Aircraft maintenance technicians devote a portion of their aviation career to ground handling and operating aircraft. Technicians also need to be proficient in operating ground support equipment. The complexity of support equipment and the hazards involved in the ground handling of aircraft require that maintenance technicians possess a detailed knowledge of safety procedures used in aircraft servicing, taxiing, runup, and in the use of ground support equipment. The information provided in this chapter is intended as a general guide for safely servicing and operating aircraft.

Human factors should be introduced to aircraft maintenance personnel to make them aware of how it affects the maintenance performed. Although there are many factors involved when dealing with human performance, several areas can be considered. Some of these include fatigue, deadline pressure, stress, distractions, poor communication skills, complacency, and lack of information. Maintenance technicians should be aware of how human factors can affect their performance and safety while performing maintenance practices.

Shop Safety

Keeping hangars, shop, and the flight line orderly and clean is essential to safety and efficient maintenance. The highest standards of orderly work arrangements and cleanliness should be observed during the maintenance of aircraft.

Where continuous work shifts are established, the outgoing shift should remove and properly store personal tools, rollaway boxes, all workstands, maintenance stands, hoses, electrical cords, hoists, crates, and boxes that were needed for the work to be accomplished.

Signs should be posted to indicate dangerous equipment or hazardous conditions. There should also be signs that provide the location of first aid and fire equipment.

Safety lanes, pedestrian walkways, and fire lanes should be painted around the perimeter inside the hangars. This is a safety measure to prevent accidents and to keep pedestrian traffic out of work areas.

Safety is everyone's business, and communication is key to ensuring everyone's safety. Technicians and supervisors should watch for their own safety and for the safety of others working around them. If other personnel are conducting their actions in an unsafe manner, communicate with them, reminding them of their safety and that of others around them.

Electrical Safety

Physiological Safety

Working with electrical equipment poses certain physiological safety hazards. It is known that when electricity is applied to the human body, it can create severe burns in the area of entrance to and at the point of exit from the body. In addition, the nervous system is affected and can be damaged or destroyed.

To safely deal with electricity, the technician must have a working knowledge of the principles of electricity, and a healthy respect for its capability to do both work and damage.

Wearing or use of proper safety equipment can provide a psychological assurance at the same time it physically protects the user. The use of rubber gloves, safety glasses, rubber or grounded safety mats, and other safety equipment contributes to the physiological safety of the technician working on or with electrical equipment.

Two factors that affect safety when dealing with electricity are fear and overconfidence. These two factors are major causes of accidents involving electricity. While both a certain amount of respect for electrical equipment is healthy and a certain level of confidence is necessary, extremes of either can be deadly.

Lack of respect is often due to lack of knowledge. Personnel who attempt to work with electrical equipment and have no knowledge of the principles of electricity lack the skills to deal with electrical equipment safely.

Overconfidence leads to risk taking. The technician who does not respect the capabilities of electricity will, sooner or later, become a victim of electricity's awesome power.

Fire Safety

Anytime current flows, whether during generation or transmission, a byproduct of that flow is heat. The greater the current flow, the greater the amount of heat created. When this heat becomes too great, protective coatings on wiring and other electrical devices can melt, causing shorting, which leads to more current flow and greater heat. This heat can become so great that metals can melt, liquids vaporize, and flammable substances ignite.

An important factor in preventing electrical fires is to keep the area around electrical work or electrical equipment clean, uncluttered, and free of all unnecessary flammable substances.

Ensure that all power cords, wires, and lines are free of kinks and bends which can damage the wire. Never place wires or cords where they will be walked on or run over by other equipment. When several wires inside a power cord are broken, the current passing through the remaining wires increases. This generates more heat than the insulation coatings on the wire are designed to withstand and can lead to a fire.

Closely monitor the condition of electrical equipment. Repair or replace damaged equipment before further use.

Safety Around Compressed Gases

Compressed air, like electricity, is an excellent tool as long as it is under control. A typical nitrogen bottle set is shown in Figure 11-1.

The following "do's and don'ts" apply when working with or around compressed gases:

- Inspect air hoses frequently for breaks and worn spots. Unsafe hoses should be replaced immediately.
- Keep all connections in a "no-leak condition."
- Maintain in-line oilers, if installed, in operating condition.
- The system should have water sumps installed and should be drained at regular intervals.

Figure 11-1. A typical nitrogen bottle.

- Air used for paint spraying should be filtered to remove oil and water.
- Never use compressed air to clean hands or clothing. Pressure can force debris into the flesh leading to infection.
- Never spray compressed air in the area of other personnel.
- Air hoses should be straightened, coiled, and properly stored when not in use.

Many accidents involving compressed gases occur during aircraft tire mounting. To prevent possible personal injury, use tire dollies and other appropriate lifting and mounting devices in mounting or removing heavy aircraft tires.

When inflating tires on any type of aircraft wheels, always use tire cage guards. Because of possible personal injury, extreme caution is required to avoid overinflation of high pressure tires. Use pressure regulators on high pressure air bottles to eliminate the possibility of overinflation of tires. Tire cages need not be used when adjusting pressure in tires installed on aircraft.

Safety Around Hazardous Materials

Material safety diamonds are very important with regard to shop safety. These forms and labels are a simple and quick way to determine the risk and, if used properly with the tags, will indicate what personal safety equipment to use with the hazardous material.

Figure 11-2. A risk diamond.

The most observable portion of the Material Safety Data Sheet (MSDS) label is the risk diamond. It is a four color segmented diamond that represents Flammability (Red), Reactivity (Yellow), Health (Blue), and special Hazard (White). In the Flammability, Reactivity, and Health blocks, there should be a number from 0 to 4. Zero represents little or no hazard to the user; 4 means that the material is very hazardous. The special hazard segment contains a word or abbreviation to represent the special hazard. Some examples are: RAD for radiation, ALK for alkali materials, Acid for acidic materials, and CARC for carcinogenic materials. The letter W with a line through it stands for high reactivity to water. [Figure 11-2]

The Material Safety Data Sheet (MSDS) is a more detailed version of the chemical safety issues. They all have the same information requirements, but the exact location of the information on the sheet varies by MSDS manufacturer. These forms have the detailed breakdown of the chemicals, including formulas and action to take if personnel come into contact with the chemical(s). The U.S. Department of Labor Occupational Safety and Health Administration (OSHA) requires certain information be on every MSDS.

These forms are necessary for a safe shop that meets all the requirements of the governing safety body, the U.S. Department of Labor Occupational Safety and Health Administration (OSHA).

Safety Around Machine Tools

Hazards in a shop's operation increase when the operation of lathes, drill presses, grinders, and other types of machines are used. Each machine has its own set of safety practices. The following discussions regarding precautions should be followed to avoid injury.

The drill press can be used to bore and ream holes, to do facing, milling, and other similar types of operations. The following precautions can reduce the chance of injury:

- Wear eye protection.
- Securely clamp all work.
- Set the proper RPM for the material used.
- Do not allow the spindle to feed beyond its limit of travel while drilling.
- Stop the machine before adjusting work or attempting to remove jammed work.
- Clean the area when finished.

Lathes are used in turning work of a cylindrical nature. This work may be performed on the inside or outside of the cylinder. The work is secured in the chuck to provide the rotary motion, and the forming is done by contact with a securely mounted tool. The following precautions can reduce the chance of injury:

- Wear eye protection.
- Use sharp cutting tools.
- Allow the chuck to stop on its own. Do not attempt to stop the chuck by hand pressure.
- Examine tools and work for cracks or defects before starting the work.
- Do not set tools on the lathe. Tools may be caught by the work and thrown.
- Before measuring the work, allow it to stop in the lathe.

Milling machines are used to shape or dress; cut gear teeth, slots, or key ways; and similar work. The following precautions can reduce the chance of injury:

- Wear eye protection.
- Clean the work bed prior to work.
- Secure the work to the bed to prevent movement during milling.
- Select the proper tools for the job.
- Do not change the feed speed while working.

- Lower the table before moving under or away from the work.
- Ensure all clamps and bolts will pass under the arbor.

Grinders are used to sharpen tools, dress metal, and perform other operations involving the removal of small amounts of metal. The following precautions can reduce the chance of injury:

- Wear eye protection even if the grinder has a shield.
- Inspect the grinding wheel for defects prior to use.
- Do not force grinding wheels onto the spindle. They fit snugly, but do not require force to install them. *Placing side pressure on a wheel could cause it to explode.*
- Check the wheel flanges and compression washer. They should be one-third the diameter of the wheel.
- Do not stand in the arc of the grinding wheel while operating, in case the wheel explodes.

Welding should be performed only in designated areas. Any part to be welded should be removed from the aircraft, if possible. Repair would then be accomplished in the welding shop under a controlled environment.

A welding shop should be equipped with proper tables, ventilation, tool storage, and fire prevention and extinguishing equipment.

Welding on an aircraft should be performed outside, if possible. If welding in the hangar is necessary, observe these precautions:

- During welding operations, there should be no open fuel tanks, and no work on fuel systems should be in progress.
- No painting should be in progress.
- No aircraft are to be within 35 feet of the welding operation.
- No flammable material should be in the area around the welding operation.
- Only qualified welders should be permitted to do the work.
- The welding area should be roped off and placarded.
- Fire extinguishing equipment of a minimum rating of 20B should be in the immediate area with 80B rated equipment as a backup. These ratings will be explained later in this chapter.
- There should be trained fire watches in the area around the welding operation.
- Aircraft being welded should be in towable condition, with a tug attached, and the aircraft parking brakes released. A qualified operator should be on the tug, and mechanics available to assist in the towing operation should it become necessary to tow the aircraft. If the aircraft is in the hangar, the hangar doors should be opened.

Flight Line Safety

Hearing Protection

The flight line is a place of dangerous activity. Technicians who perform maintenance on the flight line must constantly be aware of what is going on around them.

The noise on a flight line comes from many places. Aircraft are only one source of noise. There are auxiliary-power units (APUs), fuel trucks, baggage handling equipment, and so forth. Each has its own frequency of sound. Combined all together, the ramp or flight line can cause hearing loss.

There are many types of hearing protection available. Hearing protection can be external or internal. The external protection is the earmuff/headphone type. The internal type fit into the auditory canal. Both types will reduce the sound level reaching the eardrum and reduce the chances of hearing loss.

Hearing protection should also be used when working with pneumatic drills, rivet guns, or other loud or noisy tools or machinery. Because of their high frequency, even short duration exposure to these sounds can cause a hearing loss. Continued exposure *will* cause hearing loss.

Foreign Object Damage (FOD)

FOD is any damage caused by any loose object to aircraft, personnel, or equipment. These loose objects can be anything from broken runway concrete to shop towels to safety wire.

To control FOD, keep ramp and operation areas clean, have a tool control program, and provide convenient receptacles for used hardware, shop towels, and other consumables.

The modern gas turbine engine will create a low pressure area in front of the engine that will cause any loose object to be drawn into the engine. The exhaust of these engines can propel loose objects great distances with enough force to damage anything that is hit.

The importance of an FOD program cannot be overstressed when a technician considers the cost of engines, components, or the cost of a human life. Never leave tools or other items around the intake of a turbine engine.

Safety Around Airplanes

As with the previously mentioned items, it is important to be aware of propellers. Do not assume the pilot of a taxiing aircraft can see you. Technicians must stay where the pilot can see them while on the ramp area. Turbine engine intakes and exhaust can also be very hazardous areas. There should be no smoking or open flames anywhere near an aircraft in operation. Be aware of aircraft fluids that can be detrimental to skin. When operating support equipment around aircraft, be sure to allow space between it and the aircraft and secure it so it cannot roll into the aircraft. All items in the area of operating aircraft must be stowed properly.

Safety Around Helicopters

Every type of helicopter has its own differences. These differences must be learned to avoid damaging the helicopter or injuring the technician.

When approaching a helicopter while the blades are turning, observe the rotor head and blades to see if they are level. This will allow maximum clearance as you approach the helicopter. Observe the following:

- Approach the helicopter in view of the pilot.
- Never approach a helicopter carrying anything with a vertical height that the blades could hit. This could cause blade damage and injury to the person.
- Never approach a single-rotor helicopter from the rear. The tail rotor is invisible when operating.
- Never go from one side of the helicopter to the other by going around the tail. Always go around the nose of the helicopter.

When securing the rotor on helicopters with elastometric bearings, check the maintenance manual for the proper method. Using the wrong method could damage the bearing.

Fire Safety

Performing maintenance on aircraft and their components requires the use of electrical tools which can produce sparks, along with heat-producing tools and equipment, flammable and explosive liquids, and gases. As a result, a high potential exists for fire to occur. Measures must be taken to prevent a fire from occurring and to also have a plan for extinguishing it.

