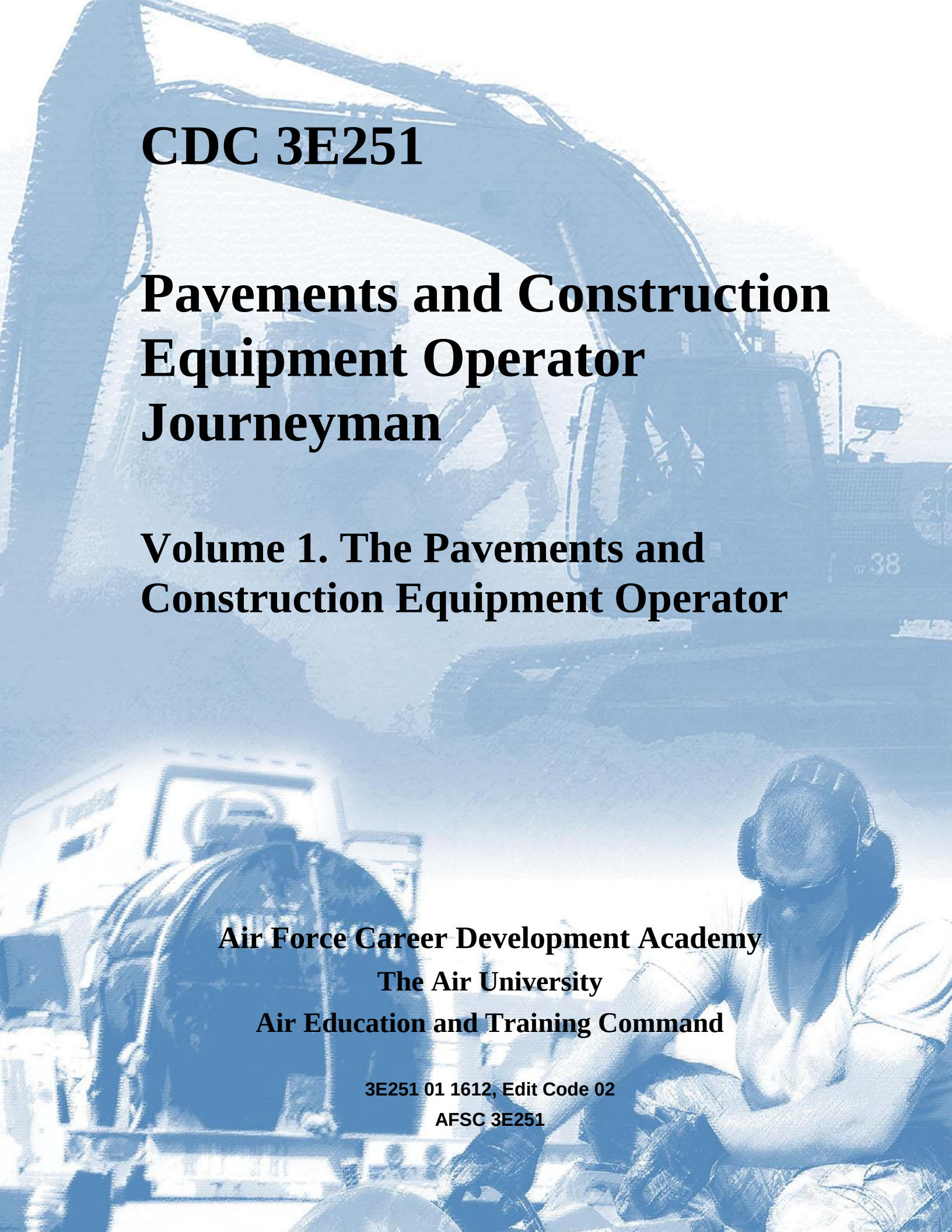

CDC 3E251

Pavements and Construction Equipment Operator Journeyman

Volume 1. The Pavements and Construction Equipment Operator

Air Force Career Development Academy

The Air University

Air Education and Training Command

3E251 01 1612, Edit Code 02

AFSC 3E251

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WELCOME to Civil Engineering (CE)! This is the first volume in your career development course (CDC) which consists of four volumes. The first volume covers your specific duties within the Pavements and Construction Equipment Operator career field. Volume 2 deals with the identification and operation of heavy equipment. Volume 3 introduces one of our main priorities, that of paved surfaces, focusing on the construction of concrete and asphalt. Finally, Volume 4 addresses your specific duties in a contingency and/or deployed environment.

In this volume, unit 1 starts you out with a very important part of daily life in the Air Force, safety. Safety standards, protective equipment and worksite safety and traffic control will all be discussed.

Unit 2 covers your obligations and duties regarding vehicle usage and license/certification needs. This will include the operator's responsibilities in performing both inspection and maintenance procedures.

Unit 3 presents project management skills you will need to complete your work. Included within the unit are fundamentals of soil, evlation and leveling of equipment, construction drawings, as well as planning and managing a project.

Unit 4 discusses the use and care/safety of powered equipment and hand tools. Finally, unit 5 presents additional responsibilities including the use of oxyacetylene cutting equipment and fencing requirements.

A glossary is included for your use.

Code numbers on figures are for preparing agency identification only.

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To get a response to your questions concerning subject matter in this course, or to point out technical errors in the text, unit review exercises, or course examination, call or write the author using the contact information on the inside front cover of this volume.

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This volume is valued at 15 hours and 5 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Please read the menu for Unit 1 and begin ➔

Unit 1. Safety

YOU ARE RESPONSIBLE for your own safety as well as for the safety of others who work with you. Dictionaries define the word “accident” as “an event that takes place without foresight or expectation.” This definition means that with enough foresight, most accidents should be prevented.

In this unit, we will discuss essential safety standards to be implemented in various environments. We will also discuss essential protective equipment, as well as worksite safety and traffic control.

1–1. Safety Standards

As a skilled worker, you should follow all safety standards when doing your work. Always operate your equipment according to the procedures given in technical orders (TO) and operator’s manuals. If there are no technical orders for the equipment, contact the manufacturer and request a copy or go to the manufacturer’s Web site and download a copy. TOs and manufacturer’s instructions were developed, first, for your protection and the protection of the people that work with you; secondly, they were developed for the protection of the equipment.

001. Enforcement of safety standards

One way to prevent accidents is to enforce safety standards, the focus of this lesson. Each supervisor is responsible for enforcing safety standards and regulations within his or her respective work centers and wherever there may be unsafe acts occurring. When you are supervising pavements and construction equipment workers, you are responsible for ensuring your people work safely. If you do not enforce directives, you are condoning conduct that may lead to accidents or, more importantly, death to the Air Force’s most valuable asset, its personnel.

Air Force Standards

Air Force Instruction (AFI) 91–203, *Air Force Consolidated Occupational Safety Instruction*, implements parts of the Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) and includes additional requirements not addressed by the OSHA standard. Major commands (MAJCOM) may have more stringent or restrictive requirements than those contained in this instruction or other Air Force Occupational Safety and Health (AFOSH) instructions and standards. It replaces and substantially changes the outdated and superseded AFOSH Standard

91–501 and all other 91-series AFOSH standards. AFI 91–203 updates and merges Air Force safety principles, concepts, and program elements into a single consolidated occupational safety and health document. This instruction incorporates the safety principles and concepts of the OSHA and other national consensus safety agencies.

OSHA Standards

OSHA safety guidance published in the Department of Labor 29 series CFR provides workers a safe and healthy workplace. OSHA dictates what must be carried out in the workplace, but not necessarily how it must be done, or by whom. Commanders are responsible for the safety of their facilities and personnel, including the correction of all hazards and deficiencies in their workplaces. AFI 91–203 assigns responsibilities to individuals or functions to help commanders manage their safety and health programs, ensuring they comply with OSHA and Air Force guidance. Also, AFI 91–203 provides a uniform program, which MAJCOM/Wing/installation commanders may supplement, as necessary, to ensure a safe and healthy workplace.

No TO, instruction, or operating instruction can address every hazard or potential hazard that may arise from a specific task or combination of tasks. Where situations exist that are not covered by existing directives, use a risk management (RM) process to assess risk associated with those situations and determine adequate safeguards or procedures to manage the risk.

002. Hazards in the work environment

In your job as a pavements and construction equipment journeyman, you are exposed to many hazards. You operate heavy construction equipment and pneumatic tools, place hot asphalt, move overhead loads with cranes, and work in and around hazardous noise areas. As required, you do manual labor tasks that involve physically shoveling, raking, and lifting heavy tools and equipment. In winter months, you may be exposed to deicing chemicals along with operating snow removal equipment in subfreezing temperatures. However, there are many more hazards you will encounter in your daily duties. Taken from AFI 91–203, the following are examples of hazards you may encounter:

- Work requiring removal of earth and/or rock is essentially simple, yet dangerous. Injury and death by suffocation or crushing as a result of cave-ins occur too frequently. Also, hazards may also be encountered when electrical, gas, and steam lines are broken in excavating operations.
- Cleaning equipment, vehicles, and tools with pressure cleaners and steam cleaners that operate at pressures in excess of 1000 pounds per square inch (PSI) and temperatures near 200 degrees Fahrenheit (°F). Improper use can result in severe personal injury. Soaps and solvents can also cause severe health problems such as dermatitis, eye irritation, and other medical problems especially if the solvents are inhaled.
- Mechanical lifting devices include a large variety of cranes, hoists, slings, jacks and forklifts. Their use is subject to certain hazards that cannot be controlled by mechanical means, but only through the use of intelligence, care, and common sense. Hazards include overloading, dropping, or slipping of the load, obstructing the free passage of the load, moving a vehicle with an unsecured load, and not using stabilizers.
- Use of the wrong tool for the work or job and the lack of inspection of tools cause mishaps, such as cuts, eye damage, and broken bones.
- Exposure to hazardous noise either in the shop, on the flight line, or in other work areas without proper hearing protection can result in temporary or permanent loss of hearing.

The recognition of hazards requires us to be alert and knowledgeable as to what is dangerous. Therefore, we can never become complacent with our assigned jobs. Bottom line, each person must concentrate on the task at hand to eliminate many hazards in his or her work area. No matter how big or small the job, the Air Force goal is ZERO mishaps to its members.

Asphalt emulsion

Use extreme care when working around *hot* asphalt. It can give you severe burns. Even in a cool state, an irritation may develop from prolonged contact. If you come in contact with the material while it is hot, cool the material with water. When working with the material in a cool state, you may clean your skin using a waterless cleaner, followed by soap and water. If irritation develops, seek medical attention. Any time the material gets into your eyes, flush your eyes with cool water and seek medical attention immediately.

If the material is spilled, create dikes or ponds as soon as possible. You can use earth, sawdust, or sand to make dikes. The emulsion can be mixed with any stabilizing material, (rock, gravel or sand) to change it back to a solid. Once the material is solid, you can pick it up with a front-end loader; unload it into a dump truck and dispose of it at an approved landfill. If no area is able to take the material, get with your local environmental flight to make arrangements for processing.

Pavement repair

The repair of concrete and asphalt pavements present unique health hazards that you should be aware of. We will cover a few of them in the following paragraphs.

Noise

It is a given that our work involves extremely noisy equipment. Concrete saws, jackhammers, and air compressors are just a few examples of equipment that could cause permanent hearing loss. Always wear hearing protection even if you don't think something is very loud.

Smoke and heat

During asphalt paving operations, smoke and heat are ever present dangers. Ensure that you wear the appropriate personal protection equipment (PPE) and always ensure you are hydrated. Smoke can also come from vehicles within an enclosed area (such as inside a building). In these situations, get into fresh air as soon as possible to alleviate any ill effects.

Dust and flying debris

Pavement sawing and jack hammering cause large amounts of dust and flying debris. Make sure you always have the appropriate PPE which should include a dust mask, hearing protection, and eye protection.

Snow removal

Snow removal operations are inherently dangerous due to temperature extremes, driving conditions, and chemicals used. Extreme cold temperatures will lead to cold weather injuries if not addressed. You can get hypothermia and frostbite within short periods of time if you are not dressed appropriately or if you ignore the warning signs.

Driving conditions can become almost impossible quickly during winter storms. As a Pavements and Construction Equipment Operator, you are still expected to drive in such conditions. It is extremely important to understand how to control a vehicle during adverse driving conditions, how to correct the vehicle during a mishap, and how to get back to carrying out the mission. The biggest things to remember are to slow down and think about what you are doing. Thinking about what you are doing will go a long way in preventing most major accidents.

The following paragraphs cover the chemicals used in snow removal operations as ice-preventive and ice removing agents. Prior to engaging in any snow removal operations involving these chemicals, review the applicable Material Safety Data Sheets (MSDS) so you know what hazards are present and the solutions to help mitigate those hazards.

Sodium chloride (rock salt)

Rock salt is used in snow removal. Store the salt in dry areas. When you load spreaders, don't inhale the dust as it can irritate your nose and throat. If it touches your skin, wash with clean water. To dispose of the chemical, get with the environmental flight for the current disposal methods.

Calcium chloride

Store calcium chloride in a dry environment. When exposed to the atmosphere, calcium chloride picks up water and forms a solution. Always wear protective clothing and avoid skin contact with the material. When dry, it mildly irritates your skin; when moist, it burns you. If the chemical gets in your eyes, flush your eyes with cold water for 15 minutes and get medical help.

If it spills, sweep it up and return it to its container or dispose of it by washing it away with large amounts of water or by burying it. Always be sure you comply with state and federal regulations. Again, the best way to dispose of any chemical is to ask the environmental flight for guidance.

Sodium formate and sodium acetate

As with other chemicals used in snow removal, sodium formate and sodium acetate should be stored in a dry and well-ventilated area. Although they are less environmentally harmful, take caution when working with these chemicals. If you inhale them, your respiratory tract will be irritated. Wear the proper mask or get to fresh air as soon as possible. If you should get the chemical dust in your eyes, flush them with cold water and seek medical help.

Fuel

You will be exposed to diesel fuel in most equipment you operate. Always refuel in a well-ventilated area away from potential ignition sources. Gasoline for small engine equipment and general purpose vehicles is far more dangerous than diesel, but with proper care and attention to detail while refueling, hazards associated with fuel become quite minimal. Make sure you have a fire extinguisher available.

Oil and other fluids

You will definitely come into contact with engine oils, transmission, hydraulic and brake fluids, and an array of other dangerous chemicals as a pavements and construction equipment operator. Get to know the all the information regarding hazards associated with these fluids and chemicals before you use them by researching the MSDS located in your work area.

003. Safe driving

In our career field, we operate heavy equipment and drive many different varieties of vehicles. It would be fitting to discuss the act of driving and how we can strive to be better drivers.

Defensive driving

The standard American National Standards Institute/American Society of Safety Engineers (ANSI/ASSE) Z15.1, *Safe Practices for Motor Vehicle Operations*, defines defensive driving as "driving to save lives, time, and money, in spite of the conditions around you and the actions of others." The National Safety Council uses this definition as the basis for their Defensive Driving Course, or DDC. It is a form of training for motor vehicle drivers that goes beyond mastery of the rules of the road and the basic mechanics of driving. Its aim is to reduce the inherent risks of driving by anticipating dangerous situations, despite adverse conditions or the mistakes of others. This can be done by following a variety of general rules, as well as practicing specific driving techniques. When you can anticipate what someone else is going to do given a specific set of factors, you can reduce the chances of getting into an accident. Knowing what may happen at any time and knowing what to do before it happens are the main objectives.

Distracted drivers

Distractions are anything that takes away your ability to react quickly while operating a motor vehicle. Distractions can be anything ranging from eating to talking on your phone while driving. The use of headphones, earphones, and cellular telephones hinders or prevents recognition of emergency signals, alarms, announcements, approach of vehicles, human speech, and the ability to determine the direction from which sounds are coming.

AFI 91–207, *USAF Traffic Safety Program*, states that while operating a government motor vehicle, a private vehicle on official government business, or a government-owned vehicle, individuals are prohibited from text messaging on or off a Department of Defense (DOD) installation. Using cell phones, any listening device, or other hand-held electronic devices that takes attention away from driving is discouraged unless the vehicle is safely parked or off the roadway or the operator is using a single ear bud or voice-activated hands-free device, where allowed by law. Use of hands-free devices is also discouraged as they create significant distractions from safe driving performance. It is hard to stay alert and focused on the task of driving if you are fiddling with your phone.

NOTE: If you are caught using your phone while driving on-base, you will be reprimanded and depending on the base, your license may be suspended for a period of time.

004. Procedures for servicing, mounting, dismounting, and moving equipment

When adjusting or servicing equipment, you must shut the machine down first. Do not do any servicing or adjusting when the machine is running. Equipment with exposed moving parts, such as belts, chains, flywheels, or moving arms, can present a serious safety hazard unless you use extreme care operating and servicing it. Even though most moving parts of machinery are enclosed in protective guards, it is essential that you be alert. Why? Because you could easily be pulled into a power takeoff shaft or drive shaft and end up losing an arm or hand or even get killed. For example, how do you think it would feel to put your elbow into the radiator fan while checking the brake fluid on a dump truck? You need to also consider whether to jack up a piece of equipment to make adjustments. Make sure that the equipment is not running, and be sure to use proper capacity jacks, jack stands, and chocks as needed for safety.

Pre-operation hazards

Remember, you will work with some very heavy machinery requiring you to use heavy-duty tools and equipment. Additionally, fueling a piece of equipment while it is running is very dangerous. The reason is that there is the potential for static electricity to build up as the equipment is running. When you insert the filler nozzle, it could create a small spark and in the case of gasoline igniting vapors causing explosion.

Operating equipment safely demands your constant attention. When mounting or dismounting equipment, always *face the machine* and use necessary handrails and steps, maintaining at least three points of contact at all times (fig. 1–1). Check the step areas and rails for any grease or oil which could cause you to lose control.

Figure 1–1. Mounting and dismounting equipment.

Before you mount the piece of equipment, do a quick walk around and tell anyone who may be near the machine to clear away. When you're ready to start the machine, make sure the transmission is in neutral, all control levers for operating attachments are in the neutral position, and the brakes are set. This keeps the machine from jumping forward and attachments from raising or tilting immediately when the engine starts.

Operation hazards

Before placing the equipment in motion, raise or adjust attachments as necessary and start out slowly, gradually reaching proper operating speed. This is necessary to give you a feel for the machine and insure attachments are operating properly. You may want to leave it in low gear or low engine speed until you get used to the characteristics of the machine.

If operating in a confined or hazardous area, keep the machine at a slow speed and use a *spotter* as necessary to help you maneuver it and lower the chances of an accident. During winter months, you may be required to remove snow from a confined area, such as an aircraft parking ramp or narrow streets in a housing area. This requires your utmost abilities. In situations such as this, get someone to work outside your equipment to identify obstacles and keep you from getting too close to vehicles or other equipment.

Post-operation hazards

When stopping the equipment or shutting down, lower all attachments, set the brakes, and shut the engine off. Pull the keys and conduct a walk-around inspection to ensure no damage or leaks have occurred during the operation. Finally, chock the wheels if you are parked on an incline or in an area where chocks are a requirement (flight line or specified parking areas inside compounds). Vehicles parked inside a building may be required to have the keys left in the vehicle (so they can be moved in case of a fire), so get with your supervisor to make sure.

005. Safe procedures for electric power tools

You may not use many hand-powered electrical tools, but if you do, you should know the hazards and the precautions to take to prevent electrical injury. Let's say, for example, you need to use a portable hand drill. As you pull the trigger, you receive a severe shock. Someone had cut the ground prong. Luckily, you were not hurt. You tell your supervisor that you braced yourself with your left hand against a pipe extending from the concrete floor. Because the drill motor was shorted to the case and the ground prong had been cut, the electrical current did not flow to the ground as it should have. Instead, the current flowed from the drill, through your left hand, down the pipe and into the ground. You could easily have been severely hurt, or even killed. However, if you had read and followed the Air Force publications governing use of electric tools, this accident might never have happened.

Several Air Force publications deal with electric tools and related hazards. The Air Force also follows the rules in the applicable AFOSH standards, the National Code, and the National Electric Code (NEC). Since this is such a broad subject, we will limit it to improper grounding, cord abuse, and safe operation of electrical power tools.

Proper grounding

Electrical tools must be equipped with a polarized (grounding) plug and a special cord with a grounded conductor. Also, the grounding plug is useless as a ground unless plugged into a suitable grounded receptacle. The objective is to ensure that there is a metallic connection of low resistance directly from all metal surfaces of an electric tool to a ground.

To break off the ground prong on an electric tool is to break the safety device that protects you which is extremely unsafe. Portable tools and appliances protected by a system of double insulation or its equivalent are not required to be grounded. Most equipment comes with a tag affixed to the cord which tells you how it's grounded and also includes some safety reminders.

Finally, if you are going to be in damp areas, make sure the outlet you are using has a ground fault interrupter (GFI). This device will trip a breaker and cut the power if there is water present in the circuit. They are mandatory items in any area where water is a danger such as in bathrooms, kitchens and outdoor areas. Additionally, you can take extra precautions in an extremely wet area by standing on a rubber mat and wearing rubber gloves.

Cord care and electric power equipment precautions

It is important to protect the cord on your power equipment. This is also true of extension cords. You must protect the conductors in the cord and the plugs to provide safe operation. Scraping, kinking, or stretching, as well as exposure to grease, oil, and even sunlight (ultra violet (UV) rays) damages electrical cords. Use heavy-duty plugs that clamp to the cord. Do *not* jerk the cord from the receptacle to unplug it because this damages the cord and sometimes loosens the connection. Pull on the plug only.

If you use an extension cord, make sure that it has a separate grounding conductor and grounding-type plugs. This means that you cannot use a two-wire extension cord, except when using a double insulated tool. Also, do not plug an extension cord into a power strip due to the increase in resistance which translates into heat (sometimes called a "daisy chain"). If you need to use a power strip, plug the item directly into it without an extension cord. Your unit safety representative will have more information in regards to electrical safety and proper cord use.

Here is a list of precautions to take when using electrically powered tools:

- Inspect the equipment, especially the external wiring before you use it.
- Use safety glasses or a face shield where chips or dust could fly.
- Do *not* wear loose gloves or loose clothing while using rotating equipment.
- Change accessories with the power turned off and the cord unplugged. Remove the safety guard only when exchanging accessories.
- Make sure the guard is in place before starting the tool.
- Do *not* wear rings, metal-rimmed glasses, watches, or other metallic objects when working with electric tools.
- Use a GFI outlet or stand on a rubber mat and wear rubber gloves if you use equipment in wet places.
- Be certain the tool is properly grounded.
- Check the operating instructions before operating electrical tools.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

001. Enforcement of safety standards

1. What actions can a supervisor take to prevent accidents from happening in the work place?

2. What Air Force instruction implements part of the OSHA 29 Code of Federal Regulations and includes additional requirements?

3. When hazardous situations that are *not* covered by existing directives exist, what can you use to mitigate risk and determine adequate safeguards or procedures to manage the risk?

002. Hazards in the work environment

1. When required to perform manual labor tasks such as shoveling, raking and lifting heavy tools and equipment, what type of job hazards might you face during winter months?

2. When you are required to remove earth and/or rock, what types of potential injuries and hazards should concern you?

3. In using mechanical lifting devices, identify two hazards that cannot be controlled mechanically?

4. What can be done to prevent many hazards in your work area?

5. Which flight will give you guidance of the proper disposal method for the chemicals we use?

003. Safe driving

1. According to the ANSI/ASSE Z15.1, what is defined as driving to save lives, time, and money in spite of the conditions around you and the actions of others?

2. What are things that take away your ability to react quickly while operating a motor vehicle?

3. Which AFI governs what is prohibited behavior while operating a government vehicle?

004. Procedures for servicing, mounting, dismounting, and moving equipment

1. What is the *primary* safety consideration in servicing or adjusting equipment?

2. Why is fueling a piece of equipment with the engine running dangerous?

3. What procedure is used when getting on or off a piece of equipment?

4. Before you place a piece of equipment in motion, what can you do to get a feel for the machine?

5. When operating a piece of equipment in a hazardous area, what may you use to help you maneuver it?

6. What should you when stopping your equipment or shutting it down?

005. Safe procedures for electric hand tools

1. Name three regulations the Air Force follows when dealing with electrical hazards.

2. What is the purpose of a grounding plug?

3. How can you damage an electrical cord?

4. What should you *not* wear when using rotating equipment?

1–2. Protective Equipment

In your job, you are exposed to many hazards. It is Air Force policy that adequate measures are in effect to eliminate these hazards, if possible. If it is not possible to eliminate the hazards, they must be minimized to the maximum extent possible. When a hazard still exists after all practical engineering control measures have been taken, workers must be given additional protection through the use of protective clothing or equipment.

006. Personnel protective equipment

Many items of protective clothing and equipment have been developed for your protection. This equipment ranges from simple items, such as gloves, eye shields, hardhats, and so forth, to more complicated items including respirators, self-contained breathing apparatus, and complete protective clothing ensembles. The information on the items of equipment given in this lesson is only introductory. At your duty station you should find out what protective clothing is available, and make sure you *learn its purpose* and *how to use it*. Your general health, and, in fact, your very life, may depend on your knowing how to use the available equipment. The following points are essential when you are working in a hazardous area or with hazardous equipment:

- Be able to recognize the hazard.
- Understand how the hazard can affect you.
- Know what safety equipment is available to combat the hazard.
- Know how to use the equipment.

Hearing protectors

It is mandatory to use hearing protectors without fail in areas where the noise level is continuously high. These areas can be on or near the flight line, when operating heavy equipment, and even when

using power tools. A sound of moderate intensity encountered for prolonged periods can be as injurious to your hearing as that of high-intensity sound encountered for a short period of time. The best thing to do with earplugs is to keep them clean and *use* them. In most cases, ear muffs are provided as extra protection and are worn over the ear plugs.

Eye protectors

If any one item of safety equipment could be described as the most important, it would probably be the eye protective equipment. It takes only a very minute piece of foreign material to damage your eye permanently and cost you your sight. To protect your eyes, find out what protective glasses, goggles, or shields are required for each particular job or area and wear this equipment.

Gloves

Wear rubber protective gloves whenever you use acids, alkalis, and other harmful chemicals. For protection against the harmful effects of petroleum products, use *plastic* or synthetic rubber gloves, since petroleum damages natural rubber. Gloves should be tested regularly for leaks and other defects.

Cotton fabric gloves covered with synthetic rubber or plastic provide protection against ordinary concentration of acids, alkalis, and salt solutions, and they may be used for handling wet materials. Because they absorb perspiration, these gloves are much more comfortable to work with than natural rubber gloves.

Leather gloves are ideal and essential to use when you work with wire rope. Even new wire rope has burrs, sometimes called fishhooks. These fishhooks can easily rip open your hand, such as when the rope is sliding through your hands while feeding wire rope onto a drum. Always wear leather gloves when working with wire rope: it is better to be "safe than sorry."

Protective helmets

Safety helmets, also known as "hard hats" protect your head from falling or flying objects. Most hard hats are water-resistant, fire resistant, and nonconductors of electricity. They are available in a variety of styles. The hard hat offering the most head protection is the one with the full brim. When you get your hat, adjust it properly. For example, proper adjustment for most hard hats on the market provides for at least 1¼ inches of space between the top of your head and the inside crown of the hat. This space provides a cushioning effect if something strikes the hat. It's best to refer to the manufacturer's instructions regarding the proper fit and wear of the hard hat. The following are some important items to consider in the use of hard hats:

- Never wear a metal hard hat around electrical hazards. This is only common sense. Metal is a conductor of electricity.
- Never drill air holes in your hard hat. If it does not already have air holes, do without them. Any hole you drill may cause the material to crack, thus degrading the structural integrity of the equipment. Also, do not put stickers or other purely decorative items on the hard hat. You may not be able to spot cracks or other flaws if you can't see them.
- The most important thing to remember about a hard hat is to be sure to wear it in designated areas or when you do types of work that require it.
- Inspect your hard hat regularly and remove it from service if you detect any cracks, splits, excessive wear or other defects which could lead to failure. Check the manufacturer's recommendations when in doubt.

Respirators

Workers who must work in a hazardous atmosphere must be given respiratory protective equipment. The life or health of the wearer of a respirator could depend on the proper functioning of the equipment. Equipment must be cleaned immediately after use, maintained and stored properly in clean, dry compartments. Filters, cartridges, and rubber parts should be inspected before each use and

at regular intervals for any signs of deterioration. Always inspect respirators before storage, and replace any suspect filter or cartridge immediately. There are many different types of respirators. Use the type recommended by the bioenvironmental flight after they do their occupational health testing. Also, schedule a mask fit-test and training on the proper wear of the respirator to ensure you are using the equipment properly. Never assume you know what type of respirator to use without first talking to the experts. You may be wearing a respirator which does no good for the environment you are in. Also, never wear a chemical defense mask for industrial hazards. They were designed for specific hazards not associated with construction work.

Safety shoes or toe guards

Whether you are operating a piece of heavy equipment or a jack hammer, you will wear safety-toe shoes. If you drop something on your foot and injure yourself, you can't perform your job. On the other hand, if you are operating a snowplow for eight hours a day, you need foot gear to keep your feet warm and dry. Know the type of shoes you must wear in different seasons and for different jobs, and wear them!

007. Seatbelts

The use of seatbelts applies not only to the government vehicles you operate, but also to your personal vehicles on base and on public highways. The Air Force is concerned about you personally. When you leave the base on Friday, the Air Force wants to see you on the job on Monday morning; not in a hospital with a broken leg or neck from being thrown out of a vehicle.

Air Force policy

AFI 91–207 governs the use of protective devices. Your command and perhaps even your shop may have supplemented this regulation. As we have stated throughout this unit on safety, learn the rules that apply to you and your job and follow them.

Seatbelts provide protection to drivers and passengers involved in accidents; they prevent or lessen the severity of injuries. The use of seatbelts prevents the wearer from being thrown out of the vehicle and also reduces the force with which he or she is likely to strike objects within the vehicle.

Seat belt statistics

Many drivers have the mistaken idea that seatbelts are necessary only at high speeds. More than half of all fatal accidents occur at speeds less than 40 miles per hour, and two thirds of all fatal accidents occur within 25 miles of the victim's home. Seatbelts must be used for low-speed urban and base driving as well as for higher highway driving speeds. Seatbelt usage is mandatory for all active duty members at all times regardless of the situation.

Statistics show that the risk of serious injury or fatality is five times greater for the person who is thrown from the vehicle than for the person who is kept inside the vehicle. Use your seatbelt and be sure that your passengers have their seat belts fastened and adjusted properly when the vehicle is in motion.

It is extremely important that you wear seatbelts when operating certain types of heavy equipment such as snow removal equipment, as this equipment is operated at speeds of 40 to 50 miles per hour. Can you imagine what would happen to you if you were operating a snowplow at only 20 miles per hour on a base street and the front wheel of the vehicle fell into an open manhole? The immediate, sudden stop could propel you through the windshield like a shell out of a gun and you could end up critically injured.

008. Rollover protection

The rollover protection system or rollover protective structure (ROPS) is the protective structure rising above the operator in many pieces of equipment we operate. It forms a protective area for the operator in case of a rollover.

Using ROPS

When ROPS is present, you will still wear a seatbelt as this ensures you will stay put within that protective area in the case of an accident. ROPS are constructed to withstand the weight of the vehicle and come in many different configurations with the same goal, protecting the occupant from harm.

If a vehicle is not fitted with a ROPS, be cautious while operating. The lack of a ROPS does not mean you don't have to use your seatbelt, but it does mean you need to be very careful when operating it. All new equipment we use today should come equipped with a ROPS. This includes rollers, farm tractors, dozers, and many others.

Inspection

Due to how important the ROPS is to the safety of the occupant, you must conduct a thorough inspection of it prior to operating it. Inspect the welds and overall appearance for structural damage or dents. You will be looking for any defects which could cause the ROPS to be ineffective in a rollover. The slightest crack could be disastrous. If you find a defect in the ROPS, immediately bring it to the attention of vehicle maintenance and make sure it is fixed correctly or replaced.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

006. Personnel protective equipment

1. What four very important points are essential when you are working in a hazardous area or with hazardous equipment?

2. What is considered the *most important* piece of safety equipment, and why?

3. When must you wear rubber protective gloves?

4. Why should you want to wear leather gloves when working with wire rope?

5. Which flight conducts an occupational health test to determine if a respirator is needed within your duty section?

007. Seatbelts

1. Which AFI governs the use of protective devices?

2. In addition to preventing the wearer from being thrown out of the vehicle, what else does the use of seatbelts do?

008. Rollover protection

1. What does ROPS stand for?

2. What should you do if you see dents or cracks in the ROPS?

1–3. Worksite Safety and Traffic Control

The safety of individuals in a work crew and the safety of motorists cannot be stressed enough. With observant workers and a clear and concise safety plan, we can complete large or small projects efficiently and safely with little disruption to the base. In this section, we will focus our attention on worksite safety, planning the control of traffic during maintenance, the devices used in traffic control and their placement.

009. Worksite safety

As a Pavements and Construction Equipment Operator, you will be on many worksites located on roadways or near traffic. There are many things you can do to ensure your safety as well as the safety of your fellow coworkers. Let's look at three especially important safety factors: observation, visibility, and communication.

Observation

Be cognizant of everything around you. It can't be stressed enough for you to observe and react to the ever-changing environment within a worksite. If you are a spotter on the ground, it is your responsibility to make sure nobody comes into your work area. You need to be cognizant of who is supposed to be there and who is not. Individuals will inadvertently show up on your worksite putting them and you in danger. If you are operating a piece of equipment, it is your responsibility to make sure you are clear of obstructions, you aren't pulling out in front of someone, and you are looking out for the people on the ground. If you are relying on a spotter, put your trust in that person and don't second guess him or her. A spotter has a different view and may see things you cannot.

Visibility

Wear reflective vests when you are on the ground. It goes without saying—the more visible you are, the more people will see you. This is especially critical when you are working near a roadway with traffic. The chance of serious injury or death increases when you don't dress appropriately. Also, if you see someone without a vest, make sure he or she gets one. In hours of dusk or darkness, it is mandatory to have reflective gear on. It is everyone's responsibility to ensure the group is following simple safety rules.

Communications

Finally, getting traffic away from the workers will ensure the safety of everyone involved. The larger the area or the more dangerous the worksite (such as a large water main break) determines the appropriate amount of signage warning people of the danger. Signs communicate to the motorists what you want them to do; you can never have too many signs. Also, make sure everyone on the worksite is aware of the plan and the sequence of events; in addition, you should brief new workers who come to the jobsite on the plan so they won't be a detriment to the crew.

010. Planning traffic control

Many times we don't plan for traffic control devices when doing work on base roadways. When planning for a roadway project always ask the following questions: "Who will the roadway repairs or

project affect?" "How many hours or days will traffic be affected?" "How will we inform base personnel about the delays of travel or the closure of the roadway?" "What type of traffic control devise should we use?" Remember the main purpose for traffic control devices is SAFETY for workers and vehicle traffic. Now it's time to address each question to plan out a project.

Who's affected?

Besides the vehicle traffic and workers being affected, emergency services will be affected by any roadwork being completed. Your duty section should have a checklist that identifies each affected service. A good example of a checklist would contain at least the following services:

- Base fire department/911 service.
- Security forces.
- Hospital emergency service.

Using the AF Form 103, Base Civil Engineering Work Clearance Request, is the best way to coordinate these services to make sure all efforts are made to inform the base prior to the beginning of work.

Timeframe

The time it takes to complete construction of road projects is largely dictated by the *primary* use of the road. For instance, if the road is *secondary* and gets minimal traffic with a large area for vehicles to bypass the site, the area can be closed off for an extended period of time. However, if the project is on the main thoroughfare for the installation with a constant flow of traffic throughout the day, you may have to complete it in phases or work at night, or both. Get a preliminary game plan together and have many people critique it to make sure it makes sense and disrupts traffic in the least possible way.

Informing the base populace

One key to making any roadwork construction easier is in keeping the public informed. There are several ways to inform base personnel before, during, and after a roadway project is completed. The following is a list of a few available resources for informing the base personnel:

- Base paper/email notification
- Commander channel of television (TV).
- Local radio.
- Wing staff meeting.
- Base operation (for airfield/flight line type work).

Informing base personnel assists in keeping traffic away from the work site and providing personnel with time to adjust their travel route before being delayed to and from the duty location.

Use of traffic control devices

No matter their type, the primary responsibility of traffic control devices is to "control" the worksite and ensure the safety of workers and pedestrians (in vehicles and on foot). You must decide what message it is you want to convey and how you want traffic to act when selecting the appropriate control device. Don't be conservative with your signage. Too many signs warning of construction ahead are never a bad thing. Also, the type of road will dictate the sizes, number, and placement of the signs you chose.

011. Traffic control devices

Traffic control management is a requirement that started with the first production of the automobile. Many times when driving in town or across country, we observe road construction that involves the use of traffic cones, barricades, drums, tubular markers, and warning signs. This section covers general types of traffic control devices, plans to use them, and placement and care of the devices. There are many types of traffic control devices. AFI 91–203 states that civil engineering will use the

US Department of Transportation (DOT) Manual on Uniform Traffic Control Devices (MUTCD) as a guide for planning and placement. In this lesson, we cover six of the most common types used at an AF base.

Traffic cone

The traffic cone is the most common type of traffic control device used in day-to-day operations within the pavements and equipment business. The two standard types of cones are the daytime and low-speed cone and the nighttime reflective cones. Let's take a closer look at these types of cones.

Daytime and low-speed cone

Figure 1–2 shows daytime and low-speed cones which must be predominantly orange and be made of a material that can be struck without causing damage to the impacting vehicle. For daytime and low-speed roadways, cones must be no less than 18 inches in height. When cones are used at night on highways, or when more conspicuous guidance is needed, they must be a minimum of 28 inches tall.

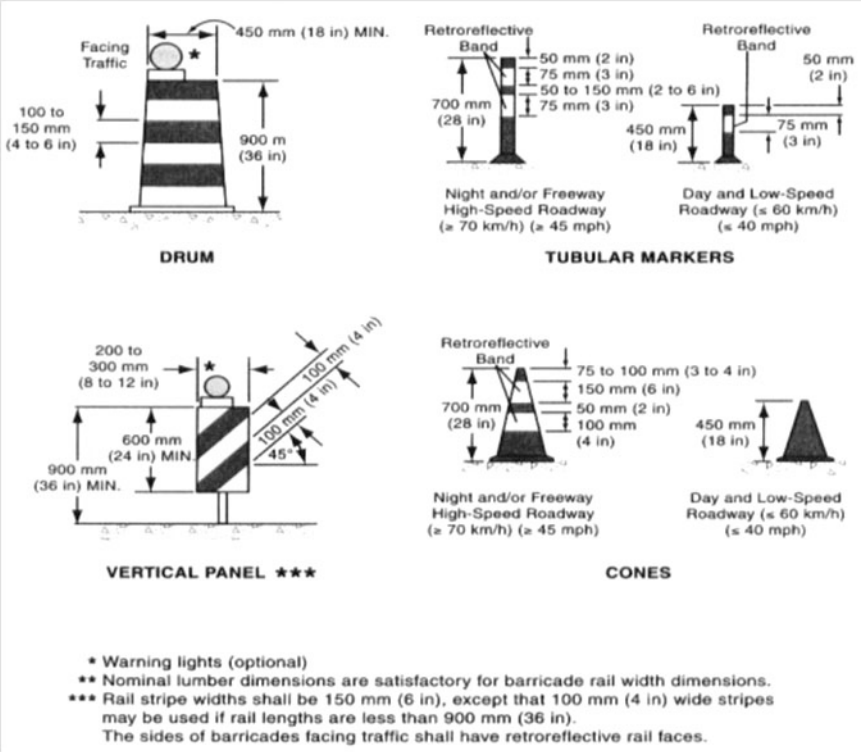


Figure 1–2. Traffic cones, tubular markers, drums, and vertical panels.

Nighttime cone

For nighttime use, cones must be reflectorized or equipped with lighting devices for maximum visibility. Reflectorized 28-inch or larger cones must be provided with a white band six inches wide located three to four inches from the top of the cone and an additional four inches wide white band located approximately two inches below the 6-inch band.

Tubular markers

Tubular markers must be predominantly orange and must be not less than 18 inches high and two inches wide facing road users (fig. 1–2). They must be made of a material that can be struck without causing damage to the impacting vehicle. Tubular markers must be a minimum of 28 inches tall when they are used on freeways and other high-speed highways, on all highways during nighttime, or whenever more conspicuous guidance is needed.

For nighttime use, tubular markers must be reflectorized with 28 inches or larger tubular markers provided with two three inches wide white bands placed a maximum of two inches from the top with a maximum of six inches between the bands.

Tubular markers have less visible area than other devices and should be used only where space restrictions do not allow for the use of other more visible devices. The tubular markers generally come with weighted bases to aid in securing them in place.

Drums

Drums used for road user warning or channelization must be constructed of lightweight, deformable materials (fig. 1–2). They must be a minimum of 36 inches in height and have at least an 18-inch width regardless of orientation. Metal drums must not be used due to the damage that could be caused to a vehicle during a collision. The markings on drums must be horizontal, spanning the entire drum, with alternating orange and white reflective stripes four to six inches wide. Each drum must have a minimum of two orange and two white stripes with the top stripe being orange. Any non-reflectorized spaces between the horizontal orange and white stripes must not exceed three inches wide. Drums must have closed tops that will not allow collection of construction debris or other debris.

Drums should not be weighted with sand, water, or any material to the extent that would make them hazardous to road users or workers when struck. Drums used in regions susceptible to freezing should have drain holes in the bottom so that water will not accumulate and freeze causing a hazard if struck by a road user.

Barricades

A barricade is a portable or fixed device having from one to three rails with appropriate markings and is used to control road users by closing, restricting, or delineating all or a portion of the right-of-way. As seen in figure 1–3, barricades fall into three types known as type I, II, or III.

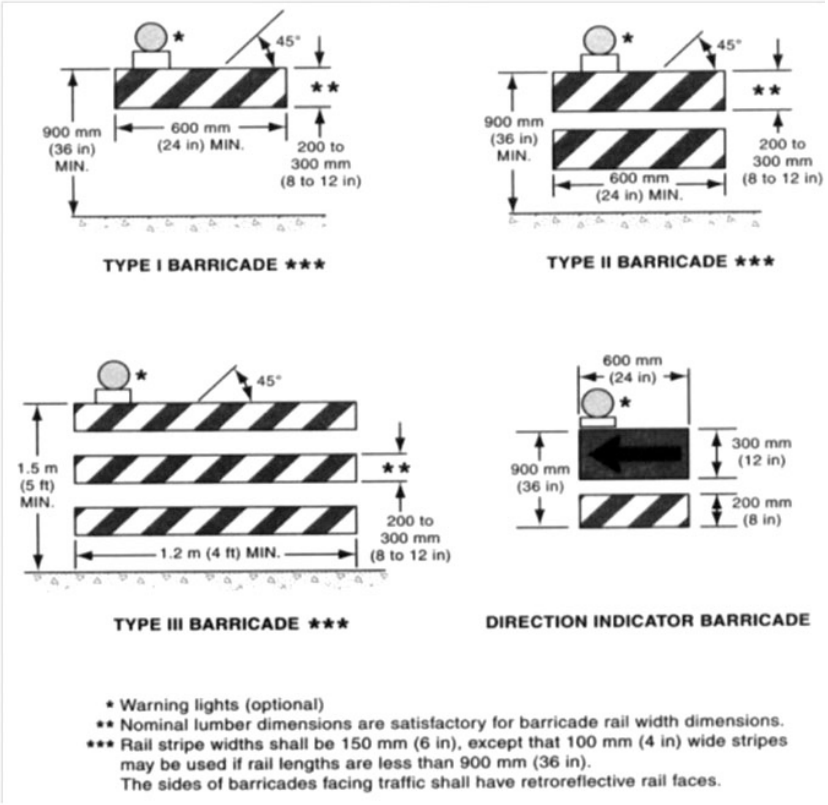


Figure 1–3. Barricades.

Stripes on barricade rails must be alternating orange and white reflective stripes sloping downward at an angle of 45 degrees in the direction road users are to pass.

The minimum length for types I and II barricades must be 24 inches, and the minimum length for type III barricades must be 48 inches. Each barricade rail must be eight to 12 inches wide. Barricades used on expressways, freeways, and other high-speed roadways must have a minimum of 270 inches of reflective area facing road users.

Where barricades extend entirely across a roadway, the stripes should slope downward in the direction toward which road users must turn. Where both right and left turns are provided, the barricade stripes should slope downward in both directions from the center of the barricade or barricades.

Where no turns are intended, the stripes should be positioned to slope downward toward the center of the barricade or barricades. Barricade rails should be supported in a manner that will allow them to be seen by the road user, and in a manner that provides a stable support that is not easily blown over or displaced. Sandbags lain over the lower frame of the barricade works well in stabilizing it.

Warning signs

The purpose of a warning sign is to provide advance warning to the road user of unexpected conditions on or adjacent to the roadway that might not be readily apparent. There are many types and varieties of warning signs; however, we will discuss warning signs that are specific to low-volume roads. These include three of the most common types of warning signs: temporary traffic control signs, horizontal alignment signs and intersection warning signs.

Temporary traffic control signs

Temporary traffic control signs were designed to inform and warn motorists on low-volume roadways (like many on Air Force installations) of construction or other hazards ahead. There are many more informational signs we could include in this broad category; however, just a small sampling temporary low-volume roadways is provided in figure 1–4.

NOTE: Temporary traffic control signs are orange.

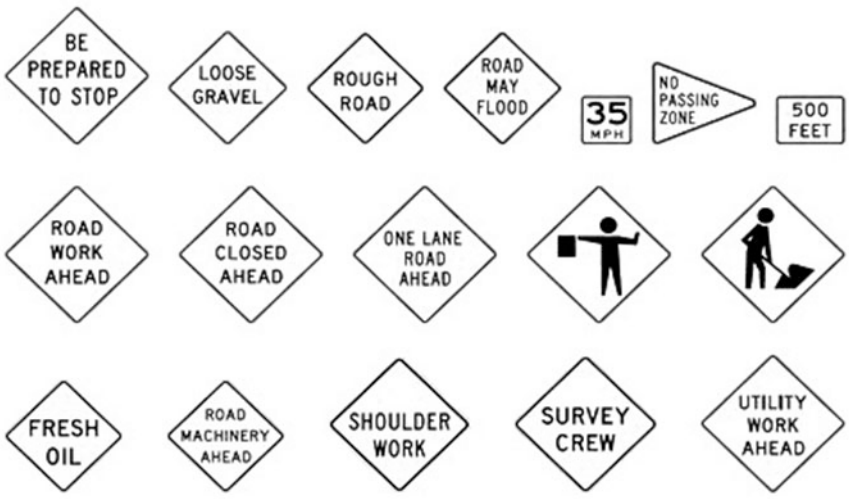


Figure 1–4. Temporary traffic control signs.

Horizontal alignment signs

Horizontal alignment signs include, turn, curve, reverse turn, reverse curve, winding road, large arrow, and chevron alignment signs. Horizontal alignment signs may be used where engineering

judgment indicates a need to inform the road user of a change in the horizontal alignment of the roadway. The horizontal alignment signs in figure 1–5 are yellow in color, signifying caution.

Figure 1–5. Horizontal alignment signs.

Intersection warning sign

Intersection warning signs (fig. 1–6) include the crossroad, side road, T-symbol, and Y-symbol signs. Intersection signs may be used where engineering judgment indicates a need to inform the road user in advance of an intersection. The intersection warning signs are also yellow.

Figure 1–6. Intersection warning signs.

Maintenance of traffic control devices

The general rule of maintenance for traffic control devices (TCD) is simple. The TCD must be in good working order at all times. If devices are covered with asphalt, concrete, or other material that reduces the function of the device, remove these devices from service. Also, ensure the reflective tape is indeed "reflective." Replace any worn or missing tape as needed. If using flashing type lights at night, the batteries for each unit must be checked and replaced if needed before sunset each day.

012. Traffic control device placement

Placement of traffic control devices is something that many people fail to do correctly. For a traffic control device to be effective, proper placement is a must! Looking at figure 1–7, we will review just one of many set-ups for a work zone area.

