Industrial
MECHANICS

Fourth Edition

Albert W. Kemp

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Contents

Learner Resources

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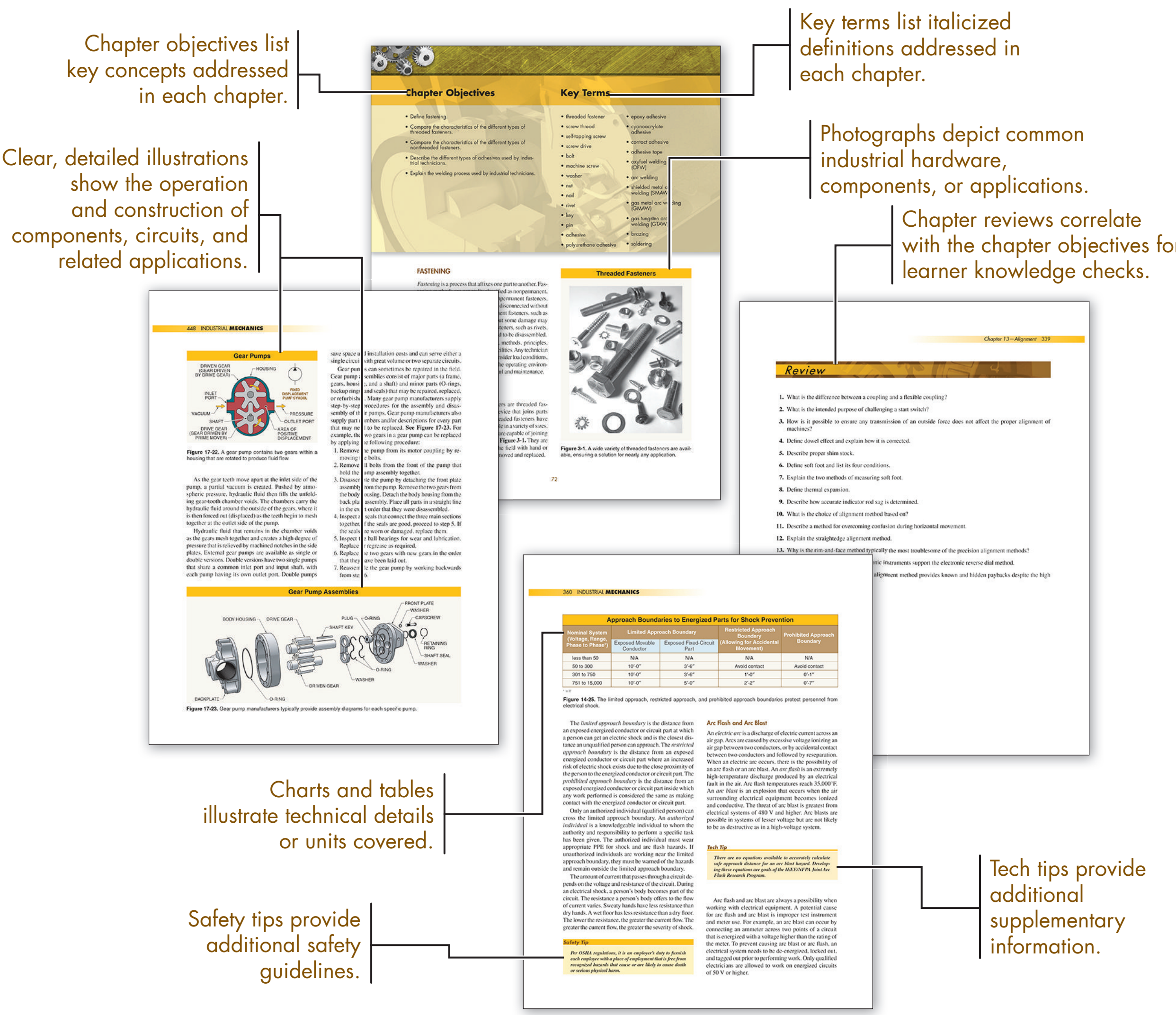
Introduction

Industrial Mechanics is a comprehensive introduction to industrial mechanical principles, components, and circuits. The textbook provides the latest information on safety and system efficiency, and is designed as a resource for mechanics, technicians, maintenance personnel, and individuals in industrial training programs. This new edition has been reorganized for easier understanding of topics covered.