The key to fire safety is knowledge of what causes fire, how to prevent it, and how to put it out. This knowledge must be instilled in each technician emphasized by their supervisors through sound safety programs, and occasionally practiced. Airport or other local fire departments can normally be called upon to assist in training personnel and helping to establish fire safety programs for the hangar, shops, and flight line.

Fire Protection

Requirements for Fire To Occur

Three things are required for a fire: (1) fuel—something that will, in the presence of heat, combine with oxygen, thereby releasing more heat and as a result reduces itself to other chemical compounds; (2) heat—accelerates the combining of oxygen with fuel, in turn releasing more heat; and (3) oxygen—the element which combines chemically with another substance through the process of oxidation. Rapid oxidation, accompanied by a noticeable release of heat and light, is called combustion or burning. [Figure 11-3] Remove any one of these things and the fire extinguishes.

Classification of Fires

For commercial purposes, the National Fire Protection Association (NFPA) has classified fires into three basic types: Class A, Class B, and Class C.

1. Class A fires occur in ordinary combustible materials, such as wood, cloth, paper, upholstery materials, and so forth.
2. Class B fires occur in flammable petroleum products of other flammable or combustible liquids, greases, solvents, paints, and so forth.
3. Class C fires occur involve energized electrical wiring and equipment.

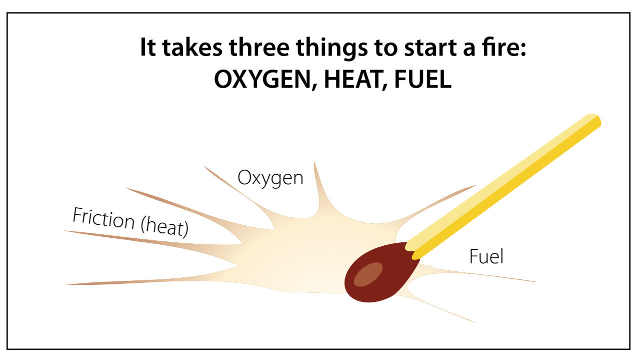

Figure 11-3. Three elements of fire.

A fourth class of fire, with which the technician should be familiar, the Class D fire, is defined as fire in flammable metal. Class D fires are not commercially considered by the National Fire Protection Association to be a basic type or category of fire since they are caused by a Class A, B, or C fire. Usually Class D fires involve magnesium in the shop or in aircraft wheels and brakes, or are the result of improper or poorly conducted welding operations.

Any one of these types of fires can occur during maintenance on or around, or operations involving, aircraft. There is a particular type extinguisher which is most effective for each type of fire.

Types and Operation of Shop and Flight Line Fire Extinguishers

Water extinguishers are the best type to use on Class A fires. Water has two effects on fire: it deprives fire of oxygen and cools the material being burned.

Since most petroleum products float on water, water-type fire extinguishers are not recommended for Class B fires.

Extreme caution must be used when fighting electrical fires with water-type extinguishers. Not only must all electrical power be removed or shut off to the burning area, but residual electricity in capacitors, coils, and so forth must be considered to prevent severe injury, and possibly death from electrical shock.

Never use water-type fire extinguishers on Class D fires. Because metals burn at extremely high temperatures, the cooling effect of water causes an explosive expansion of the metal.

Water fire extinguishers are operated in a variety of ways. Some are hand pumped, while some are pressurized. The pressurized types of extinguishers may have a gas charge stored in the container with the water, or it may contain a "soda-acid" container where acid is spilled into a container of soda inside the extinguisher. The chemical reaction of the soda and the acid causes pressure to build inside the fire extinguisher, forcing the water out.

Carbon dioxide (CO_2) extinguishers are used for Class A, B, and C fires, extinguishing the fire by depriving it of oxygen. [Figure 11-4] Additionally, like water-type extinguishers, CO_2 cools the burning material.

Never use CO_2 on Class D fires. As with water extinguishers, the cooling effect of CO_2 on the hot metal can cause explosive expansion of the metal.

Figure 11-4. Carbon dioxide fire extinguisher.

When using CO_2 fire extinguishers, all parts of the extinguisher can become extremely cold, and remain so for a short time after operation. Wear protective equipment or take other precautions to prevent cold injury (such as frostbite) from occurring.

Extreme caution must be used when operating CO_2 fire extinguishers in closed or confined areas. Not only can the fire be deprived of oxygen, but so too can the operator.

CO_2 fire extinguishers generally use the self-expelling method of operation. This means that the CO_2 has sufficient pressure at normal operating pressure to expel itself. This pressure is held inside the container by some type of seal or frangible disk, which is broken or punctured by a firing mechanism, usually a pin. This means that once the seal or disk is broken, pressure in the container is released, and the fire extinguisher is spent, requiring replacement. [Figure 11-5]

Halogenated hydrocarbon extinguishers are most effective on Class B and C fires. They can be used on Class A and D fires but they are less effective. Halogenated hydrocarbon, (commonly called Freon™ by the industry), are numbered according to chemical formulas with Halon™ numbers.

Carbon tetrachloride (Halon 104), chemical formula CCl_4, has an Underwriters Laboratory (UL) toxicity rating of 3. As such, it is extremely toxic. [Figure 11-6]

Extinguishing Materials	Classes of fire				Self-Generating	Self-Expelling	Cartridge of N_2 Cylinder	Stored Pressure	Pump	Hand
	A	B	B	D						
Water and antifreeze	X						X	X	X	X
Soda-acid (water)	X				X					
Wetting agent	X						X			
Foam	X	X			X					
Loaded stream	X	X+					X	X		
Multipurpose dry chemical	X+	X	X				X	X		
Carbon dioxide		X+	X			X				
Dry chemical		X	X				X	X		
Bromotrifluoromethane — Halon 1301		X	X			X				
Bromochlorodifluoromethane — Halon 1211		X	X					X		
Dry powder (metal fires)				X			X			X

+ Smaller sizes of these extinguishers are not recognized for use on these classes of fires.

Figure 11-5. Extinguisher operation and methods of expelling.

Hydrochloric acid vapor, chlorine and phosgene gas are produced whenever carbon tetrachloride is used on ordinary fires. The amount of phosgene gas is increased whenever carbon tetrachloride is brought in direct contact with hot metal, certain chemicals, or continuing electrical arcs. It is not approved for any fire extinguishing use. Old containers of Halon 104 found in or around shops or hangars should be disposed of in accordance with Environmental Protection Agency (EPA) regulations and local laws and ordinances.

Group	Definition	Examples
6 (Least toxic)	Gases or vapors which in concentrations up to 20% by volume for durations of exposure of up to approximately 2 hours do not appear to produce injury.	Bromotrifluoromethane (Halon 1301)
5a	Gases or vapors much less toxic than Group 4 but more toxic than Group 6.	Carbon dioxide
4	Gases or vapors which in concentrations of the order of 2 to 2½% for durations of exposure of up to approximately 2 hours are lethal or produce serious injury.	Dibromodifluormethane (Halon 1202)
3	Gases or vapors which in concentrations of the order of 2 to 2½% for durations of exposure of the order of 1 hour are lethal or produce serious injury.	Bromochloromethane (Halon 1011) Carbon tetrachloride (Halon 104)
2	Gases or vapors which in concentrations of approximately ½ to 1% for durations of exposure of up to approximately ½ hour are lethal or produce serious injury.	Methyl bromide (Halon 1001)

Figure 11-6. Toxicity table.

Methyl bromide (Halon 1001), chemical formula CH_3Br, is a liquefied gas with a UL toxicity rating of 2. Very toxic, it is corrosive to aluminum alloys, magnesium, and zinc. Halon 1001 is not recommended for aircraft use.

Chlorobromomethane (Halon 1011), chemical formula CH_2ClBr, is a liquefied gas with a UL toxicity rating of 3. Like methyl bromide, Halon 1011 is not recommended for aircraft use.

Dibromodifluoromethane (Halon 1202), chemical formula CBr_2F_2, has a UL toxicity rating of 4. Halon 1202 is not recommended for aircraft use.

Bromochlorodifluoromethane (Halon 1211), chemical formula $CBrClF_2$, is a liquefied gas with a UL toxicity rating of 5. It is colorless, noncorrosive and evaporates rapidly leaving no residue. It does not freeze or cause cold burns, and will not harm fabrics, metals, or other materials it contacts. Halon 1211 acts rapidly on fires by producing a heavy blanketing mist that eliminates oxygen from the fire source. But more importantly, it interferes chemically with the combustion process of the fire. It has outstanding properties in preventing reflash after the fire has been extinguished.

Bromotrifluoromethane (Halon 1301), chemical formula CF_3Br, is also a liquefied gas with a UL toxicity rating of 6. It has all the characteristics of Halon 1211. The significant difference between the two is: Halon 1211 forms a spray similar to CO_2, while Halon 1301 has a vapor spray that is more difficult to direct.

Note: The Environmental Protection Agency (EPA) has restricted Halon to its 1986 production level due to its effect on the ozone layer.

Dry powder extinguishers, while effective on Class B and C fires, are the best for use on Class D fires.

The method of operation of dry powder fire extinguishers varies from gas cartridge charges, or stored pressure within the container which forces the powder charge out of the container, to tossing the powder on the fire by hand, by scooping pails or buckets of the powder from large containers or barrels.

Dry powder is not recommended for aircraft use (except on metal fires as a fire extinguisher) because the leftover chemical residues and dust often make cleanup difficult, and can damage electronic or other delicate equipment.

Inspection of Fire Extinguishers

Fire extinguishers should be checked periodically utilizing a checklist. If a checklist is unavailable, check the following as a minimum:

- Proper location of appropriate extinguisher
- Safety seals unbroken
- All external dirt and rust removed
- Gauge or indicator in operable range
- Proper weight
- No nozzle obstruction
- No obvious damage

Airport or other local fire departments can usually help in preparing and often can provide extinguisher checklists. In addition, these fire departments can be helpful in answering questions and assisting in obtaining repairs to or replacement of fire extinguishers.

Identifying Fire Extinguishers

Fire extinguishers should be marked to indicate suitability for a particular class of fire. The markings on Figure 11-7 should be placed on the fire extinguisher and in a conspicuous place in the vicinity of the fire extinguisher. When the location is marked, however, extreme care must be taken to ensure that the fire extinguisher kept at that location is in fact the type depicted by the marking. In other words, if a location is marked for a Class B fire extinguisher, ensure that the fire extinguisher in that location is in fact suitable for Class B fires.

Markings should be applied by decalcomanias (decals), painting, or similar methods. They should be legible and as durable as necessary for the location. For example, markings used outside need to be more durable than those in the hangar or office spaces.

Where markings are applied to the extinguisher, they should be located on the front of the shell (if one is installed) above or below the extinguisher nameplate. Markings should be large enough and in a form that is easily seen and identifiable by the average person with average eyesight at a distance of at least 3 feet.

Where markings are applied to wall panels, and so forth, in the vicinity of extinguishers, they should be large enough and in a form that is easily seen and identifiable by the average person with average eyesight, at a distance of at least 25 feet. [Figure 11-8]

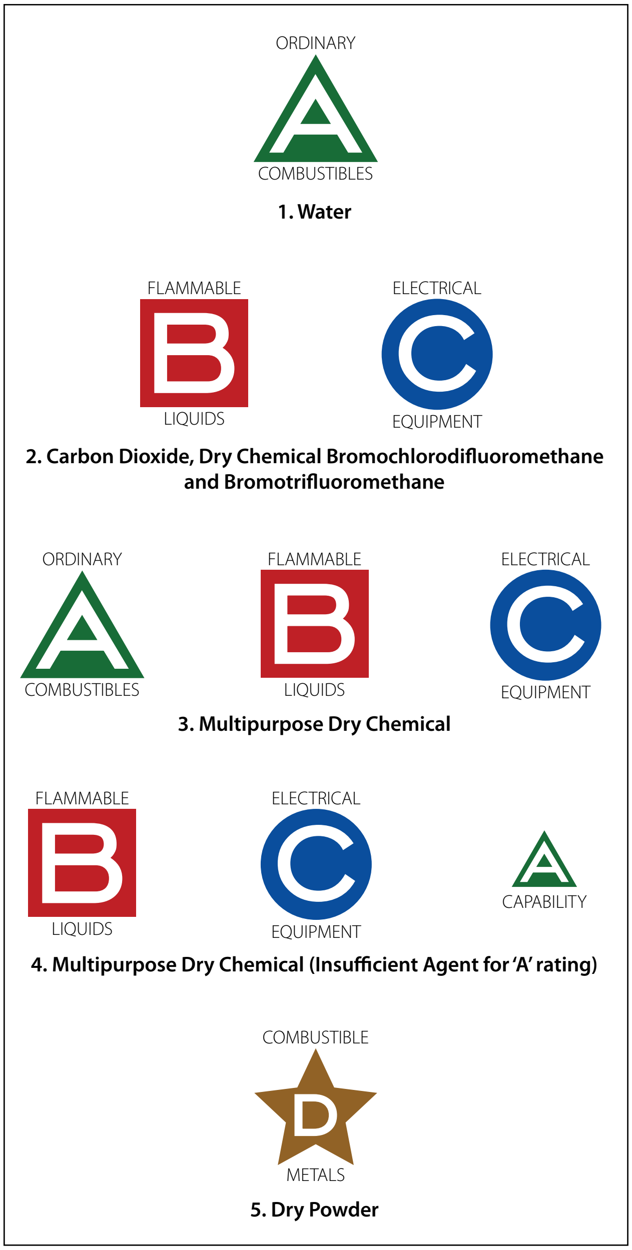

Figure 11-7. Typical extinguisher markings.