Work zones

For the safety of workers and to reduce confusion for those driving toward a construction zone in a vehicle, there are the following five work zones:

- Advanced warning area.
- Transition area.
- Active Area (Buffer).
- Active Area (work).
- Termination zone.

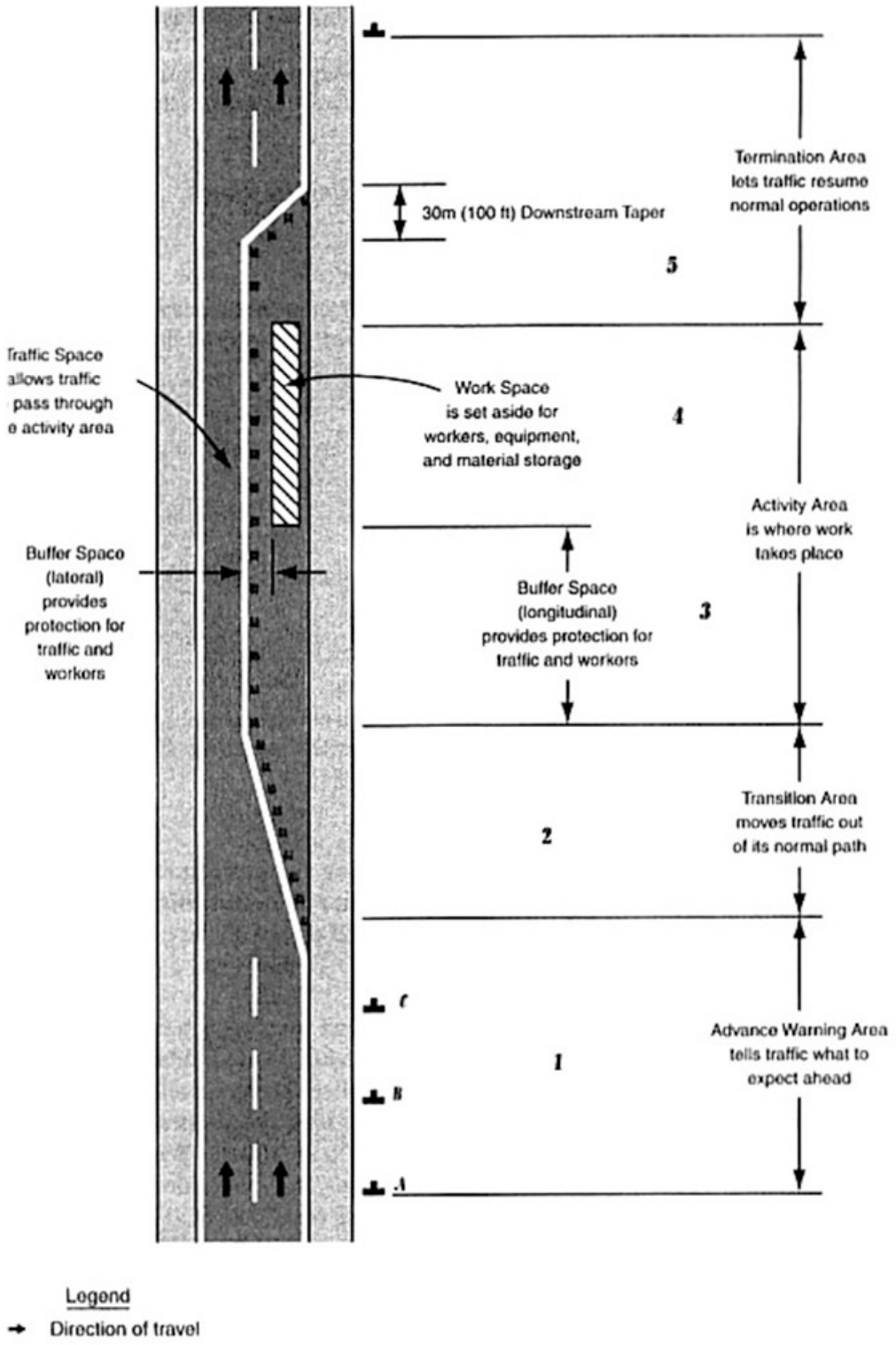


Figure 1–7. Work zone.

Advance warning area (1)

The placement of an *advance warning sign* is based on one thing: the speed of the traffic. Traffic speed dictates the space between the first and last advance warning sign. The following table provides the suggested advance warning signs spacing for Area 1 of a typical work zone (fig. 1–7).

Road Type	Distance Between Signs		
	A	B	C
Urban (low speed)	100ft	100ft	100ft
Urban (high speed)	350ft	350ft	350ft
Rural	500ft	500ft	500ft
Expressway/Freeway	1000ft	1000ft	1000ft

The type of advance warning signs used on a project can vary. The 1st sign could be “Work Ahead,” while the 2nd “Flag Men Ahead,” and the 3rd “Be Prepared to Stop.” Good planning identifies the type of signs required before placement.

Transition area (2)

The main purpose of the *transition area* is to move traffic away from the project area. The type of device used can vary, but within CE, we normally use cones. The placement between each device is based on the speed limit around the work area. In other words, the slower the speed the closer together the transition area devices will be. Always use the US DOT MUTCDs to find proper distance requirements between traffic devices.

Active area (3 and 4)

Look at figure 1–7 and you will see that the *active area* is broken into two zones. The first zone is called the *buffer zone.* The buffer zone’s sole purpose is to move traffic away from the work zone. The second zone is called the *work zone.* The work zone area is the heart of the project operation. The work zone is the line of protection from vehicle traffic for workers.

Termination zone (5)

The termination zone swings traffic back into original lane of travel. Normally, the length of this zone from the end of the active zone is 100 feet. The official end to the termination zone is the posting of a sign telling motorists to return to the original speed used for that roadway.

Airfield device placement

Almost any type of TCDs can be used on an airfield. Before any placement of TCD on the flight line, however, Base Operations must approve the type of traffic control device and your work zone plan. The main purpose for base operations’ approval is to ensure that TCD will not become an airborne hazard for aircraft movement around or near the work zone area. Base Operations will tell you whether your plan will work due to the airfield schedule and expected traffic in the proposed area. In most projects on the airfield, time is of the essence. Get in and out quickly and don’t forget to pick up your cones!

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

009. Worksite safety

1. In the lesson, what were the three important factors we considered for worksite safety?

2. Whose responsibility is it to ensure the group is following simple safety rules?

010. Planning traffic control

1. What three services need to be contacted during the planning stage of a construction project involving traffic disruption?

2. What are five ways to inform base populace about roadway construction?

011. Traffic control devices

1. What are the two types of traffic cones used on roadway projects?

2. What type drum cannot be used as a traffic control device, and why?

3. What are the three most common types of warning signs discussed in this lesson?

012. Traffic control device placement

1. How many sections are in a work zone area?

2. What is the placement of an advance warning sign based on?

Answers to Self-Test Questions

001

1. Enforce safety standards and instructions.
2. AFI 91–203.
3. An RM process.

002

1. Exposure to deicing chemicals along with hazards that accompany the operating of snow removal equipment in subfreezing temperatures.
2. Injury and death by suffocation or crushing as a result of cave-ins occur too frequently. Also, hazards may be encountered when electrical, gas, and steam lines are broken in excavating operations.
3. Any two of the following:
   (1) Overloading.
   (2) Dropping.
   (3) Slippage of the load.
   (4) Obstructing the free passage of the load.
   (5) Moving a vehicle with an unsecured load.
   (6) Not using stabilizers.
4. Be alert and knowledgeable as to what is dangerous, and concentrate on the task at hand.
5. Environmental flight.

003

1. Defensive driving.
2. Distractions.
3. AFI 91–207.

004

1. To make sure you shut the engine down.
2. Static electricity can build and led to spark when putting nozzle in the tank potentially igniting vapors causing explosion.
3. Always face the equipment and use necessary handrails and steps using three points of contact.
4. Raise or adjust the attachments as necessary, and start out slowly, gradually reaching the proper operating speed.
5. A spotter.
6. Lower all attachments, lock the brakes, shut the engine down, and then pull the keys and conduct a walk-around inspection to ensure no damage or leaks have occurred during the operation. Finally, chock the wheels if you are parked on an incline or in an area where chocks are a requirement.

005

1. AFOSH, the National Code, and the NEC.
2. To ensure there is a metallic connection of low resistance directly from all metal surfaces of an electric tool to the ground.
3. By scraping, kinking, stretching, exposing to grease and oil, as well as jerking the cord from the receptacle to unplug it.
4. Loose gloves or loose clothing.

006

1. Be able to recognize the hazard, understand how the hazard can affect you, know what safety equipment is available to combat the hazard, know how to use the equipment.
2. Eye protection, because it takes only a small minute piece of foreign material to permanently damage your eye and cost you your sight.
3. Whenever you use acids, alkalis, and other harmful chemicals.
4. Because even new wire rope has burrs, sometimes called fishhooks, which can easily rip open your hands.
5. Bioenvironmental flight.

007

1. AFI 91–207.
2. They prevent or lessen the severity of injuries, and reduces the force with which the wearer is likely to strike objects within the vehicle.

008

1. Rollover protection system or rollover protective structure.
2. Immediately bring it to the attention of vehicle maintenance and make sure it is fixed correctly or replaced.

009

1. Observation, visibility, and communication.
2. Everyone.

010

1. Base fire department/911 service, security forces, and hospital emergency service.
2. Base paper/email notification, commander channel or TV, local radio, wing staff meeting, and base operations (for airfield/flight line type work).

011

1. Daytime and low-speed and nighttime reflective cones.
2. Metal. Due to the damage that could be caused to a vehicle during a collision.
3. Temporary traffic control, horizontal alignment, and intersection warning.

012

1. Five.
2. The speed of the traffic.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (001) Which Air Force Instruction (AFI) replaces and substantially changes 91-series Air Force Occupational Safety and Health (AFOSH) standards?
   a. AFI 91–203.
   b. AFI 91–207.
   c. AFI 10–209.
   d. AFI 10–210.

2. (001) When no technical order (TO), Air Force instruction (AFI), or operating instruction (OI) covers an existing hazard, what process can you use to assess risks and determine adequate safeguards or procedures to manage the risks?
   a. Probability.
   b. Calculated loss.
   c. Calculated risk.
   d. Risk management.

3. (002) Many hazards on the job can be eliminated by
   a. working in pairs.
   b. scheduling less work.
   c. concentrating on job task.
   d. scheduling more time per job.

4. (003) What takes away your ability to react quickly while operating motor vehicles?
   a. Distraction.
   b. Orientation.
   c. Expectation.
   d. Anticipation.

5. (003) According to Air Force Instruction (AFI) 91–207, *USAF Traffic Safety Program,* what is prohibited while operating a government owned vehicle while on or off a Department of Defense (DOD) installation?
   a. Eating.
   b. Texting.
   c. Listening to music.
   d. Using a handheld device.

6. (004) What is the proper way to dismount a piece of equipment?
   a. Facing the machine.
   b. Jumping off carefully.
   c. Exiting with your back to the machine.
   d. Exiting sideways watching the ground and machine.

7. (004) Before mounting a piece of equipment, you should do a quick walk around to
   a. make sure attachments are grounded before starting.
   b. warn others near the machine to clear away.
   c. look for tools left on or near the machine.
   d. check for cleanliness.

8. (004) When operating equipment in confined or hazardous areas, how can you lower the chances of an accident?
   a. Install additional mirrors.
   b. Use a spotter outside the vehicle.
   c. Use a shotgun rider for assistance.
   d. Stick your head out of the side window.

9. (005) Electrical power tools do *not* require grounding if the
   a. operator is wearing rubber shoes and gloves.
   b. operator is standing on dry wood.
   c. tools are insulated with rubber.
   d. tools are double-insulated.

10. (005) What is produced when you have extension cords plugged into power strips?
    a. Electromagnetic field.
    b. Increased range.
    c. A ground fault.
    d. Heat.

11. (006) In reference to personnel protective equipment (PPE), which safety equipment items could be described as the *most* important?
    a. Gloves.
    b. Goggles.
    c. Safety helmet.
    d. Hearing protection.

12. (006) Which type of hardhat *should you not* you wear on jobs with heavy overhead assembly work near energized electrical lines?
    a. Impact-resistant plastic.
    b. Laminated fiberglass.
    c. Fiberglass insulated.
    d. Metal.

13. (007) Which Air Force instruction (AFI) publication governs the use of protective devices?
    a. AFI 91–207, *USAF Traffic Safety Program.*
    b. AFI 91–204, *Investigating and Reporting US Air Force Mishaps*.
    c. AFI 91–202, *The US Air Force Mishap Prevention Program*.
    d. AFI 91–201, *Safety Investigation Workbook.*

14. (007) What is an advantage, if any, for drivers and passengers who wore seatbelts when involved in accidents?
    a. They have an increase in the severity of their injuries.
    b. The seatbelts hinder their rescue after an accident.
    c. They have a decrease in the severity of their injuries.
    d. There is no discernable advantage to wearing a seatbelt.

15. (008) In reference to protection equipment, what does the acronym “ROPS” stand for?
    a. Risk or prevention system.
    b. Right of protection system.
    c. Rollover protection system.
    d. Rollover prevention system.

16. (008) Which is a *true* statement about the *presence* of a rollover protection system (ROPS)?
    a. You do *not* need to wear a seatbelt on equipment with ROPS.
    b. A seatbelt will be worn at all times, with or without ROPS.
    c. A seatbelt is never worn on equipment without ROPS.
    d. Seatbelts are optional when ROPS are present.

17. (008) What *must* you do when a rollover protection system (ROPS) is damaged?
    a. Remove the ROPS and continue operating.
    b. Turn the vehicle in to maintenance.
    c. Continue operations as usual.
    d. Fix the damages yourself.

18. (009) What *must* every member of your crew wear when working on or near a roadway with traffic?
    a. Reflective shoes.
    b. Reflective vests.
    c. Coveralls.
    d. Hardhats.

19. (010) The *primary* purpose of traffic control devices is to ensure the safety of
    a. workers only.
    b. pedestrians only.
    c. workers and pedestrians.
    d. vehicular traffic entering a work zone only.

20. (011) Air Force Instruction (AFI) 91–203, *Air Force Consolidated Occupational Safety Instruction*, states that civil engineering must use which manual as a guide for planning and placement of traffic control devices?
    a. Federal Manual 5–434.
    b. Federal Manual 5–410.
    c. Manual on Uniform Traffic Control Devices.
    d. United States Department of Transportation Manual.

21. (011) In a roadway construction worksite, what is the *most common* type of traffic control device used in day-to-day operations?
    a. Cone.
    b. Drum.
    c. Marker.
    d. Barricade.

22. (012) What is the *main* factor used to determining the placement of advance warning signs for a roadway construction work zone*?*
    a. Size of the repair.
    b. Speed of the traffic.
    c. Type of work being completed.
    d. Amount of equipment being used.

23. (012) Which of the five areas of a work zone includes two *distinctive* areas?
    a. Advance warning.
    b. Termination.
    c. Transition.
    d. Active.

24. (012) In a work zone, what signifies the official end to the termination zone?
    a. Absence of cones.
    b. “Resume speed” sign.
    c. “Men no longer working” sign.
    d. The definition of termination means “end”, nothing is needed.

Student Notes

Unit 2. Equipment Operator's Obligations

AS A PAVEMENTS construction equipment operator journeyman, you will be required to operate various types of construction equipment to do your job. This equipment includes dump trucks (DT), front-end loaders, rollers, graders, dozers, cranes, pavers, and so forth. Some of the equipment is quite large and expensive and must be taken care of as if it was your own. This unit will outline operational inspections, how to properly use the AF Form 1800 as well as operator’s maintenance such as lubricating, refueling and cleaning the equipment. Remember the advantage of using this equipment is it makes your job considerably easier and it also saves a tremendous amount of time. Be sure to do your part to ensure your equipment continues to run properly.

2–1. Operator’s Inspection and Maintenance

It’s of the utmost importance that you not only know how to operate your assigned equipment, but also know how to inspect and maintain it. This section will discuss both of these topics. The reason is that equipment breakdowns cause delays, waste work hours, and cost the Air Force money in parts and labor. You can prevent many of these delays by operating your equipment with good judgment, keeping the engine filled with the correct oil and coolant, greasing your equipment, making minor operator repairs, and keeping your equipment clean. This may sound like a lot of work, but think of the work it will take if the equipment breaks down. Try and treat all equipment as if you owned it.

013. Operator’s inspection procedures

Most of us at one time have had the unfortunate experience of having car troubles on the highway. There you are stranded in the countryside, short of your destination, and faced with the possibility of a costly repair bill. What caused the trouble? Have you been diligent in performing all checkups and maintenance, or are you a believer in the philosophy of: “if it isn’t broke, don’t fix it?”

As we stated earlier, equipment breakdowns cause delays, waste work hours, and cost the Air Force money in parts and labor—and perhaps, ultimately, cause mission failure. All reasonable efforts must be made to care for Air Force equipment. As a pavements and construction equipment operator, you play a large role in determining how well your equipment operates. Generally, your responsibilities fall under five areas:

- Operator inspection.
- Operator maintenance.
- Equipment lubrication.
- Refueling.
- Cleaning.

We will discuss the operator’s inspection responsibilities in this lesson and the other four areas in the next lesson on operator’s maintenance responsibilities.

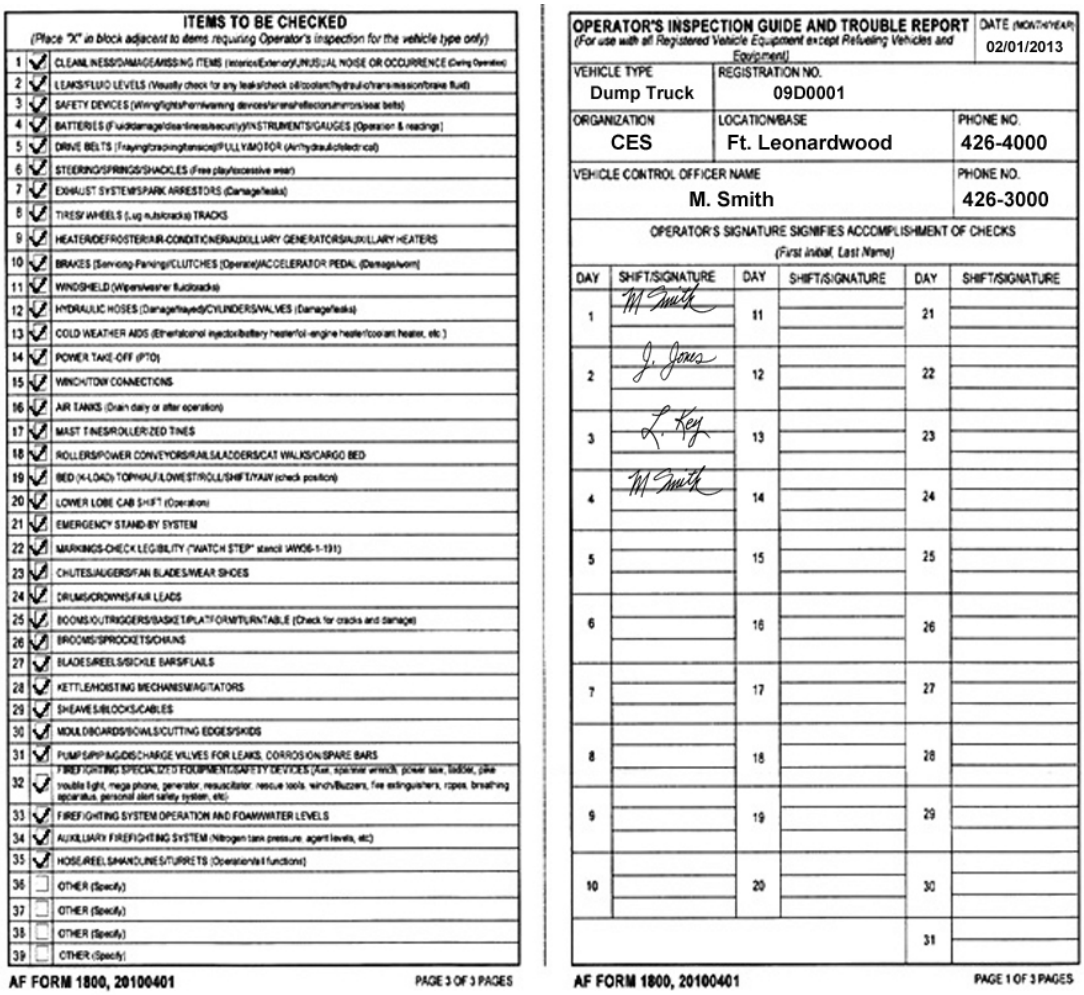
Operator inspection

The operator inspection is not just for equipment that you use daily but is required weekly even when equipment is not in use. You must inspect heavy equipment placed in storage for long periods (such as snow removal equipment) monthly. This ensures the equipment is always ready when needed. Equipment in use within Civil Engineer Squadrons is placed on a list which can be called into action during times of war at a moment's notice. The fact that any piece of equipment can be deployed and relied upon to carry out the mission is why it is imperative that we maintain our equipment in the best condition possible.

Before you operate any piece of equipment, you must inspect it for signs of damage or possible defects. A walk-around inspection can detect the most obvious defects such as leaks, broken or missing items, flat tires, and so forth. However, you must do a more detailed inspection before placing the vehicle into motion.

AF Form 1800

When performing your monthly equipment inspections, you may ask yourself, "How do I know what to look for on one of these machines?" No one intends for you to perform a thorough inspection without some type of checklist to guide you through. The AF Form 1800, Operator's Inspection Guide and Trouble Report (fig. 2–1), is the checklist used for all vehicles within our area of responsibility, to include our heavy equipment and our general purpose vehicles such as pickups. The AF Form 1800 is used to guide you through an inspection of any piece of equipment.



ITEMS TO BE CHECKED

(Place "X" in block adjacent to items requiring Operator's inspection for the vehicle type only)

1	✓	CLEANLINESS/DAMAGE/MISSING ITEMS (Interior/Exterior)/UNUSUAL NOISE OR OCCURRENCE (During Operation)
2	✓	LEAKS/FLUID LEVELS (Visually check for any leaks/check oil/coolant/hydraulic/transmission/brake fluid)
3	✓	SAFETY DEVICES (Wiring/lights/horn/warning devices/brakes/reflectors/mirrors/seat belts)
4	✓	BATTERIES (Fluid/damage/cleanliness/security)/INSTRUMENTS/GAUGES (Operation & readings)
5	✓	DRIVE BELTS (Fraying/tracking/tension)/FULLY/MOTOR (Air/hydraulic/electrical)
6	✓	STEERING/SPRINGS/SHACKLES (Free play/excessive wear)
7	✓	EXHAUST SYSTEM/SPARK ARRESTORS (Damage/leaks)
8	✓	TIRES/WHEELS (Lug nuts/cracks) TRACKS
9	✓	HEATER/DEFROSTER/AIR CONDITIONER/AUXILLIARY GENERATORS/AUXILLARY HEATERS
10	✓	BRAKES (Servicing-Fanning)/CLUTCHES (Operate)/ACCELERATOR PEDAL (Damage/worn)
11	✓	WINDSHIELD (Wipers/washer fluid/cracks)
12	✓	HYDRAULIC HOSES (Damage/frayed)/CYLINDERS/VALVES (Damage/leaks)
13	✓	COLD WEATHER AIDS (Ether/alcohol injector/battery heater/oil-engine heater/coolant heater, etc.)
14	✓	POWER TAKE-OFF (PTO)
15	✓	WINCH/TOW CONNECTIONS
16	✓	AIR TANKS (Drain daily or after operation)
17	✓	MAST TINES/ROLLER/ZED TINES
18	✓	ROLLERS/POWER CONVEYORS/RAILS/LADDERS/CAT WALKS/CARGO BED
19	✓	BED (K-LOAD) TOP/HALF/LOWEST/ROLL/SHIFT/YAW (check position)
20	✓	LOWER LOBE CAB SHIFT (Operation)
21	✓	EMERGENCY STAND-BY SYSTEM
22	✓	MARKINGS-CHECK LEGIBILITY ("WATCH STEP" stencil (AWO6-1-191)
23	✓	CHUTES/AUGERS/FAN BLADES/WEAR SHOES
24	✓	DRUMS/CROWNS/FAIR LEADS
25	✓	BOOMS/OUTRIGGERS/BASKET/PLATFORM/TURNTABLE (Check for cracks and damage)
26	✓	BROOMS/SPROCKETS/CHAINS
27	✓	BLADES/REELS/SICKLE BARS/FLAILS
28	✓	KETTLE/HOISTING MECHANISM/AGITATORS
29	✓	SHEAVES/BLOCKS/CABLES
30	✓	MOULDBOARDS/BOWLS/CUTTING EDGES/SKIDS
31	✓	PUMPS/PIPING/DISCHARGE VALVES FOR LEAKS, CORROSION/SPARE BARS
32		FIREFIGHTING SPECIALIZED EQUIPMENT/SAFETY DEVICES (Axe, spanner wrench, power saw, ladder, pike pole, trouble light, mega phone, generator, resuscitator, rescue tools, winch/Blazers, fire extinguishers, ropes, breathing apparatus, personal alert safety system, etc)
33	✓	FIREFIGHTING SYSTEM OPERATION AND FOAM/WATER LEVELS
34	✓	AUXILLIARY FIREFIGHTING SYSTEM (Nitrogen tank pressure, agent levels, etc)
35	✓	HOSE/REEL/MANDLINES/TURRETS (Operation/all functions)
36		OTHER (Specify)
37		OTHER (Specify)
38		OTHER (Specify)
39		OTHER (Specify)

AF FORM 1800, 20100401 PAGE 3 OF 3 PAGES

OPERATOR'S INSPECTION GUIDE AND TROUBLE REPORT

(For use with all Registered Vehicle Equipment except Refueling Vehicles and Equipment)

DATE (MONTH/YEAR): 02/01/2013

VEHICLE TYPE	REGISTRATION NO.	
Dump Truck	09D0001	
ORGANIZATION: CES	LOCATION/BASE: Ft. Leonardwood	PHONE NO.: 426-4000
VEHICLE CONTROL OFFICER NAME: M. Smith		PHONE NO.: 426-3000

OPERATOR'S SIGNATURE SIGNIFIES ACCOMPLISHMENT OF CHECKS

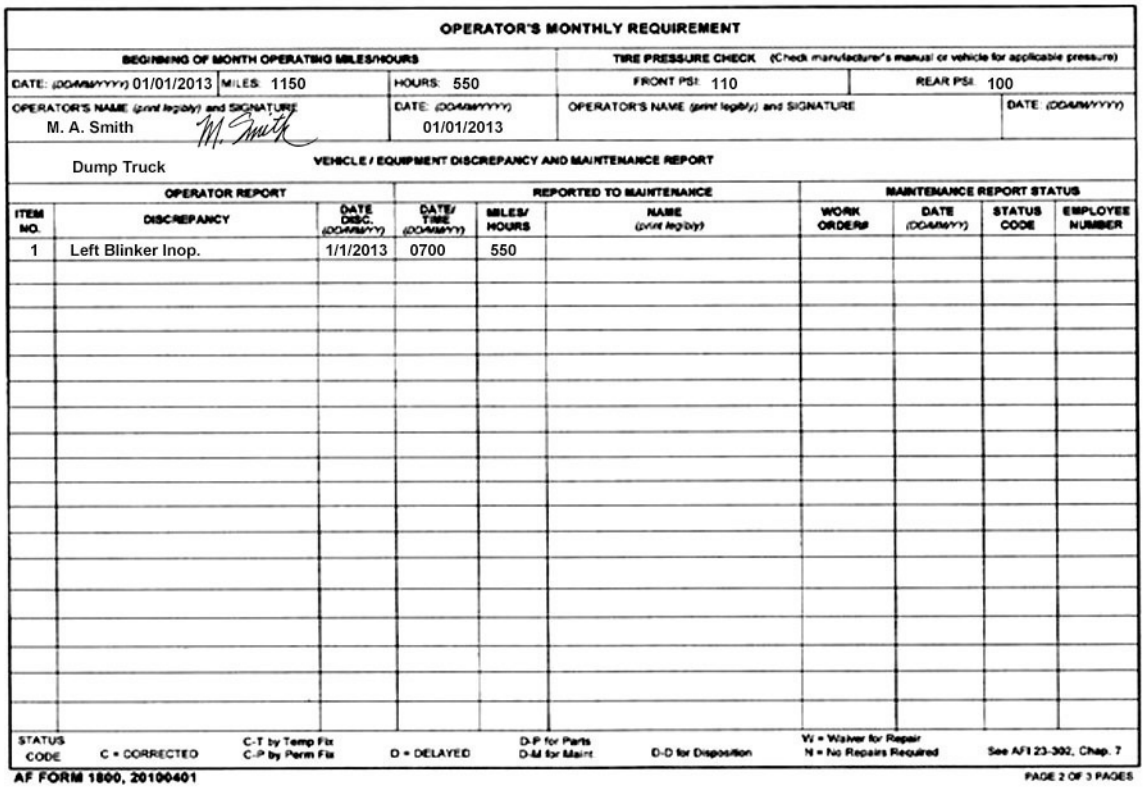
(First Initial, Last Name)

DAY	SHIFT/SIGNATURE	DAY	SHIFT/SIGNATURE	DAY	SHIFT/SIGNATURE
1	M Smith	11		21	
2	J. Jones	12		22	
3	L. Key	13		23	
4	M Smith	14		24	
5		15		25	
6		16		26	
7		17		27	
8		18		28	
9		19		29	
10		20		30	
				31	

AF FORM 1800, 20100401 PAGE 1 OF 3 PAGES

Figure 2–1. AF Form 1800 front (page 1) and back (page 3).

After you have checked all items on the checklist and determined no discrepancies exist, you must sign the form for the corresponding day of the month. If you notice any defects on the vehicle, the inside section of the form is used to annotate them (fig. 2–2). Be sure to report the problems to Vehicle Maintenance promptly.



OPERATOR'S MONTHLY REQUIREMENT

BEGINNING OF MONTH OPERATING MILES/HOURS | TIRE PRESSURE CHECK (Check manufacturer's manual or vehicle for applicable pressure)

DATE: (DD/MM/YYYY) 01/01/2013 | MILES: 1150 | HOURS: 550 | FRONT PSI: 110 | REAR PSI: 100

OPERATOR'S NAME (print legibly) and SIGNATURE: M. A. Smith | DATE: (DD/MM/YYYY) 01/01/2013 | OPERATOR'S NAME (print legibly) and SIGNATURE | DATE (DD/MM/YYYY)

Dump Truck

VEHICLE / EQUIPMENT DISCREPANCY AND MAINTENANCE REPORT

OPERATOR REPORT			REPORTED TO MAINTENANCE			MAINTENANCE REPORT STATUS			
ITEM NO.	DISCREPANCY	DATE DISC. (DD/MM/YY)	DATE/ TIME (DD/MM/YY)	MILES/ HOURS	NAME (print legibly)	WORK ORDER#	DATE (DD/MM/YY)	STATUS CODE	EMPLOYEE NUMBER
1	Left Blinker Inop.	1/1/2013	0700	550					

STATUS CODE: C = CORRECTED; C-T by Temp Fix; C-P by Perm Fix; D = DELAYED; D-P for Parts; D-M for Maint; D-D for Disposition; W = Waiver for Repair; N = No Repairs Required; See AFI 23-302, Chap. 7

AF FORM 1800, 20100401

PAGE 2 OF 3 PAGES

Figure 2–2. AF Form 1800, inside (page 2).

Using figures 2–1 and 2–2 as a guide, let's look at each section of AF Form 1800 to get a better understanding of how to use it and what information it contains. The AF Form 1800 is printed on card stock or paper and folded vertically so the short sides meet. The form consists of three pages which are described in the following paragraphs.

Page one

Page one contains vehicle and unit identification information and an area to signify completion of the vehicle checks with the operator's signature. There are three signature blocks allowing for three shifts, or if your duty section only works one shift, only sign the top block. However, if multiple individuals use the same vehicle within the same duty day, enough space is provided on the form for three individuals to sign. Even if the vehicle has already been checked, it is a good practice to check it again if you are operating it for the first time to make sure no discrepancies get overlooked.

There is an element of integrity involved with vehicle inspections. Too often, individuals do not check out their vehicle or sign the form. Failure to check out the vehicle and sign the form shows a lack of integrity as well as a violation of the rules. Take this inspection very seriously as it could mean the difference between either achieving or failing the mission and causing an incident.

Page three

Page three, or the back side of the form, consists of 35 items that can assist you when checking out the vehicle during your inspection. The items listed cover a wide variety of vehicles and as such, you don't need to check off each item on the list, only the ones that are applicable to the vehicle you are

operating. Some vehicles may have specific checks that are unique to that vehicle. In that case, you can add them to the checklist at items 36–39. For instance, the paving machine has a screed in which the operator needs to check and make sure it is smooth across the width (trueness), no edges or hard asphalt is present and generally in good condition. There isn't a section on the AF Form 1800 to address the screed of a paving machine. For the AF Form 1800, on a paving machine, your shop should add an item in number 36 for "screed-overall condition, trueness" to make it part of the inspection. Hopefully, by adding the screed check to the form, costly delays (due to a screed being unserviceable) can be avoided.

Page two

Page two, or the inside of the form, contains three areas. One area is for the beginning monthly miles and/or hours documentation. Another is an area to document the monthly tire pressure checks. You perform the tire checks within the first few days of the month, even on vehicles that have not been used. The last area is the Vehicle/Equipment Discrepancy and Maintenance Report. This is where you annotate discrepancies that must be reported to the Vehicle Maintenance Flight, as well as the time you reported them. It is a simple matter of finding the discrepancy on page three (item numbers 1–39) and annotating that item number on page two in the appropriate block under "Item No." along with a brief description of what is wrong in the "discrepancy" block on the left hand side of the page under the "Operator Report" column. This aids the Vehicle Maintenance personnel in assessing what the discrepancy is and how best to tackle fixing it. Vehicle Maintenance personnel complete the "Maintenance Report Status" using the status codes listed at the bottom right of the form.

014. Operator's maintenance procedures

The main reason you inspect your equipment is to determine what maintenance, if any, is required. As the operator, you are responsible for certain maintenance items. While these tasks vary from base to Base, they generally include, but are not limited to, the following actions:

- Adding coolant to the radiator.
- Adding oil to the crankcase.
- Filling the battery with fluid.
- Fueling the vehicle.
- Replacing broken lenses and burned out bulbs.
- Adding air to and changing tires.
- Tightening loose nuts and bolts.
- Washing and waxing the vehicle.

TOs and operator's manuals for maintenance

A TO is simply an owner's manual that has been given a number and is kept electronically by your unit's TO monitor. In most cases, you won't have ready access to TOs; therefore, it is imperative that you have the owner's manual for the specific piece of equipment you are doing maintenance on.

Owner and operator manuals have all the information needed to conduct maintenance. They list items of interest and the intervals for maintenance. For instance, the owner's manual for a dozer has pictures of where to find the fluid levels, the hazard indicators and what the symbols mean, the track adjustment parameters, and an array of other maintenance related information.

As a new piece of equipment comes into your shop, you must pull out the owner's manual and find all the things that may make it unique. You may not know where all the checks are located or where the service locations are. The owner's manual is also essential for developing a lesson plan to train individuals on that piece of equipment.

Use an illustrated parts breakdown (IPB) to locate part numbers so you can order replacements. Parts breakdown are used for parts that you, as an operator, are responsible. For instance, you, not vehicle maintenance, must maintain the head of a sweeper because it is an accessory on the prime mover (the truck). For this reason, you must be able to pull out the manual and find the parts you need to order and how they are assembled. The IPB does that for you.

Lastly, you can use an owner's or operator's manual to identify the vehicle's operating parameters. This information would include weight carrying capacity, towing capacity, and volumes of material it can haul. The manual also tells you about the vehicle's capabilities in different situations. For example, an excavator may have a maximum side hill slope that it can operate on. It may also have a load chart that will tell you what its weight limitations are in different boom configurations. The owner's manual contains all of the information needed to operate a piece of equipment safely and efficiently.

Discrepancies

If there's a discrepancy with the vehicle that's beyond your capacity to repair, you must turn the vehicle in to vehicle maintenance for a qualified mechanic to repair. Be sure the discrepancy is identified and annotated in the appropriate area of the AF Form 1800. Waiting to turn a vehicle in for maintenance could result in more damage to the vehicle. Don't wait; turn the vehicle in as soon as you find it needs maintenance to avoid a bigger problem later down the road.

For instance, during an inspection of a dump truck, you noticed chunks of rubber missing from both sets of duel tires. You conclude that the damage to the tires must have happened the previous day when another operator was hauling material out of the concrete dump area. You decide not to turn the vehicle in to maintenance because it will be down for several weeks waiting on tires to come in then you have to haul concrete again today. On your third load of the morning, both outside duals blow out while coming out of the haul road. The extra weight put on the inside set of duals is too much, and they blow out as well. You immediately stop the vehicle, effectively shutting down the haul road and bringing operations to a stop. Now, nobody can come or go. What could you have done differently to prevent this costly mistake? You should have turned the vehicle into maintenance when you noticed the chunks of rubber missing from the tires.

Equipment lubrication

Another area of responsibility for the operator is lubrication. Lubrication reduces harmful friction between moving parts. Moving parts that are deprived of oil or grease and are not lubricated properly may become overheated and melt or fuse together after a period of operation. Not only does grease preserve moving parts and make equipment last longer, but it also makes the equipment operate more smoothly with less effort on your part.

WARNING: Improper lubrication or the failure to lubricate a piece of equipment when required constitutes vehicle abuse. Vehicle abuse is administered to an individual for an action that caused damage and could have easily been prevented. If a letter of abuse is issued, you may receive disciplinary action as stated in AFI 24–301, *Vehicle Operations*.

Lubricate the vehicle according to intervals listed on the lubrication chart or TO for that vehicle. Equipment service intervals are based on hours operated and miles driven. It is a good practice to lube heavy equipment every day if it is getting a lot of use. For instance, operating a grader all day long in dusty and dirty conditions would constitute a time when it should be greased at the end of the day.

Most equipment in the Air Force today has grease fittings in convenient areas or "blocks" to make greasing easier. You don't have to climb around the machine to find them all. Make sure you check out the lube chart to visualize all the fittings needing attention are there and accessible.

Use the procedures in the following table when lubricating equipment:

Step	Procedure
1.	Keep all lubricants in clean, airtight containers. This practice will keep dirt and other harmful substances out of them.
2.	Never allow grease to get onto the clutch or brake linings when you're using grease near them. If it does, it will cause the clutch or brake linings to slip or grab.
3.	Wipe grease fittings clean before and after lubrication. This keeps dirt from entering the area to be lubricated and excess grease from falling on other moving parts.
4.	When greasing, make certain the fittings are open and free from obstructions. If a fitting is blocked, you should remove and clean it. If it's impossible for you to clean the fitting, replace it with a new one.
5.	Be careful not to over lubricate when using a pressure grease gun. This is easily done because it only takes an extra squeeze on the trigger to insert too much grease. Also, you should use a low-pressure gun to grease low-pressure fittings.
6.	Stop equipment engines while greasing equipment. If you don't, you might catch the grease gun—or even worse, yourself— in the moving parts.

Refueling

Refueling should be done every day, or the tank should be at least three-fourths full at the end of the workday, to keep condensation from forming inside the tank during temperature changes. Refueling or keeping the tank at least three-fourths full also ensures the vehicle is ready for work first thing the next day or for any emergencies that may arise. When a vehicle has to stop operations to go fuel up, time is lost and the mission is degraded. Keep in mind, you'll be operating machines that are either gasoline or diesel operated; consequently, make sure you use the proper type of fuel.

Cleaning

You should clean your equipment daily. Pick up any trash that may have collected in the operator's cab. Check under the operator's seat and sweep the cab out. Hose off the outside of the vehicle with water, and use soap if necessary. Don't rinse out the inside of the cab with the water hose because it shortens the life of the vehicle cab, causes the mats to deteriorate, and causes the floorboards to rust. You may be required to degrease the engine before turning the vehicle in to maintenance. If so, you should cover all air intakes and electrical parts to keep water from getting into internal parts or causing electrical shorts. Be sure to use a degreaser that won't affect rubber.

CAUTION: Remember, many hoses and insulation around electrical wires are made of rubber. A degreaser that deteriorates rubber can cause hoses to burst or electrical shorts to occur.

Also, ensure you are using degreaser in an area with an oil water separator such as in a wash bay. The debris is then cleaned out of the separator and treated as hazardous waste. Degreaser is certainly hazardous and must be disposed of properly.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

013. Operator's inspection procedures

1. What types of problems are walk-around inspections designed to detect?

2. Which page of the AF Form 1800 consists of 35 items that assist you when inspecting a vehicle?

014. Operator's maintenance procedures

1. What are some vehicle maintenance items the operator is responsible for maintaining?

2. Where can you find a vehicle's operating parameters such as weight carrying capacity, towing capacity, and volumes of material it can haul?

3. When inspecting a vehicle, what should you do if you notice defects in the vehicle which you cannot fix?

4. What does improper lubrication or the failure to lubricate a piece of equipment constitute?

5. Why should you refuel vehicles every day or keep their tanks at least three-fourths full?

6. Why should you *not* rinse out the inside of the cab when cleaning the vehicle?

2–2. Licensing

Getting licensed on vehicles within the Pavements and Construction Equipment Operator career field is as important as any other task with regards to upgrade training and advancement. Your work center operates more efficiently and effectively when everyone is able to contribute to the mission. Getting trained and licensed on each vehicle in your shop's fleet will only enhance the whole unit. In this section, we will briefly discuss the licensing process.

015. AF Form 171

The Air Force Form 171, Request for Driver's Training and Addition to U.S. Government Drivers License, is the source document for documenting and confirming your vehicle training. You can think of it as your government driving "learner's permit" in that you are required to have one filled out and on your person when you are conducting training. You will also have to have a trainer present at all times, either in the vehicle with you or within visual range of you in a training area.

If you already have a government driver's license, you will need an AF Form 171 to add additional vehicles to your license or to transfer your license from one base to another after a permanent change of station (PCS) move. This form is used to certify proficiency training and document necessary changes to your driver's license and to your driving record. An AF Form 171 is not valid for licensing purposes until you have been certified as having completed the prescribed training.

Certifiers

Only those individuals designated as "certifiers" can sign your AF Form 171 as a trainer. Vehicle Operations personnel maintain your unit's list of certified trainers. The unit vehicle noncommissioned officer (VCNCO) sends the Vehicle Operations flight an updated list of individuals and the vehicles they are certified to train on annually. Then, Vehicle Operations personnel verify the list to make sure

the individuals are licensed on the vehicle identified and do not have any pending vehicle infractions (i.e., speeding tickets, revoked driving privileges, etc.). Your unit's VCNCO must also sign the document confirming that you received the prescribed training for that particular piece of equipment or vehicle.

Training

A good rule of thumb for the amount of training required for an individual to operate a particular piece of equipment or vehicle is 40 hours. Your unit or your base's Vehicle Operations flight may designate specific minimum hours of training required for individual pieces of equipment or vehicles. For example, tractor trailer training at most installations is quite intensive and requires at least 40 hours of training. Find out if any other mandatory vehicle training requirements exist for the piece of equipment you need license to opreate.

016. AF Form 2293

The AF Form 2293, US Air Force Motor Vehicle Operator Identification Card, is your government driver's license. To be issued an AF Form 2293, you must have a valid motor vehicle license issued in any of the 50 United States, the District of Columbia, Puerto Rico, or a similar licensing jurisdiction. Without it, you are not allowed to operate any government vehicle.

Documentation

To receive a valid AF Form 2293, you must submit a completed and signed AF Form 171 and your state driver's license to the Licensing flight of Vehicle Operations. They will validate the information and print out your license for you to sign. It expires three years from the date of issuance. The AF Form 2293 is also used to establish and update your individual driver record. This record follows you from base to base and shows your licensing history.

The back of the AF Form 2293 lists all of the vehicles you are qualified to operate. Make sure you check every item in the list to ensure it is accurate and that no item was inadvertently removed during a transfer or addition. A good practice is to compare the old license with the new one to make sure.

Maintain certification

It is your responsibility to maintain a good driving record and driving certifications. Individuals who lose their civilian driving privileges due to traffic violations or other legal actions may lose their government driving privileges as well. You also may lose your government driver's license due to reckless operation, accident, or mishap while operating a government vehicle. Your job, as a pavements and construction equipment operator journeyman, is primarily operating equipment; without a license, you will not be as effective in your work center.

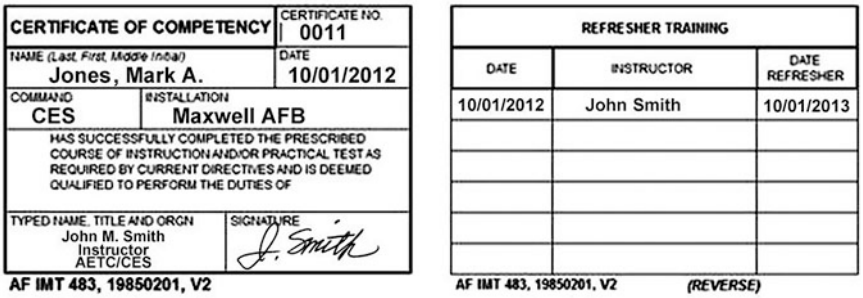
017. Certification requirements

The supervisor is responsible for obtaining certification for all people that work for him or her. Regardless of where in CE you are assigned, you will be in contact with people who are certified. For instance, heating, ventilation, and air conditioning-refrigeration (HVAC-R) technicians must be certified to handle refrigerants; electricians are certified in cardiopulmonary resuscitation (CPR); structures technicians are certified welders; and utilities technicians are Environmental Protection Agency (EPA) certified. The supervisor must be aware of all of their certification requirements and make sure that all certifications are obtained and properly documented. With what types of certifications must you be concerned?

Depending on your duty location, you may be required to receive certification before you are allowed to operate heavy equipment. The types of certification of concern to you are those required by government agencies or levels of government. If there is a certification requirement, it must be documented in the member's training records. It sounds simple, and it is as long as you know of the certification requirement, get the certification training, and keep up with the certification

documentation. The following is a list of government agencies or levels of government that may have certification requirements:

- Federal—A prime example is the crane requirement that all pavements and equipment (P&E) civil service personnel be certified in proper crane operation before operating on or off base.
- State—State law may require additional certification for certain jobs. A good example would be states requiring civil service employees to have a commercial driver's license (CDL) to operate dump trucks or tractor/trailers on or off base.
- Local/City ordinances—There may be certification requirements that apply to your locality.
- DOD/AF requirements—There are several Air Force certification requirements which include, but are not limited to, airfield driving, forklift operator, crane operator, and dump truck tailgate removal and installation. The Air Force Form 483, Certificate of Competency (fig. 2–3), is used to document that you have received the prescribed training. It is essentially proof of your abilities.



CERTIFICATE OF COMPETENCY	CERTIFICATE NO. 0011
NAME (Last, First, Middle Initial) Jones, Mark A.	DATE 10/01/2012
COMMAND CES	INSTALLATION Maxwell AFB
HAS SUCCESSFULLY COMPLETED THE PRESCRIBED COURSE OF INSTRUCTION AND/OR PRACTICAL TEST AS REQUIRED BY CURRENT DIRECTIVES AND IS DEEMED QUALIFIED TO PERFORM THE DUTIES OF	
TYPED NAME, TITLE AND ORGN John M. Smith Instructor AETC/CES	SIGNATURE J. Smith

AF IMT 483, 19850201, V2

REFRESHER TRAINING		
DATE	INSTRUCTOR	DATE REFRESHER
10/01/2012	John Smith	10/01/2013

AF IMT 483, 19850201, V2 (REVERSE)

Figure 2–3. AF Form 483, Certificate of Competency.