Industrial Mechanics covers workplace safety, tools, printreading, precision measurement, rigging and lifting, lubrication and bearings, flexible belt and mechanical drives, vibration and alignment, hydraulic and pneumatic principles and applications, and preventive maintenance programs. New topics include test tool safety and fastening methods. Expanded topics include electrical safety, electrical applications, hydraulic component testing, and hydraulic system troubleshooting.



Learner Resources

Industrial Mechanics Learner Resources include online resources that reinforce textbook content to promote learning and comprehension. These online resources can be accessed using either of the following methods:

- Key ATPeresources.com/quicklinks into a web browser and enter QuickLinks™ access code 462409.
- Use a Quick Response (QR) reader app to scan the QR code with a mobile device.

The learner resources include the following:

- **Quick Quizzes®** that provide interactive questions for each chapter, with embedded links to highlighted content within the textbook and to the Illustrated Glossary
- An **Illustrated Glossary** that provides a helpful reference to commonly used terms, with selected terms linked to textbook illustrations
- **Flash Cards** that provide a self-study/review tool of terms and definitions, DMM abbreviations and symbols, and fluid power symbols
- **Precision Measurement Techniques,** which are video-based tutorials that present common measurement techniques using precision measurement tools
- **Chapter Reviews** in interactive PDF format that provide learners with the opportunity to demonstrate comprehension of chapter objectives
- A **Media Library** that consists of videos and animations that reinforce textbook content
- **ATPeResources.com,** which links to online reference materials that support continued learning

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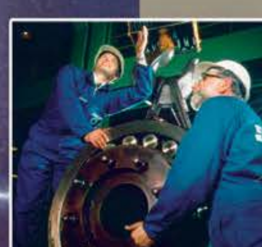
The Publisher

CHAPTER 1

WORKPLACE SAFETY

Although workplace safety is the responsibility of all workers, technicians are often the first to be aware of safety problems. Much of the work performed by technicians involves preventing hazardous conditions for all facility workers and the general public. This responsibility requires them to understand and follow general safety rules established by regulatory agencies and other specific workplace rules. For technicians, following general safety rules requires understanding how to perform basic first aid, wearing proper personal protective equipment, safe use of tools, working safely in confined spaces, and proper use of fall-arrest systems.



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Chapter Objectives

- Explain workplace safety.
- Describe the basic first aid procedures used in a workplace.
- Explain the general safety rules that should be enforced in a workplace.
- List the different types of personal protective equipment (PPE).
- Define confined spaces.
- Explain the purpose of a fall-arrest system.

Key Terms

- code
- standard
- first aid
- earplug
- earmuff
- respirator
- explosive range
- lower explosive limit (lel)
- upper explosive limit (uel)
- lanyard
- deceleration distance
- free-fall distance
- safety net

WORKPLACE SAFETY

In the past, little emphasis was placed on safety in the workplace. More recently, organizations such as the Occupational Safety and Health Administration (OSHA), created in 1971, have been established to develop and enforce safety standards for industrial workers. In addition, organizations such as the National Institute for Occupational Safety and Health (NIOSH), the National Fire Protection Association (NFPA), and others have formed codes, standards, and guidelines for a safe and healthy work environment.

A *code* is a regulation or minimum requirement. A *standard* is an accepted reference or practice. OSHA industrial safety standards were put into effect in the Code of Federal Regulations, Title 29 and is identified as OSHA 29 CFR 1910—*Occupational Safety and Health Standards.* Today, a safe and healthy work environment has become law. Safety awareness and regulations have dramatically reduced the national industrial fatality occurrences to 6632 in 1994 and 4693 in 2011 according to the U.S. Bureau of Labor Statistics.