Using Fire Extinguishers

When using a fire extinguisher, make sure you have the correct type for the fire. Most extinguishers have a pin to pull that will allow the handle to activate the agent. Stand back 8 feet and aim at the base of the fire or flames. Squeeze the lever and sweep side to side until the fire is extinguished.

Tiedown Procedures

Preparation of Aircraft

Aircraft should be tied down after each flight to prevent damage from sudden storms. The direction in which

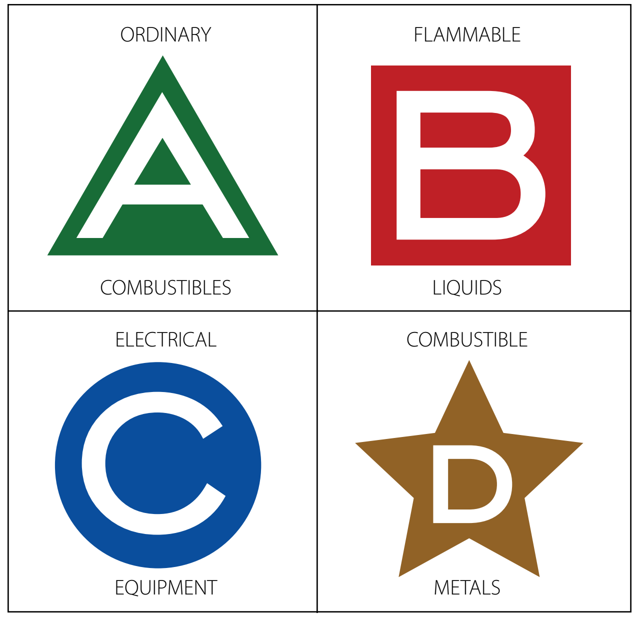

Figure 11-8. Identification of fire extinguisher type location.

aircraft are to be parked and tied down is determined by prevailing or forecast wind direction.

Aircraft should be headed as nearly as possible into the wind, depending on the locations of the parking area's fixed tiedown points. Spacing of tiedowns should allow for ample wingtip clearance. [Figure 11-9] After the aircraft is properly located, lock the nosewheel or the tailwheel in the fore-and-aft position.

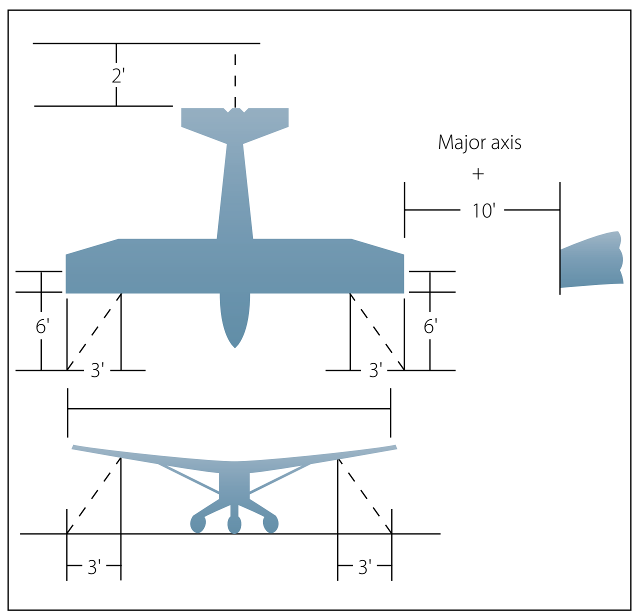

Figure 11-9. Diagram of tiedown dimensions.

Tiedown Procedures for Land Planes

Securing Light Aircraft

Light aircraft are most often secured with ropes tied only at the aircraft tiedown rings provided for securing purposes. Rope should never be tied to a lift strut, since this practice can bend a strut if the rope slips to a point where there is no slack. Manila rope shrinks when wet; about 1 inch (1") of slack should be provided for movement. Too much slack allows the aircraft to jerk against the ropes. Tight tiedown ropes put inverted flight stresses on the aircraft, many of which are not designed to take such loads.

A tiedown rope holds no better than the knot. Anti-slip knots such as the bowline are quickly tied and are easy to untie. [Figure 11-10] Aircraft not equipped with tiedown fittings should be secured in accordance with the manufacturer's instructions. Ropes should be tied to outer ends of struts on high-wing monoplanes, and suitable rings should be provided where structural conditions permit, if the manufacturer has not already provided them.

Securing Heavy Aircraft

The normal tiedown procedure for heavy aircraft can be accomplished with rope or cable tiedown. The number of such tiedowns should be governed by anticipated weather conditions.

Most heavy aircraft are equipped with surface control locks, which should be engaged or installed when the aircraft is secured. Since the method of locking controls will vary on different type aircraft, check the manufacturer's instructions for proper installation or engaging procedures. If high winds are anticipated, control surface battens can also be installed to prevent damage. Figure 11-11 illustrates four common tiedown points on heavy aircraft.

The normal tiedown procedure for heavy aircraft should generally include the following:

1. Head airplane into prevailing wind whenever possible.
2. Install control locks, all covers and guards.
3. Chock all wheels fore and aft. [Figure 11-12]
4. Attach tiedown reels to airplane tiedown loops and to tiedown anchors or tiedown stakes. Use tiedown stakes for temporary tiedown only. If tiedown reels are not available, 1/4" wire cable or $1\frac{1}{2}$" manila line may be used.

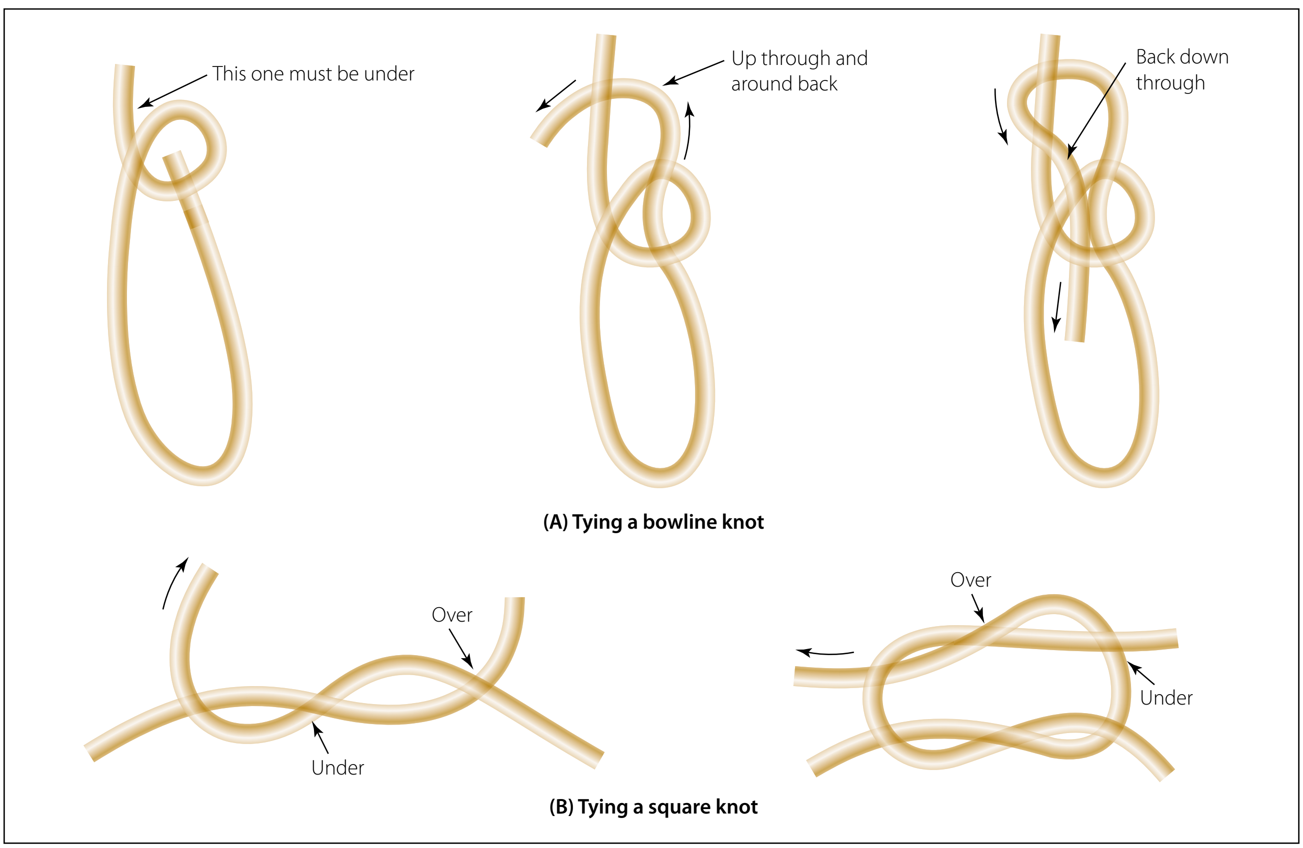

Figure 11-10. Knots commonly used for aircraft tiedown.

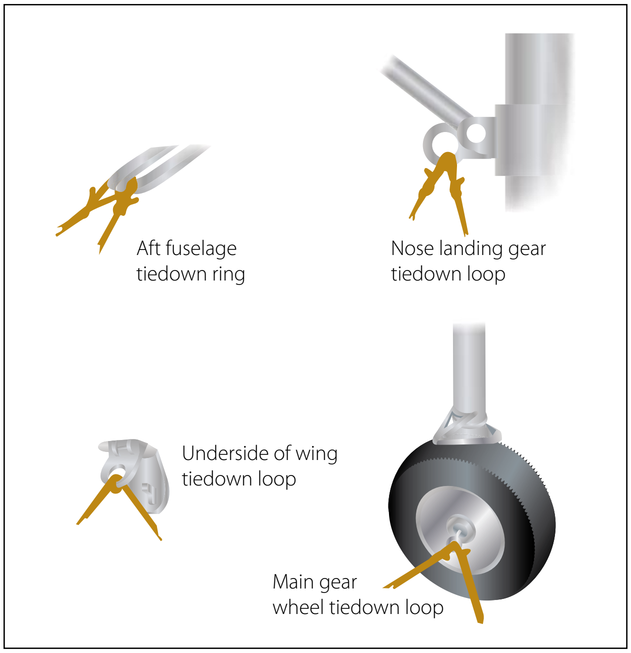

Figure 11-11. Common tiedown points.

Figure 11-12. Wheels chocked fore and aft.

Tiedown Procedures for Seaplanes

Seaplanes can be moored to a buoy, weather permitting, or tied to a dock. Weather causes wave action, and waves cause the seaplane to bob and roll. This bobbing and rolling while tied to a dock can cause damage.

When warning of an impending storm is received and it is not possible to fly the aircraft out of the storm area, some compartments of the seaplane can be flooded, partially sinking the aircraft. In addition, the aircraft should be tied down securely to anchors. Seaplanes tied down on land have been saved from high-wind damage by filling the floats with water in addition to tying the aircraft down in the usual manner.

During heavy weather, if possible, remove the seaplane from the water and tie down in the same manner as a land plane. If this is not possible, the seaplane could be anchored in a sheltered area away from wind and waves.

Tiedown Procedures for Ski Planes

Ski planes are tied down, if the securing means are available, in the same manner as land planes.

Ski-equipped airplanes can be secured on ice or in snow by using a device called a dead-man. A dead-man is any item at hand (such as a piece of pipe, log, and so forth) that a rope is attached to and buried in a snow or ice trench. Using caution to keep the free end of the rope dry and unfrozen, snow is packed in the trench. If available, pour water into the trench; when it is frozen, tie down the aircraft with the free end of the rope.

Operators of ski-equipped aircraft sometimes pack soft snow around the skis, pour water on the snow, and permit the skis to freeze to the ice. This, in addition to the usual tiedown procedures, aids in preventing damage from windstorms. Caution must be used when moving an aircraft that has been secured in this manner to ensure that a ski is not still frozen to the ground. Otherwise, damage to the aircraft or skis can occur.

Tiedown Procedures for Helicopters

Helicopters, like other aircraft are secured to prevent structural damage, which can occur from high-velocity surface winds.