Airfield driving

As a pavements and construction equipment operator, for you to enter the active airfield to conduct operations alone, you must take and pass the prescribed airfield driver's education training. While each base conducts its training differently, each has the same goal: to teach you about the airfield and how to operate safely on it. Your supervisor should team you up with a seasoned operator to train you on the airfield before you attempt to get your certification. Without airfield driver certification, you cannot drive on the airfield alone.

Most installations have the training in a computer-based format which must be completed before going to Base Operations. Once at Base Operations, you may have to do a color acuity test which tests your ability to differentiate between colors. The reason for this color acuity test is to make sure you can properly see and identify the colors of the airdrome signals used by airfield personnel to warn you of aircraft movement. If you are color blind, you may not be able to receive airfield driving privileges.

Forklift

Forklifts are defined as mobile, power-driven vehicles used to carry, lift, stack, or tier material. Operating a forklift is inherently dangerous, and as such, all operators must be certified. Training must be based on the operator's demonstrated ability to operate it safely and understand the hazards present in the workplace. Additionally, the training must consist of both classroom and practical instruction in proper operation of the vehicle, possible hazards, and other specific requirements.

These include things such as operating instructions, engine and motor operation, and vehicle stability. Initial training and refresher training is done by completing the Air Force Qualification Training Package (AFQTP) for forklifts and an approved forklift lesson plan administered by a certified

trainer. Members must receive refresher training every three years to ensure they have the knowledge and skills needed to operate forklifts safely.

Crane

As an operator of a crane, you are, or will be, faced with enormous responsibility. You are responsible for not only the safe operating conditions of your equipment and your safety, but also for the safety of all those individuals around you. Crane accidents, which must be of the utmost importance to us all, causing damage, injury, and even death, generally occur because someone did not have the knowledge, forgot the correct procedure, or simply did not think before acting. The possible losses incurred due to a crane accident indicate a need for increased attention to safety and positive action by everyone involved with these machines. Unless the fundamentals of crane safety are known and followed by all concerned, accidents can and will happen.

Crane training includes the crane AFQTP, an approved lesson plan, and a certified trainer conducting the training. Training can also be done through approved commercial training offered throughout the US and also military crane classes.

Crane operators must be recertified every 30 months which includes a written exam, skills test, and a physical examination. Operators who fail to be recertified will lose their ability to operate a crane.

Dump truck tailgate removal and installation

Prior to being licensed on a dump truck, all operators must be certified on tailgate removal and installation. Training must include completion of the AFQTP for the subject knowledge and actual hands-on training. There is also a video and slide presentation offered from Air Force Civil Engineer Center (AFCEC) which can supplement your unit's presentation. The trainer will certify that operators demonstrated the knowledge and ability to conduct the removal and installation of a tailgate safely, using the AFCEC lesson plan or one derived at your duty location.

Recertification is not necessary unless there is evidence to show there is a need. For instance, if an individual has an incident where someone gets hurt or if a supervisor deems an individual to be incompetent at the task, that individual may be required to take the training again.

Documentation

Another important part of the certification process is documentation. Use the AF Form 623, Individual Training Record Folder, (training record) and AF Form 797, Job Qualification Standard Continuation/Command JQS, to document training. If the training is an annual requirement, use the AF Form 1098, Special Task Certification and Recurring Training. Proper documentation helps the supervisor keep up with the individuals who need certification and those who have fulfilled their certification requirements.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

015. AF Form 171

1. What is another way to describe an AF Form 171?

2. Who is allowed to sign as a trainer on your AF Form 171?

3. Who designates the required minimum hours of training for individual pieces of equipment or vehicles?

016. AF Form 2293

1. What exactly is an AF Form 2293?

2. What two things must you present to the Licensing flight of Vehicle Operations to receive a valid government driver's license?

3. What information is on the back of your AF Form 2293?

017. Certification requirements

1. Which AF Form is used to document your prescribed certification training and is essentially proof of your abilities.

2. What training must you have prior to operating a vehicle alone on any airfield?

3. How often must crane operators be recertified?

4. Where can you find the subject knowledge based training for dump truck tailgate removal and installation training?

Answers to Self-Test Questions

013

1. The most obvious defects such as leaks, broken or missing items, flat tires, and so forth.
2. Page three.

014

1. Adding coolant to the radiator, adding oil to the crankcase, filling the battery with fluid, fueling the vehicle, replacing broken lenses and burned out bulbs, adding air to and changing tires, tightening loose nuts and bolts, and washing and waxing the vehicle.
2. In its owner's or operator's manual.
3. Turn the vehicle in to vehicle maintenance for a qualified mechanic to repair.
4. Annotate the defect in the appropriate area of the AF Form 1800 and turn the vehicle in to maintenance for a qualified mechanic to repair.
5. To keep condensation from forming inside the tank during temperature changes.
6. It shortens the life of the vehicle cab, causes the mats to deteriorate, and causes the floorboards to rust.

015

1. As a government driving “learner’s permit.”
2. Only those individuals designated as “certifiers.”
3. The individual’s unit or the Vehicle Operations flight.

016

1. Your government driver’s license.
2. A completed and signed AF Form 171 and your state driver’s license.
3. A list of all the vehicles you are qualified to operate.

017

1. The Air Force Form 483, Certificate of Competency.
2. Airfield driver certification.
3. Every 30 months.
4. The AFQTP.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

25. (013) Which page of the AF Form 1800, Operator's Inspection Guide and Trouble Report, has areas for operators to sign signifying completion of the vehicle inspection?
    a. One.
    b. Two.
    c. Three.
    d. Four.

26. (013) Where are the discrepancy item numbers placed on the AF Form 1800, Operator's Inspection Guide and Trouble Report, when turning in a vehicle to maintenance?
    a. Right-hand column under "reported to maintenance."
    b. Left-hand column under "operator report."
    c. "Maintenance Report Status" column.
    d. "Discrepancy" column.

27. (014) In regards to vehicle maintenance, which action *is not* normally an operator's responsibility?
    a. Replacing burned out bulbs.
    b. Filling the crankcase with oil.
    c. Tightening loose nuts and bolts.
    d. Changing the transmission fluid.

28. (014) Failure to lubricate a piece of equipment or vehicle properly when required constitutes
    a. vehicle abuse.
    b. dereliction of duty.
    c. equipment disregard.
    d. maintenance ignorance.

29. (014) While cleaning a vehicle, where would you find an oil water separator to dispose of engine degreaser?
    a. At the base's Environmental Flight.
    b. In the hazardous waste area.
    c. At the Base Exchange.
    d. In the wash bay.

30. (015) What must be completed for an AF Form 171, Request for Driver's Training and Addition to U.S. Government Drivers License, to be considered valid for licensing purposes?
    a. Applicable Air Force Qualification Training Packages (AFQTP).
    b. Specialty Training Standard (STS) core tasks.
    c. Prescribed training.
    d. A 50-question test.

31. (015) The only individuals who can sign your AF Form 171, Request for Driver's Training and Addition to U.S. Government Drivers License, for licensing purposes are those
    a. designated as "trainers."
    b. designated as "certifiers."
    c. in the rank of Staff Sergeant and above.
    d. who have been trained on that piece of equipment.

32. (015) As a good rule-of-thumb, how many hours of training should you receive before being licensed to operate a particular piece of equipment or vehicle?
    a. 10.
    b. 20.
    c. 30.
    d. 40.

33. (016) What two things *must* you have to receive a government driver's license?
    a. State driver's license and AF Form 2293.
    b. State driver's license and AF Form 483.
    c. AF Form 171 and state driver's license.
    d. AF Form 171 and AF Form 2293.

34. (016) The AF Form 2293 U.S. Air Force Motor Vehicle Operator Identification Card, is used to establish and update what document?
    a. Individual driver record.
    b. Individual certification record.
    c. AF Form 623, Individual Training Record Folder.
    d. 3E2X1 Career Field Education and Training Plan (CFETP).

35. (017) What training must you, as a pavements and construction equipment operator, have before you are certified to drive on the airfield?
    a. Airfield Management Apprentice course, airfield orientation.
    b. Airfield hazardous conditions analysis training.
    c. Airfield airdrome signal awareness training.
    d. Airfield driver's education training.

36. (017) How often must pavement and construction equipment operators be recertified on dump truck tailgate removal and installation?
    a. Annually.
    b. Biannually.
    c. Every three years.
    d. When needed.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Project Management

AS PAVEMENTS and construction equipment operators, you will be tasked to manage projects. They may be large and complex endeavors, or they may be simple and straight forward. Regardless of the size or scope of the project, you must have a firm grasp on the fundamentals of construction if you are going to be a good manager. You must be able to assess what is required to complete the project and how to go about completing it in the quickest and most efficient way. With some basic knowledge and sound guidance, the process of managing a project becomes much easier. This unit will teach you the basic fundamentals and properties of soils as well as how to survey a site for elevation using an engineer level and rod. You will also learn to read and interpret construction drawings all of which are critical to planning and managing a project.

3–1. Soil Fundamentals

We begin the discussion of Project Management with learning about soils and how to decide if they are suitable for construction. We will then look at basic stabilization techniques.

018. Soil profiles, properties, and classifications

To understand and analyze the conditions under which the pavement must function, you need information on surface composition. Such information can be determined from soil profiles, properties, and classifications, which will be the focus of this lesson. Soil conditions can tell you a lot about surface drainage, non-pavement subsurface drainage, soil stability, and resilience.

Soil profile

Soil forms the upper-most layer of the earth's crust and is made up of inorganic and organic matter. The inorganic components are weathered rock, air, water, and minerals. The organic components are the decomposing (rotting or decaying) fragments of plants and animals. The spaces between the small particles that make up the soil are filled with air or water.

Soil profiles are collected with a soil auger, a digging tool that allows you to extract a core, or narrow cylinder, of soil to a depth of a few feet or more. By observing the texture, color, and other characteristics of a profile, you can get a picture of the processes that led to the soil's formation, as well as determine the soil's stability and drainage properties.

Soils develop horizons or layers of distinct characteristics through the soil forming process. They are commonly referred to as the A, B, and C horizons (fig. 3–1).

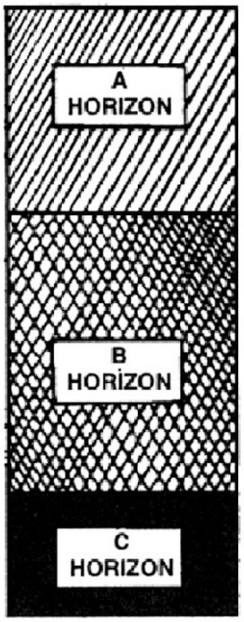


Figure 3–1. Soil profile.

"A" horizon

The upper layer of the soil profile, the "A" horizon, is made up mostly of organic materials. Because "A" horizon materials are spongy, drain poorly, and do not compact, they are not used in *any* phase of construction. You must remove the "A" horizon before building anything in the area. You will read more on excavation later. Organic soils, sometimes referred to as "top soil," are made up mostly of decayed plant and animal matter and are in the "A" horizon.

"B" horizon

The "B" horizon lies directly underneath the "A" horizon. Lighter in color, it is made up of a mixture of sand, gravel, silt, and clay. The strength and drainage properties of the soil depend on the type and amount of sand, gravel, silt, and clay in the mixture. The "B" horizon is the base for all types of pavement construction; for that reason, it is extremely important in pavement construction. Most of the common material found within this horizon can be processed to increase its stability.

"C" horizon

The "C" horizon is rock in its natural state. It is sometimes called *parent material* because this is where "B" horizon materials come from. Very seldom will you have to build anything on this horizon.

Soil properties

With experience, you will find that you can use the different properties of soil to your advantage. Soils can be enormously complex systems of organic and inorganic components. Here, we'll concentrate on expansion and contraction, plasticity, and cohesion, which are a few of the most significant physical properties.

Expansion and contraction

Expansion and contraction are *undesirable* characteristics that you must monitor closely. Clays and some forms of silt expand and contract with changes in moisture content.

Plasticity

Plasticity is the ability of a soil to be molded into shapes without cracking or appreciable volume change. Clays and some silts are good examples of plastic. Plasticity can be a problem if not controlled properly.

Cohesion

Cohesion is the ability of soil to stick together when dry. Clays are very cohesive. The more plastic soil is when wet, the more cohesive it is when dry.

Soil classification by particle size

Soils are grouped by the size of their particle grains. Using sieves is one way to distinguish soil classification (fig. 3–2). A sieve is a screen attached across the end of a cylindrical metal frame. As the sieves are shaken, the screen lets particles smaller than its openings fall through while it holds larger particles.

Sieve sizes are designated by screen opening size. By using sieves with screen openings of different sizes, you can sort soil into particle groups based on size. For example, a 3-inch, or 75 millimeters (mm), sieve has its mesh openings three inches (75 mm) square. A No. 4 (4.75 mm) sieve has four

openings per linear inch, thus having 16 openings per square inch. If soil passes the 3-inch (75 mm) sieve but does not pass the No. 4 (4.75 mm) sieve, you know that the largest particle size is less than three inches (75 mm) and the smallest size is larger than 0.187-inch (4.75 mm). This soil is classified as gravel.

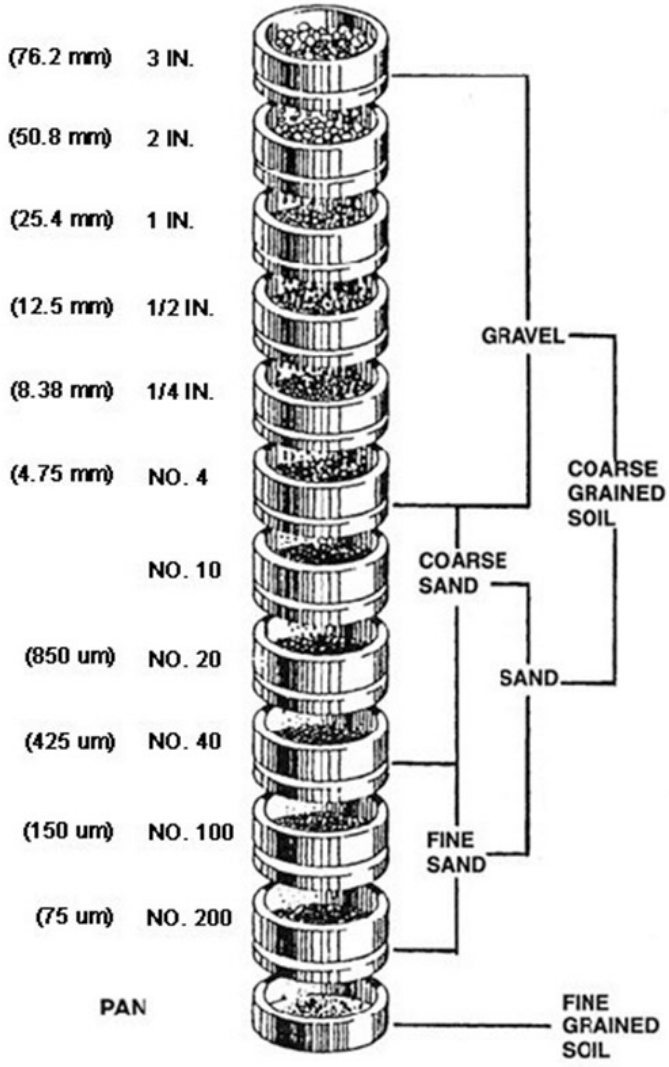


Figure 3–2. Standard sieve set.

NOTE: A micrometer is 0.001 mm and its symbol is μm.

Soils that pass the No. 4 (4.75 mm) sieve but are held on the No. 200 (75 μm) sieve are classified as sands, and are further broken down as coarse sand or fine sand. Coarse sand passes the No. 4 (4.75 mm) sieve and is held on the No. 40 (425 μm) sieve. Fine sand passes the No. 40 (425 μm) sieve and is held on the No. 200 (75 μm) sieve.

The sieve set as seen in figure 3–2 has a number 200 (75 μm) as its finest screen and the particles passing are retained in the pan and are classified as fine grained soil. You can see from these examples how you can classify soils by size using sieves. You can see what size particles are present in the sample and perhaps make an assessment as to what particle size may need to be added to the sample to make it usable. You may also be able to determine if the sample is good enough for construction.

See the U.S. standard mesh sieve sizes chart in the following table for a detailed list of all the standard sieve sizes.

U.S. Standard Mesh Sieve Sizes					
Sieve standard (Millimeters)	**Sieve alternate "Mesh"**	**Sieve opening (Inches)**	**Sieve standard (Millimeters)**	**Sieve alternate "Mesh"**	**Sieve opening (Inches)**
125 mm	5	5	2.36 mm	No. 8	0.0937
106 mm	4.24	4.24	2 mm	No. 10	0.0787
100 mm	4	4	1.7 mm	No. 12	0.0661
90 mm	3 ½	3.5	1.4 mm	No. 14	0.0555
75 mm	3	3	1.18 mm	No. 16	0.0469
63 mm	2 ½	2.5	1 mm	No. 18	0.0394
53 mm	2.12	2.12	850 µm	No. 20	0.0331
50 mm	2	2	710 µm	No. 25	0.0278
45 mm	1 ¾	1.75	600 µm	No. 30	0.0234
37.5 mm	1 ½	1.5	500 µm	No. 35	0.0197
31.5 mm	1 ¼	1.25	425 µm	No. 40	0.0165
26.5 mm	1.06	1.06	355 µm	No. 45	0.0139
25 mm	1	1	300 µm	No. 50	0.0117
22.4 mm	7/8	0.875	250 µm	No. 60	0.0098
19 mm	¾	0.875	212 µm	No. 70	0.0083
16 mm	5/8	0.625	180 µm	No. 80	0.0070
13.2 mm	0.53	0.53	150 µm	No. 100	0.0059
12.5 mm	½	0.5	125 µm	No. 120	0.0049
11.2 mm	7/16	0.438	106 µm	No. 140	0.0041
9.5 mm	3/8	0.375	90 µm	No. 170	0.0035
8 mm	5/16	0.312	75 µm	No. 200	0.0029
6.7 mm	0.265	0.265	63 µm	No. 230	0.0025
6.3 mm	¼	0.25	53 µm	No. 270	0.0021
5.6 mm	No. 3.5	0.223	45 µm	No. 325	0.0017
4.75 mm	No. 4	0.187	38 µm	No. 400	0.0015
4 mm	No. 5	0.157	32 µm	No. 450	0.0012
3.35 mm	No. 6	0.132	25 µm	No. 500	0.0010
2.8 mm	No. 7	0.11	20 µm	No. 635	0.0008

Coarse-grained soils

Soils in this classification are made up of sand and gravel and are in the "B" horizon. Coarse-grained soils have 50 percent or less material passing the No. 200 (75 µm) sieve. Their grain shape varies from rounded to angular. They have good load-bearing qualities and drain freely. Because they drain freely, moisture has no effect on volume or strength.

Fine-grained soils

Fine-grained soils are made up of silt and clay and are in the “B” horizon. They have 50 percent or more material passing the No. 200 (75 µm) sieve. Any soil passing the No. 200 (75 µm) sieve is classified as fine-grained. Both silt and clay pass the No. 200 (75 µm) sieve. These soils drain poorly, if at all. They deform when loads are applied to them. When wet, they have little or no strength. However, when dry, their strength increases. This characteristic is especially true with clay.

Soil gradation

Gradation describes the distribution of different size groups within the soil sample. If you did a sieve test on a soil sample and you found all sizes of sands to be present, from No. 4 (4.75 mm) to No. 200 (75 µm) sieve, you would have a well-graded soil (fig. 3–3, A).

Poorly graded soil may be uniform-graded (fig. 3–3, B) or gap-graded (fig. 3–3, C). If a soil is uniform-graded, most of its particles are about the same size. An example of this is a sieve test in which sand size No. 20 (850 µm) is the only size present. If a soil is gap-graded, at least one particle size is missing. For example, gap-graded soil is one in which a sieve test reveals that sand size No. 10 (2 mm) and No. 40 (425 µm) are missing and all other sizes are present.

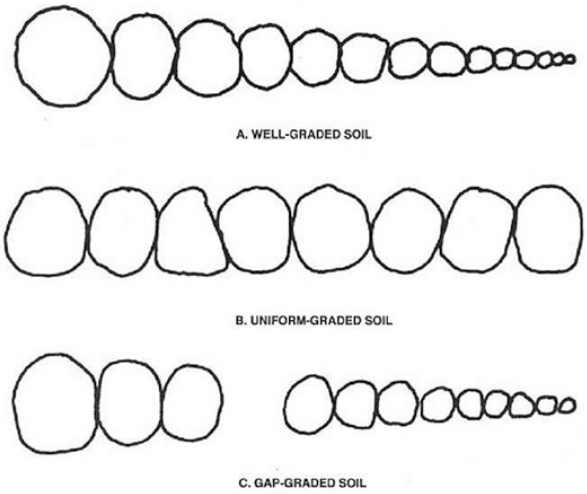


Figure 3–3. Soil gradation.

019. Soil stabilization techniques

A chain is only as strong as its weakest link. A paved surface is only as strong as its foundation. The subgrade and base course make up the foundation for paved surfaces. When you build a paved surface, the subgrade must be at the proper level and contain desirable material with correct soil properties. To reach the proper subgrade, you may have to excavate excess dirt, fill the area with the compatible subgrade material, stabilize and compact the soil, and lay a blanket or insulating course. A stable subgrade does not move under wheel loads. Stability depends on the following:

- Size of the particles in the materials.
- Shape of the particles.
- Gradation of the particles.
- Type and amount of binder in the mixture.
- Moisture content.

All of the above play an important part in subgrade stability. It’s now time to learn about procedures used to stabilize the subgrade. Subgrades may be stabilized mechanically or chemically.

Mechanical stabilization

There are two types of mechanical stabilization—blending and compaction. Mechanical stabilization is done either to improve the drainage or the compaction characteristics of soil. Blending is the addition of other grain sizes to an existing soil to achieve the desired gradation or to reduce plasticity before compaction. Compaction is the act of artificially making the soil denser. It means the pressing together of soil particles into a closer state of contact, accompanied by expelling part of the air from the soil. A sieve test tells you what grain sizes the soil contains (gradation). By comparing the sieve test results to the specified gradation requirements, you know what size particles to add to the soil to get desired qualities for drainage and compaction.

Compaction requirements for a soil can be obtained in a soil-testing lab. The compaction specifications give a range of optimum water content and percent of compaction. This percent of compaction is based on the theoretical maximum dry density obtained in the lab (i.e., 75%, 95%). This means that in the field, you should be able to get that percent of the theoretical maximum dry density from the lab test simply by adding moisture to the soil or by waiting for it to dry. Have the engineer assistants take density measurements throughout to ensure you are as close as possible to optimum.

Chemical stabilization

Chemical stabilization does two things to the soil: it cements the soil into a hard mass and it changes the soil to make it more suitable for construction. The type of chemical you should use is determined by the type of soil to be stabilized.

No matter what method or what types of material you use to stabilize a subgrade, always make sure the material is mixed well into the soil. The material you add does little good if left just on the surface. Tillers work well on small or large areas depending on the size of the tiller, and graders and harrows work well on the larger areas. There are four main types of chemicals you can use to stabilize soil: Portland cement, bituminous materials, calcium chloride, and lime.

Portland cement

Portland cement is best used on soils containing coarse-grained soils or silts. It bonds the material together to create a strong, durable subgrade. The application rate of Portland cement varies from three percent by dry weight for sand and gravel to 10 percent for silt. Portland cement is a very expensive type of soil stabilizer. Don’t use it if any other method is available.

Bituminous

If subgrade is granular and crumbly, it may be necessary to use a bituminous stabilizing material. The type and grade of bituminous material used depends on the type of soil, method of construction, and weather conditions. Bitumen is usually mixed into the existing soil with mix-in-place equipment. The required bitumen content varies from four to nine percent by weight, depending on the soil. The bitumen cements the soil particles together. The cementing action makes the mixture very resistant to water. Ensure you get with the Environmental flight prior to using any bituminous material as it may be illegal to use at your installation.

Calcium chloride

Calcium chloride works very well on highly plastic soils. It should not be used with cohesion-less sands or with gravel. Calcium chloride increases the stability by controlling moisture content. Calcium chloride absorbs moisture from the air, thus keeping the soil damp. Mix it with soil at a rate of ½ pound, or 0.23 kilogram (Kg), chemical to each square foot of soil one inch (25.4 mm) deep.

Lime

Lime is best used to stabilize soils having high clay content. The lime works on reducing the clay’s plasticity and volume change characteristics.

Compacting a subgrade

Any time soil is disturbed it expands and becomes loosely packed. During the preparation of a subgrade, loose soil must be compacted into a solid mass. The process of compressing loose soil into a solid mass is called compaction. If the soil is not compacted properly during construction, it eventually settles, and the road or runway collapses. Equipment such as sheepsfoot rollers, pneumatic-tired rollers, and steel-wheeled rollers are specifically designed for compaction work.

Methods of compaction

The correct compaction method depends on the type of material and the amount of compaction needed. The following are descriptions of methods used for various types of materials:

- Compact cohesive (plastic) soils in 6-inch (152 mm) layers. Compact each layer thoroughly with a sheepsfoot roller.
- Sand or sandy gravel is compacted best when saturated with water. The material may be saturated by ponding or jetting. Jetting is done by pushing perforated pipes into the material. This distributes the water uniformly throughout the fill. Sand and gravel are best compacted by using vibration.
- Sand and gravel that contain silts and clay are best compacted with pneumatic-tired rollers.
- Dry soils must be sprinkled with water before compaction. After sprinkling, grade the soil back and forth to get uniform moisture distribution.
- When used, rock layers usually are put on the bottom of the fill. A layer of soil is then compacted over the rocks. The larger the rocks, the harder they are to compact. Rock layers can best be compacted by vibration. A rock layer should never be thicker than the largest rock.

Construction equipment, such as tractors and trucks, may be routed over the subgrade to aid in compaction. This is very valuable, especially in the compaction of sands, gravels, rocks, and soils with low moisture content. These materials usually require some form of vibration during the compaction, and passage of the equipment over the subgrade furnishes the vibration. Maintain close control to keep the pieces of equipment from following the same path. The pieces of equipment must pass over all parts of the subgrade to get uniform compaction. It usually is best to have someone act as a spotter, directing the equipment over the fill.

After you have excavated or filled the subgrade to the proper level, you must ensure that the subgrade remains stable throughout the expected life of the road. Thoroughly compact the surface, and when required, lay a blanket course.

Blanket or insulating course

Whenever the subgrade is composed of high plastic cohesive soil, a blanket or insulating course is required. It goes on top of the subgrade. This course consists of one to two inches (25.4 to 50.8 mm) of well-compacted sand or screenings. Screening material combines small rock chips and a dust mix usually made up of 70 percent rock and 25 percent dust or dirt.

The blanket course serves two purposes: it helps prevent plastic soils from working up into the base course and it helps reduce frost action. The blanket course and the base course should be thick enough to eliminate the effects of frost action in the subgrade.

Deposit the blanket course on the subgrade directly from the transporting vehicles. Spread the material as much as possible during dumping. After dumping, spread the blanket course with a dozer or grader.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

018. Soil profiles, properties, and classifications

1. What are the three soil horizons? What are they made of?

2. Why are “A” horizon soils not used in any phase of construction?

3. Which soil horizon is the *base* for all types of pavement construction?

4. What is another name for the “C” horizon? Why?

5. What is meant by the term *plasticity*?

6. What is a sieve? How are sieve sizes designated?

7. Define the term soil *gradation*.

8. Poorly graded soil may be uniform-graded or gap-graded. What do these terms mean?

019. Soil stabilization techniques

1. What are the two types of stabilization?

2. Why should you mechanically stabilize a subgrade?

3. What does chemical stabilization do for soil?

4. What are the four main types of chemicals used for stabilization?

5. How does calcium chloride increase soil stability?

6. How much calcium chloride is added to each square yard of soil (one inch deep) to stabilize subgrade?

7. What pieces of equipment are designed specifically for compaction work?

8. What type of soil is compacted best when saturated with water?

9. Besides rollers, what other type of equipment furnishes some form of vibration on soils with low moisture content?

10. What is the purpose of a blanket or insulating course?

3–2. Elevation/leveling Equipment

Leveling is a term used by engineering specialists to determine the elevation of points on or near the earth's surface. They use different pieces of equipment to determine elevations. This section covers the equipment and procedures you will use to determine whether you need to cut or fill (a point's elevation) material in a construction area.

020. Engineer levels

Engineer levels are widely used instruments within the construction industry, especially for leveling operations. Engineer levels are classified according to their support. There are several engineer level models to choose from; however, the one you will be most concerned with is the self-leveling level (auto level).

Self-leveling Level

The self-leveling level (auto level) is a precise, timesaving leveling instrument that is equipped with a small bull's-eye level and three leveling screws (fig. 3–4). The leveling screws, which are on a triangular footplate, are used to center the bubble in the bull's-eye level. To level the instrument, stabilize the tripod and level the tripod head by eye, then center the bubble using the three leveling screws. The auto level's leveling screws can be manipulated individually to center the bubble. The bubble should stay centered in the small circle throughout the full 360-degree rotation; if it doesn't, adjust the circular leveling knob.

On the auto level, the line of sight automatically becomes horizontal and remains horizontal as long as the bubble in the bull's-eye level remains centered. A prismatic device called the *compensator* makes this possible. The compensator is suspended on fine, nonmagnetic wires. The action of gravity on the compensator causes the optical system to swing into the position that defines a horizontal line of sight. This horizontal line of sight is maintained even if the telescope is slightly out-of-level or a slight disturbance occurs in the instrument.

Figure 3–4. Self-leveling or auto level.

Care of the engineer level

As with any other instrument or precision piece of equipment, taking care of your engineer level is extremely important. You should care for your engineer level as soon as you receive it. Though it may not be a matter of life or death, as with a weapon, you need your equipment to work properly and give accurate results. After all, you don't want to do the job over again.

Initial care

Your shop may only have one type of engineer level, so use caution during set-up. Be sure to use the following steps:

1. Remove the engineer level from the box and mount it on the tripod head. Examine it for missing parts and for any sign of damage caused by bumps or jars.
2. Check the bubble to see that it is not broken, and look through the telescope to ensure the crosshairs are in place. If either hair is missing or broken, the level must be repaired or replaced.
3. Try all the clamps, motions, and screws for freedom and smoothness of action (don't force the screws). Determine the cause of any binding, friction, or malfunction, and determine whether it can be corrected at once.

NOTE: Never use a faulty engineer level.

4. Wipe all exterior metal surfaces to remove dust and any excess grease or oil. Make sure polished surfaces, such as the bearing surface of the footplate, are cleaned carefully and thoroughly. Dirt or grit can scratch these surfaces and cause undue wear (which will affect results).
5. Check the lenses for chips and cracks. Use a camel's hair brush to remove dust from the lens. Then wipe gently with a chamois to remove any film. If the lens is still dirty, use an approved lens cleaning solution to clean the lens. Clean off any finger marks.

Care during operation

When traveling to a survey starting point, transporting your engineer level over long distances, or traversing through rough terrain, always carry the engineer level in its carrying case. Vibrations, jolts, and jars can damage or misalign the level's delicate parts, so handle the case gently.

The engineer level, like all survey instruments, is highly susceptible to expansion and contraction when heated by the sun. If the sun continuously strikes only one part of the instrument, unequal expansion and contraction will cause changes in the adjustments and introduce errors in the survey results. It is a good practice to select shaded locations for instrument setups or carry an umbrella to shade the instrument.

Follow these three cardinal rules when using the engineer level:

- *Never* set up the tripod without finding good footings and setting the legs firmly.
- *Never* leave the set up instrument unattended.
- *Never* straddle the tripod legs.

Setting up and leveling the engineer level

When you are adjusting the engineer level, it is important to set up the instrument in a prescribed sequence. The reason for this is that one adjustment may depend upon, or alter, another adjustment. To ensure leveling is accurate, the tripod that the engineer level sits upon must be solid and adjusted properly. Tripods are either fixed leg or adjustable leg models. The fixed leg tripod is best for leveling because the tripod legs provide a more stable foundation.

The tripod is the base or foundation that supports the leveling instrument and keeps it stable during observations. A tripod consists of a head where the engineer level is attached, three wooden or metal legs that are hinged at the head, and pointed metal shoes on each leg that are pressed or anchored into the ground to achieve a firm setup. The tripod legs must be placed properly and anchored firmly. On level terrain, each leg should form an angle of about 60 degrees with the ground surface.

Smooth surfaces

On smooth, slippery paved, or rock surfaces tighten the tripod leg hinges while you are setting up the engineer level. This keeps the legs from spreading and stops the tripod from falling. Use holes or cracks in the ground to brace the tripod. As a safety factor, you could tie the three legs together at their current distances, and brace them with rocks or sand bags.

Sloping surfaces

When setting up on steep sloping surfaces, place the third leg uphill and the other two legs downhill. Before releasing the downhill legs, check for stability. Make sure the tripod head is not overbalanced by the weight of the instrument. If it is overbalanced, then the tripod may slip or fall.

Leveling the instrument

Use the following steps when leveling the instrument.

1. Turn the instrument its vertical axis until the Level Vial is roughly parallel to the two opposite leveling screws. With these screws, tilt the instrument until the Level Bubble is roughly centered in the vial. Note that the Level Bubble moves in the same direction as the left thumb. Turn the two screws in opposite directions at the same rate, keeping a slight pressure between the leveling foot screws and the footplate.
2. Turn the instrument 90 degrees until the Level Vial is parallel to the other pair of screws. Once again, bring the Level Bubble to center.
3. Turn the instrument back to its original position as in step 1, and re-center the bubble.
4. Repeat steps 2 and 3 until the bubble remains centered in both positions.
5. Turn the instrument 180 degrees around from its position in step 1. If the bubble stays at center, the instrument is leveled along the axis. If not, use the leveling screws to bring the bubble halfway back to center. This levels the instrument, but the vial is out of adjustment.
6. Repeat step 5, using the position of step 2 as the starting point, and again compensate for the difference in centering. Note that the bubble is in the same off-center position for any pointing of the instrument, since the vial is out of adjustment.
7. When leveling is complete, all three leveling screws must bear firmly against the footplate without binding.
8. Adjust the Level Vial as mentioned in step 5, but bring the bubble back halfway to center with the vial adjusting screw(s), and then center it completely with the leveling screws. If you

return it to the position in step 1, the bubble should stay centered. If it does not, repeat the process and be a little more careful in bringing the bubble back halfway to center with the Level Vial adjusting screw(s). Since it is extremely hard to get a perfect adjustment, step 5 should always be the last step.

021. Types of measuring rods used in measuring vertical distances

A leveling rod is a graduated pole or stick with a movable marker. It is used with the engineer level mentioned earlier and measures differences in elevation (vertical distances). A leveling rod is sometimes called a leveling pole or leveling staff. The bottom of the rod is covered with metal to protect it from wear and is usually the point of zero measurement from which graduations are numbered.

Leveling rods come in a variety of types, patterns, graduations, and in single pieces, joined sections, or sliding sections. Most of the rods you will use are graduated in tenths and hundredths of a foot, though they are available in decimals of a meter and in fractions (⅛) of an inch. Leveling rods are of two general classes: self-reading and target rods.

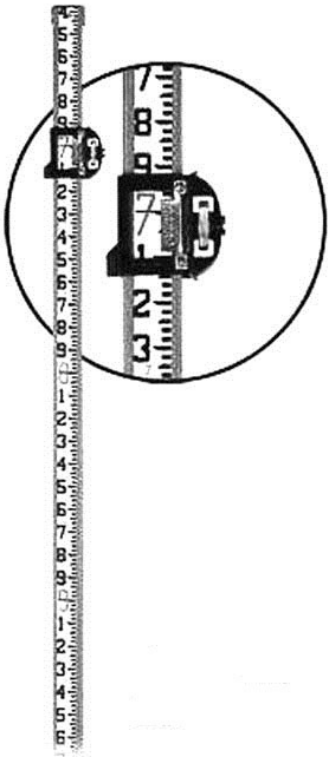


Figure 3–5. Philadelphia rod with target.

Self-reading rods

This type of rod can be read by the instrument operator by sighting through the telescope and noting the apparent intersection of the cross wire on the rod. The rod-person must hold this rod vertically.

The leveler observes the graduation at which the line of sight intersects the rod and records the reading. Observations closer than the smallest division on the rod are made by estimation. Self-reading rods can be used for distances up to 400 feet, though at this distance the graduations are hard to see. A maximum of 300 feet is preferable.

The most often-used self-reading rod is the Philadelphia rod (fig. 3–5). It is a graduated-wooden or fiberglass rod, is made of two sections, and can be extended from seven to 13 feet.

Each foot is subdivided into hundredths of a foot. Instead of each hundredth of a foot being marked with a line or tick, the distance between alternate hundredths is painted black on a white background. The top of each black hash mark represents an even hundredth of a foot, while the bottom of each hash mark represents an odd hundredth of a foot.

The large red numbers represent whole foot marks. The smaller red marks also represent whole foot marks and are spaced in between the large numbers for your convenience. The smaller red marks let you know which foot mark you are on when the large red numbers are not in the field of vision.

Target rods

This type of rod is made to accept a sliding target, as shown in figure 3–5. The rod-person, acting on signals from the level operator (leveler), moves the target up or down until it is bisected by the line of sight. The rod-person then clamps the target and observes the indicated reading. Most targets have a vernier that lets you read fractions of the graduations without estimating. The target rod's main advantage is that mistakes in reading the rod are less likely. This is especially true if both the rod-person and leveler read the rod. A target rod eases the work in very long sights, sights which the rod is partly obscured from view, or where you must establish a number of points at the same elevation.

Direct readings

Direct readings are taken from a self-reading rod, held plumb on point by a rod-person. If you are working to tenths of a foot, it is relatively simple to read the footmark below the crosshair and the tenth mark, which is closest to the crosshair. However, working to the hundredths of a foot is more complicated. For example, suppose you are making a direct reading that comes out as 5.76 feet. On a Philadelphia rod, the graduation marks are 0.01 foot wide and are 0.01 foot apart. For a reading of 5.76 feet, there are three black graduations between the 5.70-foot mark and the 5.76-foot mark, as shown in figure 3–6. Since there are three graduations, the rod can be misread as 5.73 feet instead of 5.76 feet.

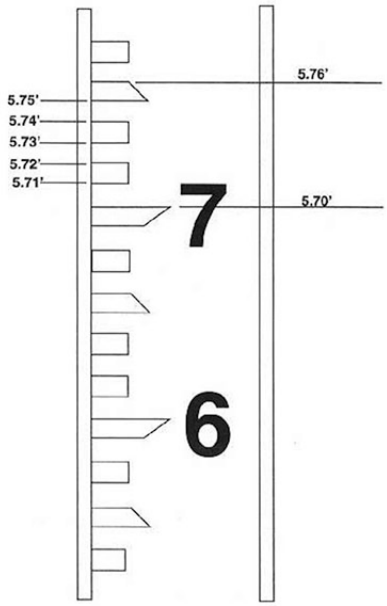


Figure 3–6. Direct reading of 5.76 feet on a Philadelphia rod.

The 5-foot mark or the 6-foot mark does not show in figure 3–6. While sighting through the level instrument, you might not be able to see the footmarks. When you cannot see the next lower footmark through the engineer level, signal or ask the rod-person to "raise for red." The rod-person should then slowly raise the rod until the next lower red number comes into view. Remember, foot measurements on the Philadelphia rod are in red.

Target reading

There may be times when you are hindered from taking a direct reading. These hindrances may be due to poor visibility, long sights, and partially obstructed sights, as through brush or leaves. When this happens, it will be necessary to use targets. The target can also be used to mark a rod reading when numerous points are set to the same elevation from one instrument setup.

Targets for the Philadelphia rod are usually oval, with the long axis at right angles to the rod, and the quadrants of the target painted alternately red and white (fig. 3–7). The target is held in place by a C-clamp and a thumbscrew. There is a lever on the face of the target you use for fine adjustment of the target to the line of sight of the engineer level. The targets have rectangular openings approximately the width of the rod and 0.15 feet high through which the face of the rod may be seen.

A linear vernier scale is mounted on the edge of the opening with the zero on the horizontal line of the target for reading to thousandths of a foot. When using the target, the rod-person takes the rod reading.

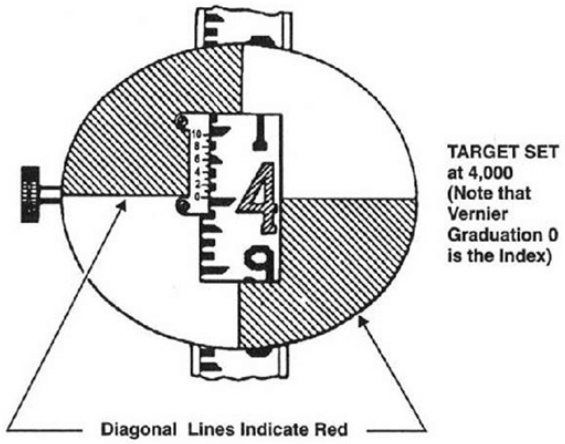


Figure 3–7. Target.

When you sight through the engineer level, you have to motion either up or down so that the rod person can place the horizontal separation of the target in line with the horizontal crosshair of the instrument. When the horizontal separation and the horizontal crosshair coincide, you then can wave the signal for "all right."

After you signal "all right," the rod-person can then tighten the target clamp. The rod-person should then hold the rod on the point again to ensure the target has not slipped. The rod should then be "waved" by pushing it about a foot away from and toward the rod-person's body to be sure the rod has been held in the first vertical position. You should then recheck the target reading. If the horizontal crosshairs do not coincide, the target must be reset. The rod-person then reads the target to feet, tenths, and hundredths of the nearest foot graduation below the horizontal quadrant separation line of the target.

022. Measuring elevations with the engineer level and rod

The vertical distance, measured during leveling, is the difference of elevation between two points. The term *elevation* refers to the height of a point or a particular spot above or below a reference line, called a *datum* or *datum plane*. There are two general types of datum: actual and assumed. An actual datum is mean sea level. An assumed datum plane is an imaginary level surface assumed to have an elevation of zero. It is used as a convenience in leveling procedures.

Bench mark

Bench marks (BM) are survey markers denoting a precise elevation and are placed all over the country. Most bench marks are placed on permanent objects serving as a reference in topographic surveys. It is used either as the starting point in leveling or as a point of closure in checking the accuracy of your work. Bench marks are classified as permanent or temporary.

Permanent

Throughout the United States, a series of permanent bench marks have been established by various governmental agencies. These identification markers are set in stone, iron pipe, manhole covers, or embedded into concrete, and are sometimes marked with the elevation referenced to sea level, either above or below. Typical markers are shown in figure 3–8.

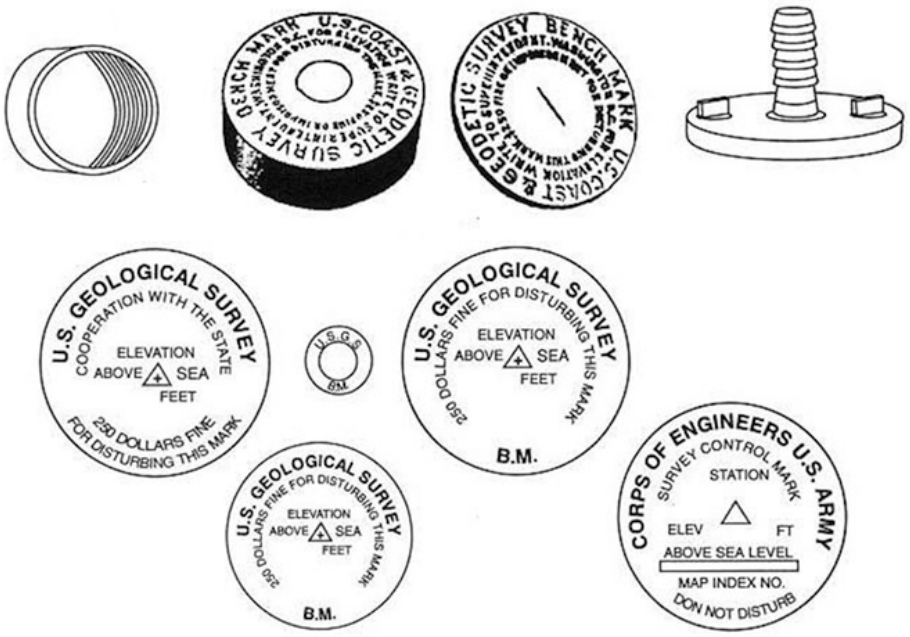


Figure 3–8. Typical bench marks.

Temporary

Temporary bench marks (TBM) are established for the use of a particular job and are kept for the duration of that job. Any substantial object may be used as a bench mark. Spikes may be driven into posts, power poles, or trees or chiseled into stone or concrete structures. Manhole covers and foundation footings can also be used successfully. For clarity, usually only one mark is chiseled or spray-painted on a flat surface. The location, elevation, and description of bench marks are usually shown on the project drawings or in the surveyor's field notes.

Determining elevations

Once a bench mark is established, certain formulas are used for determining elevations. First, you must figure the height of the leveling instrument. You can do this by taking a reading on a level rod that is placed on a known elevation, such as a bench mark. This is known as a backsight (BS).

To determine the height (HI) of the leveling instrument, add the BM elevation to the BS reading from the level rod. This formula is written as HI=BM+BS. An example is shown in figure 3–9. The bench mark elevation is 100.00 feet and the backsight is 5.5 feet. The bench mark elevation added to the backsight reading gives an instrument height of 105.5 feet. Since the BS reading is added to the elevation of the BM to obtain the instrument height, it is usually called a plus (+) sight.

To determine the elevation of a point after the height of the instrument has been established, place the level rod on the point and take a reading through the engineer level. This sighting is called the foresight (FS) reading and is subtracted from the height of the instrument to obtain the elevation (EL) of the point. This formula is written as HI – FS = EL.

For example, in figure 3–10, the height of the instrument is 105.5 feet and the FS reading is 2.3 feet. The instrument height minus the foresight reading gives that point an elevation of 103.2 feet.

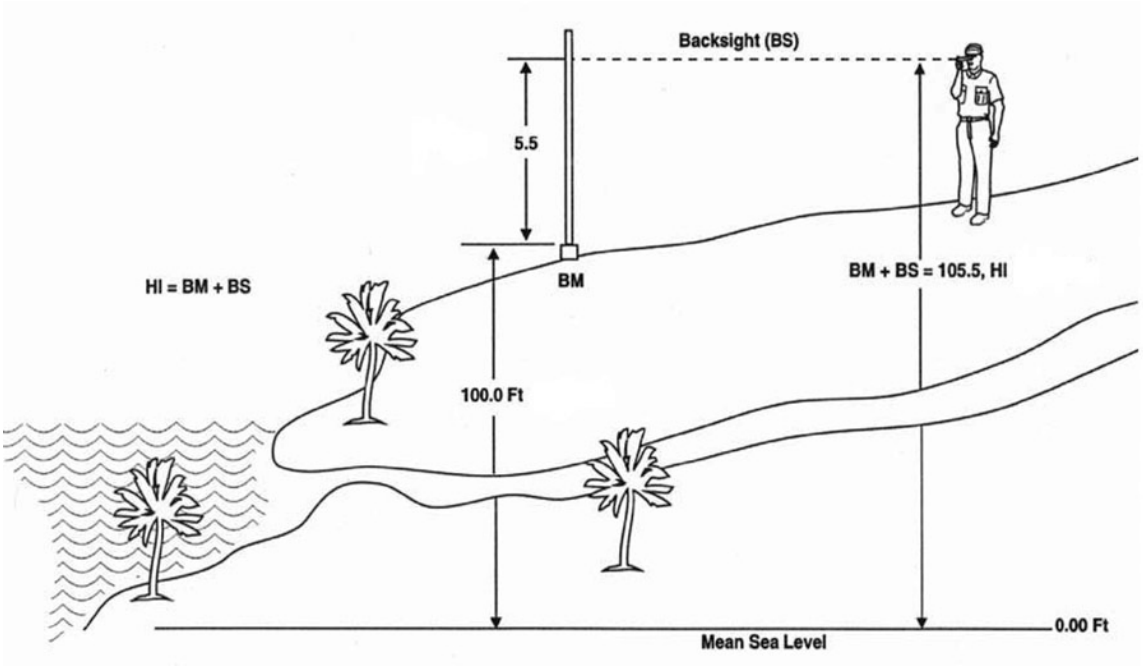


Figure 3–9. Backsight reading to determine instrument height.