On-the-job safety begins with personal safety awareness and understanding of basic first aid, general safety rules, and personal protective equipment. Personal safety awareness is being aware of safety issues and potential hazards to individuals in the workplace. A personal awareness of on-the-job safety is vital in preventing workplace injuries. Technicians must have an understanding of certain health and safety risks and requirements and the steps needed to minimize those risks. The most common types of hazards found in industrial environments include electrical, chemical, mechanical, fall, and confined-space hazards. **See Figure 1-1.**

Personal safety awareness includes keeping a mindset towards safety while on the job. Risky activities can be performed during a task when a technician's stress level is high or there is an unbalance between work and personal life. Work injuries can occur because a person either takes a chance or takes their mind off their work. In addition, taking shortcuts when in a rush can make a person make poor decisions regarding their safety and the safety of others. For example, a technician in a hurry may feel that wearing safety glasses is not required for a task, leading to a temporary or permanent eye injury.

Safety Tip

Many industrial facilities have mandatory substance testing programs to determine if an employee that was injured on the job was impaired when the injury occurred.

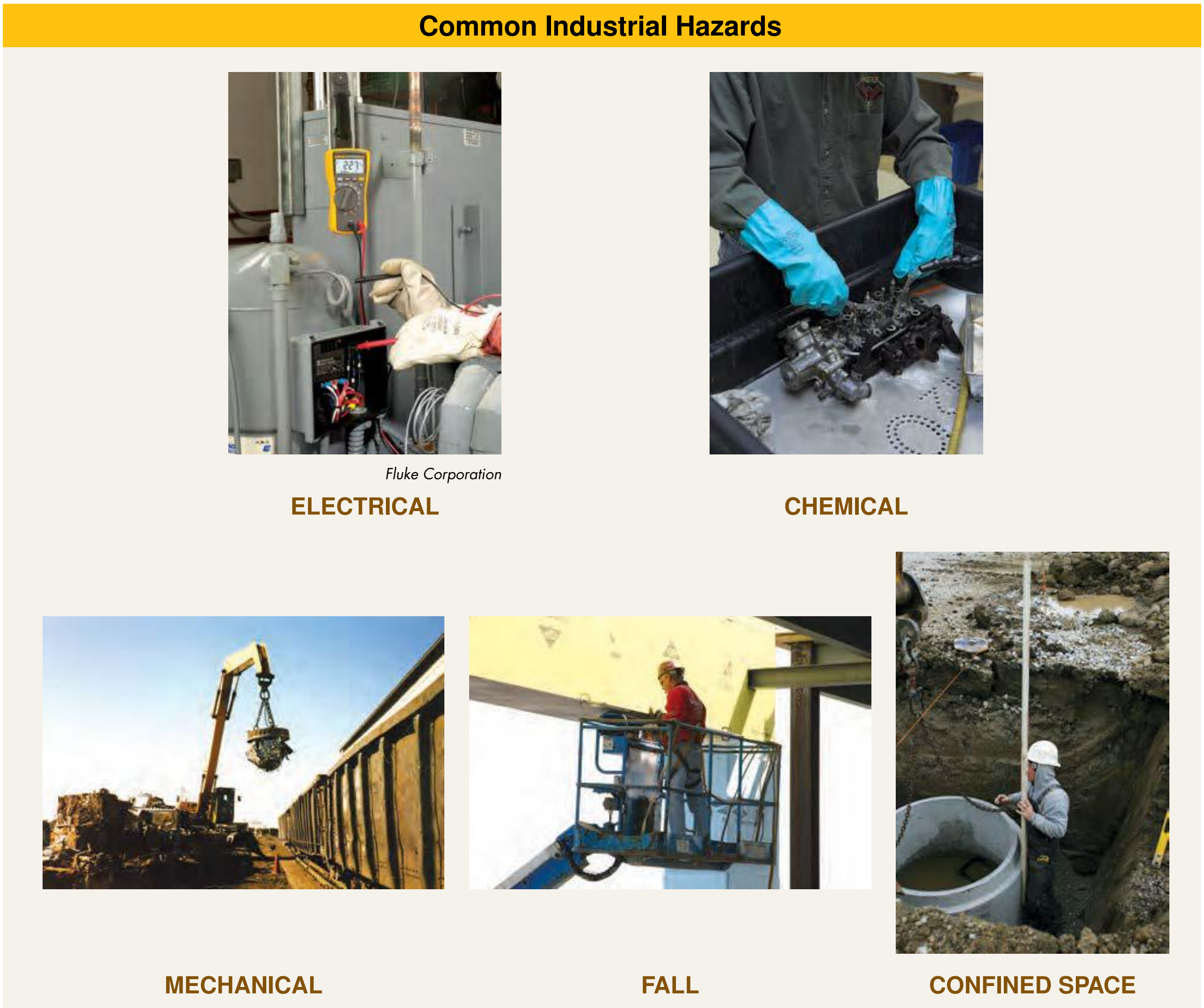

Figure 1-1. The most common types of hazards found in industrial environments include electrical, chemical, mechanical, fall, and confined-space hazards.

Basic First Aid

Accidents that cause injury to technicians can happen at any time and at any place. Immediate medical treatment is required for the victim, regardless of the extent of the injury. Often, first aid given immediately at the scene of an accident can improve the victim's chances of survival and recovery. *First aid* is help for a victim immediately after an injury and before professional medical help arrives. If someone is injured, steps taken to keep that person as safe as possible until professional help arrives include the following:

- Remain calm.
- Call 911 or the workplace emergency number immediately if a person is seriously injured.
- Never move an injured person unless a fire or explosives are involved. Moving an injured person may make the injury worse.