Helicopters should be secured in hangars, when possible. If not, they should be tied down securely. Helicopters that are tied down can usually sustain winds up to approximately 65 mph. If at all possible, helicopters should be evacuated to a safe area if tornadoes or hurricanes are anticipated.

For added protection, helicopters should be moved to a clear area so that they will not be damaged by flying objects or falling limbs from surrounding trees.

If high winds are anticipated with the helicopter parked in the open, the main rotor blades should be tied down. Detailed instructions for securing and mooring each type of helicopter can be found in the applicable maintenance manual. [Figure 11-13] Methods of securing helicopters vary with weather conditions, the length of time the aircraft is expected to remain on the ground,

Figure 11-13. Example of mooring of a helicopter.

and location and characteristics of the aircraft. Wheel chocks, control locks, rope tiedowns, mooring covers, tip socks, tiedown assemblies, parking brakes, and rotor brakes are used to secure helicopters.

Typical mooring procedures are as follows:

1. Face the helicopter in the direction from which the highest forecast wind or gusts are anticipated.
2. Spot the helicopter slightly more than one rotor-span distance from other aircraft.
3. Place wheel chocks ahead of and behind all wheels (where applicable). On helicopters equipped with skids, retract the ground handling wheels, lower the helicopter to rest on the skids, and install wheel position lockpins or remove the ground handling wheels. Ground handling wheels should be secured inside the aircraft or inside the hangar or storage buildings. Do not leave them unsecured on the flight line.
4. Align the blades and install tiedown assemblies as prescribed by the helicopter manufacturer. [Figure 11-14] Tie straps snugly without strain, and during wet weather, provide some slack to avoid the possibility of the straps shrinking, causing undue stresses on the aircraft and/or its rotor system(s).
5. Fasten the tiedown ropes or cables to the forward and aft landing gear cross tubes and secure to ground stakes or tiedown rings.

Procedures for Securing Weight-Shift Control Aircraft

There are many types of weight-shift control aircraft—engine powered and nonpowered. These types of aircraft are very suitable to wind damage. The wings can be secured in a similar manner as a conventional aircraft in light winds. But in high winds, the mast can be disconnected from the wing and the wing placed close to the ground and secured. This type of aircraft can also be partially disassembled or moved into a hangar for protection.

Procedures for Securing Powered Parachutes

Powered parachutes should have the parachute packed in a bag to prevent the chute from filling with air from the wind and dragging the seat and engine. The engine and seat can also be secured if needed.

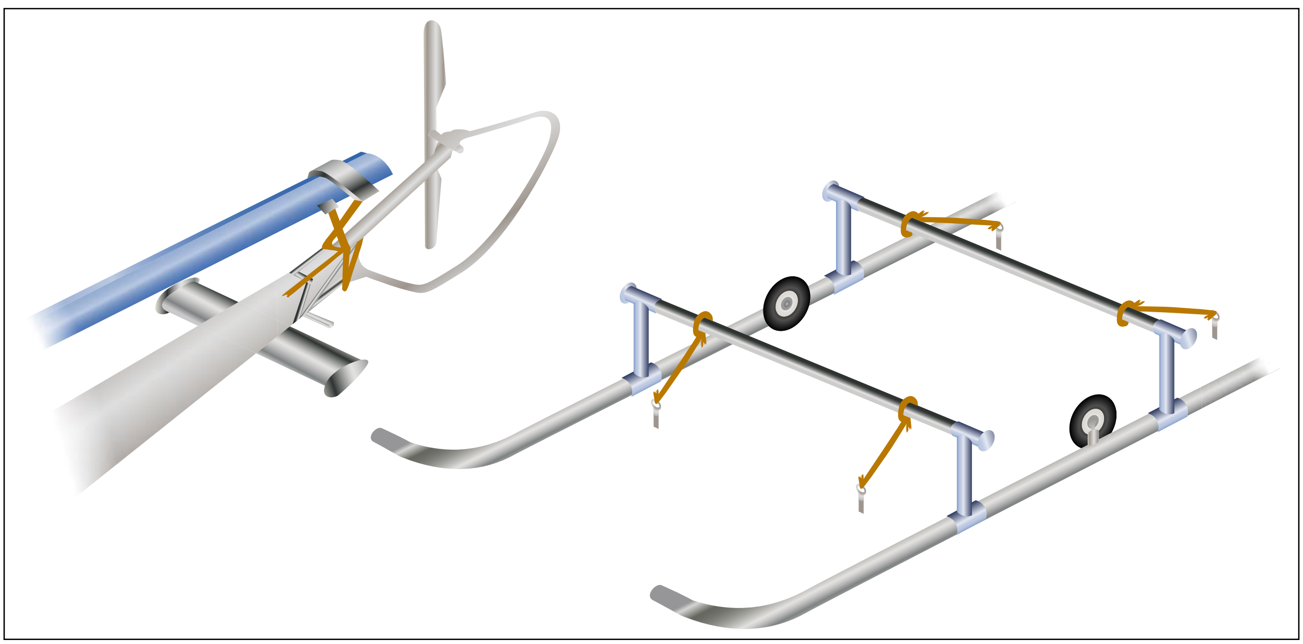

Figure 11-14. Securing helicopter blades and fuselage.

Ground Movement of Aircraft

Engine Starting and Operation

The following instructions cover the starting procedures for reciprocating, turboprop, turbofan, and auxiliary power units (APU). These procedures are presented only as a general guide for familiarization with typical procedures and methods. Detailed instructions for starting a specific type of engine can be found in the manufacturer's instruction book.

Before starting an aircraft engine:

1. Position the aircraft to head into the prevailing wind to ensure adequate airflow over the engine for cooling purposes.
2. Make sure that no property damage or personal injury will occur from the propeller blast or jet exhaust.
3. If external electrical power is used for starting, ensure that it can be removed safely and it is sufficient for the total starting sequence.
4. During any and all starting procedures, a "fireguard" equipped with a suitable fire extinguisher shall be stationed in an appropriate place. A fireguard is someone familiar with aircraft starting procedures. The fire extinguisher should be a CO_2 extinguisher of at least 5-pound capacity. The appropriate place is adjacent to the outboard side of the engine, in view of the pilot, and also where he or she can observe the engine/aircraft for indication of starting problems.
5. If the aircraft is turbine engine powered, the area in front of the jet inlet must be kept clear of personnel, property, and/or debris (FOD).
6. These "before starting" procedures apply to all aircraft powerplants.
7. Follow manufacturer's checklists for start procedures and shutdown procedures.

Reciprocating Engines

The following procedures are typical of those used to start reciprocating engines. There are, however, wide variations in the procedures for the many reciprocating engines. No attempt should be made to use the methods presented here for actually starting an engine. Instead, always refer to the procedures contained in the applicable manufacturer's instructions.

Reciprocating engines are capable of starting in fairly low temperatures without the use of engine heating or oil dilution, depending on the grade of oil used. The various covers (wing, tail, cockpit, wheel, and so forth) protecting the aircraft must be removed before attempting to turn the engine. External sources of electrical power should be used when starting engines equipped with electric starters, if possible or needed. This eliminates an excessive burden on the aircraft battery. All unnecessary electrical equipment should be left off until the generators are furnishing electrical power to the aircraft power bus.

Before starting a radial engine that has been shut down for more than 30 minutes, check the ignition switch for off; turn the propeller three or four complete revolutions by hand to detect a hydraulic lock, if one is present. Any liquid present in a cylinder is indicated by the abnormal effort required to rotate the propeller, or by the propeller stopping abruptly during rotation. Never use force to turn the propeller when a hydraulic lock is detected. Sufficient force can be exerted on the crankshaft to bend or break a connecting rod if a lock is present.

To eliminate a lock, remove either the front or rear spark plug from the lower cylinders and pull the propeller through. Never attempt to clear the hydraulic lock by pulling the propeller through in the direction opposite to normal rotation. This tends to inject the liquid from the cylinder into the intake pipe. The liquid will be drawn back into the cylinder with the possibility of complete or partial lock occurring on the subsequent start.

To start the engine, proceed as follows:

1. Turn the auxiliary fuel pump on, if aircraft is so equipped.
2. Place the mixture control to the position recommended for the engine and carburetor combination being started. As a general rule, the mixture control should be in the "idle cut-off" position for fuel injection and in the "full rich" position for float-type carburetors. Many light aircraft are equipped with a mixture control pull rod which has no detent intermediate positions. When such controls are pushed in flush with the instrument panel, the mixture is set in the "full rich" position. Conversely, when the control rod is pulled all the way out, the carburetor is in the "idle cut-off" or "full lean" position. The operator can select unmarked intermediate positions between these two extremes to achieve any desired mixture setting.
3. Open the throttle to a position that will provide 1,000 to 1,200 rpm (approximately 1/8 to 1/2 inch from the "closed" position).

4. Leave the pre-heat or alternate air (carburetor air) control in the "cold" position to prevent damage and fire in case of backfire. These auxiliary heating devices should be used after the engine warms up. They improve fuel vaporization, prevent fouling of the spark plugs, ice formation, and eliminate icing in the induction system.
5. Move the primer switch to "on" intermittently (press to prime by pushing in on the ignition switch during the starting cycle), or prime with one to three strokes of priming pump, depending on how the aircraft is equipped. The colder the weather, the more priming will be needed.
6. Energize the starter after the propeller has made at least two complete revolutions, and turn the ignition switch on. On engines equipped with an induction vibrator (shower of sparks, magneto incorporates a retard breaker assembly), turn the switch to the "both" position and energize the starter by turning the switch to the "start" position. After the engine starts, release the starter switch to the "both" position. When starting an engine that uses an impulse coupling magneto, turn the ignition switch to the "left" position. Place the start switch to the "start" position; when the engine starts, release the start switch. Do not crank the engine continuously with the starter for more than 1 minute. Allow a 3- to 5-minute period for cooling the starter (starter duty cycle) between successive attempts. Otherwise, the starter may be burned out due to overheating.
7. After the engine is operating smoothly, move the mixture control to the "full rich" position if started in the "idle cutoff" position. Carbureted engines will already be in the rich mixture position. Check for oil pressure.

Instruments for monitoring the engine during operation include a tachometer for rpm, manifold pressure gauge, oil pressure gauge, oil temperature gauge, cylinder head temperature gauge, exhaust gas temperature gauge and fuel flow gauge.

Hand Cranking Engines

If the aircraft has no self-starter, the engine must be started by turning the propeller by hand (hand propping the propeller). The person who is turning the propeller calls: "Fuel on, switch off, throttle closed, brakes on." The person operating the engine will check these items and repeat the phrase. The switch and throttle must not be touched again until the person swinging the prop calls "contact." The operator will repeat "contact" and then turn on the switch. Never turn on the switch and then call "contact."

A few simple precautions will help to avoid accidents when hand propping the engine. While touching a propeller, always assume that the ignition is on. The switches which control the magnetos operate on the principle of short-circuiting the current to turn the ignition off. If the switch is faulty, it can be in the "off" position and still permit current to flow in the magneto primary circuit. This condition could allow the engine to start when the switch is off.

Be sure the ground is firm. Slippery grass, mud, grease, or loose gravel can lead to a fall into or under the propeller. Never allow any portion of your body to get in the way of the propeller. This applies even though the engine is not being cranked.

Stand close enough to the propeller to be able to step away as it is pulled down. Stepping away after cranking is a safeguard in case the brakes fail. Do not stand in a position that requires leaning toward the propeller to reach it. This throws the body off balance and could cause you to fall into the blades when the engine starts.

In swinging the prop, always move the blade downward by pushing with the palms of the hands. Do not grip the blade with the fingers curled over the edge, since "kickback" may break them or draw your body in the blade path.

Excessive throttle opening after the engine has fired is the principal cause of backfiring during starting. Gradual opening of the throttle, while the engine is cold, will reduce the potential for backfiring. Slow, smooth movement of the throttle will assure correct engine operation.

Avoid overpriming the engine before it is turned over by the starter. This can result in fires, scored or scuffed cylinders and pistons, and, in some cases, engine failures due to hydraulic lock. If the engine is inadvertently flooded or overprimed, turn the ignition switch off and move the throttle to the "full open" position. To rid the engine of the excess fuel, turn it over by hand or by the starter. If excessive force is needed to turn over the engine, stop immediately. Do not force rotation of the engine. If in doubt, remove the lower cylinder spark plugs.

Immediately after the engine starts, check the oil pressure indicator. If oil pressure does not show within 30 seconds, stop the engine and determine the trouble.

If oil pressure is indicated, adjust the throttle to the aircraft manufacturer's specified rpm for engine warm-up. Warm-up rpm will usually be in the 1,000 to 1,300 rpm range.

Most aircraft reciprocating engines are air cooled and depend on the forward speed of the aircraft to maintain proper cooling. Therefore, particular care is necessary when operating these engines on the ground.