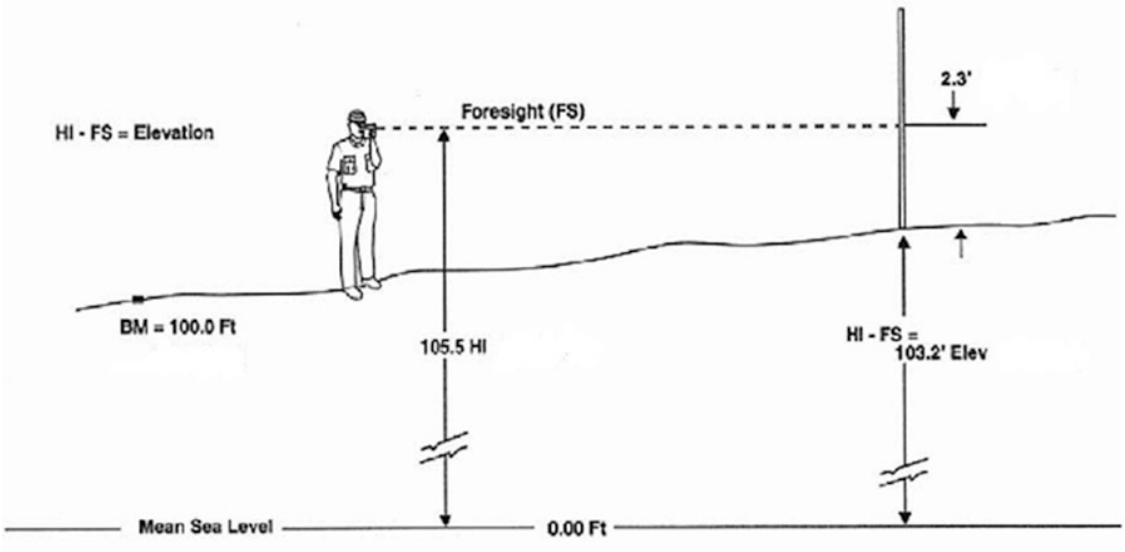


Figure 3–10. Foresight reading to determine elevation.

Checking grade with a level

Checking ground spots for desired grade with a level is shown in figure 3–11. The hub stakes at the side of the construction represent offset grade stakes. Hub stakes are usually two inches by two inches by six inches. They are driven into the ground until the top is at the exact elevation of the finished grade.

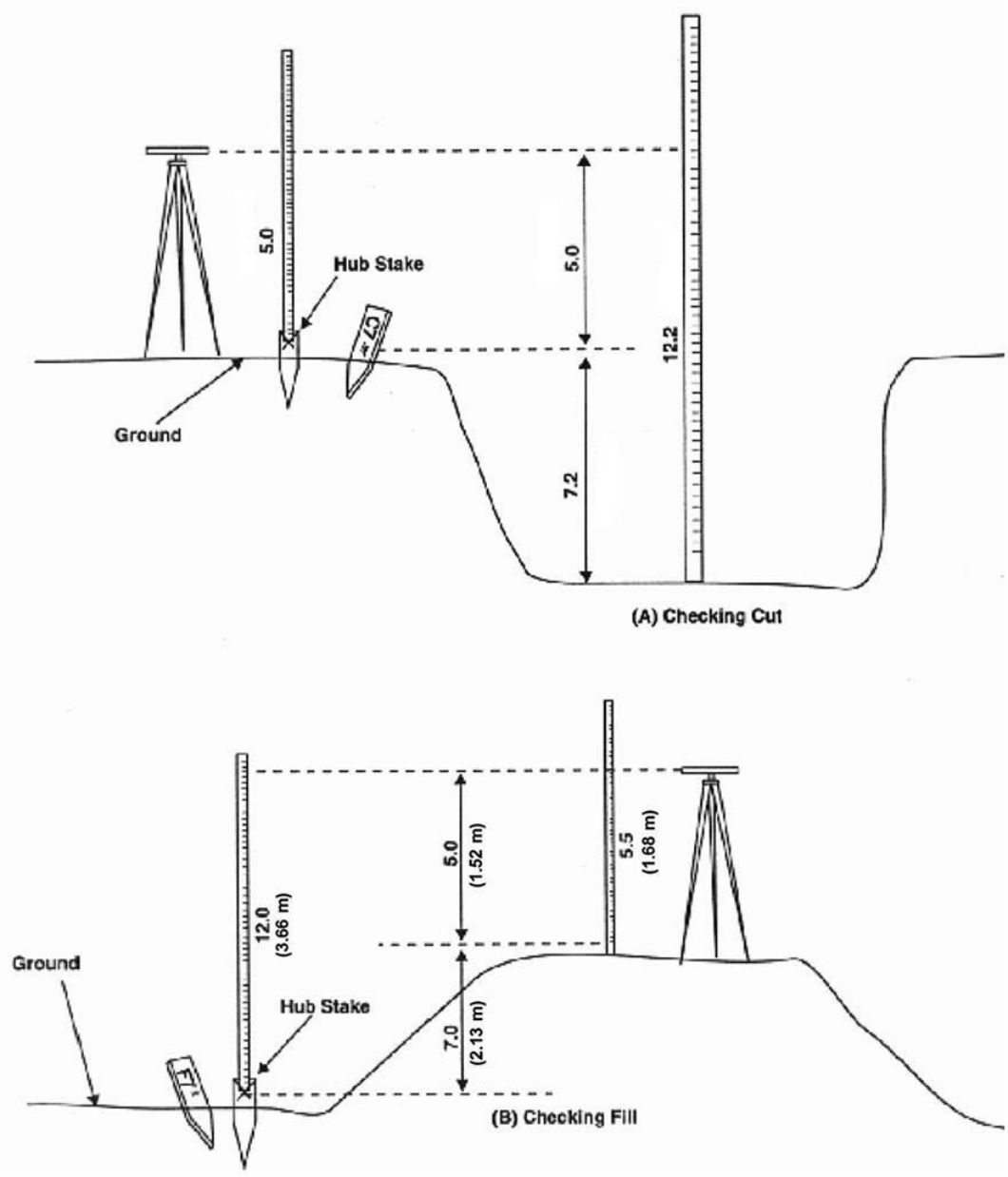


Figure 3–11. Checking cut and fill.

Look at figure 3–11, part "A." The grade stake calls for a cut of 7.5 feet. You need to set up your level and take two readings, first on the hub and then on the excavation. As you can see, your first reading is 5.0 feet. Since the excavation is supposed to be 7.5 feet below the hub, your second reading should be 12.5 (5.0 plus 7.5 as shown). But as you can see, the rod only reads 12.2 feet; therefore, you must cut 0.3 feet more to get to finished subgrade.

Look at view “B.” Your first reading is 12.0 feet on the hub. Since the stake calls for a fill of 7.0 feet, you should read 5.0 on the completed fill. But the rod reads 5.5; therefore, you must fill another 0.5 feet to finish the subgrade.

Turning point

When differences or distances of elevations are too great, or there are obstructions, you will have to make an intermediate setup and sight on point called a *turning point* (TP). When natural features (or manmade construction) are not available, a turning pin, a turning plate or pedestal, or a wooden stake may be used. These not only furnish a solid footing but also identify the same position for both sightings. Such pins or plates are generally used for short periods and are taken up for future use as soon as the instrument readings are completed. Wooden stakes are used for longer periods, except when local regulations require their removal. Turning pins are used in firm ground. This is so the elevation of the TP will not change while the rod-person waits for the engineer who is operating the engineer level to set up at the new position. You can improvise with a railroad spike. On the other hand, turning plates are used in soft ground, sandy soil, marshes, and so forth. They are also used where a pin cannot be driven into the ground (e.g., pavements).

An example of a level run is shown in figure 3–12. Let’s say there is a BM at the bottom of the bank and you want to find the elevation at the top of the bank, which is called point A. As you can see, you are not able to set up on the top of the bank to take a reading on the level rod on point A. The reason for this inability is that the level rod is too short to take a backsight reading on the BM.

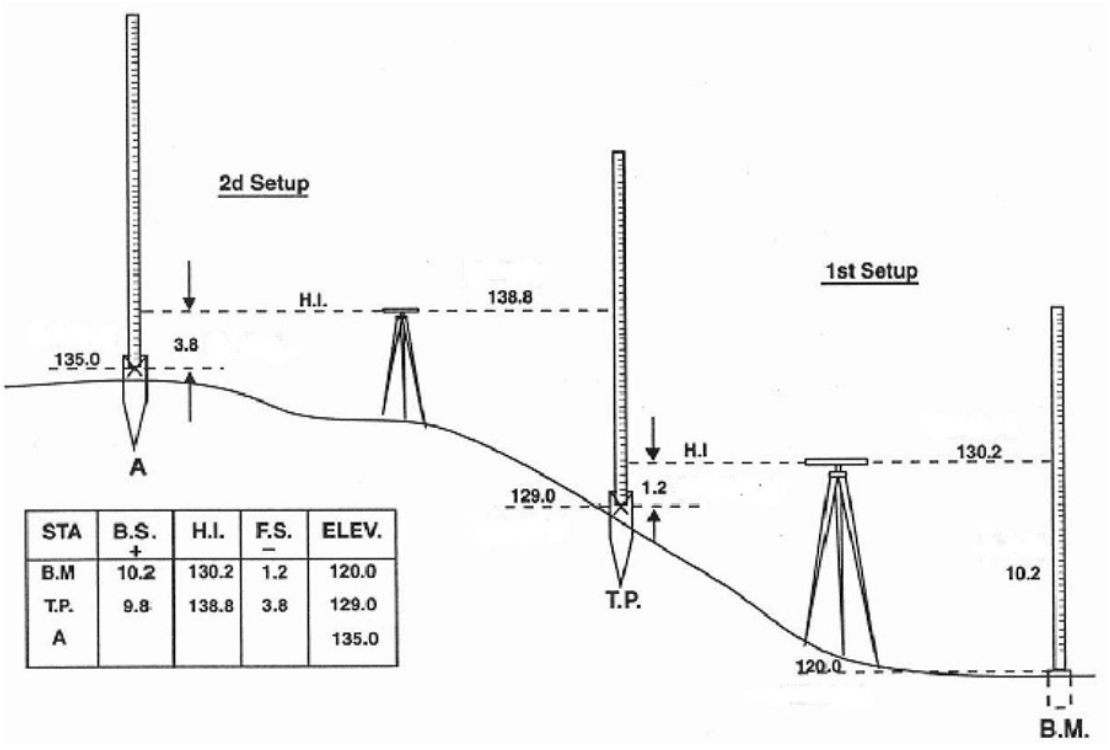


Figure 3–12. Turning point and level notes.

To find the elevation of the top of the bank, first record the BM elevation of 120.0 feet. You then add the backsight reading on the BM to get a level rod reading of 10.2 feet. Now add the backsight reading of 10.2 feet to the BM elevation of 120.0 feet to get the first instrument height of 130.2 feet. Next, take a foresight reading on the TP to get a level rod reading of 1.2 feet. After you have arrived at your reading, subtract the 1.2 feet foresight reading from the 130.2 feet instrument height to get a TP elevation of 129.0 feet.

You are now ready to move the instrument to the top of the bank. Once the instrument is set up, you can take a backsight reading on the TP to get a level rod reading of 9.8 feet. Add the 9.8 feet backsight reading to the 129.0 feet TP elevation to get a second instrument height of 138.8 feet. Your last step is to take a foresight reading on point A to get a level rod reading of 3.8 feet. Subtract the 3.8 feet foresight reading from the 138.8 feet second instrument height to get 135.0 feet elevation for point A.

Some level runs may require more than one TP. However, no matter how extensive the job, the procedure is always the same. You need to add and subtract successive rod readings from a point of known elevation to the point of unknown elevation.

023. Other levels and global positioning system

When a precise horizontal measurement is needed, some type of leveling instrument is used. Precision levels such as laser, hand, and line levels take the guesswork, mystery, and anxiety out of most leveling projects.

Laser levels

With today's technology, we try to work smarter, not harder. The construction industry is no exception, especially when construction dollars are tight. Within the military environment it is very important that we save time, materials, and labor. Laser technology allows us to do just that. Some pavement and equipment shops are using laser levels to get better accuracy and productivity when finish a grading project with dozers and graders. Some other efficient uses for the laser level are to set concrete forms, check for trench depth and slope, and do many other leveling functions.

In the Air Force, the most common laser level is the rotary laser level seen in figure 3–13. On a rotary laser, the laser level beam spins around in a circle. The laser itself is called a "diode" and it spins at a constant 600 revolutions per minute (RPM). As the rotating beam strikes the receiver, the beam hits the internal cells 600 times per minute (10 times per second). It spins so fast, your eyes will tell you that you're looking at a line instead of a moving point. The motor that spins the laser light is in a little box, and usually the box has two or three old-fashioned bubble level vials that tell you when you've got the laser set up so that the line is horizontal (or vertical if you've set the box on its side). The auto leveling feature will then take the level to a point of near perfect level in all directions.

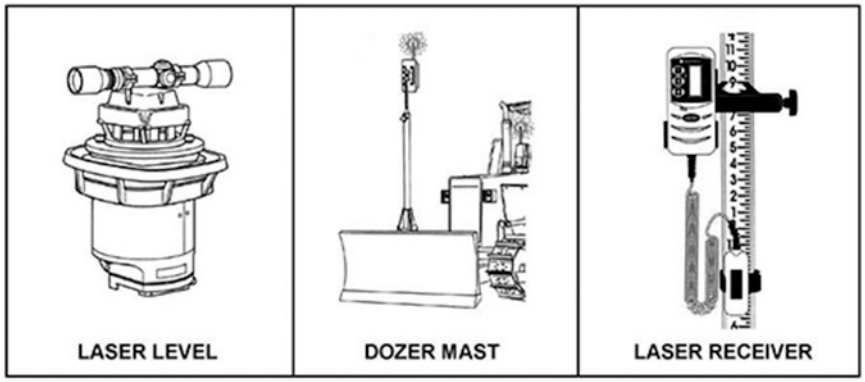


Figure 3–13. Laser, receiver, and dozer mast.

To use a rotary laser outside, you need a "detector," also called a "receiver" (fig. 3–13). The detector is usually a small-sized box with a sensing strip on one side that's a couple of inches long. The strip is tuned to the frequency (color) of the laser light and can "see" the signal that your eyeballs can't. However, what it actually "detects" isn't the strength of the light; instead, it's the pulsing of the light as it sweeps by over and over again. The faster the pulsing, the further away the detector can sense the beam.

The detector usually has two ways of telling you where the beam is located. First, it has a liquid crystal display (LCD) display with arrows that lets you know if the beam is hitting the top or bottom of the strip or (most importantly) when the beam is right in the middle. Secondly, it also has a series of different tones that beep at you when the beam is high, low, or right on.

Now you have a basic understanding on how the laser level operates. Always use the operation manual for setting up the type of laser level your section may use.

Global Positioning System

The Global Positioning System (GPS) is not a new concept within the engineering field. Today the GPS is used in many ways that touches our day-to-day life. This system is being used to survey construction sites, track vehicle location, people and supplies. The GPS is a system of 24 satellites that orbit the earth twice a day at very high altitudes. Put into place by the United States government, GPS provides precise timing and position anywhere on earth, 24 hours per day.

The GPS uses a broadcast-only radio system. The broadcast frequencies penetrate clouds, rain, and snow, and GPS can guide operations in fog, dust, and even at night although some weather phenomenon may disrupt the signal. There are limitations on the coverage depending on where in the world you are in relation to where the satellites are. There are different levels of precision and accuracy available from GPS, depending on the receivers and field methods used. The accuracy varies widely depending on many factors and should be backed up with additional final elevation checks conducted on other equipment. The method used for machine grade control in construction is the same as that used by surveyors for stakeout in construction. This method is called Real Time Kinematics (RTK) GPS.

RTK GPS

To produce positions from GPS that is less than a tenth of a foot (one-tenth of a foot equals 1.2 inches), two GPS receivers are required. One is known as the GPS reference station, and it is fixed in one place. The second receiver is known as the rover, and it may be stationary or mobile. The reference communicates to the rover through a wireless data link using a radio modem.

Both GPS receivers make measurements, or observations of the GPS signals at the same time. The reference station broadcasts its observed information, together with its location and other information, across the radio link to the rover. The rover then combines the data from the reference together with its own data to compute a very precise position relative to the reference. A single reference station can support unlimited rovers, provided they are within about 6 miles, or 10 Kilometers (km). Normally, the range of the radio link is the limiting factor. Radio repeaters can be used, but the number of repeaters allowable depends upon the type of radio used.

GPS reference station

GPS is an RTK rover configuration. It requires a GPS reference station somewhere near the project. We'll briefly describe the reference station, and then look closely at the machine components.

A GPS reference station consists of the GPS receiver, GPS antenna, radio modem, cables, and power supply. In addition, there may be a tripod for the GPS antenna and possibly the radio, depending on the particular site. For construction sites where the work continues for extended periods of time, a semi-permanent location, such as the roof of the site office or some other permanent structure with protection from being moved, is recommended. A reliable power supply is also highly recommended.

This reference station is similar to a laser beacon used in laser machine control systems. However, the GPS reference station has several significant advantages over a laser beacon:

1. It provides not only vertical information, but also horizontal positioning anywhere within the project area or anywhere on the planet.
2. It broadcasts over a large area (up to about six miles with appropriate radios).

3. Its broadcast is not restricted to a plane.
4. It can broadcasts through dust and around obstructions if properly equipped.

The GPS reference station requires a starting location. For best results, the reference receiver is set up on a surveyed point (a bench mark is ideal). It must be a known elevation so as to calibrate the reference. A simple and effective way to establish these survey points is through the services of a surveyor experienced with GPS equipment.

When properly utilizing the methods we just discussed in conjunction with earth moving equipment, we have the ability to move a lot of material in a short period of time. We will discuss how using one of the three available equipment mounted systems allows us to establish grade quickly and efficiently.

Blade control devices on earth moving equipment

The components used in GPS to position the machine's blade include the following:

- One GPS receiver with dual antenna ports.
- Two GPS antennas.
- One radio.
- On-board computer and control box with compact flash data card.
- Two GPS antenna masts, cables and mounting brackets.
- Three light bars (for the older system; hardwired into the hydraulic system for newer models).

The GPS antennas are mounted with one mast at each end of the blade of the dozer or grader (fig. 3–14). The radio antenna may be mounted in any convenient location near the high point of the machine. The GPS receiver is normally mounted away from the operator where it does not impede movement. The control box is mounted inside the cab, close to the operator and within easy reach. The light bars may be mounted inside the cab or outside. In both cases, the brackets are designed for quick release and daily removal. Using a rugged cable harness, the system components are connected together and to machine power through the ignition switch or directly to the battery.

Figure 3–14. GPS dozer masts.

Figure 3–15. Control box.

GPS first requires a detailed computer design of the site, which is entered into the on-board computer and displayed throughout the project. The design is used to compute the cut or fill at any particular location using elevation data from the GPS. The GPS calibration provides the information necessary to work in the computer program's coordinate system. Once the design and calibration are input into the on-board computer, GPS data is used to manipulate the blade. GPS signals are received through the antennas and sent to the receiver.

At the same time, reference station data is received through the radio link and sent to the receiver. The data is combined to produce blade position and blade crossfall (the transverse sloping of a roadway toward the shoulder or gutter on either side). This information is passed to the on-board computer. The operator can toggle between separate cut sections or phases of project at any time. The display accounts for the heights of the antennas above the base of the blade, and it performs another very important function. The display compares the GPS positions at the base of the blade to design elevations and computes the cut or fill to grade in real-time. In older systems, the computer passes this cut/fill data to the GPS light bars, which guide the operator up or down for blade control and right or left of a defined alignment. However, newer systems which are hardwired into the hydraulic system manipulate the blade controls autonomously without input from the operator. The operator is literally "along for the ride" at that point.

NOTE: A GPS system is an efficient and cost effective way to move a lot of earth in a hurry; however, as a result of its accuracy issues (due in large part to the system you are using, the satellite coverage in your area, and the set-up of the reference station), the GPS system is not meant to be used for projects with slight tolerances (<¼ inch from finished elevation). The best way to tackle large projects with tight tolerances is with a combination of GPS for the initial dirt work and finish the elevations to within an inch, then adding a laser system for greater accuracy.

Laser operated blade control systems are attached to heavy equipment (Dozers, Graders, etc.) and they help the equipment operator know when he or she is "on grade." Being "on grade" means you are "at level" or "on level." A rotary laser is mounted on a tripod somewhere on the construction site out of the way, preferably on a fixed elevation, and the receiver is mounted to the blade of the equipment. The laser receiver will inform the operator when they are aligned with the laser using green lights or a combination of red/green lights, and if equipped you will hear a series of beeps (off grade) to a steady tone (on grade), so the operator will know when they need to cut material, or provide fill. Equipment-mounted receivers are usually larger than normal receivers, due to most rough grading jobs being on rough terrain, which means that you benefit from the receiver having a larger "window" to detect the laser line. If the receiver's display is *not* equipped for sound then the equipment operator will have to monitor the display lights which indicate when it's "on grade."

These laser systems can significantly improve the productivity and accuracy of grading equipment by as much as 50 percent over conventional methods.

Line level

The line level, commonly referred to as a string level, is usually made of aluminum with a glass tube mounted in the case. The line level is a short level with a hook on each end for hanging on a cord (fig. 3–16). Its length varies, but the most commonly used US line level is three inches long. Line levels are used to check whether two points are level, especially where no flat surface is available. For instance, a line level can be attached to a string stretched between two points, allowing the user to make an accurate comparison of heights between the two points. Always use nylon string because it stretches tight without breaking when setting up a string line/line level. They are ideal for smaller jobs, such as patios, sidewalks, and small pads.

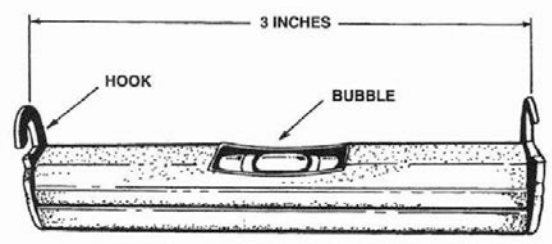


Figure 3–16. Line level.

When you use the line level, stretch a cord taut between the two points so the cord is at the exact elevation and lies along the desired working line. Hang the line level by the hooks about midway between the two end points, and adjust the line at each end so that the bubble in the glass tube lies between the hairlines. Do not use a line level where the cord is over 25 feet long; if you do, the weight of the line level causes the cord to slack and you will get an inaccurate elevation reading.

Carpenter's hand level

Small-sized projects, such as patios and sidewalks, can be effectively laid out using a string line and carpenter's level (fig. 3–17). During the layout phase of your project, measure the dimensions of the area and then mark them off. This gives you a guide to go by. Keep in mind, you should always level when you remove large amounts of material. To use the carpenter's level, place the instrument on the surface of the area to be leveled; if the bubble falls between the two black lines, then your area is level. If the area isn't level, you may have to add or remove material to obtain the desired elevation. The most common carpenter's level we use is four feet in length; it also comes in 2- and 6-foot lengths.

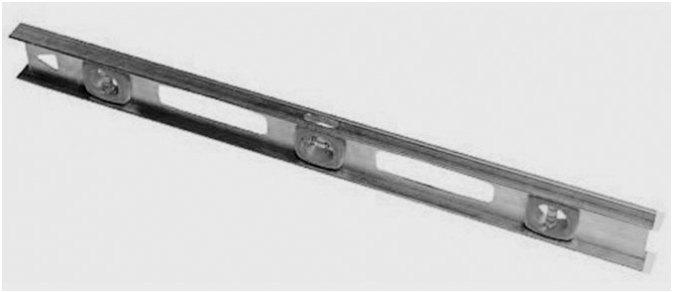


Figure 3–17. Carpenter's level.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

020. Engineer levels

1. What is used to center the bubble of the bull's-eye level?

2. How is the compensator suspended on the self-leveling level?

3. When should you start maintaining and caring for your engineer level?

4. Why should most leveling instruments be set up in the shade?

5. What are the three cardinal rules of surveying?

6. How is the tripod legs of the leveling instrument set on sloping surfaces?

7. When leveling the engineer level, how many times should you turn the instrument 90° then back to its original position, before you turn it 180° from its original position?

8. After leveling is complete, how many leveling screws must bear firmly against the leveling head of the engineer level?

021. Types of measuring rods used in measuring vertical distances

1. Describe what a leveling rod is and for what is it used.

2. List the two general classes of leveling rods.

3. What do the large red marks represent on the Philadelphia rod?

4. Why is there an advantage in using a target rod to measure vertical distances?

5. What should you do if you cannot see the next lower foot mark through the level instrument?

6. When using a leveling instrument to measure distances, what can the rod person do to ensure that the rod is vertical?

022. Measuring elevations with the engineer level and rod

1. Define the term *elevation*.

2. Once a bench mark is established, what is the first thing you need to do to determine an elevation?

3. What are hub stakes used for when checking ground spot for desired grade with a level?

4. Which type of turning point should you use on sandy soil? On firm ground?

023. Other levels and global positioning system

1. The rotating beam from the laser level strikes the receiver how many times per minute?

2. What does GPS stand for?

3. A GPS reference receiver is set up on what type of point?

4. Why does GPS on board computer require a detailed computer design of the site?

5. What type of slight tolerance projects is the GPS system not well suited for?

6. What is a line level used for?

7. Why should you *not* use a line level with over 25 feet of cord?

8. What types of small projects are carpenter’s levels used with?

3–3. Construction Drawings

Within our career field, we need to be able to look at plans for a project and be able to execute that project with minimal explanation and maximum efficiency. The basic component of a construction project is the construction drawing. In this lesson, we will discuss construction drawings and their components.

024. Construction drawings

Construction drawings (also called working drawings or plans) furnish enough information for a builder to complete an entire project. Construction drawings include architectural, electrical, and mechanical drawings as well. The main construction drawing is usually prepared from a freehand sketch or a design illustration. Project drawings include all the drawings necessary for the different Civil Engineer personnel (i.e., carpenters, electricians, and pavement and construction equipment operators) to complete the project.

The construction drawings that you will be using have solid and dashed lines that show areas of construction and their dimensions and areas of work. You can compare the lines and symbols on construction drawings to the lines and symbols on road maps. On road maps, different kinds of lines indicate the varying types of roads, and symbols identify state capitals, airports, and points of interest. Maps also show the distances between towns and cities and their size.

Drawings are pictures

When you see a picture of a proposed construction project, your mind can see the finished project even before you start the work. *Engineers* usually draw these pictures, showing various views. A drawing shows more than what has to be built and how it should look; among other things, it gives dimensions from which you can estimate how much labor and materials are needed to do the job. A set of drawings and specifications should describe the construction of any project. Drawings and specifications give you a complete graphic description of a proposed construction project. In most cases, a set of working drawings starts by showing the boundaries, contours, and outstanding physical characteristics of the construction site and its adjoining areas. Succeeding drawings give instructions for the excavation of utility lines, disposition of existing ground, erection of foundations, and anything else needed to complete the construction project. Normally, working drawings are presented as general and as detail drawings. General drawings show overall relationships; they consist of plans and elevations. Detail drawings show specific features; they consist of sectional and detail views.

Projection of views

You may need to see a drawing of a project from more than one view to determine the size, the shape, and the material with which the project is to be built. To complete the project, you may need a two-dimensional drawing (fig. 3–18) or a three-dimensional drawing (fig. 3–19). You must be able to read the different views provided with each drawing. Interpreting drawings is a critical part of your job.

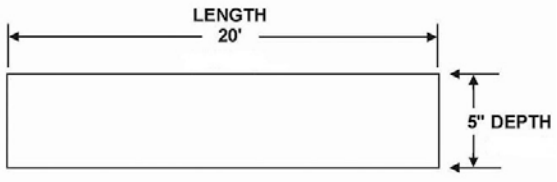


Figure 3–18. Two-dimensional drawing.

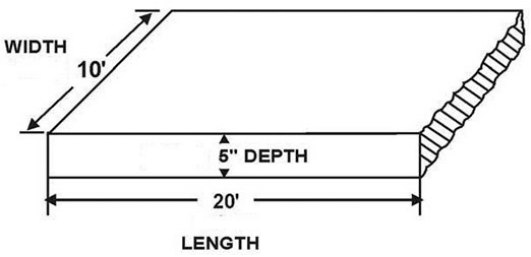


Figure 3–19. Three-dimensional drawing.

Plan views

In working drawings, plan views are obtained by looking down on the project from a bird's eye view. These views correspond to "top" views and involve only horizontal dimensions of width and depth. There are several types of plan views used for specific purposes, such as plot plans, foundation plans, framing plans, and floor plans. Here, you will study the plot and foundation plans since these are the two you will work with most.

Plot plan

A plot plan (also called site plan) shows the boundaries of the construction site and the location of the project in relation to boundaries and existing structures. The plot plan shows the ground contour, roads, and walks. It also locates utility lines, such as sewer, electric, water, and gas.

Foundation plan

The foundation is the starting point in the actual construction. Foundation plans show a top view of the footings or foundation walls, displaying their area and location by distances between centerlines and distances from reference lines or boundary lines.

025. Identifying lines, symbols, and abbreviations on construction drawings

Reading a drawing involves the same process as reading a book. To read a book, you convert standard symbols used by the writer into sound or thought patterns. In reading a drawing, you convert standard symbols used by the engineer into thought patterns.

Lines

The most basic symbol on drawings, yet the one requiring the greatest understanding, is the line. Refer to figure 3–20 as you study the following paragraphs explaining the types of lines you typically find on drawings.

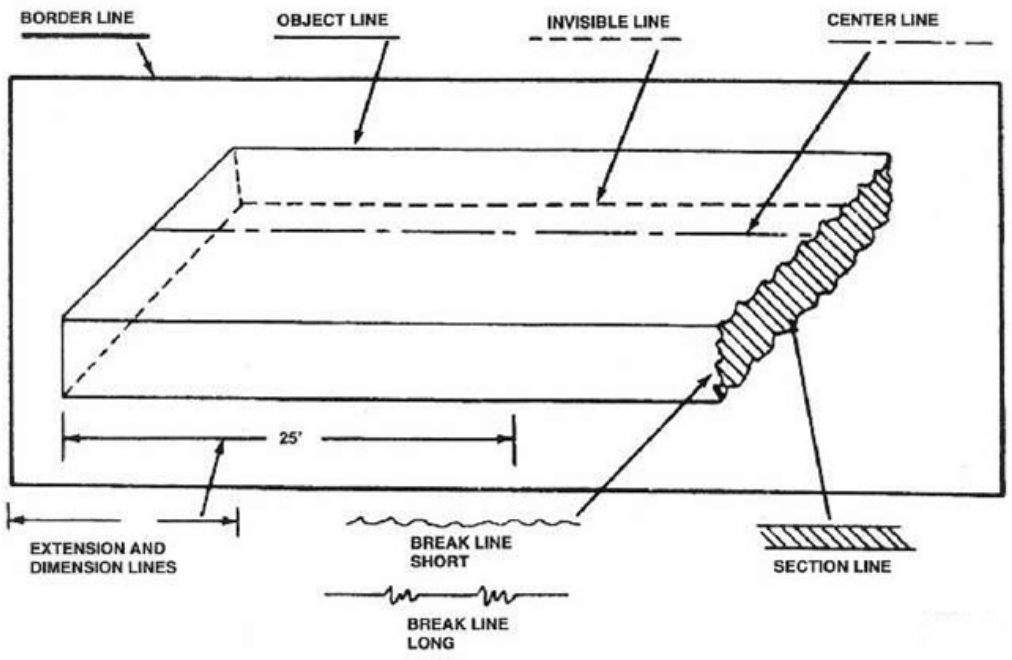


Figure 3–20. Types of lines.

Border line

A border line is a heavy, continuous line around the outer edge of a drawing. It tells the reader the drawing is complete within the border line. Exactly what the illustration is supposed to be is noted on the legend in the lower right-hand corner, along with other reference material.

Object line

The object line outlines the specific item illustrated by the engineer. It is a heavy, unbroken line that shows the visible outline or edges that a person looking at the house, building, sidewalk, or pavement would see. Because the object line forms the outline of the object being illustrated, it is one of the most important parts of the working drawing.

Center line

A center line is made up of alternate long and short dashes. It generally is called the dash-and-dot line. Use it when you must use the center of the object as a reference.

Dimension and extension lines

Dimension lines show the distance between two points. The figure in the break or on the top of the dimension line states the exact measurement. Extension lines serve as stops for the dimension line. An arrowhead at each end of the dimension line touches one of the extension lines. Extension lines do not touch the object. Each extension line starts $^{1}/_{16}$ inch from the object and extends ⅛ inch beyond the dimension arrow. When a dimension must be shown inside, the centerline and the object line serve as stops for the dimension line.

Break lines

A break line is a wavy line or a straight line with wavy intervals. A break line shows that parts have been left out or that the full length of a part has not been drawn.

Hidden lines

A series of short dashes shows hidden or invisible edges—edges that are hidden under some other parts of the structure.

Section lines (shading)

Shading on detail drawings shows the type of material used, in addition to showing a cutaway of an object.

Symbols

As you see, lines on a drawing convey certain thoughts and ideas from the engineer to you, the reader. Since lines alone do not tell the full story, symbols and abbreviations must also be used. Symbols stand for words or groups of words. Without the use of symbols, every item in construction would have to be spelled out on the drawings. Figures 3–21 and 3–22 show some common symbols used in working drawings.

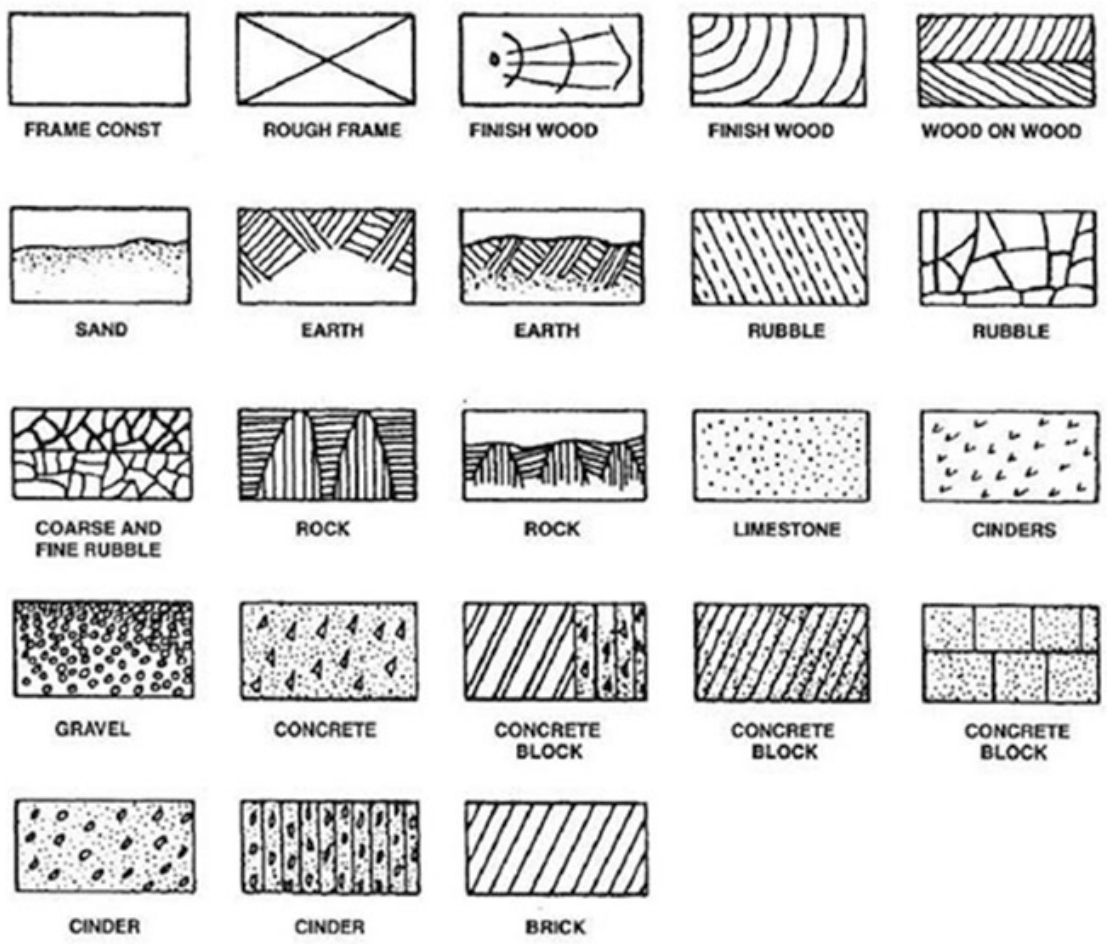


Figure 3–21. Symbols of common materials.

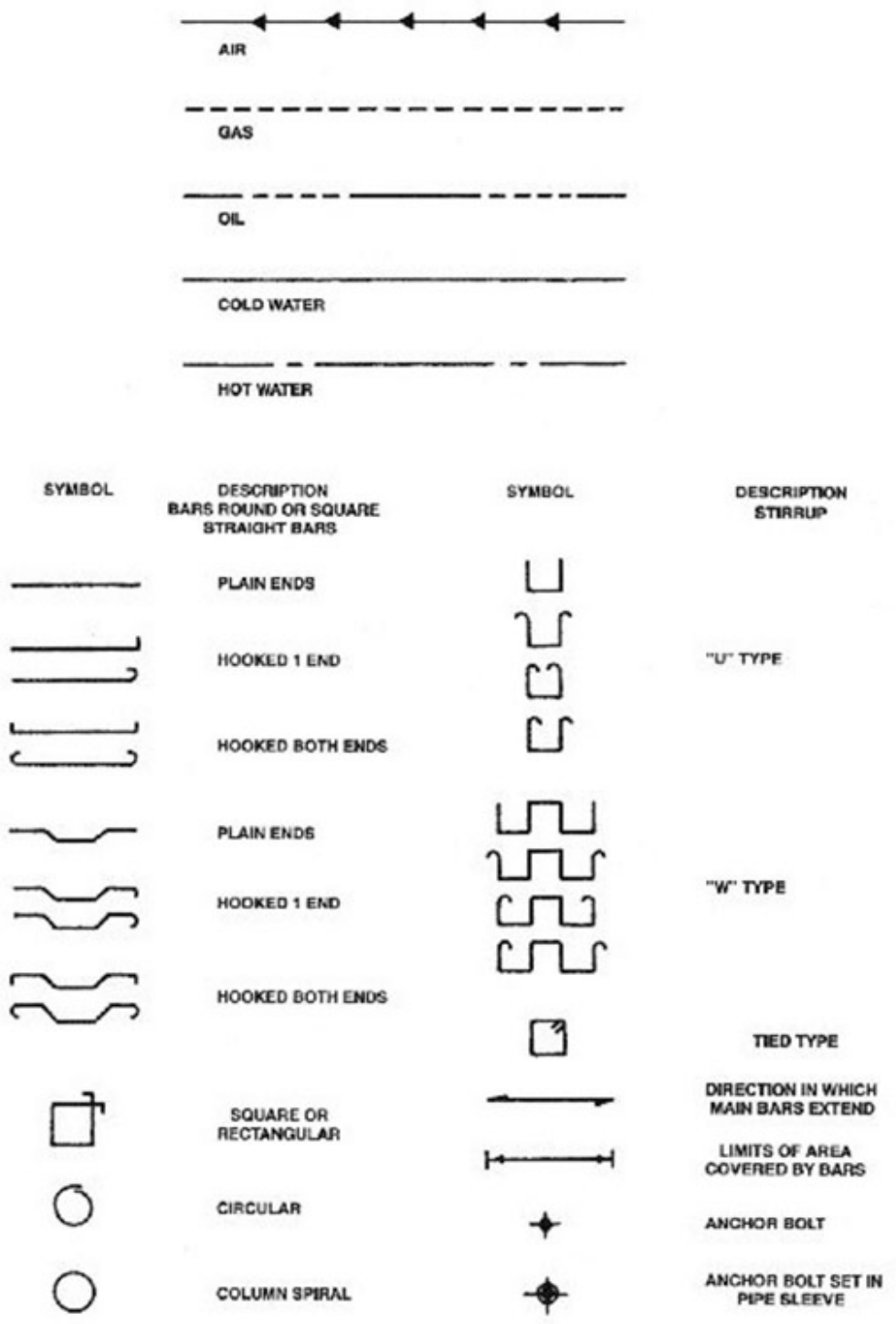


Figure 3–22. Fluid lines and reinforcement symbols.

Abbreviations

Standard abbreviations are used for the same reason that symbols are used. For example, the letters "CTR" on a drawing stand for center. But, since some abbreviations have more than one meaning, find out for sure the meaning of any questionable abbreviation before you go on with a job. Some of the most important abbreviations for you to know are listed in the following table:

Name	Abbreviation	Name	Abbreviation
Aggregate	AGGR	Drain	D or DR
Anchor bolt	AB	Excavate	EXC
Area	A	Expansion joint	EXP JT
Area drain	AD	Floor	FL
Asphalt	ASPH	Floor drain	FD
Asphalt cement	AC	Footing	FTG
Asphalt tile	AT	Foundation	FND
Basement	BSMT	Gas	G
Blueprint	BP	Inside diameter	ID
Brick	BRK	Limestone	LS
Building	BLDG	Masonry opening	MO
Building line	BL	Material	MATL
Cast stone	CS	Maximum	MAX
Catch basin	CB	Minimum	MIN
Cellar	CEL	Mortar	MOR
Cement	CEM	Plumbing	PLBG
Cement floor	CEM FLR	Precast	PRCST
Center	CTR	Reinforce	REINF
Channel	CHAN	Rough	RGH
Cleanout	CO	Sewer	SEW
Concrete	CONC	Soil pipe	SP
Contract	CONT	Specification	SPEC
Cubic Feet	CUFT	Square feet	SQ FT
Down	DN	Unexcavated	UNEXC

026. Preparing a working drawing for a sidewalk project

Occasionally, you may have to make a drawing of a proposed project. Don't panic, it's not a hard job. The first thing to do is get the tools you need: a straightedge (ruler), a soft-leaded pencil, some plain white paper, and, if possible, a plastic 90° triangle.

Assume you need to build a sidewalk from an office building to a parking lot (fig. 3–23). The sidewalk is to run parallel to a road and to connect at the southwest corner of the parking lot.

First, physically check the construction site. Then, draw and label the pertinent items (office building, road, parking lot, etc.) on your paper. Next, draw in (and label) the proposed sidewalk in its approximate location. Even though you are not expected to make a professional drawing, you can draw straight lines and print legibly.

Next, measure the applicable distances and put these figures on your drawing. You need to know the distance from the sidewalk to the road,

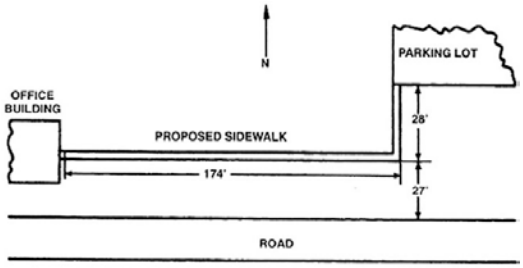


Figure 3–23 Sketch of a proposed sidewalk.

as well as the distance from the porch (on the office building) to the corner where the sidewalk turns toward the office building.

In a clear space on your drawing, make a list of special instructions. This list should contain such things as the following:

- Width and thickness of the concrete.
- Type of finish on the sidewalk.
- Type and mixture of the concrete to be used.
- Required site preparation.
- Reinforcement requirements, if needed.
- Types of forms to be used.
- Any other special instructions.

Now check your drawing. Could you build the sidewalk without any other instructions? Ask yourself, "If I gave this drawing to another pavement and construction equipment operator, would this worker be able to build the sidewalk?" If you can answer yes, then you have a good drawing.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

024. Construction drawings

1. Who uses construction drawings?

2. What gives you a complete graphic description of a proposed construction project?

3. Besides showing you what has to be built, what else will a drawing show you?

4. What views are shown in detail drawings?

5. When used for a specific purpose, what are four types of plan views?

6. In addition to the boundaries of the construction site, what does a plot plan show?

025. Identifying lines, symbols, and abbreviations on construction drawings

1. On a construction drawing, how is an *object* line identified, and what does it show the reader?

2. When is a *center* line used on a drawing?

3. Why is *shading* used in drawings?

4. On a construction drawing, what do symbols illustrate?

5. If you are not sure of a specific abbreviation on a drawing, what should you do?

026. Preparing a working drawing for a sidewalk project

1. What tools might you need prior to preparing a construction drawing?

2. After physically checking the construction site, what is the next step in preparing a working drawing for a sidewalk project?

3. What would be some *special* instructions to list on a working drawing you are preparing for a sidewalk?

4. How can you know whether you have made a good working drawing of a sidewalk?

3–4. Project Management

Project management is the application of knowledge, skills, and techniques to execute projects effectively and efficiently. Projects can range from small concrete pads to whole heating, ventilation, and air conditioning (HVAC) units all the way up to paving many miles of roads. The basic tenets of project management apply no matter the size of the project. For our purposes in discussing project management within this section, we will concentrate on small projects as those are what we will most likely be tasked to do.

027. Planning a project

Planning starts immediately after receiving the work order from your supervisor. Let us assume the work order is to construct the sidewalk from the previous lesson. As stated earlier, the first thing you must do is to visit the site. Once there, you must assess the area and decide if you need to do anything to the site prior to starting. For instance, is there adequate room for equipment? Are there existing structures which need to be removed? Are there overhead obstructions which could hinder your operations? Is the site accessible from a road or parking lot? How much green-space is going to be damaged in the process of construction? All of these questions and any others you may come up with will help you in planning the project and later managing it. If these items are addressed early on, they

won't become impediments later. Let's look at some specific planning requirements which will help you successfully complete a project.

Equipment requirements

The relative size of your project dictates the types and amount of equipment you have on your project. For the sidewalk project, we would probably want to have at least a skid-steer loader, a dump truck, a plate tamper, and an assortment of hand tools. It may seem inconsequential to worry about equipment for such a small project, but when there are several of these projects going on at the same time, equipment may get scarce. Remember to use the least amount necessary to achieve the goal, but enough to get it done quickly and efficiently.

Personnel requirements

Regardless of the size of the project, you must assess how many personnel are available, or more importantly, how many personnel will be allocated to your project. Having a good idea in your head as to how you want to carry out the project will enable you to come up with a good idea of how many people you will need. You could assign people to each piece of equipment and have two people on the ground; therefore, a total of four for your project. Also, remember that if a piece of equipment is no longer needed or a task is completed, that operator can become a laborer and continue on with the project.

Material requirements

While you are thinking of the way you want to complete the project and how many people you need to complete it, you must also come up with a list of materials that will be needed. This list is called a Bill of Material (BOM). The BOM lists the materials needed and the quantities of each to be ordered for the job. This document is often used by the CE supply personnel to order materials or check present stock to assure material availability before the job is scheduled. The BOM developed for each job should be as accurate as possible and contain sufficient information to allow supply to pull from stock, order non-stock items, and bring together the required items for the job.

If your CE unit does not use a supply system for ordering materials, a BOM must still be initiated. To get the materials needed, you may have to use a government purchase card (GPC); on the other hand, if the item is over a certain dollar amount, you may need to initiate an AF Form 9, Request for Purchase. When you complete the Form 9, you include a detailed description of the item, sources for the item, and a current purchase price from the sources. The Form 9 then goes to the Contracting Squadron for purchase. This can be a long process, but if your cardholder cannot purchase the item, it may be the only way to obtain it.

Items on the BOM may consist of those in the following list:

- Concrete.
- 2 × 4s for framing.
- Expansion material.
- Base course.
- Curing compound.
- Grass seed.

Once your completed list has been ordered and received, you can begin the project.

