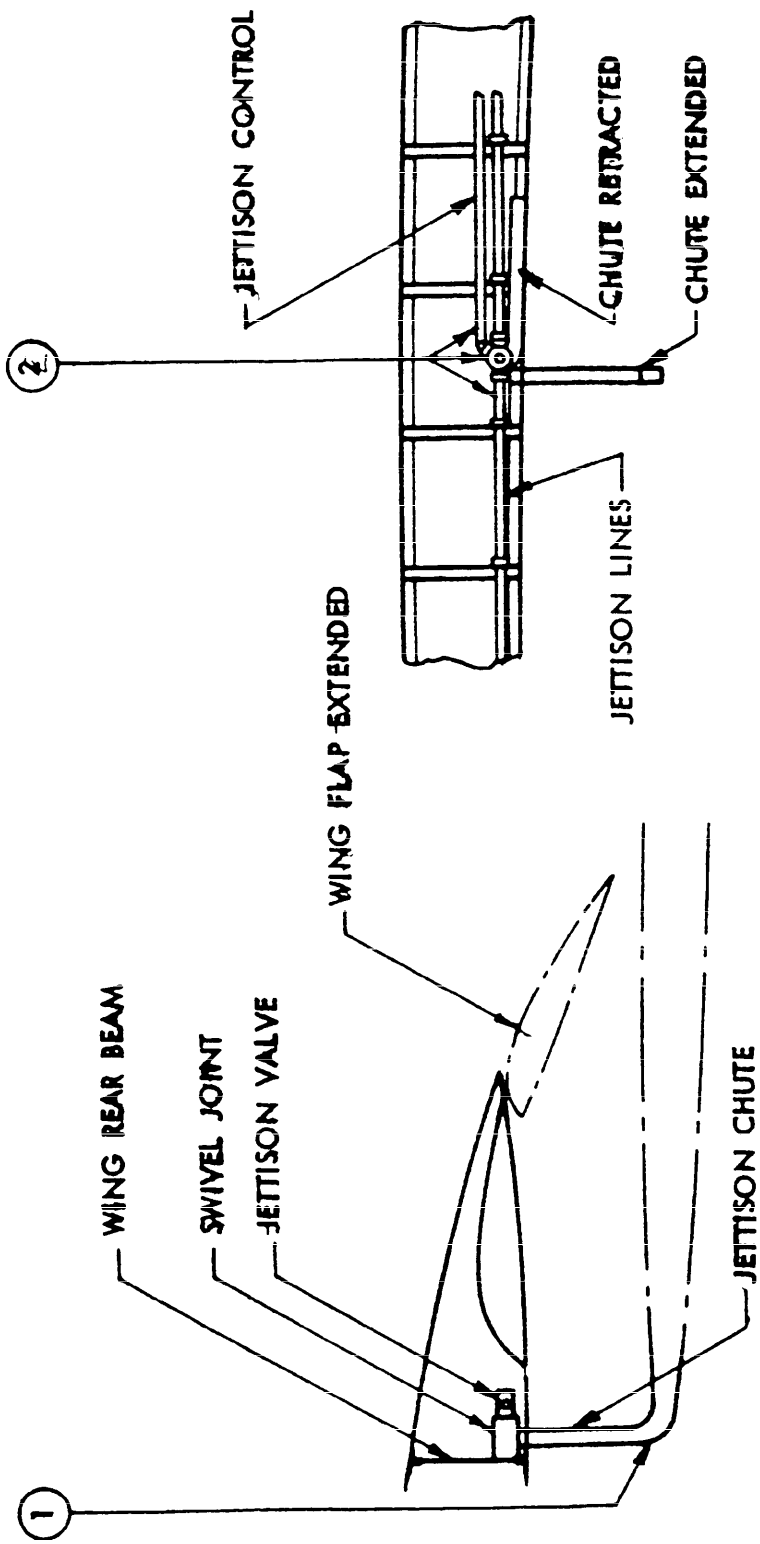


FIGURE 12 - 2.6 FUEL JETTISONING

2.7 ELECTRICAL SYSTEMS (See figures 13, 14 and 15 on pages 59, 61 and 63).

2.7.1 SPECIFICATION

Electric and electronic equipment shall comply with the fire protection requirements of MIL-E-7080 and 5040 and the wiring installation shall comply with the fire protection requirements of MIL-W-5088.

2.7.2 COMPONENT LOCATION

Electric components shall not be located in compartments where a single failure, such as leakage of flammable fluid, can cause ignition. If electric components must be located in compartments containing flammable fluid components, or in compartments adjacent to fuel tanks, or in compartments into which leakage of flammable vapor from other compartments is likely due to lack of adequate sealing, they shall be explosion-proof, and protected against hazardous overheat and short circuits as specified in 2.7.3.1, 2.7.3.2, 2.7.3.3, 2.7.3.4. Safety of flight components with potential hazardous overheating, or components for which thermal protection is not practical shall not be located in compartments with potential flammable leakage. In addition, electric components shall be located so that leaking flammable fluid will not come in contact with electric equipment and wiring by the effect of gravity, airflow, or battle damage. This shall be accomplished by locating electric components and wires above and away from flammable fluid components. High pressure hydraulic components, or the electric components shall be shielded, where necessary, to prevent hydraulic fluid from being squirted on electric components.

High power electric components can represent an ignition source not only to flammable fluids and vapors, but also to solid combustibles, such as plastics and wood, when resistance heating occurs due to a failure. Such components shall not contain combustible material, and shall be located away from any combustible material. When sufficiently remote location cannot be effected, adequate shielding, and insulation if necessary, shall be provided. The shielding and insulation shall be made of a material which will not ignite at the maximum component temperature which can be expected under the most severe failure condition. Laminated fiberglass containers shall be made using the best grade of fire-resistant materials and shall be treated with a fire retardant coating to limit out-gassing at the vaporization temperature of the binder.

If compliance with above requirements cannot be accomplished for justifiable reasons, the compartment shall be treated as a potential fire zone (see 2.11).

For location of electric components and wires for reasons of crash fire preventi.. see 2.15.

Fo. location of electric components and wires in potential fire zones see 2.7.4.

For location of electric components and wires relative to oxygen components see 2.7.6.

2.7.3 COMPONENTS IN FLAMMABLE FLUID ZONES

Electric components which are permanently or temporarily located in compartments containing flammable fluid components with potential leakage, or in compartments adjacent to fuel tanks, or in compartments into which leakage of flammable vapors from other compartments is likely due to lack of adequate sealing, shall comply with the following requirements:

2.7.3.1 EXPLOSION PROOFNESS

The electric components, including connectors, shall be explosion-proof as defined in MIL-E-5272, Procedure IV, unless equivalent precautions are taken which have approval of BuWeps. Procedure III of Specification MIL-E-5272 is acceptable only for such components which cannot develop internal spark producing failures, such as loose wires and contacts, or other loose objects.

2.7.3.2 OVERHEAT PROTECTION

Overheat protection shall be provided for electric components, if case temperatures can cause ignition of the fluids involved under any potential condition of failure. The thermal protection shall cut off the power to the equipment so that no point exposed to the fluids exceeds at any time a temperature which is 50°F below the minimum autogenous ignition temperature of the fluids. The thermal protection should not be resettable in flight. Where resettable protection must be used, the thermal protection shall be designed on the basis that it may be continuously reset as rapidly as is practicable after each time the power is cut off.

2.7.3.3 SHORT CIRCUIT

All bare conductors or other exposed current carrying parts shall be adequately protected against short circuits caused by loose objects. This protection can be obtained by locating them in such a manner that additional protection is not required, or by means of suitable coverings. Protection by location or covering is not sufficient for terminals, ground studs and similar components which can cause ignition by sparking or heating because of loose connections. Allowance shall be made for cumulative heating over extended periods and all affected materials shall be selected to prevent deterioration or electric breakdown under these conditions. These components shall comply with 2.7.3.1 and 2.7.3.2.

2.7.3.4 WIRES

The installation and routing of electric wires shall comply with the fire protection requirements of MIL-W-5088.

For connections in potential fire zones, see 2.7.4.

2,7.4 COMPONENTS IN FIRE ZONES

Electric components which are essential for safety of flight, or are required to perform emergency operations, should not be located in or close to a fire zone. If they must be located in or close to a fire zone for justifiable reasons, components essential for safety of flight shall be able to withstand a 2000° F flame of the type likely to be encountered in the area for at least 15 minutes. Components required to perform emergency operations shall be able to withstand such a flame of 2000° F for at least five minutes, without failure.

Firewall connections shall not allow flame penetration when exposed to such a flame of 2000° F for at least 15 minutes.

Shock mounts for electric components located in potential fire zones should be all-metal.

For materials used in potential fire zones, see 2.7.9.

Wire in fire zones which is essential for safety of flight or for emergency operations shall be in accordance with MS 24284.

2.7.5 COMPONENTS IN FUEL TANKS

See 2.1.1.4 for general requirements, 2.2.3 for pumps for flammable fluids, 2.2.4 for quantity gages, and 2.18 for static electricity.

2.7.6 OXYGEN EQUIPMENT

Electric components and wires should be located away from oxygen equipment. When such separation cannot be obtained for justifiable reasons, electric wires and wire bundles shall be provided with frequent supports, including protective conduits if necessary, or other suitable means of support to prevent a free end of a broken wire from touching any oxygen tube. Electric wires shall not be attached to oxygen components, unless required for electric operation or monitoring of the component.

2.7.7 CRASH FIRE PREVENTION (See 2.15)

2.7.8 ELECTRICAL COMPARTMENT PRESSURE

The pressure in electrical and electronic compartments should, when practicable, be above that of an adjacent compartment which contains volatile flammable fluid components with potential leakage, to compensate for the lack of complete sealing which may be expected after reasonable maintenance and service. Tests should be made to substantiate that flammable zones run at lower pressures than any adjacent ignition zone.

2.7.9 NONMETALLIC MATERIAL

Nonmetallic material used in electric components shall not ignite spontaneously under all environmental temperatures of installation, and shall be self-extinguishing after removal of a flame. When used in fire zones with fire extinguishing capabilities, it shall not afterglow. Nonmetallic material used in or close to electric components which can attain excessive temperatures due to resistance heating caused by a failure, shall not ignite at the maximum temperature of a failed component. Flammable fluid shall not be used in electric equipment such as ballasts in neon lights, etc.

2.7.10 EXTERNAL POWER RECEPTACLES

External power receptacles shall be located as remote as possible from points of potential flammable fluid or vapor release, such as vent and drain exits. They shall be located in areas of the aircraft where flammable vapors from leakage within the aircraft cannot accumulate, or they shall be enclosed in a vapor tight compartment.

2.7.11 MAIN STORAGE ELECTRIC BATTERIES

Batteries shall comply with the requirements of the applicable military specifications, or should be approved by BuWeps.

Hermetically sealed batteries shall not be used without specific BuWeps approval. Where used, they shall be provided with frangible safety blow-out plugs or the equivalent.

Batteries should have gasketed covers held down by reliable fasteners, in conjunction with the use of sealed type electric connections. Lead-acid batteries shall be vented overboard to a place where ignition or re-entry cannot occur. Nickel-cadmium batteries shall be provided with pressure-relief vents to limit internal pressure build-up. Battery vent lines and fittings shall be resistant to the electrolytes and their products of decomposition.

Safe cell temperatures and charging rates shall be maintained when the battery is recharged (after previous complete discharge) at maximum regulated voltage, during a flight of maximum duration, under the most adverse cooling condition likely to occur in service.

2.7.12 STATIC ELECTRICITY (See 2.18)

2.7.13 ELECTROEXPLOSIVE SYSTEMS

Since safe design of electroexplosive systems such as ejectors, igniters, destructors, flares, etc., is dependent upon proper design of the initiator system, the following design recommendations are directed toward initiator systems.

2.7.13.1 SPECIFICATIONS

Electric initiators shall be designed in accordance with the fire protection requirements of MIL-I-23659.

2.7.13.2 INITIATOR SYSTEMS

An initiator system consists basically of a fusible link (bridge wire), the external power supply and the triggering device which initiates the firing current. The fusible link generally ignites a small primer charge which in turn explodes an actuating powder charge. Sensitive, low electrical energy initiators should be avoided, whenever possible.

2.7.13.3 SHUNT FUSES

An electric shunt fuse connected across the bridge wire circuit should be included within the initiator circuit. This fuse should have not more than one fifth of the resistance of the parallel bridge wire path and its blow-out rating should be equal to the minimum all-fire current of the bridge. A resistor may also be installed in series with the complete initiator to provide current limiting during firing and prevent opening the initiator wiring circuit breaker.

2.7.13.4 BRIDGE WIRE CIRCUIT

The bridge wire circuit should be a two-wire, ungrounded system. Where a ground is necessary, the ground shall be made at a single point only.

The external firing circuit wires to the initiator bridge wire should be a twisted-pair cable, encased in a flexible metallic shield. This shield should be covered with an insulating sleeving, but should be electrically bonded to the disconnect plug shell at the initiator with a wire as short as possible. The twisted-pair firing cable to one initiator should not be placed within the shielding braid of another initiator firing cable. Where an isolating relay is used in the firing circuit, it should be located as close to the initiator as is practicable, and it should open both initiator leads.

2.7.13.5 INITIATOR SHIELDING AND GROUNDING

The initiator shall be encased in a complete metallic shield container, with a metallic electric receptacle for external connections. The initiator case shall be thoroughly electrically grounded to basic metallic structure by means of the mounting installation.

2.7.13.6 RADIO FREQUENCY FILTER

In addition to metallic shielding of the bridge wire and its twisted-pair shielded wiring, a radio frequency filter should be included within the initiator circuit.. The longer the twisted-pair shielded wiring, the more important the radio frequency filter becomes. The filter may be the conventional inductor-capacitor network or a "solid state attenuator" incorporated in the bridge wire leads.

2.7.13.7 LOCATION OF INITIATORS AND WIRING

The wiring and the initiator should be routed separately from aircraft wiring, especially radio frequency coaxial cables and heavy A.C. power cables. The initiator and its wiring should be located, insofar as practicable, within and close to the metallic skin or structure of the vehicle for shielding purposes. The initiator should not be located adjacent to transmitting antennas in the aircraft.

2.7.13.8 ACCESSIBILITY

All initiators should be easily accessible and replaceable.

2.7.13.9 EXPLODING BRIDGE WIRE INITIATOR SYSTEMS

Exploding bridge wire electric initiators employ bridge wires of much larger diameter adjacent to but not necessarily touching the normal charge of explosive. Since there is no heat sensitive explosive in contact with the bridge wire, any heating that may result from the passage of currents caused by stray voltages, electromagnetic radiation, or other accidental causes will have no effect on this type of initiator. Because of the inherently safer construction of the exploding bridge wire systems, only the recommendations of 2.7.13.6 need be applied.

		PARAGRAPH
(1)	COMPONENT LOCATION	2.7.2
(2)	EXPLOSION PROOFNESS	2.7.3.1
(3)	OVERHEAT PROTECTION	2.7.3.2
(4)	SHORT CIRCUITS	2.7.3.3
(5)	WIRES	2.7.3.4
(6)	COMPONENTS IN FIRE ZONES	2.7.4
(7)	COMPONENTS IN FUEL TANKS	2.7.5
(8)	STATIC ELECTRICITY	2.18

2.7 ELECTRICAL SYSTEMS

FIGURE 13

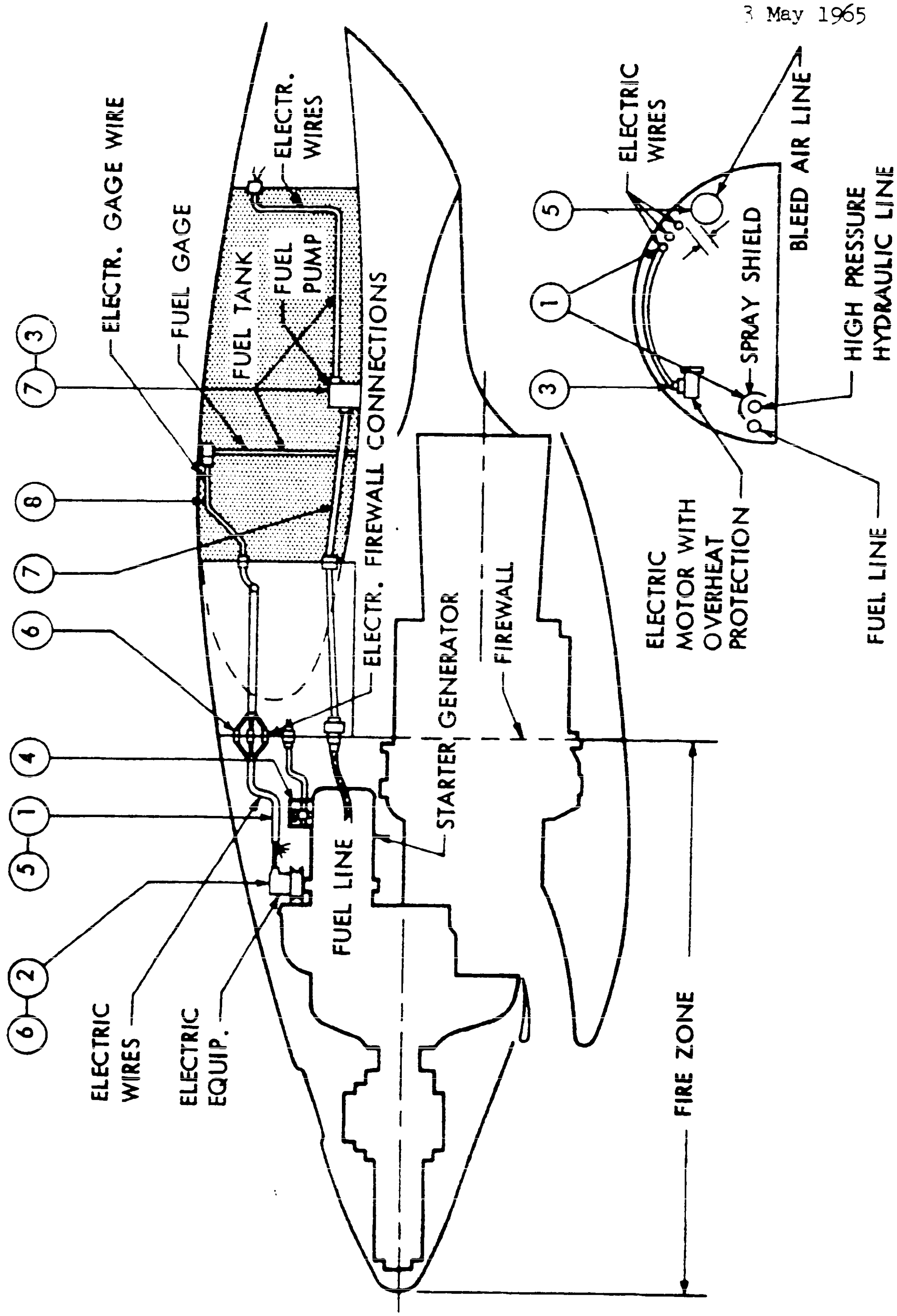


FIGURE 13 - 2.7 ELECTRICAL SYSTEMS

		PARAGRAPH
(1)	COMPONENT LOCATION	2.7.2
(2)	SHORT CIRCUIT	2.7.3.3
(3)	WIRES	2.7.3.4
(4)	COMPONENTS IN FIRE ZONES	2.7.4
(5)	OXYGEN EQUIPMENT	2.7.6
(6)	CRASH FIRE PREVENTION	2.15
(7)	ELECTRICAL COMPARTMENT PRESSURE	2.7.8
(8)	NON METALLIC MATERIAL	2.7.9
(9)	EXTERNAL POWER RECEPTACLES	2.7.10
(10)	MAIN STORAGE ELECTRIC BATTERIES	2.7.11

2.7 ELECTRICAL SYSTEMS

FIGURE 14

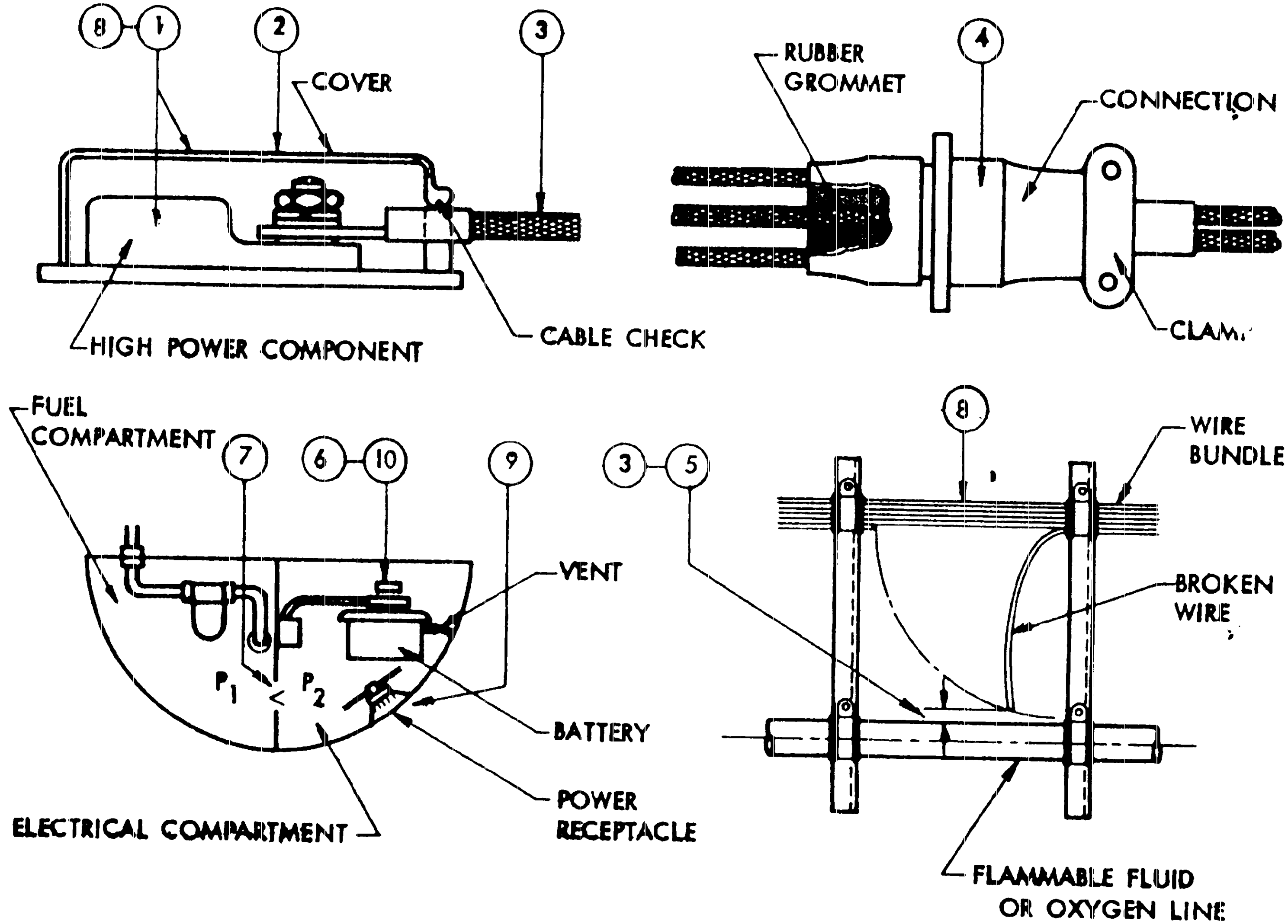


FIGURE 14 - 2.7 ELECTRICAL SYSTEMS

		PARAGRAPH
(1)	SHUNT FUSES	2.7.13.3
(2)	BRIDGE WIRE CIRCUIT	2.7.13.4
(3)	INITIATOR SHIELDING AND GROUNDING	2.7.13.6
(4)	RADIO FREQUENCY FILTER	2.7.13.6
(5)	LOCATION OF INITIATORS AND WIRING	2.7.13.7
(6)	ACCESSIBILITY	2.7.13.8

2.7 ELECTRICAL SYSTEMS

FIGURE 15

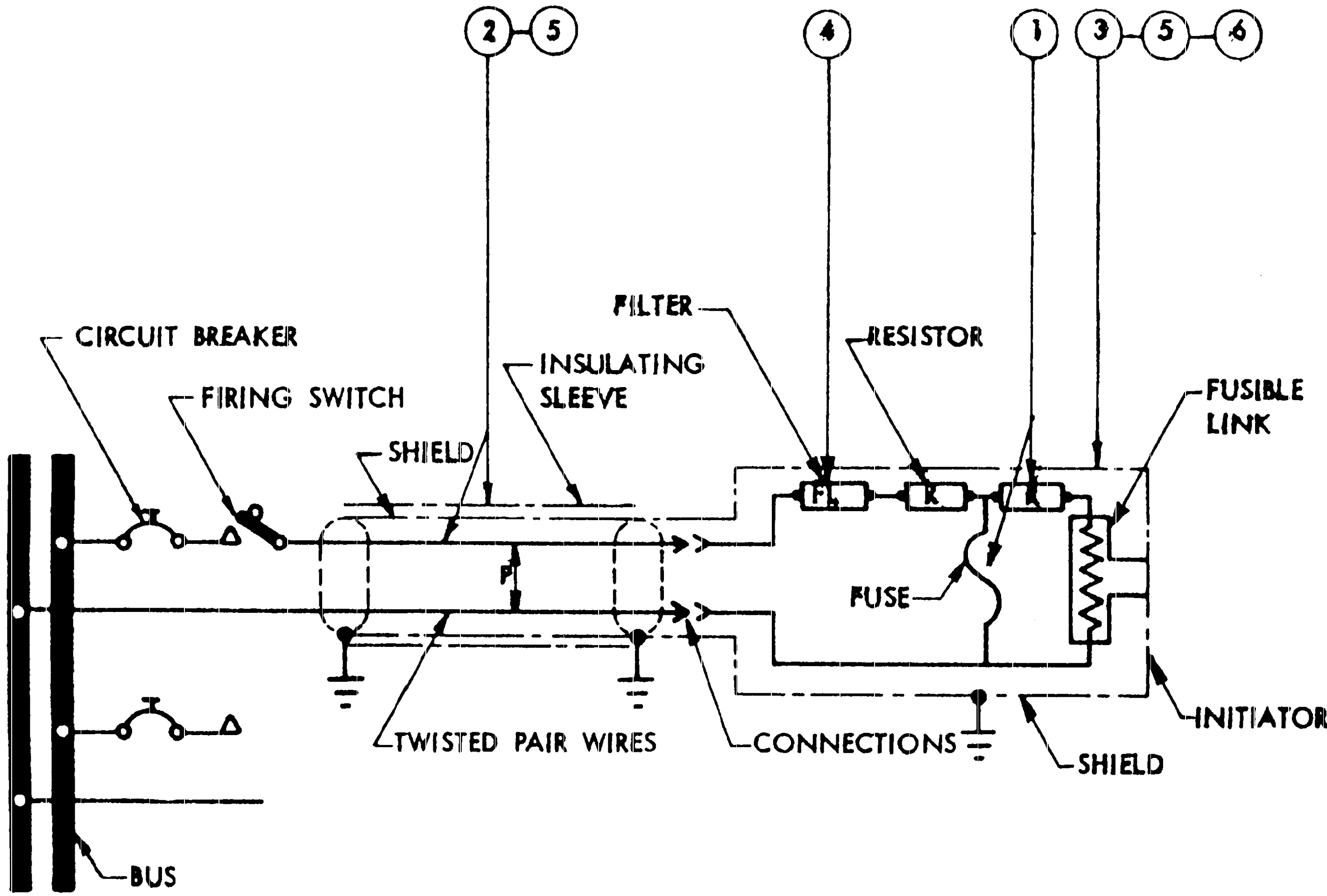


FIGURE 15 - 2.7 ELECTRICAL SYSTEMS

2.8 BLEED AIR SYSTEMS (See Figures 16 and 17 on pages 69 and 71).

2.8.1 LOCATION

Hot bleed air and other hot gas ducts and their components shall not be located in compartments containing flammable fluid components with potential leakage, or in compartments adjacent to fuel tanks, or in compartments into which leakage of flammable vapor from other compartments is likely, if the following conditions apply:

Condition 1: The maximum surface temperature of the bleed air ducts and components, under any normal or emergency condition, is equal to or higher than the minimum autogenous ignition temperature (MAIT) minus 50°F of the flammable fluids in question.

Condition 2: The maximum bleed air temperature under any normal or emergency condition is equal or higher than the minimum hot gas ignition temperature (MHGIT) minus 50°F of the flammable fluids in question.

If, for justifiable reasons, bleed air ducts and components must be located in such compartments, the installation of the ducts shall comply with the following requirements, for above Conditions 1 and 2:

Condition 1: The ducts shall be located as high within a compartment as practical, and away from potential flammable fluid leakage. The compartment shall be drained, and ventilated in conformance with 2.4. In addition the bleed air ducts and components shall be insulated in conformance with 2.8.2.

Condition 2: Bleed air ducts and components shall be isolated by fluid and vaportight, preferably permanent, barriers.

2.8.2 INSULATION

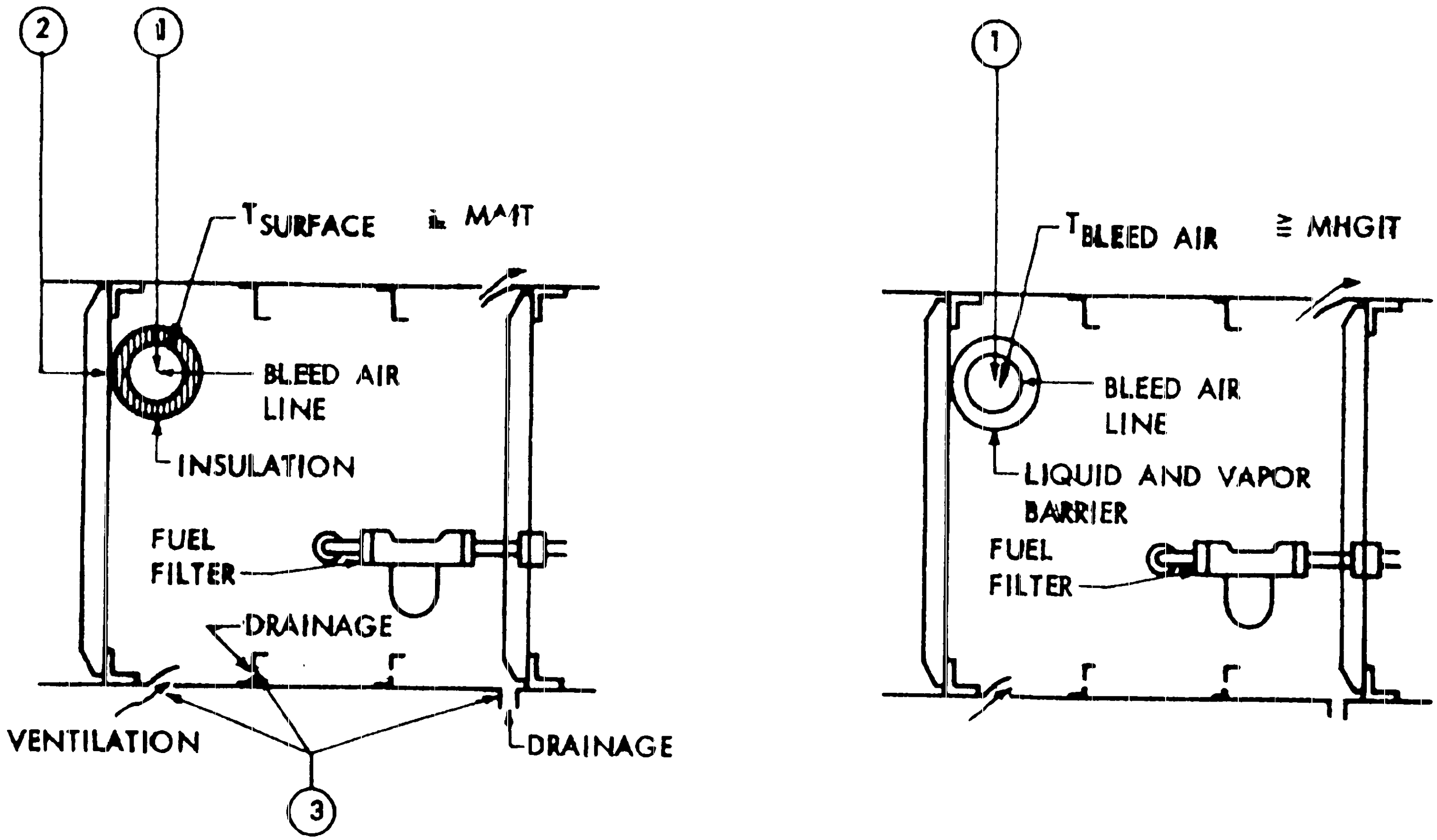
The insulation of hot bleed air and other hot gas ducts shall be nonabsorbent as a material configuration, and so designed and installed that fluids will not be retained on or under it. The insulation shall be designed so that all surfaces, edges, cutouts and seams are effectively sealed to prevent the entrance of flammable fluids. Sandwich-type insulation blankets shall be vented, and drained at their lowest point. The vent and drain holes shall be shielded if required, to prevent entrance of fluid. The insulation material shall be "nonpacking" under service conditions. Insulation shall be attached to ducts and components so that a "single failure" cannot cause ignition.

2.8.3 BLEED AIR DUCTS IN FIRE ZONES (See 2.11)

2.8.4 ANTI-STALL BLEED AIR

Air bled from the engine to prevent compressor stall shall be discharged directly overboard, and shall not discharge inside any airplane compartment. Discharge into turbine and tailpipe compartments is permitted, except if water-alcohol is added to the compressor air for thrust augmentation upstream of the bleed air takeoff. The ducts for anti-stall bleed air discharge shall be made of steel, or equivalent material, within fire zones.

		PARAGRAPH
(1)	LOCATION	2.8.1
(2)	INSULATION	2.8.2
(3)	DRAINAGE, VENTILATION AND VENTS	2.4



MAIT - MINIMUM AUTOGENOUS IGNITION TEMPERATURE

MHGIT - MINIMUM HOT GAS IGNITION TEMPERATURE

FIGURE 16 - 2.8 BLEED AIR SYSTEMS

		PARAGRAPH
(1)	BLEED AIR DUCTS IN FIRE ZONES	2.11
(2)	ANTI-STALL BLEED AIR	2.8.4

2.8 BLEED AIR SYSTEMS

FIGURE 17

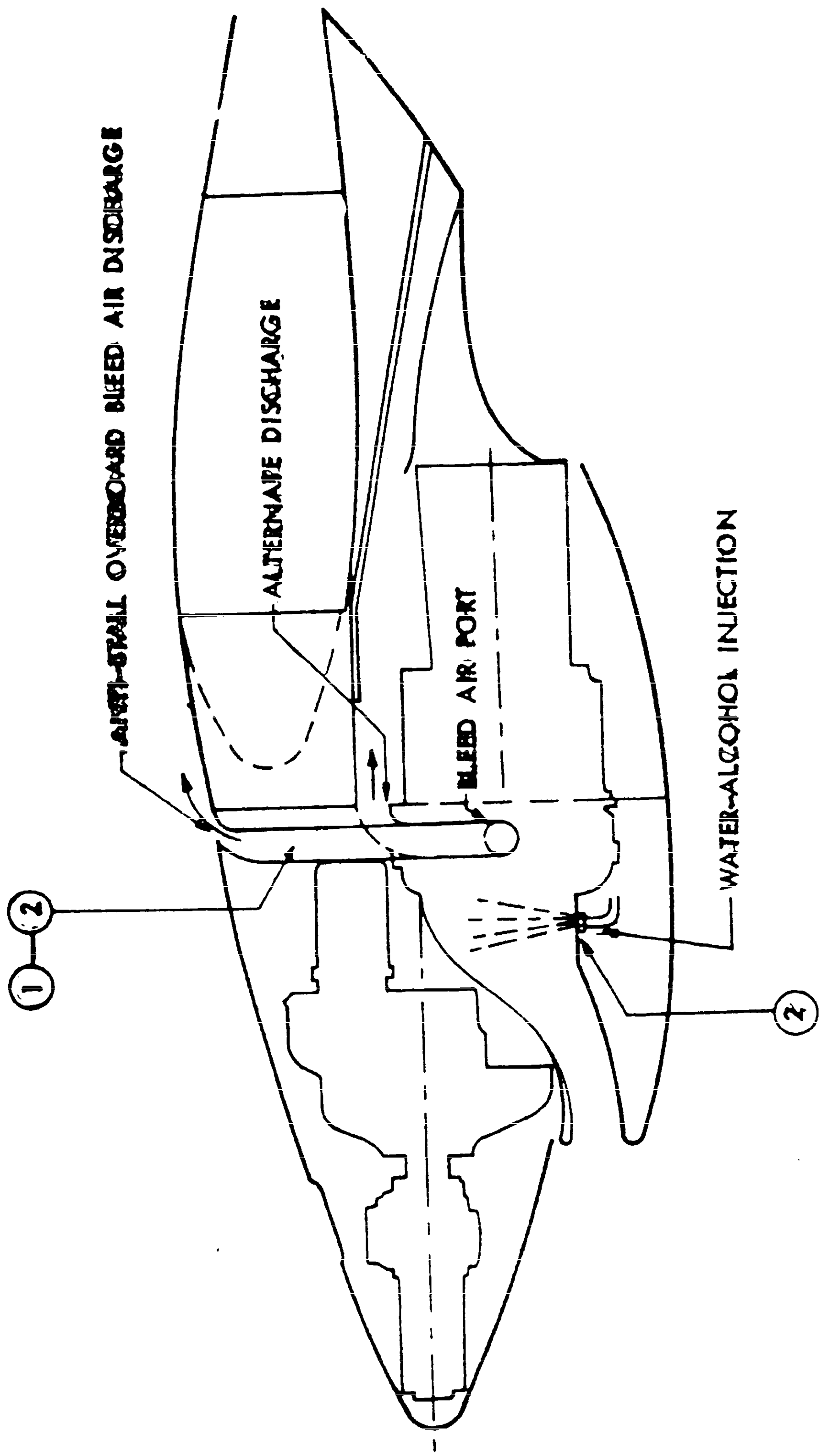


FIGURE 17 - 2.8 BLEED AIR SYSTEMS

2.9 OXYGEN SYSTEMS (See Figure 18 on page 77).

2.9.1 SPECIFICATIONS

Gaseous oxygen systems shall comply with the fire protection requirements of MIL-I-8683. Liquid oxygen systems shall comply with the fire protection requirements of MIL-I-19326.

2.9.2 LOCATION

2.9.2.1 COMPONENT TEMPERATURES

Oxygen components shall not be located in or close to potential fire zones, or in other areas where they could be subjected to temperatures in excess of those specified in the individual component specification, under normal operating conditions, or in case of a fire, hot duct rupture, etc. If such location is not possible, permanently installed shielding and insulation, if necessary, shall be provided to keep the component temperatures within specification values.

2.9.2.2 PORTABLE OXYGEN CONTAINERS

Portable oxygen containers shall be stored in areas where the likelihood of a fire is remote, or they shall be stored in enclosures which can withstand a fire likely to occur at their location, and they shall be insulated so that such fire will not cause discharge of oxygen from the container into the fire.

2.9.2.3 SYSTEM LAYOUT

The layout of the oxygen system and the location of the components should be such that all lines are as short as practical, and that high pressure lines are held to a minimum length. Oxygen containers, however, should not be located immediately adjacent to the crew, and in combat aircraft they should be located, whenever practical, so that they are protected against gunfire.

2.9.2.4 FLAMMABLE FLUID COMPONENTS

Insofar as practicable, oxygen lines and components shall not be grouped with lines and components carrying flammable fluids, and shall not be located above each other. When necessary to keep potential flammable fluid leakage away from oxygen lines and components, shrouding shall be used.

2.9.2.5 COMPONENT CLEARANCE

A clearance of at least two inches shall be provided between oxygen tubing and components, and control cables and other flexible moving parts. A clearance of at least 1/2 inch shall be provided between oxygen tubing and components, and other parts of the aircraft under any condition of operation and accumulation of manufacturing tolerances, unless the oxygen lines and components are rigidly attached to these parts.

For routing of electric wires near oxygen systems see 2.7.6.

2.9.2.6 PROPELLERS AND TURBINE ROTORS

Oxygen containers shall not be located within six inches of the plane of rotation of aircraft propellers or turbine rotors.

2.9.3 LINES AND FITTINGS

Aluminum or stainless steel tubing should be used in oxygen systems, and the connectors shall be of a type approved by BuWeps for use in oxygen systems.

2.9.4 CONTAINER SUPPORT

The oxygen container supports should be designed to withstand the same inertia loads as the seats of the occupants. The container supports in combat aircraft shall be designed to prevent the container from tearing loose when hit by gunfire.

2.9.5 FILLING PROVISIONS

The filler connections shall not be located where there is any possibility of oil coming in contact with the filler valve. The filler connection shall be installed within a closed box behind a cover plate with a dirt and oiltight seal.

Contaminants such as dirt, lint, metal chips, etc., should be prevented from entering filler connections of the oxygen system by means of fine mesh or sintered filters installed in the system.

2.9.6 CLEANLINESS

The entire oxygen system shall be completely free from oil, grease and other foreign matter. Open ends of cleaned and dried tubing and components shall be plugged at all times. There shall be no unplugged opening in the installation at any time, except during attachment or detachment of parts.