- Assess the injured person carefully and perform basic first aid procedures.
- Maintain first aid procedures until professional medical help arrives.
- Report all injuries to the supervisor.

A conscious accident victim must provide consent before care can be administered. To obtain consent, the victim must be asked if help can be provided. Once the victim gives consent, the appropriate care can be provided. If the victim does not give consent, care cannot be given. In such a case, 911 or the workplace emergency number should be called. Consent is implied in cases where an accident victim is unconscious, confused, or seriously injured. Implied consent allows an individual to provide care to an accident victim because the victim would agree to the care if he or she could.

Various states have enacted Good Samaritan laws to give legal protection to individuals who provide emergency care to accident victims. These laws are designed to encourage individuals to help others in emergencies. Good Samaritan laws vary from state to state. A legal professional or the local library should be consulted for information regarding the Good Samaritan laws in a particular state.

No attempt should be made to provide care without proper training. The American Red Cross may be consulted for training programs covering basic first aid and CPR. Basic first aid procedures can be used to help treat shock, bleeding, burns and scalds, choking, and poisoning.

Emergency eyewash stations and deluge shower units are used to flush chemicals and other contaminants from the eyes and body and provide first aid to burn victims.

Shock. Shock usually accompanies severe injury. Shock can threaten the life of an injured person if not treated quickly. Shock occurs when the body's vital functions are threatened by lack of blood or when the major organs and tissues do not receive enough oxygen. Symptoms of shock include cold, clammy, or pale skin, chills, confusion, nausea or vomiting, shallow breathing, and unusual thirst. To treat shock, the victim should lie down with his or her legs elevated if there is no sign of broken bones or spinal injury. The victim should also be covered to prevent chills or loss of body heat. Any obvious signs of bleeding should be controlled. A victim who is unconscious or bleeding from the mouth should lie on one side so breathing is easier. Professional medical help should be sought as soon as possible.