028. Managing a project

Managing a project started the minute you began planning. It was your responsibility to make sure everything was ready to go prior to starting construction. You came up with a workable plan for the number of people you needed, the equipment you will use, and all the materials needed to successfully complete the job. Now it's time to put all that planning into action and manage the results of your plan.

Timeline, schedule, and sequence of events

A timeline, schedule, and sequence of events should accompany any project, but it is essential for large projects. The larger the project, the more important these items become. Without them, you have no way of knowing where you are, how long it will take you to finish, or if you are using your personnel efficiently.

For a relatively small sidewalk project, a schedule or timeline is not important. However, a sequence of events may be. A sequence of events is your ideas for how you envision the project progressing. Another way of looking at it is a list of "tasks" to be completed. The following table provides a possible sequence of events:

Sequence	Event
1.	Excavate the area and haul off spoil.
2.	Backfill the base course and compact.
3.	Form.
4.	Pour, finish, and cure concrete.
5.	Cut the joints.
6.	Pull the forms and landscape the area.

This list was only for illustration purposes and may not include all the events needed to complete the project. However, as a project manager, it will be your job to make sure everyone knows the sequence and following them as required.

Preventative maintenance task list

The Air force has adopted the commercial industry's approach to preventative maintenance. The approach is based on life-cycle costing and best practices, and is intended to ensure the Air Force's real property is maintained at optimal levels, while keeping costs to a minimum.

Preventative maintenance is a schedule of planned maintenance actions aimed at the prevention of breakdowns and failures. This work should be at the heart of any maintenance program. Standardized preventative maintenance increases the life cycle of assets and reduces the need for major repairs (or even replacement) before the expected life cycle ends. This practice maximizes the life of assets while minimizing mission failure. This type of maintenance may include adjustments, cleaning, repairing, and replacing materials.

Preventative Maintenance Task Lists (PMTL) have been developed to guide these actions of preventative maintenance on equipment as well as horizontal structures. The primary goal of PMTLs is to prevent equipment and horizontal structural failures before they occur. Consequently, PMTLs have been aligned with best practices and incorporates the commercial industry's approach to preventative maintenance. To be considered preventative maintenance, it must be possible to predict the exact scope of a task tied to the frequency, possible variation, and costs to complete the task. The PMTLs have been developed to reflect this information for each task to which preventative maintenance can be performed. As a general rule, if there are no PMTLs developed for a task and the item is not real property, then preventative maintenance will **not** apply to that item.

P&E personnel will use a number of PMTLs to maintain horizontal structures to which they are assigned. The following are examples of a few of these lists:

- Street Signs.
- Inspect Non-Paved Roads.
- Inspect Paved Roads.
- Inspect Non-Paved Parking Lot.
- Inspect Paved Parking Lot.

- Sidewalk.
- Airfield Pavement.
- Chainlink Fence Inspection.
- Fence, Non-Chainlink (ex. barbed wire).

PMTL for inspecting paved roads

The PMTL system is fairly new and currently under development for implementation at all installations. A copy of the PMTL for inspecting paved roads is provided in the following table to help you gain an idea of what preventative maintenance on a paved road will entail when following this PMTL.

Equipment Type:	**G2045 150 1950 02**			
Component:	**Inspect Paved Roads, Culverts and Ditches (per 1 mile, per person)**			
	Preventive Maintenance (PM) Components (Task Description)	**Labor-hrs**	**S**	**A**
	Perform maintenance on the following road features listed:			
1	Evaluate condition of pavements and determine distress levels IAW UFC 3–270–06 (Flexible) and/or 3–270–05 (rigid). Compile results as directed in the UFC and submit to the Pavement Engineer for updating of the Non-airfield Pavement Management Plan. Collect pictures as needed and include with report	3.000		x
1a	Painted symbols/Lines >=20% of symbol not visible (obscured or worn)			
1b	Damaged/Worn signs (Traffic flow, Reserved Parking)			
2	Inspect Drainage features such as culverts and storm drains (perform at least one inspection per year during a rain storm)	0.500	x	x
2a	Obstructed/Damaged drainage (Grates, Grate Collars, Gutters, etc.)			
2b	Areas of sediment, debris, or dead vegetation build-up on surface			
2c	Inspect headwall for concrete damage and scour			
2d	Inspect for washouts greater than 6in depth/height along headwall			
2e	Identify built up soil/debris when blocking ≥40% inlet/outlet			
3	Clear Drainage (Sediment, Foliage, Debris) if present	0.500	x	x
4	Remove vegetation intrusions if present	0.500	x	x
5	Inspect roadside ditches (perform at least one inspection per year during a rain storm)	0.500	x	x
5a	Identify blockage and excessive vegetation ≥25% of designed depth			
5b	Identify areas of the ditch bottom where grade does not allow proper drainage			
5c	Identify areas on front slopes and back slopes with severe erosion/washout for follow-up repair			
6	Clear miscellaneous trash and debris if present	0.500	x	x
	Total Semi-Annual Hours	2.500		
	Total Annual Hours	5.500		
	Annualized Hours	8.000		

Using personnel

Properly using the people you have assigned to your project may be one of the hardest management tasks you face. You may be assigned four people in the morning and by the afternoon, you may only have two due to appointments or the boss pulling them for something else. These are things you must learn to deal with. You may have to adjust your sequence of events to accommodate the shortfalls.

The opposite may also happen. You may get too many people and keeping them working may be difficult. Think ahead and come up with a list of things that you could have them perform as well as

helping with the project. Also, you could merely add them to the crew and finish the tasks on your list much faster. However, if you just can't use them, know when to send them back to the shop. Having too many people working in the same area is as inefficient as having too few.

You must also consider your people's abilities. Putting the right person in the right task will pay dividends in efficiency; however, having the wrong person in a task could be disastrous. Know your people's strengths and weaknesses and put them where they will do the most good.

Safety

As we mentioned earlier, safety is of the utmost importance. Managing a project not only includes making sure your crew is working effectively and efficiently, but also includes making sure your crew is safe. No project is worth people getting hurt. Additionally, the project manager must take every effort to ensure the safety of pedestrians. In the case of our sidewalk, make sure you coordinate with the building's occupants to make sure there are no special considerations. Remember, the occupants of the building are our customers and we need to make every effort to accommodate them and to ensure they are in no danger.

Follow-up

Finally, the project manager must follow-up to make sure the project is completed to the specifications set by the customer and that there are no issues stemming from the construction. Make sure the site gets cleaned up and the occupants are happy with the results. If there are issues, make sure you address them immediately. In the case of the sidewalk, make sure the concrete cured properly, the landscaping looks professional, and the site has been cleaned up. Once the follow-up is complete, you can close the work order and move on to the next one.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

027. Planning a project

1. When does planning a project start?

2. What dictates the types and amount of equipment you have on your project?

3. What is included on the BOM?

4. Which AF Form is used as a purchase request?

028. Managing a project

1. For a construction project, what is another way to view a sequence of events?

2. How is preventative maintenance defined?

3. What information must be reflected on a PMTL for an item to be considered preventative maintenance?

4. List five items that P&E personnel will be assigned to inspect and maintain.

5. What must you know about your people in order to use them properly?

6. What is the last step in managing a project?

Answers to Self-Test Questions

018

1. A, B and C horizons. The "A" horizon is made up primarily of organic materials. The "B" horizon is made up of different materials, such as sand, gravel, silt, and clay. The "C" horizon is rock in its natural state.
2. Because they are spongy, drain poorly, and do not compact.
3. The "B" horizon.
4. It is sometimes called *parent material* because it is where "B" horizon material comes from.
5. The ability of a soil to mold into shapes without cracking or appreciable volume change.
6. A screen attached across the end of a cylindrical metal frame; by screen opening size.
7. The distribution of different size groups within the soil sample.
8. In uniform-graded soil, most particles are about the same size; in gap-graded soil, at least one particle size is missing.

019

1. Mechanical and chemical.
2. To improve the drainage or compaction characteristics of a soil.
3. It cements the soil into a hard mass, and it changes the soil to make it more suitable for construction.
4. Portland cement, bituminous materials, calcium chloride, and lime.
5. By controlling moisture content. It absorbs moisture from the air, thus keeping the soil damp.
6. Half a pound.
7. Sheepsfoot roller, pneumatic-tired roller, and steel-wheel roller.
8. Sand or sandy gravel.
9. Construction equipment, such as tractors and trucks.
10. To help prevent plastic soils from working up into the base course and help reduce frost action.

020

1. Leveling screws on a triangular footplate.
2. On fine, nonmagnetic wires.
3. Immediately upon receipt.
4. Because the level is highly susceptible to expansion and contraction from direct sunlight.
5. Never set up the tripod without finding good footings and setting the legs firmly, never leave the setup instrument unattended, and never straddle the tripod legs.

6. With two legs downhill.
7. As many as necessary (until the bubble remains centered in both positions).
8. All three.

021

1. A graduated pole or stick with a movable marker, and it is used to measure differences in elevation.
2. Self-reading and target rods.
3. Whole foot marks.
4. Mistakes in reading the rod are less likely.
5. Signal or ask the rod-person to raise for red.
6. Wave the rod.

022

1. The height of a point or a particular spot above or below a reference line.
2. Figure the height of the leveling instrument.
3. To give the exact elevation of the finished grade.
4. Turning plate; turning pin.

023

1. Six hundred.
2. Global Positioning System.
3. Surveyed.
4. The design is used to compute the cut or fill at any particular location using elevation data from the GPS.
5. Tolerances of less than ¼ inch from finished elevation.
6. To check whether two points are level, such as in elevation.
7. Because the weight of the level causes the line to slack and you will get an inaccurate elevation reading.
8. Patios and sidewalks.

024

1. Builders, including carpenters, electricians, and pavement and construction equipment operators.
2. Drawings and specifications.
3. The boundaries, contours, and outstanding physical characteristics of the construction site and its adjoining areas. Succeeding drawings will provide instructions for the excavation of utility lines, disposition of existing ground, erection of foundations, and anything else needed to complete the construction project.
4. Sectional and detail.
5. Plot, foundation, framing, and floor plans.
6. The location of the project in relation to boundaries and existing structures, along with the ground contour, roads, and walks; it also locates utility lines, such as sewer, electric, water, and gas.

025

1. It consists of a heavy, unbroken line and shows the visible outline or edges that a person looking at the house, building, sidewalk, or pavement would see.
2. When the center of the object must be used as a reference.
3. To show the type of material used, in addition to showing the cutaway of an object.
4. Words or groups of words.
5. Find out its true meaning before proceeding—some abbreviations can have more than one meaning.

026

1. Straightedge (ruler), a soft-leaded pencil, plain white paper, and, if possible, a plastic 90° triangle.
2. Draw and label pertinent items.

3. The width and thickness of the concrete, type of finish on the sidewalk, type and mixture of the concrete to be used, required site preparation, reinforcement requirements, and the types of forms to be used.
4. If a fellow worker could build the sidewalk from it without other instructions.

027

1. Immediately after receiving the work order from your supervisor.
2. The size of the project.
3. The materials needed to do the project and the quantities of each.
4. Form 9.

028

1. Tasks to be completed.
2. A schedule of planned maintenance actions aimed at the prevention of breakdowns and failures.
3. Frequency, possible variation, and costs to complete the task.
4. Street signs; inspect non-paved roads; inspect paved roads; inspect non-paved parking lot; inspect paved parking lot; sidewalk; airfield pavement; chainlink fence inspection; fence, non-chainlink (ex. barbed wire).
5. Their strengths and weaknesses.
6. Follow-up.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

37. (018) Which soil horizon is the base for *all types* of pavement constructions?
    a. A.
    b. B.
    c. C.
    d. D.

38. (018) The soil property "cohesion" refers to the soil's ability to
    a. expand and contract with changes in moisture.
    b. stick together when dry.
    c. be molded into shapes.
    d. to shed water.

39. (018) Which soil classification is made up of sand and gravel in the "B" horizon and has 50 percent or *less* material passing the No. 200 sieve?
    a. Coarse-grained.
    b. Fine-grained.
    c. Organic.
    d. Plastic.

40. (019) When compacting soil (subgrade) for stabilization, which function does a blanket or insulating course serve?
    a. Distributes the wheel loads.
    b. Helps waterproof the base.
    c. Helps reduce frost action.
    d. Prevents segregation.

41. (020) The device on the self-leveling level used to center the bubble on the bull's-eye is the
    a. azimuth clamp.
    b. leveling screw.
    c. tangent screw.
    d. compensator.

42. (020) When you carry the engineer level over rough terrain between points on a survey, you should always
    a. return it to the carrying case.
    b. leave the instrument on the tripod.
    c. tighten the clamp screw as tight as possible.
    d. loosen the clamp to let the instrument move in case it is hit.

43. (020) When you are setting up the tripod of the engineer level on sloping surfaces, place the third leg
    a. uphill.
    b. downhill.
    c. to the left.
    d. to the right.

44. (021) When measuring vertical distances, who moves the target up or down until it is bisected?
    a. Engineer assistant.
    b. Level operator.
    c. Signal person.
    d. Rod person.

45. (022) What is *actual* datum used as a reference for measuring elevations?
    a. Finished grade.
    b. Mean sea level.
    c. Sea level at high tide.
    d. A grade stake with an elevation of zero.

46. (022) Bench marks are survey markers denoting a precise elevation. Where would be a good place to put a *permanent* bench mark?
    a. Spikes driven into a power pole.
    b. Spray-painted on a flat surface.
    c. Embedded into concrete.
    d. Chiseled into a stone.

47. (023) How many satellites make up the Global Positioning System (GPS)?
    a. 6.
    b. 12.
    c. 18.
    d. 24.

48. (023) The Global Positioning System (GPS) operates off of what type of signal?
    a. Microwave.
    b. Television.
    c. Electric.
    d. Radio.

49. (023) What type of slight tolerance projects is the Global Positioning System (GPS) not well suited for?
    a. <1/4” from finish elevation.
    b. >1/4” from finish grade.
    c. +/–1/2” from grade.
    d. >1/2” from grade.

50. (023) What percentage of increased accuracy are laser systems capable of providing over conventional methods?
    a. 75%.
    b. 50%
    c. 30%.
    d. 25%.

51. (023) What is the *most common* length of a carpenter’s level we use on small projects?
    a. 2-foot.
    b. 3-foot.
    c. 4-foot.
    d. 5-foot.

52. (024) In working drawings, plan views correspond to the orientation of looking
    a. down on the project from a bird's eye view.
    b. at a cutaway of the proposed finished project.
    c. from ground elevation at the front of the completed project.
    d. at three dimensions from slightly above the proposed finished project.

53. (025) What basic symbol in work drawings requires the *greatest* understanding?
    a. Dimension.
    b. Elevation.
    c. Utility.
    d. Line.

54. (025) A line composed of a series of short dashes on a construction drawing
    a. shows everything inside the line is complete.
    b. shows the kind of material that is to be used.
    c. represents a hidden line.
    d. represents a center line.

55. (026) When preparing a sketch for a sidewalk, which step should you perform *first*?
    a. Draw and label pertinent items.
    b. Draw and label proposed sidewalk.
    c. Physically check the construction site.
    d. Measure distances and place figures on the sketch.

56. (026) When preparing a sketch for a sidewalk, what should you add in the clear space on your working sketch?
    a. Your name.
    b. Cost estimate.
    c. Special instructions.
    d. Estimated time of completion.

57. (027) When managing a construction project, what dictates the types and amount of equipment you have on your project?
    a. Size of the project.
    b. Cost of the project.
    c. Number of pieces of equipment in the yard.
    d. Number of personnel assigned to your shop.

58. (027) Which document do you use to list all the materials you need to order for a specific construction project?
    a. Materials Request Query (MRQ).
    b. Request for Purchase (MFP).
    c. Supply Requisition (SR).
    d. Bill of Material (BOM).

59. (027) If an item for your construction project costs more than the allowable government purchase card (GPC) limit and supply is unable to purchase the item for you, you must submit an
    a. AF Form 9 to the Contracting Squadron.
    b. AF Form 1875 to the Contracting Squadron.
    c. AF Form 9 to the Base Supply shipping section.
    d. AF Form 1875 to the Base Supply shipping section.

60. (028) Managing a construction project begins when
    a. planning begins.
    b. materials arrive onsite.
    c. the “notice to proceed” is given.
    d. something goes wrong and decisions need to be made.

61. (028) When managing a construction project, what items let you know when it will be complete?
    a. Materials and resources.
    b. Timeline, personnel, and schedule.
    c. Personnel, equipment, and materials.
    d. Timeline, schedule, and sequence of events.

62. (028) What is the *final* step of managing a project?
    a. Follow-through.
    b. Reconstitution.
    c. Restitution.
    d. Follow-up.

Please read the unit menu for unit 4 and continue ➔

Unit 4. Hand Tools and Powered Equipment

YOUR JOB WILL expose you to a wide variety of hand tools, power tools, and powered equipment. Knowing how to operate and maintain these tools and equipment is an indispensable part of your job. Also, knowing which tool or what equipment is appropriate for the task you are working on is a fundamental part of getting the job done quickly and efficiently.

4–1. Hand Tools and Power Tools

Tools are such a common part of our lives that it is difficult to remember that they may pose hazards. Tragically, a serious incident can occur before steps are taken to identify and avoid or eliminate tool-related hazards. The two most common hazards associated with the use of hand and power tools are misuse and improper maintenance. The lessons in this section discuss the proper use, care, and repair of hand and power tools and equipment.

029. Proper use of hand and power tools

Hand tools are tools that are powered manually. Hand tools include anything from axes to wrenches. The types of power tools are determined by their power source: electric, pneumatic, liquid fuel, hydraulic, and powder-actuated. As stated earlier, the greatest hazards posed by hand and power tools result from misuse and improper maintenance. This lesson covers the proper use of hand and power tools to help you, as a Pavements and Construction Equipment Operator, avoid the hazards associated with using these tools.

Hazard prevention

When using hand and power tools, you are exposed to the hazards of falling, flying, abrasive, and splashing objects; or to harmful dusts, fumes, mists, vapors, or gases. You must be provided the appropriate PPE to protect yourself from these hazards. All electrical connections for these tools must be suitable for the type of tool and the working conditions (wet, dusty, flammable vapors) in which these tools are used. When you use a temporary power source for construction, you must use a GFI.

Hand tools

The following are some examples of hazards presented by hand tools when they are misused or not maintained properly:

- If a chisel is used as a screwdriver, the tip of the chisel may break and fly off, hitting the user or other employees.
- If a wooden handle on a tool, such as a hammer or an axe, is loose, splintered, or cracked, the head of the tool may fly off and strike the user or other employees.

- If the jaws of a wrench are sprung, the wrench might slip.
- If impact tools such as chisels, wedges, or drift pins have mushroomed heads, the heads might shatter on impact, sending sharp fragments flying toward the user or other employees.

When using saw blades, knives, or other tools, you should direct the tools away from aisle areas and away from other people working in close proximity. Knives and scissors must be sharp; dull tools can cause more hazards than sharp ones. Cracked saw blades must be removed from service.

NOTE: Iron or steel hand tools may produce sparks that can be an ignition source around flammable substances. Where this hazard exists, you should use spark-resistant tools made of non-ferrous materials.

Power tools

To prevent hazards associated with the use of power tools, workers should observe the following general precautions:

- Never carry a tool by the cord or hose.
- Never yank the cord or the hose to disconnect it from the receptacle.
- Keep cords and hoses away from heat, oil, and sharp edges.
- Disconnect tools when not using them, before servicing and cleaning them, and when changing accessories such as blades, bits, and cutters.
- Keep all people not involved with the work at a safe distance from the work area.
- Secure work with clamps or a vise, freeing both hands to operate the tool.
- Avoid accidental starting. Do not hold fingers on the switch button while carrying a plugged-in tool.
- Maintain tools with care; keep them sharp and clean for best performance.
- Follow instructions in the user's manual for lubricating and changing accessories.
- Be sure to keep good footing and maintain good balance when operating power tools.
- Wear proper apparel for the task. Loose clothing, ties, or jewelry can become caught in moving parts.
- Remove all damaged portable electric tools from use and tag them: "Do Not Use."

Power tools must be fitted with guards and safety switches because these tools are extremely hazardous when used improperly. The exposed moving parts of power tools need to be safeguarded. Belts, gears, shafts, pulleys, sprockets, spindles, drums, flywheels, chains, or other reciprocating, rotating, or other moving parts of equipment must be guarded. Machine guards, as appropriate, must be provided to protect the operator and others from the following:

- Point of operation.
- In-running nip points.
- Rotating parts.
- Flying chips and sparks.

Safety guards must never be removed when a tool is being used. For example, portable circular saws having a blade greater than two inches in diameter must be equipped at all times with guards. An upper guard must cover the entire blade of the saw. A retractable lower guard must cover the teeth of the saw, except where it makes contact with the work material. The lower guard must automatically return to the covering position when the tool is withdrawn from the work material. If there is a guard, do not remove it for any reason when it is in use.

Safety rules

All members of your shop must be trained in the proper use of the tools available. Workers should be able to recognize the hazards associated with the different types of tools and the safety precautions necessary. Five basic safety rules can help prevent mishaps associated with potential hazards when using hand and power tools:

- Keep all tools in good condition with regular maintenance.
- Use the right tool for the job.
- Examine each tool for damage before use and do *not* use damaged tools.
- Operate tools according to the manufacturers' instructions.
- Provide and use properly the right PPE.

Workers and supervisors should work together to establish safe working procedures. If a hazardous situation is encountered, it should be brought immediately to the attention of the proper individual for hazard abatement. Your immediate supervisor is that person.

030. Cleaning, treating, lubricating, and storage of tools and equipment

The word "maintenance" can almost be substituted for the word "safety." For example, when you maintain your tools and equipment properly, you are making them safe—renewing them; that is, they become like new again. Maintenance of tools not only includes minor repair, but also cleaning, treating, lubricating, and properly storing them. With proper maintenance, the life of a tool, or an equipment item, used under ordinary conditions, can be extended indefinitely.

Craftsmen are proud of the tools and equipment they have had for a long time because the tools are still as accurate and serviceable as they were the day they were bought. Proper cleaning, treating, lubricating, and storage of tools can make your work more enjoyable and help extend the useful life of your tools.

Cleaning

Proper cleaning is especially important for your tools. After using a tool or item of equipment, clean it with an oily rag to prevent it from rusting. Tools and equipment can be cleaned in a variety of ways.

Use a brush (a painter's duster or a bench brush) or a vacuum cleaner to clean machines and benches in the shop. An ordinary whiskbroom can be used to clean a drill press. Do *not* use compressed air to clean equipment—the chips and dust thrown into the air create hazards. Another dangerous practice to avoid is using your hands to clean a machine or bench; you can pick up splinters or metal filings that could injure your hands.

When an aircraft engine has operated a specified number of hours, it is disassembled, cleaned, inspected, maintained as necessary, and reassembled. This is called *preventive maintenance*. The Air Force and private industry have found that the correction of minor problems prevents the development of major problems. This type of maintenance, in the long run, saves time, saves money, extends the service life of the machine, and reduces the number of accidents. Although you may not have to completely disassemble shop tools and equipment, you must do routine maintenance on these items according to TOs or manufacturer's instructions. Your maintenance includes cleaning, inspecting the parts for defects, lubricating, and treating.

Treating

After you clean a machine or hand tool, wipe it off with a soft rag impregnated with WD–40® or similar penetrating oil. If the tool has a wooden handle, wipe the handle with linseed oil to keep the wood from drying out. This oil treatment serves to preserve the wooden handle.

Lubricating

The purpose of lubricating tools and machines is to reduce the amount of friction or resistance between two surfaces when one slides against the other. To do this, a film of lubricant is forced into the space between the moving parts, thus reducing friction.

Many equipment items manufactured today have sealed bearings and need no lubrication. If a machine has bearings that need lubrication, refer to the service manual or technical publication for the right type of lubrication and lubricating procedures. On many pieces of equipment we use today, there is a lubrication chart mounted on the machine in a conspicuous place to make lubrication points easy to locate.

Storage

In addition to proper cleaning, treating, and lubricating procedures, it is important that you take care of your equipment when you are not using it to get satisfactory service. Let's see how to store equipment properly.

The way you store tools is an indication of your ability to use tools and your appreciation for tools. If each tool has a particular storage place or special rack, it is an indication of good care and an appreciation for properly maintained tools. There is a close correlation of proper tool care and good workmanship. You should abide by the old motto, "A place for everything and everything in its place." Most tool rooms will have a plan for everything so as to make the room clean, neat and orderly. Some shops even have full time personnel assigned to the tool room to make sure everything stays that way.

If your shop and tool storage area doesn't have racks and tool holders, you can easily make them from wood or metal. Hooks and holders can also be obtained at a reasonable price. A good way to encourage the return of a tool to its proper place is to silhouette the tool on a tool board. This can be done very easily with spray paint, stencils, and masking paper and tape.

If tools and equipment are kept clean and well lubricated, they normally will give good service and will last a lifetime. However, occasionally a tool or item of equipment needs minor repairs. In the next lesson, you will see how to make these minor repairs.

031. Minor repair of tools and equipment

It is a satisfying experience to use a tool or machine in good repair. New tools and equipment normally are in good condition. But after considerable use, they often need simple repairs and adjustments, such as replacing handles, replacing small parts, or installing or adjusting belts, just to name a few. In this lesson, we will discuss some minor repairs you can make to the tools you use.

Replacing hammer handle

To replace the handle of a hammer, drive the new handle through the eye in the hammer head with a wooden mallet or simply tap the end of the hammer against a firm surface. After the handle is in the eye of the hammer, cut the extended part off with a hacksaw and drive a wedge into the saw kerf to spread the end of the handle against the inside of the hammer head to make a tight friction bond. Sand all rough edges and wipe the handle with a rag soaked with linseed oil. The procedures for replacing handles in sledge hammers, hoes, and shovels are quite simple and similar. By looking at a new handle in a tool, you can see how a replacement should fit. A shovel, for example, may require a rivet or screw rather than a wedge.

Replacing small parts

Your hand tools, portable power tools, and shop equipment ordinarily will give you long and trouble-free service; however, they occasionally need replacement parts. It is normally a simple matter to replace parts. When a part requires replacement, refer to the TO or manufacturer's manual and order a new part. If possible, use parts manufactured for your specific brand and model of tool. It may be

more expensive than off-the-shelf replacement parts, but the manufacturer's parts are almost always guaranteed to fit. Unless the tool is extremely old and obsolete, manufacturers have Internet web sites for making ordering replacement parts easy and, in most cases, cost effective.

Installing V-belts

Some portable power tools and many stationary machines are equipped with pulleys; as such, they need V-belts to provide power for operation. One good example of a machine we regularly change belts on is the self-propelled or push-type concrete saw. A concrete saw usually has multiple belts side-by-side on the pulley or specially manufactured belts just for it. Regardless of what type of belt the concrete saw takes, you need to check the belts every time you operate it.

To get adequate power, the V-belts must be of the right size for the pulleys, and they must be adjusted and installed properly. There are many sizes of V-belts. To get maximum power, the belt must fit the pulleys (fig. 4–1). Make sure the belt matches the pulley or sheave grooves so that it will not ride the bottom of the pulley. The sides of the belt pulling against the pulley provide the traction.

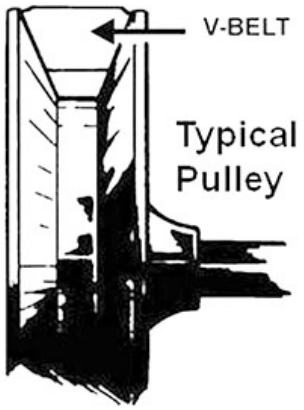


Figure 4–1. V-belt position in pulley.

Another important factor to consider in getting adequate power is to select a belt so that the motor will be as close to the machine as practical. This will prevent some power loss. To get efficient operation, the tension of V-belts must be adjusted properly. Make sure the length of the new belt is the same as the old one. If the new belt is longer, no amount of adjustment will get it tight enough. Without the manufacturer's specifications for belt tension, allow ¾ inch of sag for each foot of distance between pulley centers while applying thumb pressure to the belt. This is just a rule-of-thumb that will work for most applications. However, if you have the manual handy, use the manufacturer's specifications.

Some equipment requires the use of multiple belts to get sufficient traction. If one belt gets worn or breaks, replace all the belts, so that a "matched" set of belts is operating, such as on the concrete saw mentioned earlier. When you install a V-belt, do not roll the belt onto the pulley, because it will break the cords in the belt. Rather, release the tension adjustment before you install the belt.

Replacing bearings

Most equipment manufactured today, both stationary machines and portable power tools, have sealed ball bearings or roller bearings and need very little, or no maintenance. Some parts of the machine may have sleeve bearings. Sleeve bearings are serviceable and require more attention than ball bearings. A good example of bearing sets that you may need to replace is those on a power screed. The bearings need to be constantly adjusted and tightened but also replaced periodically due to the extreme environment in which they live.

Sleeve bearings depend on a film of oil between the shaft of the rotating equipment and the pillow block which holds the sleeve. The sleeve is simply a cylindrical bushing, such as shown in figure 4–2. It is pressed into the block, and an oil hole in the top gives proper lubrication. Make sure the oil holes are aligned and kept open.

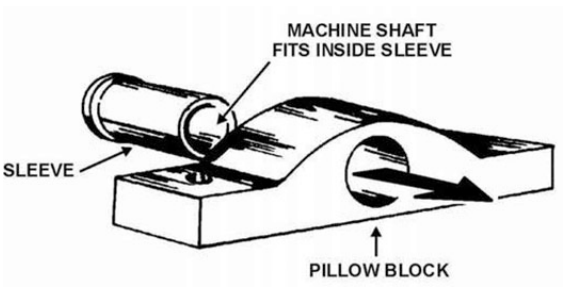


Figure 4–2. Sleeve bearing.

To function properly, the rings on both sides of a ball bearing must fit into the housings and over the shaft snugly. Bearing pullers usually are needed to

pull the old bearing, and a press is very handy to install the new one. Never use a hammer on the ring of a bearing. You can use a sleeve or pipe to install a bearing if a press is not available (fig. 4–3). You will simply use a hammer on a piece of wood placed on the pipe. Make sure the bearing is lubricated so that it will slip onto the shaft easily. You can use the same procedure when you fit the outside ring into the housing.

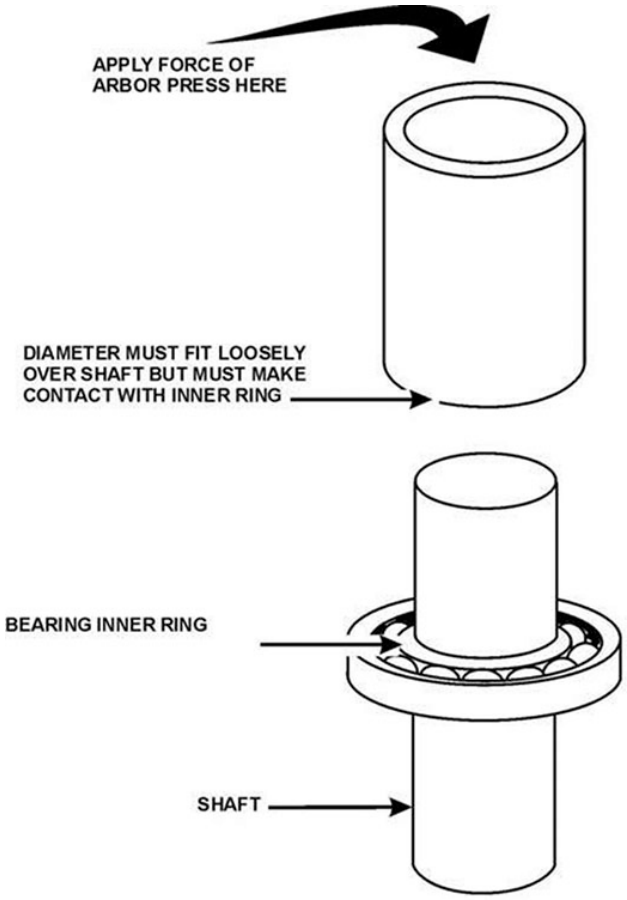


Figure 4–3. Installing a bearing.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

029. Proper use of hand and power tools

1. How are types of power tools determined?

2. What are the two most common hazards associated with the use of hand and power tools?

3. What types of hazards are you exposed to when using hand and power tools?

4. When must you use a GFI?

5. What are some of hazards hand tools can present when they are misused or not maintained properly?

6. What type of hand tools should you use when working around flammable substances?

7. What must be provided on power tools to protect the operator and others from point of operation, in-running nip points, rotating parts and flying chips and sparks?

8. When can you remove a power tool's safety guard when it's in use?

9. To whom do you report any hazardous situation you encounter while doing your job?

030. Cleaning, treating, lubricating, and storage of tools and equipment

1. Explain why you should *not* use compressed air to clean equipment.

2. Though you may not have to completely disassemble shop tools and equipment for maintenance, what maintenance must you do?

3. What is the purpose of lubricating tools and machines?

4. What does the way you store your tools indicate?

031. Minor repair of tools and equipment

1. When replacing small parts on your tools or shop equipment, why is it important to use the manufacturer's replacement parts, although they may be more expensive than the off-the-shelf parts?

2. When selecting a replacement V-belt, what are two important factors to consider in making sure you have adequate power for the operation of your power tool?

3. What should you do if only one belt out of a set of four breaks?

4. If a press is not available, what should you use to install bearings?

4–2. Powered Equipment

Operators of powered equipment normally do not make major repairs. As an operator, however, you are responsible not only for operating the equipment safely but also for performing daily tasks called "operator's inspection and maintenance." For this lesson, we will concentrate on small powered equipment you, as an equipment operator, use day to day. The following examples are by no means all of the equipment you will use throughout your career, but only a small sampling. This discussion will, however, give you a good general idea of what to expect on the job.

032. Operator inspection and maintenance

The Air Force ensures that its assets are ready for day-to-day use and ready for deployments if required through proper operator's inspection and maintenance. As an operator, you must always know what to inspect and how to maintain equipment assigned to your unit. You can find the information you need to conduct a thorough inspection in the equipment's operator's manual. The only difference between inspection and maintenance of powered equipment and heavy equipment is the size and scope of the equipment.

NOTE: Remember, when you sign out a saw or an air compressor from the tool room, you have just accepted the responsibility for that machine and must make sure it is in good working order *before* you take it out to the jobsite as well as when you return it.

Inspection

Each piece of Air Force equipment has an operator's checklist. These checklists are designed to protect you and the equipment you operate. If there is not a checklist for a piece of equipment, use the manual to develop one. For example, when you are operating an asphalt kettle, you must check the bituminous pump as the checklist requires, making sure the pump is free to turn and is not frozen with semisolid asphalt. Another checklist item is before you engage the clutch, you must warm the pump body with the burner to soften the bituminous material around the pump motor to prevent damaging the pump or the clutch.

If you have not operated a particular piece of equipment and don't know how, the first place to go for help is to a supervisor. If the piece of equipment is new to the shop, get everyone together to review the operator's manual until everyone understands the equipment's operating procedures. Why is having everyone review the operator's manual important? The following incident may help you answer this question:

> An operator caused severe damage to a brand new gasoline engine powered air compressor that had never been operated before because the operator ignored the caution signs on the unit. The operator did not even open and look at the checklist provided in a sealed envelope. The operator was charged with equipment abuse. The manufacturer refused to repair the compressor because the guarantee required service and inspection before starting. The fault was not with the equipment—it was clearly neglect by the operator.

Reviewing the operator's manual with everyone will make sure nobody damages the equipment.

Assume that you are assigned to operate a piece of equipment on a certain day. Your checklist may require you to check these items before you start:

- Damage to equipment.
- Fuel level.
- Coolant (radiator) level.
- Leaks under equipment.
- Tools in toolbox.
- Tire condition and pressure.
- Battery and connections.
- Special lubrication.
- Belts and pulleys.
- Horn and bells (or other audible safety signals).
- Lights and reflectors.
- Brakes.
- Instruments.

Maintenance

If you find any deficiencies with a piece of equipment, you must either repair them or bring them to the attention of the appropriate personnel. Low tires or a leak in a hose that needs only tightening with a screwdriver is your (the operator's) responsibility.

When you fuel equipment, you must follow safety precautions to prevent the possibility of fire or explosion. Space does not permit listing all of the safety rules for each piece of equipment you may use. The following examples on fueling vehicles should give you some idea of the importance of this task:

- Do not fuel equipment near open flames or spark-producing devices.
- Do not fuel indoors (ventilation is extremely important).
- Do not smoke during fueling.
- Stop the engine. Fueling the equipment with the engine running could result in a fire or explosion.
- Apply the parking brake or chock the wheels so the vehicle doesn't roll away.
- Keep nozzle of fuel hose in constant contact with tank intake pipe to prevent the discharge of static electricity, which can cause a spark with enough intensity to ignite the fuel vapor.
- When fueling gasoline, use a nozzle without a hold-open latch (it may not shut off in the case of overfilling the tank).
- If reserve supplies of fuel are required on the vehicle, carry them in an approved safety container only, marked appropriately. Protect them from external damage and lash or anchor them to prevent accidental movement.

033. Generator maintenance and operations

The majority of generators used by P&E technicians are equipped with small gasoline engines. They typically weigh between 28 and 220 pounds.

NOTE: Caution should be taken when trying to load or unload any generator by yourself. Wait for assistance if necessary to prevent personal injury.

The generator produces electrical current by utilizing a small gasoline engine to turn an alternator. The electrical current produced is 110/220 volts at 1000 to 6500 watts.

NOTE: It is imperative to know how much power is required for the electric tools to be powered by the generator. If operators fail to take this step, the generator or power tool can be overloaded and damaged.

P&E technicians operate a host of electric powered equipment such as drills, saws, mixers, vibratory consolidators, and grinders. P&E technicians mainly work in remote locations such as the flight line, streets, or conducting Bare Base operations. Since these locations offer no electrical outlets, a generator will be utilized to supply electric power. A critical safety hazard associated with using a generator is the risk of electrocution. Technicians must remain aware of the weather and ground conditions around them to keep the generator, power cord, and tools dry.

Operational checks

The generator must have a pre-op/post-op inspection performed daily when used. The pre-operational inspection consists of performing the following, at a minimum:

- Determine how much power is required for the electric tools to be powered by the generator.
- Make sure all dirt, mud, etc. are thoroughly removed from the unit prior to operation. Special consideration should be given to the electrical panel and the areas next to the cooling air inlet of the engine, carburetor, and air cleaner.
- Ensure the generator is on level, firm, and dry ground.
- Check all bolts and screws for security and tightness. Loose bolts and screws may cause damage to the unit.
- Check engine oil level ensuring that it is within manufacturer's specifications.
- Check fuel level to ensure there is enough in the tank to perform operations.
- Check that circuit breakers and ground protection equipment is set/reset to the ON position.

Operator maintenance

- The operator is responsible for keeping the generator dry and clean. The generator needs to be dry; free of dirt and mud before use. If the generator is wet, be sure to dry it paying special attention to the electrical panel. Always keep the generator covered during wet weather conditions.
- If loose bolts or screws are discovered during inspection. They need to be tightened before operation. The operator is responsible for performing this level maintenance.
- If the engine oil level is low, the operator is responsible for adding enough oil to ensure it is within the manufacturer's specifications. Remember to check the oil specifications to ensure the correct oil is being used.
- If the engine fuel is low, be sure to use the correct fuel to top off the tank. Remember that several pieces of equipment with small engines are equipped with 2-cycle engines that use a special fuel/oil mixture. Check to ensure the correct fuel is being added to the generator.
- If the ground is uneven, soft, or wet, find a more suitable location to place the generator. There may even be a need to build the area up with dunnage to support the generator.

Generator start-up procedure

The following table provides general start-up procedures:

Step	Procedure
1.	Determine the power requirement of the tools to be operated by the generator.
2.	Turn the circuit breaker to the **OFF** position.
3.	Check to be sure the fuel valve is open.
4.	Set the choke to the **ON** position.
5.	Use the key to start the engine (or the pull cord if needed, key in **ON** position)

Step	Procedure
NOTE: Before this step, ensure hearing protection is in place. Excessive noise from the generator over time may cause hearing loss.	
6.	When the engine starts, slowly decrease the choke until the engine idles smoothly and is warmed up.
7.	Last increase the engine speed to full throttle and turn the circuit breaker to the **ON** position.

Generator shutdown procedure

As soon as the generator is no longer needed, the generator needs to be turned OFF. It is important to turn the generator off to mitigate the possible risk of electrocution. The following table provides general shutdown procedures:

Step	Procedure
1.	Turn the circuit breaker **OFF**.
2.	Turn the engine switch to the **OFF** position.
3.	Lastly, turn the fuel valve to the **OFF** position.
NOTE: In the event of an emergency, quickly turn the circuit breaker to the **OFF** position. Also when changing attachment, ensure generator is turned off or power tool is unplugged.	

034. Operation and troubleshooting of small engines.

There are generally two types of small engines used by P&E personnel: 2-stroke and 4-stroke engines, as shown in figures 4–4 and 4–5. Often these engines are referred to as 2-cycle and 4-cycle engines. This use of different terminology should not be allowed to cause confusion; seeing the words “cycle” and “stroke” are frequently used interchangeably when referring to small engines. There is no hard and fast rule as to what type of equipment will be powered by which type of small engine, so it is important to pay attention to the details of both.

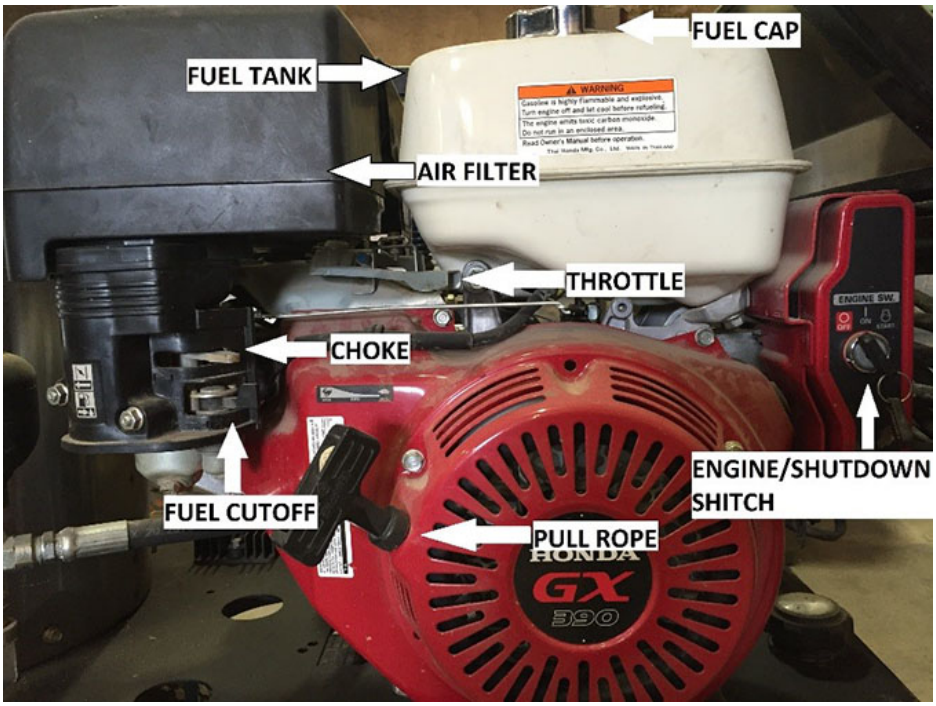


Figure 4–4. Four stroke engine.

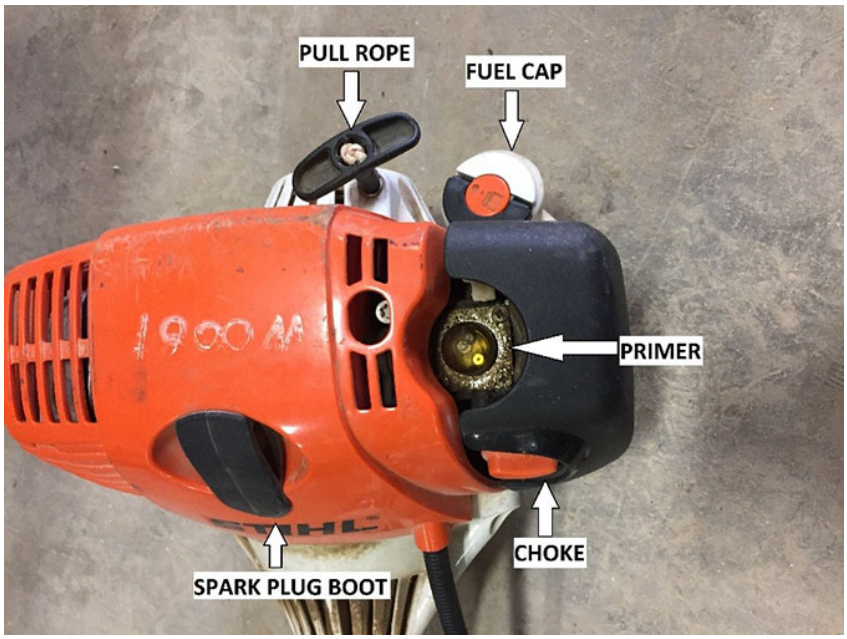


Figure 4–5. Two stroke engine.

Both types of engines operate on the same three essential elements to power equipment. These three elements include: air, fuel, and ignition resulting in engine combustion. Engines go through a series of events as they run. These events are called “strokes.” The strokes are called the intake stroke, compression stroke, power stroke and exhaust stroke. A brief explanation will be provided to demonstrate how these series of events work to produce the combustion used to power equipment.

First consider the three elements that produce combustion. The first element is air. This is the same air used to breathe. The air gives the engine the oxygen required to burn in the engine cylinder for combustion. The second element is fuel. In most cases this fuel is going to be unleaded gasoline. The third element is ignition. This ignition is a powerful electrical current used to ignite the air and fuel mixture resulting in combustion. For all of these elements to come into play to produce combustion, they must happen at a specific time and sequence.

Operation of a 4-cycle engine

The following table provides the steps of operation for a 4-cycle engine:

Step	Procedure
1.	The first sequence of events is called the intake stroke. During this event, the piston is moving downward pulling a precise mixture of air and fuel through the carburetor into the engine cylinder. This step is followed by an upward stoke of the piston.
2.	This upward stroke of the piston is referred to as the compression stroke. During this upward stroke, the piston moves back up the cylinder and compresses the air and fuel mixture. This step is followed by ignition.
3.	Engine ignition takes place while the piston is at the top of the cylinder finishing the compression stroke. The engine is timed so that ignition occurs at exactly the correct moment the air and fuel compression is optimal. Combustion occurs when the air-fuel mixture is ignited. This step is followed by a downward stroke of the piston.
4.	This downward stroke of the piston is referred to as the power stroke. This third stroke begins when the engine combustion forces the piston back down the cylinder. This step is followed by one last upward stroke of the piston.
5.	This upward stroke of the piston is called the exhaust stroke. The last stroke is where the piston moves back up the cylinder forcing combusted gases out of the cylinder. This step is followed by a new intake stroke restarting the steps of operation.

These four strokes are what gives a 4-stroke engine its name. The same steps apply to a 2-stroke engine but with fewer stroke of the piston.

Operation of a 2-cycle engine

A 2-cycle engine combines all four strokes discussed in the operation of the 4-cycle engine into two strokes. For this to happen, the 2-cycle engine combines the intake and compression stroke during the upward movement of the piston. Likewise, the power stroke and exhaust stroke are combined into the downward stroke of the piston.

The following table provides the steps of operation for a 2-cycle engine:

Step	Procedure
1.	The first sequence of events is called the compression stroke. Remember that the intake and compression stroke have been combined in this stroke of the 2-cycle engine. During this upward movement of the piston, the air and fuel mixture is drawn into the cylinder. This step is followed by ignition.
2.	As with the 4-cycle engine, ignition takes place while the piston is at the top of the compression stroke. The engine is timed so that ignition occurs at exactly the correct moment the air and fuel compression is optimal. Combustion occurs when the air-fuel mixture is ignited. This step is followed by a downward stroke of the piston.
3.	This downward stroke of the engine is referred to as the power stroke. Remember that the exhaust and power stroke have been combined in this stroke of the 2-cycle engine. During this downward movement of the piston, engine combustion has forced the piston back down the cylinder. Combusted air is forced out of the cylinder at the end of the piston stroke. This step is followed by a new compression stroke restarting the steps of operation.