During all ground running, operate the engine with the propeller in full low pitch and headed into the wind with the cowling installed to provide the best degree of engine cooling. Closely monitor the engine instruments at all times. Do not close the cowl flaps for engine warm-up; they should be in the open position while operating on the ground. When warming up the engine, ensure that personnel, ground equipment that may be damaged, or other aircraft are not in the propeller wash.

Extinguishing Engine Fires

In all cases, a fireguard should stand by with a CO_2 fire extinguisher while the aircraft engine is being started. This is a necessary precaution against fire during the starting procedure. The fireguard should be familiar with the induction system of the engine so that in case of fire he or she can direct the CO_2 into the air intake of the engine to extinguish it. A fire could also occur in the exhaust system of the engine from liquid fuel being ignited in the cylinder and expelled during the normal rotation of the engine.

If an engine fire develops during the starting procedure, continue cranking to start the engine and blow out the fire. If the engine does not start and the fire continues to burn, discontinue the start attempt. The fireguard should extinguish the fire using the available equipment. The fireguard must observe all safety practices at all times while standing by during the starting procedure.

Turboprop Engines

The starting of any turbine engine consists of three steps that must be carried out in the correct sequence. The starter turns the main compressor to provide airflow though the engine. At the correct speed (which provides enough airflow) the igniters are turned on and provide a hot spark to light the fuel which is engaged next. As the engine accelerates, it will reach a self-sustaining speed and the starter is disengaged.

The various covers protecting the aircraft must be removed. Carefully inspect the engine exhaust areas for the presence of fuel or oil. Make a close visual inspection of all accessible parts of the engines and engine controls, followed by an inspection of all nacelle areas to determine that all inspection and access plates are secured. Check sumps for water. Inspect air inlet areas for general condition and foreign material. Check the compressor for free rotation, when the installation permits, by reaching in and turning the blades by hand.

The following procedures are typical of those used to start turboprop engines. There are, however, wide variations in the procedures applicable to the many turboprop engines, and no attempt should be made to use these procedures in the actual starting of a turboprop engine. These procedures are presented only as a general guide for familiarization with typical procedures and methods. For starting of all turboprop engines, refer to the detailed procedures contained in the applicable manufacturer's instructions or their approved equivalent.

Turboprop engines are usually fixed turbine or free turbine. The propeller is connected to the engine directly in a fixed turbine, which results in the propeller being turned as the engine starts. This provides extra drag which must be overcome during starting. If the propeller is not at the "start" position, difficulty may be encountered in making a start due to high loads. Because of this, the propeller is in flat pitch at shut down and subsequently in flat pitch during start.

The free turbine engine has no mechanical connection between the gas generator and the power turbine which is connected to the propeller. In this type of engine, the propeller remains in the feather position during starting and starts to turn only as the gas generator accelerates.

Instrumentation for turbine engines varies according to the type of turbine engine. Turboprop engines use the normal instruments — oil pressure, oil temperature, interturbine temperature (ITT) and fuel flow. They also use instruments to measure gas generator speed, propeller speed, and torque produced by the propeller. [Figure 11-15] A typical turboprop uses a set of engine controls, such as power levelers (throttle), propeller levers, and condition levers. [Figure 11-16]

The first step in starting a turbine engine is to provide an adequate source of power for the starter. On smaller turbine engines, the starter is an electric motor which turns the engine through electrical power. Larger engines needed a much more powerful starter. Electric motors would be limited by current flow and weight. Air turbine starters were developed which were lighter and produced sufficient power to turn the engine at

Figure 11-15. Typical examples of turboprop instruments.

Figure 11-16. Engine controls of a turboprop aircraft.

the correct speed for starting. Where an air turbine starter is used, the starting air supply may be obtained from an auxiliary power unit onboard the aircraft, an external source (ground air cart), or an engine cross-bleed operation. In some limited cases, a low-pressure large-volume tank can provide the air for starting an engine. Many smaller turboprop engines are started using the starter/generator, which is both the engine starter and the generator.

While starting an engine, always observe the following:

- Always observe the starter duty cycle. Otherwise, the starter can overheat and be damaged.
- Assure that there is enough air pressure or electrical capacity before attempting a start.
- Do not perform a ground start if turbine inlet temperature (residual temperature) is above that specified by the manufacturer.
- Provide fuel under low pressure to the engine's fuel pump.

Turboprop Starting Procedures

To start an engine on the ground, perform the following operations:

1. Turn the aircraft boost pumps on.
2. Make sure that the power lever is in the "start" position.
3. Place the start switch in the "start" position. (This will start the engine turning.)
4. Place the ignition switch on. (On some engines, the ignition is activated by moving the fuel lever.)
5. The fuel is now turned on. This is accomplished by moving the condition lever to the "on" position.
6. Monitor the engine lights of the exhaust temperature. If it exceeds the limits, the engine should be shut down.
7. Check the oil pressure and temperature.
8. After the engine reaches a self-sustaining speed, the starter is disengaged.
9. The engine should continue to accelerate up to idle.
10. Maintain the power lever at the "start" position until the specified minimum oil temperature is reached.
11. Disconnect the ground power supply, if used.

If any of the following conditions occur during the starting sequence, turn off the fuel and ignition switch, discontinue the start immediately, make an investigation, and record the findings.

- Turbine inlet temperature exceeds the specified maximum. Record the observed peak temperature.

- Acceleration time from start of propeller rotation to stabilized rpm exceeds the specified time.
- There is no oil pressure indication at 5,000 rpm for either the reduction gear or the power unit.
- Torching (visible burning in the exhaust nozzle).
- The engine fails to ignite by 4,500 rpm or maximum motoring rpm.
- Abnormal vibration is noted or compressor surge occurs (indicated by backfiring).
- Fire warning bell rings. (This may be due to either an engine fire or overheat.)

Turbofan Engines

Unlike reciprocation engine aircraft, the turbine-powered aircraft does not require a preflight run-up unless it is necessary to investigate a suspected malfunction.

Before starting, all protective covers and air inlet duct covers should be removed. If possible, the aircraft should be headed into the wind to obtain better cooling, faster starting, and smoother engine performance. It is especially important that the aircraft be headed into the wind if the engine is to be trimmed.

The run-up area around the aircraft should be cleared of both personnel and loose equipment. The turbofan engine intake and exhaust hazard areas are illustrated in Figure 11-17. Exercise care to ensure that the run-up area is clear of all items, such as nuts, bolts, rocks, shop towels, or other loose debris (FOD). Many very serious accidents have occurred involving personnel in the vicinity of turbine engine air inlets. Use extreme caution when starting turbine aircraft.

Check the aircraft fuel sumps for water or ice, and inspect the engine air inlet for general condition and the presence of foreign objects. Visually inspect the fan blades, forward compressor blades, and the compressor inlet guide vanes for nicks and other damage. If possible, check the fan blades for free rotation by turning the fan blades by hand. All engine controls should be operated, and engine instruments and warning lights should be checked for proper operation.

Starting a Turbofan Engine

The following procedures are typical of those used to start many turbine engines. There are, however, wide variations in the starting procedures used for turbine engines, and no attempt should be made to use these procedures in the actual starting of an engine. These procedures are presented only as a general guide for familiarization with typical procedures and methods. In the starting of all turbine engines, refer to the detailed procedures contained in the applicable manufacturer's instructions or their approved equivalent.

Most turbofan engines can be started by either air turbine or electrical starters. Air-turbine starters use compressed air from an external source as discussed earlier. Fuel is turned on either by moving the start lever to "idle/start" position or by opening a fuel shutoff valve. If an air turbine starter is used, the engine should "light off" within a predetermined time after the fuel is turned on. This time interval, if exceeded, indicates a malfunction has occurred and the start should be discontinued.

Most turbofan engine controls consist of a power lever, reversing levers, and start levers. Newer aircraft have replaced the start levers with a fuel switch. [Figure 11-18] Turbofan engines also use all the normal instruments speeds, (percent of total rpm) exhaust gas temperature, fuel flow, oil pressure, and temperature. An instrument that measures the amount of thrust being delivered is the engine pressure ratio. This measures the ratio between the inlet pressure to the outlet pressure of the turbine.

The following procedures are useful only as a general guide, and are included to show the sequence of events in starting a turbofan engine.

1. If the engine is so equipped, place the power lever in the "idle" position.
2. Turn the fuel boost pump(s) switch on.
3. A fuel inlet pressure indicator reading ensures fuel is being delivered to engine fuel pump inlet.
4. Turn engine starter switch on; note that the engine rotates to a preset limit; check for oil pressure.
5. Turn ignition switch on. (This is usually accomplished by moving the start lever toward the "on" position. A micro switch connected to the leveler turns on the ignition.)
6. Move the start lever to "idle" or "start" position; this will start fuel flow into the engine.
7. Engine start (light off) is indicated by a rise in exhaust gas temperature.
8. If a two spool engine, check rotation of fan or N1.
9. Check for proper oil pressure.
10. Turn engine starter switch off at proper speeds.
11. After engine stabilizes at idle, ensure that none of the engine limits are exceeded.

Newer aircraft will drop off the starter automatically.

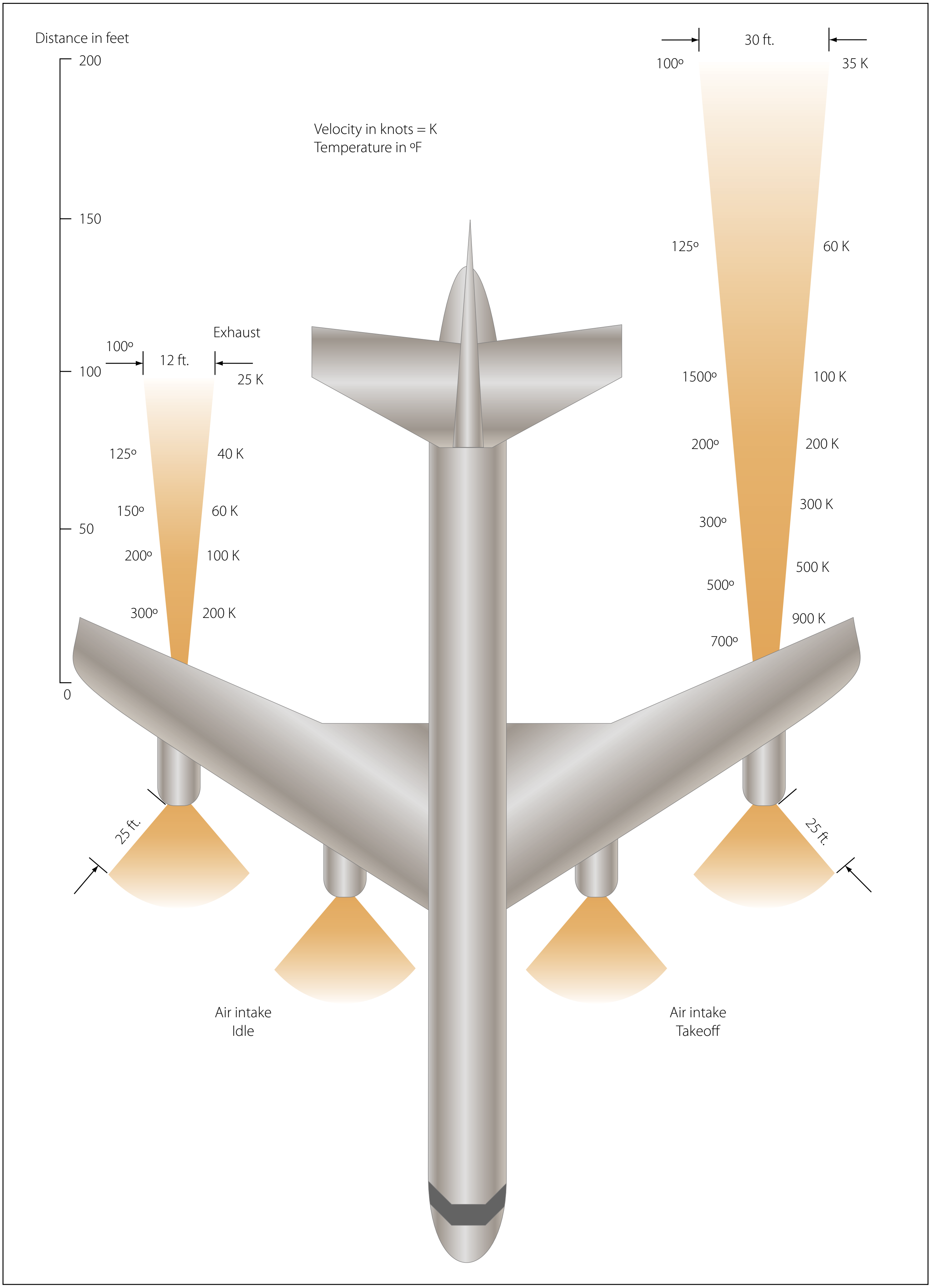

Figure 11-17. Engine intake and exhaust hazard areas.