Bleeding. Bleeding is the most visible result of an injury. Most people can lose a small amount of blood without major problems. However, if a quart or more of blood is lost quickly, shock and/or death is possible. Bleeding is controlled by placing a clean, dry cloth on the wound and applying pressure with a finger or the palm of the hand, depending on the severity of the wound. The pressure should be kept on the wound until the bleeding stops.

If there are no signs of broken bones, the wound should be elevated above the victim's heart to slow the bleeding at the wound. Once the bleeding stops, the cloth against the wound should not be removed, as it could disturb the blood clotting and restart the bleeding. If possible, rubber or latex gloves should be worn before touching any blood, because touching blood involves health risks. If rubber or latex gloves are not available, a clean plastic bag may be used to cover the hands. If the injury is extensive, the victim may go into shock and should be treated for it. Professional medical help should be sought as soon as possible.

Burns and Scalds. Burns can be caused by heat, chemicals, or electricity. For burns caused by heat or chemicals, the burn should be immediately flushed with cool water for a minimum of 30 min. Ice should not be applied, because it may cause further damage to the burned area. This treatment should be maintained until the pain or burning stops. After flushing the burn with cool water, the burn should be covered with a clean cotton cloth. If a clean cotton cloth is not available, the burn should not be covered.

Clothing that is stuck to a burn should not be removed. The burn should not be scrubbed and soap, ointments, greases, and powders should not be applied. Blisters that appear should not be broken. The burn victim should not be offered anything to drink or eat. The victim should be kept covered with a blanket to maintain a normal body temperature. All burn victims should be treated for shock. Professional medical help should be sought as soon as possible.

A burn caused by electricity requires first ensuring that the victim is removed from the power source. Once the victim is clear of the power source, the victim is checked for any airway obstructions, and his or her breathing and circulation is checked. CPR should be administered if necessary and the individual administering the CPR is trained to do so. Once the victim is stable, the burn is flushed with cool water for a minimum of 30 min. The victim should not be moved, and the burn should not be scrubbed. Soap, ointments, greases, and powders should not be applied. After flushing the burn with cool water for 30 min, the burn should be covered with a clean cotton cloth. If a clean cotton cloth is not available, the burn should not be covered. The victim should be treated for shock and a normal body temperature should be maintained. Professional medical help should be sought as soon as possible.

Choking. Choking occurs when food or a foreign object obstructs the throat and interferes with normal breathing. Permission must be obtained from a conscious victim before providing care. The following steps are advised if a choking victim is unable to speak or cough:

1. Ask the victim if they are choking.
2. Shout for help if the victim cannot cough, speak, or breathe.
3. Call 911 or the workplace emergency number.
4. Perform abdominal thrusts. Abdominal thrusts are performed by wrapping the arms around the victim's waist, making a fist, and placing the thumb of the fist on the middle of the victim's abdomen just above the navel. The fist is grasped with the other hand and pressed into the abdomen with a quick upward thrust.

Poisoning. Poisons may be in solid, liquid, or gas form. If the poison has been ingested in a solid form, such as pills, any poison that is in the victim's mouth should be removed using a clean cloth wrapped around a finger. If the poison is a corrosive liquid on the skin, any clothing should be removed from the affected area and the skin should be flushed with water for 30 min. If the poison is in contact with the eyes, the victim's eyes should be flushed for a minimum of 15 min with clean water. When calling for medical help, the poisonous product container or label should be available. This enables the caller to answer questions about the poison.

When the poison is in the environment, the victim must be removed immediately from the poison source. Once the victim is removed from the poison source, the appropriate treatment should be administered based on the form of the poisoning. If the poison is a gas, a respirator may be required for protection when entering the area. The victim should be moved to fresh air and professional medical help should be sought as quickly as possible.

First Aid Kits. To administer effective first aid, adequate supplies must be maintained in a first aid kit. A first aid kit can be purchased stocked with the necessary supplies, or one can be made by assembling a kit containing adhesive bandages, butterfly closures, rolled gauze, nonstick sterile pads, and various first aid tapes. Additional items can be included as required, such as tweezers, aspirin, an additional analgesic, first aid cream, a thermometer, and an ice pack.