4-Cycle versus 2-Cycle Engines

Both types of engines, 4-cycle and 2-cycle, are similar in many ways. Both need fuel, air and ignition to create the combustion, which produces power. If the air is restricted to either type of engine, operation will be severely hampered. Likewise, the correct fuel is needed to ensure proper engine operation. Additionally, unless the electrical system produces the electrical current for the ignition system, the both types of engines will fail to run.

Both engines also must be properly lubricated or their lifetime will be greatly decreased. Though they are lubricated differently, it is important to remember that both types of engines have this need. In addition, they must both be cooled during operation. This cooling is mainly dependent on air being able to flow freely along the outside surface of the engine block. When dirt or mud is allowed to build up on the engine block, engine cooling is obstructed. Prolonged cooling obstruction will also result in severe engine damage.

There are number of differences between 4-cycle and 2-cycle. What comes immediately to the mind of operators of small engines is the difference in the type of fuel needed for each. The 4-cycle engine requires straight gasoline without any additives. This gasoline is almost always regular unleaded fuel. On the other hand, 2-cycle engines require a fuel and oil mixture to operate properly. The mixture must be of the correct fuel to oil ratio or engine damage can occur. As an operator of small engines, it is always important to ensure the correct fuel is added to an engine.

The internal components of 4-cycle and 2-cycle engines are also lubricated differently. A 4-cycle engine is lubricated by oil that is contained in the engine crank case. Operators ensure proper lubrication of this engine by checking the oil level before operation and ensuring the correct grade of oil is added if found to be low. However, the 2-cycle engine is lubricated differently. This engine depends on the oil added to the fuel and oil mixture. During combustion, this oil is a residual component remaining in the cylinder to provide lubrication. Operators ensure the 2-cycle engine is properly lubricated by providing the correct fuel and oil ratio as the engine manufactures specify.

Perform operator checks

Small engines must have a pre-op/post-op inspection performed daily when used. The preoperational inspection consists of performing the following at a minimum:

- Check fuel level in the tank to ensure there is enough fuel to perform operations.

NOTE: Be sure the correct fuel is added depending on the cycle of the engine.

- Check engine oil level ensuring that it is within manufacturer's specifications. Remember that this check only applies to 4-cycle engines.
- Make sure all dirt, mud, etc. are thoroughly removed from the engine prior to operations. Special consideration should be given to the carburetor and air cleaner inlets.
- Check all bolts and screws for security and tightness. Loose bolts and screws may cause damage to the unit.

Engine malfunctions

P&E Technicians need to be able to identify and correct basic engine malfunctions to avoid unnecessary work stoppage. Multitudes of man hours are lost due to equipment failures that could be easily repaired if operators have received proper instruction. Many small engine manufactures develop troubleshooting guides for the engines they produce to help operators perform basic maintenance. The following material will describe why engines either fail to start or lack power; the possible cause for these engine malfunctions; and the corrections operators can take to return an engine to full operability. Of course, there is a point where an operator will have to simply carry the engine to an engine repair shop to receive assistance. This point will also be addressed.

Malfunctions Associated with engine starting

If the engine fails to start, the operator checks provided in the following table should be made to correct basic malfunctions:

Step	Procedure
1.	Check control positions. 1) Fuel Cutoff should be in the "OPEN" position. 2) Choke should be in the "ON" position. 3) Engine/Shutdown Switch should be in the "ON" position.
2.	Check fuel. 1) Ensure fuel tank is filled with correct fuel; 2-cycle fuel for 2-cycle engine, etc. 2) If engine has been sitting for an extended period of time, ensure fuel in fuel tank is drained and replaced with fresh fuel.
NOTE: If engine is to be stored for an extended period of time (such as during the winter), fuel system should either be drained or fuel should be treated to prevent contamination.	
3.	Remove and inspect the spark plug. 1) If the spark plug has a dark and sooty build-up or is improperly gapped, the spark plug should be cleaned, properly gapped or entirely replaced. 2) If the spark plug is wet with fuel, the engine is most likely flooded. The spark plug should be wiped dry and reinstalled. Close the choke by moving it to the "OFF" position; move the throttle to the "Full Throttle" position; and attempt to restart.
4.	Take engine to a small engine repair shop. If the engine still fails to start after performing these engine checks and corrections, it is time to take the engine to a small engine repair shop for assistance.

Malfunctions associated with the engine lacking power

If the engine starts but runs erratically, there are a couple corrections operators can make to correct this problem. These corrections include those presented in the following table:

Step	Procedure
1.	Check the Air Filter. Remove the Air Filter to check for clogs and obstructions. Check the condition of the filter by holding it up to light. It should be easy to see the light through the filter. If the filter is obstructed, attempt to clear the filter by shaking or tapping it in an area away from the engine. If this effort fails to clear the filter, replace it with a new one.
2	Check fuel. If engine has been sitting for an extended period of time, ensure fuel in fuel tank is drained and replaced with fresh fuel. Additionally, there are times when the wrong fuel has been placed in the engine. An operator may have filled the tank on a 4-cycle engine with 2-cycle fuel or vice versa. In either case, the fuel should be replaced with fresh fuel.
3.	Take engine to a small engine repair shop. If the engine still lacks power after performing these engine checks and corrections, it is time to take the engine to a small engine repair shop for assistance.

035. Compaction equipment

The operation of the powered equipment used in Civil Engineer (CE) is the foundation of what we, as P&E operators, do to carry out the mission. Not every job can be done from inside the cab of the loader. We will begin this next discussion with the first of many pieces of compaction equipment you, as a pavement and construction equipment operator, will use—the vibratory tamper.

Vibratory tampers (compactors)

Pictured in figure 4–6 are two of the most common tampers you will see. The one on the left is a typical plate tamper that can be used to compact material down to about three inches. It is used for compacting granular (sand or gravel) type base material for small projects. The tamper on the right is different in that it has a smaller foot, thus increasing the bearing pressure exerted. This tamper is called an “elephant’s foot” or “jumping jack” tamper and is good for compacting loose fill material such as found in trenches. Because the foot is narrower, it can fit in most trench excavations.

Figure 4–6. Tampers.

Compaction equipment safety

Tampers are extremely heavy and cumbersome. Make sure you have help when loading, unloading, or relocating them. Keep your feet away from the metal plates as they could do serious harm to an unprotected foot. As always, wear steel-toed boots, hearing protection, and gloves. If you are compacting a pavement repair, use caution when getting up close to the vertical walls (either concrete or asphalt) as the vibrating steel plates of the plate tamper can cause chipping or spalling. Always keep people away from the tamper.

Preparation

Make sure the tamper is in good working order prior to using it. Pull the air filter and make sure it isn't plugged as tampers are operated in dusty areas. Check the fuel and oil levels and check the belts running to the vibrator. The belts run the vibratory unit on the tamper. Dirt and rocks can accumulate in and around the belt area causing damage. Also, check to make sure the throttle and pull cord are operating properly. Pull the cord out and inspect it for fraying. Replace it if necessary.

Operational procedures

Before you attempt to start the tamper, place it into the area to be compacted. Since the tamper is semi-self-propelled, driving it down into an excavation could cause damage to the sides of your repair or to the machine. Always place the tamper where it will be used rather than running it over our edges and into the project. Put on your PPE and start it up. Put the throttle to full speed and keep both hands firmly on the handles. The plate tamper will go pretty much wherever you want it to go and only needs minor adjustments to keep it on track. The jumping jack tamper is slightly more cumbersome than the plate tamper and takes a firm grip to keep it going in the right direction. It takes some getting used to, so don't expect to become an expert the first time out. Make sure you maintain your balance to avoid falls when operating this type of tamper.

036. Saws and routers

We will start this lesson with a discussion of a few of the saws we keep in our inventory—the chainsaw, K–12 saw, and walk behind concrete saw. We will finish the lesson with pavement routers and crack saws.

Chainsaws

Chainsaws are one of the more dangerous tools that you will operate. One misstep with a chainsaw could cause serious injury. However, if you use some basic safety procedures and use your head, you can operate this essential piece of equipment safely. Always make sure that you review the operator's manual prior to use.

General information

The chainsaw has a two-cycle engine requiring two-cycle oil mixed with gasoline. Always be sure you use the right fuel and fuel mixture before using the saw. If not, internal damage can occur. You can find the mixture on the saw or in the operator's manual. Try not to use fuel from a can that is not marked with the mixture. Mix up some fresh fuel and then mark the container. The parts of the chainsaw are identified in figure 4–7; its main parts are the engine (not shown), sprocket, chain, spur, hand grips (not shown) and the handguards.

Saws and router safety

The chainsaw is an excellent tool for cutting and clearing trees and shrubs. However, it is also a very dangerous piece of equipment if not used properly. Serious injury can result if proper safety procedures are not followed.

Because the exhaust produces carbon-monoxide which can lead to asphyxiation, always use the saw in well ventilated areas. Use extreme caution when cutting small branches, saplings, and limbs under pressure—they may snap back at you. *Never* operate the saw from a tree limb or from a ladder.

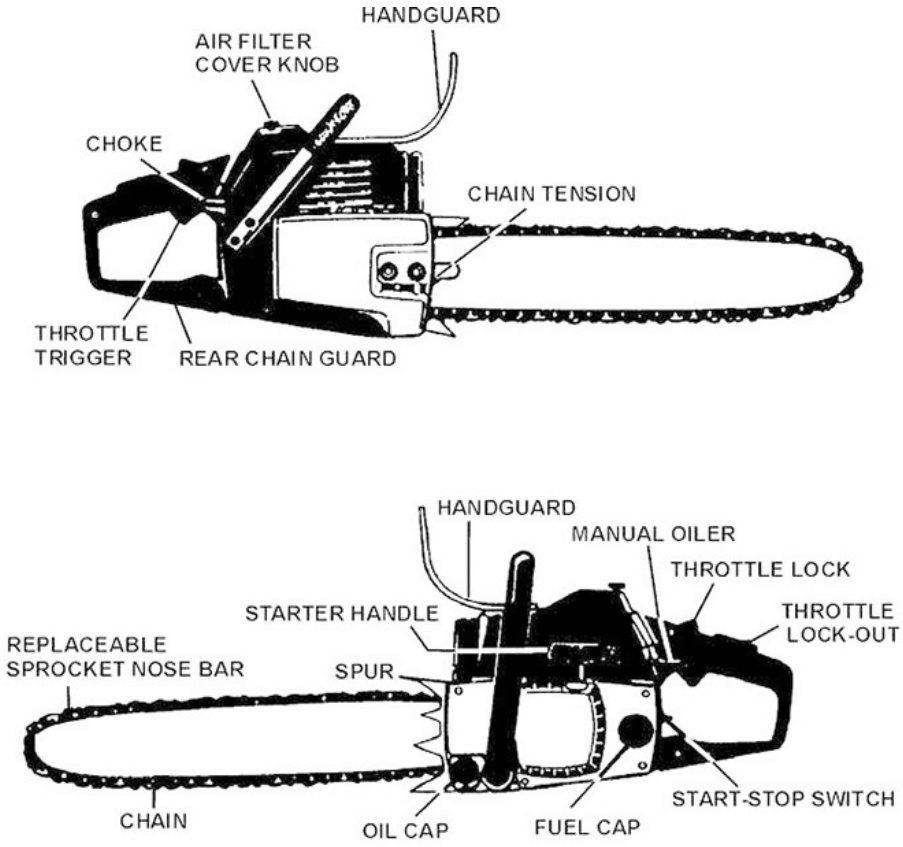


Figure 4–7. Chainsaw nomenclature.

Be sure you always wear the proper safety gear such as a hard hat, hearing and eye protection, gloves, safety shoes, and leg protection such as chaps. Depending on the condition of the wood and the procedures you use, the saw may react with the wood you are cutting. You must avoid negative and dangerous reactions such as pinch, kickback, and pull-in.

Pinch

Pinching occurs when the wood you are cutting closes together against the chain causing the chain to stop. You can keep this from happening by using wedges to spread the cut apart. Also, you could properly support either side of the cut before sawing. In this way, the ends of the piece you are cutting are free to fall away from the cut.

Kickback

This reaction occurs when the saw is kicked back toward the operator. This can happen by either undercutting a piece of wood or hitting a foreign object while cutting. You can avoid kickback by cutting at full throttle. Also, keeping the spur against the wood while cutting creates a stable situation where there is less chance of the saw moving around.

Pull-in

Pull-in happens when the spur is not fully against the wood, causing the saw to be pulled into the wood. You can counteract it the same way you do kickback; this is by keeping the spur against the wood and cutting at full throttle.

Chain adjustments

The chain adjustment should differ depending upon the type of chain used. If you use a sprocket tip chain, the chain should fit tightly on the bar without sagging and also move freely around the bar. You should be able to lift the chain ⅛ inch off the middle of the bar. The hard tip chain should sag just slightly off the bar and move freely around the bar. If you need to adjust the chain, slightly loosen the bar clamp nuts, hold the guide bar up and turn the adjusting screw. Turning the adjusting screw clockwise tightens the chain tension; turning the adjusting screw counterclockwise loosens the chain tension. Always recheck the chain tension often during use of the saw. A tight chain increases friction and, therefore, wears on the bar and the chain. A lose chain is less efficient and could possibly come off creating a safety hazard. Always check the manual for proper adjustments.

Figure 4–8. Safe Operating procedure.

Operating procedures

When operating the chainsaw, firmly grip the saw with both hands. Do this by keeping your left hand on the front handlebar and your right hand on the rear grip. Position yourself to the left of the saw and the cut while keeping your weight evenly distributed on both legs (fig.4–8). Increase the throttle to full speed as you guide the saw through the wood applying slight down pressure. Do not force the saw; let it do the cutting. As you near the end of the cut, lighten up on the amount of down pressure. After you have used the saw, shut it down and do a post operational check. This way, the saw is ready and operational for the next job.

K–12 saws

The K–12 saw is a multipurpose saw that allows you to cut many types of material. By doing a simple blade change, you can cut material from concrete to metal. The saw's configuration is very similar to that of the chainsaw you just read about. You can use the saw to cut wood, reinforcing steel, concrete and asphalt. Pictured in figure 4–9 is a typical K–12 saw.

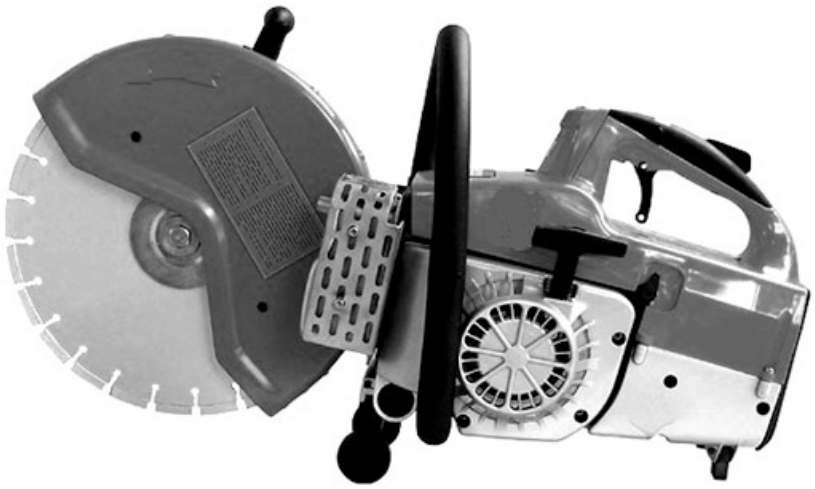


Figure 4–9. Typical K–12 saw.

K–12 saw safety

As with any power tool, be sure you wear the proper clothing and safety equipment. These include goggles, steel-toed boots, hardhat, hearing protection, dust mask, and properly fitting nonflammable clothing. You should use the following safety guidelines when operating the K–12 saw:

- Never operate the saw without the guard in place.
- Avoid getting in direct line with the cutting wheel while cutting.
- Remove any flammable objects from the area before cutting.
- Have a fire extinguisher with you when cutting metals and where there are combustibles present.
- Operate the saw only in well ventilated areas.
- Keep bystanders clear of the work area.

Preparation

Before you start the K–12 saw, inspect it for safety items and to be sure it is in proper operating condition. Look for damage and loose nuts or bolts. Inspect the cutting wheel or blade for damage, wear, and proper fit. If the cutting wheel becomes unserviceable, or if it is the wrong type for the cutting you are about to do, replace it. There is a vast array of different cutting wheels and blades available for K–12 saws.

Adjust the belt tension

For the cutting wheel to cut effectively, be sure the belt tension is properly adjusted. A properly adjusted belt should be tight and not slip if the blade should bind when cutting at full throttle.

Fuel the engine

Avoid fueling the saw when the engine is hot. Spilled fuel on the engine could cause the fuel to ignite. When fueling the saw, use the 2-cycle oil mixture designated in the operator's manual or stated on the saw itself (usually stenciled on or near the fuel cap). Never substitute any other type of oil for 2-cycle. Most other oils are not designed to be burnt like 2-cycle and will not work in the saw.

Clean the air filter

The air filter on a K–12 saw must be cleaned prior to operating. This is due to the extremely dusty conditions it endures. If you don't clean it out often enough, the saw will be underpowered and may even quit unexpectedly.

Operational procedures

The operational procedures for the K–12 saw are much the same as those for using the chainsaw, with some minor differences. First, firmly grip the saw with both hands, keeping your left hand on the front handle and your right hand on the rear grip. Stand to one side of the saw so that no part of your body is in line with the cutting wheel. Balance your weight to offset any kickback reaction of the saw. Always cut at full throttle and reduce down pressure if the engine should bog down. When cutting thick material, use a back and forth cutting action. Be sure to keep the wheel moving. If you keep the wheel in one spot for only a few seconds, the wheel and the material will become hot, causing the wheel to overheat. Never apply side pressure to the wheel as this could cause the wheel or blade to break causing a severe situation. When you cut squares or rectangles, overlap the cuts at the corners by approximately half the diameter of the wheel.

Walk behind concrete saw

Pictured in figure 4–10 is a typical walk behind concrete saw. As the name implies, you literally walk behind it as you cut. There are many different manufacturers and sizes of concrete saws and you will likely see many of them. We will generalize with a typical saw and highlight the basics.

Figure 4–10. Typical walk-behind concrete saw.

Concrete saw safety

Always do a good inspection of the machine prior to starting it. Make sure nothing is loose and the blade guard is in place. Also, make sure the blade is secure to the arbor and that the water system is operating correctly. Check the blade to make sure it goes up and down without binding. Do not drop the blade too quickly into the cut because doing so could cause damage to the machine and to the blade, and it could also make the saw lurch forward. Finally, start the engine and make sure it is running properly. As always, make sure you wear the appropriate PPE.

Concrete saw blades

The first step in using a concrete saw is to choose the correct blade for the job. Is the concrete green (just poured within the last 12 hours or so) or is it older. There are blades for green concrete as well as cured concrete. Additionally, you need to determine if you will be using water which would necessitate a wet cut blade or if you don't have access to a water source which would necessitate a dry cut blade. If you will be cutting asphalt, there is a blade for that as well. When shopping for a blade, you need to specify what the job is so the manufacturer or sales representative can help find the right blade for you.

The sheer number of blades available is daunting, but a few good choices of blades will make the job of choosing one much easier. For instance, a good dual purpose dry cut blade for asphalt would be a good choice because you don't have to worry about water saturating your base during an asphalt repair. Generally, one way to differentiate between a dry cut and wet cut blade is the spaces are wider and deeper in the dry cut which provides an air cooling effect to keep the blade from warping. You will know fairly quickly if you are using a wet cut blade without water. The blade will start "wobbling" and distorting as you move forward. If this happens, stop immediately and change the blade! Just remember to use a dust mask and clean the air filter of the saw after cutting with a dry-cut blade.

Additionally, a good quality wet cut blade for concrete would be a good choice because the water reduces the dust and also extends the life of the blade. There are dry cut blades for concrete, but they tend to wear quicker and will need to be replaced sooner than wet cut blades. Regardless of the blade choice, make sure the blade's specifications are legibly written on the side of the blade so you don't mix them up. All the information you need should be on the blade itself.

Operational procedures

Once you have inspected the saw and chosen the appropriate blade, mark the area to be cut. If you are using water for the cut, choose a waterproof paint or other medium that won't just wash away. Start the saw and position it over the marks. If the saw you are using has a saw guide (a pointer or similar apparatus sticking out in front of the machine), place the guide on the marks. When you have the saw positioned properly, slowly lower the blade into the pavement. Adjust the depth of the cut for the material you are cutting. A good rule of thumb is to cut at least two inches. This will ensure you have gone far enough to be able to break away the remaining material below the cut without affecting the material above. For thicker material, you will need to make the cut deeper. Check the blade for the maximum depth of cut.

Begin your forward motion slowly—***DO NOT FORCE THE SAW***. Forcing the saw could damage the blade and possibly bog the motor down until it stalls. Make all cuts as straight as possible. When you reach the end of your mark, ensure cuts overlap at least one-half the blade diameter. For example, if you are using a 12-inch diameter blade, your overlap would be approximately six inches. This ensures that the patch has square corners.

Pavement router

The router is just one example of a tool that can be used in repairing joints and cracks in pavement. Let's look at the machine itself and highlight some basics. Pictured in figure 4–11 is a typical walk behind impact router and one of its corresponding cutting bits.

Figure 4–11. Impact router and one cutting bit.

Router safety

Impact routers and vertical routers employ spinning cutters or bits to cut pavement. As such, there will be flying debris that you must be aware of. As you can see from figure 4–11, there is a curtain in front of the machine to stop flying debris from going in all directions. If you lower the machine too quickly into the cut, you could cause it to jump forward or even damage the machine. Make sure you read and understand the procedures established by the manufacturer of the machine you are using. Also, make sure you wear the proper PPE and know exactly how to operate the machine prior to starting it.

Preparation

Besides checking the obvious things like fluid levels and damage, you must also check the cutting bits. The operator's manual will guide you in deciding if the bits are good or not. Operating this type of router with worn or broken bits is inefficient and could be dangerous. Change them if needed. Make sure the machine raises and lowers as it should and make sure the throttle works properly. Finally, check to make sure the safety curtain is affixed and in good condition.

Operational procedures

Once the machine is thoroughly checked out and you are satisfied, fire it up and center the machine over the crack. Most models of routers have a pointing device to make alignment easy. Lower the cutter into the pavement slowly until you reach the desired depth. Don't try to go too deep or too fast as this could make the machine lurch forward, causing you to lose control. Walk the machine back slowly, following the crack as you do. Stop occasionally to make sure you are making satisfactory progress. Follow up by sweeping the entire area.

Crack saw

Crack saws are similar to routers in that you use them to prepare cracks and joints for sealing. They have blades similar to a typical concrete saw, except much smaller. This small blade enables you to manipulate the machine in a way to follow the crack much the same way as a router. While the maximum cutting depth for most crack saws is approximately one inch; however, in most instances you should set the machine at a deep enough depth to create a suitable reservoir for the sealant, typically ½ to ¾ of an inch deep. Crack saws are typically smaller than a concrete saw or an impact router; as such, they are more economical and easier to use.

037. Air compressors and accessories

Air compressors generate compressed air used to power many pneumatic tools you need to carry out your job. They come in many sizes and configurations, ranging from small bicycle pumps to massive machines the size of a small building. A typical air compressor you will use is shown in figure 4–12. An air compressor uses two units of measure to determine the air flow and pressure they are:

- Air flow, measured in cubic feet per minute (CFM).
- Pressure, measured in PSI. The model pictured in figure 4–12 is a fairly large commercial compressor capable of powering several tools at once.

Figure 4–12. Air compressor.

To make sure your compressor is up to the task, read the specifications tag on the tool. The tag should indicate the CFM needed at certain pressures. For example, a typical 90 lb. jackhammer requires a minimum of 75–80 CFM air flow at 90 PSI to operate efficiently. For comparison sake, a 10 gallon air compressor used for airing up the tires on your car may only produce 6–7 CFM.

Air compressors safety

The most important aspect to remember when using an air compressor is that when you energize the line (sending air pressure to the hoses and your tool) huge amounts of air pressure are trying to escape any way they can. If your connections are not secure, the hose can come free and flail around until the valve is closed or the compressor is shut down. Also, worn or damaged hoses can burst, potentially catapulting debris at you. It is a good idea to have someone manning the controls just in case something happens and you need to shut it down quickly. All air compressors have an emergency shutdown switch which cuts pressure immediately. Having someone close that can shut the machine down quickly may be the difference between avoiding an accident and actually getting hurt. Before you uncouple any attachments from the compressor, turn the compressor off and release air from the supply line. As always, become thoroughly familiar with how to operate the air compressor *before* you start it up.

Operational procedures

Most compressors are diesel powered and have an operator's station with gauges and an ignition. Make sure you do a thorough inspection of the compressor before you use it. Check all the hoses and

connections. If it has an inline dryer, make sure it is functioning properly. Once the machine is started and running, check the gauges to make sure it is operating within the “normal” ranges prior to energizing the air. Also, make sure the connection to the tool is solid and does not leak. Once you are confident all is well, energize the system and check to make sure there are no leaks. Tell-tale signs there is a leak are a loud whistling noise and the sound of the engine RPMs increasing quickly. If you hear either of those two things, shut the compressor down immediately and address the problem.

Air compressor accessories

Tools using compressed air are too numerous to count for this discussion. We will, however, discuss three of the more common tools you will likely be using on the job. The rock drill, the jackhammer (or breaker as it is sometimes called), and the tamper are shown in figure 4–13.

Figure 4–13. Typical air compressor accessories.

Pneumatic drill

You can use the pneumatic drill to determine the thickness of the pavement; aid in the removal of defective pavement; and install dowels, grounding rods, and aircraft tie-downs. Before you operate the drill, do a preoperational inspection. Check all nuts and bolts to ensure they will not come off during operation. Oil the drill to lubricate it internally. Secure the hose with safety wire, as shown in figure 4–14, to reduce the possibility of the hose coming loose during operation.

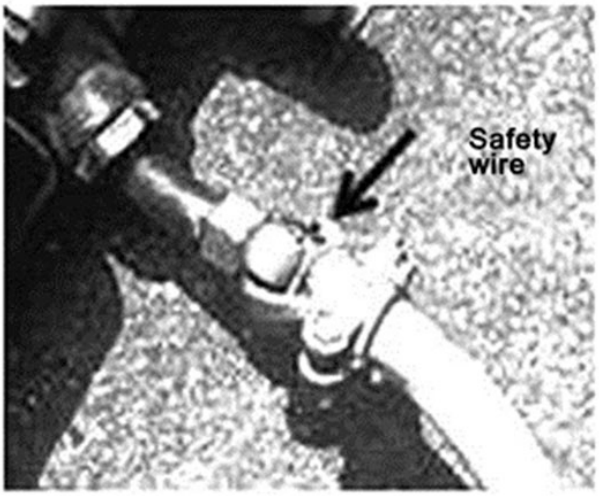


Figure 4–14. Air compressor hose.

Once the preoperational check is done, you are ready to drill. Install the proper size cutting bit on the drill drive shaft. Hold the drill firmly against the material to be drilled and make sure the bit is aligned properly. Position the operating lever to a slow speed to make sure that the drill does not skip around on the pavement. Once the drill has begun to penetrate the pavement, slowly increase the speed. Once you have drilled down to the required depth, reverse the operating lever fully to stop the drill and pull it out of the hole. Use a sounding rod to see if you have reached solid pavement. If needed, drill down a couple more inches again until sound pavement is found. Make sure after each use of the pneumatic drill that you do a post-operational check and service it as needed.

Pneumatic hammer

The most common way to remove defective concrete is by use of a pneumatic hammer, commonly called a “jackhammer.” Figure 4–13 shows a typical pneumatic hammer and figure 4–15 shows some typical bits for different applications.

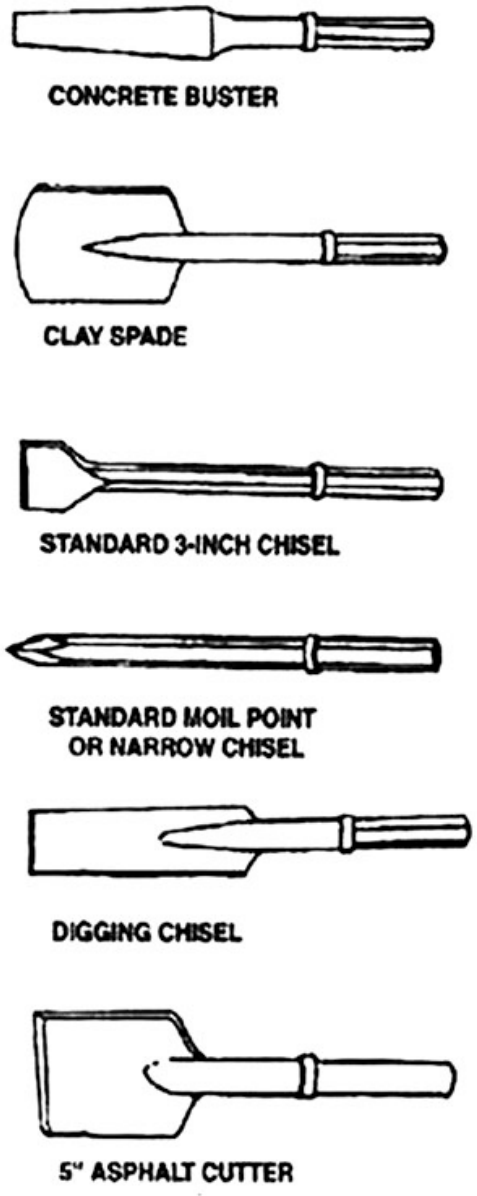


Figure 4–15. Bits used in the pneumatic hammer.

Pneumatic hammers are available in many sizes. For breaking concrete slabs, the pneumatic hammer most commonly used is the 30- to 90-pound class. The thicker the concrete, the heavier the hammer; however, if working near joints, you may want to use a lighter hammer in an effort to save the edges of the concrete slab from chipping and spalling. Air pressure far in excess of the manufacturer's recommendations may cause internal damage to the hammer.

WARNING: When you use a pneumatic hammer, you must wear steel-toed boots or toe guards, as well as eye and ear protection. Everyone in the work area or otherwise near the compressor unit must use adequate protection to prevent injury from high noise levels and flying debris.

You must always work inside the sawed area. Never stand outside the defective area to try to break out the pavement. The bit will tend to vibrate against the vertical face and damage the adjacent area.

It is easier if you start breaking the pavement somewhere close to the defect itself. The pavement is weaker here and is easier to break. If working near joints or spalls, use only 30-lb. hammers; this will help prevent damaging sound pavement below the affected area. Avoid breaking the pavement into large, bulky pieces. It will be easier for you to pick small pieces for loading.

Pneumatic tampers

It isn't always possible to get large pieces of compaction equipment into all areas. Pneumatic tampers become very useful in these areas (refer back to fig. 4–13 for an example). For maximum control of the tamper, put one hand in the middle of the tamper and one hand on the top of the trigger. When you are ready to start tamping, slowly squeeze the trigger. Don't exert any pressure on the tamper. The weight of the tamper is sufficient.

Because of the bouncing motion of the pneumatic tamper, you must be aware of the potential safety hazards involved. As with all pneumatic tools, you must wire the connection between the hose and the tamper. Make sure you keep the top of the tamper pointed away from yourself. The tamper could very easily jump up and hit you in the face.

038. Portable concrete mixers and power screeds

Portable concrete mixers and power screeds make concrete jobs much easier. Portable mixers are ideal for small to medium jobs and are used when getting a concrete truck would be inefficient and not worth the added expense. Power screeds make the job of screeding fresh concrete much easier and more efficient. Let's take a look at both of these time savers.

Portable concrete mixers

Most of the concrete you will use is prepared at a central plant and delivered by transit truck to your job site. This is normal for jobs requiring large amounts of concrete. For jobs that take reasonably small amounts of concrete, you can use a portable concrete mixer if the handling of individual materials (gravel, sand, cement, and water) is acceptable. Very small jobs can be hand mixed in a wheelbarrow, mortar box, or on a wooden platform. The type of mixer primarily depends on the size of the job.

Portable concrete mixers come in many different sizes, ranging from a few cubic feet all the way up to two or three cubic yards. They can be electric or gas powered as well. The mixer shown in figure 4–16 is approximately 6.75 cubic feet, which is equivalent to ¼ cubic yard.

Figure 4–16. Typical mixer.

Let's assume for a moment the pad you are building requires ¾ cubic yard of concrete; you would need to fill the mixer three times to complete the project.

Concrete mixer safety

When using the portable concrete mixer, the work area should be clear of debris and obstructions, which could cause the operator to slip, trip or fall into the mixer. The cement mixer should be on a flat and level surface to prevent tipping, rolling, or falling. Do not wear loose clothing or jewelry as they can be caught in moving parts such as the rotating drum. Check for proper machine guards and make sure the electrical power cord is in good condition. Have GFI protection when using an electric powered mixer outdoors or in damp locations to prevent a shock/fire hazard. Be aware of hot exhaust and do not use gas powered mixer indoors as carbon monoxide may accumulate and cause an atmospheric breathing hazard. Do not use the cement mixer if it is not in proper working order. The cement mixer should be rotating when filling or emptying the mixer. The rotating drum aids in removing all the concrete. Do not overload mixer beyond what is recommended in the operator's manual as this could damage the mixer. Never leave the mixer running unattended as the machine could encounter a problem, it could overturn or some other incident and if no one is around.

CAUTION: Do *not* move the mixer during operation. The mixer could possibly tip over damaging the motor and hurting someone.

Always keep guards in place during operation. The guards are there to keep operators safe. Disconnect the power or shut off the engine from the mixer and place the switch in the locked or off position before servicing, adjusting, or installing accessories or attachments. Such preventive measures reduce the risk of starting the mixer accidentally.

Operational procedures

After thoroughly checking the machine out, start the engine and let it warm up (for gasoline powered machines). Engage the drum and make sure it spins freely and is working properly. During this time, you can ensure everything is working as it is supposed to.

The water goes in the drum first. You only want to add about 10 percent at first as this ensures the mixture will stay consistent. You then add your dry ingredients and another 80 percent of water. Once everything is in the drum and mixing, add the final 10 percent of water if it is needed. You can see the consistency of the mix and must decide whether to add more water. The length of time the ingredients should be mixed varies with the type of mixer. In most cases, concrete should be mixed at least one minute for the first cubic yard with an increase of 15 seconds for each additional cubic yard or fraction thereof. If you are mixing batches smaller than one cubic yard (like our example above), follow the manufacturer's instructions or the TO for the mixer you are using.

When you are finished with the mixer, clean it out. If multiple layers of concrete are allowed to accumulate, the capacity and efficiency of the machine is greatly reduced. After cleaning, do a quick inspection to ensure no damage occurred during operations.

Power screeds

Two examples of the power screeds we use to make our job much easier are shown in figure 4–17. The lattice boom screed, sometimes called an "A-Frame" screed, is constructed of sections bolted together making a rigid structure capable of screeding sections of concrete spanning 10 – 30 feet wide. Changing the width of the screed is simply a matter of removing or adding sections and then adjusting for trueness (how flat and level it is). The lattice boom screed also employs vibration which aids in consolidation of the concrete. (We will discuss that later in the volume 2.) The vibratory system is gasoline engine powered and the hydraulic or hand-operated winches assist in propelling the screed across the top of concrete forms.

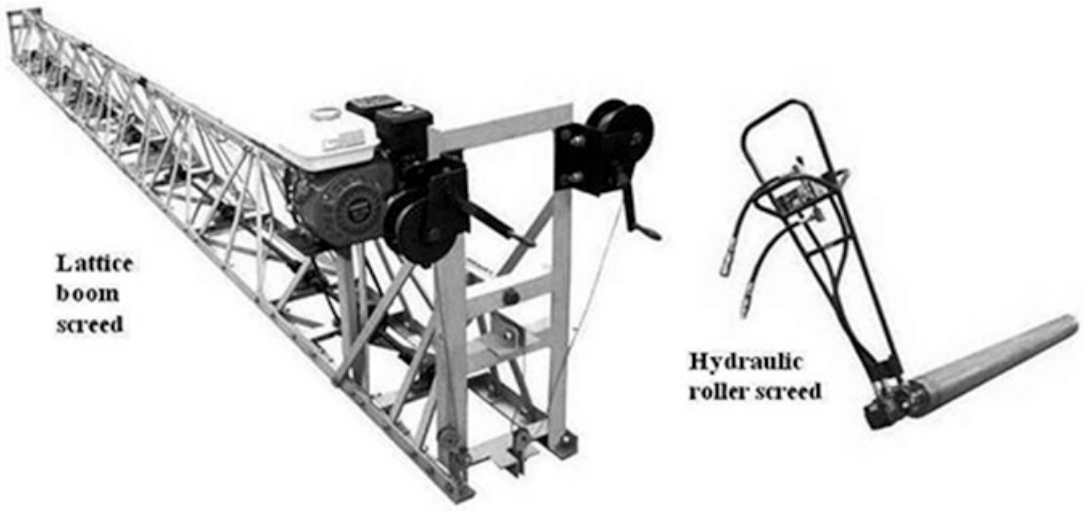


Figure 4–17. Power screeds.

The roller screed (fig. 4–17) is driven by an auxiliary unit powering a hydraulic motor at one end. The hoses pictured connect to the power unit. There are many sizes and configurations of roller screeds you may use, but in general, they all operate the same way. The roller "strikes" off the top layer of concrete as it moves along the forms, creating a smooth surface to finish. Roller screeds don't usually have vibrators for consolidating the concrete, so the resulting finish will be pervious or porous (small voids throughout) and may not be suitable for some finished surfaces. If the concrete needs to be consolidated, you may not want to use the roller screed.

Power screed safety

Both types of screeds we discussed pose serious safety concerns. The lattice boom screed is extremely heavy. Make sure you have a lot of help when moving one around the jobsite. A skid-steer loader with forks or a loader will make the job of moving it much easier. Additionally, when using the winches, either manual or hydraulic, keep fingers and loose clothing away from the rotating parts. As always, do not operate a gas-powered screed inside unless you have adequate ventilation. Check the winch cable to make sure there is no fraying as there is a considerable amount of tension on them during screeding.

The roller screed is lighter and easier to manipulate than the lattice boom screed, but no less dangerous. The hydraulic motors are quite powerful and can literally pull you along if you are not careful. If you lose your footing while operating it, you could end up in the fresh concrete. Make sure the hydraulic lines are in good condition and replace them if they look at all damaged. A ruptured hydraulic line is extremely dangerous due to the high working pressures.

Operational procedures

Successfully operating a lattice boom screed begins with the set up. You must ensure the screed is true and level. You can do this easily by blocking the screed and running a string line from side to side and pulling it tight. View down the string to see if there is any sag or deviation from the line. If there is, simply adjust the sections by loosening or tightening the threaded couplers adjoining each section. Remember, the longer the screed, the greater the chance of sagging in the middle due to the added weight. If you put your blocks out near the ends of your screed and leave the center without support, you should get a true idea if it is sagging.

Once the screed is true and level, make sure you check it out thoroughly. You want to inspect every section paying particular attention to the offset bearings, shafts, and couplers used to make it vibrate.

Vibration tends to loosen parts. Also, make sure there is no excessive accumulation of concrete on the structure. If there is, you may have to remove the excess concrete to make sure the screed will operate properly.

Set the screed on the forms at the beginning of the pour, pull the winch cables out to the end of the pour, or as far as they will go, and make sure they are secure. Start the engine and let it idle so you can test the hydraulic winches. For manual winches, just make sure they are operational. Bring the engine slightly above idle to test the vibrators. When everything checks out satisfactorily, shut down the motor and wait for the concrete to arrive.

While actively screeding, keep a slow and steady pace. Try not to stop, but if have to stop, reduce engine RPMs down to an idle so the vibrators turn off. You may have to pick the screed up and move it back slightly to erase any creases left in the surface after stopping.

The roller screed is much easier to operate and has very little set up involved. Make sure the hydraulic lines are attached properly and there is no obvious damage to the roller or any of its components. After a thorough inspection, bring the screed to the beginning of the pour and start the engine. Let the engine run for a few minutes to warm the fluid, then slowly engage the motor to make sure it is working properly. Once you are ready, slowly engage the motor and walk backward, just steering the screed as it does all the work for you. Going too fast can allow screed to ride up on top of the concrete.

After operations are completed with either screed, clean them with a pressure washer to make sure no concrete is allowed to dry. Dried concrete left on a screed will make the job for the next P&E personnel much harder.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

032. Operator inspection and maintenance

1. What is the *only* difference between inspection and maintenance of *powered* equipment and *heavy* equipment?

2. What is an operator’s inspection checklist designed to do?

3. If you have not operated a particular piece of equipment and do *not* know how, where is the first place you should go for help?

4. Whose responsibility is it to put air in the tires of powered equipment?

5. List four examples of safety precautions you must follow when you fuel equipment.

033. Generator maintenance and operations

1. Why must operators know how much power is required for the electric tools to be powered by the generator?

2. Due to the potential risk of electrocution, what is important for technicians to be aware of when operating near generators?

3. What might a technician have to do if the area is too uneven or damp for placement of the generator?

034. Operation and troubleshooting of small engines

1. What three essential elements are both types of small engines you will typically encounter operate on?

2. During the 2-Strokes sequence, what elements are combined, and makes it different from the 4-stroke?

3. What are the fuel requirements of the 2 and 4-stroke engines?

4. How are the internal components of a 2 and 4-stroke engine lubricated?

5. What are three operator checks you should perform if an engine fails to start prior to taking to a small engine repair shop?

035. Compaction equipment

1. A plate tamper is used for compacting what type of soil?

2. What size projects are good for a plate tamper?

3. What is a “jumping jack” tamper good for compacting?

4. On a plate tamper, what can damage the belts?

036. Saws and routers

1. Explain why the chainsaw should be used only in well-ventilated areas.

2. When you are cutting wood with a chainsaw, what causes pinching?

3. On a chainsaw, how do you adjust a hard tip chain?

4. What must be cleaned before operating the K–12 saw to avoid the saw stopping unexpectedly?

5. What is the *first* step before operating a concrete saw?

6. What is one way you can tell the difference between a *dry* and a *wet* cut blade on a concrete saw?

7. What may happen if you lower the machine too quickly into the cut while routing?

037. Air compressors and accessories

1. Air compressor size is based on what two basic pieces of information?

2. How much air flow does a typical 90 lb. jackhammer require to operate efficiently?

3. What is a sign there may be a connection leak when operating an air compressor?

4. Why should you never stand outside the sawed or defective area when using a pneumatic hammer?

038. Portable concrete mixers and power screeds

1. What is the capacity range of portable concrete mixers?

2. Why should the concrete mixer be placed on a flat and level surface?

3. How do you change the width of a lattice boom screed?

4. What does the roller screed do to the top layer of concrete as it moves along the forms?

Answers to Self-Test Questions

029

1. By their power source.
2. Misuse and improper maintenance.
3. Falling, flying, abrasive, and splashing objects; or to harmful dusts, fumes, mists, vapors, or gases.
4. When you use a temporary power source for power tools during construction.
5. If a chisel is used as a screwdriver, the tip of the chisel may break and fly off, hitting the user or other employees; if a wooden handle on a tool, such as a hammer or an axe, is loose, splintered, or cracked, the head of the tool may fly off and strike the user or other employees; if the jaws of a wrench are sprung, the wrench might slip; if impact tools such as chisels, wedges, or drift pins have mushroomed heads, the heads might shatter on impact, sending sharp fragments flying toward the user or other employees.
6. Spark-resistant tools made of non-ferrous materials.
7. Guards.
8. Never.
9. Your supervisor.

030

1. Because of the hazards created by the chips and dust it throws into the air.
2. Cleaning, inspecting the parts for defects, lubricating, and treating.
3. To reduce the amount of friction or resistance between two surfaces when one slides against the other.
4. Your ability to use tools and your appreciation for them.

031

1. Because the manufacturer’s parts are almost always guaranteed to fit.
2. Making sure the V-belt is the right size for the pulley and selecting a belt so that the motor is as close to the machine as practical to prevent some power loss.
3. Replace all the belts.
4. A sleeve or pipe.

032

1. The size and scope of the equipment.
2. To protect you and the equipment you operate.
3. To a supervisor.

4. The operator's.
5. Any four of the following:
   (1) Do not fuel equipment near open flames or spark-producing devices.
   (2) Do not fuel indoors (ventilation is extremely important).
   (3) Do not smoke during fueling.
   (4) Stop the engine. Fueling the equipment with the engine running could result in a fire or explosion.
   (5) Apply the parking brake or chock the wheels so the vehicle doesn't roll away.
   (6) Keep nozzle of fuel hose in constant contact with tank intake pipe to prevent the discharge of static electricity, which can cause a spark with enough intensity to ignite the fuel vapor.
   (7) When fueling gasoline, use a nozzle without a hold-open latch (it may not shut off in the case of overfilling the tank).
   (8) If reserve supplies of fuel are required on the vehicle, carry them only in an approved safety container, marked appropriately. Protect them from external damage and lash or anchor them to prevent accidental movement.

033.

1. The generator or power tool can be overloaded and damaged.
2. Weather and ground conditions around them to keep the generator, power cord, and tools dry.
3. Find a more suitable location or build the area up with dunnage to support the generator.

034

1. Air, fuel and ignition/combustion.
2. Two-stroke combines intake with compression during the upstroke and power stroke with exhaust stroke during the downstroke.
3. Two-strokes require proper ratio of a fuel/oil mixture. Four-strokes require straight gasoline (unleaded).
4. Two-strokes are lubricated through the oil fuel mixture. Four-strokes are lubricated from the oil located within the engine crank case.
5. Check control positions, check the fuel, and remove and inspect spark plugs.

035

1. Sand or gravel (granular type base material).
2. Small.
3. Loose fill material in trenches.
4. Dirt and rocks accumulating in and around the belt area.

036

1. Because the exhaust produces carbon monoxide which can lead to asphyxiation.
2. The wood you are cutting closes together against the chain, causing the chain to stop.
3. Slightly loosen the bar clamp nuts, hold the guide bar up and turn the adjusting screw. Turning the adjusting screw clockwise tightens the chain tension; turning the adjusting screw counterclockwise loosens the chain tension.
4. The air filter.
5. Choosing the correct blade for the job.
6. The spaces are wider and deeper in the dry cut which provides an air cooling effect to keep the blade from warping.
7. This could make the machine lurch forward, causing you to lose control.

037

1. Air flow, measured in CFM; and pressure, measured in PSI.
2. 75–80 CFM.

3. A loud whistling noise and the sound of the engine RPMs increasing quickly.
4. The bit will tend to vibrate against the vertical face and damage the adjacent area.

038

1. A few cubic feet, all the way up to two or three cubic yards.
2. To prevent tipping, rolling, or falling.
3. By removing or adding sections, and then adjusting for trueness.
4. “Strikes” it off.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

63. (029) What are the two *common examples* of hazards associated with the use of hand tools?
    a. Abuse and improper use.
    b. Misuse and improper maintenance.
    c. Flying debris and excessive vibration.
    d. Faulty workmanship and improper maintenance.

64. (029) When working in areas where sparks could be an ignition around flammable substances, you should use hand tools made from what type of metal?
    a. Non-ferrous metal.
    b. High carbon steel.
    c. Malleable iron.
    d. Ferrous metal.

65. (030) What is the life-span of a tool or item of equipment when properly maintained and used under normal conditions?
    a. Indefinite.
    b. Five to ten years.
    c. Limited to quality.
    d. Just until the warranty runs out.

66. (030) A good way to encourage workers to put a tool in its proper place is to
    a. use the honor system of issuing tools to promote responsibility.
    b. order extra tools to hang up to identify their proper places.
    c. issue individual tools to workers.
    d. use a silhouette board.