		PARAGRAPH
(1)	COMPONENT TEMPERATURES	2.9.2.1
(2)	PORTABLE OXYGEN CONTAINERS	2.9.2.2
(3)	SYSTEM LAYOUT	2.9.2.3
(4)	FLAMMABLE FLUID COMPONENTS	2.9.2.4
(5)	COMPONENT CLEARANCE	2.9.2.5
(6)	PROPELLERS AND TURBINE ROTORS	2.9.2.6
(7)	LINES AND FITTINGS	2.9.3
(8)	CONTAINER SUPPORT	2.9.4
(9)	FILLING PROVISIONS	2.9.5

2.9 OXYGEN SYSTEMS

FIGURE 18

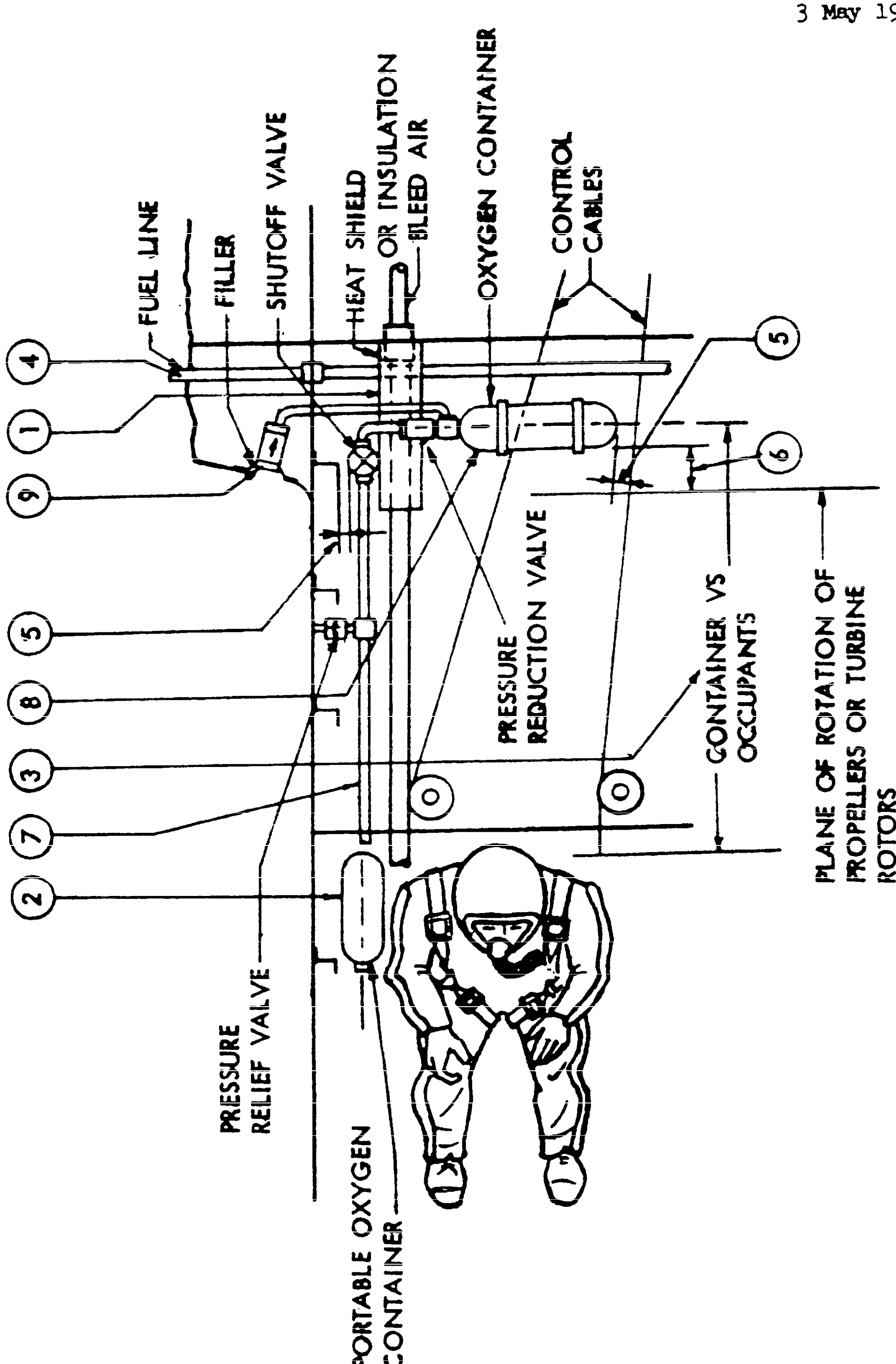


FIGURE 18 - 2.9 OXYGEN SYSTEMS

2.10 HAZARDOUS SYSTEMS (See Figures 19, 20, 21, 22 and 23 on pages 87, 89, 91, 93 and 95).

2.10.1 GENERAL

The systems treated or referenced in this section are potential fire and explosion hazards if not properly designed, located or installed.

2.10.2 HIGH SPEED ROTATING EQUIPMENT

2.10.2.1 LOCATION

High speed rotating equipment such as starters, auxiliary power units, drive shafts, etc., shall be located, whenever possible, to prevent damage of flammable fluid components, explosives, oxygen containers, and in particular fuel tanks by flying fragments in case of disintegration of a rotating part.

2.10.2.2 OVERSPEED PROTECTION

If location recommended in 2.10.2.1 is not possible for justifiable reasons, high speed rotating equipment, except main propulsion engines, shall be designed to incorporate either one of the following features:

2.10.2.2.1 CONTAINMENT

Capability of containing all rotor fragments within the equipment under the conditions of the most adverse "single failure" which causes maximum overspeed at maximum operating temperature.

2.10.2.2.2 ROTOR STRENGTH

Strength of all rotor parts to withstand a speed which produces 1.50 times the kinetic energy of a maximum overspeed which can be caused by the most adverse "single failure," and at maximum operating temperature.

2.10.2.2.3 AERODYNAMIC SPEED LIMITATION

Aerodynamic speed limitation such that failure of the rotor cannot occur at a speed producing 1.5 times the kinetic energy of the limit speed and at maximum operating temperature. If the equipment requires controlled ingestion of air for aerodynamic speed limitation, the equipment model specification shall give all the requirements necessary for satisfactory duct design.

2.10.2.2.4 FRICTION BRAKING

Speed limitation by friction braking between rotor and case such that failure of the rotor cannot occur at a speed producing 1.50 times the kinetic energy of the maximum limit speed, and at any operating temperature.

2.10.2.2.5 SPEED LIMITING DEVICE

In order to limit the maximum overspeed in 2.10.2.2.1 and 2.10.2.2.2, two reliable and independent speed limiting devices should be considered. One of these devices may be the normal speed control and the other one should be a topping device with the sole purpose of preventing the equipment from exceeding a predetermined maximum speed. The topping device should incorporate a "self-exercising," or a testable feature to prevent sticking from inactivity. The speed limiting device should be located as close as practicable to the component which is to be protected against overspeed by the device. Any electrical portion of the topping device shall be located or protected so that it will not be rendered inoperative by the lubricating oil of the equipment, under normal operating condition or in case of a "single failure."

2.10.2.3 OTHER HAZARDS

High speed rotating equipment shall be carefully analyzed for other potential fire hazards such as ignition of flammable fluids by high case temperature due to normal operation or due to failure, such as oil starvation and bearing failure. Satisfactory protection shall be provided if such hazards exist. High speed rotating equipment shall be supported in such a manner that imbalance due to potential failures will not cause failure of the support with consequent fire potentiality.

High speed drive shafts should be encased, if necessary to protect flammable fluid components, fuel tanks, explosives, oxygen containers, etc.

2.10.2.4 POWER TURBINES

Compartments containing fuel burning power turbines shall comply with 2.11.

2.10.3 HIGH PRESSURE AIR SYSTEMS

2.10.3.1 SPECIFICATIONS

High pressure air systems shall comply with the fire protection requirements of MIL-P-5518.

2.10.3.2 GENERAL

High pressure air compressors and related components utilizing lubricating oil as piston lubricant which ultimately is mixed with the compressor air can experience explosions with destructive results to the equipment and to adjacent components, if not properly designed.

2.10.3.3 LOCATION

High pressure air compressors and related equipment shall be located, whenever possible, to minimize damage of flammable fluid components, explosives, oxygen containers, and in particular fuel tanks, by flying fragments in case of an explosion.

2.10.3.4 EXPLOSION HAZARDS

High pressure air compressors and related equipment shall comply with MIL-P-5518. An explosion hazard report shall be submitted to BuWeps as required by MIL-P-5518. Particular attention shall be given in this report to potential hazardous conditions caused by equipment malfunctions. The oil-air mixture in a compressor, which is precharged with compressed bleed air, may move from "too lean" to "explosive" when the mass airflow is reduced due to a severed compressor air intake line. The same result can be experienced when the lubricating oil flow to the cylinders of the compressor is increased due to a malfunction of the lubricating system. Breakdown of the cooling system due to a fan failure may also cause explosion when the air temperature exceeds the autogenous ignition temperature of the lubricating oil.

2.10.3.5 SUPPORT

Compressors and reservoirs for compressed air shall be supported so that compressor unbalance caused by malfunction, or reservoir damage caused by gunfire, will not result in failure of a support with resultant fire potentiality.

2.10.4 EXPLOSIVES

2.10.4.1 SPECIFICATIONS

Explosives shall comply with the fire protection requirements of the following specifications:

INITIATORS, ELECTRIC, DESIGN AND EVALUATION OF	MIL-I-23659
DESIGN AND EVALUATION OF CARTRIDGES FOR CARTRIDGE ACTUATED DEVICES	MIL-D-21625
INSTALLATION AND TEST OF AIRCRAFT PYROTECHNIC EQUIPMENT, GENERAL SPEC. FOR	MIL-I-8672

2.10.4.2 LOCATION

Explosives shall not be installed or stowed in the proximity of heat sources if these heat sources can cause ignition of the explosives under any normal condition, or if a "single failure" can cause ignition of the explosives. Explosives shall not be installed or stowed in the proximity of potential fire zones. If explosives must be located close to real or potential heat sources for justifiable reasons, they shall be adequately protected by permanently installed insulation, or shields, or both.

2.10.4.3 INSTALLATION

Explosives can be a hazard to manufacturing and maintenance personnel. Designs should permit installation of explosives as late as possible in manufacturing sequence, preferably at the flight line. Explosives shall be interchangeable without force or rework.

2.10.5 ENGINE STARTERS

2.10.5.1 SPECIFICATIONS

Air turbine starters shall comply with the fire protection requirements of MIL-S-7848.

2.10.5.2 OVERSPEED PROTECTION

Failure of a starter coupling to disengage after engine lightoff can cause overspeed of the starter. Starter disintegration due to this type of failure and due to failure in the speed control mechanism shall be prevented by overspeed protection per 2.10.2.2.

2.10.5.3 OTHER HAZARDS (See 2.10.2.)

2.10.5.4 CARTRIDGE STARTERS

In addition to the requirements of 2.10.5.2 and 2.10.5.3, a cartridge starter shall comply with the following requirements:

2.10.5.4.1 INADVERTENT IGNITION

A cartridge starter shall be suitably protected against inadvertent ignition of the cartridge. It shall be possible to arm the starter only after securing the breech. It shall be possible to disarm the starter at any time prior to actuation.

2.10.5.4.2 GAS LEAKAGE

There shall be no leakage of gases into the starter compartment or into any other compartment from any part of the starter during or following operation throughout the operating range.

2.10.5.4.3 OVERPRESSURE PROTECTION

An overpressure relief device shall be incorporated in the starter which will limit the maximum breech pressure in the event of abnormal cartridge burning. The device shall bypass the turbine. The relief pressure shall not exceed the breech proof pressure.

2.10.5.4.4 CARTRIDGE STORAGE (See 2.10.4.2)

2.10.5.4.5 EXHAUST

Exhaust from the turbine and from the overpressure relief device shall be disposed of in conformance with 2.11.1.13.

2.10.5.4.6 CARTRIDGES

Cartridges shall comply with the fire protection requirements of MIL-D-21625.

2.10.6 GUN INSTALLATIONS

2.10.6.1 GENERAL

Gun gases leaving the muzzle and leaking from the breech contain considerable quantities of unburned combustibles. Appropriate measures shall be taken so that the gas-air mixture within the gun compartment does not fall within the explosive range.

2.10.6.2 GUN GAS DATA

The maximum gun gas release rate into the gun compartment and the maximum content of combustibles by volume in the gas shall be determined and specified by the gun manufacturer. The lower explosive limit of gun gas is approximately nine percent by volume.

2.10.6.3 VENTILATION

If ventilation is used for diluting the gas-air mixture in the gun compartment, air intake shall be located away from the gun muzzle to prevent gases from the muzzle from entering the ventilating air. Gun icing by ventilating air shall be prevented. This can be accomplished with a ventilating system operating only while the gun fires. The ventilation airflow rate should be high enough to result in an average concentration of combustibles of 4.5 percent with good mixing, and 2.25 percent with less thorough mixing.

2.10.6.4 FUEL TANKS

Fuel tanks shall not be located immediately adjacent to gun compartments; they shall be separated from such compartments by at least one liquid and vaportight bulkhead in addition to the tank boundary structure.

2.10.7 LANDING WHEEL BRAKES

Wheels which serve as housings for highly loaded brakes shall be provided with pressure relief devices actuated by heat. Consideration shall also be given to the use of a heat shield between the brake and the wheel. The purpose of these devices is to prevent tire explosion caused by brake overheating or by brake fire.

In addition, serious consideration shall be given to a brake overheat warning system. Use of a brake warning system shall be based on the type of vehicle, its intended usage, the characteristic of the brake, and the probability and the consequences of the hazards.

2.10.8 EXTERNAL ROCKETS

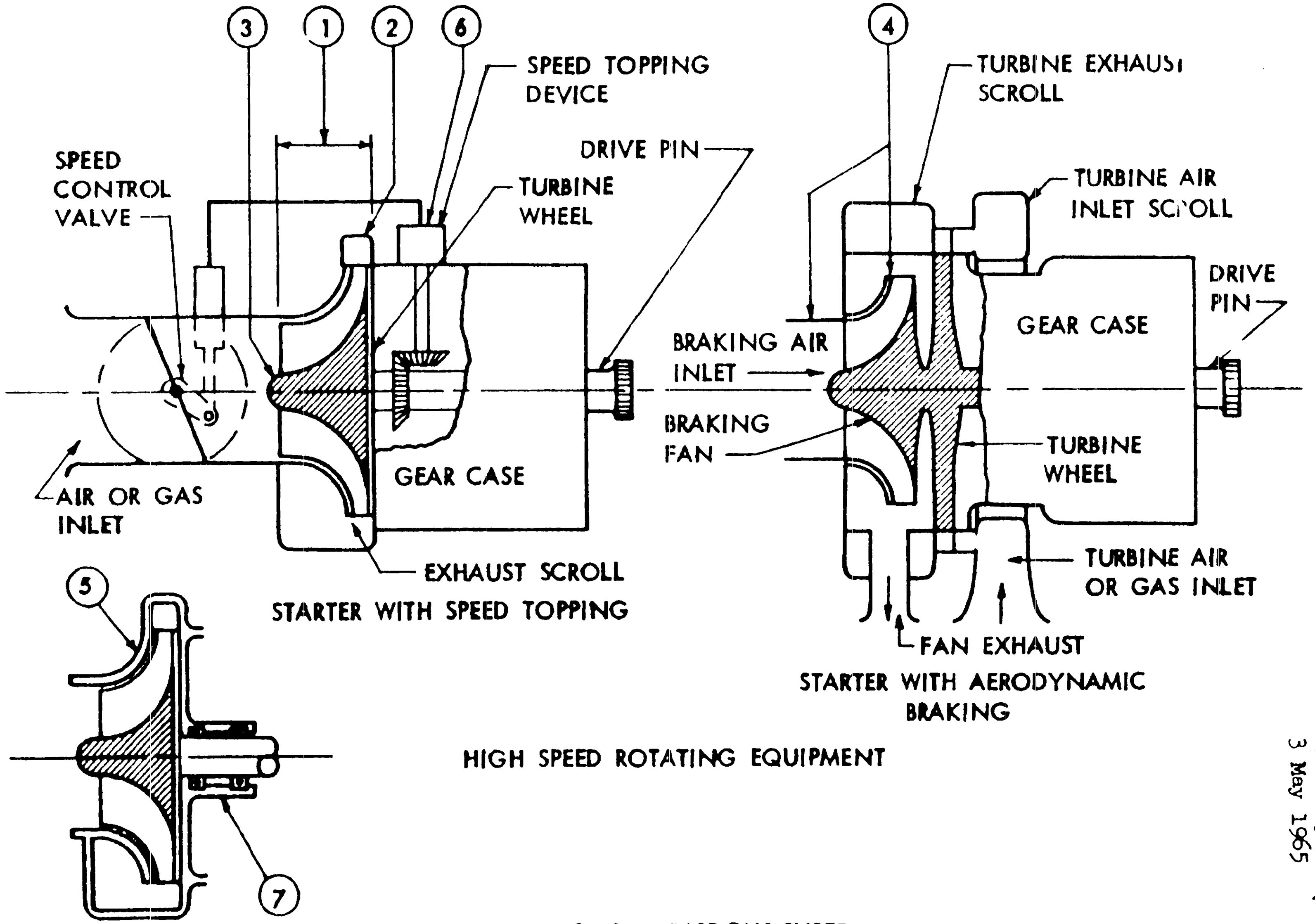
External rockets shall be installed so that the rocket exhaust will not be a hazard to fuel tank vent lines. If fuel vent exits cannot be located at a safe distance from the rocket exhaust, the vent line exits shall be protected by flame arrestors or other effective means to prevent flame propagation into the tanks.

Surfaces of rocket exhaust impingement shall be designed for heat and corrosion resistance. Protection shall be provided, if necessary, for flammable fluid components, fuel tanks, explosives, etc., located in compartments exposed to the exhaust wake.

		PARAGRAPH
(1)	LOCATION	2.10.2.1
(2)	CONTAINMENT	2.10.2.2.1
(3)	ROTOR STRENGTH	2.10.2.2.2
(4)	AERODYNAMIC SPEED LIMITATION	2.10.2.2.3
(5)	FRICTION BRAKING	2.10.2.2.4
(6)	SPEED LIMITING DEVICE	2.10.2.2.5
(7)	OTHER HAZARDS	2.10.2.3

2.10 HAZARDOUS SYSTEMS

FIGURE 19



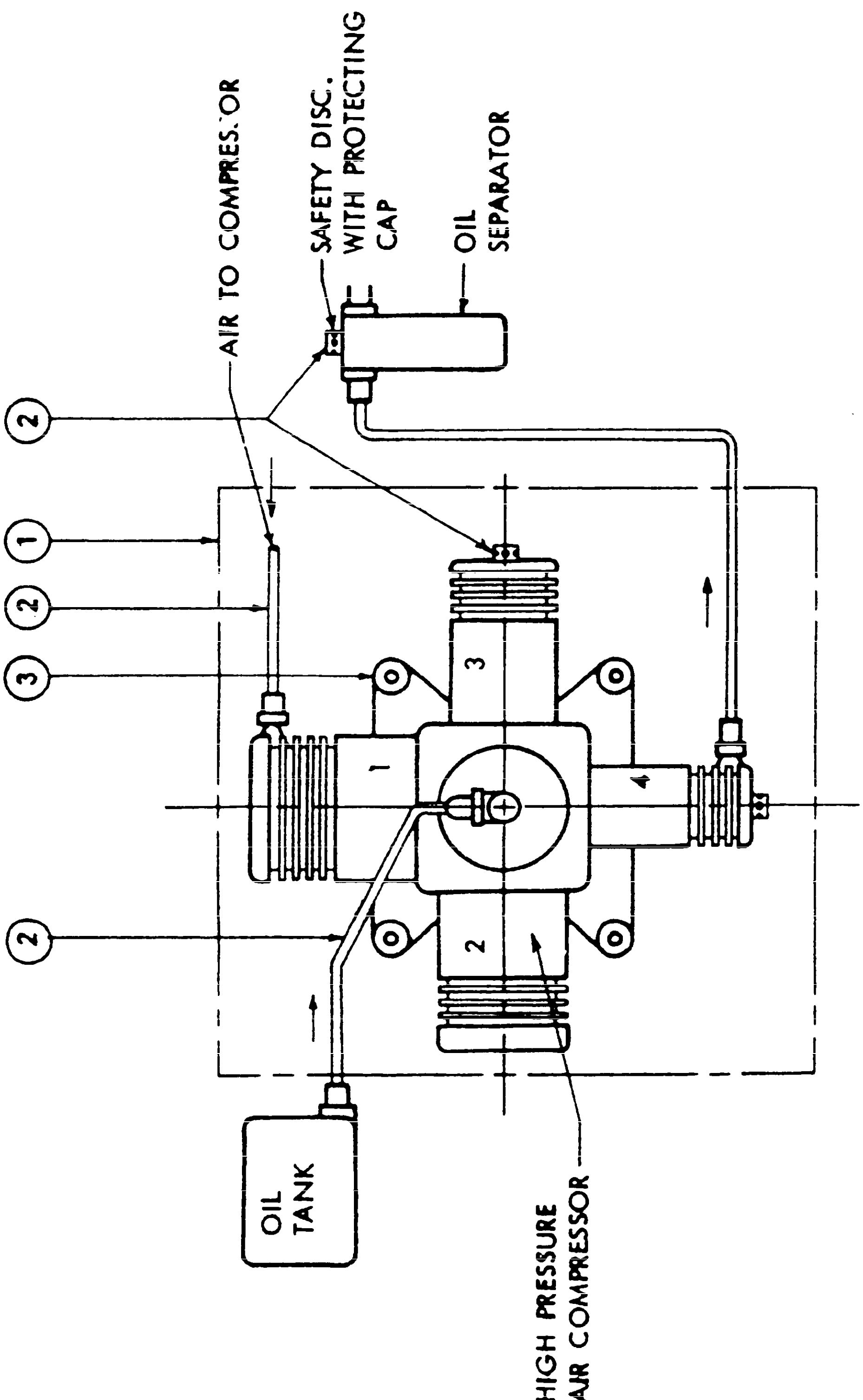
HIGH SPEED ROTATING EQUIPMENT

FIGURE 19 - 2.10 HAZARDOUS SYSTEMS

		PARAGRAPH
(1)	LOCATION	2.10.3.3
(2)	EXPLOSION HAZARDS	2.10.3.4
(3)	SUPPORT	2.10.3.5

2.10 HAZARDOUS SYSTEMS

FIGURE 20



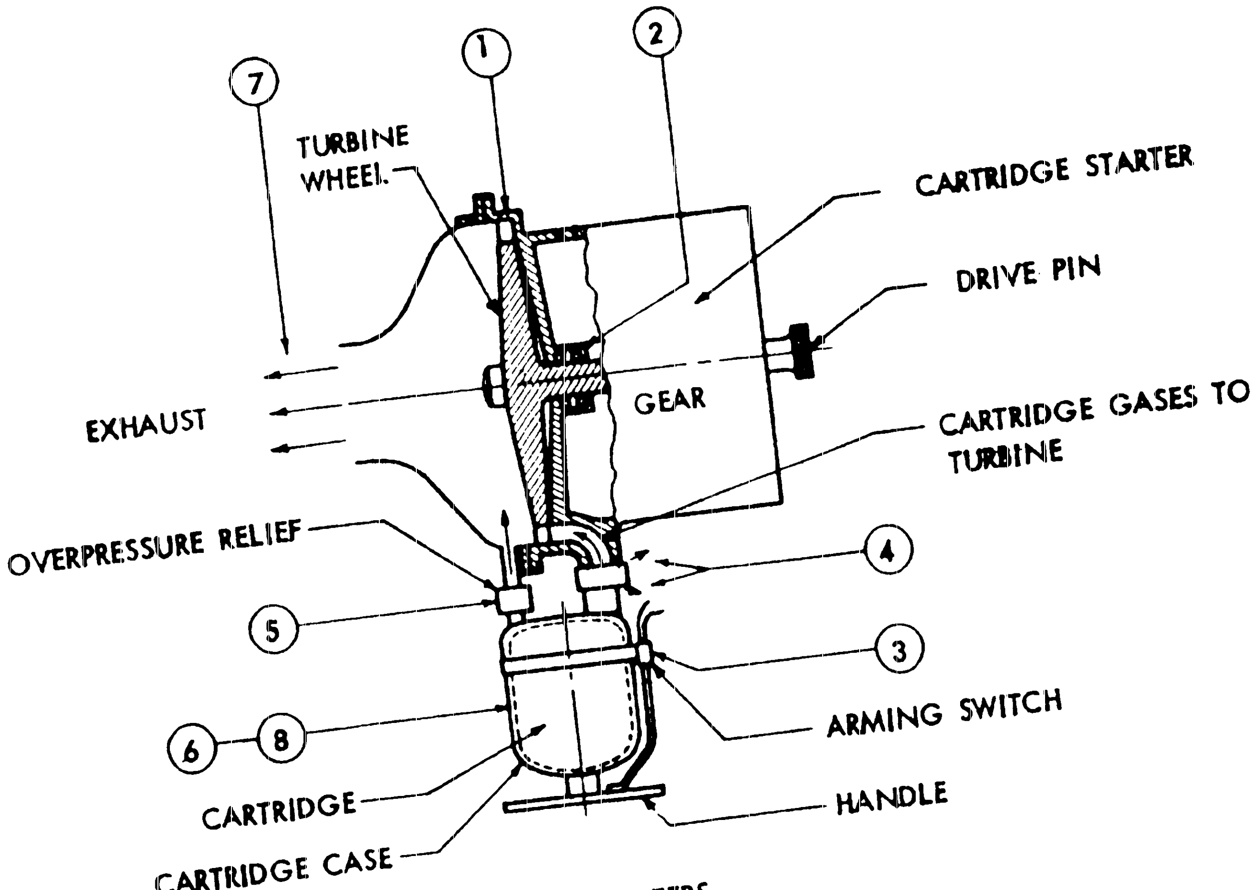
HIGH PRESSURE AIR SYSTEMS

FIGURE 20 - 2.10 HAZARDOUS SYSTEMS

		PARAGRAPH
(1)	OVERSPEED PROTECTION	2.10.5.2
(2)	OTHER HAZARDS	2.10.5.3
(3)	INADVERTENT IGNITION	2.10.5.4.1
(4)	GAS LEAKAGE	2.10.5.4.2
(5)	OVERPRESSURE PROTECTION	2.10.5.4.3
(6)	CARTRIDGE STORAGE	2.10.5.4.4
(7)	EXHAUST	2.10.5.4.5
(8)	CARTRIDGES	2.10.5.4.6

2.10 HAZARDOUS SYSTEMS

FIGURE 21



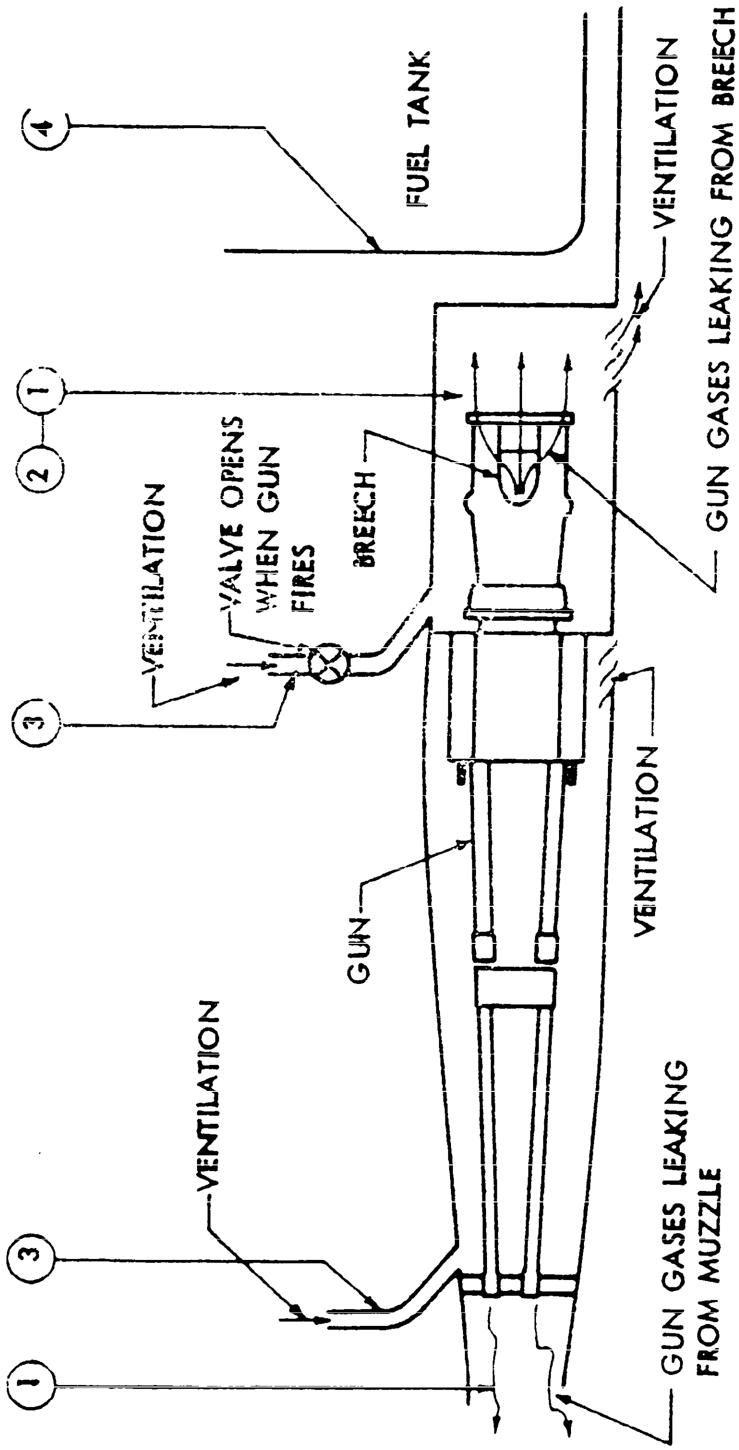
ENGINE STARTERS

FIGURE 21 - 2.10 HAZARDOUS SYSTEMS

		PARAGRAPH
(1)	GENERAL	2.10.6.1
(2)	GUN GAS DATA	2.10.6.2
(3)	VENTILATION	2.10.6.3
(4)	FUEL TANKS	2.10.6.4

2.10 HAZARDOUS SYSTEMS

FIGURE 22



GUN INSTALLATIONS

FIGURE 22 - 2.10 HAZARDOUS SYSTEMS

		PARAGRAPH
(1)	LANDING WHEEL BRAKES	2.10.7
(2)	EXTERNAL ROCKETS	2.10.8

2.10 HAZARDOUS SYSTEMS

FIGURE 23

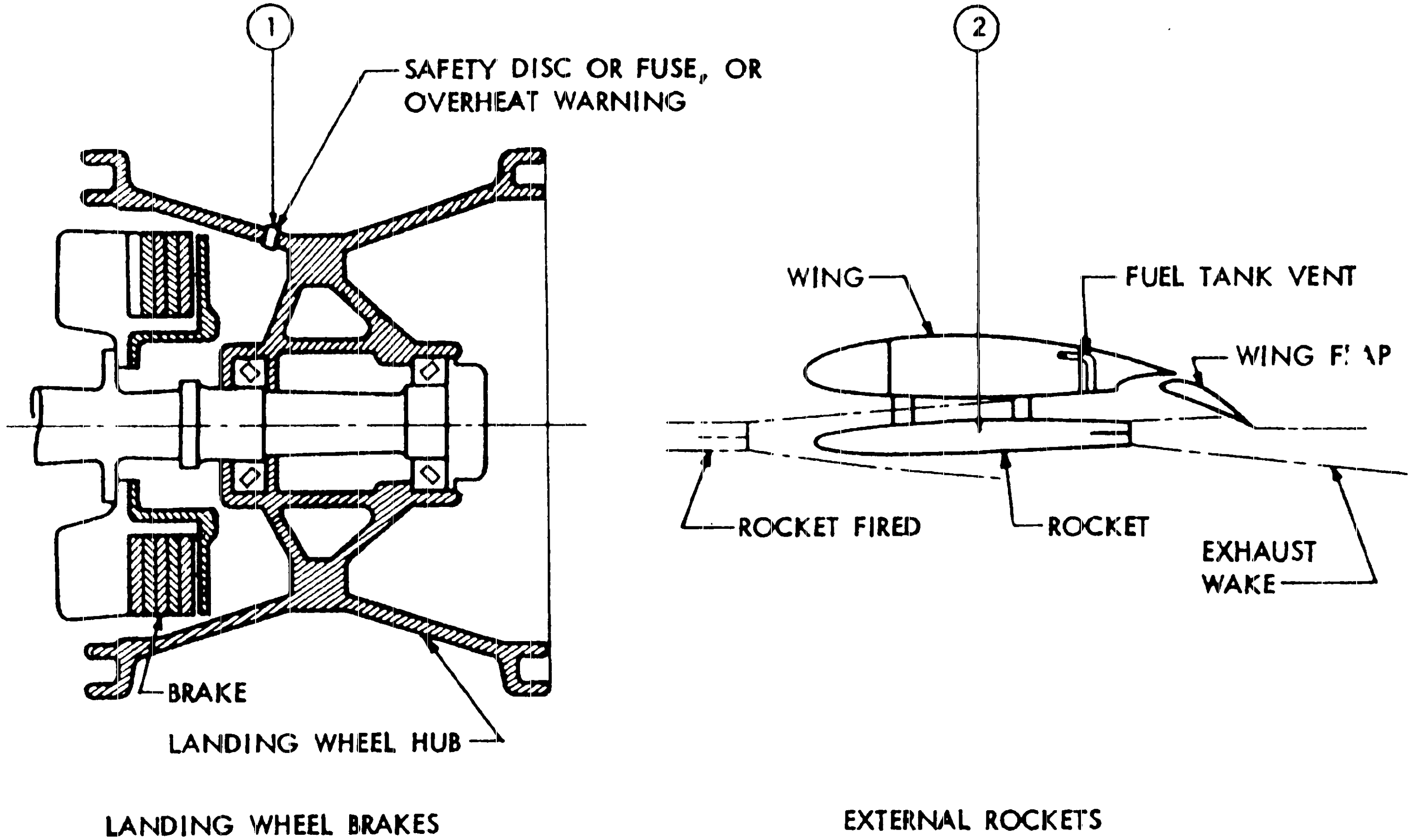


FIGURE 23 - 2.10 HAZARDOUS SYSTEMS

2.11 POTENTIAL FIRE ZONES (See Figures 24, 25, 26, 27, 28 and 29 on pages 113, 115, 117, 119, 121 and 123).

2.11.1 GENERAL

2.11.1.1 DEFINITION

The following compartments shall be treated as potential fire zones in conformance with the requirements of this section:

(1) Compartments which contain flammable fluid components with potential leakage, and potential ignition sources, if the following applies:

(a) One "single failure" can cause a fire or explosion. A combustor and turbine compartment is in this category if it contains external flammable fluid lines with leakage potential as well as an unprotected engine case hot enough to ignite the flammable fluid, or when a combustor burnthrough can cause leakage from the flammable fluid lines.

(b) A dual failure is needed to cause ignition, but the flammable fluid components and potential ignition sources are not sufficiently separated and shielded, or are present in high concentration, so that contact of flammable fluid and vapor with ignition sources by gravity, ventilation airflow or squirt is likely. Accessory sections of engines are, and hydraulic and fuel service centers may be in this category.

This requirement is based on the assumption that protective features of ignition sources may be rendered ineffective, at least temporarily, by poor maintenance. A cover left off from explosion-proof electric equipment, for instance, can invalidate the explosion protective feature of the equipment and go undetected for some time.

(2) Any zone containing flammable fluid components if the zone is adjacent to a potential fire zone and is not sufficiently separated from the fire zone to minimize the possibility of flame propagation.

2.11.1.2 FIRE ZONE ISOLATION

Fire zone isolation from the rest of the aircraft shall be accomplished by fire barriers. Such fire barriers are:

2.11.1.2.1 FIREWALLS

Firewalls separate potential fire zones from adjacent compartments of the aircraft. Firewalls shall be made of stainless steel or titanium, at least 0.012 inches thick, or equivalent material. Titanium shall not be used for firewall material in the vicinity of burner cans, where molten material can drip on it when a burnthrough occurs, or when the firewall is a vital load-carrying structural member. The firewall shall be as tight as possible; a hole of 0.04 inches diameter in a firewall 0.015 inches thick can cause propagation of flames through the firewall. Firewall connectors and the passage of all plumbing, ducts, wiring, controls, etc., through firewalls shall be as fireproof as the firewall itself, i.e., under no conditions of fire shall fire penetrate through the firewall because of failure of fittings. Firewalls may buckle severely due to heat, therefore access doors or joints shall be avoided in firewalls. If access doors or joints must be provided in firewalls for justifiable reasons, they shall be closed by closely spaced fasteners of such type that hazardous gaps will not result during a fire. Whenever a firewall is closer than eight inches from the outer case of a combustor, additional protection shall be considered against the torchlike flame resulting from a burned-through combustor. All grommets and fillers used at points where items pass through firewalls shall be made of material possessing the same fireproof characteristics as the firewall material. Fillers shall be used sparingly and only where necessary. Consideration shall be given to the difficulties of removing and replacing any movable pieces of airframe which have been sealed with fillers. Unique firewall connectors or passages shall be demonstrated to be satisfactory by actual test. Firewalls should not be stressed by airloads, mounted equipment, etc., so that early failure would occur due to the loss of strength, even though flame penetration was not imminent.

Materials used close to the protected side of the firewall shall be a type which will not burst into flames as a result of heat conduction and radiation from a fire in the potential fire zone. Structure and equipment shall be protected by insulation, shielding or cooling if heating due to a fire can cause a safety of flight hazard. High strength fasteners with aluminum components such as lockbolts and Hi-Shear rivets shall not be used.

2.11.1.2.2 SKIN AND SKIN STRUCTURE

The skin and skin structure of potential fire zone enclosures, or portions thereof, or the skin and skin structure adjacent to potential fire zone enclosures, or portions thereof, shall be made of stainless steel or titanium, at least 0.012 inches thick, or of equivalent material, if necessary to protect against the following:

(1) Burning of a fire out of a potential fire zone and subsequent burning into nonprotected, adjacent areas, around the firewall, either through the skin or through openings in the skin.

(2) Burning of a fire out of a potential fire zone through the skin and subsequent impingement of flames on vital structure or on integral fuel tanks, if such impingement can cause safety of flight hazard.

In order to prevent re-entry or impingement of a fire with the minimum use of stainless steel or titanium skin structure, the following should be considered:

(a) Openings such as ventilation outlets in the skin of potential fire zones should be so located and designed that re-entry of flames, or impingement with resulting hazard, downstream of the fire zone cannot occur.

(b) Fire egress should be encouraged at places where re-entry or impingement cannot occur. This can be done by proper location of ventilation openings, or by burnout panels.

(c) Fire penetration is most likely in areas of potential flammable fluid leakage, at ventilation air exits, and at and near the bottom of the compartment. These areas should receive highest attention in a fire containment analysis.

2.11.1.2.3 AIR DUCTS

Air ducts passing through potential fire zones, when allowed to burn through, might give a fire the opportunity to travel from one fire zone to another or to the rest of the aircraft, and they may also allow a high air mass flow to enter the potential fire zone and feed the fire. Such air ducts shall be made of stainless steel or titanium not less than 0.015 inches thick, or equivalent material, where they pass through fire zones. Air ducts originating in fire zones shall be made of stainless steel or titanium not less than 0.015 inches thick, or equivalent material, for a sufficient distance beyond the fire barrier to assure that any fire can be contained within the duct. For air ducts originating in potential fire zones, and flowing air to potential fire zones shutoff means shall be provided as required by 2.11.1.4.

2.11.1.3 EXPLOSIONS

Explosions in potential fire zones due to presence of flammable vapors shall be prevented by adequate drainage and ventilation in conformance with 2.4. However, explosions in potential fire zones happen occasionally and precaution must be taken to restrain the consequences of this hazard to the greatest practical extent. For this reason, the compartment walls should be strong enough to withstand a pressure differential of 5 psig. Quick opening relief holes in the outside wall should be considered to prevent a pressure rise over 5 psig, if natural relief is not provided. Ducts inside the potential fire zones shall be designed strong enough to prevent a failure caused by an explosion, such as collapse of an intake duct or an exhaust pipe, to the extent that a safety of flight hazard is prevented.

2.11.1.4 SHUTOFF MEANS

Provisions shall be made for shutting off the flow of hazardous quantities of air and flammable fluids into or through each potential fire zone. This requirement may be waived (a) if the design is such that leakage into a fire is impossible, or (b) if the fluid (e.g. hydraulic fluid, feathering oil) is necessary for control of the emergency. (2.11.1.6)

Shutoff means shall be located outside of and remote from fire zones, unless the following conditions are met:

(1) Shutoff valves, when exposed to a flame of 2000°F, are easily operable during the first five minutes of a fire, and are capable of remaining closed without internal or external leakage for the duration of the fire.

(2) Mechanical and electric controls for shutoff valves are operable for a minimum of five minutes when exposed to a flame of 2000°F, and are capable of holding their valves closed for the duration of the fire. Hydraulic controls shall meet this requirement without leakage of hydraulic fluid.

Fuel shutoff valves shall comply with the requirements of MIL-V-8608.

For oil shutoff valves in main power plants, see 2.11.2.7.

Shutoff valves are not required in flammable fluid lines if the maximum flow rate through a line is 0.1 gallons per minute or less. If more than one flammable fluid line without shutoff valve are used for one fire zone, and the lines are in the same area so that simultaneous fire damage is likely, the total maximum flow rate shall not exceed 0.1 gallons per minute.

Air shutoff valves shall be provided for potential fire zones which are equipped with fire extinguishing, for any single air inlet flowing more than five cu. ft. per minute of air to a fire zone, unless it can be demonstrated by analysis or test that the airflow is not defeating the effectiveness of fire extinguishing. (See 2.13.) Bleed air shutoff valves shall be provided on multi-engine aircraft, using an interconnected distribution system, unless the duct is made of stainless steel or titanium not less than 0.015 inches thick, or equivalent material, within the fire zone. The shutoff valve may be a simple check valve or a controlled valve. Shutoff valves shall be provided in air ducts which originate in a potential fire zone and lead to another compartment in the aircraft.