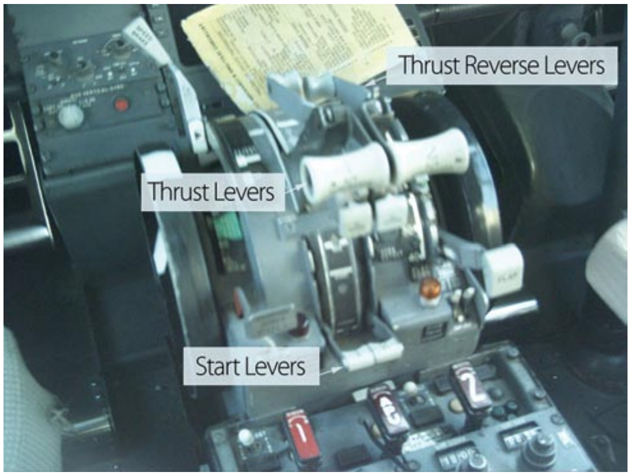

Figure 11-18. Turbofan engine control levers.

Auxiliary Power Units (APUs)

APUs are generally smaller turbine engines that provide compressed air for starting engines, cabin heating and cooling, and electrical power while on the ground. Their operation is normally simple. By turning a switch on and up to the start position (spring loaded to on position), the engine will start automatically. During start, the exhaust gas temperature must be monitored. APUs are at idle at 100 percent rpm with no load. After the engine reaches its operating rpm, it can be used for cooling or heating the cabin and for electrical power. It is normally used to start the main engines.

Unsatisfactory Turbine Engine Starts

Hot Start

A hot start occurs when the engine starts, but the exhaust gas temperature exceeds specified limits. This is usually caused by an excessively rich fuel/air mixture entering the combustion chamber. This condition can be caused by either too much fuel or not enough airflow. The fuel to the engine should be shut off immediately.

False or Hung Start

False or hung starts occur when the engine starts normally, but the rpm remains at some low value rather than increasing to the normal starting rpm. This is often the result of insufficient power to the starter, or the starter cutting off before the engine starts self-accelerating. In this case, the engine should be shut down.

Engine Will Not Start

The engine will not start within the prescribed time limit. It can be caused by lack of fuel to the engine, insufficient or no electrical power to the exciter in the ignition system, or incorrect fuel mixer. If the engine fails to start within the prescribed time, it should be shut down.

In all cases of unsatisfactory starts the fuel and ignition should be turned off. Continue rotating the compressor for approximately 15 seconds to remove accumulated fuel from the engine. If unable to motor (rotate) the engine, allow a 30-second fuel draining period before attempting another start.

Towing of Aircraft

Movement of large aircraft on an airport and about the flight line and hangar is usually accomplished by towing with a tow tractor (sometimes called a "tug"). [Figure 11-19] In the case of small aircraft, some moving is accomplished by hand, by pushing on the correct areas of the aircraft. Aircraft may also be taxied about the flight line, but usually only by certain qualified persons.

Towing aircraft can be a hazardous operation, causing damage to the aircraft and injury to personnel, if done recklessly or carelessly. The following paragraphs outline the general procedure for towing aircraft; however, specific instructions for each model of aircraft are detailed in the manufacturer's maintenance instructions and should be followed in all instances.

Before the aircraft to be towed is moved, a qualified person must be in the cockpit to operate the brakes in case the tow bar should fail or become unhooked. The aircraft can then be stopped, preventing possible damage.

Some types of tow bars available for general use can be used for many types of towing operations. [Figure 11-20] These bars are designed with sufficient tensile strength

Figure 11-19. Example of a tow tractor.

Figure 11-20. Tow bar for a large aircraft.

to pull most aircraft, but are not intended to be subjected to torsional or twisting loads. Many have small wheels that permit them to be drawn behind the towing vehicle going to or from an aircraft. When the bar is attached to the aircraft, inspect all the engaging devices for damage or malfunction before moving the aircraft.

Some tow bars are designed for towing various types of aircraft; however, other special types can be used on a particular aircraft only. Such bars are usually designed and built by the aircraft manufacturer.

When towing the aircraft, the towing vehicle speed must be reasonable, and all persons involved in the operation must be alert. When the aircraft is stopped, do not rely upon the brakes of the towing vehicle alone to stop the aircraft. The person in the cockpit should coordinate the use of the aircraft brakes with those of the towing vehicle. A typical smaller aircraft tow tractor (or tug) is shown in Figure 11-21.

Figure 11-21. Typical smaller aircraft tow tractor.

The attachment of the tow bar varies on different types of aircraft. Aircraft equipped with tailwheels are generally towed forward by attaching the tow bar to the main landing gear. In most cases, it is permissible to tow the aircraft in reverse by attaching the tow bar to the tailwheel axle. Any time an aircraft equipped with a tailwheel is towed, the tailwheel must be unlocked or the tailwheel locking mechanism will be damaged or broken. Aircraft equipped with tricycle landing gear are generally towed forward by attaching a tow bar to the axle of the nosewheel. They may also be towed forward or backward by attaching a towing bridle or specially designed towing bar to the towing lugs on the main landing gear. When an aircraft is towed in this manner, a steering bar is attached to the nosewheel to steer the aircraft.

The following towing and parking procedures are typical of one type of operation. They are examples, and not necessarily suited to every type of operation. Aircraft ground-handling personnel should be thoroughly familiar with all procedures pertaining to the types of aircraft being towed and local operation standards governing ground handling of aircraft. Only competent persons properly checked out should direct an aircraft towing team.

1. The towing vehicle driver is responsible for operating the vehicle in a safe manner and obeying emergency stop instructions given by any team member.
2. The person in charge should assign team personnel as wing walkers. A wing walker should be stationed at each wingtip in such a position that he or she can ensure adequate clearance of any obstruction in the path of the aircraft. A tail walker should be assigned when sharp turns are to be made, or when the aircraft is to be backed into position.
3. A qualified person should occupy the pilot's seat of the towed aircraft to observe and operate the brakes as required. When necessary, another qualified person is stationed to watch and maintain aircraft hydraulic system pressure.
4. The person in charge of the towing operation should verify that, on aircraft with a steerable nosewheel, the locking scissors are set to full swivel for towing. The locking device must be reset after the tow bar has been removed from the aircraft. Persons stationed in the aircraft should not attempt to steer or turn the nosewheel when the tow bar is attached to the aircraft.
5. Under no circumstances should anyone be permitted to walk or to ride between the nosewheel of an aircraft and the towing vehicle, nor ride on the outside of a moving aircraft or on the towing vehicle. In the interest of safety, no attempt to board or leave a moving aircraft or towing vehicle should be permitted.
6. The towing speed of the aircraft should not exceed that of the walking team members. The aircraft's engines usually are not operated when the aircraft is being towed into position.
7. The aircraft brake system should be charged before each towing operation. Aircraft with faulty brakes should be towed into position only for repair of brake systems, and then only with personnel standing by ready with chocks for emergency use. Chocks must be immediately available in case of an emergency throughout any towing operation.
8. To avoid possible personal injury and aircraft damage during towing operations, entrance doors should be closed, ladders retracted, and gear downlocks installed.
9. Prior to towing any aircraft, check all tires and landing gear struts for proper inflation. (Inflation of landing gear struts of aircraft in overhaul and storage is excluded.)
10. When moving aircraft, do not start and stop suddenly. For added safety, aircraft brakes must never be applied during towing except in emergencies, and then only upon command by one of the tow team members.
11. Aircraft should be parked in specified areas only. Generally, the distance between rows of parked aircraft should be great enough to allow immediate access of emergency vehicles in case of fire, as well as free movement of equipment and materials.
12. Wheel chocks should be placed fore and aft of the main landing gear of the parked aircraft.
13. Internal or external control locks (gust locks or blocks) should be used while the aircraft is parked.
14. Prior to any movement of aircraft across runways or taxiways, contact the airport control tower on the appropriate frequency for clearance to proceed.
15. An aircraft should not be parked in a hangar without immediately being statically grounded.

Taxiing Aircraft

As a general rule, only rated pilots and qualified airframe and powerplant technicians are authorized to start, run up, and taxi aircraft. All taxiing operations should be performed in accordance with applicable local regulations. Figure 11-22 contains the standard taxi light signals used by control towers to control and expedite the taxiing of aircraft. The following section provides detailed instructions on taxi signals and related taxi instructions.

Taxi Signals

Many ground accidents have occurred as a result of improper technique in taxiing aircraft. Although the pilot is ultimately responsible for the aircraft until the

Lights	Meaning
Flashing green	Cleared to taxi
Steady red	Stop
Flashing red	Taxi clear of runway in use
Flashing white	Return to starting point
Alternating red and green	Exercise extreme caution

Figure 11-22. Standard taxi light signals.

engine is stopped, a taxi signalman can assist the pilot around the flight line. In some aircraft configurations, the pilot's vision is obstructed while on the ground. The pilot cannot see obstructions close to the wheels or under the wings, and has little idea of what is behind the aircraft. Consequently, the pilot depends upon the taxi signalman for directions. Figure 11-23 shows a taxi signalman indicating his readiness to assume guidance of the aircraft by extending both arms at full length above his head, palms facing each other.

The standard position for a signalman is slightly ahead of and in line with the aircraft's left wingtip. As the signalman faces the aircraft, the nose of the aircraft is on the left. [Figure 11-24] The signalman must stay far enough ahead of the wingtip to remain in the pilot's field of vision. It is a good practice to perform a foolproof test to be sure the pilot can see all signals.

Figure 11-23. The taxi signalman.

If the signalman can see the pilot's eyes, the pilot can see the signals.

Figure 11-24 shows the standard aircraft taxiing signals published in the FAA Aeronautical Information Manual (AIM). It should be emphasized that there are other standard signals, such as those published by the Armed Forces. In addition, operation conditions in many areas may call for a modified set of taxi signals. The signals shown in Figure 11-24 represent a minimum number of the most commonly used signals. Whether this set of signals or a modified set is used is not the most important consideration, as long as each flight operational center uses a suitable, agreed-upon set of signals.

Figure 11-25 illustrates some of the most commonly used helicopter operating signals.

The taxi signals to be used should be studied until the taxi signalman can execute them clearly and precisely. The signals must be given in such a way that the pilot cannot confuse their meaning. Remember that the pilot receiving the signals is always some distance away, and must often look out and down from a difficult angle. Thus, the signalman's hands should be kept well separated, and signals should be over-exaggerated rather than risk making indistinct signals. If there is any doubt about a signal, or if the pilot does not appear to be following the signals, use the "stop" sign and begin the series of signals again.

The signalman should always try to give the pilot an indication of the approximate area in which the aircraft is to be parked. The signalman should glance behind himself or herself often when walking backward to prevent backing into a propeller or tripping over a chock, fire bottle, tiedown line, or other obstruction.

Taxi signals are usually given at night with the aid of illuminated wands attached to flashlights. [Figure 11-26] Night signals are made in the same manner as day signals with the exception of the stop signal. The stop signal used at night is the "emergence stop" signal. This signal is made by crossing the wands to form a lighted "X" above and in front of the head.