67. (031) What should you do if one belt of a matched set of four needs to be replaced on a piece of equipment, such as the concrete saw?
    a. Replace them all.
    b. Replace only the bad one.
    c. Replace only the belt adjacent to the bad one.
    d. Do not replace any, the machine will still work well with the good three.

68. (031) What types of bearings do you have to replace more often than others?
    a. Ball.
    b. Sealed.
    c. Plastic.
    d. Sleeve.

69. (032) What can you use, if anything, to develop a checklist for equipment without one?
    a. A commercial guide for building checklists.
    b. Nothing; no checklist for equipment is required.
    c. The operator’s manual for that piece of equipment.
    d. A technical order for a dissimilar piece of equipment.

70. (032) On powered equipment, which item is *not* the operator's responsibility to check?
    a. Battery fluid level.
    b. Engine timing.
    c. Tire pressure.
    d. Fuel level.

71. (033) Which is the correct order of steps to follow when starting a generator?
    a. Determine the power requirement of the tools to be operated by the generator, turn the circuit breaker to the OFF position, check to be sure the fuel valve is open, set the choke to the ON position, use the key or pull cord to start the engine.
    b. Set the choke to the ON position, turn the circuit breaker to the OFF position, determine the power requirement of the tools to be operated by the generator, check to be sure the fuel valve is open, use the key or pull cord to start the engine.
    c. Turn the circuit breaker to the OFF position, set the choke to the ON position, check to be sure the fuel valve is open, determine the power requirement of the tools to be operated by the generator, use the key or pull cord to start the engine.
    d. Determine the power requirement of the tools to be operated by the generator, turn the circuit breaker to the ON position, check to be sure the fuel valve is open, set the choke to the ON position, use the key or pull cord to start the engine.

72. (033) Both types of small engines you will typically encounter operate on what three essential elements?
    a. Fumes, air, and 2-cycle oil.
    b. Compression, air, and fuel.
    c. Exhaust, fuel, and air.
    d. Ignition, fuel, and air.

73. (033) In a four-cycle engine ignition takes place while the piston is in what position of the compression stroke?
    a. Bottom of the cylinder.
    b. Halfway up the cylinder.
    c. Top of the cylinder.
    d. When the key is turned on.

74. (033) What causes a spark plug to be wet?
    a. Engine is flooded.
    b. Engine has no fuel
    c. Engine air is restricted
    d. Improperly gapped spark plug.

75. (033) The "jumping jack" tamper's smaller foot increases what during compaction?
    a. Static load.
    b. Perpetual load.
    c. Bearing pressure.
    d. Volumetric pressure.

76. (036) Which type of material can you cut with the K–12 saw?
    a. Wood only.
    b. Asphalt only.
    c. Steel and concrete only.
    d. Wood, asphalt, and concrete.

77. (036) When operating the K–12 saw, how can you offset the kickback reaction?
    a. Use wedges.
    b. Balance your weight.
    c. Stand directly behind the saw.
    d. Apply side pressure to the wheel.

78. (036) The benefits of using a wet cut blade on a concrete saw are the water
    a. decreases cutting time and makes a straighter cut.
    b. counteracts side loading and makes a straighter cut.
    c. reduces dust and extends the life of the saw's blade.
    d. reduces operator fatigue and extends the life of the saw's blade.

79. (036) When using the concrete saw, you overlap saw cuts where they intersect to
    a. ensure square corners.
    b. ensure rounded corners.
    c. make sure the blade cuts to the base course.
    d. make sure saw cuts are as straight as possible.

80. (037) What are the two measurements used to express an air compressor's air flow and pressure?
    a. CFM and PSF.
    b. CCM and PSI.
    c. CFM and PSI.
    d. CCM and PSF.

81. (037) What is one way to quickly shut off the flow of air to the hose of an air compressor?
    a. Switching the ignition key to the off position.
    b. Using the emergency shutdown switch.
    c. Disconnecting the hose from the tool.
    d. Kinking the hose.

82. (038) What powers a typical roller screed?
    a. An air compressor mounted to the screed.
    b. A diesel motor attached to the screed.
    c. An auxiliary hydraulic power unit.
    d. A motor carried in a backpack.

Please read the unit menu for unit 5 and continue ➔

Unit 5. Oxyacetylene Cutting and Welding and Fencing Responsibilities

IN THIS UNIT, we will cover two areas of instruction and focus on two additional tasks that may be your responsibility. These include oxyacetylene cutting and welding and fencing. While these two tasks are dissimilar, they are no less important to the overall mission. You may be tasked to use an oxyacetylene cutting outfit to cut off stubborn bolts on a rusty cutting edge or possibly even cut sticks of rebar for a concrete project. Additionally, fencing is very important to the safety and security of Air Force assets and, therefore, will be discussed at great length in this unit.

5–1. Oxyacetylene Equipment

The process of oxyacetylene cutting is the result of mixing oxygen with acetylene; once the gases are mixed in the correct proportions, the resulting flame can reach a temperature of 6300°F and can be used to either remove or fuse metal.

039. Components of an oxyacetylene outfit

This lesson covers some of the oxyacetylene welding processes. Before you study the various oxyacetylene operations, you will be acquainted with the equipment you'll use and how it works.

Portable equipment

An illustration of a portable cutting torch outfit is shown on figure 5–1. As you can see, it consists of a cart, an acetylene cylinder, an oxygen cylinder, two-stage oxygen and acetylene pressure regulators complete with gauges and connections, two lengths of hose with adapter connections for the regulators and torch, flashback arresters, a torch wrench, a safety flint igniter, gloves, and welding goggles. In addition, a fire extinguisher is considered part of the basic equipment.

NOTE: If any part of the basic equipment is damaged, the whole welding outfit is out of commission until the damaged part is replaced or repaired.

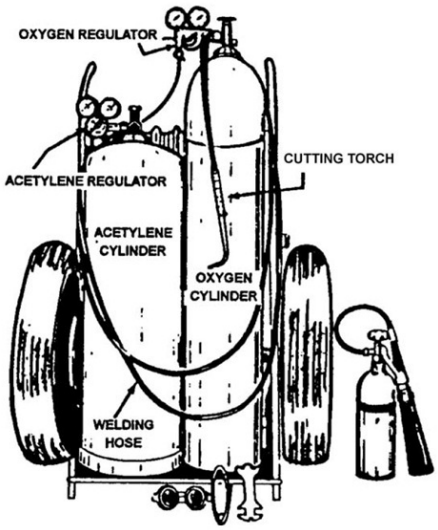


Figure 5–1. Portable oxyacetylene equipment.

Cylinders

Acetylene is a gas formed by the mixture of calcium carbide and water. It's a colorless gas with a very distinctive nauseating odor. Acetylene is highly

combustible when mixed with oxygen or air. Although it's stable under low pressure, it becomes *very* unstable if it is compressed to more than 15 pounds PSI when mixed with air.

CAUTION: Acetylene becomes dangerous if line pressures exceed 15 PSI and explosive at 29.4 PSI!

Acetylene

An acetylene cylinder is yellow in color. It's designed to store acetylene under pressures up to 250 PSI because there is no oxygen present. The cylinder is made of fusion-welded or braze-welded steel. To safely store acetylene, the manufacturer packs the cylinder with a porous material (calcium silicate or wood pulp). This material is saturated with acetone which is a chemical liquid that absorbs large quantities of acetylene under pressures greater than 15 PSI. The cylinder is filled with acetone to only 40 percent of its liquid volume. This allows space for expansion as the acetone absorbs the acetylene to stabilize it under pressure. The cylinder is equipped with a cylinder valve and a protective cap. As a safety precaution, the valve has left-handed threads to prevent an improper connection. The cylinder valve is operated by means of a T-wrench.

WARNING: *Never* open the valve more than 1½ turns. This slight opening is advisable since it permits rapid closing of the valve in case of an emergency and prevents the acetone from being drawn up into the valve and cooling the system.

Another safety precaution is the safety plug for releasing the gas if the cylinder is overheated. This plug melts at temperatures between 212°F and 220°F. It's small enough to keep the gas from burning back into the cylinder. Acetylene cylinders must be stored upright to prevent the escape of the acetone.

Oxygen

The oxygen cylinder is green in color. It's made of seamless steel and contains oxygen at pressures of up to or over 2,000 PSI. It is essential to handle the cylinder with great care. For example, the container is equipped with a safety cap to protect the valve. Always keep this cap in place when moving or storing cylinders. The high pressure in an oxygen cylinder makes it a potential missile if the valve is broken off or the tank is pierced. The valve has a bursting disc to release pressure if the cylinder overheats. It has right-hand threads to keep it from being confused with the acetylene connections. The valve is operated by a hand wheel. Always open the valve by hand, *not* with a pipe wrench or heavy-duty pliers. Turn the hand wheel slowly to permit a gradual pressure load on the regulator. Then, turn the hand wheel as far as the valve will turn (all the way open). Unless the valve is wide open, the high oxygen pressure may cause oxygen to leak around the valve.

Store both oxygen and acetylene cylinders according to Air Force instructions. Here are a few safety rules to follow for handling and storing cylinders:

1. Always refer to *acetylene* as *acetylene* and *oxygen* as *oxygen*; not as *gas* and *air*.
2. Keep oxygen cylinders away from oil and grease. Oil or grease mixed under pressure with oxygen may explode.
3. *Never* test for acetylene leaks with an open flame. Use soapy water for this purpose.
4. *Don't* drop cylinders or handle them roughly.
5. Store cylinders in a cool, dry, well-ventilated building.
6. Store oxygen and acetylene cylinders in an upright, secured position.
7. Separate full and empty cylinders.
8. *Never* try to substitute oxygen for compressed air to drive pneumatic tools.
9. Do *not* use oxygen to try to blow obstructions from piping.

10. *Never* use a hammer, pliers, vice-grips, or a pipe wrench to loosen or tighten fitting connections. If you do, you'll surely damage the soft metal connections. Always use the correct size wrench to remove or install regulators and hoses.
11. When a cylinder is *empty*, replace the safety cap and write "MT" on the cylinder in chalk.
12. If your unit owns the cylinders, make sure all acetylene and oxygen cylinders have been hydrostatic and leak tested as required by AFOSH and local guidance. If they are exchanged with a local vender, make sure the vender is doing the leak tests as required.

CAUTION: Never use oxygen or acetylene from a cylinder to blow dust or dirt from your clothing.

Regulators

The regulators, or reducing valves, are mechanical devices used to reduce the high pressure of the gasses as they flow from the cylinders. There are two basic types of regulators—single-stage for the acetylene and two-stage for the oxygen. Single-stage regulators reduce the pressure in one step, while two-stage regulators (fig. 5–2) reduce the pressure in two steps.

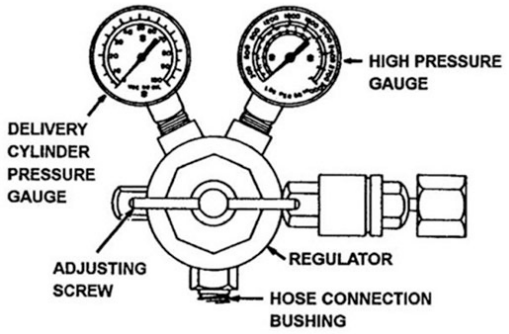


Figure 5–2. Regulator.

Hoses

The hoses take the gases (at working pressure) from regulators to torch needle valves. The color of the hoses informs the user of which tank to attach it to. The following table provides an overview of which colors apply:

Color	Purpose or Description
Green	Oxygen hoses will always be colored green.
Red	Fuel gases (acetylene) are red to distinguish them from either oxygen or inert-gases.
Black	Inert-gases or air are black to distinguish them from either oxygen or acetylene gases.

To prevent interchange, the oxygen hose connection has right-hand threads and the acetylene hose connection has two items to prevent a wrong connection; left-hand threads and a V-notch on the connecter.

For safety reasons, never drag the hoses through any grease or oil. Also, try to route the hoses so no one will walk on them. When you finish using the oxyacetylene equipment, always shut off the cylinder valves and drain the hoses to eliminate the possibility of a fire hazard. Additionally, always roll up the hoses and secure them out of the way.

Safety equipment

Welding goggles, gloves, flashback arrestors, flint igniters, protective clothing, and fire extinguishers are all items of safety equipment used with the outfit. This equipment is designed to protect the operator from injury and to prevent damage to property or the equipment.

Welding goggles

Wear welding goggles when you operate the oxyacetylene equipment. Sunglasses don't provide you the level of protection welding goggles provide. As you perform oxyacetylene welding, the glare from the oxyacetylene flame and molten metal can give off harmful rays of light. Welding goggles protect your eyes from these hazards. There are various lens shades from which you can choose. For cutting operations, a lens shade of four to six is required.

Welder's gloves

Wear nonflammable gloves to protect your hands from the intense heat produced during operation of the oxyacetylene equipment. Even though the flame coming from the torch is generally going away from you, heat reflects off of the metal you're working with and can burn your skin if you're not wearing welder's gloves. Sometimes, you may have to handle the hot metal suddenly and without any warning. If you're wearing your welder's gloves, you reduce the possibility of receiving severe burns on your hands.

Flashback arrestor

Flashback arrestors are normally installed on the oxygen and acetylene torch gland nuts. They keep a flashback from burning back into the oxygen or acetylene hoses.

Flint igniter

Never use matches or a cigarette lighter to ignite the oxyacetylene torch; instead, use a flint igniter. Your hands are too close to the torch tip to light the torch with matches or a cigarette lighter and you could receive severe burns by doing so. Also, it's an unsafe practice to use the molten pool of metal to re-light the torch should it go out while you're welding.

Protective clothing

Always wear some sort of protective clothing or apron when performing any kind of welding. You never know when sparks or tiny molten globules will land on you or your clothing. These sparks and tiny globules can burn holes in your clothing or burn your skin before they cool off. If you wear an apron or some other protective clothing (coveralls, leather jacket, leather sleeves, etc.), you'll protect the front of your body from receiving severe burns from flying sparks and tiny globules of molten metal—perhaps you'll also save the expense of new uniforms.

How to assemble oxyacetylene welding equipment

To properly assemble the portable oxyacetylene outfit, use the procedure in the following table:

Step	Procedure
1.	Put the acetylene and oxygen cylinders on the cart, secure them, and remove the cylinder valve protective caps.
2.	Open (crack) each cylinder outlet valve slightly for an instant to blow out any dirt lodged in the outlet nipple (fig. 5–3).
3.	Attach the two-stage regulators to their respective cylinders and tighten the union nut with the torch wrench (fig. 5–4).

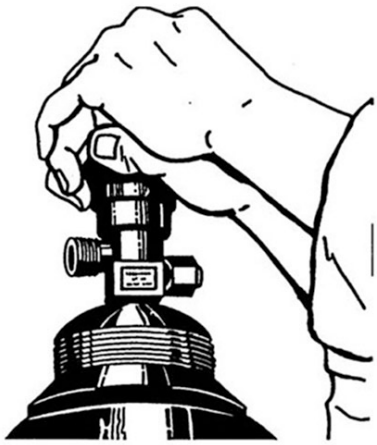


Figure 5–3. Cracking the valve.

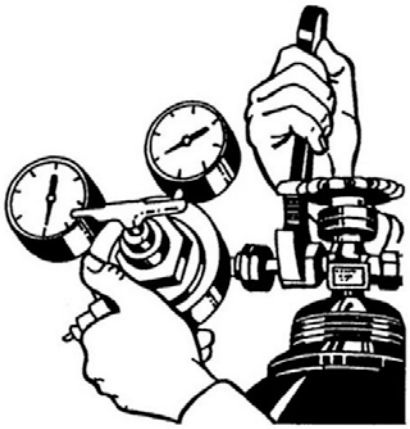


Figure 5–4. Tightening the union nut.

Attach the red acetylene hose to the acetylene regulator outlet (left-hand threads). Attach the green oxygen hose to the oxygen regulator outlet (right-hand threads). Screw the nuts tightly with the torch wrench (fig. 5–5). To make sure the regulator adjusting screws are backed out, turn them counterclockwise until they're loose.

NOTE: Purge the system during each step to ensure gas flow.

Never open cylinder valves before releasing the regulator adjusting screws (fig. 5–6). As we stressed earlier, open the acetylene cylinder valve a *maximum* of 1½ turns and preferably no more than ¾ of a turn which allows you to close it quickly in an emergency.

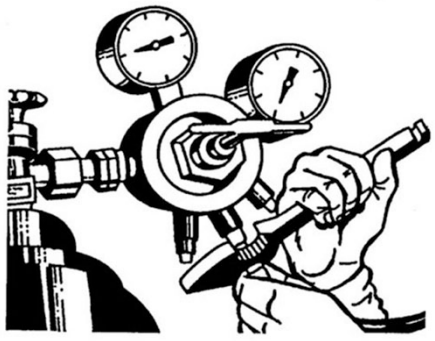


Figure 5–5. Attaching the hose.

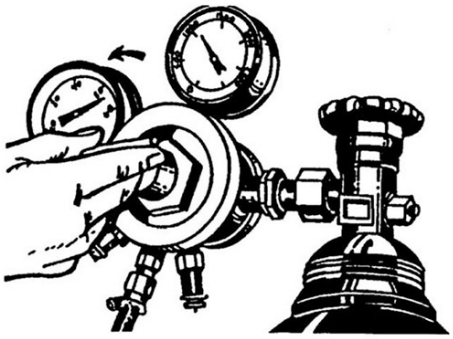


Figure 5–6. Relieving pressure on the diaphragm.

Next, open the oxygen valve slowly at first, and then fully open it. Read the high-pressure gauges to check the pressure of each cylinder. Open each regulator by turning the adjusting screw clockwise. Blow out the hoses one at a time at 3–5 PSI for 5 to 10 seconds, as shown in figure 5–7.

After you blow out the hoses, release the adjusting screws. Install flashback arrestors between the hoses and torch. As we said earlier, these are normally installed on the oxygen and acetylene torch gland nuts. They keep a flashback from burning back into the oxygen or acetylene hoses. After you install the flashback arrestors, connect the hoses to them. The red hose connects to the acetylene

flashback arrester with the left-hand threads, and the green hose connects to the oxygen flashback arrestor with the right-hand threads (fig. 5–8).

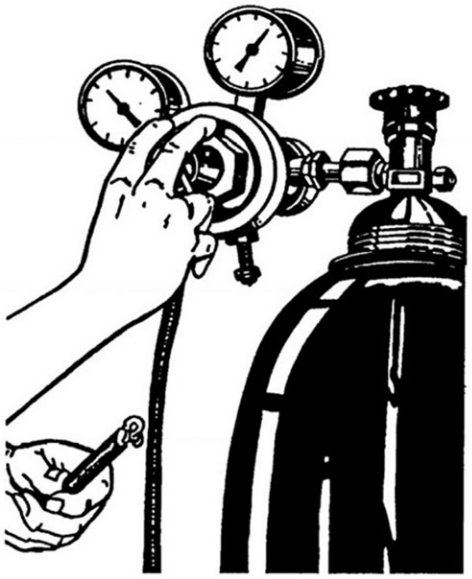


Figure 5–7. Blowing out a hose.

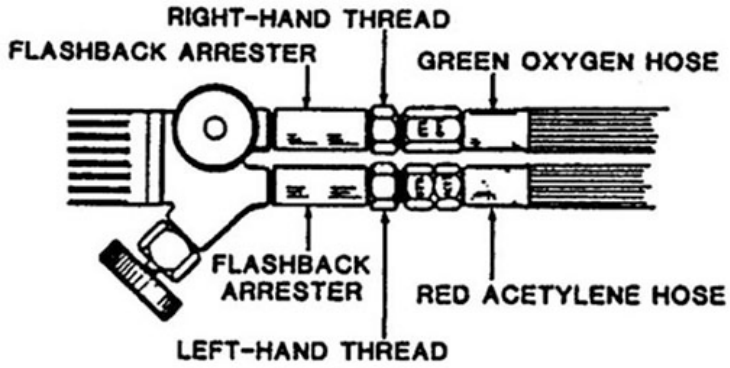


Figure 5–8. Connecting the hose.

Select a torch tip and attach it to the torch and tighten it only enough to prevent leaks, not too much as to cause damage to the brass fittings. Now the outfit is assembled and ready to operate.

NOTE: Remember for safety all acetylene connections are left-handed threads, and all oxygen connections are right-handed threads. This helps to prevent improper connections.

How to light the torch and adjust its flame

Before you can operate oxyacetylene welding equipment, you must adjust the regulators for the working pressures. To do this, first open the torch acetylene valve and adjust the regulator and then close the valve. Adjust the oxygen working pressure in the same way. The chart below lists the suggested working pressures for acetylene and oxygen regulators. Now you're ready to light the torch.

TIP Number	Metal Thickness (inches)	Oxygen Pressure (PSI)	Acetylene Pressure (PSI)
0	1/32	3	3
1	1/16	3	3
2	3/32	3	3
3	1/8	3	3
4	3/16	4	4
5	1/4	5	5

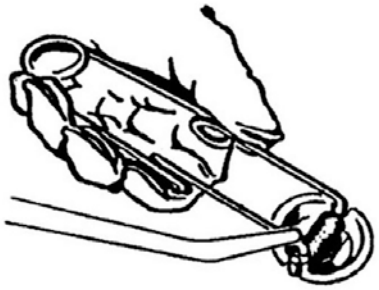


Figure5–9. Lighting the torch.

To light the cutting torch, *first*, open only the acetylene valve. Strike the flint igniter in front of the tip keeping your hand at one side, as shown in figure 5–9. Use *only* a flint igniter. Hold the torch so the flame is directed *away* from you, the cylinders or manifold, the hose, and any flammable material. The pure acetylene flame is long and bushy and has a yellowish color. Since the oxygen valve is closed at this point, the acetylene burns in combination with the air. Because there isn't enough oxygen in the air to burn the acetylene completely, the flame is smoky. This type flame produces a soot of fine, unburned carbon. As such, the pure acetylene flame is unsuitable for welding. When the oxygen valve is opened, the flame shortens and the gases burn in contact with the tip face. The flame changes to a bluish white and forms a bright inner cone surrounded by an outer envelope. The inner cone develops the high temperature needed for cutting or welding. At the same time, the outer envelope contains varying amounts of incandescent carbon soot, depending on the proportion of oxygen to acetylene. To adjust the torch for a neutral flame, open the torch oxygen valve slowly until the feather at the end of the central cone disappears. You can obtain the following distinct flames with the oxyacetylene welding outfit:

- Reducing or carburizing.
- Neutral.
- Oxidizing.

Reducing or carburizing flame

The reducing or carburizing flame (fig. 5–10) is produced by slightly more than one part of acetylene to one part oxygen. To get this flame, adjust the welding flame to neutral and then open the acetylene torch valve slightly to produce a white streamer or "feather" of acetylene at the end of the inner cone.

You can recognize the reducing or carburizing flame by the presence of three distinct flame cones:

1. The clearly defined, intense white inner cone.
2. A white feather or intermediate reducing cone indicating the amount of excess acetylene.
3. The light-orange outer flame envelope.

The flame has a temperature of approximately 5,700°F at the tip of the central cone.

Neutral flame

There are two clearly defined cones in a neutral flame. The inner cone is luminous and bluish white. Around this cone is a colorless area surrounded by a large flame envelope or sheath, which is faintly luminous and has a light bluish tint, as shown in figure 5–11. The neutral flame is produced by a

mixture of equal parts of acetylene and oxygen supplied from the torch. The temperature at the tip of the inner cone is approximately 5,850°F.

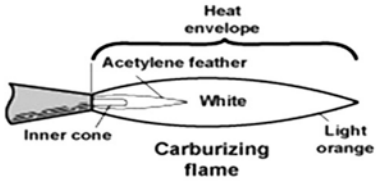


Figure 5–10. Reducing or carburizing flame.

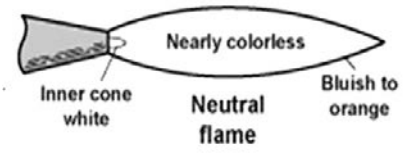


Figure 5–11. Neutral flame.

Oxidizing flame

This oxidizing flame (fig. 5–12) is produced by slightly more than one part oxygen mixed with one part acetylene. To get this type of flame, adjust the torch to a neutral flame. Then, increase the flow of oxygen by opening the oxygen torch valve. You can recognize this flame by the short, pointed central cone; a white or colorless middle cone; and a somewhat shorter outer envelope. In addition, the oxidizing flame produces a distinct hissing sound. This flame has a temperature of 6,300°F.

Figure 5–12. Oxidizing flame.

Shutting down the portable welding outfit

To shut down the portable welding outfit, turn off the torch oxygen valve first and then the torch acetylene valve quickly to avoid smoke. Close both cylinder valves. Open the torch valves one at a time (acetylene first) and bleed the regulators. Close the torch valves. Turn the regulator adjusting screws counterclockwise to relieve the pressure on the diaphragm. Hang the torch and hose up properly to prevent kinking the hose or damaging the torch. Be careful not to damage the tip of the torch by letting it hit the cylinder or cart.

NOTE: If you have to close down the portable welding outfit because of an emergency, *always* shut off the oxygen torch valve *first*, then the oxygen cylinder valve. A flame can't burn back inside the torch without oxygen.

The emergency shutdown of equipment may be necessary because of a flashback or other reason. A flashback is an occurrence initiated by a backfire where the flame continues to burn inside the equipment instead of being reestablished at the tip. A flashback is usually recognized by a high-pitched whistling or squealing sound. Flashback arrestors are installed between the torch and hoses. However, flashback arrestors aren't foolproof—you must still shut down the equipment if a flashback occurs. If the flashback reaches the cylinder, the cylinder may explode.

Don't confuse a flashback with a backfire. Backfires can be caused by shutting off the acetylene first, allowing the flame to burn back in the oxygen rich mixture. As noted earlier, the flame can't burn without oxygen, so always shut off the oxygen first. A backfire can also be caused by a dirty tip, a tip size that's too small, a tip being held too close to the work, or too little gas pressure. A backfire gives off a "popping" sound.

040. Oxyacetylene cutting equipment

To make the rapid cutting of metal possible, it's necessary to have a tool or mechanism that can heat sections of the metal to a molten state and then blast a stream of oxygen through that heated section. The oxyacetylene cutting torch is such a mechanism. Although, oxyacetylene cutting is fast and economical, it requires some special equipment. The basic equipment is a cutting torch or cutting attachment with cutting tips. Additional items are radial or multiple cutting machines and aids for performing manual cutting operations. In this lesson, we look at the specific equipment used to do oxyacetylene cutting. Oxyacetylene cutting equipment is generally the same as oxyacetylene welding equipment, except for the oxygen regulator and the torch. Let's look at the functions of cutting equipment.

Oxygen regulator

The oxygen regulators used for heavy cutting operations furnish a larger volume and higher pressure than is needed for welding. To make this possible, the oxygen outlet is fitted with a working pressure gauge graduated to 400 PSI. In addition, the oxygen hose is designed to withstand these higher pressures.

Cutting torch

The hand cutting torch looks like a welding torch, but it differs in construction and the method of control. The cutting torch varies from the regular welding torch in that it has an additional high pressure oxygen lever or trigger for the control of oxygen flow during the cutting operation.

Functions of cutting torches

During the cutting operation, the cutting torch carries out the following three functions:

1. Mixes oxygen and acetylene in definite proportions.
2. Burns the mixture in a preheating flame, which heats the work.
3. Directs a jet of high-pressure oxygen to sever the metal along the line of cut.

Figure 5–13 illustrates all the components of a typical cutting torch. You can see there are several parts; however, the main parts are a handle, connecting tubes, and a head. At the rear of the handle are the oxygen and acetylene hose connections. A needle valve in the acetylene inlet connection controls the acetylene supply. The preheating oxygen is regulated by a preheat valve on the side of the handle. A high-pressure oxygen valve, which is operated by the earlier mentioned trigger or lever, controls the cutting oxygen.

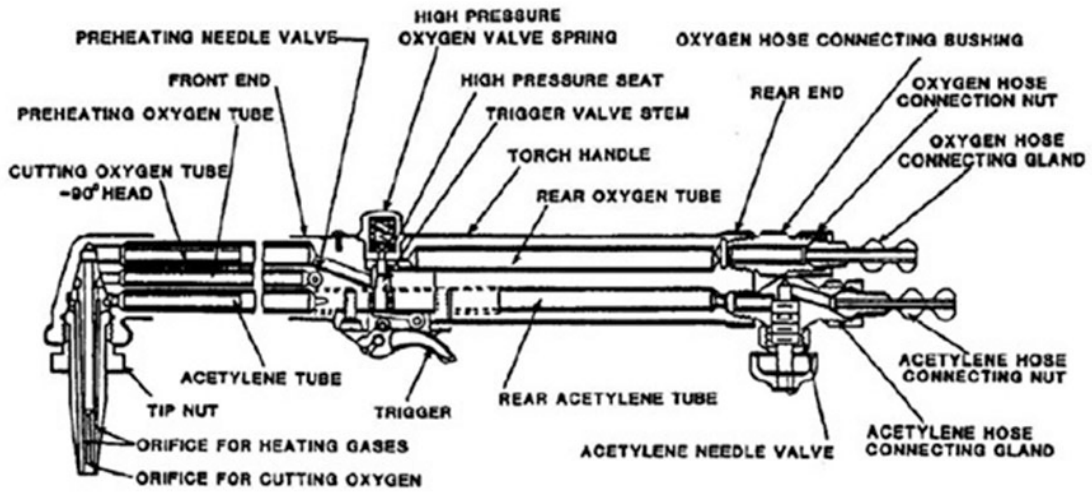


Figure 5–13. Cutting torch.

Gas tubes

In some cutting torches, the preheating oxygen and the acetylene don't mix until they're in the cutting tip. These cutting torches have three gas tubes—one for high-pressure oxygen, one for preheating oxygen, and one for acetylene. In other cutting torches, the preheating oxygen and acetylene mix in the torch body in a common mixing chamber. These torches have only two gas tubes—one for high pressure oxygen and one for the mixed oxygen and acetylene.

Cutting attachment

The construction and operation of the cutting attachment are like those of an ordinary cutting torch. This is illustrated on figure 5–14. The simple cutting attachment fits the body of the standard welding torch, converting it quickly into a cutting torch. Since it's unnecessary to disconnect the hoses, you can quickly change the welding torch into a cutting torch. This attachment is very useful for the occasional cutting of lighter sections; however, it isn't recommended for the constant cutting of heavy materials. Instead, do such work with a regular cutting torch.

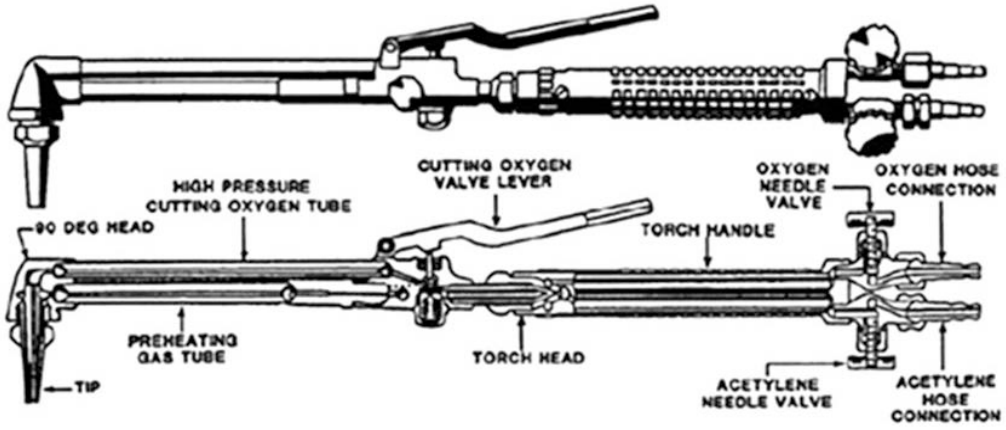


Figure 5–14. Cutting torch attachment.

Cutting tips

A typical cutting tip is shown in figure 5–15. As you can see, the taper-seated cutting tip is held in the cutting torch head by a tip nut. The tip has a central orifice through which the cutting oxygen flows. This orifice is surrounded by several preheating holes. Cutting tips with cutting and preheating orifices of various sizes are available for cutting practically any thickness of metal and are supplied in various lengths for special jobs. Bent tips are also used under certain conditions.

Figure 5–15. Cutting tips.

Many special operations such as flame machining, gouging, and rivet cutting are done with cutting tips designed for the purpose. Figure 5–16 shows these different designs (taper and bent tips) and their uses.

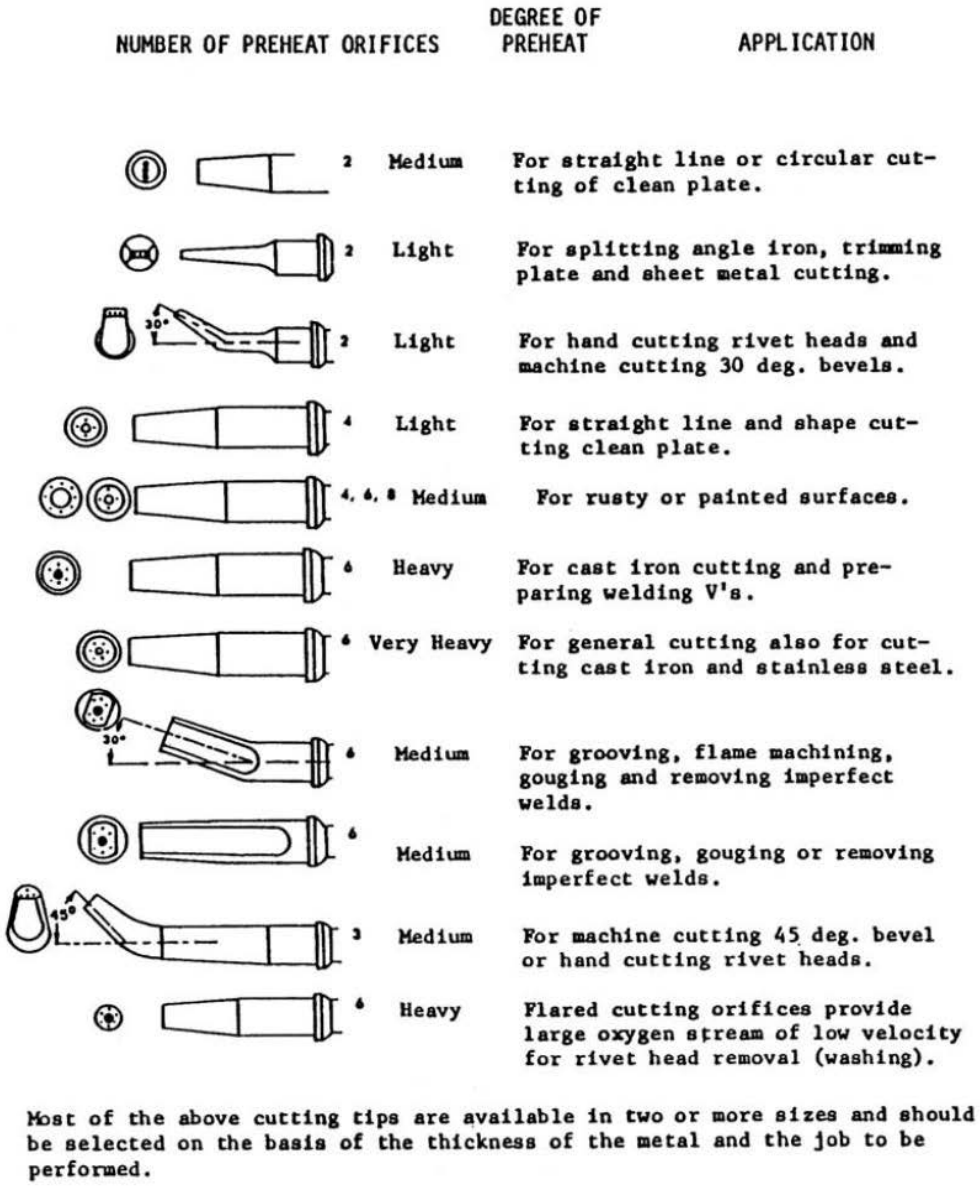


Figure 5–16. Cutting tips and their uses.

Cutting aids

Cutting aids are any devices that help you with a desired operation. They can be a simple straightedge, such as a piece of angle iron for straight-line cutting; a circular cutting attachment for cutting circles; or a sheet metal pattern for cutting specific shapes and angles.

041. Oxyacetylene cutting operations

The speed and economy with which you can cut and shape steel by oxyacetylene cutting make the cutting torch a valuable tool. Its uses are numerous and varied. For example, it’s useful for cutting plate to the desired shape, for beveling plate edges before welding operations, and for all types of fabrication and repair.

Characteristics of the oxyacetylene cutting process

To cut metal by the oxyacetylene cutting process, there must be rapid oxidation of the metal within in a localized area. To produce this oxidation, you heat the metal to a bright red or "kindling" temperature and direct a free jet of high-pressure oxygen against it. This oxygen blast combines with the red hot metal and burns it to an oxide. The resultant reaction generates the intense heat that's used for cutting. As you proceed with the cut, the high-temperature oxide heats the metal in its path to the ignition temperature as it passes down the side of the cut. The affected area combines with the cutting oxygen and also burns to an oxide. The oxide on the opposite side of the piece leaves a narrow slot or "kerf" which separates the metal.

Only the metal in the path of the oxygen jet is acted upon. In linear cutting, a narrow kerf with uniformly smooth and parallel walls is cut. A skilled worker, using a mechanically guided and controlled torch, can make very accurate cuts. Heavy sections that can't be cut economically by any of the other mechanical methods can be cut easily and smoothly by the oxyacetylene process.

Practically, all metals combine readily with oxygen when they're heated to a high temperature. However, some of them can't be cut successfully by this method because their oxides have a higher melting point than the parent metal. In these cases, the oxides mix with the parent metal when they're melting, instead of separating from it. This problem occurs when you attempt to cut nonferrous metals, such as aluminum and copper.

Oxyacetylene cutting procedures

You can cut all steels of low and medium carbon content successfully with the oxyacetylene process without special preparation. In contrast, you can cut high-carbon tool steels if you first properly preheat the entire section. For ordinary tool steel, a black heat is usually sufficient, although some alloy tool steels require a full red heat. Cast iron is more difficult to cut than steel because it melts at a lower temperature than its oxide. Chromium and stainless steels require a special process. There are many commercial resources available to aid in the oxyacetylene cutting operation which will help you choose the right set up and procedures according to the type of metal you are cutting. To get ready to cut metal with the oxyacetylene torch, first select the right tip size and adjust the regulators for the correct pressure.

Recommended Pressures and Tip Sizes

The following table gives the recommended pressures and tip sizes to use to cut various thicknesses of low-carbon steel. Seek out other resources available to help with cutting other types of metal.

Recommended Pressures and Tip Sizes

Plate thickness (inches)	Tip size (number)	Acetylene pressure PSI	Oxygen pressure PSI
¼	0	3	25 to 30
⅜ to ½	1	3	30 to 40
¾ to 1	2	3	40 to 50
1½	3	3	45 to 50
2	4	3	50 to 55
3 to 4	4	4	55 to 65
5 to 6	6	5	55 to 60
8 to 10	7	6	60 to 70
12	8	6	70 to 80

Steps to lighting torch

To light the torch, use the following steps:

1. Open the control valve all the way.
2. Open the acetylene about ⅛ of a turn and light with a flint igniter.
3. Increase the acetylene until smoke disappears.
4. Slowly open the pre-heat oxygen control valve until you achieve a neutral flame (see fig. 5–11).

Because of rapid oxidation, the oxygen actually separates the metal. Make sure the metal on both sides of the line of cut is free from scale and heavy rust deposits. To start the cut, on low-carbon steel, hold the torch perpendicular to the work with the inner cone of the preheating flame slightly above the surface of the metal. As the torch produces a *red* heat in the metal, press down on the cutting lever as shown in figure 5–17. If you start the cut properly, a shower of sparks will fall from the opposite side. This indicates the cut is penetrating all the way through the metal. If you use proper pressures and cutting speeds, you can cut the metal without interruption. If you've performed the cut properly, it will be a fairly clean, narrow kerf, comparing with a cut made by sawing, except much quicker.

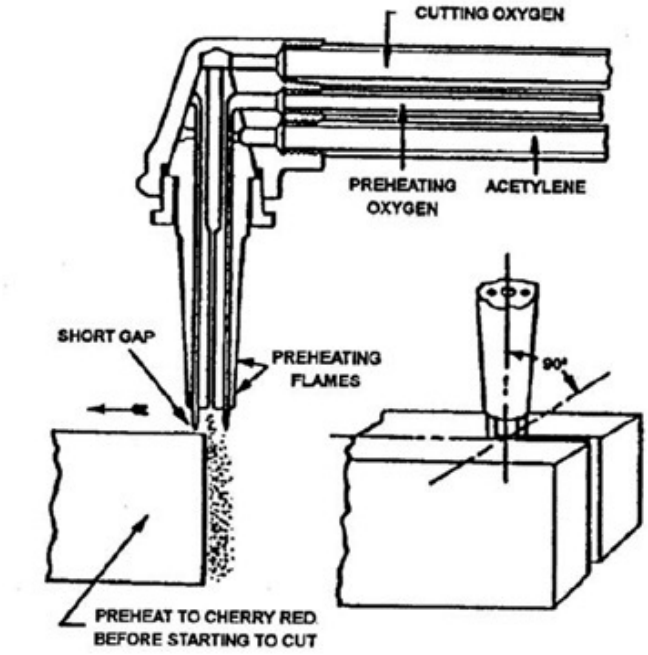


Figure 5–17. Starting a cut.

Figure 5–18 illustrates different results that you can obtain in cutting. In each of the views, consider such factors as oxygen pressure, preheating, and speed of travel. The views also show work views, drag, and direction of cut. If the speed is too fast, the metal isn't preheated sufficiently to continue the cut. To restart, direct the flame slightly *behind* the point where you lost the cut. When the metal is preheated properly, resume cutting.

Safe cutting practices

During all cutting operations, you must be alert to prevent damage to equipment and injury to personnel from fire and explosion. To ensure safe operation, always observe the following rules:

- Always get a welding permit (available from the Fire Department) when your cutting job is *not* in the immediate area of the metal shop.
- Never dismantle or salvage magnesium parts with an oxyacetylene cutting torch.

- Never cut *new or used* drums, barrels, tanks, or other containers until they've been thoroughly cleaned. Do the cutting as soon after the cleaning as possible. Drums and barrels should have the head removed with a drum de-header before heat is applied.
- Move combustible materials to a safe location, or move your work to a safe distance from such materials. Set up sheet metal guards or flame resistant blankets if they're needed.
- Don't cut material in a position that permits sparks, hot metal, or the severed section to fall on the cylinder, hose, or on your legs or feet.
- Always wear proper clothing, such as over-the-ankle boots, gloves, and clothing without cuffs. Cuffs can collect hot metal and cause a serious burn.
- Use a fireguard if the work requires protection against fire.
- When you stop cutting for short periods, release the regulator adjusting screw. Close the complete outfit down when you leave the job.

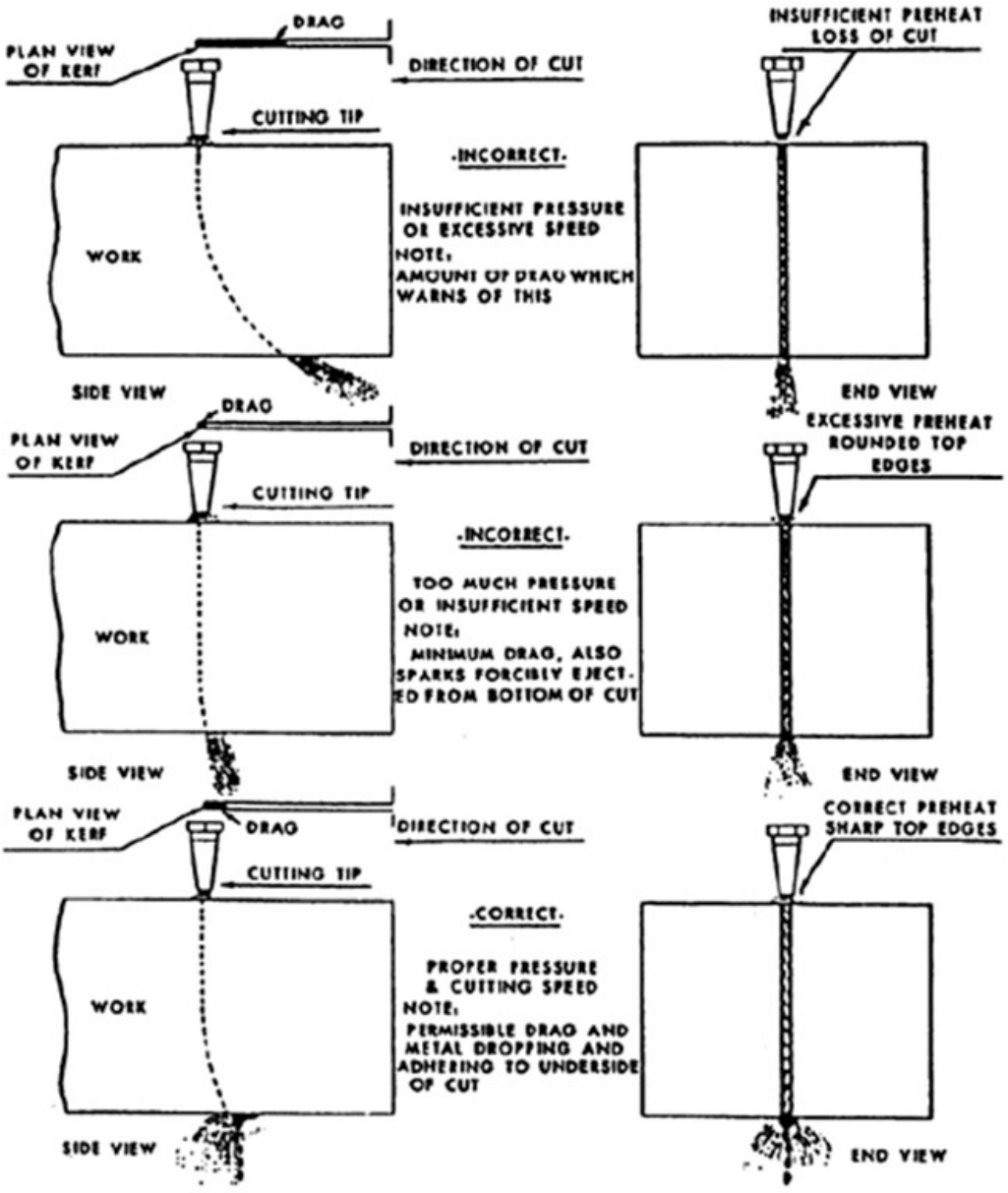


Figure 5–18. Cutting results.

Specific cutting tasks

As you now know, we can do several cutting operations with the oxyacetylene process. Among these are the following:

- Straight-line cutting.
- Circular cutting.
- Piercing holes.
- Beveling.
- Cutting round stock.
- Flame gouging

Straight-line cutting

To do straight-line cutting, mark the line of cut clearly with *center punch marks*, or clamp a guide bar into position to guide the torch accurately, as shown in figure 5–19.

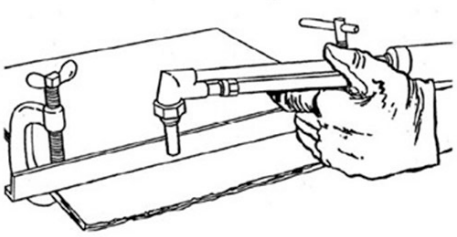


Figure 5–19. Straight-line cutting.

The latter method is preferred for a cut of any considerable length. To make a straight-line cut, follow this procedure:

1. Start at the edge of the metal.
2. Hold the torch tip vertical to the surface of the metal, with the inner cone of the heating flame approximately $^{1}/_{16}$ inch above the cut line. Keep the torch in this position until a spot in the metal heats to a bright red.
3. Gradually press down on the oxygen lever and move the torch slowly along the cut line. Make your movement just rapid enough to ensure a fast but continuous cut.
4. A shower of sparks can be seen to fall from the underside, indicating the penetration is complete and the cut is proceeding correctly.