Shutoff valves actuated by a servomechanism shall travel from full open to full closed in one second or less. Electric shutoff valves which employ terminal switches for limitation of valve travel shall be so designed that reasonable tolerances are allowed for adjustment of the terminal switches. Solenoid shutoff valves shall not be used for equipment which is essential for performance of a mission and shall be designed to shut off the flow to a fire zone, when failed.

Shutoff valves for potential fire zones shall be actuated in conformance with 2.14.

2.11.1.5 FLAMMABLE FLUID TANKS (See 2.1.1.1.1)

2.11.1.6 LINES FOR FLAMMABLE FLUIDS

Tubes carrying flammable fluids in or close to a potential fire zone shall be made of stainless steel, or equivalent. Hoses carrying flammable fluids in or close to a potential fire zone shall withstand a flame of 2000°F for at least five minutes without leakage, at the lowest fluid flow rate and the highest fluid temperature, and under vibration of operation. Fittings shall have an equal resistance to fire. These requirements of fire resistance apply also to vent and drain lines, unless a failure of such lines and fittings will not add to a fire hazard. Hoses for emergency equipment in fire zones should be as fireproof as possible and they should be routed, and protected if necessary, so that they are not damaged by consequence of the failure which started the fire, thereby incapacitating the hoses when they are needed most.

Flammable fluid lines in potential fire zones shall be reduced to the minimum total length and to the minimum number of connectors, consistent with other requirements of MIL-I-18802. They shall be arranged as low as practical in the compartment and away from potential fire sources. Shielding of high pressure hydraulic lines should be considered to minimize the possibility of hydraulic fluid contacting ignition sources by spray. Hose assemblies shall be protected by shielding or other means against temperatures in excess of the maximum specified allowable operating temperature for the particular hose.

2.11.1.7 FLAMMABLE FLUID ACCESSORIES

Flammable fluid accessories shall be located in potential fire zones only when justifiable reasons for such locations exist. Flammable fluid accessories which must be located in potential fire zones shall comply with the requirements of 2.2.8.

2.11.1.8 DRAINAGE AND VENTILATION (See 2.4)

2.11.1.9 ELECTRIC EQUIPMENT

Electric equipment shall be located in potential fire zones only when justifiable reasons for such location exist. Electric equipment, which must be located in potential fire zones, shall comply with the requirements of 2.7.

2.11.1.10 MATERIALS

In addition to the requirements for materials used for firewalls (2.11.1.2.1), lines for flammable fluid (2.11.1.6), materials close to firewalls (2.11.1.2.1), and flammable fluid tanks in engine compartments (2.1.1.1.1), the following is required in or close to potential fire zones:

(1) Aluminum alloy shall not be used within or close to a potential fire zone for structure or equipment, the breakdown of which will endanger the integrity of the aircraft structure or controls necessary for flight, jeopardize the controlability of the aircraft, or cause hazardous spread of fire.

(2) Magnesium shall not be used unless approved by BuWeps (see "Design and Construction of Aircraft Weapon Systems" SD-24 Vol. I, and Vol. II).

(3) Insulation shall be nonabsorbent as a material, or as a material configuration, and so designed and installed that fluids will not be retained on or under it.

(4) Nonmetallic material which is combustible shall be used only when use of more fire resistant material is impractical. Nonmetallic material shall not ignite spontaneously under all environmental temperatures of installation, and it shall be self-extinguishing after removal of a flame. When used in potential fire zones with fire

extinguishing capabilities, it shall not afterglow. Also see 2.7.9 for material used in or close to electric components.

2.11.1.11 AIR INLETS AND OUTLETS

Airscoops into potential fire zones shall be located and constructed so that flammable fluids and vapors, or flames, cannot enter a potential fire zone under any reasonable flight attitude. For air outlets see 2.11.1.2.2.(a).

2.11.1.12 MOUNTING SYSTEMS

Metallic shock absorbing elements should be used in potential fire zones, whenever practical, instead of elements made of elastomeric material. When metallic shock absorbing elements cannot be used, the elements shall be so designed that the supported components will remain adequately supported and continue to function effectively, in spite of failure of the nonmetallic material in the mounting system due to fire.

2.11.1.13 EXHAUST SYSTEMS

Exhaust systems should be located as high in a compartment and in the airplane as practicable. Flammable fluid equipment, tanks, and lines should be kept remote from exhaust systems. For location of fuel, oil, hydraulic, and water/alcohol tanks with respect to exhaust systems, see 2.1.1.1.

Whenever satisfactory isolation of exhaust systems from flammable fluid equipment, lines and tanks by location is not practical, isolation by steel shrouds shall be considered. Sufficient distance between exhaust pipe and shroud, plus forced air cooling and insulation, if necessary, shall be applied to keep the surface on the side of the potential flammable fluid leakage at least 50°F below the autogenous ignition temperature of the flammable fluids involved. The shrouds shall be liquid tight.

Exhaust ejectors have been used successfully for the cooling of exhaust pipes and ventilation of compartments. This method is particularly suitable for helicopters and auxiliary power plants where ram air is not available in all flight and ground phases. When exhaust ejectors are used which draw the cooling air from compartments containing flammable fluid components with potential leakage, protection shall be provided against ignition of flammable fluids and vapors by the exhaust or exhaust pipes, or by the hot turbine wheel after shutdown.

Where shrouds cannot be used for separation of exhaust systems from flammable fluid components, sandwich type or other suitable insulation blankets may be used for covering the hot exhaust surfaces. They shall be designed and installed so that all surfaces, edges, cutouts and seams are effectively sealed to prevent the entrance of flammable fluids. The insulation blankets should have stainless steel surfaces on both sides, and they shall be vented and drained at their lowest point. The vent and drain holes shall be shielded, if required, to prevent entrance of liquid. The insulation material shall be "nonpacking" under service conditions. Insulation shall be attached to the exhaust system so that a "single failure" of an attachment will not cause an ignition hazard.

Exhaust systems and shrouds tend to warp. Such warpage shall be considered in design of exhaust systems so that leakage of exhaust and flammable fluids will not occur to an extent which can cause a fire hazard or a false fire warning signal.

Heat radiation from exhaust flanges and annular heavy sections may be sufficient to directly damage wiring, aluminum alloy structure, hose assemblies, etc., located in the plane of the flange. Adequate shielding or insulation shall be provided, if necessary.

Burning fluids will occasionally run out the end of exhaust pipes. Positive provisions shall be made either to let this fluid run free and clear of the aircraft to the ground, or to trap and drain it within the adjacent structure.

Discharge of exhaust shall not impinge on unprotected surfaces, on skin of integral tanks, or other places where a hazard may result during normal operation or when a failure occurs. Exhaust shall not pass over access doors and filler wells, and it shall be remote enough from flammable fluid and vapor vents and ventilation and fuel jettison outlets to avoid a hazard. Drain discharge shall not create a hazardous condition when in contact with exhaust gases under any condition of aircraft maneuvering.

2.11.1.14 FIRE DETECTION

All potential fire zones shall have fire detector systems (see 2.12).

2.11.1.15 FIRE EXTINGUISHING

Fixed fire extinguishing systems will be provided only if required by the airplane detail specification. Where potential fire zones are recognized by a contractor, and not covered in MIL-F-22285, appropriate recommendations shall be made to the Bureau of Naval Weapons.

2.11.1.16 COMPARTMENT CONFIGURATION

Potential fire zones with high airflows which are equipped with fire extinguishing systems, should be devoid of sheltered areas in the lower quarter of the installations. Use of smooth fireproof inner liners in these areas shall be considered. Where a liner is used, the edges shall be sealed so that burning fluid cannot penetrate under the liner.

2.11.2 MAIN POWER PLANTS

In addition to the general requirements of 2.11.1 through 2.11.1.16 for potential fire zones, main power plants shall comply with the following:

2.11.2.1 FIRE EXTINGUISHING

Fire extinguishing system shall be provided in the main power plant installation of all multi-engine aircraft. Fire extinguishing systems are not required in single engine aircraft, except for first procurement of a small quantity of a new model aircraft. The fire extinguishing system shall comply with the requirements of 2.13.

2.11.2.2 FIRE SHIELD

The accessory section of a power plant should be separated from the hot burner, turbine and tailpipe section by a fire shield, when practicable. The entire fire shield, or portions thereof, may be made of aluminum alloy if the hazard from an existing fire is not increased in case of burnthrough. Partial aluminum alloy fire shields, with the rest of the fire shield made of stainless steel, should be considered when local burnthrough is desired as discussed in 2.11.1.2.2.(b). Careful consideration shall be given to the possibility of high pressures building up in the hot engine compartment, in case of a failure which causes release of exhaust gases. Such pressure in combination with the high exhaust temperature could cause penetration of an aluminum fire shield and carry an ignition source into the accessory compartment, thereby increasing the hazard potential.

The fire shield shall be liquid and vapor tight. It is desirable to govern the pressure of the burner, turbine and tailpipe section above that of the accessory section to compensate for the lack of perfect sealing which may occur after a reasonable service time.

Engines with high compression ratios may require location of the fire shield forward of the last compressor stage to prevent ignition of leaking flammable fluid by the hot compressor case.

2.11.2.3 DUAL-ENGINE INSTALLATION

Engines arranged in close proximity to each other shall be separated by a firewall.

2.11.2.4 ENGINE AIR INLETS

Engine air inlets should be designed, whenever possible, so that air cannot be drawn from a compartment with potential flammable leakage during any ground or flight phase. Low pressure in the air inlet ducts relative to pressures in adjacent compartments during ground runs and low flight speeds can cause ingestion of flammable leakage with resulting engine stall, flash-back of combustor flames through the compressor, and fire and explosion in the adjacent compartment. It also causes reverse flow of air in the compartment with the related problems of detector, and extinguishing discharge nozzle location.

2.11.2.5 EXHAUST SYSTEMS

See 2.11.1.13. As flight altitude increases, turbine engine exhaust wake fans out to a wider effective area, so caution shall be taken that exhaust does not impinge on unprotected surfaces or create a hazard by coming close to flammable fluid and vapor drain, vent, and dump outlets.

Re-entry of exhaust gases into wing cavities may occur on installations with engines mounted on the wing. Gases may travel spanwise under some flight conditions. The wing cavities shall be analyzed for potential fire hazards and for hazardous deterioration of structural material, and appropriate protection shall be provided.

2.11.2.6 COMPONENTS IN HOT ENGINE SECTION

Lines and equipment which carry flammable fluid and are located close to the burner, turbine, and exhaust section of the engine shall be of the highest possible order of reliability, and shall be fireproof. All nuts, bolts and fasteners which can cause leakage of flammable fluid, when loose, shall be safety-wired or otherwise mechanically locked.

No lines and equipment carrying flammable fluid shall be located in the plane of the turbine wheels, or aft and close to the fuel injection nozzles, except that lines may cross these areas in a longitudinal direction when necessary.

2.11.2.7 OIL SHUTOFF VALVES

An oil shutoff valve shall be provided for each engine of all multi-engine aircraft in accordance with Spec. MIL-O-19838.

Valves and controls shall comply with 2.11.1.4, except that the emergency procedure should incorporate a separate step for closure of the oil valve if engine rotation cannot be stopped and if a major damage of the engine can be expected from oil starvation. The control shall be such that the oil valve is always open when the fuel feed valve is open.

2.11.2.8 OIL, HYDRAULIC AND WATER-ALCOHOL TANKS (2.1.1.1.1)

2.11.2.9 OIL COOLERS

Aluminum oil coolers and other heat exchangers for flammable fluids, and their air intakes, should be separated from the engine compartment by stainless steel or titanium sheet metal not less than 0.015 inches thick. Oil coolers and other heat exchangers for flammable fluid should be located as low as practical in a power plant installation and so that fluid cannot enter the engine air intake system in case of a failure. Oil coolers shall not be located in the hot engine section. Also see 2.11.2.6.

2.11.2.10 FIRE ACCESS DOOR

Spring-loaded fire access doors in main power plants shall be provided only if required by the aircraft model specification. This door shall be in such a position that the nozzle of a CO_2 extinguisher can be thrust against the door, forcing it open, and permitting CO_2 to be injected directly into the compartment. The spring shall be sufficiently strong to hold the door shut against air loads. Quick-release latches should not be used. The size of the door should be 5-1/2 x 10 inches. The door should be located near the bottom, at a point where burning flammable fluid cannot drain on the operator of the extinguisher nozzle. The door should be marked "Access for Fire Extinguisher."

2.11.2.11 EMERGENCY FIRE PROVISIONS (See 2.14)

2.11.3 AUXILIARY POWER PLANTS

In addition to the general requirements of 2.11.1 through 2.11.1.16 for potential fire zones, and 2.10.2 for high speed rotating equipment, auxiliary power plants shall comply with the following:

2.11.3.1 SPECIFICATIONS

Auxiliary gas-turbine power plants shall comply with the fire protection requirements of MIL-P-8686.

2.11.3.2 VENTILATION

If an exhaust ejector is used to provide ventilation for an auxiliary power plant compartment, protection shall be provided against ignition of flammable fluids and vapors by the exhaust or exhaust pipes, or by the hot turbine after shutdown.

Ventilation of auxiliary power plant compartments shall be provided in flight, regardless of the power plant being used or not in flight.

2.11.3.3 FIRE SHIELDS

A fire shield should be provided between the hot section and the accessory section of an auxiliary power plant, when practicable. The fire shield shall be liquid and vapor tight. It is desirable to govern the pressure of the hot section above that of the section containing the flammable fluid components.

2.11.3.4 AIR INLETS

Combustion air inlets should be designed, whenever possible, so that air cannot be drawn from a compartment with potential flammable leakage during any ground or flight condition.

2.11.3.5 OIL TANKS

Oil tanks for auxiliary power plants may be located in their surrounding compartment, but shall be designed to withstand a 2000°F fire for ten minutes without leakage.

2.11.3.6 FIRE ACCESS DOORS

Spring-loaded fire access doors in auxiliary power plants in conformance with 2.11.2.10 shall be provided only if required by the aircraft model specification. A door shall be provided if a fixed fire extinguishing system is not provided.

2.11.4 COMBUSTION HEATERS

In addition to the general requirements of 2.11.1 through 2.11.1.16 for potential fire zones, combustion heaters shall comply with the following:

2.11.4.1 SPECIFICATIONS

Combustion heaters shall comply with the fire protection requirements of MIL-H-005484.

2.11.4.2 HEATING AIR DUCTS

Portions of heating air ducts passing through regions in the aircraft where flammable fluid systems are located shall be so constructed or isolated from such systems that failure or malfunction of the flammable system components cannot introduce flammable fluids or vapors into the heating airstream.

2.11.4.3 COMBUSTION AIR DUCTS

Combustion air ducts shall be of fireproof construction for a distance sufficient to prevent damage from backfiring or reverse flame propagation. Combustion air ducts shall not communicate with the heating airstream unless it is demonstrated that flames from backfires or reverse burning cannot enter the heating airstream under any conditions of ground or flight operation including conditions of reverse flow or malfunctioning of the heater or its associated components. Combustion air ducts shall not restrict prompt relief of backfires which can cause heater failure due to pressures generated within the heater.

2.11.4.4 AIR INLETS

Combustion and ventilating air intakes shall be so located that no flammable fluids or vapors can enter the heater system under any conditions of ground or flight operation either during normal operation or as a result of failure.

2.11.4.5 EXHAUST SYSTEM

In addition to complying with the requirements of 2.11.1.13, the exhaust shall be released without restriction which could cause heater failure due to pressure within the heater.

2.11.4.6 DRAINS

Fuel drainage from the combustion chamber shall be carried overboard in conformance with 2.4.

2.11.5 OTHER POTENTIAL FIRE ZONES

Compartments which qualify as fire zones per 2.11.1.1 and are not power plant or combustion heater compartments must be analyzed for the most effective fire protection, whereby the following must be considered:

(1) If shutoff of flammable fluid flow to a fire is not possible without rendering flight essential components inoperative, effective fire protection is impossible for all practical purposes.

(2) It is therefore mandatory that greatest possible separation between flammable fluid components and ignition sources be accomplished when components are involved which are safety of flight items.

Whenever an unusual potential fire zone has been recognized as a necessity, the fire protection philosophy for such a zone shall be submitted to BuWeps for approval.

		PARAGRAPH
(1)	FIREWALLS	2.11.1.2.1
(2)	SKIN AND SKIN STRUCTURE	2.11.1.2.2
(3)	AIR DUCTS	2.11.1.2.3
(4)	EXPLOSIONS	2.11.1.3
(5)	SHUTOFF MEANS	2.11.1.4
(6)	FLAMMABLE FLUID TANKS	2.1.1.1.1

2.11 POTENTIAL FIRE ZONES

FIGURE 24

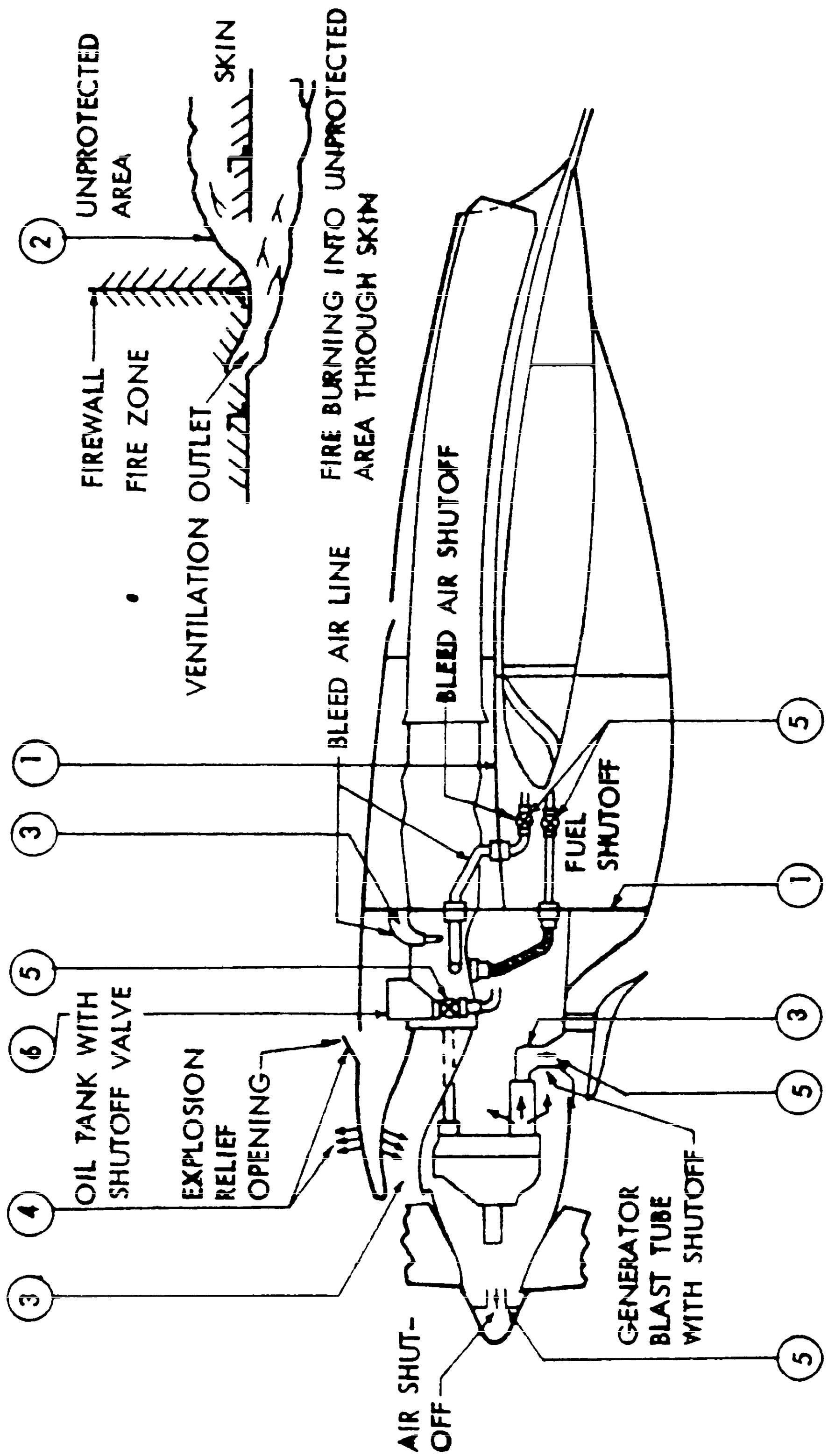


FIGURE 24 - 2.11 POTENTIAL FIRE ZONES

		PARAGRAPH
(1)	LINES FOR FLAMMABLE FLUIDS	2.11.1.6
(2)	FLAMMABLE FLUID ACCESSORIES	2.11.1.7
(3)	DRAINAGE AND VENTILATION	2.4
(4)	ELECTRIC EQUIPMENT	2.11.1.9
(5)	MATERIALS	2.11.1.10
(6)	AIR INLETS AND AIR OUTLETS	2.11.1.11

2.11 POTENTIAL FIRE ZONES

FIGURE 25

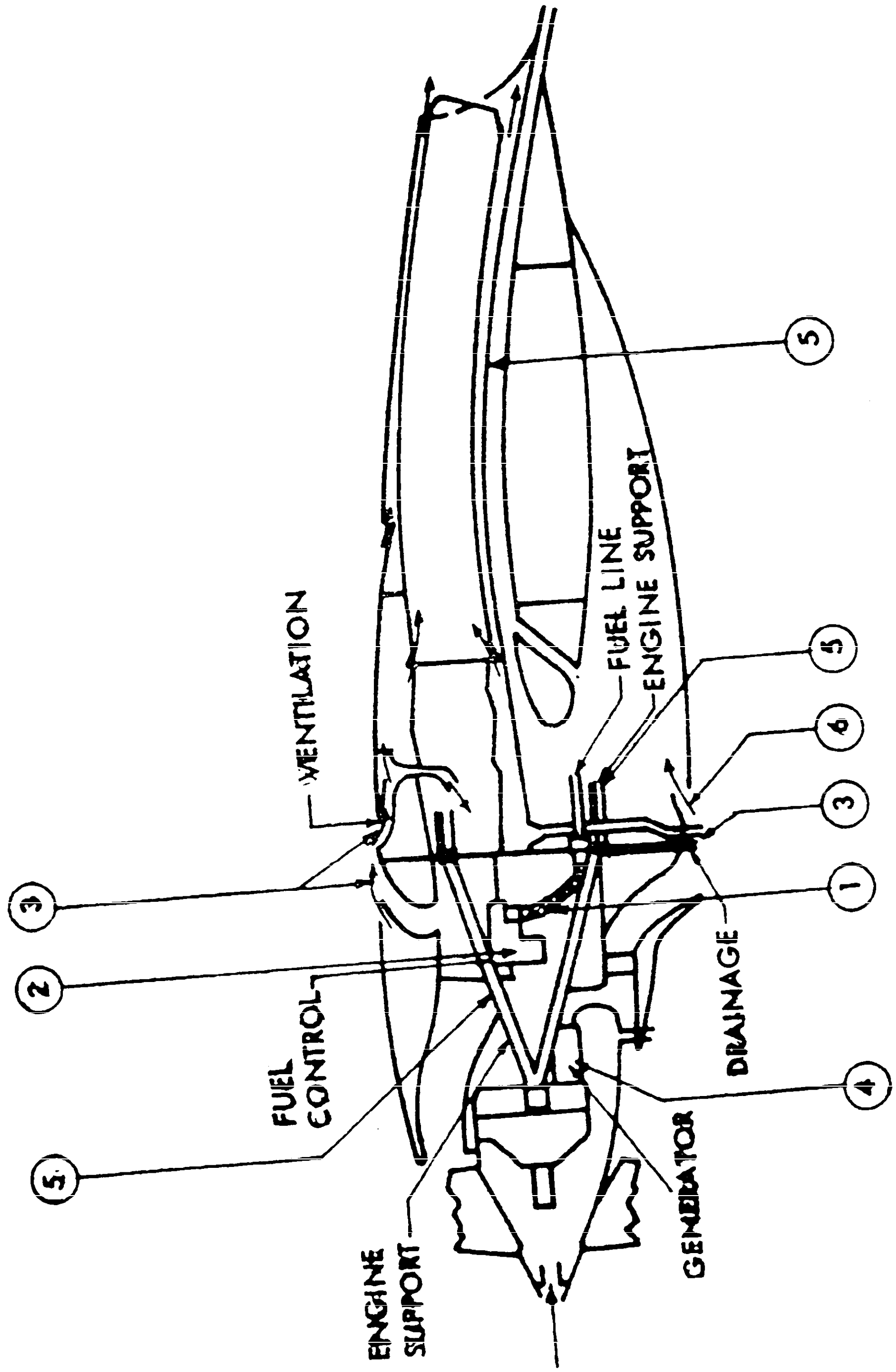


FIGURE 25 - 2.11 POTENTIAL FIRE ZONES

		PARAGRAPH
(1)	MOUNTING SYSTEMS	2.11.1.12
(2)	EXHAUST SYSTEMS	2.11.1.13
(3)	FIRE DETECTION	2.11.1.14
(4)	FIRE EXTINGUISHING	2.11.1.15
(5)	COMPARTMENT CONFIGURATION	2.11.1.16

2.11 POTENTIAL FIRE ZONES

FIGURE 26

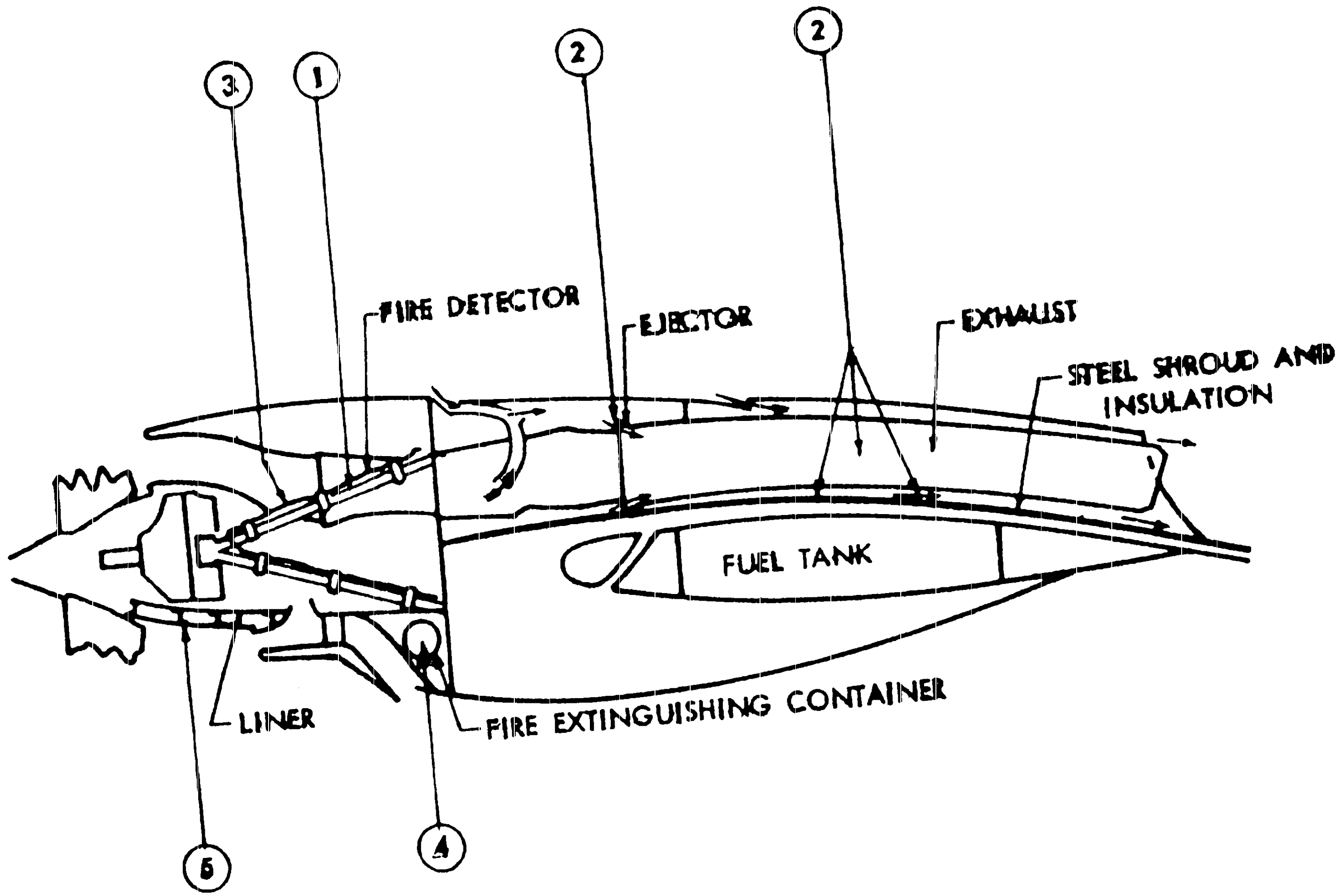
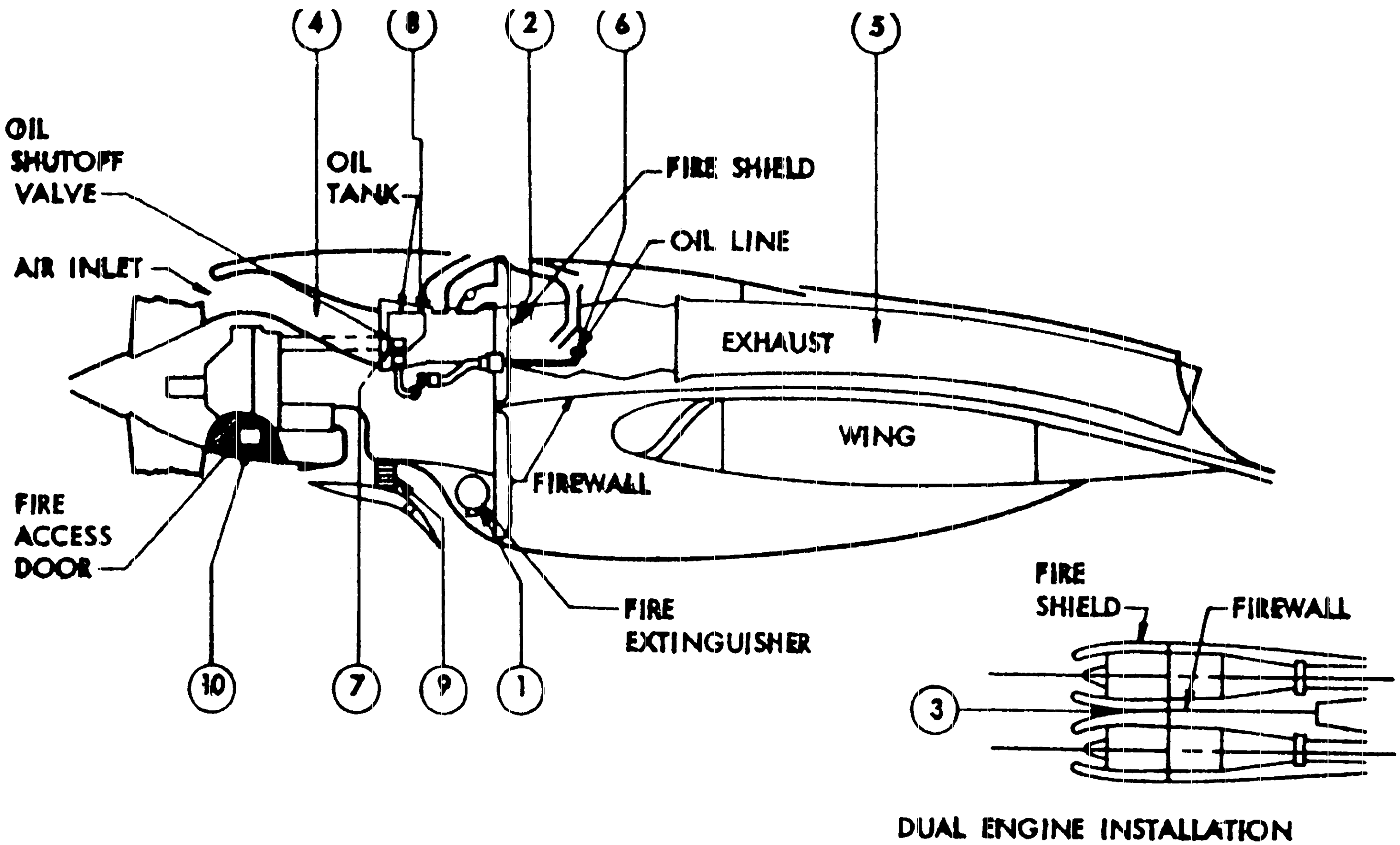


FIGURE 26 - 2.11 POTENTIAL FIRE ZONES

		PARAGRAPH
(1)	FIRE EXTINGUISHING	2.11.2.1
(2)	FIRE SHIELD	2.11.2.2
(3)	DUAL ENGINE INSTALLATION	2.11.2.3
(4)	ENGINE AIR INLETS	2.11.2.4
(5)	EXHAUST SYSTEMS	2.11.2.5
(6)	COMPONENTS IN HOT ENGINE SECTION	2.11.2.6
(7)	OIL SHUTOFF VALVES	2.11.2.7
(8)	OIL, HYDRAULIC AND WATER-ALCOHOL TANKS	2.1.1.1
(9)	OIL COOLERS	2.11.2.9
(10)	FIRE ACCESS DOORS	2.11.2.10

2.11 POTENTIAL FIRE ZONES

FIGURE 27



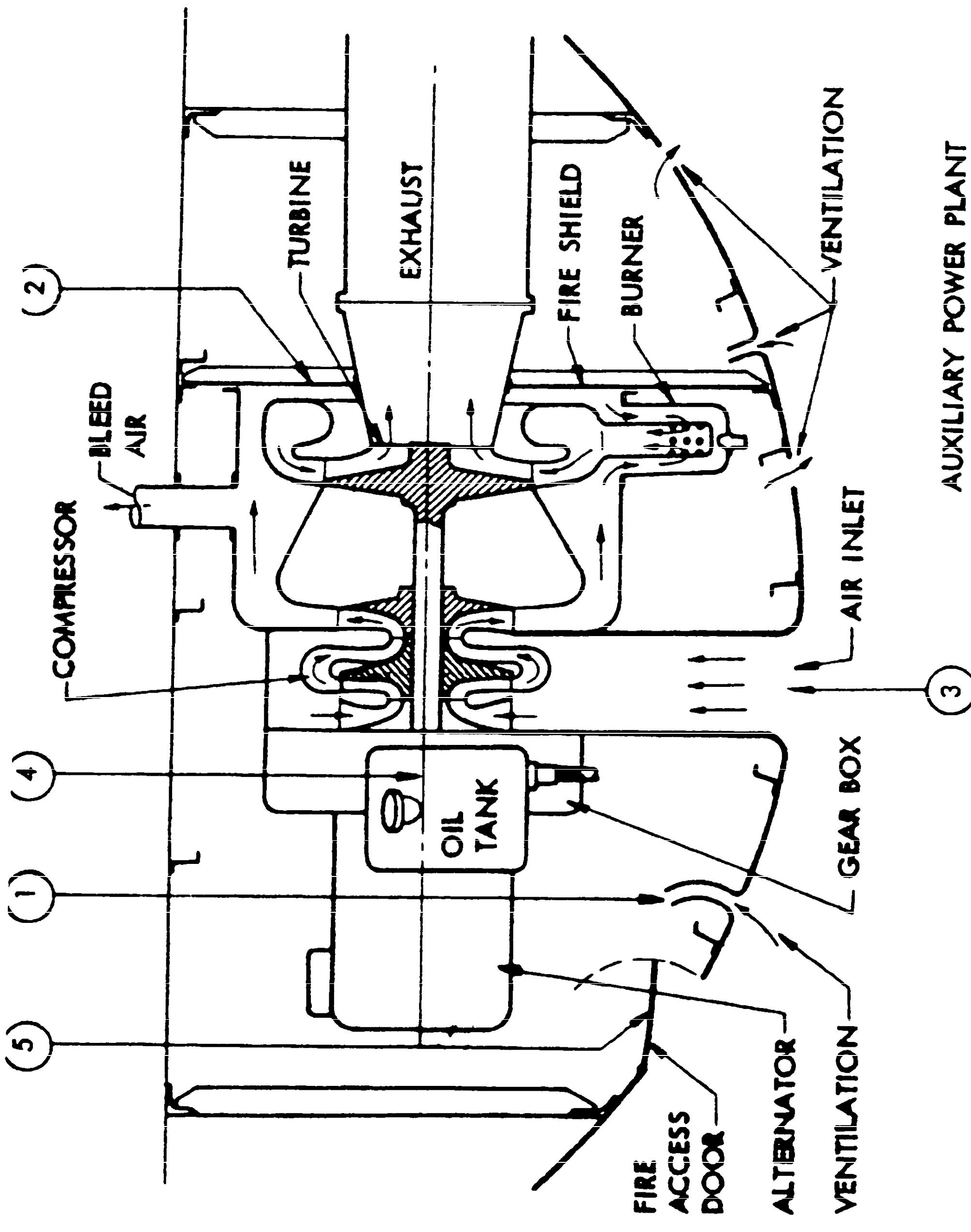
MAIN POWER PLANT
(ALSO SEE FIGURES 24, 25 AND 26)

FIGURE 27 - 2.11 POTENTIAL FIRE ZONES

		PARAGRAPH
(1)	VENTILATION	2.11.3.2
(2)	FIRE SHIELDS	2.11.3.3
(3)	AIR INLETS	2.11.3.4
(4)	OIL TANKS	2.11.3.5
(5)	FIRE ACCESS DOORS	2.11.3.6

2.11 POTENTIAL FIRE ZONES

FIGURE 28



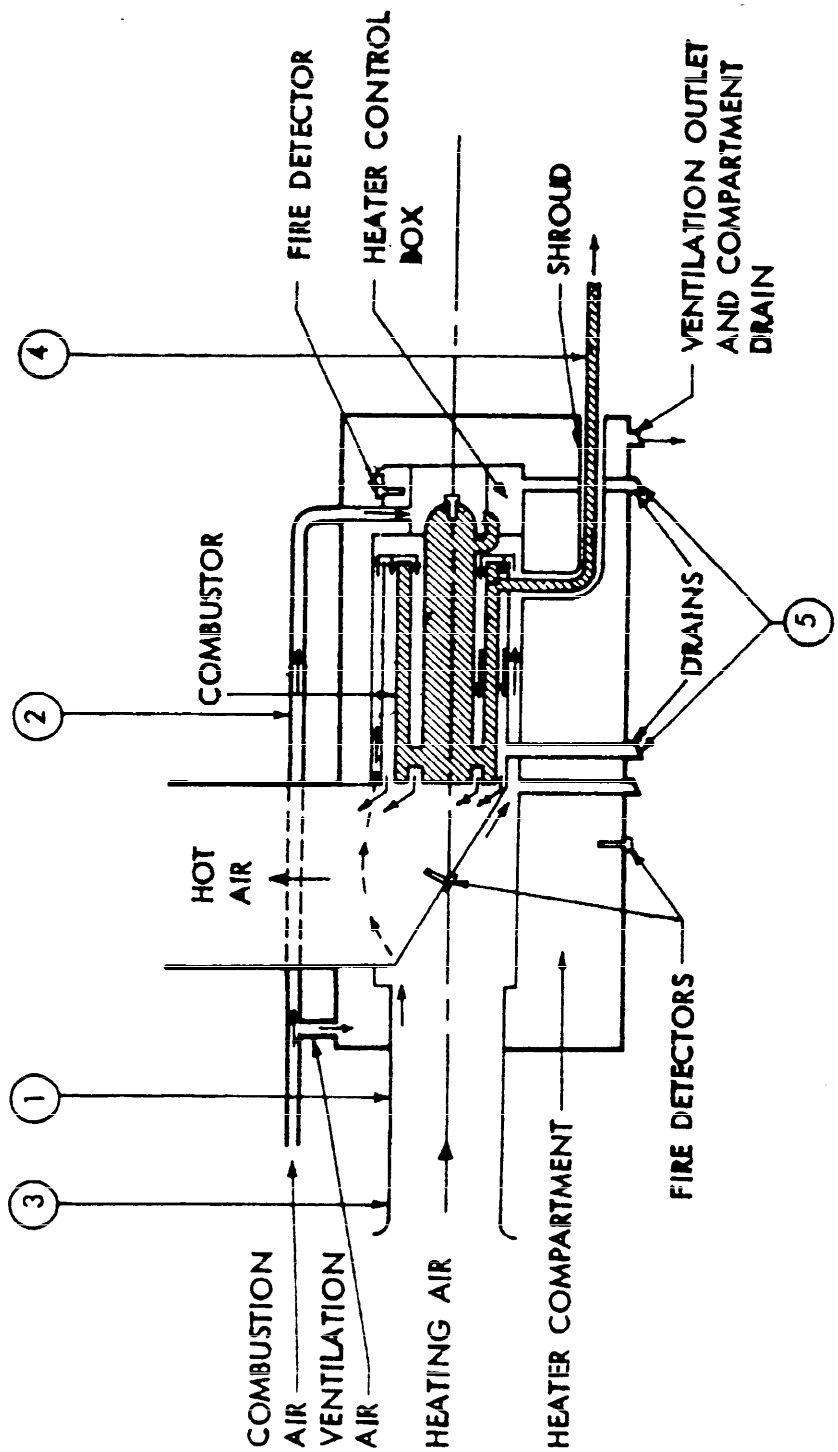
AUXILIARY POWER PLANT
(ALSO SEE FIGURES 24, 25 AND 26)

FIGURE 28 - 2.11 POTENTIAL FIRE ZONES

		PARAGRAPH
(1)	HEATING AIR DUCTS	2.11.4.2
(2)	COMBUSTION AIR DUCTS	2.11.4.3
(3)	AIR INLETS	2.11.4.4
(4)	EXHAUST SYSTEM	2.11.4.5
(5)	DRAINS	2.11.4.6

2.11 POTENTIAL FIRE ZONES

FIGURE 29



COMBUSTION HEATERS
(ALSO SEE FIGURES 24, 25 AND 26)

FIGURE 29 - 2.11 POTENTIAL FIRE ZONES

2.12 FIRE DETECTION (See Figures 30 and 31 on pages 131 and 133)

2.12.1 GENERAL

Fire detection systems shall be provided for all potential fire zones (see 2.11). The detector system should be designed for highest reliability to detect a fire and to minimize the occurrence of false alarms. It is desirable that it only respond to a fire and misinterpretation with a lesser hazard such as engine overtemperature, harmless exhaust gas and bleed air leakage should not be possible. If indication of lesser hazard conditions is desirable, an independent system shall be used. A fire detection system should be reserved for a condition requiring immediate measures such as engine shutdown, fire extinguishing, or bailout. A separate detector system shall be provided for each fire zone. One single detector system may be provided for two or more fire zones if a fire or overheat condition in either zone requires the same emergency procedure. Fire detection systems shall not be incorporated with other systems, which if failed, could prevent normal operation of the detector system. Diodes shall not be used to separate detector systems.