Servicing Aircraft

Servicing Aircraft Air/Nitrogen, Oil, and Fluids

Checking or servicing aircraft fluids is an important maintenance function. Before servicing any aircraft, consult the specific aircraft maintenance manual to determine the proper type of servicing equipment and procedures. In general, aircraft engine oil is checked with a dipstick or a sight gauge. There are markings

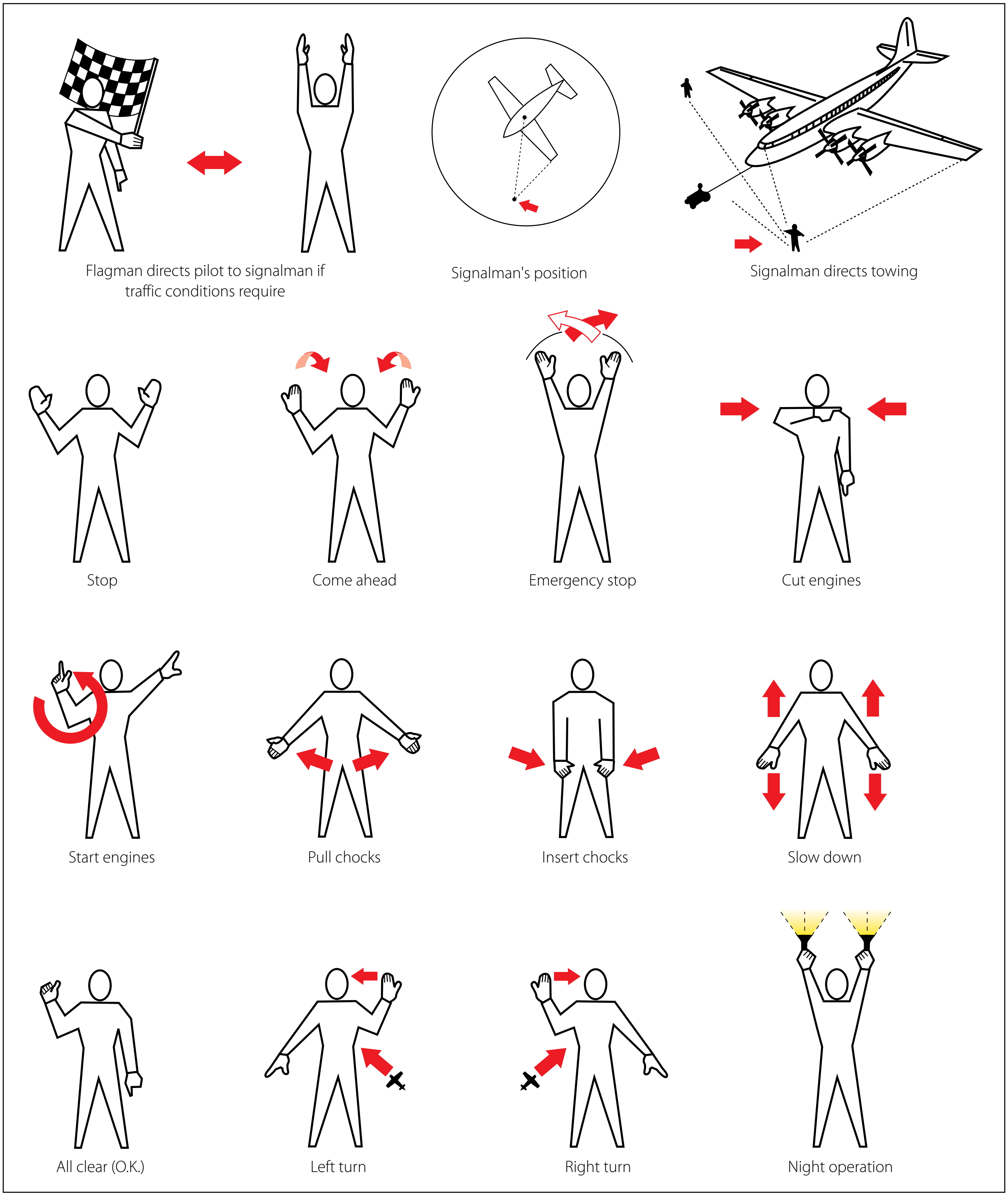

Figure 11-24. Standard FAA hand taxi signals.

on the stick or around the sight gauge to determine the correct level. Reciprocating engines should be checked after the engine has been inactive, while the turbine engine should be checked just after shutdown. Dry sump oil systems tend to hide oil that has seeped from the oil tank into the gear case of the engine. This oil will not show up on the dipstick until the engine has been started or motored. If serviced before this oil is pumped back into the tank, the engine will be overfilled. Never overfill the oil tank. Oil will foam as it is circulated through the engine. The expansion space in the oil tank allows for this foaming (oil mix-

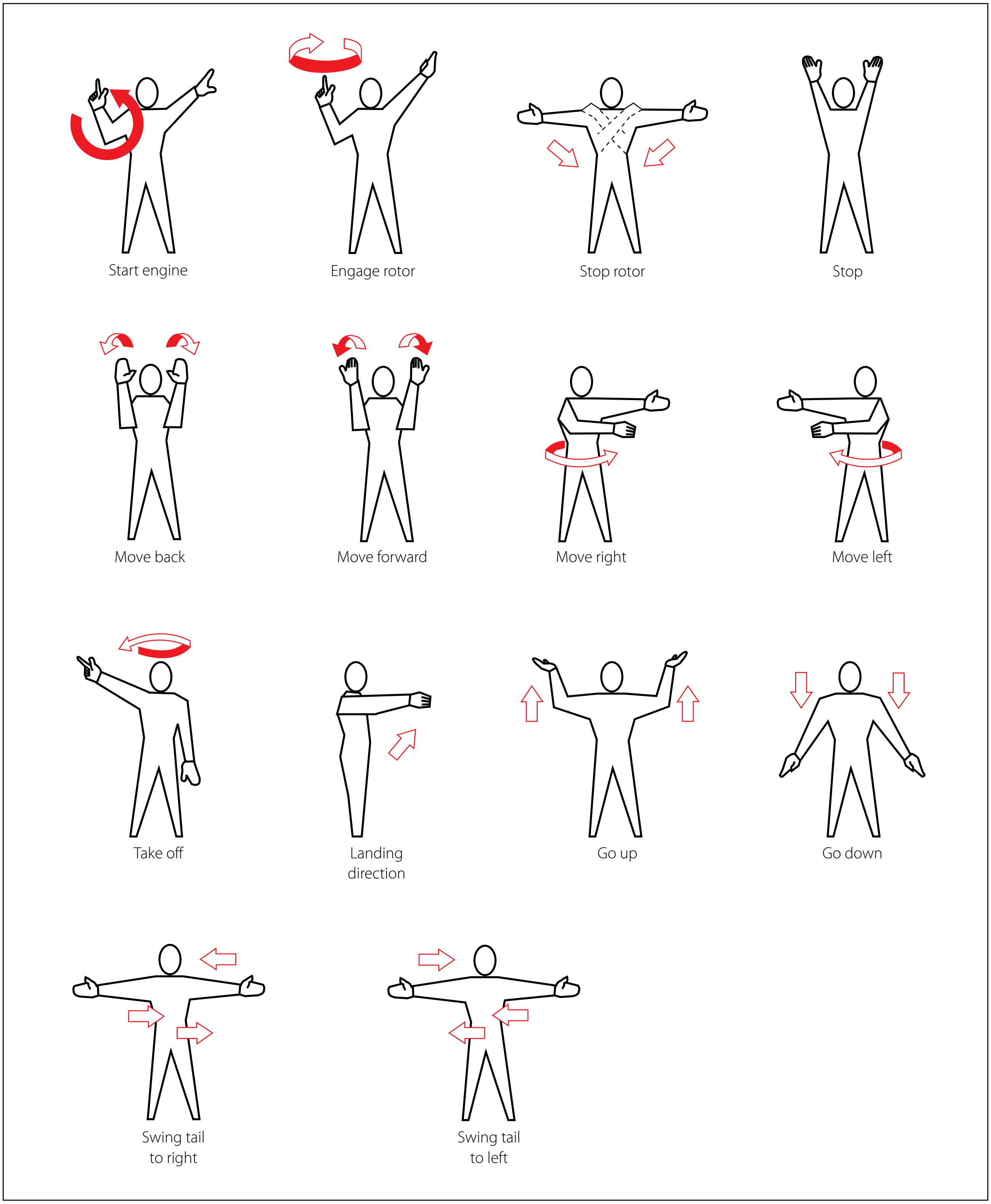

Figure 11-25. Helicopter operating signals.

ing with air). Also the correct type of oil must be used for the appropriate engine being serviced. Hydraulic fluid, fuel, and oil, if spilled on clothes or skin, must be removed as soon as possible because of fire danger and health reasons.

When servicing a hydraulic reservoir the correct fluid must be used. Normally, this can be determined by the container or by color. Some reservoirs are pressurized by air which must be bled off before servicing. Efforts must be made to prevent any type of contamination dur-

Figure 11-26. Night operations with wands.

ing servicing. Also, if changing hydraulic filters, assure that the pressure is off the system before removing the filters. After servicing the filters (if large amounts of fluids were lost) or system quantity, air should be purged and the system checked for leaks. While servicing tires or struts with high pressure nitrogen, the technician must use caution while performing maintenance. Clean areas before connecting filling hose and do not overinflate**.**

Ground Support Equipment

Electric Ground Power Units

Ground support electrical auxiliary power units vary widely in size and type. However, they can be generally classified by towed, stationary, or self-propelled items of equipment. Some units are mainly for in-hangar use during maintenance. Others are designed for use on the flight line either at a stationary gate area or towed from aircraft to aircraft. The stationary type can be powered from the electrical service of the facility. The movable type ground power unit (GPU) generally has an onboard engine that turns a generator to produce power. Some smaller units use a series of batteries.

The towed power units vary in size and range of available power.

The smallest units are simply high-capacity batteries used to start light aircraft. These units are normally mounted on wheels or skids and are equipped with an extra-long electrical line terminated in a suitable plug-in adapter.

Larger units are equipped with generators. Providing a wider range of output power, these power units are normally designed to supply constant-current, variable-voltage DC electrical power for starting turbine aircraft engines, and constant-voltage DC for starting reciprocating aircraft engines. Normally somewhat top-heavy, large towed power units should be towed at restricted speeds, and sharp turns should be avoided. An example of a large power unit is shown in Figure 11-27.

Self-propelled power units are normally more expensive than the towed units and in most instances supply a wider range of output voltages and frequencies. Another example, the stationary power unit shown in Figure 11-28 is capable of supplying DC power in varying amounts, as well as 115/200-volt, 3-phase, 400-cycle AC power continuously for 5 minutes.

Figure 11-27. A mobile electrical power unit.

Figure 11-28. A stationary electrical power unit.

When using ground electrical power units, it is important to position the unit to prevent collision with the aircraft being serviced, or others nearby, in the event the brakes on the unit fail. It should be parked so that the service cable is extended to near its full length away from the aircraft being serviced, but not so far that the cable is stretched or undue stress is placed on the aircraft electrical receptacle.

Observe all electrical safety precautions when servicing an aircraft. Additionally, never move a power unit when service cables are attached to an aircraft or when the generator system is engaged.

Hydraulic Ground Power Units

Portable hydraulic test stands are manufactured in many sizes and cost ranges. [Figure 11-29] Some have a limited range of operation, while others can be used to perform all the system tests that fixed shop test stands are designed to perform. Hydraulic power units, sometimes called a hydraulic mule, provide hydraulic pressure to operate the aircraft systems during maintenance. They can be used to:

- Drain the aircraft hydraulic systems.
- Filter the aircraft system hydraulic fluid.
- Refill the aircraft system with clean fluid.
- Check the aircraft hydraulic systems for operation and leaks.

This type of portable hydraulic test unit is usually an electrically powered unit. It uses a hydraulic system capable of delivering a variable volume of fluid from zero to approximately 24 gallons per minute at variable pressures up to 3,000 psi.

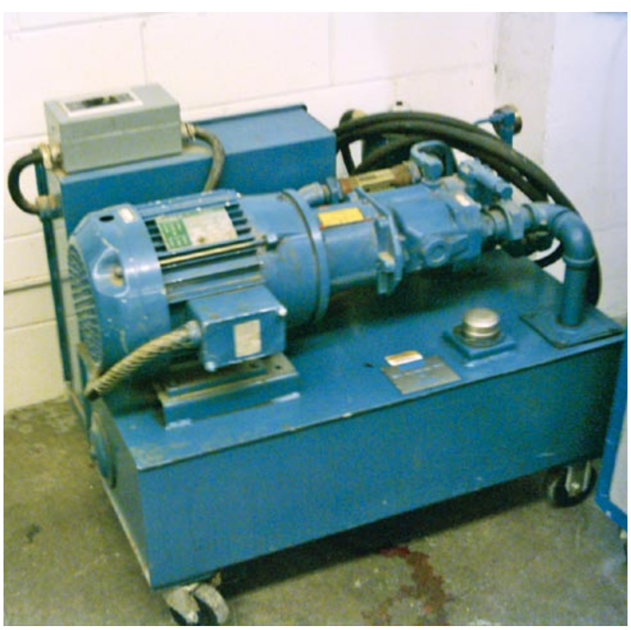

Figure 11-29. A portable hydraulic power unit.

Operating at pressures of 3,000 psi or more, extreme caution must be used when operating hydraulic power units. At 3,000 psi, a small stream from a leak can cut like a sharp knife. Therefore, inspect lines used with the system for cuts, frays, or any other damage, and keep them free of kinks and twists. When not in use, hydraulic power unit lines should be stored (preferably wound on a reel) and kept clean, dry, and free of contaminants.

Ground Support Air Units

Air carts are used to provide low pressure (up to 50 psi high volume flow) air which can be used for starting the engines, and heating and cooling the aircraft on the ground (using the onboard aircraft systems). It generally consists of an APU built into the cart that provides bleed air from the APU's compressor for operating aircraft systems or starting engines. [Figure 11-30]

Ground Air Heating and Air Conditioning

Most airport gates have facilities that can provide heated or cooled air. The units that cool or heat the air are permanent installations, which connect to the aircraft by a large hose that connects to the aircraft's ventilation system. Portable heating and air conditioning units can also be moved close to the aircraft and connected by a duct, which provides air to keep the cabin temperature comfortable.