Circular cutting

Circular cutting with a hand cutting torch is best when done with a circular cutting attachment like the one shown in figure 5–20. This attachment is a rod with a clamp attached to one end. The clamp fits the torch head. The rod has an adjustable center point that can be set to the desired radius. When starting the cut away from the edge of the metal, drill or pierce a small hole through the metal in the scrap portion a short distance from the circular outline. Start the cut from the edge of this hole.

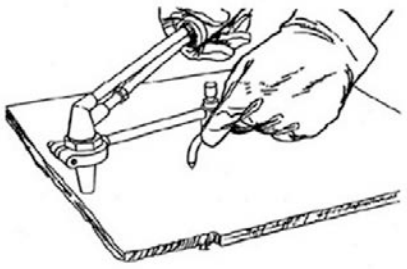


Figure 5–20. Using a circular cutter.

Piercing holes

To pierce a hole, more time is needed to heat the metal to a kindling temperature than is needed for edge starting. When the desired spot is sufficiently heated, raise the torch about ½ inch above the normal position for cutting and open the cutting oxygen valve slowly. After the torch burns through the metal, lower the torch to the normal height of work and complete the cut. Try to keep slag from plugging the cutting orifice, which occurs if you hold the torch too close to the work when the cutting oxygen valve is open.

Beveling

Torch control during beveling is more difficult than for straight square-edge cutting. The proper speed and a steady hand on the torch are essential to obtain a smooth bevel cut. A line made with chalk to

indicate the top edge of the bevel and a straightedge clamped into position as a rest both help to maintain the proper torch angle. The angle made by the torch tip with the surface of the metal produces the bevel.

Cutting round stock

To cut round stock, use a chisel to raise a burr on the surface of the metal where the cut is to begin. The burr makes it possible to start cutting without prolonged heating. Start the cut at the side, about 90° from the vertical centerline, as shown in figure 5–21. After starting the cut, raise the torch to the vertical position and hold it in this position for the remainder of the cut. Hold the preheating flame the same distance from the surface of the metal as you would for cutting sheet stock.

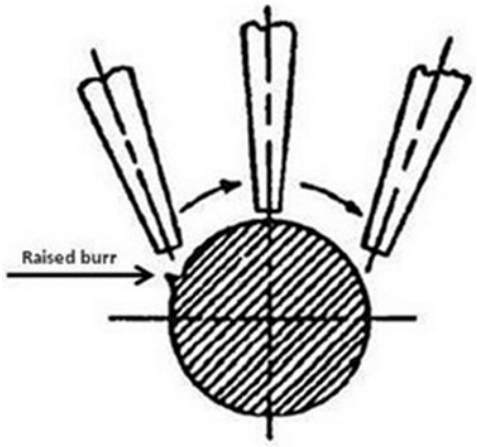


Figure 5–21. Cutting round stock.

Flame gouging

By using flame gouging, you can remove a narrow metal strip from the surface of steel plate, forgings, and castings. Flame gouging differs from other flame cutting because the cut does not go all the way through the metal (fig. 5–22). By using a tip that delivers a relatively large jet of oxygen at low velocity and by controlling and manipulating it properly, you can gouge a smooth, accurately defined groove out of the metal surface. Use different tips and torch manipulations to vary the width and depth of the groove. The two flame-gouging techniques include progressive gouging and spot gouging. In the first, make the groove progressively across a plate, like when removing metal from the back of a weld or in preparing remote cracks for welding. In the other, gouge out a small area, such as when removing isolated weld defects.

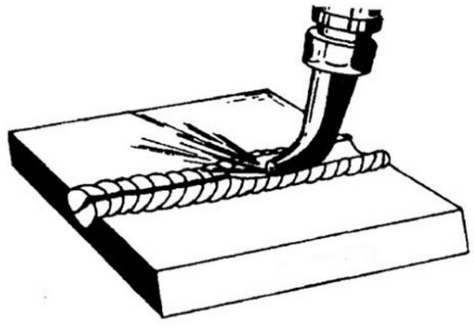


Figure 5–22. Flame gouging.

Progressive gouging

To start the cut for progressive gouging, hold the torch with the end of the tip at a 20° angle to the horizontal. Direct the preheat flame to the starting point until the surface reaches red heat; then, gradually open the cutting oxygen lever. To start the cut, lower the angle of the torch to produce the depth of cut required. The groove depth depends on the tip size, the travel speed, and the angle between the cutting oxygen stream and the work. The speed at which you move the torch greatly affects the gouge that you make. Moving too fast makes a gouge that is shallow and narrow; moving too slow makes a gouge that is wide and deep. To cut a deep groove, increase the torch angle in relation to the groove and decrease the speed correspondingly. To make a

shallow groove, reverse the procedure. The groove contour depends on the tip characteristics and operating conditions. If your cutting oxygen pressure is too low, the cutting has a washing effect, leaving ripples in the bottom of the groove. If your oxygen cutting pressure is too high, the cut is advanced nearest the surface ahead of the molten pool. This results in cutting loss and is especially common when cutting shallow grooves.

Spot gouging

To gouge out a single spot, as in spot gouging a weld defect, first mark the surface of the area to be removed. Adjust the preheat flame to slightly oxidizing. Preheat a point slightly to the rear of the defect and start the cut in the usual way. Gradually increase the torch angle so that the oxygen jet is directed downward, making the cut increasingly deeper. You can detect defects during gouging because they appear as dark spots in the molten zone. Hold the torch with the preheating flame about $^{1}/_{16}$ inch above the plate surface during the cut. To eliminate the need for raising a burr for starting the cut, you can use an oxidizing preheat flame to provide enough concentrated heat for starting the cut.

042. Maintaining oxyacetylene cutting equipment

You are required to maintain the oxyacetylene welding equipment that you use. This lesson covers how to test and do operator's maintenance on your equipment. Of course, the manufacturer may have to do some repairs; however, if you can do the operator's maintenance successfully, your equipment will be more productive and last longer.

Disassembling welding equipment

Disassembling a welding outfit is literally the opposite of assembling it. You can use a simple checklist like the one in the following table, as it lists each step in the order that it must be accomplished:

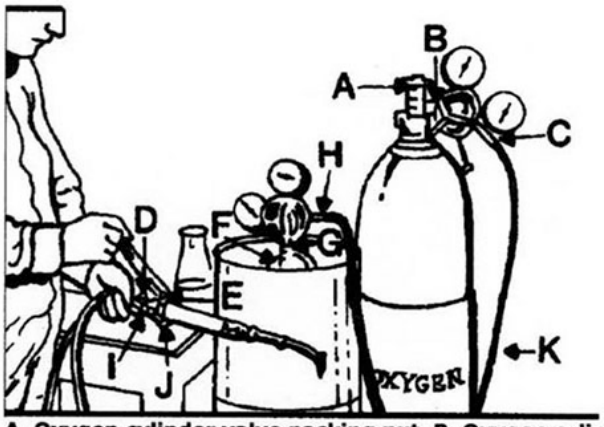
√	Be sure the gas supply is off.
√	Bleed the regulators (allow gas to escape).
√	Remove the torch tip.
√	Disconnect the hoses from the torch.
√	Disconnect the hoses from the regulators.
√	Disconnect the regulators from the cylinder or manifold line.
√	Re-install the cylinder valve safety cap or line protective nuts.

NOTE: When disassembling an oxyacetylene welding outfit, use the torch wrench to keep from rounding the corners on the connecting nuts. Also, handle the tips, torches, and regulators carefully to keep from damaging them.

Testing cutting equipment for gas leaks

Before you light any welding outfit torch, thoroughly check the entire outfit for gas leaks. Testing the outfit is a very simple but critical task. You can do it with a container of soapy water, a small paintbrush or acid brush, and a bucket of clear water or commercially available leak detection liquid. After you assemble the apparatus and adjust it to a working pressure, test all connections by brushing soapy water onto them. Wherever bubbles form, there is a leak. The connections to check are shown in figure 5–23.

There are various ways to test hoses for leaks. We recommend that you simply submerge the hoses in a bucket of clear water. A leak is indicated by a string of bubbles. This method is inexpensive and instantly identifies all leaks.



A. Oxygen cylinder valve packing nut. B. Oxygen cylinder regulator connection. C. Oxygen regulator hose connection. D. Oxygen hose torch connection and flashback arrester.

E. Torch oxygen needle valve nut.

F. Acetylene cylinder valve packing nut.

G. Acetylene cylinder regulator connection. H. Acetylene regulator hoes connection.
I. Acetylene hose torch connection end flashback arrester_
J. Torch acetylene needle valve nut. K. Hoses

Figure 5–23. Checkpoints for leaks.

Stopping leaks in cutting equipment

Stopping gas leaks in your welding equipment is an obvious task that you do before you attempt to light the torch. Let's take a look at areas that are prone to leaks, possible causes of leaks, and methods that you can use to stop leaks.

Regulators

The primary problem with regulators is gas leakage between the regulator seat and the nozzle (fig. 5–24). You can detect leakage by observing a gradual pressure rise on the working pressure gauge after you open the cylinder or manifold valve. This condition we know as a *creeping regulator*; it is caused by worn or cracked seats or by dirt particles lodged between the seat and the nozzle. If you have a creeping regulator, see your supervisor about getting it repaired or replaced.

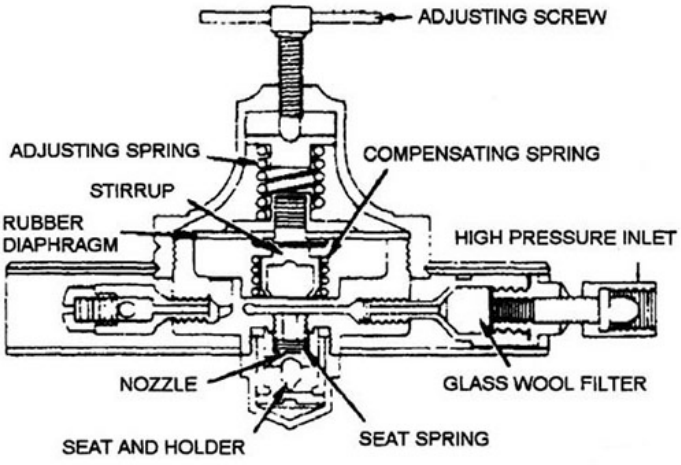


Figure 5–24. Pressure regulator, cutaway view.

Gauges

Bourdon tube pressure gauges are just one type of gauge used in oxyacetylene outfits. A cracked bourdon tube usually causes a gas leak in a gauge. A fluctuating gauge pressure or gas leaking from the gauge case is an indication that the bourdon tube is cracked and allowing gas to escape. Figure 5–25 shows how a bourdon tube works in a pressure gauge.

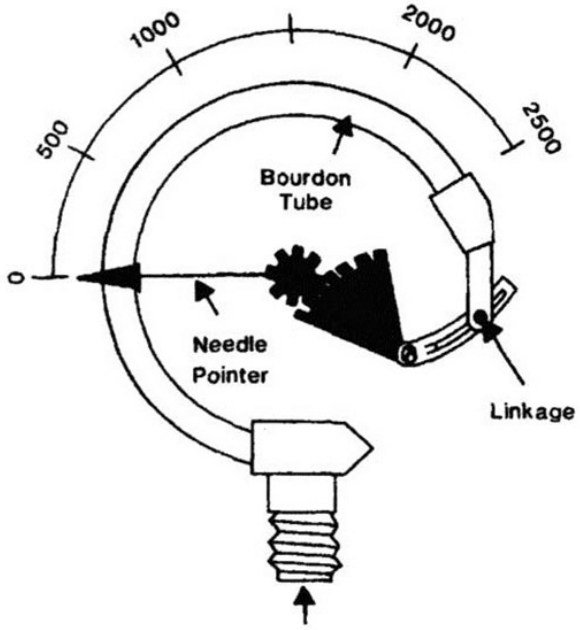


Figure 5–25. Bourdon tube gauge.

The bourdon tube is a steel tube attached to the needle through a linkage. When gas pressure fills the bourdon tube, the tube begins to straighten out. As the tube straightens, it moves the linkage and the needle pointer. A bourdon tube is a precision instrument that can be damaged easily. If the cylinder valve is opened quickly, and the regulator adjusting screw is not released, the sudden pressure increase can crack the bourdon tube and cause it to leak. If the leak is minor, you can repair it with silver brazing, but the manufacturer should make major repairs. It may make sense to just replace the gauge if the repairs are too costly.

Torches

Leaks in torches are common in the mixing head seat, needle valves, and clogged torch tubes. When gas continues to flow after the valve is closed, you know the needle valve is leaking. A worn or bent valve stem, a damaged valve seat, or loose packing around the needle valve can cause this condition. A leak in the mixing head seat allows the gases to escape. Unless you correct the trouble immediately, flashback can result. Repair needle valve leaks around the seat by tightening the packing gland nut. If the leak is in the seat, remove the needle valve with a wrench and clean it (fig. 5–26). If it is worn or pitted, replace it with a new one. If the valve seat is scored, pitted, or otherwise damaged, return the torch to the

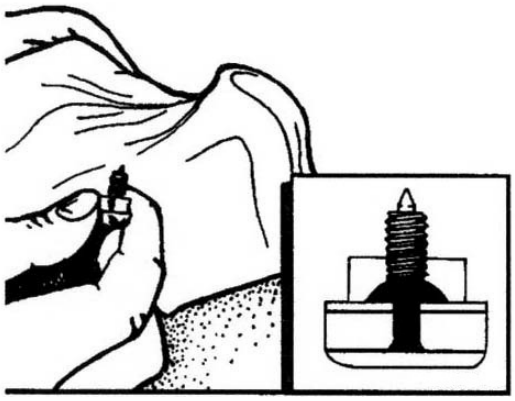


Figure 5–26. Cleaning a needle valve.

manufacturer for repair, or replace it with a new one. Remove and clean leaking mixing head seats. Replace them if they are damaged. Clean clogged torch tubes by removing the hoses and mixing head and then blowing out each tube with 20 to 30 pounds of oxygen pressure.

Hoses

Check welding hoses at regular intervals for leaks, worn spots, and loose connections. To find leaks in the hoses, immerse them in clean water while they're pressurized. Since worn or leaking hoses are dangerous and wasteful, repair or replace them immediately. Repair leaks in the hose by removing the damaged section and inserting a hose splice. In figure 5–27, the hose splice and sleeves shown are part of a hose repair kit.

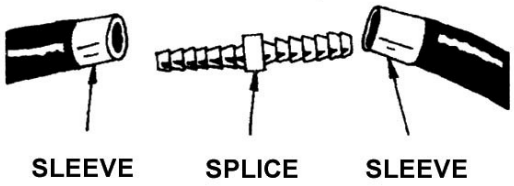


Figure 5–27. Hose splice and sleeves.

To make this repair, cut and remove the damaged section of hose. Then place the sleeves over the ends of the hose. After the sleeves are in place, slide both hose ends over the splice. The final step of the repair is to crimp the sleeves with the crimping tool included in the hose repair kit. Before you place the hose back in service, test it for leaks using the procedures we described earlier.

WARNING: Do *not* (by way of a shortcut or for other reasons) use a piece of copper tubing in place of a brass hose splice. Why? When copper and acetylene are placed together, they form copper acetylide, an unstable compound that explodes violently at the slightest shock. In short, *don't use copper with acetylene.*

Repair hoses leaking at the regulator or torch connection by cutting off one or two inches of the hose and replacing the connections.

Repairing welding and cutting torch tips

If welding and cutting torch tips are dirty or improperly cared for, they can't function properly. The two major malfunctions of both welding and cutting tips include accumulating dirt and leaking gas.

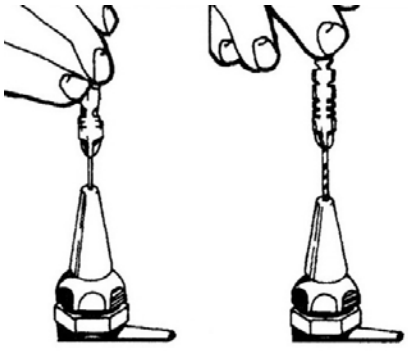


Figure 5–28. Cleaning an assembled torch tip.

Dirty torch tips

Torches require frequent cleaning because small particles of metal and oxide collect on the torch tip surface and inside of the tip orifice. Use a soft wire or drill-type tip cleaner to clean the tip. The tip cleaner should be approximately one size smaller than the tip orifice to prevent enlarging the orifice during cleaning. There are two correct ways of using a tip cleaner. One method is to remove the tip from the torch and insert the cleaner from the threaded end, as shown in figure 5–28. The other method is to open the oxygen valve and insert the tip cleaner, as shown in figure 5–29. Whichever method you use, always use a straight back-and-forth motion to prevent enlarging the orifice. If a tip orifice becomes scored, out of round, or enlarged, replace the tip.

Figure 5–29. Cleaning a disassembled torch tip.

NOTE: Remember, improper cleaning enlarges the orifice.

Slag accumulation (fig. 5–30) is a bigger problem on cutting tips than on welding tips. To remove slag from the tip, use a file placed on a tip, as shown in figure 5–31. Open the oxygen valve to blow out the slag and dirt after you loosen it. Be very careful not to remove too much of the tip when using this method. If you remove too much of the tip, the orifices are enlarged because of their original taper. In addition to cleaning the slag from the tip face, remove the slag from the tip sides.

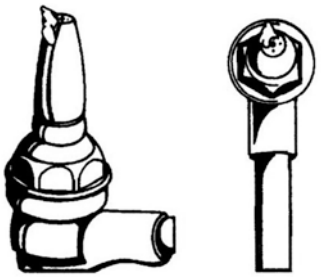


Figure 5–30. Slag on a torch tip.

When you dress the tip (fig. 5–31), remove the slag from the sides. Maintain a sharp edge at the meeting of the face and sides of the tip to prevent distorting the flame. Distorted welding and cutting tips cause uneven preheating and create problems when making a weld or cut.

Gas leakage

Gas leakage around a tip usually indicates that the tip is damaged. An inspection usually reveals a nick or flat spot in the tip seat. If this is the case, discard the tip. Always check for bad torch seats as well. Gas leakage around the tip can cause a flashback.

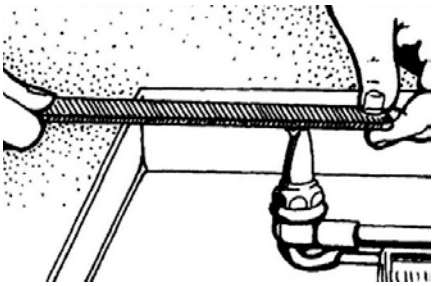


Figure 5–31. Slag removal.

NOTE: Never use welding or cutting equipment that has a gas leak.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

039. Components of an oxyacetylene outfit

1. How long must a whole welding outfit be out of commission if you damage any part of it?

2. What color are oxygen cylinders?

3. Why must you handle oxygen cylinders carefully?

4. What's the difference between the threads on oxygen and acetylene cylinders connections?

5. Why do you crack cylinder outlet valves before you attach the two-stage regulators while assembling the oxyacetylene welding equipment?

6. When assembling the oxyacetylene welding equipment, how far do you open each cylinder valve on the oxyacetylene outfit?

7. When you light the cutting torch on the oxyacetylene welding outfit, which valve do you open first?

8. Once you light the oxyacetylene welding outfit torch, how can you recognize the reducing flame?

9. Give the type and temperature of the *hottest* oxyacetylene welding outfit flame.

10. When you're bleeding regulators to shut down the portable welding outfit, which valve must you shut *first*?

11. Why do you shut off the oxygen torch valve *immediately* when a flashback occurs?

040. Oxyacetylene cutting equipment

1. How do the regulators used for heavy cutting operations differ from those used for oxyacetylene welding?

2. What are the functions of the cutting attachment?

3. How is the cutting tip held in the cutting torch head?

4. What are the outer orifices on a cutting tip used for?

041. Oxyacetylene cutting operations

1. When cutting metal using the oxyacetylene cutting process, how does the oxygen stream affect the red hot metal?

2. What do we call the *space* (narrow slot) that develops in the metal from the cutting action?

3. What pressure and tip size would you use to cut metal with a plate thickness of 1½ inches?

4. Why should you be alert and follow safety rules during oxyacetylene cutting operations?

5. List the specific cutting operations you can do using the oxyacetylene process.

6. What are the two types of flame-gouging techniques?

042. Maintaining oxyacetylene cutting equipment

1. What is the *first* action you take in disassembling a welding outfit?

2. Why do you use a *torch* wrench to disassemble oxyacetylene welding equipment?

3. What is the recommended way of checking welding hoses for gas leaks?

4. What can you use to clean a torch tip orifice, and what must you avoid while cleaning the orifice?

5. What is the most effective way to remove slag from a torch tip? What can happen through improperly removing it?

6. What must you do if you notice gas leakage around the torch tip? Why?

5–2. Fencing Requirements

In our career field, we have numerous duties to perform that may seem unrelated to the construction and repair of pavement, streets, run-ways and other paved surfaces. One such duty is to erect and maintain fences. Most of the fencing you will work with is security fencing that is used to protect government property. Besides providing security, fencing can be used for recreational reasons and provide a certain degree of privacy and safety. Not only should you have knowledge of the types of fencing available, but you should also be familiar with the various uses for each type of fence. Therefore, you need to know the construction, maintenance, and repair procedures of fences used by the Air Force.

043. The types and uses of security fencing

The type of fencing (whether it is a chain link, barbed wire, snow, or privacy) indicates what the fence is to be used for. You should become familiar with the various types of fencing available for your use. Most requirements for fencing can be satisfied by the types of fencing described in this lesson, which can be used individually or in any combination.

Type A

Type A chain link fence is seven feet high and topped with three strands of barbed wire angled outward for a total height of eight feet. This type is used for nuclear weapon storage areas, alert aircraft areas, and areas containing resources of high mission or monetary value. It is also used as a barrier between flight line activities and the barracks, or base, and immediately next to housing areas.

Type B–1

B–1 fencing is barbed wire consisting of 4-point barbs spaced four to six inches apart constructed with three strands of wire spaced approximately 16 inches apart, totaling four feet in height. Barbed wired strands need to be stretched with each strand secured to each post to prevent the strand from becoming loose or slipping. All barbed wire and woven wire should be secured to the post facing away from the flight line. Care should be taken when stretching the wire. Stretching it too tightly may cause the wire to break in cold weather, possibly loosen corner posts, or seriously injure your coworkers if the wire breaks during the stretching process.

Safety cannot be over-stressed when working with barbed wire. When unreeling the wire, roll the wire straight off the roll and not off the side. Stretch the wire only until it is fairly tight being careful not to break it. Be sure to wear protective clothing at all times when working with this wire. Typical uses include extension of flight line area barriers, perimeter boundary for isolated portions of installations, livestock barrier, and boundary for on-base bulk material storage areas.

Type B–2

B–2 fence is made of barbed wire, 4-strand, and is four feet high. This fence is provided for livestock barriers at the boundaries of livestock grazing lands that adjoin airfield operational areas. Livestock barrier fencing may be designed to higher standards, if necessary, to satisfy the requirements of local and state laws or land-use agreements.

Type C

Type C fence is made of concertina or razor wire. In normal use, one coil provides a barrier three feet in diameter. It should be used in multiple-stacked coils. Primarily, it is considered for short-term use or pending the erection of permanent fencing during contingency operations. A frangible fence may be installed wherever the base boundary fences cross the transverse limits of the runway clear zone. This fence should present a physical barrier equivalent to the fence system in which it is a part.

In areas subject to heavy sustained snowfall, the positioning of security fencing should include consideration of snow removal to retain security effectiveness. If snow removal is impractical, the height of the fence may be increased commensurately with anticipated snow accumulation. In such cases, type A fencing should not exceed an overall height of nine feet. If the depth of the snow in relation to the height of the fence comes into question (someone may be able to get over the fence), you may have to figure out a way to remove it.

Snow fence

A snow fence can be made from wood, plastic, or other materials that can withstand the winter elements. Most bases use a general-purpose plastic snow fence made of high-density polymer, usually available in 4-ft × 100-ft orange-colored rolls. Snow fence is highly visible and can be used for temporary security of an area. It is also a good product to use around excavations due to its high visibility.

044. Installation of fencing

You must be prepared to keep existing fences in the same shape as they were when they were first built. A fence not properly repaired and maintained does not give the security for which it was designed. Proper maintenance can stop minor defects from becoming major failures. High quality materials without quality installation result in a sub-par project. Therefore, you must follow each installation step to make sure you carry out each fencing installation project in an expert manner.

Tools and equipment required

You have, no doubt, heard the statement, “Use the right tool for the right job.” The same statement holds true for fences. There are a variety of tools you can use to make the fencing job easier, faster, and safer. Some may be more practical to use than others, depending on the size of the fencing job that must be done. A small stake-bed truck would be much easier to load and unload materials than a dump truck would be for the same job. For large fencing jobs, a skid steer-mounted auger would make digging post holes easier. Using a ready-mix truck or portable concrete mixer is faster than mixing concrete by hand for the post holes. Of course, you must have shovels to place the concrete. A wire stretcher or “come-along” must be available to stretch the fabric. Wire cutters or bolt cutters must also be used to cut the wire to the desired length. Fencing pliers are also handy to use in securing tension wire with hog rings to the fabric. Adjustable wrenches are used in various areas of fence erection such as attaching extension arms, draw bars, rail ends, offset bands, and other associated hardware.

Layout of area

Before the erection of any fences, make sure you are certain of any boundaries. After boundaries have been established, lay out the area to be fenced in. You should use a reference string to ensure your posts are on line. Measure 10 feet and drive a stake of wood or steel to mark the area where each post is to be set. Measure the distance between any gate posts adding the recommended amount of space for hardware.

Most fencing projects you will deal with will not require surveys. Areas such as high voltage terminals, swimming pools, tennis courts, individual buildings on base, and so forth, are examples of projects in which a survey would not be needed. When dealing with government property boundaries, you must take a survey to prevent encroachment onto private property. For example, in establishing a base perimeter (which will be done by engineer personnel), you must know where government boundaries exist before you begin any construction. It would be very embarrassing to you and the Air Force for you to remove a fence you had previously built on property that did not belong to the Air Force.

Fencing hardware

The following table, provided in figure 5–32, briefly describes fencing hardware.

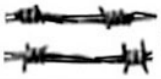
FENCING HARDWARE	ILLUSTRATION
Terminal post caps are used to cover the terminal post. They prevent moisture from entering the posts.	 Terminal Post Cap Sizes: 1 ⅞", 2 ½", 3" and 3 ½"
Top rail bands are used to secure the rail ends to the corner post.	 Top Rail Bands Sizes: 1 ⅞", 2 ½", 3" and 3 ½"
Rail ends are used to secure the top rail to end or terminal posts.	 Rail Ends Sizes: 1 ⅜" and 1 ⅝"
Offset bands secure the draw bars to the end or terminal posts.	 Offset Band Sizes: 1 ⅞", 2 ½", 3" and 3 ½"
Line post caps secure the top rail and prevent debris from entering the post.	 Line Post Caps Sizes: 1 ½", 1 ⅞" and 2 ½"
Draw bars slip through the fabric to permit tension to be applied to the fabric and are secured to the terminal posts by offset bands.	 Draw Bars Sizes: 1 3/16" x ¾" flat
The fork latch is used to secure the gate.	 Fork Latch (Standard)
Barbed wire extends the height of security fence, and it makes entry into the area more difficult. Three strands usually provide sufficient security.	 Galvanized Steel Barbed Wire at 16" intervals
A corner lookout arm usually supports barbed wire on corners.	 Corner Lookout Arm Size: 3 ½"
A vertical barbed wire arm supports wire to provide additional height to the fence.	 Vertical Barbed Wire Arm is 18" tall with slots spaced at 6" intervals
Sleeves are used to connect sections of top rail. The sleeves slip onto the rail to splice rails together.	 Sleeves, Top Rail Sizes: 1 ⅜" or 1 ⅝"
Gate post collars are used to secure bracing on the gate.	 Gate Post Collars Sizes: 2 ½", 3, and 3½"
Male hinge hooks protrude through the main post to accept the female hinge and provide a pivot point for the gate.	 Male hinge hooks (Standard)

Figure 5–32. Fencing Hardware Table.

Fence installation

To install a fence properly, you need to know how to install each fence component correctly. Though a chain link fence has several components, some items are not always required. However, you should know how and where these components are used. Of course, the size and type of chain link fence you install are normally determined by planners, who also order the materials required to install the fence. However, you may be required to plan the installation and order the materials. Sizes for fence vary, but the procedures for their installation are the same.

Line posts

Line posts are used to support the security fence in a vertical position. They do not, nor should they be used to, support the tension of the fence fabric. Install line posts no more than 10 feet apart. The length of the post should provide for placement at least 36 inches into the ground. You should connect the fence fabric to the line posts only after the fence is pulled to the proper tension. To tie the fence fabric to the line post, use a 9-gauge tie wire spaced about 12 inches apart. Smaller fences such as those used for residential areas, need only 24 inches placed in the ground and secured with concrete or compacted with earth.

Terminal posts

Terminal posts are used to support the tension of the fence fabric. For this reason, they must be larger than line posts. Terminal posts are used at corners and ends and for gates. You should place the terminal post at least 36 inches into the ground with concrete (fig. 5–33). Smaller fences, such as those used for residential areas, need to be only 30 inches in the ground, secured with concrete. Allow enough time for the concrete to harden before you stretch the fence fabric.

To stretch the fabric, you must first connect one end of the fence to a terminal post with a draw bar and clamps. Then connect the other end of the fence to a fence stretcher. Pull the fence until snug. Be careful not to overstretch the fence because this distorts the mesh. When you have the proper tension, you can then attach the fence to the terminal post. You should again use a draw bar and clamps to attach the fence to the terminal post. On security fences, you must make sure all hardware is mounted so that it can be removed only from the inside.

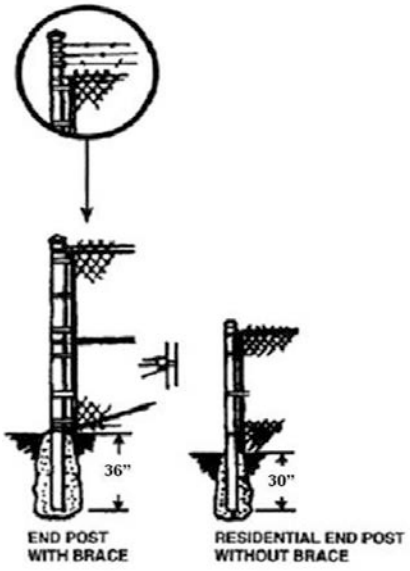


Figure 5–33. Terminal post footings.

Post footings

Determine the footings for fence post by what the post is used. Secure all terminal posts with concrete. You can secure line posts with concrete or backfill and compact them with soil. Make sure the post holes for those posts you set in concrete are slightly deeper than the posts you must set without concrete. Posts set in concrete should be 10 to 12 inches in diameter.

Fence fabric

The fence fabric selected for your job should be either a 6- or a 9-gauge woven wire fabric with 2-inch mesh openings. Normally, a galvanized fence fabric is used. You can use a wire stretcher, farm tractor, dump truck, or any combination of these to stretch the fence fabric. Again, you should be careful when stretching the fence fabric to prevent deforming it.

Tension wire

Use tension wire with fences without top rail. Normally, a 7-gauge zinc-coated wire is used for tension wire. If possible, you should weave the wire into the fence so that it runs along the top.

If you are unable to weave the tension wire through the fabric, you should attach it to the fabric with hog rings every two feet.

Top rail

Use a top rail only around areas that are *not* controlled, high voltage, or security areas. Fences that need top rail should have the top rail run the entire length of the fence minus the gates. You should install the top rail so that the rail passes through the openings in the post tops (either barbed or rounded). To connect top rail sections, use a sleeve between the pieces. After the top rail is in place, you can tie the fence fabric to the rail using a 9-gauge-wrap tie wire.

Extension arms

Extension arms (fig. 5–34), also referred to as “barbed wire arms” or “outriggers,” are used to support the barbed wire of your fence. They should be able to handle three strands of wire spaced six inches apart. Most extension arms have the angle preset at 45°. If the angle needs to be set, set it before you place the barbed wire. Position the extension arms on the post so they point away from the secured area.

In figure 5–34, you see two additional types of extension arms. One extension arm has two arms going in opposite directions; the other type is installed so that the arm is parallel to the post.

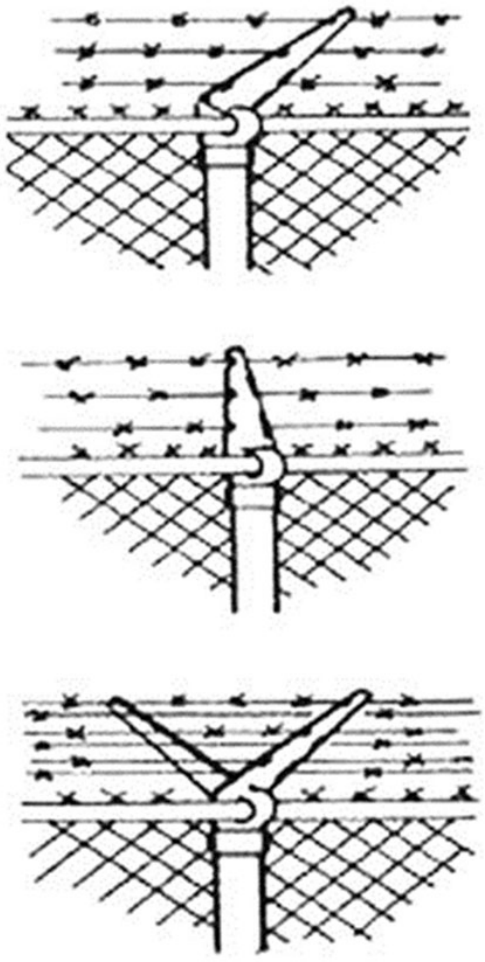


Figure 5–34. Extension arms.

Barbed wire

Barbed wire for fence is normally a 4-point barb placed at 6-inch intervals. You install the barbed wire in the slots on the extension arms. You should not install the barbed wire until it has been stretched. Stretch the wire with a fence stretcher until it is snug. Be careful *not* to overstretch barbed wire. If the wire breaks, it will whip-lash and could cause serious injuries. Once stretched, the wire can be placed into the grooves on the extension arm. Some extension arms require a keeper (piece of tie wire) placed in the groove to hold the barbed wire in place.

Truss braces

Use truss braces for all fences without top rail and fences over 6 feet tall. They are used for added support between the corner posts and each adjoining line post (fig. 5–35), and they should be used in combination with turnbuckles.

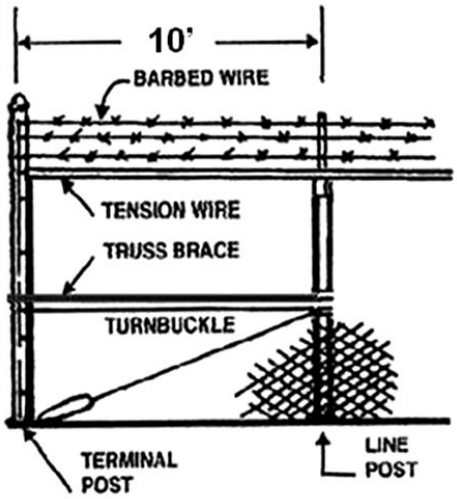


Figure 5–35. Truss braces.

Gates

Most gates come assembled from the factory. To install a gate, you need hinge hooks, which are normally installed through the terminal post. Position the hinge hooks so that the gate cannot be lifted off the hinges. Place the bottom hinge hook pointing up and the top hinge pointing down. Gates should be installed so that they swing freely.

Installing a snow fence

Normally before the beginning of snow season, a snow fence is erected at locations near the fight line or roadways that lack natural protection from drifting snow. A snow fence is also an inexpensive alternative to barricades for blocking work areas especially excavations. Using a general-purpose plastic snow fence made of high-density polymers requires driving t-post firmly into the ground and no more than 10 feet apart. Roll out the snow fence and place upright against the t-post. Tie off one end of the fence to the first t-post with plastic zip tie or wire. Stretch by hand going down the row until tight. Finish by securing the fence to the last post.

045. How to maintain security fencing

There are various issues that may occur in security fencing. Some of the more common ones are loose or broken strands of barbed wire, extension arms missing or barbed wire not secured in proper position on extension arms, bent or missing posts, holes or loose areas in fence fabric, missing sections of top rail, and tie wires missing or hog rings gone.

Maintenance procedures

You must do maintenance on security fencing as needed. Annual inspections will be required through tririga but a specified time cannot be readily established for maintenance of fencing as we do with most of our other work. A vehicle may run through the fence, prompting immediate action for repair to provide security of government property.

Heavy rains may cause erosion severe enough to require a crew of several people along with needed equipment to make repairs to maintain security. Proper maintenance is needed for the safety of people and wildlife as well as the security of Air Force assets. Proper maintenance can prevent minor defects in a fence from becoming major failures.

Safety in fence maintenance

If you have ever seen anyone tangled in barbed wire, then you know that you could be injured while working with fencing materials. If you use your safety guidelines and take the necessary precautions, you should not have problems.

Proper clothing

To protect yourself, make sure you wear the proper clothing. Gloves, hard-hat, and loose clothing are a must when working with fencing material or repairing a fence.

Proper clearance

Use caution when repairing the fence. Keep people who are not actually working on the fence clear of the area. Stay clear of barbed wire or fencing fabric that is being stretched. Barbed wire, if it breaks while being stretched, recoils with a whip-like action that can seriously cut you or others. Do not overstretch the wire. Stay clear of equipment being used on the pull.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

043. The types and uses of security fencing

1. What can happen if type B–1 fencing wire is stretched too tightly?

2. What are some *typical* uses of type B–1 security fencing?

3. Which fence type is used as a livestock barrier for livestock grazing lands that adjoin airfield operational areas?

4. What type fence is used during a contingency operation when the erection of a permanent fence is pending?

5. Snow fences used on most bases are made of what type of material?

044. Installation of fencing

1. What tool is used to stretch the fence fabric?

2. In the erection of fences, what types of areas would not require a survey?

3. What is the purpose of a terminal post caps?

4. What are rail ends used for?

5. How many strands of barbed wire *usually* provide sufficient security?

6. What should you use to attach the fence fabric to the terminal post?

7. In fence installation, what is *normally* used for tension wire?

8. What should you do if you cannot weave the tension wire through the fabric?

045. How to maintain security fencing

1. What are some of the more common defects that may occur in security fencing?

2. What happens if barbed wire breaks while being stretched?

Answers to Self-Test Questions

039

1. Until the damaged part is repaired or replaced.
2. Green.
3. Because oxygen is under tremendous pressure. A broken valve or pierced cylinder could make a missile out of the cylinder. This could cause injury and damage.
4. Oxygen connections have right-hand threads, and acetylene connection has two items to prevent a wrong connection; left-hand threads and a V-notch on the connecter.
5. To blow out any dirt which may be lodged in the outlet nipple.

6. Open the acetylene cylinder valve a *maximum* of 1½ turns; open the oxygen valve fully.
7. Acetylene.
8. By the presence of three distinct flame cones: the clearly defined, intense white inner cone, a white feather or intermediate reducing cone, and the light-orange outer flame envelope.
9. Oxidizing flame with a temperature of approximately 6,300°F.
10. Acetylene.
11. To prevent the fire from moving through the hose and regulator into the supply line or cylinder and causing an explosion.

040

1. The oxygen regulators used for cutting heavy material furnish a larger volume and higher pressure than is needed for welding.
2. The welding torch can be quickly converted into a cutting torch, and is useful for the occasional cutting of lighter sections.
3. By the tip nut.
4. Preheating.

041

1. To cut metal by the oxyacetylene cutting process, there must be rapid oxidation of the metal within in a localized area. To produce this oxidation, you heat the metal to a bright red or "kindling" temperature and direct a free jet of high-pressure oxygen against it. This oxygen blast combines with the red hot metal and burns it to an oxide.
2. Kerf.
3. Acetylene pressure 3 PSI, oxygen pressure 45 to 50 PSI, and tip size 3.
4. To prevent damage to equipment and injury to personnel from fire and explosion.
5. Straight-ling cutting, circular cutting, piercing holes, beveling, cutting round stock, flame gouging.
6. Progressive and spot.

042

1. Be sure the gas supply is shut off.
2. To keep from rounding the corners on the connecting nuts.
3. Submerge the hoses in a bucket of clear water; a leak is indicated by a string of bubbles. This method is inexpensive and instantly identifies all leaks.
4. A soft wire or drill-type tip cleaner; enlarging the orifice.
5. File placed on the tip. Improper cleaning eventually enlarges the orifice.
6. Discard the tip; gas leakage around the tip can cause a flashback.

043

1. The wire can break in cold weather or can loosen corner post.
2. Extension of flight line area barriers, perimeter boundary for isolated portions of installations, livestock barrier, and boundary for on-base bulk material storage areas.
3. B–1.
4. Type C.
5. A high-density polymer, usually available in 4-ft × 100-ft orange-colored rolls.

044

1. Wire stretcher or "come-a-long."
2. High-voltage terminals, swimming pools, tennis courts, and individual buildings on base.
3. They cover the terminal posts and prevent moisture from entering.
4. To secure the top rail to end or terminal posts.
5. Three.

6. A draw bar and offset bands.
7. A 7-gauge zinc-coated wire.
8. Attach it to the fabric with hog rings every two feet.

045

1. Loose or broken strands of barbed wire, extension arms missing or barbed wire not secured in proper position on extension arms, bent or missing posts, holes or loose areas in fence fabric, missing sections of top rail, and tie wires missing or hog rings gone.
2. It recoils with a whip-like action that can seriously cut you or others.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

83. (039) How many (if any) damaged parts can you have in an oxyacetylene welding system and still be able to use the system?
    a. None.
    b. One.
    c. Two.
    d. Three.

84. (039) Oxygen and acetylene hoses are colored
    a. green and red respectively.
    b. black and green respectively.
    c. green or black and red or maroon respectively.
    d. red or black and maroon or green respectively.

85. (039) When you light the oxyacetylene welding equipment cutting torch, a *pure* acetylene flame is smoky because there is
    a. a high percentage of oxides in it.
    b. a high percentage of nitrides in it.
    c. not enough oxygen in the air to burn the acetylene completely.
    d. not enough hydrogen in the air to burn the acetylene completely.

86. (039) If an emergency occurs in oxyacetylene welding equipment, your *first* action is to immediately close the
    a. oxygen torch valve.
    b. acetylene torch valve.
    c. oxygen cylinder valve.
    d. oxygen and acetylene valves simultaneously.

87. (040) What is the *main* difference between the oxygen regulators used in oxyacetylene cutting and the oxygen regulators used in oxyacetylene welding operations?
    a. Cutting operations necessitates a smaller volume of oxygen and lower pressure.
    b. Welding operations necessitates a larger volume of oxygen and lower pressure.
    c. Cutting operations necessitates a larger volume of oxygen and higher pressure.
    d. Welding operations necessitates a smaller volume and higher pressure.

88. (040) The items that help you carry out oxyacetylene cutting tasks are cutting
    a. apparatus.
    b. devices.
    c. tools.
    d. aids.

89. (041) You can do oxyacetylene cutting *without* any special preparations on
    a. cast iron.
    b. aluminum.
    c. stainless steel.
    d. all low and medium carbon steels.

90. (041) How many types of flame-gouging techniques are there?
    a. One.
    b. Two.
    c. Three.
    d. Four.

91. (041) During *progressive* gouging, if you move the cutting torch too slow, your cut will be too
    a. shallow and narrow.
    b. shallow and wide.
    c. narrow and deep.
    d. wide and deep.

92. (042) What is a very *simple* but *critical* task that you must always do before you light the torch of an oxyacetylene cutting outfit?
    a. Review the shop operating procedures.
    b. Read the manufacturer's instructions.
    c. Make sure the serial numbers match.
    d. Check the entire outfit for gas leaks.

93. (042) What metal must *never* be used on an acetylene hose because it forms an unstable compound with acetylene?
    a. Aluminum.
    b. Copper.
    c. Brass.
    d. Steel.

94. (043) Type A fences are used for alert aircraft areas and areas containing
    a. high mission or monetary value resources.
    b. flight line activities.
    c. military housing.
    d. barracks.

95. (044) When you are installing a security fence, at what *maximum* distance apart should you place line posts?
    a. 6 feet.
    b. 8 feet.
    c. 10 feet.
    d. 12 feet.

96. (044) At least how many inches into the ground should you place security fence line posts?
    a. 12.
    b. 30.
    c. 36.
    d. 48.

97. (044) Which fence component is used to support the tension of the fence fabric?
    a. Terminal post.
    b. Tension wire.
    c. Post footings.
    d. Line post.

98. (044) What is the diameter of post holes for posts required to be set in concrete?
    a. 12 to 14 inches.
    b. 10 to 12 inches.
    c. 8 to 10 inches.
    d. 6 to 8 inches.

99. (045) Which issue with security fencing does *not* require maintenance?
    a. Bent or missing posts.
    b. Missing sections of top rail.
    c. Fence hardware mounted on the inside.
    d. Loose or broken strands of barbed wire.

100. (045) If barbed wire is stretched too tightly, it could
    a. put excess strain on corner posts causing them to lean.
    b. break and snap back at you or those around you.
    c. become too difficult to secure it.
    d. lose its tensile strength.

Glossary of Abbreviations and Acronyms

A	area
AB	anchor bolt
AC	asphalt cement
AD	area drain
AFCEC	Air Force Civil Engineer Center
AFI	Air Force instruction
AFOSH	Air Force Occupational Safety and Health
AFQTP	Air Force Qualification Training Package
AGGR	aggregate
ANSI	American National Standards Institute
ASPH	asphalt
ASSE	American Society of Safety Engineers
AT	asphalt tile
BL	building line
BLDG	building
BM	bench mark
BOM	bill of material
BP	blueprint
BRK	brick
BS	backsight
BSMT	basement
CB	catch basin
CDL	commercial driver’s license
CE	Civil Engineer
CEL	cellar
CEM	cement
CEM FLR	cement floor
CFM	cubic feet per minute
CFR	Code of Federal Regulations
CH	channel
CO	cleanout
CONC	concrete
CONT	contract
CPR	cardiopulmonary resuscitation

CS	cast stone
CTR	center
CUFT	cubic feet
D	drain
DDC	Defensive Driving Course
DN	down
DOD	Department of Defense
DOT	Department of Transportation
DR	drain
DT	dump truck
EL	elevation
EPA	Environmental Protection Agency
EXC	excavate
EXP JT	expansion joint
F	Fahrenheit
FD	floor drain
FL	floor
FND	foundation
FS	foresight
FTG	footing
G	gas
GFI	ground fault interrupter
GPC	government purchase card
GPS	Global Positioning System
HI	height
HVAC	heating, ventilation, and air conditioning
HVAC-R	heating, ventilation, and air conditioning-refrigeration
ID	inside diameter
IPB	illustrated parts breakdown
Kg	kilogram
Km	kilometer
LCD	liquid crystal display
LS	limestone
MAJCOM	major command
MATL	material
MAX	maximum

MIN	minimum
mm	millimeter
MO	mansonry opening
MOR	mortar
MSDS	material safety data sheet
MUTCD	Manual on Uniform Traffic Control Devices
NEC	National Electrical Code
OSHA	Occupational Safety and Health Administration
P&E	pavement and equipment
PCS	permanent change of station
PLBG	plumbing
PM	Preventive maintenance
PMTL	Preventative Maintenance Task List
PPE	personal protection equipment
PRCST	precast
PSI	pounds per square inch
REINF	reinforce
RGH	rough
RM	risk management
ROPS	rollover protection system/structure
RPM	revolutions per minute
RTK	real time kinematics
SEW	sewer
SP	soil pipe
SPEC	specification
SQ FT	square feet
TBM	temporary bench mark
TCD	traffic control devices
TO	technical orders
TP	turning point
TV	television
UNEX	unexcavated
UV	ultra violet
VCNCO	vehicle non-commissioned officer
µm	micrometer

Student Notes

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AFSC 3E251
3E251 01 1612
Edit Code 02