2.12.2 TYPES OF DETECTORS

Fires or dangerous fire conditions shall be detected by one or any combination of the following techniques:

(1) Radiation sensing detectors: Radiation detectors operate on the principle of sensing visible flame. They are most useful where the material present will burn brightly soon after ignition, such as in a powerplant accessory section.

(2) Continuous type fire detectors. These detector systems employ continuous lengths of heat sensing wires and can be used wherever the hazard is evidenced by temperatures exceeding a predicted set value. Also, some continuous type systems operate on a temperature rate-of-rise principle in addition to a discrete level. For alarm temperature setting and system response, refer to 2.12.5.

(3) Unit type. As the name implies, the unit type detector is a single element, which operates on a heat sensing principle. Unit type detectors are most effectively used in small compartments or confined passages. The use of unit detectors must be negotiated with BuWeps.

2.12.3 SPECIFICATIONS

Fire warning systems with the exception of the unit type and smoke and carbon monoxide detectors shall comply with the requirements of their applicable specification: Fire Warning Systems, Continuous, Aircraft; Test and Installation of, MIL-F-7872; Fire Warning Systems, Aircraft, Radiation Sensing Type, Test and Installation of MIL-F-23447.

2.12.4 DETECTOR SYSTEM REQUIREMENTS

2.12.4.1 FUNCTION

The detector system should:

(1) Indicate fire immediately after ignition and show the compartment in which the fire is located

(2) Remain "on" for the duration of the fire

(3) Indicate when the fire is out

(4) Indicate re-ignition of a fire

2.12.4.2 SYSTEM RELIABILITY

The system should be designed to minimize the occurrence of false warnings and of being inoperative under any flight or ground conditions.

2.12.4.3 CONSTRUCTION

The detector system should be of rugged construction, to resist maintenance handling, exposure to fuel, oil, dirt, water, cleaning agent, extreme temperatures, fire, vibration, salt air, fungus, and altitude. The detector units should be light in weight, small and compact, and readily adaptable to desired positions of mounting.

2.12.4.4 OPERATION

Each detector system should actuate an individual light or lights which are in the direct line of sight of the crew member responsible for execution of the emergency procedure. The lights shall indicate the location of the fire. If these indicator lights are not also in the direct line of sight of the remaining cockpit crew members, master warning lights shall be provided which are in the direct line of sight of these crew members. The master warning light shall be illuminated when any indicator light is illuminated.

When overheat detectors as well as fire detectors are used, the warning system shall be distinctly different such as a steady light for fire, and a flashing light for overheat.

2.12.4.5 FIRE RESISTANCE

Detector system components located within and close to potential fire zones shall withstand, without failure, a 2000°F flame for a period not less than 5 minutes.

2.12.4.6 SYSTEM ROUTING

Detector system components for any fire zone shall not pass through or be close to other fire zones, unless they are protected against false warnings and being rendered inoperative from fires in such zones. This requirement shall not be applicable with respect to zones which are simultaneously protected by the same warning and extinguisher system.

2.12.4.7 MULTI-ENGINE INSTALLATIONS

Two or more engines shall not be dependent upon a single detector system. The installation of common zone detection equipment prevents the detection system from distinguishing between the engine installations, necessitating shutting down both engines in the event of fire.

2.12.5 DETECTOR LOCATION

Heat sensing fire detector sensing elements shall be located as close as practicable to sources of flammables such as fuel strainers, and ignition sources such as generators and alternators, where the proximity of these flammables and ignition sources constitute a possible source of fire. They also should be located at points where the ventilation air leaves the compartments so that temperature indication can be obtained with a minimum length or minimum number of sensing elements. Radiation detectors should be located such that any flame within the compartment is sensed, considering the cone of vision of the sensor and the fact that direct flames as well as reflected flames are sensed. Detectors should not be located directly adjacent to combustion sections or any area where in the event of "burnthrough," the high temperature would incapacitate the system prior to providing alarm. They should however be located so that they will indicate the "burnthrough."

2.12.6 DESIGN REQUIREMENTS

The minimum allowable bend radius of continuous type sensing elements, as recommended by the manufacturer, shall be rigidly adhered to. Mounting brackets should be as short as possible, and spaced according to the manufacturer's recommendation in order to prevent damage by vibration. Where sensors are located in the area of high pressure ratio exhaust systems, special provisions, such as close interval support should be made to prevent destructive-sensor vibration.

Sensor systems shall be designed so that it is not necessary to disassemble or remove sections to perform frequent maintenance on the aircraft. Connectors should be readily accessible.

Connectors used in firewalls shall remain intact and prevent flame penetration for at least 15 minutes when exposed to a 2000°F flame and the vibration of application. Firewall connectors and connectors used in or close to potential fire zones shall be able to remain operable for at least 5 minutes when subjected to a 2000°F flame and the vibration of application. All connectors used in the detector systems shall be environment-free. Connectors used in areas which are not potential fire zones shall comply with specification MIL-C-26482. Exposed terminal blocks shall not be used in any portion of the system.

Electric wires or components for the detector system which are located in or close to a fire zone shall withstand a flame of 2000°F for five minutes under the vibration of application.

		PARAGRAPH
(1)	GENERAL	2.12.1
(2)	FIRE RESISTANCE	2.12.4.5
(3)	DETECTOR LOCATION	2.12.5
(4)	DESIGN REQUIREMENTS	2.12.8

2.12 FIRE DETECTION

FIGURE 30

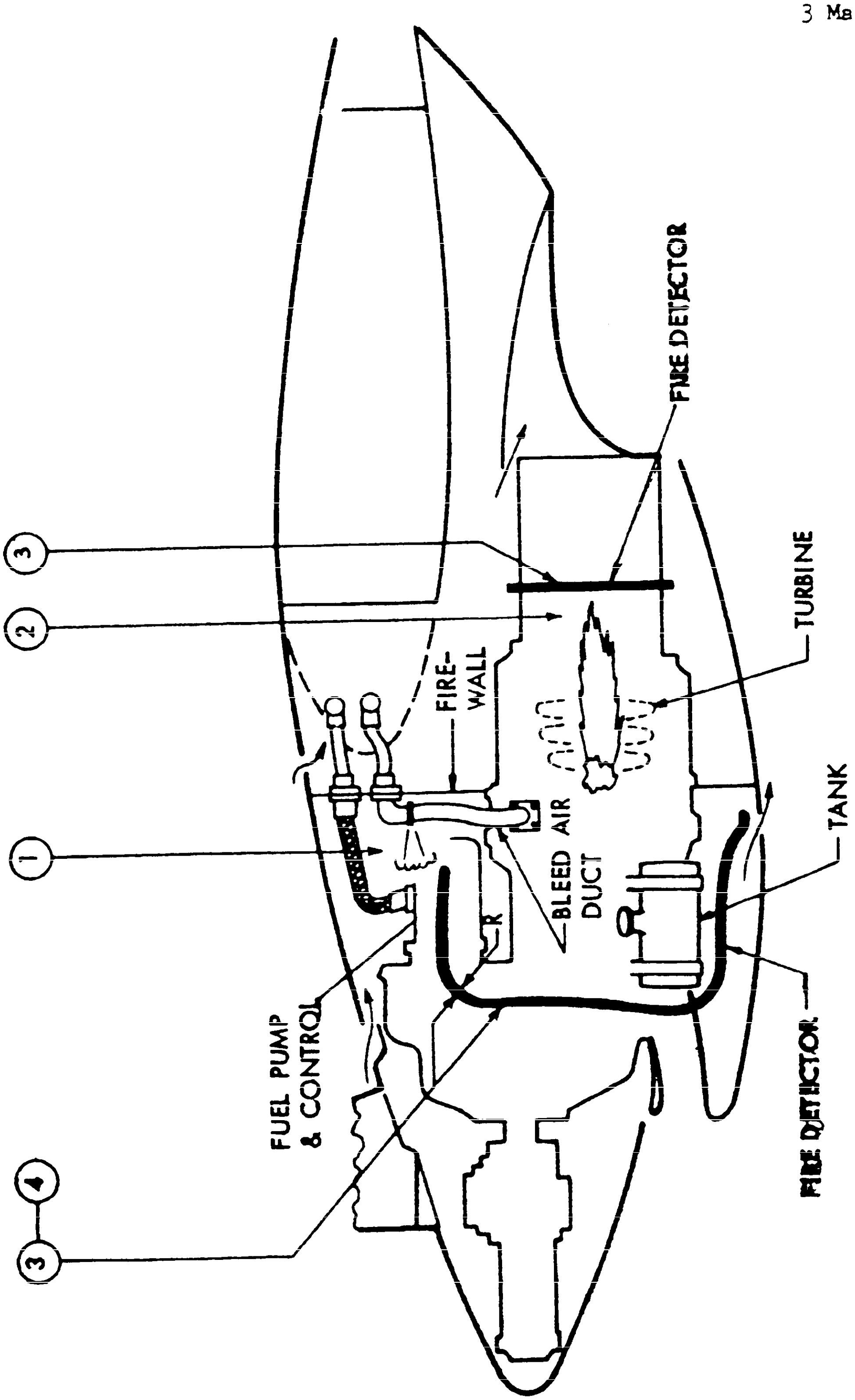


FIGURE 30 - 2.12 FIRE DETECTION

		PARAGRAPH
(1)	OPERATION	2.12.4.4
(2)	SYSTEM ROUTING	2.12.4.6
(3)	MULTI-ENGINE INSTALLATIONS	2.12.4.8
(4)	DETECTOR LOCATION	2.12.5
(5)	DESIGN REQUIREMENTS	2.12.6

2.12 FIRE DETECTION

FIGURE 31

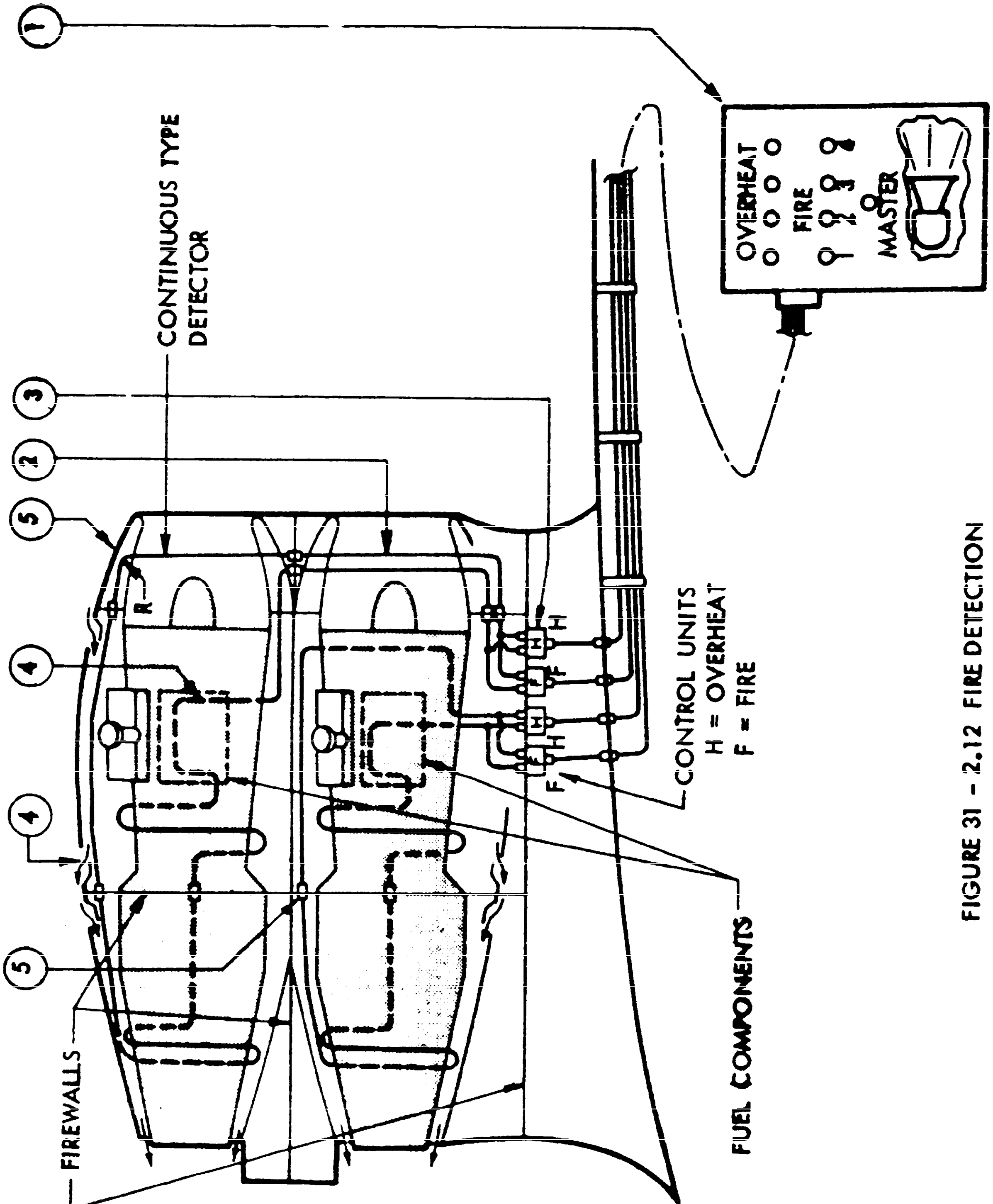


FIGURE 31 - 2.12 FIRE DETECTION

2.13 FIRE EXTINGUISHING (See Figures 34 and 35 on pages 143 and 145)

2.13.1 GENERAL

A fixed fire extinguishing system shall be provided only if required by the airplane detail specification. Fire extinguishing systems in single engine aircraft are not required except for first procurement of a small quantity of a new model aircraft.

Fire extinguishing systems which incorporate a second discharge when required per MIL-E-22285 shall be so designed that the first discharge is directed to its respective compartment without requiring positioning of valves to select the compartment.

The discharge openings of the lines shall not be threaded so as to minimize the possibility of closure by caps which could be left on by oversight.

2.13.2 SPECIFICATIONS

Fire extinguishing systems shall comply with the requirements of the following specifications: EXTINGUISHING SYSTEM, FIRE AIRCRAFT, HIGH-RATE-DISCHARGE TYPE, INSTALLATION AND TEST OF MIL-E-22285; and CONTAINER, AIRCRAFT FIRE EXTINGUISHING SYSTEM, BROMOTRIFLUOROMETHANE, CF_3BR, MIL-C-22284.

2.13.3 SYSTEM MATERIALS

Stainless steel or other material with equivalent fire barrier qualities shall be used for all portions of extinguishing systems within and close to potential fire zones with the exception of discharge tubing in cargo and baggage compartments, which may be of aluminum alloy, and valve seals which may be of an elastic material. This material shall not react chemically with the agent and cause leakage. Some seal materials which are compatible and have been used with Bromotrifluoromethane are summarized below:

ELASTOMER	SPEC	TEMP	% SWELL	COMP SET	REMARKS
Perbunan 26	MIL-R-7362 MIL-R-6855 CLASS I	-65 to 250°F	0	Good	Poor Storage & Ozone Properties
Neoprene Type GN-A	MIL-R-6855 CLASS II	-65 to 250°F	0	Good	Good Weathering, Ozone & Storage Resistance
Hycar OR-15	MIL-R-7362 MIL-R-6855 CLASS I	-65 to 250°F	1	Good	Poor Storage & Ozone Properties
GR-5	NONE	-65 to 225°F	1	Good	Poor Storage & Ozone Properties
Thiokol FA	NONE	-65 to 175°F	1	Poor	Excellent Weathering, Ozone and Storage Properties

2.13.4 CONTAINER LOCATION

Agent containers shall not be located in a fire zone. Ambient temperature around the container shall neither rise to a point causing inadvertent discharge at maximum ambient operating temperature, nor fall below the minimum temperature necessary for adequate rate of discharge. If the container is located adjacent to the area which it protects and could be subjected to overheat in case of a fire, discharge through the relief line into the protected area is acceptable. See 2.13.10. The containers shall be readily accessible for installation, removal and inspection. Containers shall be located in such a manner that the pressure gage is readily visible for inspection by maintenance personnel.

2.13.5 CONTROL SYSTEM

Control systems for fire extinguisher systems shall not pass through any potential fire zone. Any portion of the controls which must be located in a potential fire zone for justifiable reasons shall be able to operate for a period of no less than five minutes when subjected to a 2000°F flame. The fire extinguishing system may be electrically or mechanically controlled.

2.13.6 ELECTRICAL COMPONENTS AND CIRCUITRY

Electrical components and circuitry of fire extinguishing systems should be as simple and reliable as possible and when located in fire zones shall be able to operate for at least 15 minutes when subjected to a 2000°F flame. They should tie into the aircraft electrical system in a manner so that any other electrical failure will not affect the operation of the system. Complete electrical circuits should be insured by providing direct ground contact for all electrical components such as agent containers, solenoids, directional valves, etc. The reliability of grounding through tubing or support structure is poor because the anodized fittings offer considerable electrical resistance. Relays should be avoided if possible but if relays must be used, two independent relays shall be used in such a way that failure of one relay does not cause malfunction of the system. When the discharge triggering device is electrically operated (squib or solenoid), two such devices with two separate and independent electrical circuits from the circuit breaker outward should be provided. A single circuit with single relay is acceptable for protection of equipment which is used on the ground only. Electric control systems should be designed so that accidental grounding of the circuit through a discharged squib does not cause malfunction of other circuits of the system. Care should be taken to make certain the power supply is not affected by fire control procedures. For prevention of inadvertent triggering of squib operated systems, see section on electro-explosive systems (2.7.13).

2.13.7 SQUIBS

Squibs in container discharge valves shall be protected against inadvertent discharge due to heat influx from a fire if such discharge jeopardizes the intended function of the extinguisher system. Any squib should be an integral part of the electric connector or other provisions shall be made to insure that the squib(s) cannot be left out when the connector is attached to the container.

2.13.8 PRESSURE INDICATORS

Pressure indicators shall be of such design as to enable reading with an accuracy of plus or minus 30 psi or better. An indicator with temperature compensation should be used whenever possible. If temperature compensated gages are not used, a placard shall be placed near the gage to provide container pressure variation with agent temperature. (See Figure 32.) For maintenance purposes, this placard shall be used as follows: When the pressure indication is below the value shown on the placard at the estimated agent temperature, the container shall be removed and weighed. If the weight is below the weight indicated on the container, the container shall be recharged and leakage-checked. The container shall be charged with nitrogen to 600 psi +25 -0 at 70°F as indicated on the container gage.

2.13.9 AGENT QUANTITY

Agent quantity may be determined emperically by use of the formulas presented in MIL-E-22285. Note that the specification requires 15 percent of additional agent trapped in the container and lost in wetting the discharge tubing.

It should be noted that the quantity formulas are emperical aids for the designer. The final adequacy of the system shall be determined by actual test, to assure that the required agent concentration and time of concentration throughout the compartment are attained as required in MIL-E-22285. In these tests special attention should be given to sheltered areas and areas of high airflow by judicious placement of concentration detectors to assure that adequate agent concentration in these areas is attained.

2.13.10 SAFETY OUTLET

Each container shall be furnished with a safety outlet incorporating a frangible disc type diaphragm or a fusible alloy type plug in order to relieve excessive pressure that may occur in the container. The blowout pressure of the disc should be equal to the container pressure at the maximum ambient temperature plus 50°F but not less than 210°F. A curve of container pressure variation with temperature is presented in Figure 33. The fusible plug relief setting shall be 50°F in excess of the maximum ambient temperature but not less than 210°F.

The discharge line from the pressure relief connection shall terminate outside the aircraft in a location convenient for inspection on the ground. An indicator shall be provided at the discharge end of the line to provide a visual indication when the container has been discharged through the relief line. The indicator shall be on the outside of the aircraft and readily visible from the ground. If the container pressure gage is readily accessible for checking, the discharge indicator is not necessary. If the container is located adjacent to the area which it protects and could be subjected to overheat in the case of a fire, the discharge line from the pressure relief connection may be terminated in the protected area to afford some protective capability. However, this type of installation must incorporate a pressure gage readily visible from the ground to show when the container has been discharged, and it must have BuWeps approval.

2.13.11 NITROGEN VOLUME

Determination of required nitrogen volume in the container is obtained by means of the following formula:

$$V_N = \frac{200}{P_b} V_S$$

Where: V_N = Volume of N_2 in container at pressure P_b (cu. in.)

P_b = Container total pressure at lowest expected environmental temperature * (psia)

V_S = Total volume of system (container plus lines plus valves) (cu. in.)

* For lowest pressure, see Figure 2.

2.13.12 HAND FIRE EXTINGUISHERS

See 2.19.12.

FIRE EXTINGUISHER BOTTLES
FOR REMOVAL AND INSTALLATION SEE MAINTENANCE MANUAL

WARNING
THESE EXTINGUISHER BOTTLES ARE HIGH PRESSURE CONTAINERS
HANDLE WITH CARE

BOTTLE MUST BE REMOVED AND CHECKED IF PRESSURE GAGE READING IS BELOW MINIMUM FOR TEMPERATURES GIVEN IN TABLE BELOW

DEGREES FAHRENHEIT	-40	-20	0	20	30	40	50	60	70	80	90	100	110	120	140
DEGREES CENTIGRADE	-40	-29	-18	-7	-1	5	10	16	21	27	32	38	43	49	60
	PRESSURE PSI														
BROMOTRIFLUOROMETHANE	332	365	403	449	475	502	532	565	600	640	682	727	775	825	935

FIGURE 32 - PLACARD-HRD FIRE EXTINGUISHER BOTTLES

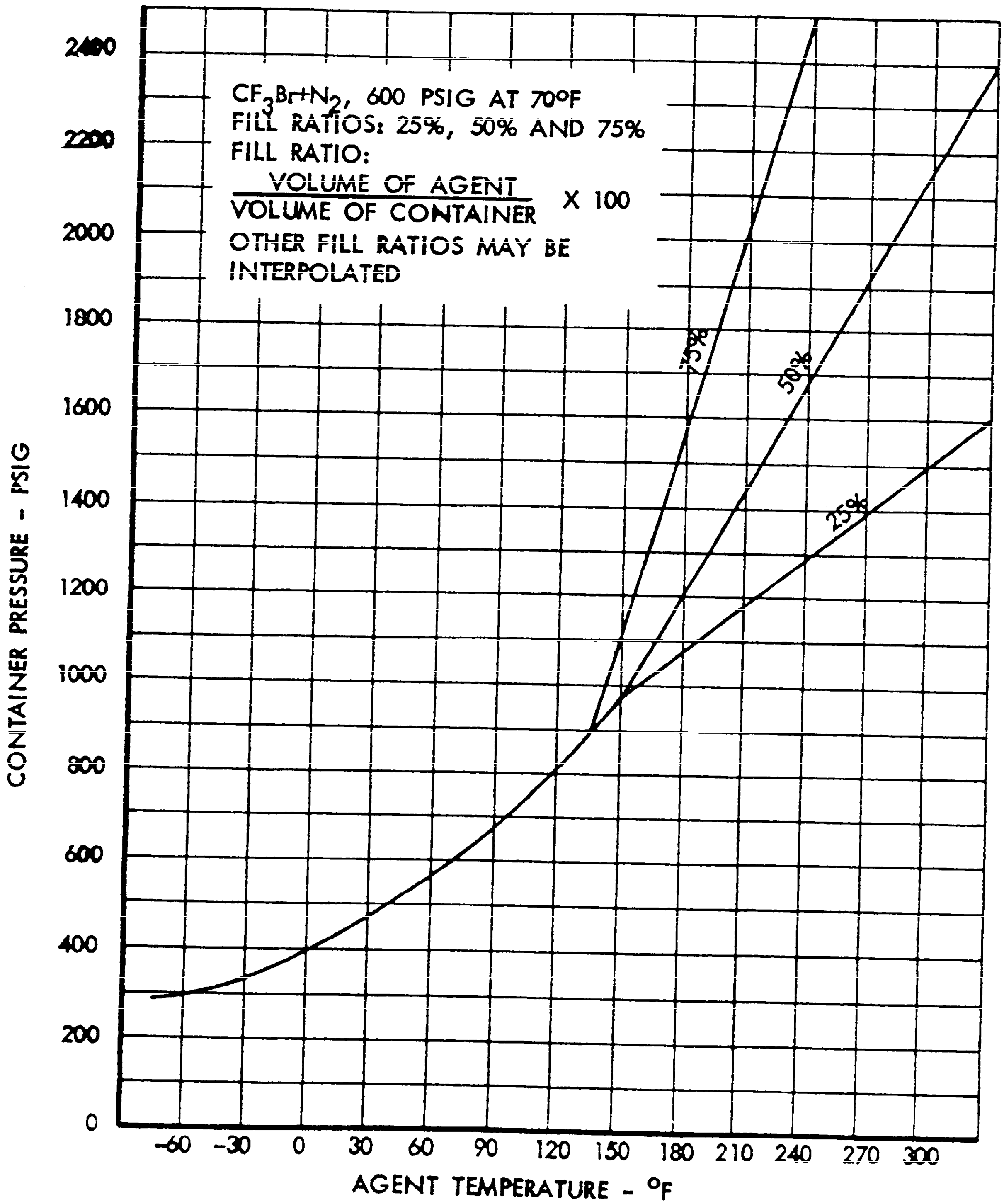


FIGURE 33 - CONTAINER PRESSURES OF CF_3 Br & N_2 VS TEMP.

		PARAGRAPH
(1)	GENERAL	2.13.1
(2)	CONTAINER LOCATION	2.13.4
(3)	ELECTRICAL COMPONENTS AND CIRCUITRY	2.13.6
(4)	SQUIBS	2.13.7
(5)	PRESSURE INDICATORS	2.13.8
(6)	SAFETY OUTLET	2.13.10

2.13 FIRE EXTINGUISHING

FIGURE 34

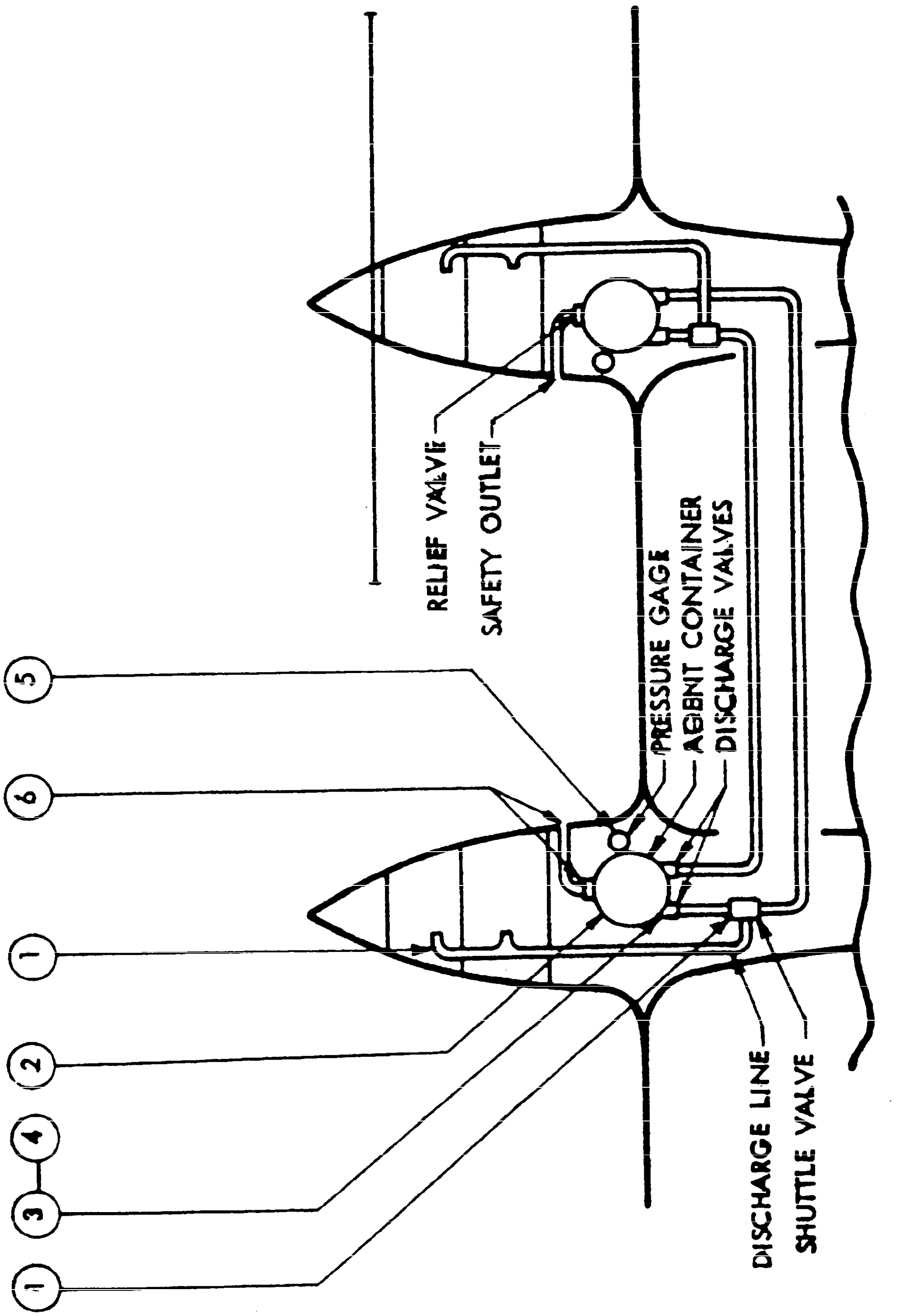


FIGURE 34 - 2.13 FIRE EXTINGUISHING

		PARAGRAPH
(1)	ELECTRICAL COMPONENTS AND CIRCUITRY	2.13.6
(2)	SQUIBS	2.13.7

2.13 FIRE EXTINGUISHING

FIGURE 35

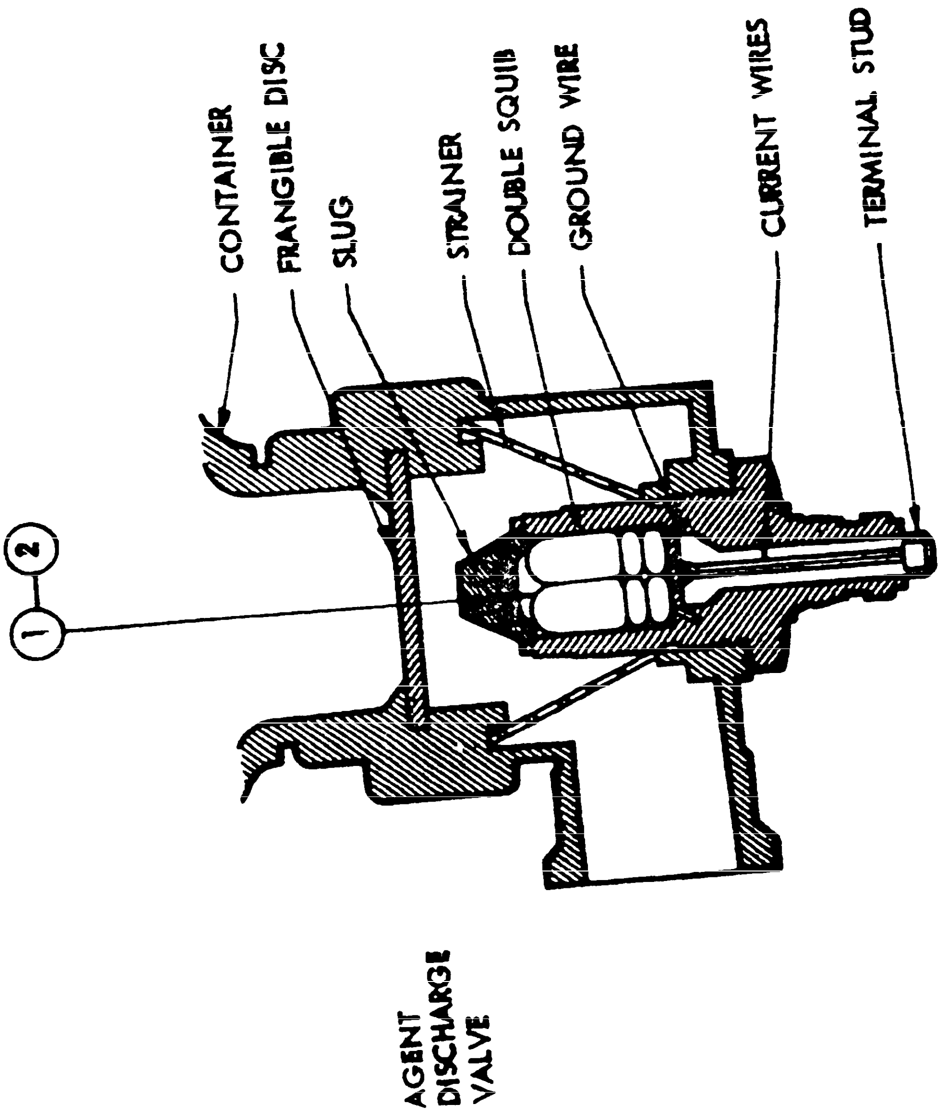


FIGURE 35 - 2.13 FIRE EXTINGUISHING

2.14 EMERGENCY FIRE PROVISIONS (See figures 36, 37 and 38 on pages 151, 153 and 155)

2.14.1 GENERAL

After a fire and its location have been detected it is necessary to perform the correct emergency operation immediately and in the proper sequence to effect prompt extinguishment. For this reason the basic design of the emergency system and the arrangement of the handles, switches and circuitry should be such that the emergency procedure is as simple and clear as possible. Each new aircraft should be analyzed to determine the type of fire control system which should be incorporated, considering such factors as:

(1) The number of emergency operations required for the specific aircraft.

(2) The ability of the pilot or crew to perform the required operations in the required time.

(3) The compromises involved in a more complex fire fighting control system.

(4) System cost and weight.

2.14.2 EMERGENCY OPERATIONS

Emergency operations and their sequencing may vary with different aircraft. However, in general, the following emergency operations are required in the event of fire:

2.14.2.1 ENGINE FIRE

(a) Feather propeller if applicable.

(b) Shut off engine.

(c) Apply engine brake if applicable.

(d) Shut off all nonessential flammable fluid to the engine (fuel, oil, hydraulics, anti-icing fluid, etc.). Essential fluids are those required to: prevent further damage to the engine; allow safe continuation of flight; allow safe auto-rotation landing; or provide for accomplishing required emergency procedures.

(e) Shut off ventilating and cooling air if required. (See potential fire zones 2.11.)

(f) Shut off bleed air from other engines if they can discharge into a fire zone such as in the case of a bleed air duct burnthrough in a fire zone. (See potential fire zone 2.11.1.2.3 and 2.11.1.4.)

(g) De-energize electric circuits to the engine compartment or nacelle (with the exceptions of the feathering, fire fighting and essential circuits).

(h) Select and arm the circuit for discharge of the extinguishing agent.

(i) Actuate fire extinguishing system.

2.14.2.2 EQUIPMENT FIRES

(a) Shut off equipment.

(b) Shut off all flammable fluids to the equipment.

(c) Shut off ventilating and cooling air if required (see potential fire zones 2.11).

(d) De-energize electric circuits to the equipment compartment.

(e) Select and arm the circuit for discharge of the fire extinguishing agent.

(f) Actuate fire extinghisher.

A single emergency handle (panic handle) shall be used to perform the above operations in their proper sequence, with the exception of agent discharge, in every region possibly affected by the fire (which may consist of multiple zones), and also initiate necessary operational functions evolving from the shutdown. If engine rotation cannot be stopped and if a major damage of the engine must be expected from oil starvation, the emergency procedure should incorporate a separate step for closure of the oil valve. On uncomplicated installations, a multiple control system may be used, however, only after approval is obtained from BuWeps.

2.14.3 EMERGENCY HANDLE

The emergency handle should be red in color and have the words "FIRE-PULL" engraved or embossed thereon, or the words should be integrally lighted in accordance with MIL-STD-411A. Each emergency handle should be identified by adequate marking, adjacent to the handle, to indicate the potential fire zone associated with the control.

Single emergency handles should require 20 to 25 pounds of pull to operate them. The operation of the emergency handle should either be reversible, or reactivation of the shut-down engine shall be established by other means.

The cockpit installation and location shall be according to MIL-STD-203 for fixed wing aircraft, or MIL-STD-250 for helicopters.

2.14.4 INDICATOR LIGHTS

The indicator lights which are illuminated by the detector system should be arranged close to the emergency handle so that association with the emergency handle is obvious, or they should be incorporated into the emergency handle in accordance with MIL-STD-411A.

The indicator lights shall stay illuminated as long as a fire detection persists.

Dimming provisions shall not be provided for the indicator lights.

2.14.5 LAMPS

Where light signals are used for fire warning, each signal shall include at least two MS 2531-313 lamps, or at least two MS or AN lamps of equivalent wattage.

2.14.6 MASTER FIRE WARNING LIGHTS AND AUDITORY SIGNALS

See 2.12.4.4.

2.14.7 FIRE EXTINGUISHING

When fire extinguishing is provided the switches for its activation shall be located so that they are covered by the emergency handles and cannot be activated before the emergency handle is pulled.

When a reserve supply of agent is provided (second shot) the second switch or handle should be guarded or a separate transfer switch should be provided so that accidental discharge of both shots simultaneously is unlikely. The system shall be designed so that the first shot can be applied to the desired zone without activation of a transfer device and activation of a second shot is not possible before transfer is accomplished.