Oxygen Servicing Equipment

Before servicing any aircraft, consult the specific aircraft maintenance manual to determine the proper type of servicing equipment to be used.

Two personnel are required to service an aircraft with gaseous oxygen. One person should be stationed at the

Figure 11-30. A portable compressed air cart.

control valves of the servicing equipment and one person stationed where he or she can observe the pressure in the aircraft system. Communication between the two people is required in case of an emergency.

Aircraft should not be serviced with oxygen during fueling, defueling, or other maintenance work, which could provide a source of ignition. Oxygen servicing of aircraft should be accomplished outside hangars.

Oxygen used on aircraft is available in two types: gaseous and liquid. The type to use on any specific aircraft depends on the type of equipment in the aircraft. Gaseous oxygen is stored in large steel cylinders, while liquid oxygen (commonly referred to as LOX) is stored and converted into a usable gas in a liquid oxygen converter.

Oxygen is commercially available in three general types: aviator's breathing, industrial, and medical. Only oxygen marked "Aviator's Breathing Oxygen" which meets Federal Specification BB-0-925A, Grade A, or its equivalent should be used in aircraft breathing oxygen systems. Industrial oxygen may contain impurities, which could cause the pilot, crew, and/or passengers to become sick. Medical oxygen, although pure, contains water, which can freeze in the cold temperatures found at the altitudes where oxygen is necessary.

Oxygen Hazards

Gaseous oxygen is chemically stable and is nonflammable. However, combustible materials ignite more rapidly and burn with greater intensity in an oxygen-rich atmosphere. In addition, oxygen combines with oil, grease, or bituminous material to form a highly explosive mixture, which is sensitive to compression or impact. Physical damage to, or failure of oxygen containers, valves, or plumbing can result in an explosive rupture, with extreme danger to life and property. It is imperative that the highest standard of cleanliness be observed in handling oxygen and that only qualified and authorized persons be permitted to service aircraft gaseous oxygen systems.

In addition to aggravating the fire hazard, because of its low temperature (it boils at −297 °F), liquid oxygen causes severe "burns" (frostbite) if it comes in contact with the skin.

Fuel Servicing Of Aircraft

Types of Fuel and Identification

Two types of aviation fuel in general use are aviation gasoline, also known as AVGAS, and turbine fuel, also known as JET A fuel.

Color	Grade
Red	80
Blue	100
Green	100LL
Purple	115

Aviation gasoline (AVGAS) is used in reciprocating-engine aircraft. Currently, there are three grades of fuel in general use: 80/87, 100/130, and 100LL (low lead). A fourth grade, 115/145, is in limited use in the large reciprocating-engine aircraft. The two numbers indicate the lean mixture and rich mixture octane rating numbers of the specific fuel. In other words, with 80/87 aviation gasoline, the 80 is the lean mixture rating and 87 is the rich mixture rating number. To avoid confusing the types of AVGAS, it is generally identified as grade 80, 100, 100LL, or 115. AVGAS can also be identified by a color code. The color of the fuel should match the color band on piping and fueling equipment.

Turbine fuel/jet fuel is used to power turbojet and turbo-shaft engines. Three types of turbine fuel generally used in civilian aviation are JET A and JET A-1, which are made from kerosene and JET B, which is a blend of kerosene and aviation gasoline. While jet fuel is identified by the color black on piping and fueling equipment, the actual color of jet fuel can be clear or straw colored.

Never mix AVGAS and turbine fuel. Adding jet fuel to AVGAS will cause a decrease in the power developed by the engine and could cause damage to the engine (through detonation) and loss of life. Adding AVGAS to jet fuel, although allowed, can cause lead deposits in the turbine engine and can lead to reduced service life.

Contamination Control

Contamination is anything in the fuel that is not supposed to be there. The types of contamination found in aviation fuel include water, solids, and microbial growths.

The control of contamination in aviation fuel is extremely important, since contamination can lead to engine failure, or stoppage and the loss of life. The best method of controlling contamination is to prevent its introduction into the fuel system. Some forms of contamination will still occur inside the fuel system.

Either way, the filter, separators, and screens should remove most of the contamination.

Water in aviation fuels will generally take two forms: dissolved (vapor) and free water.

The dissolved water is not a major problem until, as the temperature lowers, it becomes free water. This then poses a problem if ice crystals form, clogging filters and other small orifices.

Free water can appear as water slugs or entrained water. Water slugs are concentrations of water. This is the water that is drained after fueling an aircraft.

Entrained water is suspended water droplets. These droplets may not be visible to the eye, but will give the fuel a cloudy look. The entrained water will settle out in time.

Solid contaminants are insoluble in fuel. The more common types are rust, dirt, sand, gasket material, lint, and fragments of shop towels. The close tolerances of fuel controls and other fuel-related mechanisms can be damaged or blocked by particles as small as one-twentieth the diameter of a human hair.

Microbiological growths are a problem in jet fuel. There are a number of varieties of micro-organisms that can live in the free water in jet fuel. Some variations of these organisms are airborne, others live in the soil. The aircraft fuel system becomes susceptible to the introduction of these organisms each time the aircraft is fueled.

Favorable conditions for the growth of micro-organisms in the fuel are warm temperatures and the presence of iron oxide and mineral salts in the water.

The effects of micro-organisms are:

- Formation of slime or sludge that can foul filters, separators, or fuel controls.
- Emulsification of the fuel.
- Corrosive compounds that can attack the fuel tank's structure. In the case of a wet wing tank, the tank is made from the aircraft's structure. They can also have offensive odors.

The best way to prevent microbial growth is to keep the fuel dry.

Fueling Hazards

The volatility of aviation fuels creates a fire hazard that has plagued aviators and aviation engine designers since the beginning of powered flight. Volatility is the ability of a liquid to change into a gas at a relatively low temperature. In its liquid state, aviation fuel will not burn. It is, therefore, the vapors, or gaseous state to which the liquid fuel changes that is not only useful in powering the aircraft, but also a fire hazard.

Static electricity is a byproduct of one substance rubbing against another. Fuel flowing through a fuel line causes a certain amount of static electricity. The greatest static electricity concern around aircraft is that during flight, the aircraft moving through the air causes static electricity to build in the airframe. If that static electricity is not dissipated prior to refueling, the static electricity in the airframe will try to return to ground through the fuel line from the servicing unit. The spark caused by the static electricity can ignite any vaporized fuel.

Breathing the vapors from fuel can be harmful and should be limited. Any fuel spilled on the clothing or skin must be removed as soon as possible.

Fueling Procedures

The proper fueling of an aircraft is the responsibility of the owner/operator. This does not, however, relieve the person doing the fueling of the responsibility to use the correct type of fuel and safe fueling procedures.

There are two basic procedures when fueling an aircraft. Smaller aircraft are fueled by the over-the-wing method. This method uses the fuel hose to fill through fueling ports on the top of the wing. The method used for larger aircraft is the single point fueling system. This type of fueling system uses receptacles in the bottom leading edge of the wing, which is used to fill all the tanks from this one point. This decreases the time it takes to refuel the aircraft, limits contamination, and reduces the chance of static electricity igniting the fuel. Most pressure fueling systems consist of a pressure fueling hose and a panel of controls and gauges that permit one person to fuel or defuel any or all fuel tanks of an aircraft. Each tank can be filled to a predetermined level. These procedures are illustrated in Figures 11-31 and 11-32.

Prior to fueling, the person fueling should check the following:

1. Ensure all aircraft electrical systems and electronic devices, including radar, are turned off.
2. Do not carry anything in the shirt pockets. These items could fall into the fuel tanks.

Figure 11-31. Refueling an aircraft by the over-the-wing method.

3. Ensure no flame-producing devices are carried by anyone engaged in the fueling operation. A moment of carelessness could cause an accident.
4. Ensure that the proper type and grade of fuel is used. Do not mix AVGAS and JET fuel.
5. Ensure that all the sumps have been drained.
6. Wear eye protection. Although generally not as critical as eye protection, other forms of protection, such as rubber gloves and aprons, can protect the skin from the effects of spilled or splashed fuel.
7. Do not fuel aircraft if there is danger of other aircraft in the vicinity blowing dirt in the direction of the aircraft being fueled. Blown dirt, dust, or

other contaminants can enter an open fuel tank, contaminating the entire contents of the tank.

8. Do not fuel an aircraft when there is lightning within 5 miles.
9. Do not fuel an aircraft within 500 feet of operating ground radar.

When using mobile fueling equipment:

1. Approach the aircraft with caution, positioning the fuel truck so that if it is necessary to depart quickly, no backing will be needed.
2. Set the hand brake of the fuel truck, and chock the wheels to prevent rolling.
3. Ground the aircraft and then ground the truck. Next, ground or bond them together by running a connecting wire between the aircraft and the fuel truck. This may be done by three separate ground wires or by a "Y" cable from the fuel truck.
4. Ensure that the grounds are in contact with bare metal or are in the proper grounding points on the aircraft. Do not use the engine exhaust or propeller as grounding points. Damage to the propeller can result, and there is no way of quickly ensuring a positive bond between the engine and the airframe.
5. Ground the nozzle to the aircraft, then open the fuel tank.
6. Protect the wing and any other item on the aircraft from damage caused by spilled fuel or careless handling of the nozzle, hose, or grounding wires.
7. Check the fuel cap for proper installation and security before leaving the aircraft.
8. Remove the grounding wires in the reverse order. If the aircraft is not going to be flown or moved soon, the aircraft ground wire can be left attached.

When fueling from pits or cabinets, follow the same procedures as when using a truck. Pits or cabinets are usually designed with permanent grounding, eliminating the need to ground the equipment. However, the aircraft still must be grounded, and then the equipment must be grounded to the aircraft as it was with mobile equipment.

Defueling

Defueling procedures differ with different types of aircraft. Before defueling an aircraft, check the maintenance/service manual for specific procedures and cautions.

Defueling can be accomplished by gravity defueling or by pumping the fuel out of the tanks. When the gravity method is used, it is necessary to have a method of collecting the fuel. When the pumping method is used, care must be taken not to damage the tanks, and the removed fuel should not be mixed with good fuel.

General precautions when defueling are:

- Ground the aircraft and defueling equipment.
- Turn off all electrical and electronic equipment.
- Have the correct type of fire extinguisher available.
- Wear eye protection.

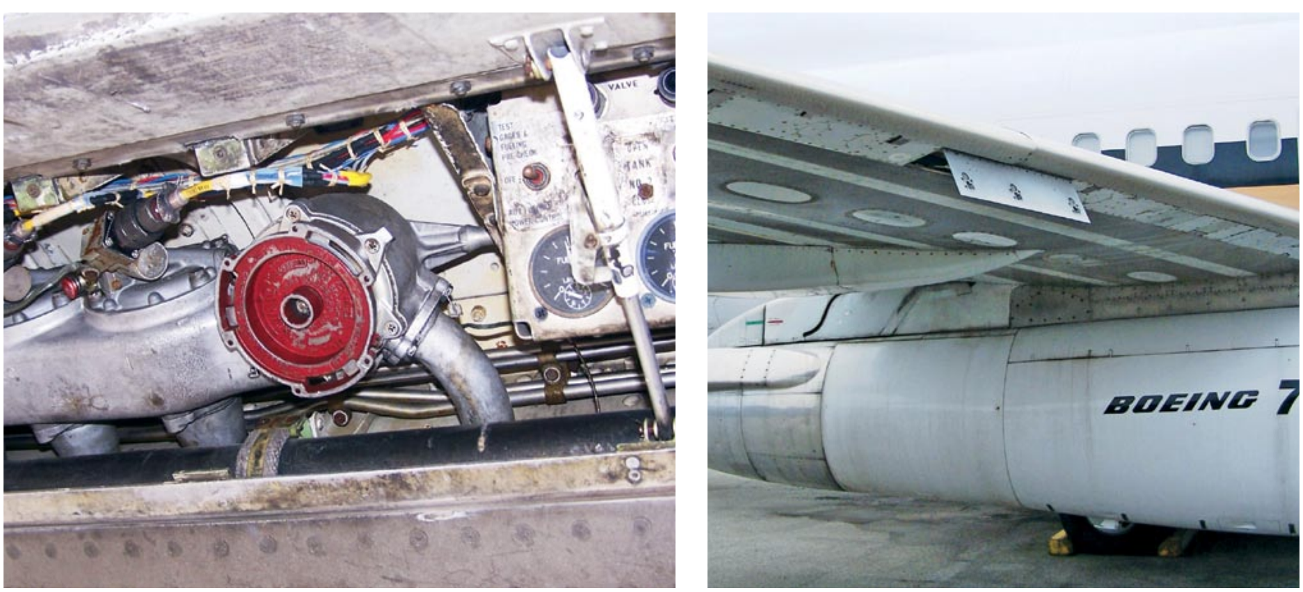

Figure 11-32. Single point refueling station of a large aircraft.