		PARAGRAPH
(1)	EMERGENCY HANDLE	2.14.3
(2)	INDICATOR LIGHTS	2.14.4
(3)	MASTER FIRE WARNING LIGHTS AND AUDITORY SIGNAL	2.14.6
(4)	FIRE EXTINGUISHING	2.14.7

2.14 EMERGENCY FIRE PROVISIONS

FIGURE 36

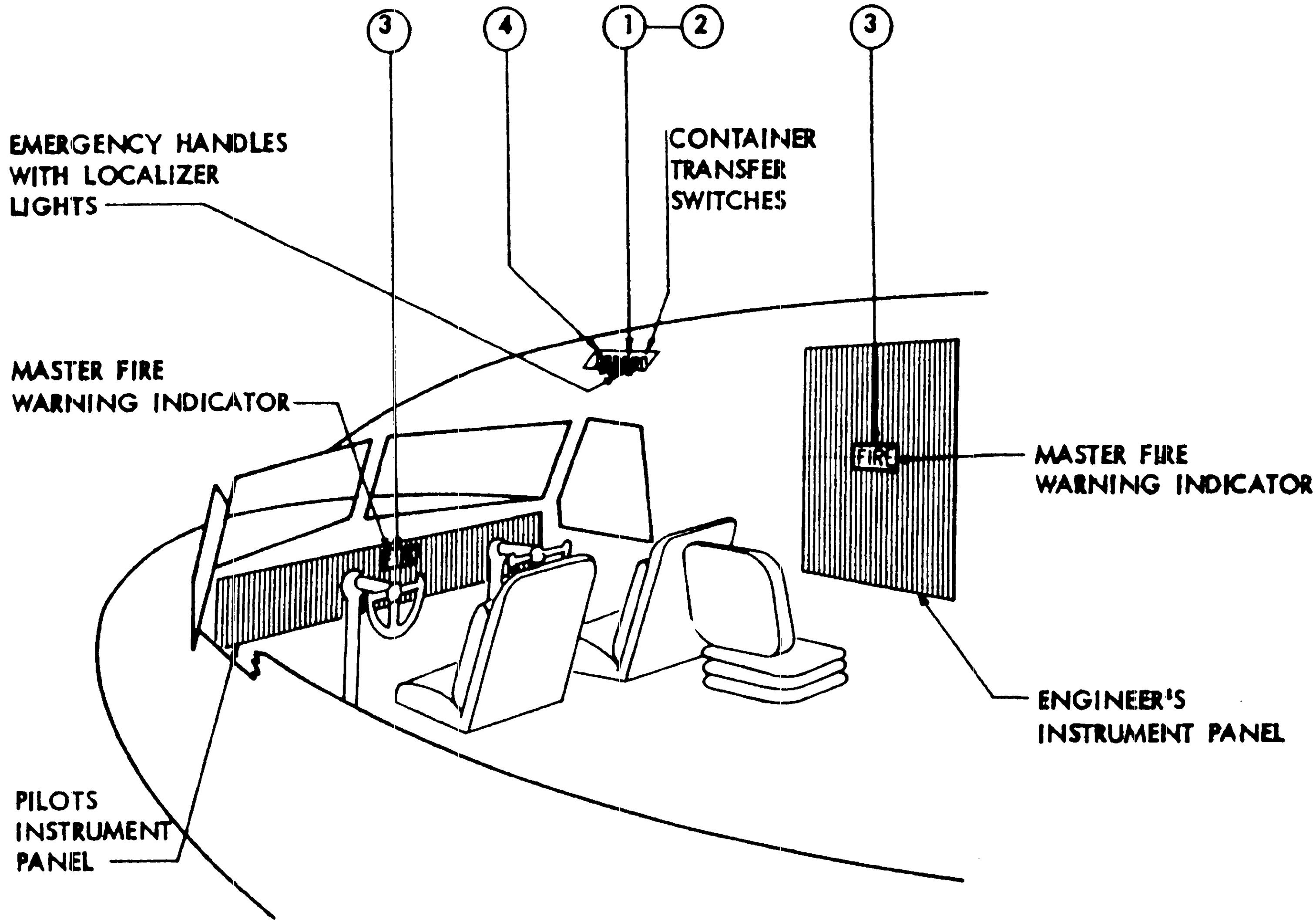


FIGURE 36 - 2.14 EMERGENCY FIRE PROVISIONS

		PARAGRAPH
(1)	EMERGENCY OPERATIONS	2.14.2
(2)	EMERGENCY HANDLE	2.14.3
(3)	INDICATOR LIGHTS	2.14.4
(4)	LAMPS	2.14.5
(5)	FIRE EXTINGUISHING	2.14.7

2.14 EMERGENCY FIRE PROVISIONS

FIGURE 37

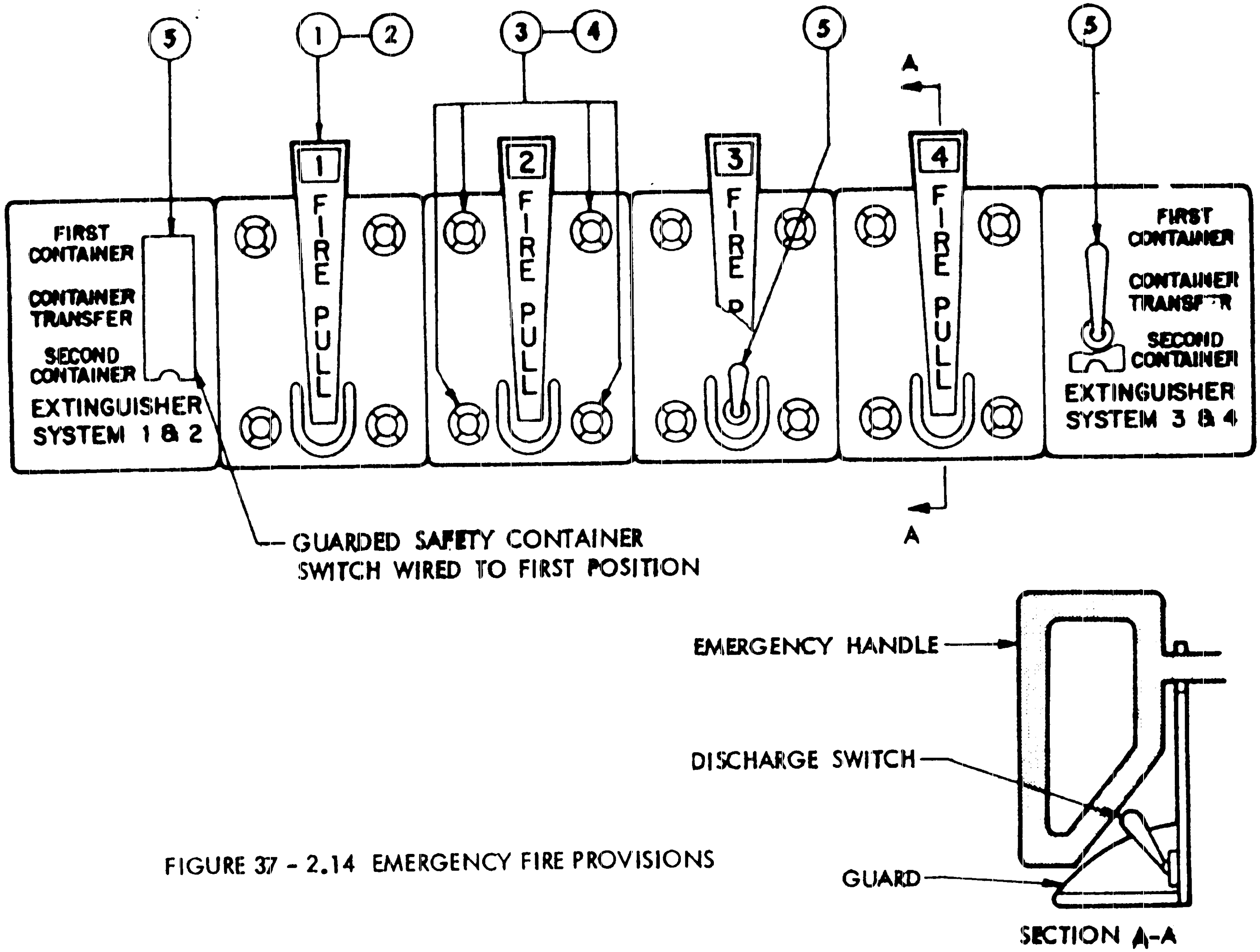


FIGURE 37 - 2.14 EMERGENCY FIRE PROVISIONS

		PARAGRAPH
(1)	FEATHER PROPELLER	2.14.2.1 (a)
(2)	SHUT OFF FLAMMABLE FLUIDS	2.14.2.1 (d)
(3)	SHUT OFF VENTILATING AND COOLING AIR	2.14.2.1 (e)
(4)	SHUT OFF BLEED AIR FROM OTHER ENGINES	2.14.2.1 (f)
(5)	DE-ENERGIZE ELECTRIC CIRCUITS	2.14.2.1 (g)
(6)	SELECT AND ARM FIRE EXTINGUISHING SYSTEM	2.14.2.1 (h)

2.14 EMERGENCY FIRE PROVISIONS

FIGURE 38

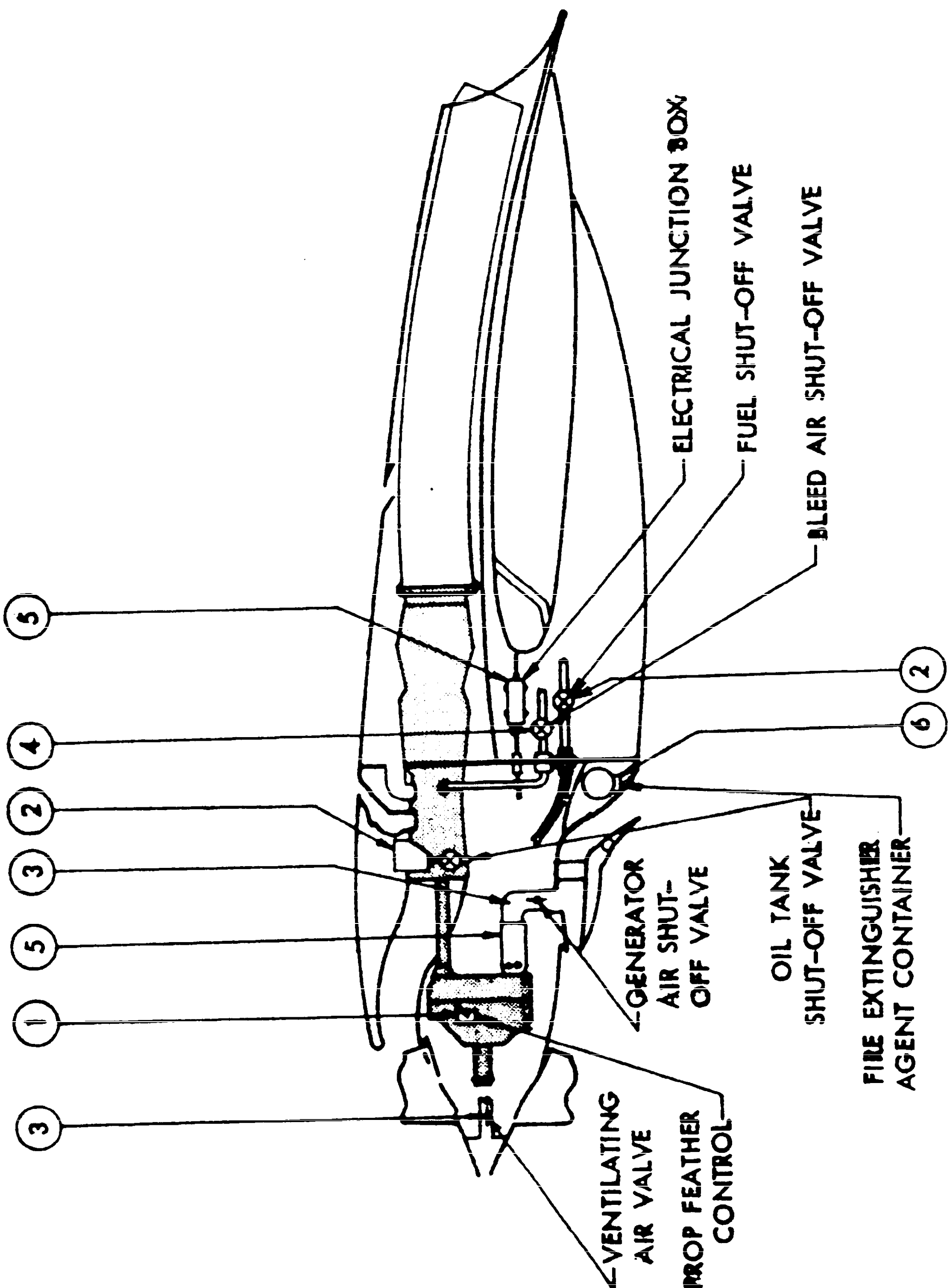


FIGURE 3B - 2.14 EMERGENCY FIRE PROVISIONS

2.15 CRASH FIRE PREVENTION (See Figures 39 and 40 on pages 161 and 163)

2.15.1 FUEL TANK LOCATION

Wing fuel tanks should be located behind heavy spars and leading edges to give them maximum protection against horizontal crash impact loads. Integral fuel tanks in and close to the wing roots are exposed to high bending and twisting loads in a crash landing and should be avoided, whenever practical.

Fuselage fuel tanks should not extend close to the bottom of the fuselage and should be protected by heavy bottom structure, whenever practical. If fuel tanks must extend close to the bottom of the fuselage, tank fittings and tank accessories should not protrude from the tank surface, or they should be so designed that they tend to recede into the tank without leakage in a crash. Fuel tanks should, whenever practicable, be located so that a collapsing landing gear does not result in a major fuel tank leakage.

2.15.2 FUEL TANK DESIGN

Prevention of major fuel tank leakage caused by fuel inertia loads in the tanks during a crash landing should be considered in tank design to the greatest practicable extent. Fuel tanks which withstand, without major leakage, the same inertia loads as the seats of the occupants are desirable for a balanced crash safety level of an aircraft.

Bladder cells should be considered in locations where damage to fuel tanks is likely in a belly landing. Three and four ply nylon fabric with rubber liner and with plies laminated on the bias have proven to be very suitable for cell construction due to their inherently high elongation values and strength.

2.15.3 DRIP FENCES

Engine nacelles and pylons should be constructed so that fuel leakage from ruptured wing fuel tanks, which is carried spanwise by wetting conduction, is prevented from entering an engine compartment. The nacelle and pylon skin joint with the lower wing surface, and pylon and nacelle skins should be as liquid tight as practical, and necessary to dispose of major leakage of fuel along the skin to the ground.

2.15.4 FLAMMABLE FLUID LINES

Flammable fluid lines should be routed so that they are protected by structure from impact. Fuel and hydraulic lines should not be located in the leading edge section. Flexible flammable fluid lines with ample slack should be used in areas where deformations are likely to occur in a crash.

2.15.5 FLAMMABLE FLUID ACCESSORIES

Oil tanks, oil cooler, fuel controls and fuel strainers should not be located at points of contact with ground in a belly landing.

2.15.6 FRICTION SPARKS

Metals which have low friction spark tendency should be used in areas of the aircraft which are in contact with the ground in a belly landing. The spark characteristics of the three most common construction materials and their ignition capabilities are as follows:

Material	Spark Appearance	Ignition Capability
Aluminum	No Sparks	None
Steel	Thin Orange Streaks	Inconsistent
Titanium	Bright	Consistent

2.15.7 LANDING LIGHTS

The filaments of landing lights have been proven to be hot enough to ignite flammable vapors after the glass bulbs are shattered by crash impact. Landing lights should, therefore, be located where they are not exposed to crash impact and where they are not likely to come in contact with flammable vapors. A location in the vicinity of the trailing edge is considered satisfactory.

2.15.8 ELECTRIC BATTERIES

Electric batteries which can be an ignition source should be located where they are unlikely to be exposed to crash damage. Battery retention should be designed to withstand the same acceleration loads as the crew seats.

2.15.9 CRASH INERTING

Inerting of engines or other areas for the purpose of ignition prevention shall not be considered, unless required by aircraft detail specification or unless approved by BuWeps.

		PARAGRAPH
(1)	FUEL TANK LOCATION	2.15.1
(2)	FUEL TANK DESIGN	2.15.2

2.15 CRASH FIRE PREVENTION

FIGURE 39

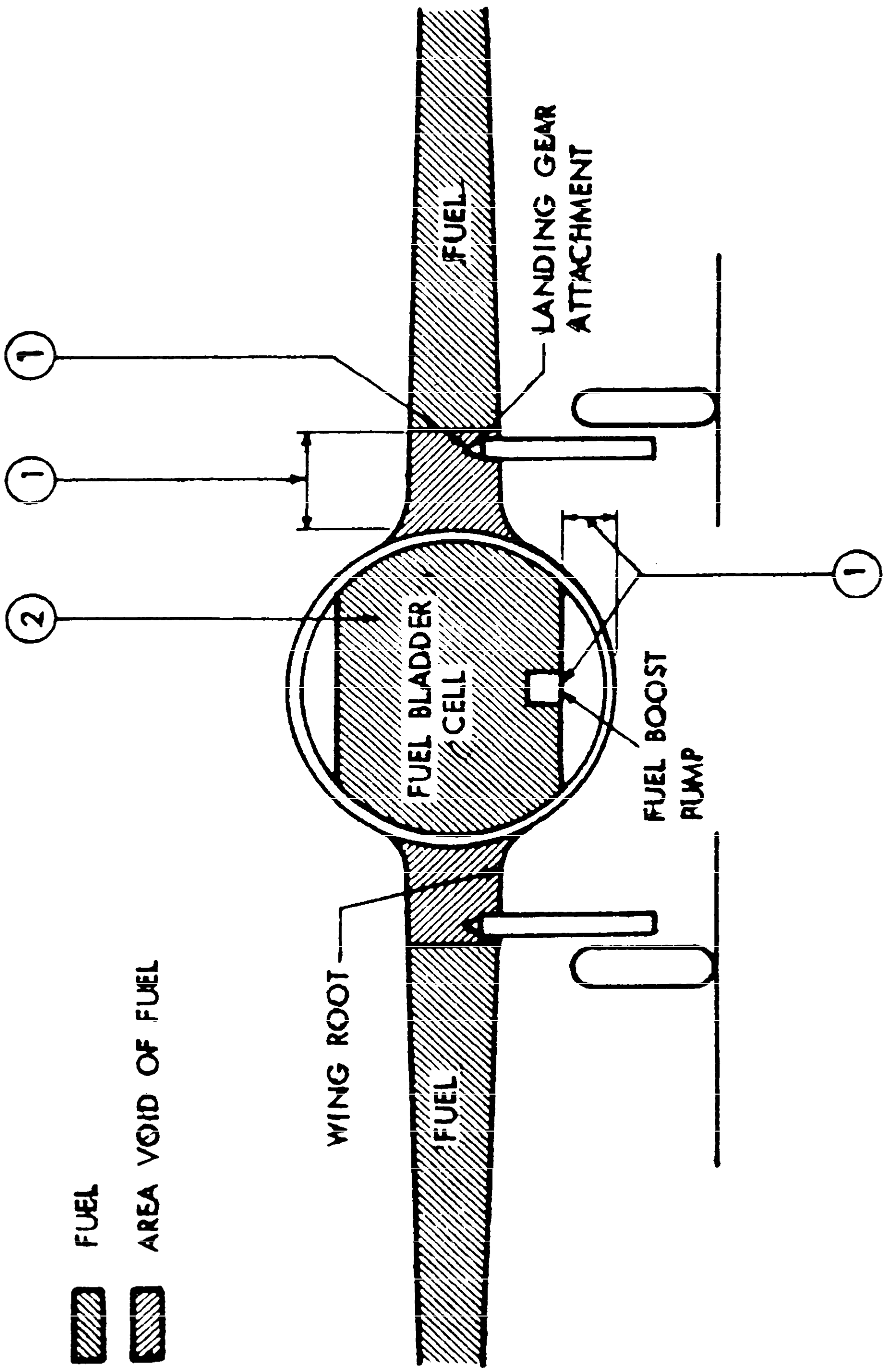


FIGURE 39 - 2.15 CRASH FIRE PREVENTION

		PARAGRAPH
(1)	FUEL TANK LOCATION	2.15.1
(2)	FUEL TANK DESIGN	2.15.2
(3)	FLAMMABLE FLUID LINES	2.15.4
(4)	FLAMMABLE FLUID ACCESSORIES	2.15.5
(5)	FRICTION SPARKS	2.15.6
(6)	LANDING LIGHTS	2.15.7
(7)	ELECTRICAL BATTERIES	2.15.9
(8)	CRASH INERTING	2.15.9

2.15 CRASH FIRE PREVENTION

FIGURE 40

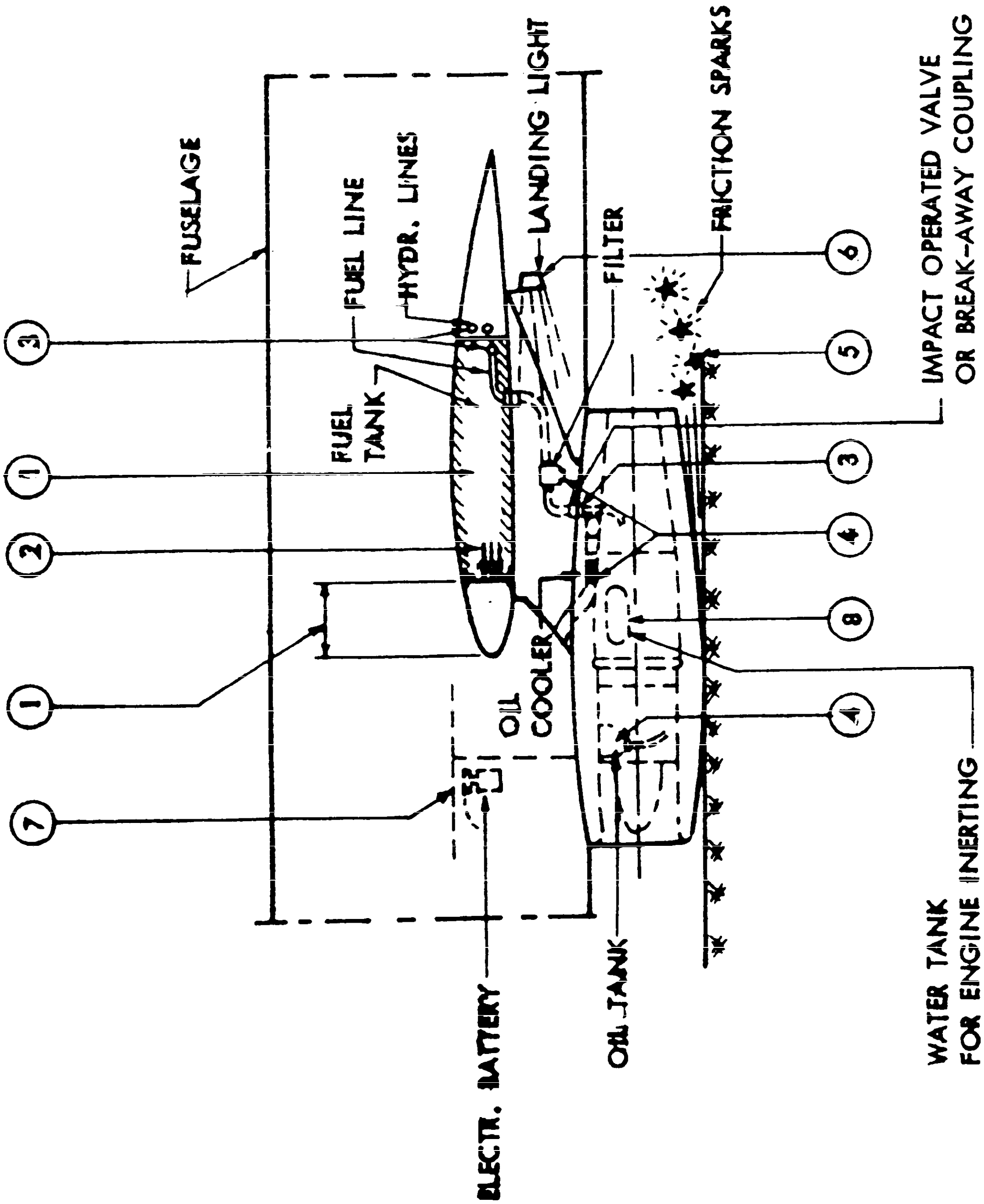


FIGURE 40 - 2.15 CRASH FIRE PREVENTION

2.16 INERTING (See Figures 41 and 42 on pages 167 and 169)

2.16.1 GENERAL

Inerting is the limitation of oxygen concentration in a fuel-air mixture by dilution with an inert gas for the purpose of prevention of explosions or limitation of explosion pressures.

2.16.1.1 OXYGEN CONCENTRATION

The maximum allowable oxygen concentration in a hydrocarbon fuel-air vapor mixture depends on the total pressure of the mixture before ignition and on the maximum tolerable pressure rise after ignition. (See Figure 41.)

2.16.1.2 OXYGEN EVOLUTION

Oxygen which is in solution in hydrocarbon fuels when a tank is fueled at sea level, is released when the pressure in the tank is reduced. This oxygen increases the concentration in the vapor space with increasing altitude. The oxygen evolution rate is low from a quiescent fuel volume and increases rapidly with agitation of the fuel.

2.16.2 INERTING REQUIREMENTS

An inerting system shall be applied in an aircraft only when required by the aircraft detail specification or when approved by BuWeps.

The inflow of inerting agent to the tank, the distribution of the agent, and the oxygen evolution from the bulk fuel shall be so controlled that a predetermined maximum allowable tank pressure will not be exceeded due to chemical reaction in the tank vapor space. The protection shall be effective for the time and conditions specified in the aircraft specification or as approved by BuWeps. Valves used to maintain the operating tank pressure within predetermined limits shall comply with 2.2.6. Maximum pressures caused by chemical reaction (initiated by enemy attack or other kinetic phenomena) shall not cause inability of the aircraft to return to home base.

2.16.3 INERTING GAS

The inerting gas, when entering the tank, shall be free of harmful amounts of water, corrosive material, and material which contaminates the fuel or fuel system. The gas shall not adversely affect pumpability, and burning and electrical characteristics of the fuel.

Inert gas generating systems shall not require unusually short overhaul periods, or excessive and costly maintenance and servicing.

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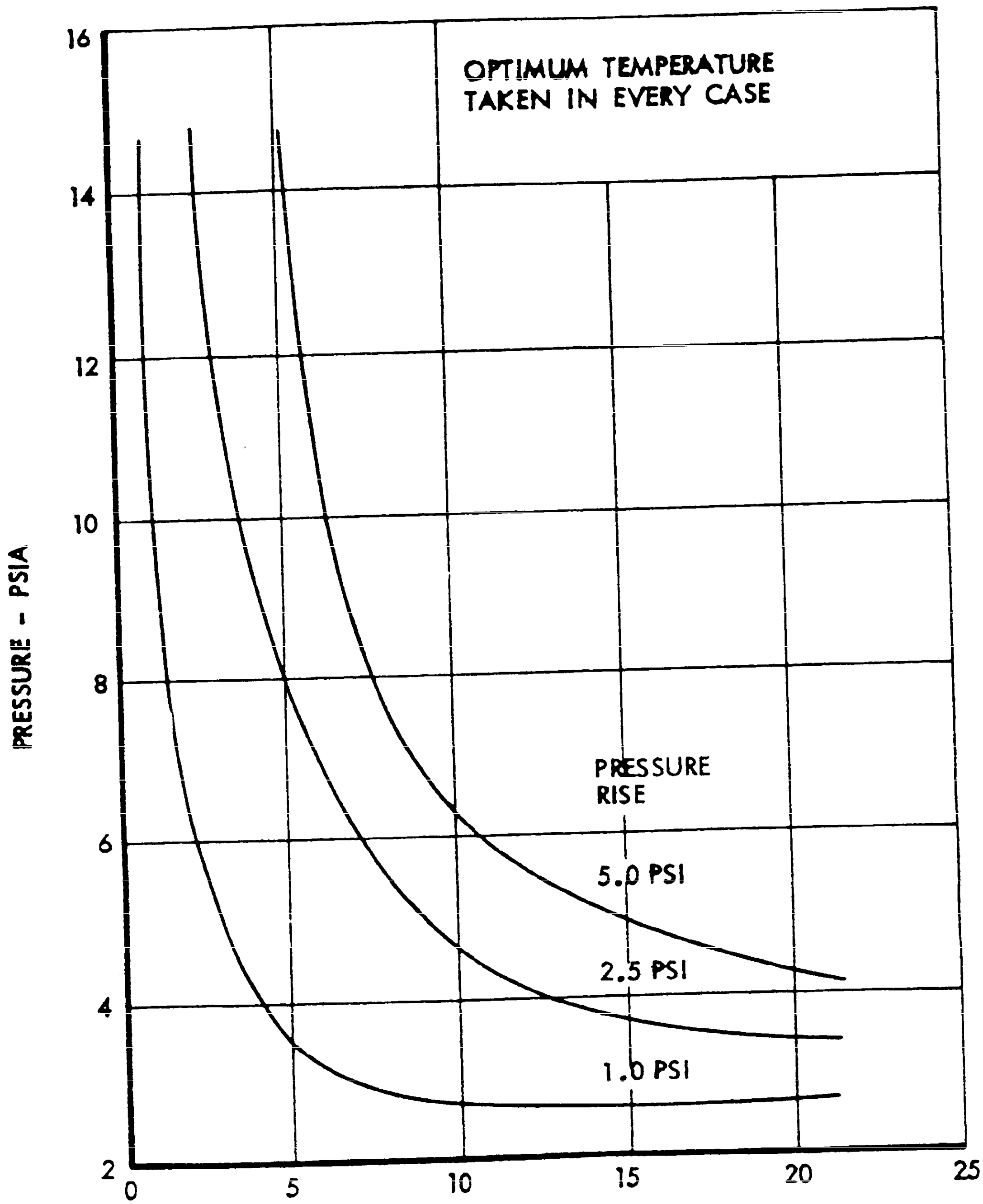


FIGURE 41 - EFFECT OF DILUENT ON PRESSURE RISE

		PARAGRAPH
(1)	OXYGEN CONCENTRATION	2.16.1.1
(2)	OXYGEN EVOLUTION	2.16.1.2
(3)	INERTING REQUIREMENTS	2.16.2
(4)	INERTING GAS	2.16.3
(5)	SYSTEM MONITORING	2.16.4
(6)	REDUNDANT INERTING SYSTEM	2.16.5

2.16 INERTING

FIGURE 42

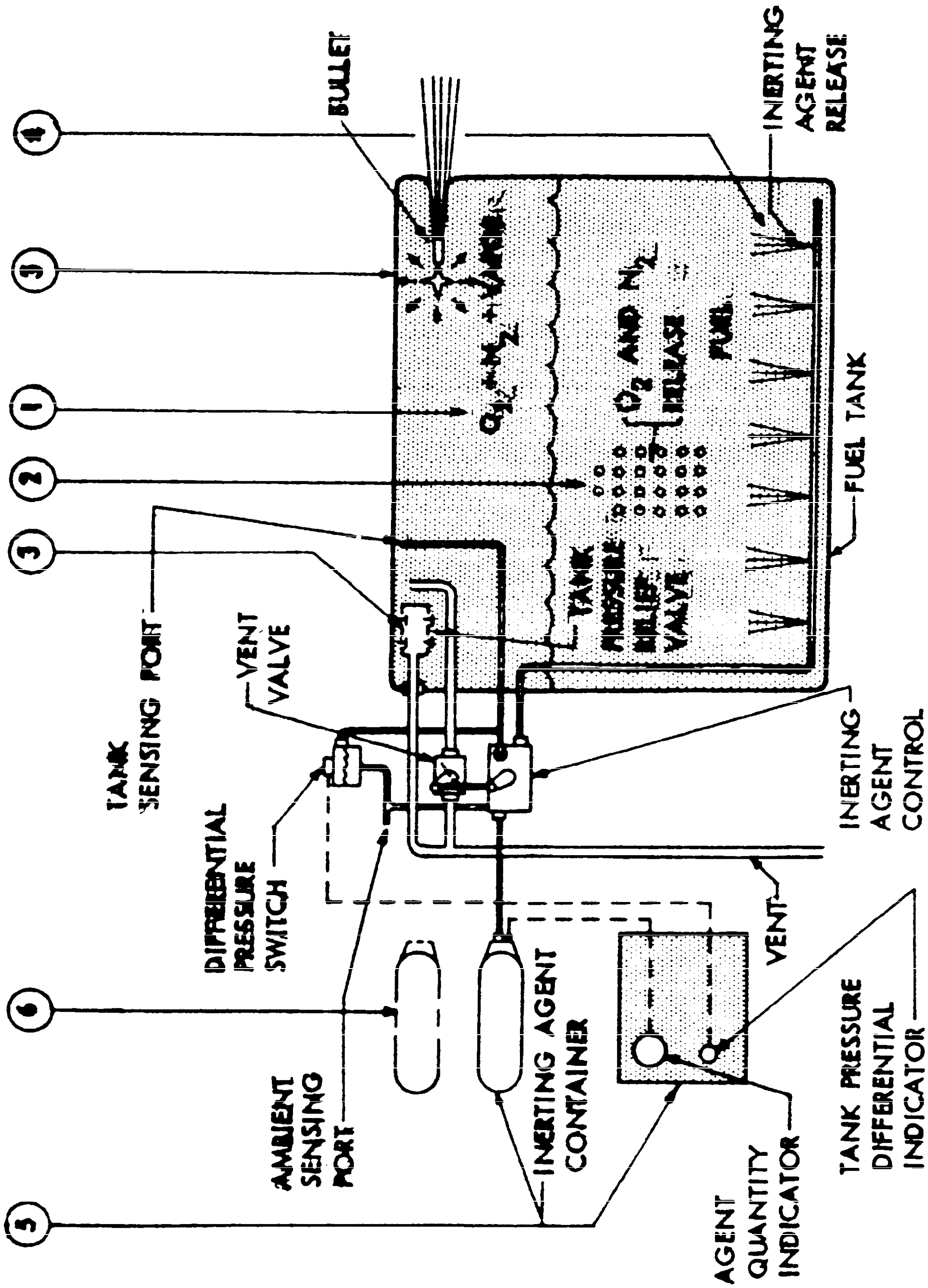


FIGURE 42 - 2.16 INERTING

2.17 EXPLOSION SUPPRESSION (See Figures 43 and 44 on pages 173 and 175)

2.17.1 APPLICATIO'

Explosion suppression systems should be used only if recurrence of an explosion, due to the same cause during a flight, is unlikely or can be prevented by action of the flight crew. The limited range of action of a single capsule makes this type of protection suitable for small tanks or compartments. When application is considered for large tanks or compartments the potential ignition hazard from an extensive electrical system in the vicinity of the tanks or compartments must be carefully weighed. Any application of an explosion suppression system shall be approved by BuWeps.

2.17.2 RESPONSE TIME AND TANK PRESSURE

The response time of the system from initiation of the explosion to quenching of burning shall be such that a safe pressure in the protected tank or compartment is not exceeded. The safe pressure is that pressure which cannot be exceeded without causing inability of the aircraft to continue safe flight.

2.17. 3 SYSTEM MONITORING

The electrical system shall be so designed that continuity can be readily pre-flight checked. The condition of a discharged explosion suppression system shall be indicated by an amber light in the flight station, if no immediate action by the flight crew is required. If immediate action is required, a red light should indicate the operation of the system.

2.17.4 INSTALLATION

The installation of the explosion system shall be such that the complete volume is protected. All electrical equipment in the protected zone and in the areas adjacent to the protected zone shall comply with 2.1.1.2, 2.1.1.4 and 2.7.

		PARAGRAPH
(1)	APPLICATION	2.17.1
(2)	SYSTEM MONITORING	2.17.3
(3)	INSTALLATION	2.17.4

2.17 EXPLOSION SUPPRESSION

FIGURE 43

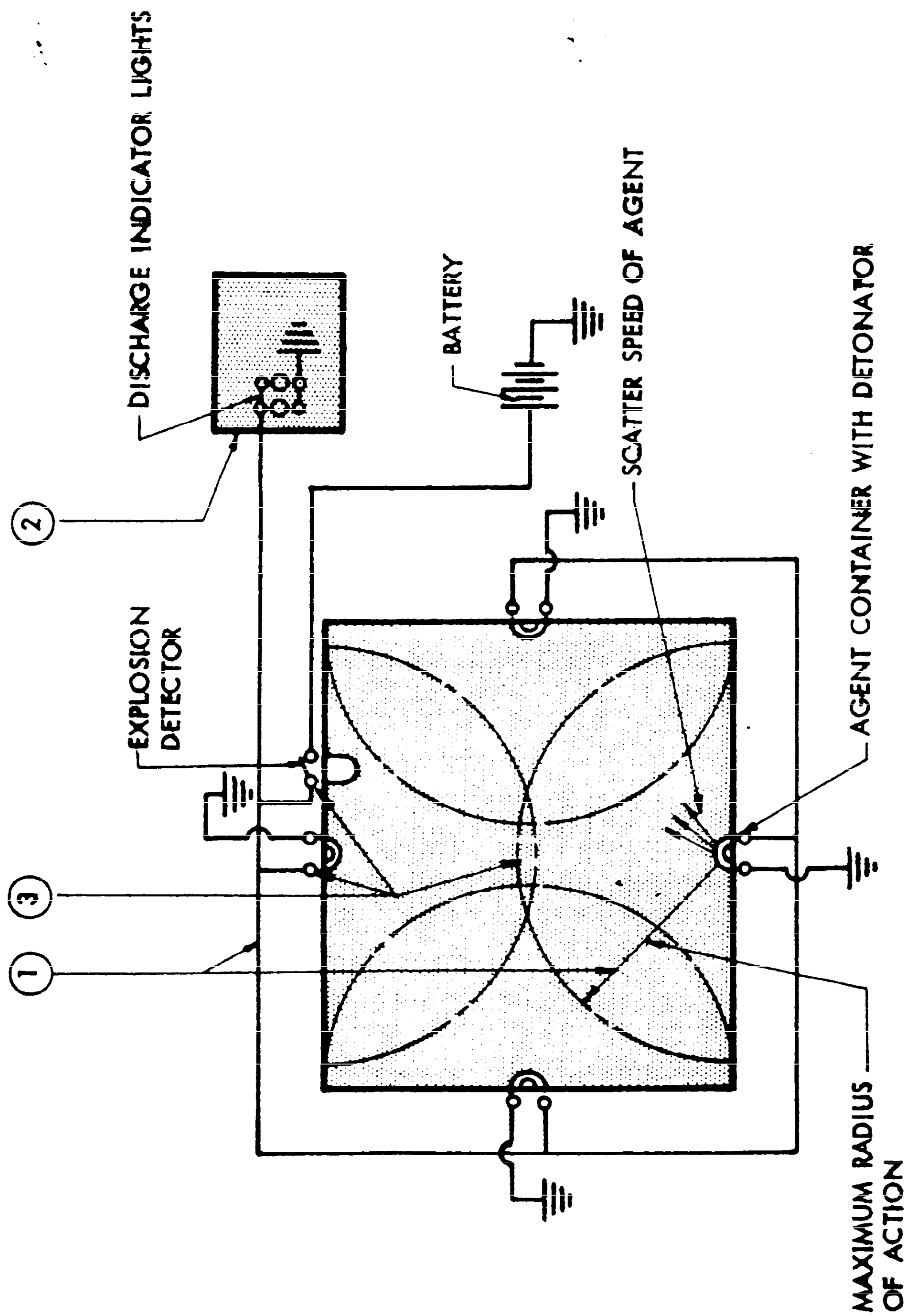


FIGURE 43 - 2.17 EXPLOSION SUPPRESSION

		PARAGRAPH
(1)	RESPONSE TIME AND TANK PRESSURE	2.17.2

2.17 EXPLOSION SUPPRESSION

FIGURE 44

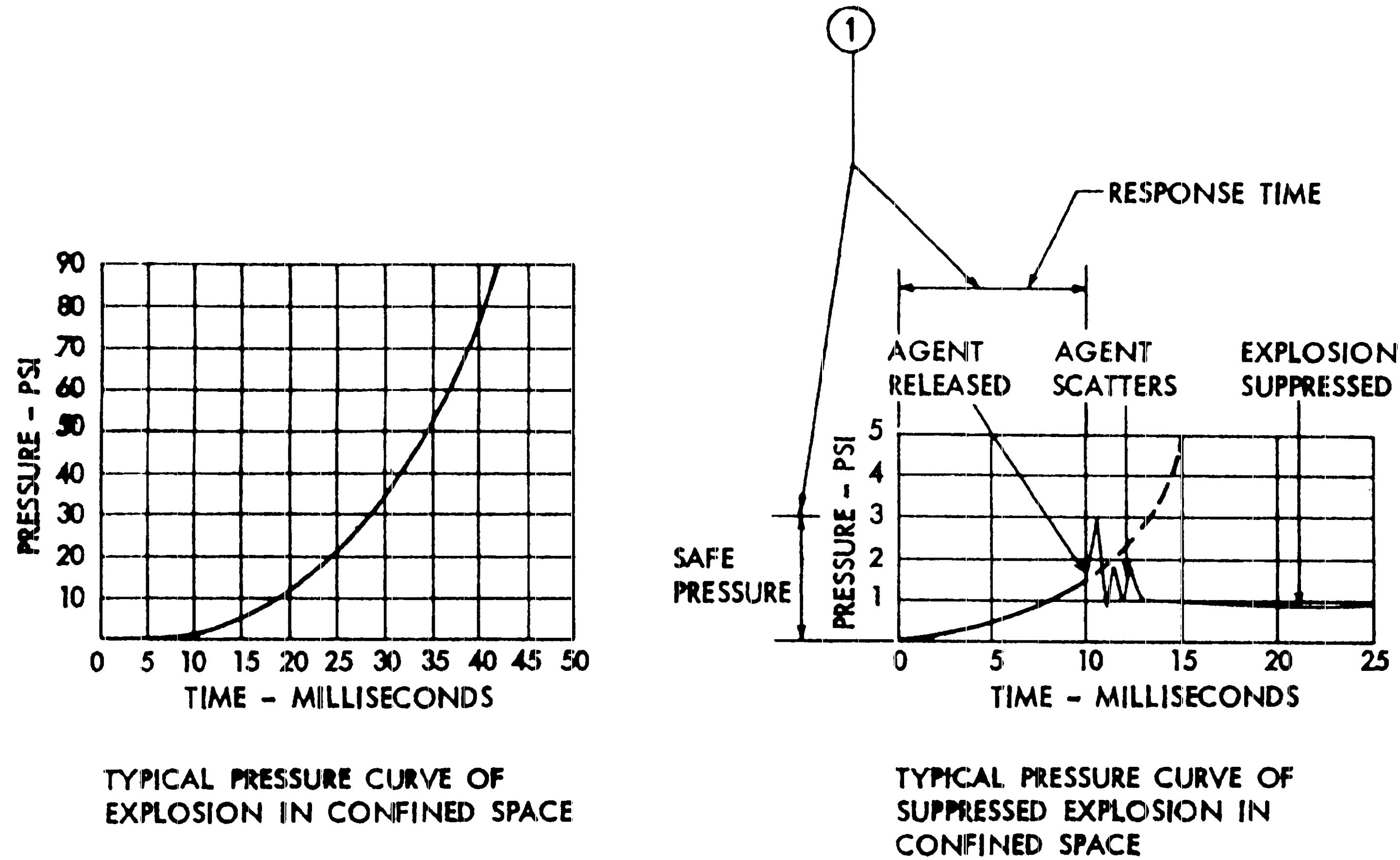


FIGURE 44 - 2.17 EXPLOSION SUPPRESSION

2.18 STATIC ELECTRICITY (See Figures 45, 46, 47, 48 and 49 on pages 181, 183, 185, 187, and 189)

2.18.1 LIGHTNING

The shell of an aircraft generally provides satisfactory protection against lightning strikes causing ignition within this shell. There are a few exceptions, however, where precautions must be taken in design to prevent penetration of fuel tank walls, arcing within fuel tanks, and flame propagation through vent lines into fuel tanks. In the following paragraphs, methods are described which can be applied to minimize lightning hazards to fuel tanks. An analysis of the most adequate protection for each new aircraft shall be made, commensurate with the potential extent of exposure of the particular aircraft to lightning. The analyses shall be submitted to BuWeps together with a proposal for testing, where deemed necessary.

2.18.1.1 FUEL TANK WALL PENETRATION

Some areas on the aircraft, primarily extremities, have been found to be prone to frequent direct lightning strikes of the type which penetrates aircraft skins. See 2.1.1.1.5.

If fuel must be stored in any of these areas, for justifiable reasons, the following means of protection shall be evaluated:

(1) Tank skin thickness sufficient to carry the electrical current surge of lightning at the points of potential entrance to and exit from the skin, without causing skin penetration due to resistance heating. Skin thicknesses of 0.08 inches seem to give satisfactory safeguard against skin penetration for most lightning strikes.

(2) A composite skin structure consisting of the load carrying skin, a Fiberglas cloth layer and an aluminum sheet bonded together. The resistance of such composite structure to lightning penetration has been demonstrated to be considerably better than a single aluminum sheet of the same total thickness.

(3) Lightning diverters (see 2.18.1.4).

2.18.1.2 ARCS IN FUEL TANKS

Lightning current traveling through the fuel tank skin on its path from the point of entrance to the aircraft, to the point of exit, shall not cause electric arcs within fuel tanks with the possible consequence of vapor ignition. The use of electrically conducting gaskets or seals should be considered for all access doors, flanges of filler units, quantity gages, pumps, etc., in the plane of the skin to ensure a direct and omnidirectional path for the current. If other current bridges are incorporated across openings in the skin, the tendency of inductive current to follow a straight path and the necessity to make the function of the bridge independent of potential maintenance omissions shall be considered. The load carrying capacity of the bridge shall not be less than the equivalent of a bonding jumper consisting of tinned copper stranded cable with a cross-sectional area of 20,000 circular mils. Materials and surface treatments shall be selected at joints in the bridge which prevent current resistant corrosion deposits at the surfaces of contact. Chains or other spark producing metallic links shall not be used for securing filler caps against loss.

2.18.1.3 FUEL TANK VENT DISCHARGE

Some areas on the aircraft have been found to be prone to frequent direct or swept lightning strikes which have sufficient energy to ignite fuel vapors emanating from a fuel tank vent line under certain conditions. Fuel tank vent discharge openings should therefore be avoided in the following areas:

(1) In the wing plan form area closer than twelve inches to the wing leading and trailing edges, and in the area at the wing tip which is indicated in Figure 47 by cross hatching, and not closer than twelve inches from the wing tip.

(2) Within a zone extending behind a propeller which is thirty-six inches wider than the diameter of the propeller.

(3) In extremities and protrusions of the aircraft and in the wake of such extremities and protrusions.

(4) Close to any sharp corners, or in the wake of such corners, or in vent masts, or in the proximity of static discharge wicks.

If required, flame arrestors of a proven design shall be installed in fuel tank vent discharge openings. One type of a proven flame arrestor is shown in Figure 45. The flame arrestors shall be installed so that the exteriors of the flame arrestors are flushed by the ambient airstream to prevent flames from clinging to sheltered pockets.

If location of fuel vent discharge openings per paragraphs (1) through (4) is not practical, or vent masts must be used, present-day flame arrestors alone are not sufficient protection. A configuration with vent outlets shielded against direct lightning strikes has proven to be successful in simulated lightning tests where simple flame arrestors failed. Lightning diverters in combination with present-day flame arrestors may also give satisfactory protection, whereby the diverters prevent direct hits to the vent opening and the flame arrestors protect against potential swept strikes and heat radiation. See Figure 46.

2.18.1.4 LIGHTNING DIVERTERS

Lightning diverters, when used as suggested in the previous paragraphs, shall be arranged strategically so that the critical areas or points are shielded from all directions of potential lightning approach. The diverters shall be erosion resistant, resistant to the airstream loads, and shall carry the current through the diverter base without skin puncture. The tendency of a lightning stroke to be swept away from a lightning diverter by the airflow, or to seek a shortcut, make the design of an effective diverter difficult and testing of every new arrangement almost mandatory. Some examples of diverter arrangements and their inherent problems are shown in Figure 48.

2.18.1.5 LIGHTNING INDUCED VOLTAGES

Under certain conditions lightning discharges have sufficiently steep rates of current rise to produce an inductive potential sufficient to not only cause arcing across fuel tank discontinuities, but to also induce voltages into fuel capacitance gage wiring and into the probes within the tanks. The latter can easily be caused by a strike to a wing tip light or an antenna, if its wiring is contained in the same bundle as the fuel capacitance gage probe. Such induced voltage also can cause inadvertent discharge of a fire extinguisher, or can trigger ordnance equipment. Circuitry prone to lightning strikes shall be routed away from other electrical wiring, or shall be shielded.

2.18.1.6 ANTENNAS

Antenna lead-in wires shall incorporate lightning arrestors which are in conformance with MIL-A-9094 if they are not sufficiently shielded against lightning by the aircraft shell.

2.18.2 LOW ENERGY STATIC ELECTRICITY

Pressure fueling inlets to fuel tanks shall be sized and designed to minimize fuel splashing. Splashing is an important contributing factor to electrostatic charging of the fuel and can lead to sparking in the tank vapor space.

Fuel dipsticks shall be designed in conformance with 2.2.7 to prevent arc-over from a dipstick to tank structure during gaging.

Electric ground receptacles for grounding pressure and gravity fueling nozzles shall be provided in conformance with 2.2.2.

		PARAGRAPH
(1)	FUEL TANK WALL PENETRATION	2.18.1.1
(2)	ARCS IN FUEL TANKS	2.18.1.2
(3)	FUEL TANK VENT DISCHARGE	2.18.1.3

2.18 STATIC ELECTRICITY

FIGURE 45

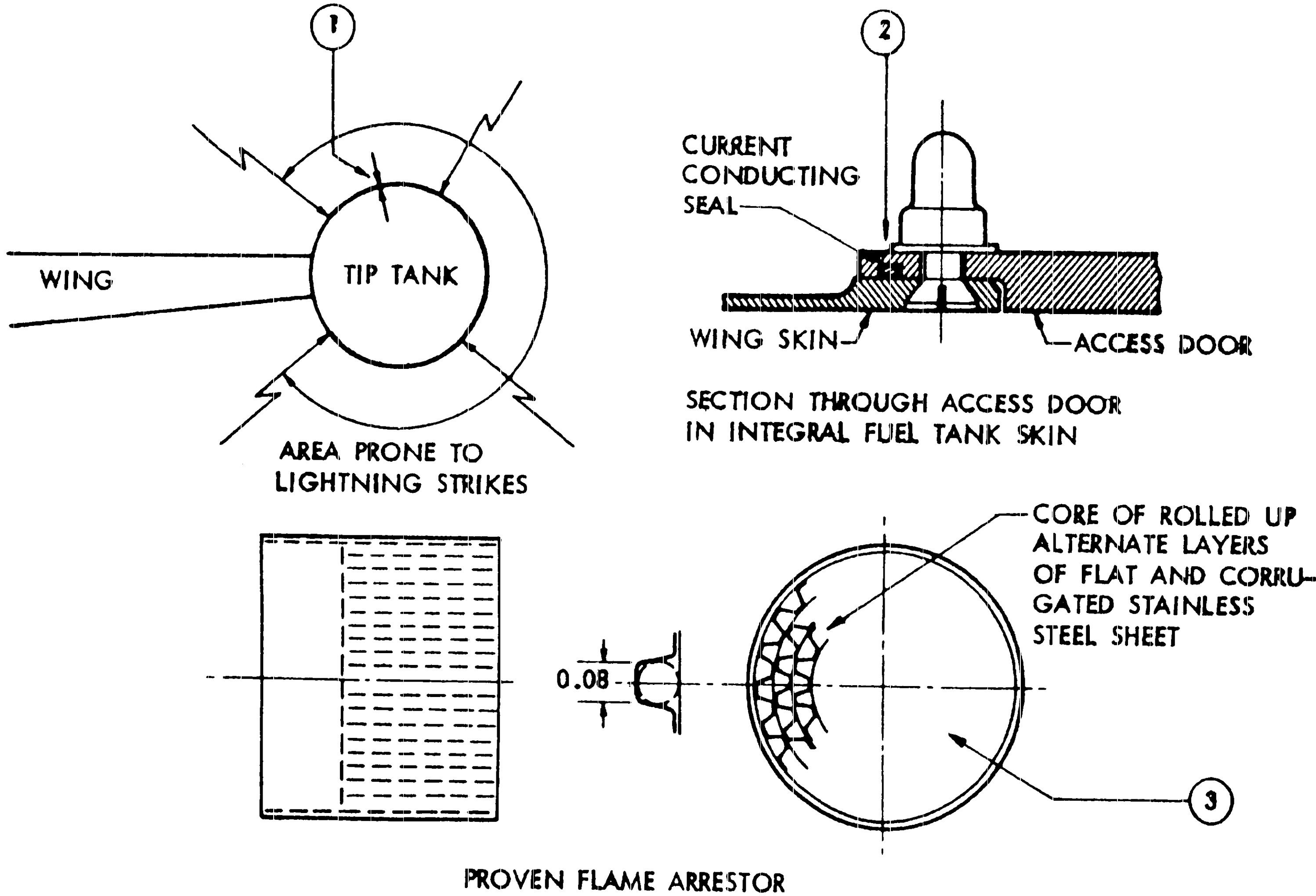


FIGURE 45 - 2.18 STATIC ELECTRICITY

PARAGRAPH	
(1) FUEL TANK VENT DISCHARGE	2.18.1.3

2.18 STATIC ELECTRICITY

FIGURE 46

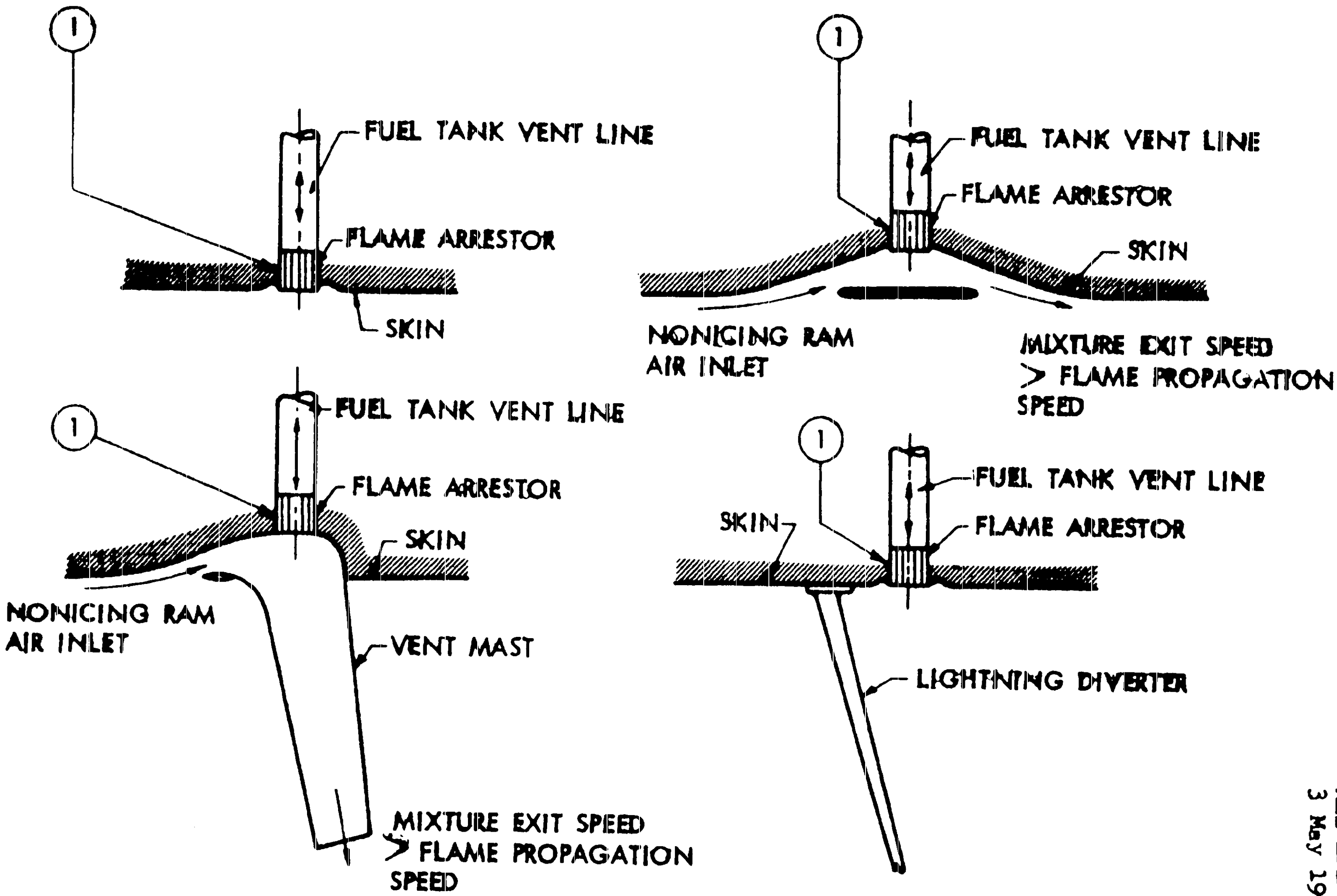


FIGURE 46 - 2.18 STATIC ELECTRICITY

		PARAGRAPH
(1)	LEADING EDGE, TRAILING EDGE AND WING TIP	2.18.1.3 (1)
(2)	PROPELLER AREA	2.18.1.3 (2)
(3)	EXTREMITIES AND PROTRUSIONS	2.18.1.3 (3)
(4)	SHARP CORNERS, VENT MASTS AND WICKS	2.18.1.3 (4)

2.18 STATIC ELECTRICITY

FIGURE 47

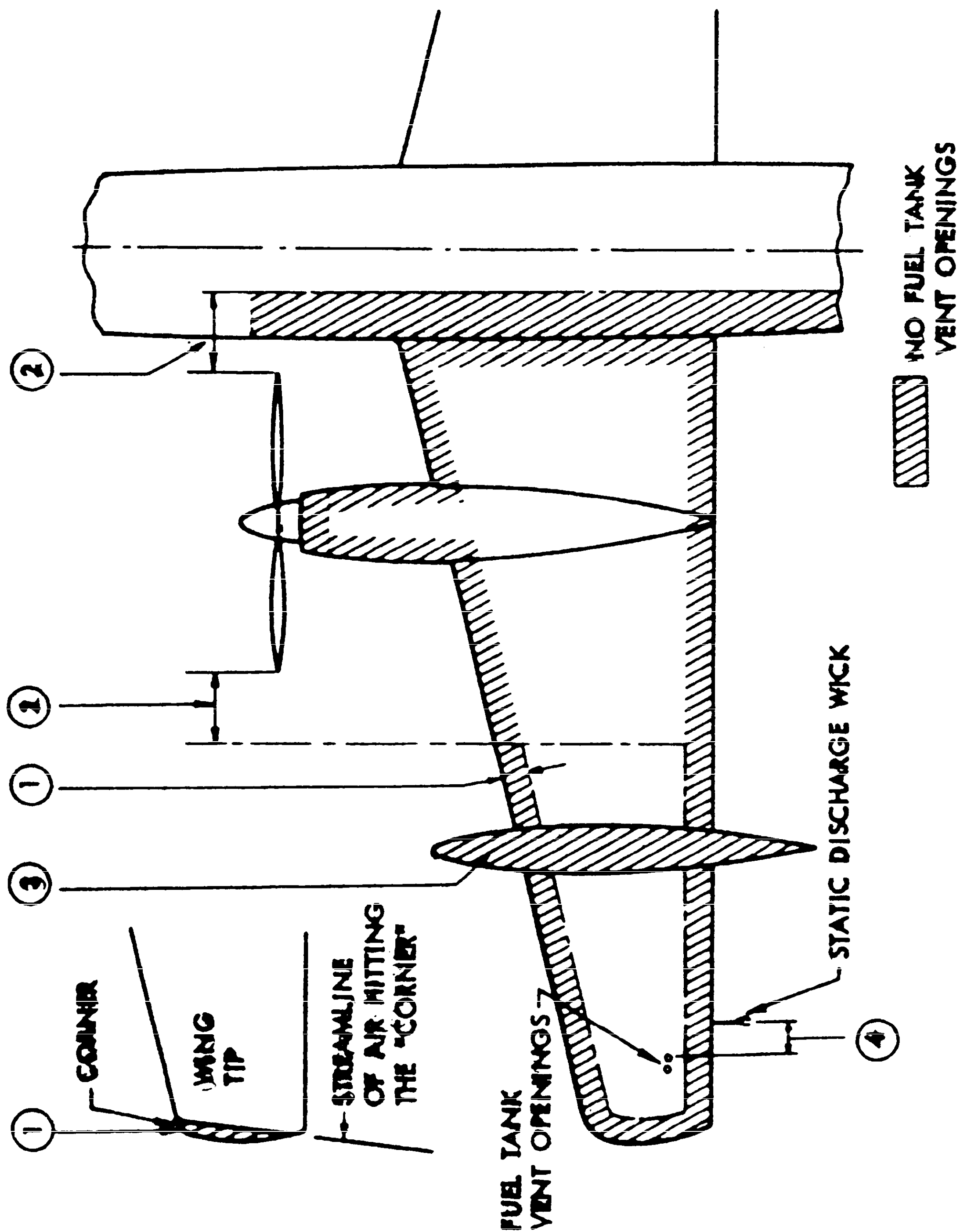


FIGURE 47 - 2.18 STATIC ELECTRICITY

PARAGRAPH	
2.18.1.4	(1) LIGHTNING DIVERTERS

2.18 STATIC ELECTRICITY

FIGURE 48

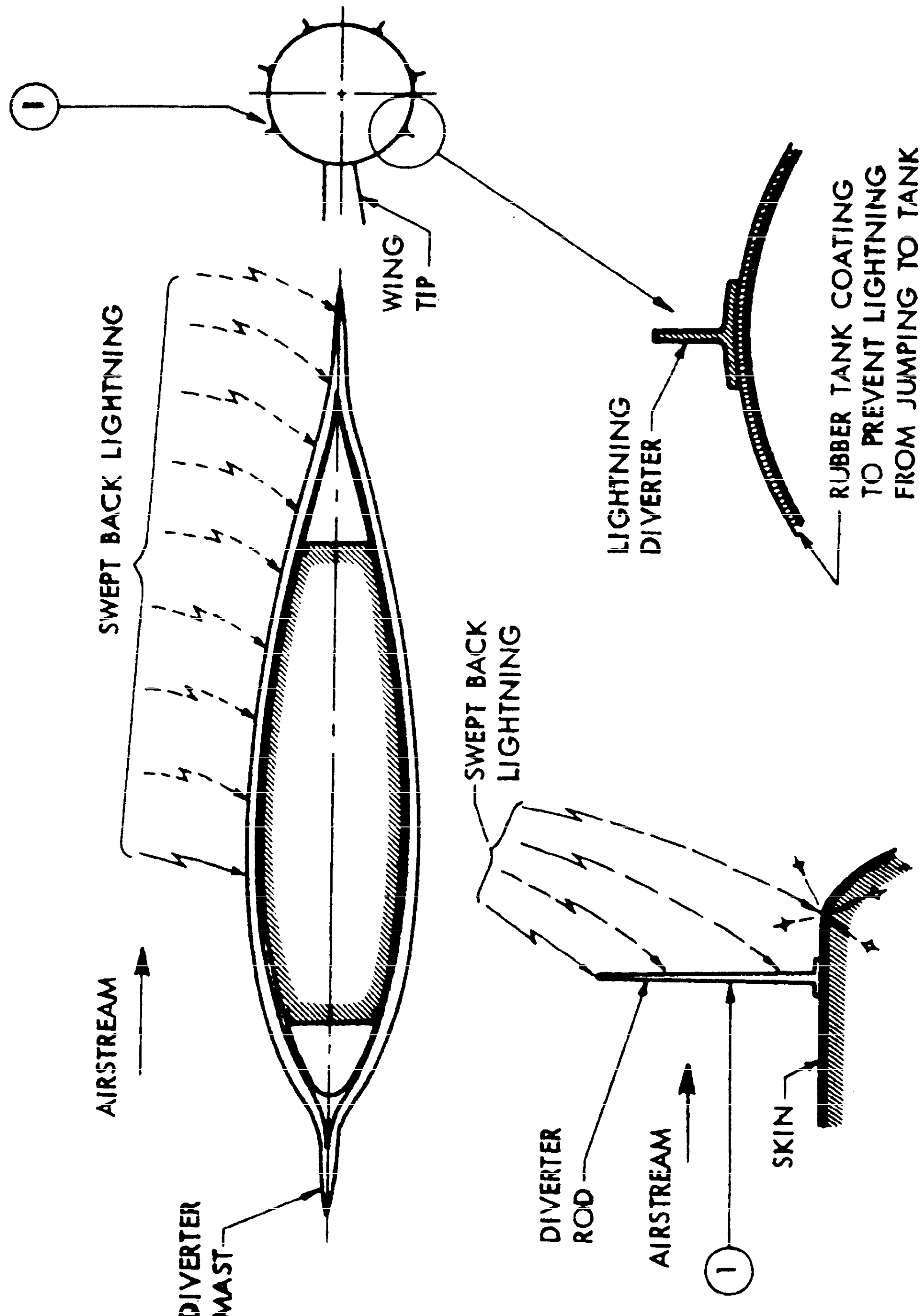


FIGURE 48 - 2.18 STATIC ELECTRICITY

		PARAGRAPHS
(1)	ARCS IN FUEL TANKS	2.18.1.2
(2)	LIGHTNING INDUCED VOLTAGES	2.18.1.5
(3)	ANTENNAS	2.18.1.6
(4)	LOW ENERGY STATIC ELECTRICITY	2.18.2

2.18 STATIC ELECTRICITY

FIGURE 49

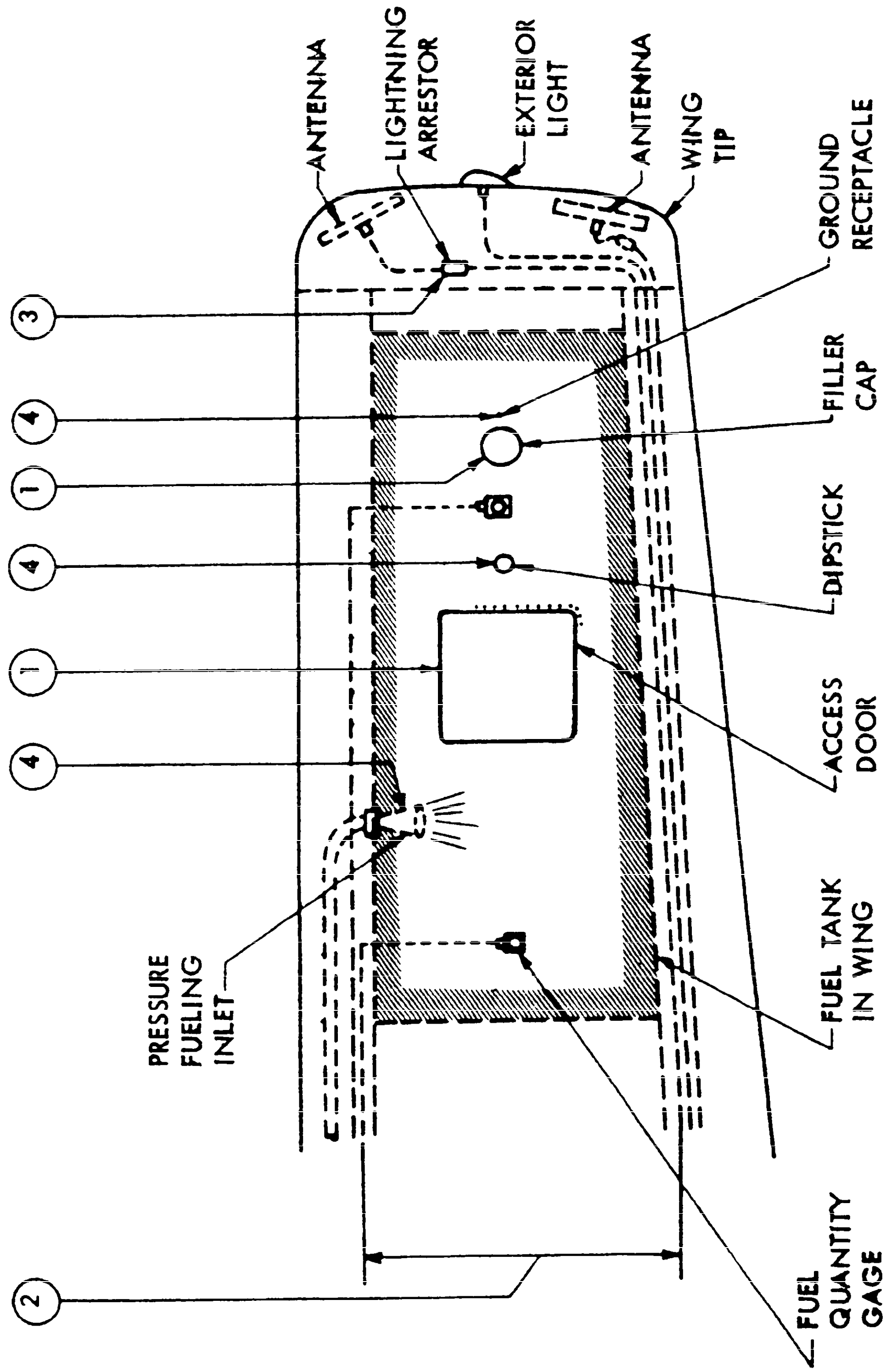


FIGURE 49 - 2.18 STATIC ELECTRICITY

2.19 INHABITED AREAS (See Figure 50 on page 195)

2.19.1 MATERIALS

2.19.1.1 GENERAL

Materials used for cabin interiors shall not ignite spontaneously at the highest temperatures of installation, or at temperatures lower than 140°F. They shall be self-extinguishing after removal of the flame. Whenever possible, cabin interior finish materials should be those which produce the smallest amount of toxic gases when burned or decomposed by heat.

2.19.1.2 TEXTILES

Textiles which are used for upholstery, floor covering, interior trim, etc., which are made flame resistant by treatment shall not lose their flame resistant quality after dry cleaning or laundering. If treated textiles are used which lose flame resistance with age, or dry cleaning, or laundering, suitable safe maintenance requirements shall be given in the applicable Maintenance Instruction Manual.

2.19.1.3 BLANKETS

Blankets are acceptable without treatment if they contain a minimum of 95% wool. Closely woven, short napped textiles are superior.

2.19.1.4 WOOD AND PLYWOOD

Wood and plywood used for cabin interiors shall be permanently covered with a flame resistant material.

2.19.2 AMBIENT TEMPERATURES

Fabrics of vegetable, animal and synthetic textile fibers and plastics shall not be used where ambient temperatures exceed 250°F. Materials less fire resistant than aluminum alloys shall not be used where ambient temperatures exceed 500°F.

2.19.3 TREATMENT OF MATERIALS

Treatment of materials of any kind (coating, doping, etc.) shall not impair their flame resistance qualities. Nitrate dope shall not be used in cabin interiors.

2.19.4 BERTHS

Berths shall be placarded against smoking.

2.19.5 STORAGE FACILITIES

Storage facilities provided for storage of blankets, pillows, magazines, newspapers, etc., shall be located and designed so that the contents will not be ignited by light bulbs, matches, cigarette ashes, etc.

2.19.6 SMOKING FACILITIES

Smoking facilities shall be provided in the form of an adequate number of fireproof self-contained, removable ash receptacles with covers. Compartments where smoking facilities are not provided shall be placarded against smoking.

2.19.7 WASTE MATERIAL

Waste material must be stowed in closed, fire resistant containers made of aluminum alloy or other material with equivalent fire barrier qualities.

2.19.8 AIR CONDITIONING

Recirculation fans or other high speed rotating equipment should not contain magnesium parts.

2.19.9 DUCTS AND THEIR CONNECTIONS

Ducts and their connections which terminate in the cabin or which are routed through the cabin should be made of aluminum or equally fire resistant material.

2.19.10 FLAMMABLE FLUID EQUIPMENT AND LINES

Flammable fluid and vapor shall not enter inhabited areas. Flammable fluid equipment and lines should be avoided in inhabited areas unless they are enclosed in a fluid and vaportight shroud, which is drained and ventilated overboard, or unless they do not incorporate fittings and are sufficiently well protected against damage.

2.19.11 VENTILATION AND SMOKE EVACUATION

Means should be provided to close off airflow between crew and passenger compartments. Provisions of smoke masks and goggles for crew members should be considered.

Provisions should be made to evacuate smoke and fire extinguishing agent from crew and passenger compartments following extinguishment of a fire. After every discharge of extinguishing agent in the cabin or baggage compartment, the crew and passenger compartments should be ventilated whether or not smoke is present. It is therefore desirable that the cabin ventilation system have capacity sufficient to supply fresh air in quantities great enough to allow quick purging of personnel compartments. To prevent re-ignition, ventilation should not be re-established too soon to confined areas such as lavatories and coat compartments.

2.19.12 HAND FIRE EXTINGUISHERS

Portable CO_2 extinguishers shall be as required by the aircraft detail specification.

		PARAGRAPH
(1)	MATERIALS	2.19.1
(2)	AMBIENT TEMPERATURE	2.19.2
(3)	TREATMENT OF MATERIALS	2.19.3
(4)	STORAGE FACILITIES	2.19.5
(5)	SMOKING FACILITIES	2.19.6
(6)	WASTE MATERIAL	2.19.7
(7)	AIR CONDITIONING	2.19.8
(8)	DUCTS AND THEIR CONNECTIONS	2.19.9
(9)	FLAMMABLE FLUID EQUIPMENT AND LINES	2.19.10
(10)	VENTILATION AND SMOKE EVACUATION	2.19.11
(11)	HAND FIRE EXTINGUISHERS	2.19.12

2.19 INHABITED AREAS

FIGURE 50

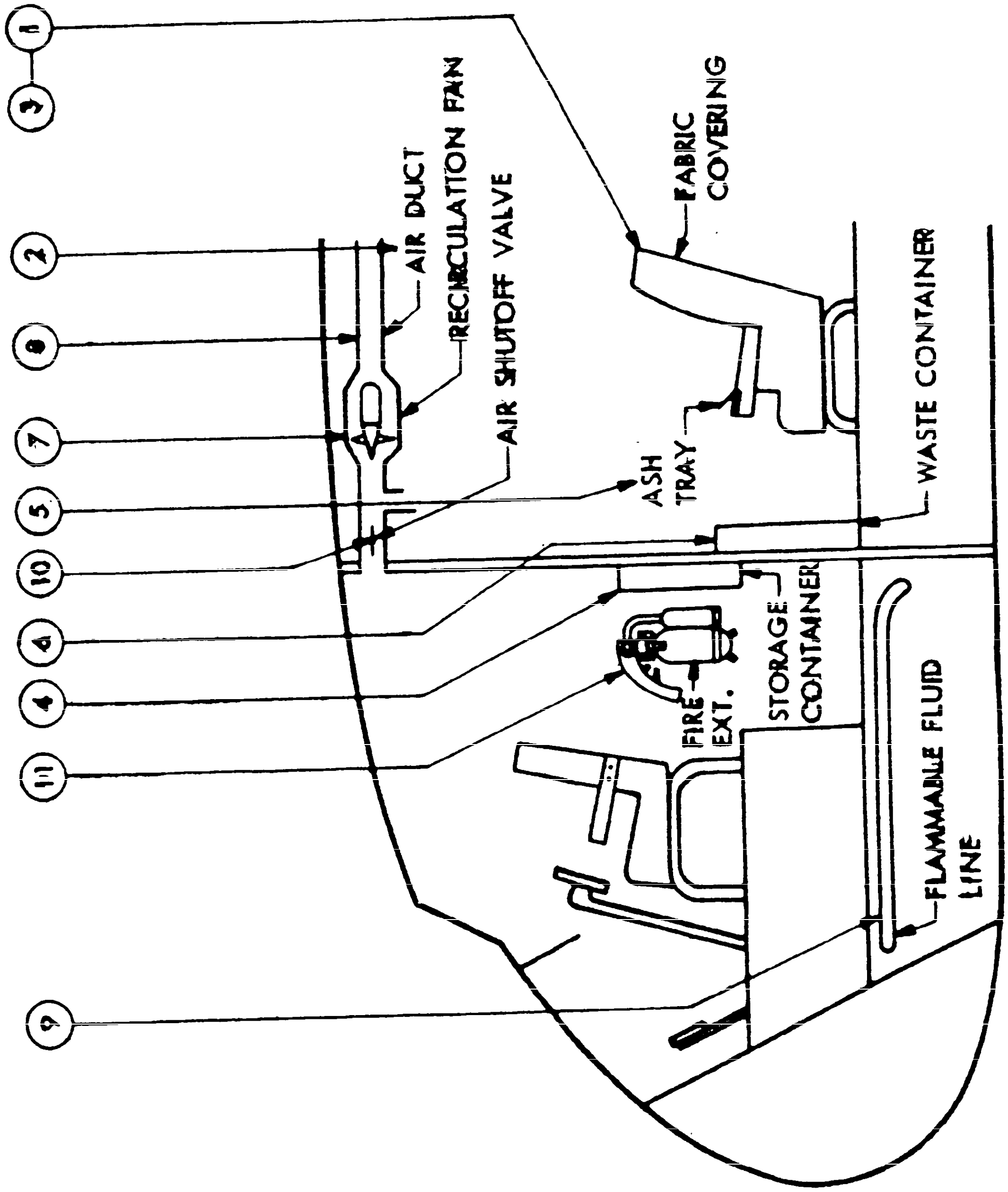


FIGURE 50 - 2.19 INHABITED AREAS

2.20 BAGGAGE AND CARGO COMPARTMENTS (See Figure 51 on page 20)

2.20.1 GENERAL

The occurrence of ignition and sustained burning within baggage is very unlikely. Generation of moisture and inert gases during the smoldering action within baggage may cause any fire to die out or many hours will probably pass before even a small open flame results. The probability of continued burning is further reduced by increased altitude, decreased air temperature, increased relative humidity, and increased density of clothing pack. Increasing velocity of air passing over baggage containing fire increases the burning rate of the fire. The degree of increase depends on the compactness of the baggage.

2.20.2 PROTECTION REQUIREMENTS

Requirements for specific configurations are as follows:

(a) If a fire is easily discernible and is accessible in flight, a hand fire extinguisher for each baggage and cargo compartment shall be provided.

(b) If sufficient access to baggage and cargo compartments is available in flight to extinguish a fire with a hand fire extinguisher, but a fire is not easily discernible, a separate system of smoke or fire detectors for each compartment, and a hand fire extinguisher readily available for each compartment, shall be provided. No hazardous quantities of smoke, flames, or extinguishing agent shall enter crew or passenger compartments when access to the baggage and cargo compartment is opened. The compartment shall be lined with aluminum or equally fire resistant material.

(c) If the fire is not easily discernible and is not accessible in flight, separate systems of smoke or fire detectors for each baggage and cargo compartment, and a built-in fire extinguisher system shall be provided. No hazardous quantity of smoke, flames or extinguishing agent shall enter the crew or passenger compartments. Ventilation and draft within each baggage and cargo compartment shall be controlled so that fire extinguishing is effective. The baggage and cargo compartment shall be lined with aluminum or equally fire resistant material.

(d) If a fire can be completely confined without endangering the aircraft or the occupants, no detector or extinguishing system is required. However, neither flame nor smoke or noxious gases shall enter crew or passenger compartments in hazardous quantities. Ventilation and draft within the baggage and cargo compartments shall be controlled. Ventilation and draft airflow through such compartments shall not exceed three cu.ft. per hour per cu.ft. of volume and should preferably be less. The method for measuring the airflow rate described in CAA Technical Development Report No. 146, dated June 1951, is recommended. For larger compartments lesser airflow may be applicable. The compartments shall be lined with aluminum or equally fire resistant material. No critical effects shall be caused by heat on adjacent parts.

(e) For aircraft used exclusively to transport cargo the following configuration is acceptable: Separate systems of smoke or fire detectors shall be provided. Means shall be provided to shut off the ventilating airflow to or within the compartment. No hazardous quantities of smoke, flames, or extinguishing agent shall enter the flight crew area. The compartment shall be lined with aluminum or equally fire resistant material.

2.20.3 BAGGAGE AND CARGO COMPARTMENT CONSTRUCTION

2.20.3.1 VENTILATING AIR

Shutting off ventilating air in case of fire permits the extinguishing agent to be retained for a longer period of time. Shutoff means are therefore desirable for all types of baggage and cargo compartments. Compartment sealing and ventilation shutoff should be so designed and maintained that at least a 25% concentration of agent is maintained after a two-hour cruise level flight. The compartment sealing must allow the necessary breathing, for maximum climb and descent rates, so that the design pressure differentials are not exceeded.

2.20.3.2 COMPARTMENT LINING

Compartments so specified in 2.20.2 shall be completely lined with fire resistant material (Aluminum Alloy or other material with equivalent fire barrier qualities). Consideration shall be given to the effect of heat within the compartment on adjacent parts of the aircraft.

2.20.3.3 ELECTRICAL WIRING AND FLAMMABLE FLUID LINES

Electrical wiring and flammable fluid lines should be excluded from baggage and cargo compartments. If this is not possible such wires and lines shall be installed as to be protected from damage by cargo being loaded, carried or shifted. (Also see 2.2.1.7.8)

2.20.3.4 LIGHTS

Baggage and cargo compartment lights shall be located or protected in such a manner that baggage and cargo cannot be ignited by them.

2.20.4 FIRE DETECTION

See 2.12.

2.20.5 FIRE EXTINGUISHING

In addition to the requirements of 2.13, fire extinguishing containers shall not be located in the baggage or cargo compartments.

		PARAGRAPH
(1)	PROTECTION REQUIREMENTS	2.20.2
(2)	VENTILATING AIR	2.20.3.1
(3)	COMPARTMENT LINING	2.20.3.2
(4)	ELECTRICAL WIRING AND FLAMMABLE FLUID LINES	2.20.3.3
(5)	LIGHTS	2.20.3.4
(6)	FIRE DETECTION	2.20.4
(7)	FIRE EXTINGUISHING	2.20.5

2.20 BAGGAGE AND CARGO COMPARTMENTS

FIGURE 51

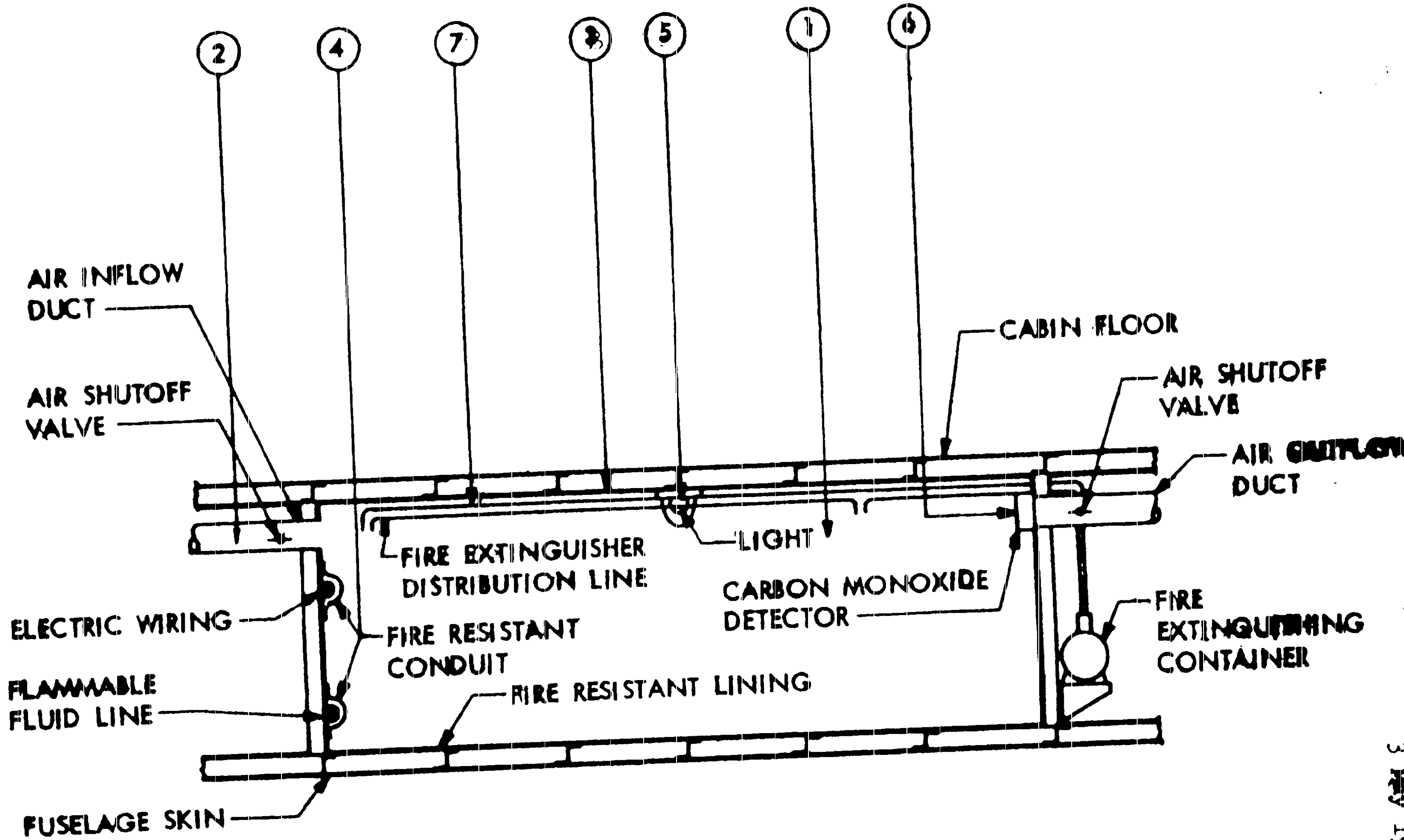


FIGURE 51 - 2.20 BAGGAGE AND CARGO COMPARTMENTS

3. IGNITION AND COMBUSTION FUNDAMENTALS.

(See Figures 52 through 64 on pages 221 through 233).

3.1 GENERAL

The requirements and design directives of Section 2 of this Handbook are the results of world-wide flight experience over many years of operation by commercial and military aircraft of all types. They have proven to be a compromise aviation can live with, both with regard to the penalty of performance and cost, and remaining hazard potentials.

In order to comply with the requirements and design directives in the most economical manner, the designer must have, or must acquire knowledge about the physical phenomena of air, fuel and ignition sources and their interrelation which lead to ignition. If he does not have the necessary knowledge at his command, he may end up with an unsafe aircraft, or he may be forced to be overly cautious at the expense of performance and cost.

The purpose of this section is to introduce a designer to basic knowledge which in connection with the bibliography of Appendix A, should enable him to cope with a great deal of his problems. Even though, the many variable parameters involved in ignition and their intricate interrelation make it necessary to resort to specifically tailored tests for many applications. In order to make these tests meaningful and to arrive at the desired results with the least expense, knowledge of the state-of-the-art again is a prerequisite.

Conditions necessary for starting a fire sound deceptively simple; the simultaneous presence of a flammable substance and a suitable ignition source. In the case of fires involving aircraft turbine engine fuels, formation of a flammable substance requires the mixing of an oxidizer with the fuel vapor. Under ordinary circumstances the most likely oxidizer is air. Three principal ingredients then are involved in producing a fire: air, fuel, and an ignition source. Their pertinent characteristics are described next, after which their interrelation with respect to fire will be discussed.

3.2 ATMOSPHERIC AIR

In a precise sense, the earth's atmosphere is a rather heterogeneous mixture of gases and small solid particles. From a practical standpoint, however, it may be considered a relatively uniform mixture. "U. S. Standard Atmosphere 1962" assumes that the air of the standard atmosphere is dry and has the same relative composition at all altitudes concerned. This composition is given in Table I. Using Table I, the standard equivalent molecular weight for air of 28.97 may be derived from a summation of the products of mol fractions times molecular weights. While such things as smoke, dust, and industrial gases are noticeable contaminants, their total is negligible, since it is not likely to exceed that of carbon dioxide, which in itself constitutes a very small percentage of the atmosphere.

TABLE I

Composition of Standard Atmosphere

Constituent Gas	Mol Fraction, %	Molecular Weight
Nitrogen (N_2)	78.09	28.016
Oxygen (O_2)	20.95	32.000
Argon (A)	0.93	39.944
Carbon Dioxide (CO_2)	0.03	44.010
Neon (Ne)	1.8×10^{-3}	20.183
Helium (He)	5.24×10^{-4}	4.003
Krypton (Kr)	1.0×10^{-4}	83.7
Hydrogen (H_2)	5.0×10^{-5}	2.0160
Xenon (Xe)	8.0×10^{-6}	131.3
Ozone (O_3)	1.0×10^{-6}	48.000
Radon (Rn)	6.0×10^{-18}	222

Temperature and pressure of static atmospheric air both decrease as the altitude increases. Figure 52 shows static pressure variations with altitude for ICAO standard day and Air Force - Navy standard cold atmosphere and hot atmosphere.

Figure 53 shows static temperature variations with altitude for the ICAO standard day and for the Air Force - Navy standard cold atmosphere and hot atmosphere.

In actual operation it would be extremely rare for any local atmosphere to conform exactly to any of the standards shown in Figure 52 and Figure 53. The figures are primarily indicative of the range of variations which might be encountered. Functions related to ignition and combustion are dependent upon absolute temperatures and pressures; therefore the various standard atmospheres indicate a range of altitudes over which certain conditions might be encountered.

As an aircraft moves through the atmosphere, the stagnation pressure and temperature increase as a function of velocity. Figure 54 shows the ratios of stagnation pressures and temperatures to free stream (static) pressures and temperatures for Mach numbers between 0 and 3.5. These ratios are then applied to static absolute temperature and pressure conditions being investigated to determine actual stagnation values.

Figure 55 shows stagnation temperature as a function of Mach number for the sea level condition and for the isothermal condition. Figure 56 shows stagnation pressures at several standard day pressure altitude conditions as functions of Mach number. These figures illustrate the general magnitude of temperatures and pressures to be expected at high velocities. They also serve as references for whatever calculations designers might wish to make. It should be understood that the stagnation pressures and temperatures at locations other than the stagnation point must be calculated on the basis of the individual configuration in question.

Several important points should be kept in mind: 1) For practical purposes air consists of 21% oxygen and 79% inert gases by volume. 2) The proportionality of gases is constant for the atmosphere in which air-breathing engines can operate. 3) The supply of oxidizer in the form of atmospheric air is virtually inexhaustable. 4) Pressure and temperature of the air will depend on weather conditions and operating altitude.

3.3 FLAMMABLE FLUIDS

3.3.1 AIRCRAFT TURBINE ENGINE FUELS

Standard fuels used in turbine engines on Navy aircraft conform to specification MIL-J-5624(F), Grade JP-4 and Grade JP-5. For emergency operation, many engines permit limited use of aviation gasoline of the lowest available performance rating, conforming to specification MIL-G-5572.

The "Material" section of both of the above specifications states that the fuel shall consist completely of hydrocarbon compounds except as otherwise specified. Since there are literally millions of possible hydrocarbon compounds it is impossible to predict the chemical composition for a given fuel. From a statistical standpoint aviation gasoline may contain as many as 200 different compounds, and the turbine fuels perhaps 5000 or more different compounds. The blending of compounds and groups of compounds permits utilization of the advantages of these compounds and results in economical production of fuels suitable for combustion in aircraft engines. Fuel specifications control a number of physical characteristics as shown in Figure 57.

From a practical standpoint aircraft fuels consist of four series of hydrocarbon compounds: paraffins, cycloparaffins, olefins, and aromatics. Each of these series of compounds displays both favorable and unfavorable characteristics. Figure 58 presents comparative characteristics for the four series of hydrocarbons. It can be seen that paraffins and cycloparaffins are desireable fuels and usually constitute 70% to 80% of the fuel blend. Aromatics are desirable primarily because of their high specific gravity, which produces a higher heat per unit volume. Inclusion of olefins is in many cases an economic measure to reduce the over-all cost of the fuel.

Since net heat of combustion and flame temperature show only a small variation between the various fuels mentioned, the question naturally arises: Is one fuel more hazardous than any of the others? This becomes a difficult question to answer in simple terms. Liquid fuel of itself will not burn. If there is either too little or too much gaseous fuel in the fuel-air mixture, the mixture will not support combustion. A brief discussion on vapor pressure should help to clarify the situation.

Fundamentally, vapor pressure is a measure of molecular activity, and represents the tendency of a substance to vaporize. It can be defined as the minimum pressure at which a substance will remain liquid or solid at the given temperature. Figure 59 is a generalized diagram of the vapor pressure function. It shows how the temperature and pressure determine whether a substance is solid, liquid, or gas. The junction of the three branches of the diagram is called the "triple point" at which the substance can exist simultaneously in the solid, liquid, and gaseous forms. As the temperature increases, a critical point is attained. If temperature is increased beyond this point, the substance is gaseous no matter what the pressure. A simple, practical example of this relationship is a conversion of ice to steam in an open vessel, which is accomplished at a constant pressure with only the addition of heat to increase the temperature. In the liquid-gas relationship it can also be seen that liquid can be converted to gas either by increasing the temperature or by decreasing the pressure. With respect to fire hazard, the liquid-gas relationship is the important portion of the vapor pressure diagram.

Vapor pressure as described above is equivalent to the partial pressure of fuel vapor in a fuel-air mixture under equilibrium conditions in a closed vessel. This vapor pressure is a true absolute pressure and must not be confused with Reid Vapor Pressure. Reid Vapor Pressure is always measured at 100°F, is influenced by the partial pressure of the air volume in the measuring chamber, and is intended primarily as a measure of relative volatility of various fuels.

Figure 60 shows the effect of temperature on the vapor pressure of the fuels under consideration. For JP-4, the shaded area between the two curves indicates the range permissible by specification. Since the Reid Vapor Pressure is not specified for JP-5, the curve represents average values. For aviation gasoline the shaded area represents the specification tolerance; performance rating of the various grades of gasoline is independent of the vapor pressure.

Molecular weight of the fuel vapor does not of itself affect flammablity. In general, however, it should be remembered that molecular weight will increase as fuel volatility decreases. As a matter of interest, average molecular weights for fuel vapors are: a) aviation gasoline, 75; b) JP-4, 85; c) JP-5, 140. These values have a probable accuracy of ±5%.

The hydrogen to carbon ratio of the fuel vapor will affect the stoichiometric fuel-air ratio. This will be discussed in a section concerning formation of flammable mixtures.

3.3.2 OTHER FLAMMABLE FLUIDS

In addition to its fuel supply, an aircraft carries a number of other flammable fluids. Principal among these are:

(1) Alcohol and alcohol mixtures

(2) Hydraulic fluid

(3) Engine lubricating oil

Methanol (methyl alcohol) is widely used for engine thrust augmentation and for de-icing. Isopropyl alcohol has also been used. Both are relatively volatile; at ordinary temperatures, methanol is slightly less volatile than gasoline, and isopropyl alcohol slightly less volatile than JP-4. Although the net heat of combustion is less than that of gasoline and jet fuel, any alcohol should be handled with the same respect accorded the other fuels. Alcohols are miscible with water, and the resultant mixture is flammable.

Standard petroleum base hydraulic fluid MIL-H-5606 is essentially a hydrocarbon mixture. It has a vapor pressure lower than kerosene; therefore it is only moderately hazardous at ordinary temperature and pressure. When it is heated or when the pressure is reduced, a flammable mixture can result. With respect to autogenous ignition it is as hazardous as JP-4 and JP-5, and more hazardous than gasoline. Fluids such as Skydrol 500 and Monsanto OS-45-1 are only relatively fire-resistant; they require higher temperatures than the MIL-H-5606 fluid to become flammable.

Lubricating oils are derived both from petroleum products and from synthetic compounds. Their low volatility requires that they be heated considerably before equilibrium flammable mixtures are formed. This is evidenced by flash points (basically the lean limit) ranging from 225°F to 510°F. On the other hand, autogenous ignition temperatures range from 470°F to 760°F, which is similar to the range for fuel.

Considering all factors, these three types of fluids are only slightly less hazardous than fuel, and must be treated accordingly; each has, at some time, caused aircraft fires.

3.4 FLAMMABLE FUEL-AIR MIXTURES

Formation of fuel-air mixtures is best described by considering equilibrium conditions in a closed system. Visualize a tank containing both air and liquid fuel, with no means for fuel vapor or air to escape. Some fuel molecules penetrate the surface and enter the air space while others re-enter the fuel. Eventually an equilibrium condition is attained in which the number of molecules leaving the fuel is equal to the number re-entering. The gas volume above the fuel contains both fuel vapor and air. At this time the proportionality between fuel vapor and air can be calculated from the relationship of partial pressures given below.

By volume, $(F/A)_v = P_v/(P_a - P_v)$

By weight, $(F/A)_w = (P_v)(M.W._v)/(P_a - P_v)(M.W._a)$

Where $(F/A)_v$ = Fuel-air ratio by volume

$(F/A)_w$ = Fuel-air ratio by weight

P_v = Vapor pressure of fuel (absolute)

P_a = Pressure at surface of fuel (absolute)

$(P_a - P_v)$ = Partial pressure of air

$M.W._v$ = Molecular weight of fuel vapor

$M.W._a$ = Equivalent molecular weight of air

From these equations it can be seen that the fuel-air ratio by weight in the gas volume is dependent upon the vapor pressure of the fuel, the molecular weight of the fuel, the absolute pressure at the surface of the fuel, and the molecular weight of the air. It can also be seen that when the fuel vapor pressure is equal to the absolute pressure at the surface of the fuel, the partial pressure of the air becomes zero. Under these conditions the fuel is at its boiling point, for the temperature in question, or in other words is on the dividing line between gas and liquid.

In the combustion process the carbon and hydrogen contained in the fuel vapor combine with the oxygen in the air. For completely efficient combustion each carbon atom combines with two oxygen atoms to form a carbon dioxide molecule, while each hydrogen molecule, containing two hydrogen atoms, combines with an oxygen atom to form a water molecule. For example, pentane containing 5 carbon atoms and 12 hydrogen atoms, combines with 8 oxygen molecules to form 5 carbon dioxide molecules and 6 water molecules.

$$C_5H_{12} + 8\ O_2 \longrightarrow 5\ CO_2 + 6\ H_2O$$

Another example is the aromatic benzene, in which two benzene molecules, each containing 6 carbon atoms and 6 hydrogen atoms, combine with 15 oxygen molecules to form 12 carbon dioxide molecules and 6 water molecules.

$$2\ C_6H_6 + 15\ O_2 \longrightarrow 12\ CO_2 + 6\ H_2O$$

Fuel-air ratio in a stoichiometric mixture is dependent on the hydrogen and carbon atoms present in the fuel vapor and is calculated as described below. In the case of pentane the 8 oxygen molecules are divided by the percent oxygen by volume in the atmosphere (0.2095) to show that 38.2 equivalent air molecules are required for each pentane molecule. Volumetric fuel-air ratio for the stoichiometric mixture is simply the ratio of the number of molecules, in this case 0.0260. Fuel-air ratio by weight is determined by dividing the product of fuel vapor molecular weight times the number of fuel molecules by the product of air molecular weight times number of air molecules, or in the case of pentane 0.0647.

$$(F/A)_v = 1 \Big/ (8/0.2095) = 1 \Big/ 38.2 = 0.0260$$

$$(F/A)_w = (1)(72.1) \Big/ (8/0.2095)(28.97) = 0.0647$$

In the case of benzene the 15 oxygen molecules required to combine with 2 benzene molecules require the equivalent of 71.6 air molecules. Volumetric fuel-air ratio for the stoichiometric mixture is then 0.0279, and weight fuel-air ratio for the same mixture is 0.0753.

$$(F/A)_v = 2 \Big/ (15/0.2095) = 0.0279$$

$$(F/A)_w = (2)(78.1) \Big/ (15/0.2095)(28.92) = 0.0753$$

For the fuels under discussion, the composition of the fuel vapor is quite likely to be different than the composition of the liquid. This relationship can also change with changes in altitude and because of fuel weathering (loss of more volatile constituents), and can be defined precisely only by extensive testing. From a practical standpoint the assumption of a stoichiometric fuel-air ratio by weight of 0.068 probably will be accurate to approximately ±5%. This is due to the predominance of paraffins and cycloparaffins in the fuels.

Experience in adjusting fuel-air mixtures in such apparatus as Bunsen burners, gas stoves, and automotive carburetors, demonstrates that flammability occurs at mixtures other than stoichiometric. In the combustion process the exothermic or heat-producing reaction takes place between a definite proportion of fuel molecules and air molecules. Loss of energy to either excess air or excess fuel vapor eventually can prevent the combustion process from sustaining itself. For turbine engine fuels the lean limit and rich limit mixtures at one atmosphere can be calculated from the information given below.

$$L = 18.7 \times 10^6 / (q_n)(M)$$

$$L_{f/a} = (L)(M) / (100 - L)(28.97)$$

$$R = L + 143 / M^{0.7}$$

$$R_{f/a} = (R)(M) / (100 - R)(28.97)$$

Where: L = lean-limit concentration by volume

q_n = net heat of combustion, BTU/lb.

M = molecular weight of fuel vapor

$L_{f/a}$ = lean-limit fuel-air ratio by weight

R = rich-limit concentration by volume

$R_{f/a}$ = rich-limit fuel-air ratio by weight

Flammability limits expressed in terms of fuel-air ratio by volume or by weight are relatively insensitive to changes in absolute pressure. The diminishing temperature spread shown in Figure 61 merely reflects the reduced vapor pressure range dictated by the reduced absolute pressure. Combustion in test apparatus has been obtained at pressures equivalent to 75,000 foot altitude. Moreover, test data at low absolute pressures is rather meager, and the tests can be affected significantly by test apparatus size and configuration. If low ambient pressure is to be used as a protecting feature against explosion, realistic tests tailored to the actual condition and configuration must be conducted.

Flammable fuel-air mixtures can also be formed when a mist is generated such as from severe agitation or impact. When the droplet diameter is 10 microns or less, the mixture acts very similar to a vapor-air mixture. As droplet size increases the lower flammability limit decreases and then shows an increase once more. Data on this subject is extremely limited; the most important point to remember is that the normal limits of flammability for an equilibrium fuel vapor-air mixture are not applicable to mists and sprays.

When fuel is stored in an open container it is a practical impossibility to form an equilibrium fuel-air mixture. The greatest fuel concentration will be at the surface of the liquid and will diminish with both distance from the liquid and circulation of the composite mixture. If the pressure and temperature conditions existing for the storage facility indicate that equilibrium fuel-air ratio would be less than the lean flammability limit, the hazard is greatly reduced. On the other hand, if the conditions indicate that equilibrium fuel-air ratio would be considerably above the rich flammability limit, it must be assumed that somewhere between the surface of the fuel and the uncontaminated surrounding air a region of flammable fuel-air mixture will exist. Other hazardous situations will be discussed later.

Once the fuel-air mixture has left its container and emerges into the atmosphere, it diffuses rapidly into the surrounding air. If this were not the case, fuel handling operations would be much more hazardous than they are.

3.5 SOURCES OF IGNITION

Ignition usually is considered the process of producing a propagating flame in a combustible mixture. In order to initiate the combustion, energy must be added to the mixture; after which a propagating flame is self-sustaining until the fuel is consumed, or it is extinguished because of lack of oxygen or by quenching.

The following mechanisms of ignition must be considered in aircraft design:

(1) Autogenous or spontaneous ignition is caused by contact of a flammable mixture with a hot surface.

(2) Friction spark ignition is in fact caused by contact with hot surfaces but is generally not called autogenous ignition.

(3) Ignition by electric arcs and sparks.

(4) Hot gas ignition caused by mixing hot gas with a flammable mixture.

Ignition of flammable mixtures by severe shock waves is theroetically possible but it has never been proven to be responsible for a fire in an aircraft.

The ignition mechanisms (1) through (4) shall be described briefly.

3.5.1 AUTOGENOUS IGNITION

Autogenous ignition is evidenced by fires resulting from fuel spillage on hot tail pipes, exhaust stacks, turbine cases, overheated electronic equipment, hot bleed air lines, overheated high speed equipment, etc. Surface temperatures required to initiate combustion are subject to a number of variables such as configuration, composition of the fuel-air mixture, surface material and area, pressure and exposure time (dwell or residence time); therefore, apparatus and techniques for determining autogenous ignition characteristics are quite diversified and have resulted in a wide range of values. Among the most important methods are:

(1) Dropping measured quantities of fuel into a heated flask filled with air or oxidizer, at a wide range of pressures.

(2) Dropping of fuel onto a heated open surface over which the air may be either quiescent or flowing.

3.5.2 FRICTION SPARKS

Friction sparks can cause ignition in crash landings. Due to the small surface areas of sparks and short contact times, relatively high spark temperatures are needed to ignite fuel air mixtures. Steel sparks in the orange color region (1650 to 1750°F) caused erratic ignition, and titanium sparks in the white color region (above 2000°F) caused repeated ignition in tests simulating aircraft skin sliding along a runway surface.

3.5.3 ELECTRIC SPARKS AND ARCS

Electric discharges are excellent ignition sources because of their ability to concentrate high energy in a very small volume. Although there are many methods of using electrical discharges, the resultant sparks can be categorized generally as either inductive or capacitance sparks or arcs.

Inductive sparks can be generated easily by transformers, ignition coils, magnetos, and similar devices, and by interruption of an inductive circuit. Because inductance sparks are usually caused by high impedance sources, the current is low and the spark is of relatively long duration. Capacitance sparks are produced by the discharge of charged condensers. Electric discharges such as those generated by friction, impact, pressure, successive contact and separation of unlike surfaces, and transference of fluids are the same as capacitance sparks except for manner of generation. Natural atmospheric electrical discharges such as corona, streamers, and lightning, are basically capacitance discharges. Duration of ordinary capacitance sparks may be extremely short, such as less than 0.01 microseconds for low energies. With higher energies and with resistance added to the system, the duration of the discharge can be increased considerably, such as to 5 milliseconds in a lightning stroke.

Perhaps the most important aspect of electrical discharge is the extremely small amount of energy required to produce ignition. Under conditions favorable to ignition, the energy can be less than 1 millijoule. Under ideal conditions the energy has been as low as 0.2 millijoules. (In terms of mechanical energy, 1 millijoule equals 0.7376×10^{-3} foot pounds; in terms of thermal energy it equals 0.9478×10^{-6} BTU)

3.5.4 HOT GAS IGNITION

The ability of hot gases to cause a fire are well known. Exhaust gases and hot bleed air leaking into a flammable mixture, or vice versa, can cause ignition. Hot gas ignition temperatures vary with such factors as mixture composition, hot gas volume, turbulence, etc. The minimum hot gas ignition temperature for a given hydrocarbon is approximately twice the minimum autogenous ignition temperature in degree centigrade. Experiment-l data are influenced considerably by apparatus effects. For instance, the container for the hot gas usually provides a heated surf-ce and renders it difficult to separate the effects of the hot gas from those due to the heated surface.

When development testing is required to investigate potential hazardous situations, the tests must be tailored to simulate closely the most adverse operating conditions.

3.6 VARIABLES INFLUENCING IGNITION

Many, although not all ignition phenomena, are better understood when they are analyzed from the viewpoint of molecular energy necessary to cause ignition. In order to ignite a mixture this mixture must reach a certain energy level typical for the particular fuel. It is known that chemical reaction in a mixture occurs before visible flame indicates an ignition. This kind of reaction may or may not be indicated by pressure when taking place in a closed vessel, and it is suspected that it may prevent ignition in marginal cases by inerting caused by the decomposition products. Since the pressure rises of preignition reactions are low compared to those of ignition, and ignition is likely to follow a preignition type reaction in nearly all cases, preignition reaction can be disregarded, at least for the aircraft covered by this Handbook.

It is easy to understand that the energy transfer from an ignition source to a mixture is influenced by the temperature and volume of an ignition source (energy flow rate), the contact time between ignition source and mixture, the molecular contact and the heat transfer coefficient from a heated surface to a mixture. It is also quite clear that a mixture which has a high energy content to start with, will ignite faster, and that energy applied to molecules in the mixtures which do not contribute to burning, is wasted. Energy lost to adjacent cool surfaces will delay, or even prevent ignition if the energy supply is limited. If the net rate of energy transfer (rate of energy input minus rate of energy losses) is below a certain value for a specific fuel, ignition is impossible regardless of such factors as size of energy source, contact time, molecular mixing, etc.

Although the conditions needed for ignition are simply the simultaneous presence of a flammable substance and a suitable ignition source, a number of variables will influence the ease of ignition. The more influential of these conditions are: 1) composition of the flammable mixture; 2) absolute pressure; 3) temperature of mixture and ignition source; 4) time; 5) velocity and turbulence; 6) surface finish and material; 7) surface area; 8) distance between surfaces; 9) nature of electrical energy.

Precise definition of the effects caused by varying these conditions is beyond the scope of this discussion because of the interaction of the variables. However, the general effects of each variable can be described and are discussed below.

3.6.1 COMPOSITION OF MIXTURE

Theoretically, ignition should be easiest with a stoichiometric mixture. In many cases tests have shown that minimum ignition energies are achieved with mixtures slightly richer than stoichiometric, while in a few cases ignition has been easiest with somewhat lean mixtures. Hydrocarbon type and molecular weight can also influence ignition characteristics. For aircraft turbine fuels, ignition is easiest at fuel-air ratios approximately 20% richer than stoichiometric.

Equilibrium conditions are seldom attained except in a quiescent storage vessel. During aircraft fueling and other fuel transfer functions, mists and sprays are generated and any spillage aggravates the release of fuel vapor. Diffusion of the fuel vapor into the surrounding air is quite rapid, so that for normal circumstances the existing fire prevention requirements for areas around aircraft are adequate. However, it must be remembered that a severe spillage of fuel, particularly in warm weather or onto a warm surface, will greatly increase the hazard zone because of the tremendous volume of vapor which will be released.

3.6.2 ABSOLUTE PRESSURE

The vast majority of test work indicates that ignition can be accomplished at lower temperatures and energy levels as absolute pressure increases. With electrical ignition, the minimum energy required for ignition is proportional approximately to the inverse square of the absolute pressure. An example is shown in Figure 63. Autogenous ignition temperatures show a similar trend, except that the function is not well defined numerically.

3.6.3 TEMPERATURE

Since increased temperature of either the flammable mixture or the ignition source indicates an increase in energy level, the fact that ignition is easier at higher temperatures is quite logical. In autogenous ignition the effect of temperature is best defined in terms of ignition lag. This function is approximately hyperbolic; the limits are the minimum time required for the chemical reaction and the minimum temperature required for ignition regardless of time lag. Test data in Figure 64 involving a gasoline-oxygen mixture in a platinum crucible shows an ignition lag of approximately 1.2 seconds at 610°F and 25 seconds at 544°F. A similar effect occurs with electrical ignition. Using pentane, minimum ignition energies ranged from 45.0 millijoules at -22°F to 2.5 millijoules at 347°F.

3.6.4 TIME

From a practical standpoint this is an extremely important variable since it can often be the difference between ignition and non-ignition. It is primarily a dependent variable since it is intimately interrelated with the other conditions. Time becomes increasingly important when mixture composition, pressure, and ignition energy are at levels least conducive to ignition. There are undoubtedly many unrecorded instances in which the conditions were all within the limits of ignitibility but ignition did not occur because these conditions did not exist simultaneously for a sufficiently long time.

3.6.5 VELOCITY AND TURBULENCE

Velocity and turbulence of the flammable mixture affect both the minimum ignition energy and the ability of a flame to sustain itself. Test data shows that minimum ignition energy increases as velocity and/or turbulence increase, whether the energy is in the form of increased electrical energy or increased surface temperature. It also becomes increasingly difficult to sustain a propagating flame as velocity increases. This effect is indicated by the diminishing fuel-air ratios over which the propagating flame can sustain itself as velocity increases. Carefully controlled tests have produced flames which propagate with the flow at mixture velocities up to approximately 250 feet per second; in this case the flame is traveling with the flow. It is very difficult for a flame to propagate against the flow; with turbine engine fuels the limit in this case is approximately 30 feet per second. However, this can only be attained with ideal fuel-air mixtures and diminishes rapidly at other mixture ratios.

3.6.6 SURFACE CONDITION AND COMPOSITION

If scale or ash forms on a heated surface, the insulating action tends to increase the material temperature required for ignition. The material used to form the heated surface can also influence the temperature required for ignition. Reasons for this are not completely known, but thermal conductivity, catalytic activity, and oxidation properties are among the probable contributing factors. Platinum is extremely catalytic, and the resultant action when wires of this material are exposed to fuel-air mixtures can generate sufficient heat to cause ignition. This is the principle and the material used in some types of cigarette lighters. Another curiosity concerning materials is that glass often displays the lowest surface temperatures required for ignition of a given flammable mixture.

3.6.7 SURFACE AREA

Starting with very small surface areas, ignition temperature decreases as area increases until some minimum temperature is approached. After this point further increases in surface area have no effect on minimum ignition temperature. Fine wires must be heated to incandescence to cause ignition. While heated particles such as those emanating from a grinding wheel or similar abrasive function are not very effective as ignition sources, they must be classed as potential ignition sources.

3.6.8 DISTANCE BETWEEN SURFACES

The ability of a flammable mixture to support combustion is influenced by the distance between any surfaces which might contain the flammable mixture. When parallel surfaces are sufficiently close, or a tube diameter or slit width is sufficiently small, it becomes impossible to propagate a flame. This "quenching distance" is considerably influenced by fuel-air ratio, pressure, and temperature. Quenching distance will be at a minimum with slightly richer than stoichiometric fuel-air ratio, high temperature, and high absolute pressure. The most important point is that practical flame arrestors are feasible and that test data is available to provide design information.

REF. (1) "U. S. STANDARD ATMOSPHERE, 1962"
(2) ANA BULLETIN NO. 421

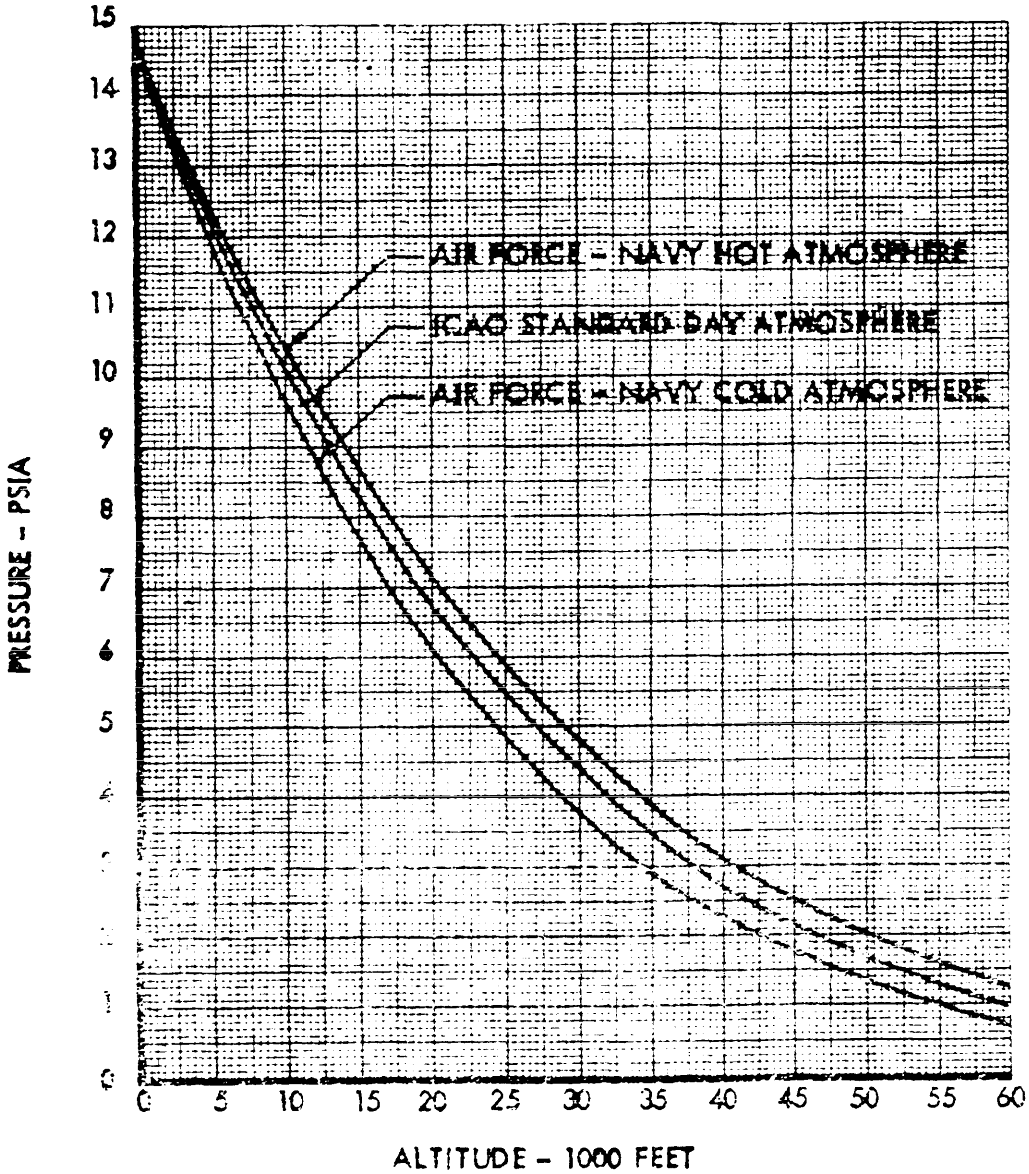
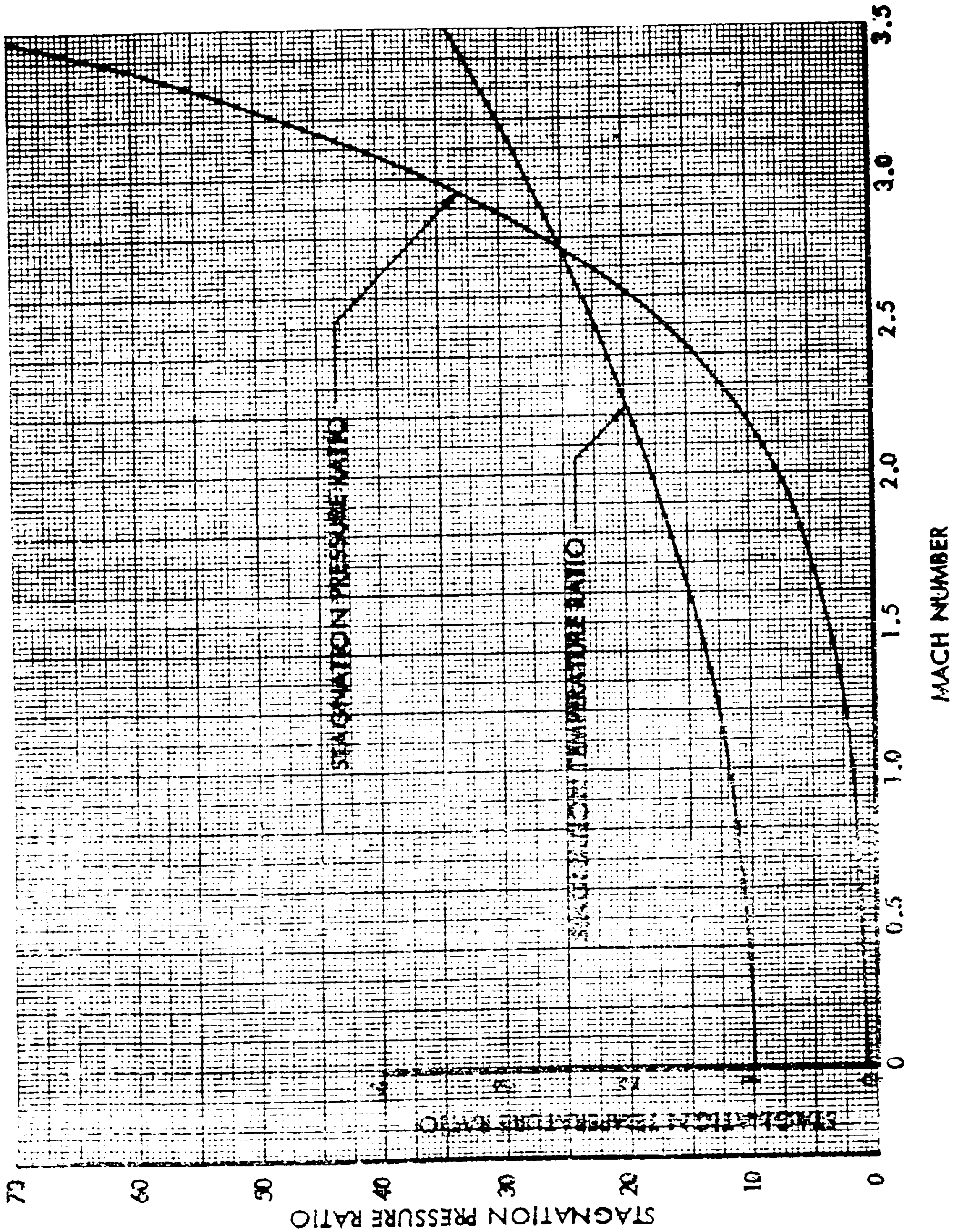


FIGURE 52 - VARIATION OF STANDARD ATMOSPHERIC PRESSURE WITH ALTITUDE



VARIATION OF STAGNATION TEMPERATURE AND PRESSURE RATIOS WITH MACH NUMBER

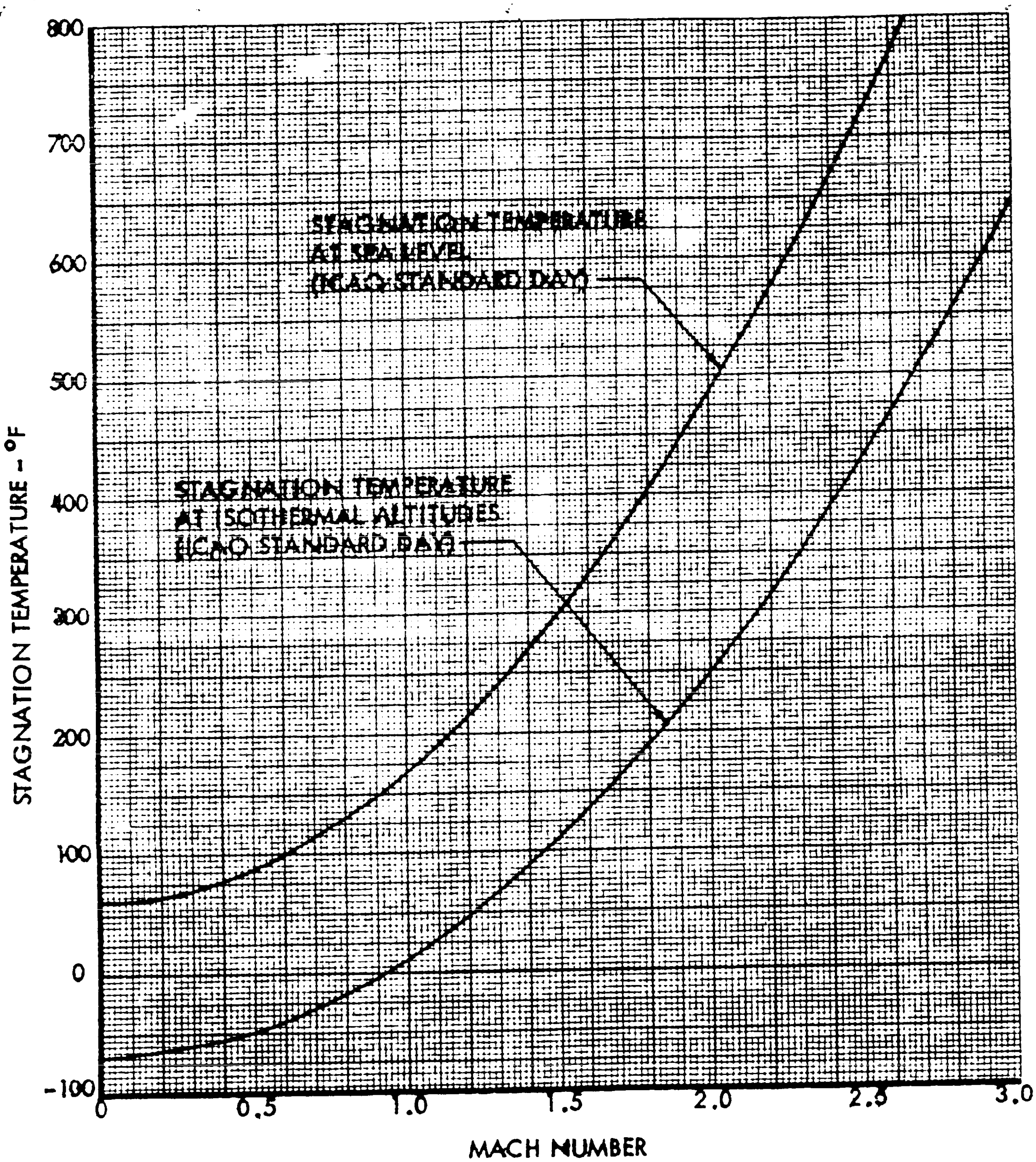


FIGURE 55 - EFFECT OF MACH NUMBER ON STAGNATION TEMPERATURE

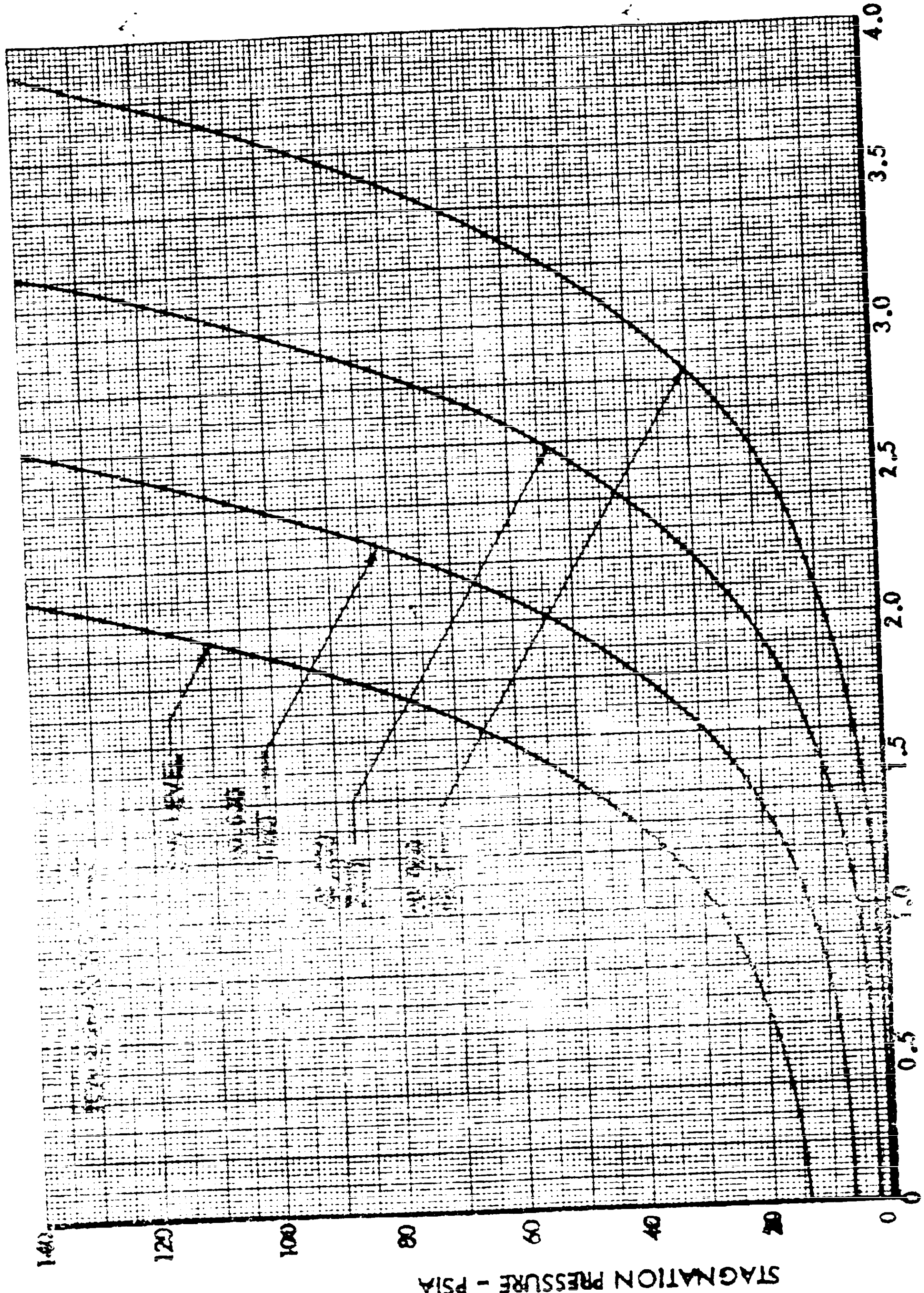
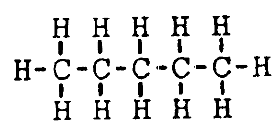
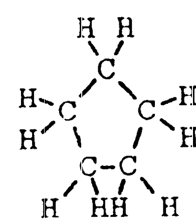
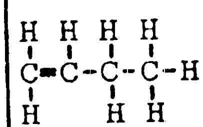
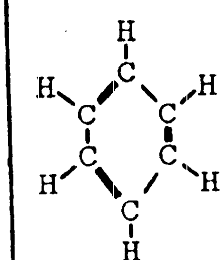


FIGURE 56 - EFFECT OF MACH NUMBER ON STAGNATION PRESSURE

SPECIFICATION	MIL-J-5624F		MIL-G-5572C
Fuel Grade	JP-4	JP-5	80/87
Distillation:			
Initial boiling point, min.	(1)	(1)	-
10 percent min. at	(1)	400°F	167°F
20 percent min. at	290°F	(1)	-
50 percent min. at	370°F	(1)	221°F
90 percent min. at	470°F	(1)	275°F
End point, max.	(1)	550°F	338°F
Percent evaporated, at 400°F	(1)	-	-
Residue, vol. percent max.	1.5	1.5	1.5
Distillation loss, vol. percent max.	1.5	1.5	1.5
Gravity °API-min. (sp.gr.max.)	45.0 (0.802)	36.0 (0.845)	(1)
Gravity °API-max. (sp.gr.min.)	57.0 (0.751)	48.0 (0.788)	
Existent gum, mg/100 ml. max.	7	7	3.0
Total potential residue, 16 hr aging, mg./100 ml. max.	14	14	6.0
Sulfur, total, percent weight max.	0.4	0.4	0.05
Mercaptan sulfur, percent wgt. max.	0.001	0.001	-
Reid vapor pressure, 100°F, psi, min. (gm./cm., min.)	2.0 (140.6)	-	5.5
Reid vapor pressure, 100°F, psi, max. (gm./cm., max.)	3.0 (210.9)	-	7.0
Freezing point, °F, max.	-76°F	-55°F	-76°F
Heating value (see 3.2.2) heat of combustion (lower or net) BTU/lb. min.	18,400	18,300	18,700
Or aniline-gravity product, min.	5,250	4,500	7,500
Viscosity, centistokes at -30°F (-34.4°C); max.	-	16.5	-
Aromatics, vol. percent max.	25.0	25.0	-
Olefin, vol. percent max.	5.0	5.0	-
Smoke point, mm min.	-	19.0	-
Explosiveness, percent max.	-	50	-
Flash point, min.	-	140°F	-
Smoke volatility index, min.	52.0	-	-
Copper strip corrosion, ASTM classification, max	No. 1	No. 1	-
Water separometer index	(1)	(1)	-
Water reaction, interface rating max.	1b	1b	-
Thermal stability:			
Change in pressure drop in 5 hours, in. Hg, max	13	13	-
Preheater deposit	<3	<3	-

(1) To be reported-not limited

FIGURE 57 TABLE 1 - SPECIFICATIONS OF AIRCRAFT FUELS

Hydrocarbon Group	Paraffins	Cycloparaffins	Olefins	Aromatics
Chemical Formula	$C_n H_{2n} + 2$	$C_n H_{2n}$	$C_n H_{2n}$	$C_n H_{2n} - 6$
Molecular Arrangement	Chain	Ring	Chain or Ring	Ring, Multi-Ring
Mass Heat Content	High	Moderate	Moderate	Low
Specific Gravity	Low	Medium	Low	High
Combustion	Clean	Clean	Fairly Clean	Smoky
Stability	Excellent	Very Good	Poor	Very Good
Boiling Point	Low	Medium	Low to Med.	Medium to High
Elastomer Reaction	Negligible	Negligible	Swelling	Much Swelling
Typical Molecular Arrangement	 (Normal Pentane)	 (Cyclopentane)	 (Butene-1)	 (Benzene)

Notes:
1. Olefins generally are not found in crude petroleum, but are formed in large quantities in refinery cracking process.
2. Freezing points and pour points are variable within groups.

FIGURE 58 COMPARATIVE CHARACTERISTICS OF FOUR GROUPS OF HYDROCARBON COMPOUNDS

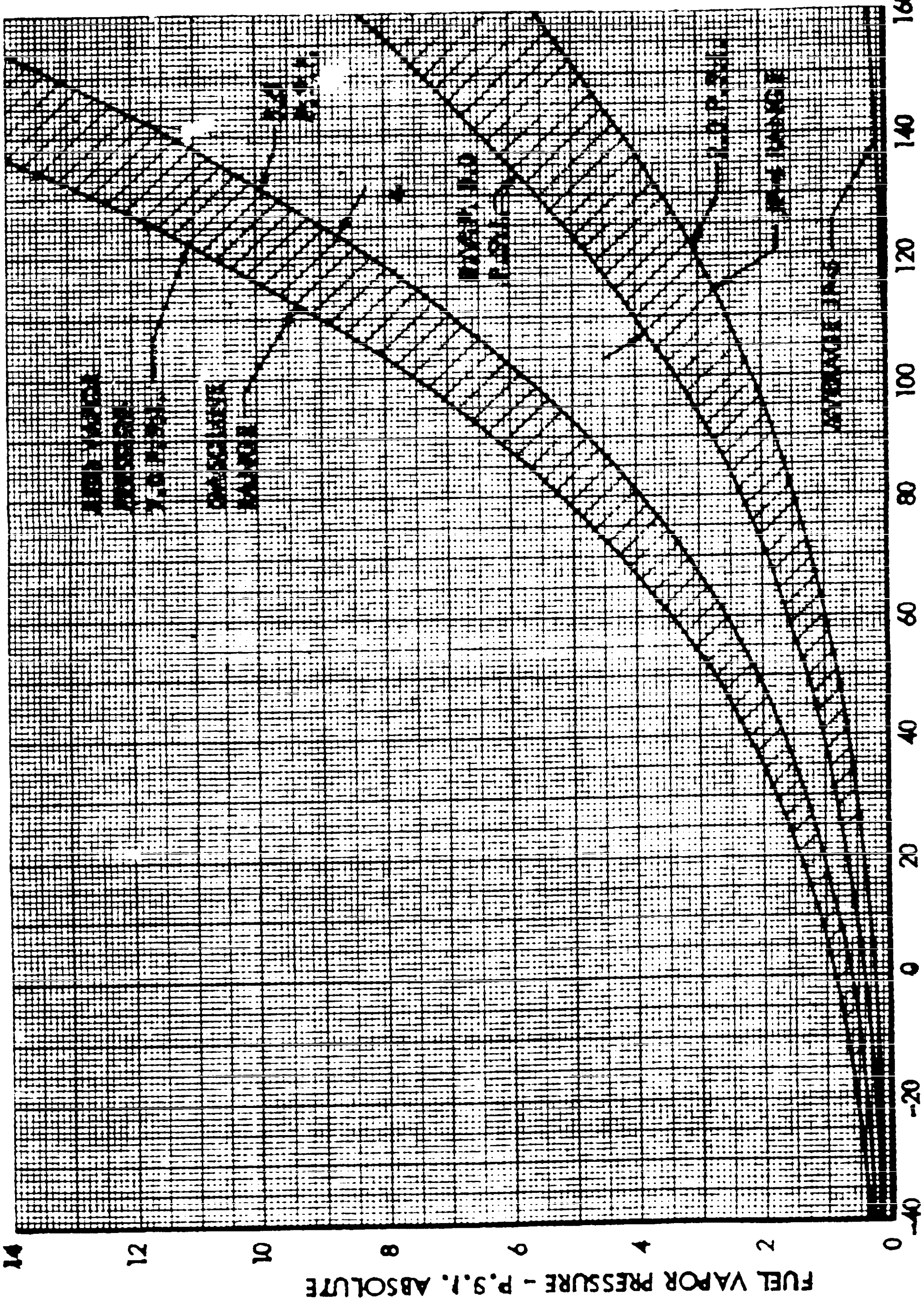


FIGURE 60 - VAPOR PRESSURE OF AIRCRAFT TURBINE FUELS

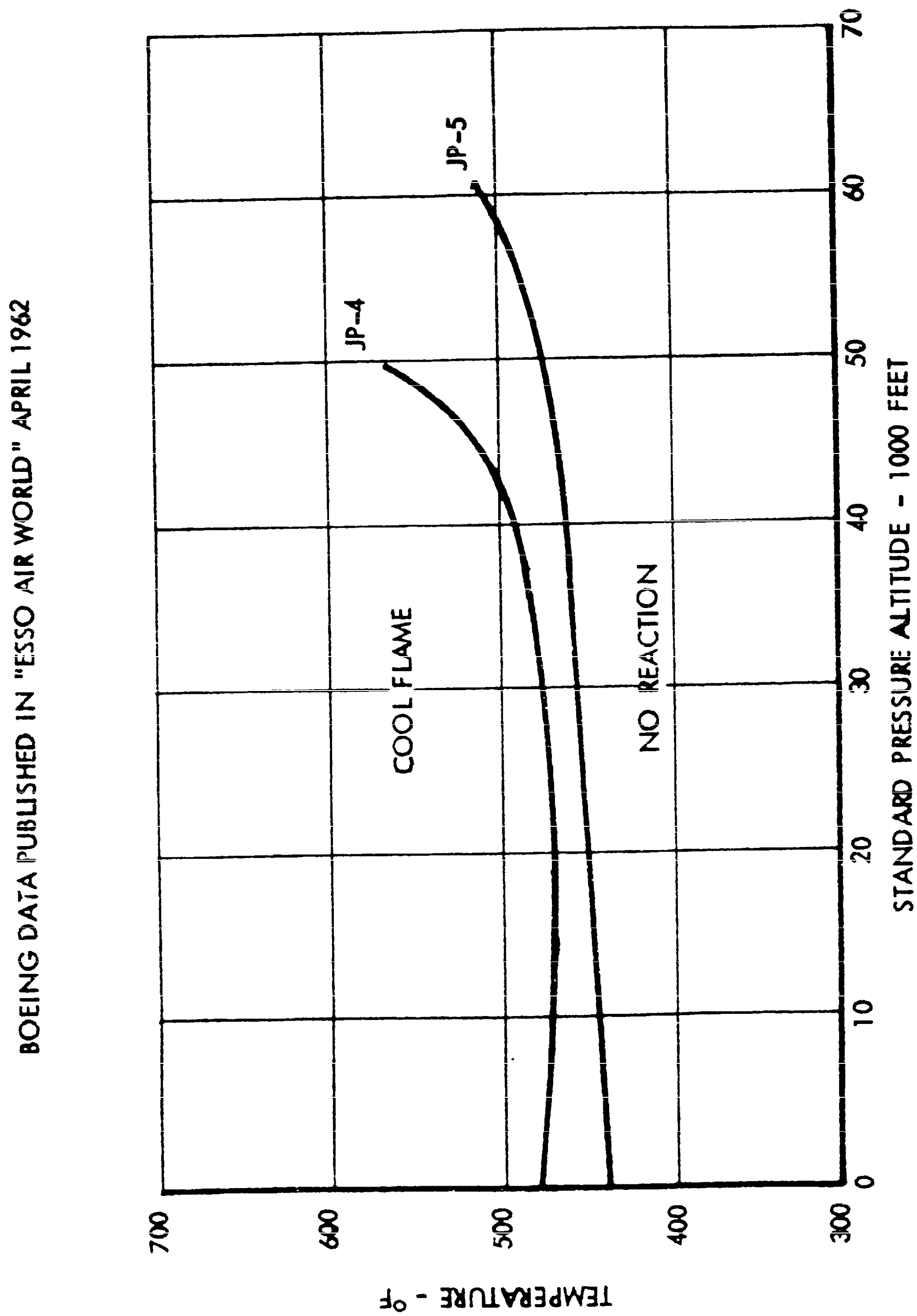


FIGURE 62 - MINIMUM AUTOGENOUS IGNITION TEMPERATURE FOR JP-4 AND JP-5

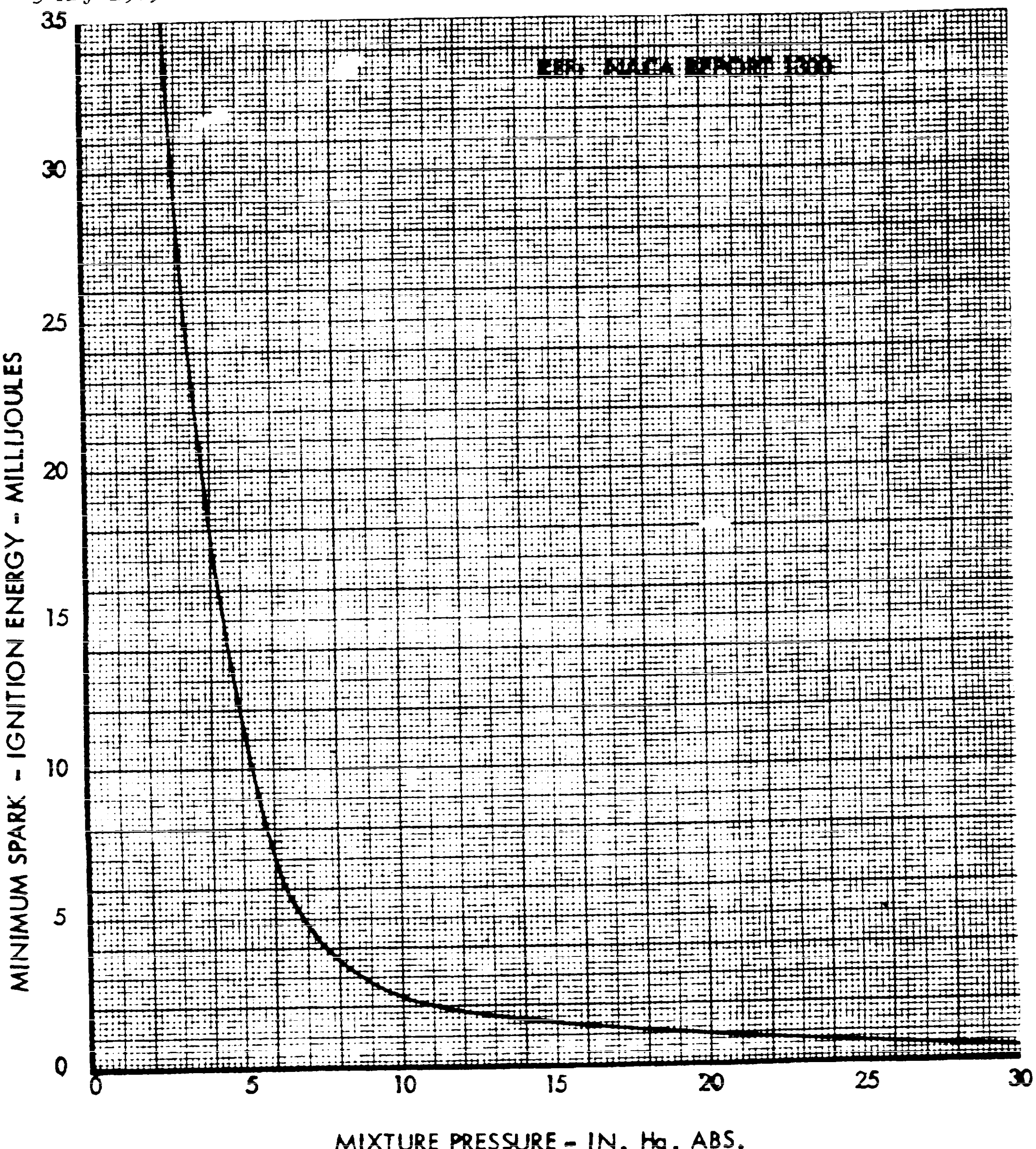


FIGURE 63 - EFFECT OF MIXTURE PRESSURE ON MINIMUM IGNITION ENERGY

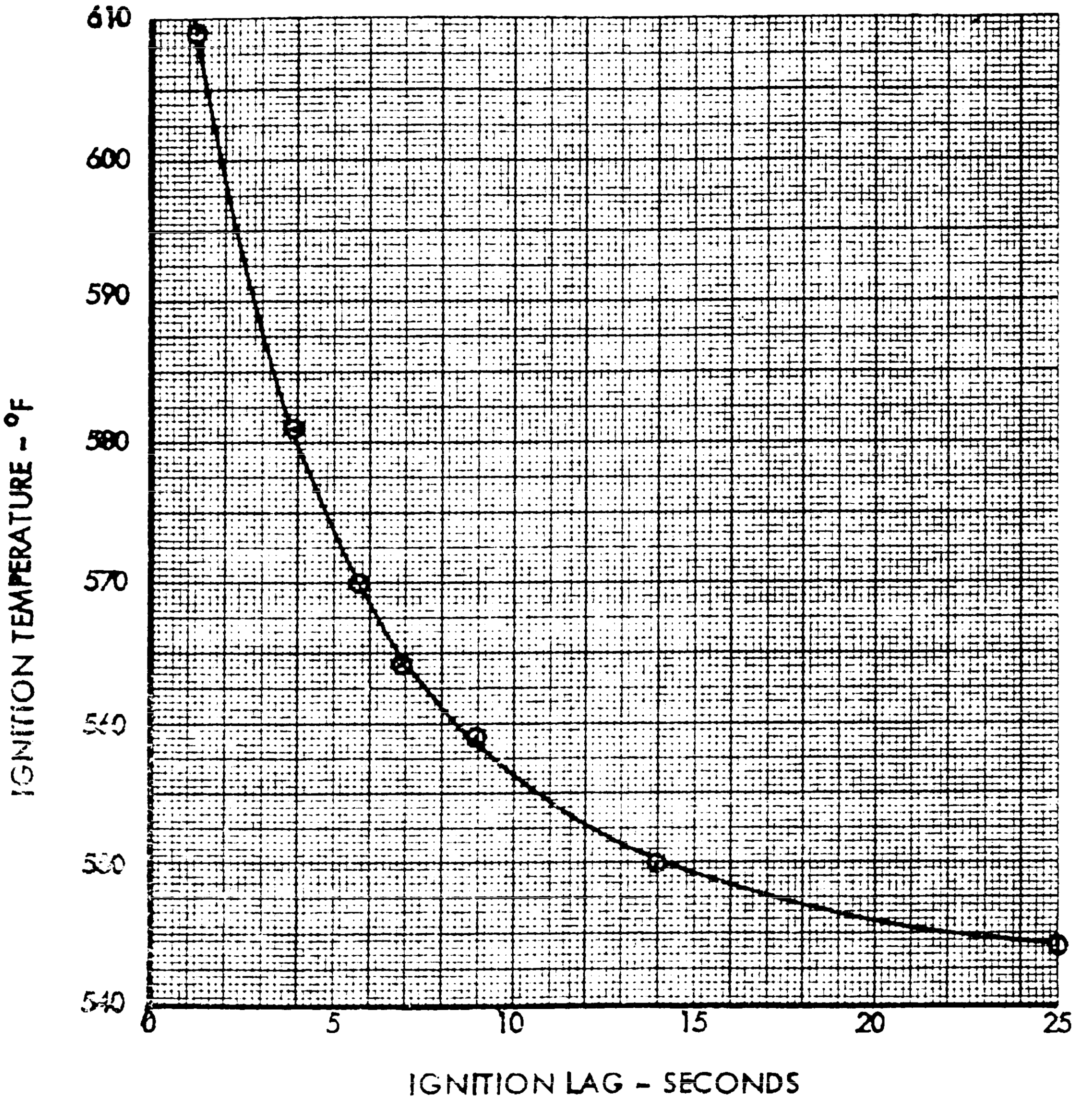


FIGURE 64 - VARIATION OF IGNITION TEMPERATURE WITH IGNITION LAG

APPENDIX A

BIBLIOGRAPHY

1. FIRE PREVENTION

1.a. Fuel Systems

Investigation of Autoignition and Other Phenomena in High Temperature Aircraft Fuel Systems, ASD Technical Report 61-480, R. Wolfshagen, et al, Sept. 1961.

Spontaneous Ignition Within A Heated Fuel Tank When Pressurized With Air Under Simulated Diving Flight Conditions, Ministry of Aviation, Great Brit. Royal Aircraft Establishment Technical Note, Mech. Eng. 341, J. A. MacDonald, Sept. 1961.

Preliminary Discussion of Fuel Temperatures Attained in Supersonic Aircraft, NACA Research Memo E55A25 (CONF.), Louis C. Gibbons, March 15, 1955.

Report on Investigation of Possible Fire Hazards in Aircraft Fuel Quantity Gages, Naval Air Material Center, U.S. Naval Base Station, Philadelphia 12, Pa., NAES-INSTR-48-52, ASTIA AD94776.

Fueling Aircraft on the Ground, National Fire Protection Association, NFPA 407.

1.b. Electricity

Investigation of Mechanisms of Potential Aircraft Fuel Tank Vent Fires and Explosions Caused by Atmospheric Electricity, Lockheed-California Company, NASA/FAA Contract NASr-59, May 31, 1963.

Aircraft Protection From Thunderstorm Electromagnetic Effects, ASD-TDR-62-438 Part V, M.M. Newman, May 1963.

Lightning Stroke Diverting Methods for Aircraft Fuel Tank Areas, Lightning & Transients Research Inst. L & T Report 393, M.M. Newman, 1961.

Comparative Lightning Damage to Aluminum and Stainless Steel Sheets, Lightning & Transients Research Inst. L & T Report 395, M.M. Newman, 1961.

Interim Lightning Protection for Aircraft Fuel Vents, Lightning & Transients Research Inst. L & T Report 392, M.M. Newman, 1961.

Aircraft Protection From Atmospheric Electrical Hazards, Lightning & Transients Research Inst., WADD TN-60-35, Jan. 1960.

Lightning Hazards to Aircraft Fuel Tanks Part II - Corona Discharge Ignition of Fuel Vapors, Lightning & Transients Research Inst. L & T Report 364, M.M. Newman, Dec. 1959.

Lightning Hazards to Aircraft Fuel Tanks, NACA TN 4326, J.D. Robb, Sept. 1958.

Teflon Aircraft Hose Investigation, Relation Between Tube Resistance, Current and Voltage, National Bureau of Standards Report 8043, Mr. Shafer, July 17, 1963.

A Study of Electrostatic Charge Generation During Low Temperature Refueling of Aircraft, National Research Council of Canada Aeronautical Report LR 387, C. Bruinzeel Et. Al., Oct. 1, 1963.

Shipboard Studies of Fuel-Vapor Ignition By Radio-Frequency Arcs, U.S. Naval Research Laboratory, NRL Report 5443, F.J. Woods, Jan. 25, 1960.

Static Electricity in Aircraft Operations and Maintenance, National Fire Protection Association, NFPA 404.

Fuel Sloshing Electrification Hazards of Aircraft Fuel Tank Sealers, Lightning & Transients Research Inst. L & T Report 394, M.M. Newman, 1961.

Minimum Spark-Ignition Energies of 12 Pure Fuels at Atmospheric and Reduced Pressure, NACA Research Memo E53H31, Allen J. Metzler, Oct. 29, 1953.

Electrostatic Spark Ignition-Source Hazard in Airplane Crashes, NACA TN 3026, Arthur M. Busch, Oct. 1953.

Protection Against Ignition Arising Out of Static, Lightning and Stray Currents, American Petroleum Institute, API 2003, Aug. 1956.

Investigation of Electrical Fire Hazards in Aircraft, U.S. Naval Test Center, Patuxent River, Electronics Test Div., NATC Report Serial No. ET 501, Aug. 26, 1948.

1.c. Baggage Compartments

Evaluation of Flight Fire Protection Means for Inaccessible Aircraft Baggage Compartments, CAA Tech. Dev. Rep. No. 146, L.A. Asadourian, June 1951.

1.d. Oxygen Systems

Investigation of Fires Originating from an Aircraft Oxygen System, Civil Aeronautics Administration Technical Development Report No. 327, Paul R. Dierdorf, March 1958.

1.e. Inerting

An Investigation Into the Effectiveness of Existing and Experimental Anti-Fire Installations for Aircraft, Royal Aircraft Establishment Tech. Note Mech. Eng. 273, E. Bade, Sept. 1963.

Treatment of Aircraft Fuel With Nitrogen to Reduce Tank Explosion Hazards, Royal Aircraft Establishment Tech. Note Mech. Eng. 210 (CONF.), H.W.G. Wyeth, April 1957 Part II, May 1957 Part III.

Symposium on Passive Defense and Aircraft Purging-Prevention of Explosion and Fire in Combat Aircraft, WADC MR 524-3079.

Principles of Aircraft Purging, Wright-Patterson AFB, AF Technical Report No. 6066 (CONF.), R.E. Guynes, May 1950.

The Effect of Carbon Dioxide Blanketing on JP Fuels, WADC TN 58-375, Lt. T.L. Gossage, Nov. 1938.

Inerting Conditions for Aircraft Fuel Tanks, WADC TR 55-418, Paul B. Stewart, Sept. 1955.

Effectiveness of Purge Mats Against Gun Fire, WADC TN WCLP-53-220, Mr. Strunk, July 22, 1953.

2.e. Magnesium Fires

Fire Tests on Magnesium Alloy Castings, AMC Memorandum Report TSEAc12-45121-3-1, Nov. 5, 1947.

Protection of Aircraft against Magnesium Fires, Army Airforces Air Material Command, AAF TR 5526, Aug. 27, 1946.

2.f. Emergency Control

Study of Fire-Emergency Control Systems, WADC TR 54-96, Howard W. Naulty, June 1954.

3. CRASH FIRE PREVENTION

A Feasibility Study of a Crash-Fire Prevention System for the Supersonic Commercial Transport, Southwest Research Inst., ASD TDR 63-478, L.A. Eggleston et al, Aug. 1, 1963.

Calculation of the Strength of Crash-Resistant Fuel Cells for the Wings of a Twin-Engine and a Four-Engine Transport Airplane, FAA Task 59-203-4, D.A. Hillman, April 1961.

Studies on the Fuel-Ignition-Suppression Capability of Foam-Covered Runways for Aircraft, U. S. Naval Research Lab., NRL Report 5492, H. B. Peterson, July 22, 1960.

Crash-Fire Protection System for T-56 Turbopropeller Engine Using Water as Cooling and Inerting Agent, NASA Memorandum M 6-12-59E, Arthur M. Busch, May 1959.

An Engineering Study of Aircraft Crash-Fire Prevention, WADC TR 57-370, ASTIA Document No. AD 155846, R. B. Jones, June 1958.

Origin and Prevention of Crash Fires in Turbo Jet Aircraft, NACA Report 1363, I. Irving Pinkel, 1958.

Origin and Prevention of Crash Fires in Turbo Jet Aircraft, NACA TN 3973, I. Irving Pinkel, May 1957.

Appraisal of Hazards of Friction-Spark Ignition of Aircraft Crash Fires, NACA TN 4042, John A. Campbell, May 1957.

Impact Tests of Flexible Non-Metallic Aircraft Fuel Tanks Installed in Two Categories of Simulated Wing Structures, CAA TDR No. 291, Charles V. Bennett, January 1957.

Proposed Initiating System for Crash-Fire Prevention System, NACA TN 3774, Jacob C. Moser, Dec. 1956.

Mechanism of Start and Development of Aircraft Crash Fires, NACA Report 1133, I. Irving Pinkel, 1953.

Appraisal of Hazards to Human Survival, NACA TN 2996, G. J. Pesman, Sept. 1953.

4. COMBUSTIBLES AND FLAMMABLES

Review of Fire and Explosion Hazards of Flight Vehicle Combustibles, ASD TR 61-278, Bureau of Mines, April 1961, April 1962-Supplement I, April 1963-Supplement II.

Ignition Characteristics of Fuel and Lubricants, APL-TDR-64-25, Joseph M. Kuchta, Dec. 1963.

Flammability Characteristics of High Temperature Hydrocarbon Fuels, ASD-TDR-62-328, Joseph M. Kuchta, et al, April 1962.

Flammability Characteristics of High Temperature Hydrocarbon Fuels, ASD-TDR-62-328-Part II, Joseph M. Kuchta, et al, Dec. 1962.

Autoignition Characteristics of JP-6 Jet Fuel, ASD-TDR-62-615, Joseph M. Kuchta, et al, June 1962.

Report of the Working Party on Aviation Kerosene and Wide-Cut Gasoline, Great Brit. Ministry of Aviation, C.A.P. 177, 1962.

Combustion, Flames and Explosions of Gases, Lewis and von Elbe, Academic Press, Inc., Book, 1961.

Flammability Characteristics of High Temperature Hydrocarbon Fuels, WADC TR 59-663, Joseph M. Kuchta, Feb. 1960.

The Effects of Cabin Atmospheres on Combustion of Some Flammable Aircraft Materials, WADC TR 59-456, Howard A. Klein, Maj. USAF Res., April 1960.

Suppression and Transmission of Explosions by Cylindrical Channels, Bureau of Mines Report of Investigations 5495, H. G. Wolfhard, 1959.

Research on the Flammability Characteristics of Aircraft Hydraulic Fluids - Part I, WADC TR 57-151, ASTIA No. 130764, Michael T. Zebetakis, May 1957, Supplement I - ASTIA No. AD 155510, May 1958; Part II, ASTIA No. AD 210715, Mar. 1959.

Determination of Means to Safeguard Rotary-Wing Aircraft from Powerplant Fires in Flight - Part I, FAA TDR 351, Glenn S. Laudig, Feb. 1959.

Communication of Flame through Cylindrical Channels, Bureau of Mines Report of Investigation 5457, H. G. Wolfhard, 1959.

The Ignition of Combustible Mixtures by Hot Gases, United States Bureau of Mines TR-BUM-24-P, ASTIA No. AD 147702, H. G. Wolfhard, Dec. 1957.

Development of High Temperature Sealants, WADC TR 58-89, ASTIA No. 155606, Irvin P. Seegman, June 1958.

Aircraft Fire Resistant Hydraulic Fluids, WADC TR 57-312, ASTIA No. AD 118327, Donald I. Hackney, June 1957.

Spontaneous Ignition Studies Relating to Lubricants of Reduced Flammability, NACA TN 3560, Kenneth T. Mecklenborg, January 1956.

Properties of Aircraft Fuels, NACA TN 3276, Henry C. Barnett, August 1956.

Research on the Flammability Characteristics of Aircraft Fuels, WADC TR 52-35, G. W. Jones, June 1952: Jan. 1954-Supplement I; August 1954-Supplement II; February 1955-Supplement III; January 1956-Supplement IV.

Effect of Pressure on the Spontaneous Ignition Temperature of Liquid Fuels, NACA TN 3829, Cleveland O'Neal, Jr., October 1956.

Spontaneous Ignition of Liquid Fuels, Butterworths Scientific Publications, Book, B. P. Mullins, 1955.

Effect of Hydrocarbon Structure on Reaction Processes Leading to Spontaneous Ignition, NACA TN 3384, Donald E. Swarts and Charles E. Frank, July 1955.

Fire Retardant Coatings, WADC TR 53-73, Sam Collis, August 1954.

Pressure Limits of Flame Propagation of Pure Hydrocarbon-Air Mixtures at Reduced Pressure, NACA RM E52H15, A. E. Spakowski, September 30, 1952.

Limits of Flammability of Gases and Vapors, Bureau of Mines Bulletin 503, H. F. Conrad, 1952.

Investigation of Hydrocarbon Ignition, NACA TN 2549, Charles E. Frank, January 1952.

Investigation of Spontaneous Ingition Temperatures of Organic Compounds with Particular Emphasis on Lubricants, NACA TN 2848, Charles E. Frank, December 1952.

Determination of Ignition Characteristics of Hydraulic Fluids, Part I - CAA Technical Development Report 64, Simulated Flight and Crash Conditions, April 1951; Part II - CAA Technical Development Report 142, Flammability Reference Scale, May 1951, J. J. Gassmann.

Spontaneous Ignition Temperatures of Pure Hydrocarbons and Commercial Fluids, NACA Research Memorandum E50J10, Joseph L. Jackson, December 20, 1950.

Extinction of Gasoline Flames by Inert Gases, Bureau of Mines RI 3871, G. W. Jones, April 1946.

Basic Considerations in the Combustion of Hydrocarbon Fuels with Air, NACA Report 1300, Henry C. Barnett, 1957.

Preliminary Survey of Airplane Combat Fire Problems, NACA RM E52G51, Lewis A. Rodert, 1952.

Relation between Inflammables and Ignition Sources in Aircraft Environments, NACA 1019, Wilfred E. Scull, 1951.

5. HANDBOOKS

Study on Minimization of Fire and Explosion Hazards in Advanced Flight Vehicles, ASD TR 61-288, October, 1961.

Design Manual on Aircraft Fire Protection for Reciprocating and Gas Turbine Engine Installations, Aerospace Industries Association, January 1963.

Handbook of Instructions for Aircraft Designers, Air Research and Development Command, HIAD, ARDCM 80-1.

General Specification for Design and Construction of Aircraft Weapon Systems, U. S. Navy Specification SD-24.

Explosives Safety Handbook, Air Force Systems Command AFSCP 127-1, February 28, 1964.

APPENDIX B

DEFINITIONS

Air, bleed - See bleed air.

Anoxemic - Indicates deficient aeration of the blood.

Arc, electric - See electric arc.

Armor - Steel or iron plating designed to resist gunfire or other high kinetic energy pieces, used to protect fuel tanks and other vulnerable components.

Arrestor, flame - See flame arrestor.

Arrestor, lightning - See lightning arrestor.

Autogenous ignition temperature, minimum, (MAIT) - The lowest temperature at which a flammable fuel-air mixture will ignite spontaneously under specified conditions.

Barrier, fire - See fire barrier.

Barrier, vapor - See vapor barrier.

Bladder cell - Tank formed by an elastic bag which is contained in a rigid cavity.

Bleed air - Air tapped from a turbine engine compressor for the purpose of energy extraction, or compressor stall prevention. The air may be tapped after the final compressor stage or at any intermediate stage.

Bonding, electric - See electric bonding.

Butt - To meet or adjoin at the end. Example: butting wing skin.

Carbon monoxide detector - A device for detection of hazardous concentrations of carbon monoxide or fire, especially a smoldering or incipient fire.

Cell, bladder - See bladder cell.

Combustible - Solids or liquids which will ignite and burn, but are not explosive or rapidly burning in the environment of application.

Cut hose - Nonmetallic hose usually cut to size from stock material and secured by a hose clamp.

Deflagration - A chemical reaction (flame) moving through the material at a speed <u>less</u> than that of sound.

Detector, carbon monoxide - See carbon monoxide detector.

Detector, flame - See radiation sensing detector.

Detector, heat - See heat detector.

Detector, smoke - See smoke detector.

Detonation - A chemical reaction (flame) moving through the material at a speed greater than sound.

Diverter, lightning - See lightning diverter.

Drainage - Generally used for the emptying of liquid by flow. In aircraft, rapid drainage of flammable fluid leakage overboard from an aircraft is very effective in minimizing fire and explosion hazards. Liquid fuel must vaporize and diffuse into the air before being rendered ignitable, and rapid drainage reduces the time for vaporization.

Dwell time - The time a flammable mixture is in contact with a hot surface. This time is significant for the total amount of heat energy transferred from the hot surface to the flammable mixture. The dwell time is therefore one of the factors influencing the autogenous ignition temperature of a mixture.

Electric arc - A sustained brilliantly luminous glow, sometimes having the appearance of a curved line of flame, that is formed under certain conditions when a break is made in an electric circuit.

Electric bonding - The connection between two electric conductors for the purpose of maintaining them at substantially the same electrical potential. For the purpose of this manual this is meant to be the potential of the aircraft structure.

Environment-free - This term is applied to electric connections and denotes a connector which has either no interior spaces where gas, vapor, or fluid can accumulate, or which is sealed so that gas, vapor, or fluid cannot enter.

Explosion - A violent expansion or bursting that is accompanied by noise and is caused by sudden release of energy.

Explosion proof - Explosion proof aeronautical equipment is designed to prevent ignition of a flammable mixture within the equipment when operated, or to prevent an internal explosion from propagating to the exterior.

Explosion suppression - An inerting system in an aircraft fuel tank or other compartment containing an explosive fuel vapor, which is triggered by the initial phase of an explosion. Rapid dispersion of the inerting agent prevents a pressure rise beyond safe limits. Agent discharge is triggered by pressure rise or radiation sensing.

Extremity - Extremities of an aircraft are major end portions of an aircraft such as wing tips, wing tip tanks, fuselage nose, stabilizer and fin tips, etc.

Failure, single - See single failure.

Faying - Fitting closely together, such as faying surfaces of wing structure.

Fire barrier - A partition which will resist flame penetration under the most severe condition of fire, duration and vibration likely to occur at its location.

Fireproof - Fireproof structure, equipment, wiring, controls and piping must be able to perform their intended functions under the most severe conditions of fire and vibration likely to occur at their location.

Fire resistant - Fire resistant structure, equipment, wiring, controls, and piping must be able to perform their intended functions under the most severe conditions of fire and vibration likely to occur at the particular location for a period of at least five minutes.

Fire shield - Tight fitting fire shields made of aluminum, or equally fire resistant material, are used for separation of potential fire zones from adjacent compartments, if the hazard is minor.

Fire wall - See fire barrier.

Fire zone, potential - A compartment where a fire is possible due to specified conditions prevailing in this compartment or in adjacent compartments.

Flame arrestor - A device which quenches a flame front to the point that flame propagation is stopped. Quenching is effected by forcing the flames along narrowly spaced walls or through small tubes. Flame arrestors are rendered ineffective by sustained exposure to flame.

Flame detector - See radiation sensing detectors.

Flame resistant - Flame resistant material shall not ignite spontaneously under all environmental temperatures of installation, and shall be self-extinguishing after removal of a flame. When used in fire zones with fire extinguishing capabilities, it shall not afterflow.

Flammable - Flammables are solids, fluids or gases which will ignite readily in air, such as hydrocarbon fuels and lubricants.

Fueling, gravity - See gravity fueling.

Fueling, pressure - See pressure fueling.

Gas, inert - See inert gas.

Lightning diverter - A device which protects areas of the aircraft from a lightning strike where a lightning strike could cause a hazard. The device can be a rod or a strip which protrudes from the skin of the aircraft, attracting lightning and carrying the current to the skin without dangerous resistance heating.

Pressure fueling - Filling of an aircraft fuel tank through a fueling line which ultimately is attached to the fuel tank. The force of fluid motion is pressure applied to the fluid.

Protrusion - Minor components of an aircraft protruding from the main contour of the airframe, such as search lights, bomb racks, certain types of antennas, ventral and dorsal fins, etc.

Purge - To clean or slush such as fuel vapors or smoke from a compartment.

Radiation sensing detector - A device which detects a visible flame through radiation. These devices are often referred to as visual, flame, or surveillance detectors.

Residence time - See dwell time.

Single failure - In addition to the obvious, the following combinations are considered safety-wise, equivalent to a single failure: (a) A combination of failures which cannot be detected during a preflight check or normal flight but which may be found to be in a failed or unsafe condition when an additional failure occurs; (b) A combination or chain reaction of failures caused by one single failure.

Scupper - A small basin incorporating a filler cap, and a drain for disposal of spilled or overflowed fluid.

Smoke detector - A unit which detects smoke by photo-electric, visual or olfactory means.

Spark, electric - A luminous disruptive electrical discharge of very short duration between two conductors separated by air or other gas.

Store - Equipment stored internally or externally of an aircraft, easily removable or interchangeable, such as bombs, rockets and auxiliary tanks.

Surveillance detector - See radiation sensing detector.

Squib - A pyrotechnic device used to initiate fire extinguishing agent release or ignition of an explosive device.

Vapor barrier - Wall through which any anticipated vapor cannot penetrate.

Ventilation - Circulation of a current of air. Ventilation of aircraft compartments with potential leakage of flammable fluid or vapor tends to lean out a fuel-air mixture below the lower flammable limit, reduces the residence time of flammable vapor at hot surfaces, and lowers the temperature level in the compartment.

Venting - Discharge of gases and vapors through an opening. Cavities in aircraft, such as fuel, oil, water, etc., tanks are vented to reduce pressure differentials between these cavities and ambient caused by altitude changes and vaporization.

Visual type detectors - See radiation sensing detectors.

tment.

Exhaust systems should be located as high in a compa

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so that air cannot be drawn from a compartment with potential flammable

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SPECIFICATION ANALYSIS SHEET	Form Approved Budget Bureau No. 119-R004

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This sheet is to be filled out by personnel either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Department of Defense. This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost. Comments and the return of this form will be appreciated. Fold on lines on reverse side, staple in corner, and send to preparing activity *(as indicated on reverse hereof)*.

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3 May 1965

MILITARY STANDARDIZATION HANDBOOK

FIRE PROTECTION DESIGN HANDBOOK FOR

U.S. NAVY AIRCRAFT POWERED BY TURBINE ENGINES

FSC 7610

FOREWORD

This Aircraft Fire Protection Handbook contains requirements and design objectives for Navy aircraft. It also contains some fundamental information on physical properties of air, fuel and ignition sources, and their interrelation in causing a fire and explosion. A bibliography of relevant literature is added which, in connection with the fundamentals, should facilitate the designers' tasks of implementing the requirements and objectives of the Handbook.

The Handbook will be incorporated in the specification requirements of contracts for new Navy aircraft models.

Amendments to this Handbook will be issued as necessary to maintain up-to-date requirements consistent with the state-of-the-art. Amendments will be by page revisions and revised paragraphs will be suitably identified.

Where the requirements of this Handbook conflict with any applicable Government specifications, the requirements of the specifications shall take precedence. Where no such conflict exists, compliance with the requirements of this Handbook is mandatory.

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