Safety Tip

When performing CPR, always remember "A-B-C," for "airway-breathing-cardio." First, check the victim's airway for blockage. Then, determine if victim is breathing. Lastly, check for the presence of a pulse. Once these three items are checked, proper CPR can be performed until first responders arrive on the scene.

General Safety Rules

Accidents are caused by the lack of attention to safety rules and regulations. Constant reminders are needed so individuals understand that safety is everyone's responsibility. Safety is learned by reading, observing, and practicing safe habits. Technicians should review safety materials related to the environment and equipment used on the job. Technicians should observe safe actions and practice safe work habits to avoid harmful and injurious activities.

Professional Behavior. Technicians should emulate professional behavior at all times. Pranks and horseplay in an industrial environment are serious industrial hazards that cause accidents through inattention, carelessness, and recklessness and may lead to injury or death. Nearly all workplaces have rules that make horseplay an offense punishable by discipline or discharge.

Stair Safety. Although ascending and descending stairs is a common function, many injuries occur from individuals falling down stairs. Ascending stairs is relatively safe because most people observe each step they take, and if a trip occurs, falling forward is relatively safe. However, injuries from descending stairs occur more frequently because if a trip occurs, an injury is more likely than when falling while ascending stairs. Caution must be used and attention given to each foot placement when descending stairs, especially when carrying objects. Holding a handrail when available improves safety.

Slip and Fall Prevention. Slips and falls are the second most common cause of accidents, accounting for 35% of nonfatal injuries, such as fractures and amputations, and 21% of over-three-day injuries, such as sprains, strains, and minor fractures. Slips and falls are generally due to poor housekeeping. Spills, tools or equipment, and electrical wires located in high traffic areas are tripping hazards. Poor or inappropriate footwear is also a cause of slips and falls. Slips and falls may be avoided by being aware of each step traveled, removing or cleaning obstacles so others may not be injured, and wearing the appropriate footwear.

Safe Lifting and Moving. Back injury is one of the most common injuries resulting in lost work time. Improper lifting and moving techniques can result in back injuries. Back injuries are extremely common but preventable through a combination of safe lifting and moving techniques.

Before lifting, the weight of the object should be determined and the lifting and moving method should be planned based on the object's size, shape, weight, and path of travel. Assistance should be sought when necessary. The entire pathway should be clear of obstacles, obstructions, and other hazards. The knees should be bent and the object grasped firmly. The object is then lifted while straightening the legs and keeping the back as straight as possible. Finally, movement can occur after the entire body is in the vertical position. The load should be kept as close to the body as possible. **See Figure 1-2.**

Carts or hand trucks should be used when objects are excessively heavy or oddly shaped. The load must be balanced to avoid tipping. When moving a load on a cart, the technician's body weight should be used while taking even, short steps.

Poor physical condition is a major contributor to all types of back problems. An individual's weight, strength, and flexibility all play a part in minimizing strain on the muscles and tendons that support the spinal column (core muscles) and contributing to or preventing back problems. When possible, forklifts should be used to move heavy loads and objects. **See Figure 1-3.**

Heat-Related Illnesses. Working in high-temperature environments can cause fatigue, fainting, muscle cramps, heat exhaustion, and heat stroke. In addition, working in high-temperature environments increases the risk of injuries due to accidents caused by slippery hands, sweat, fogged glasses, or dizziness.

Proper Lifting Technique

Figure 1-2. Proper lifting requires that an individual uses his or her legs to lift an object.

Forklifts

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Figure 1-3. When possible, forklifts should be used to move heavy loads and objects.

Muscle cramps usually occur during the first days of hot stressful work, especially if individuals are not accustomed to this type of work. To avoid muscle cramps, individuals should drink plenty of water to replace the fluids lost from sweating.

A loss of large amounts of fluid from the body can cause heat exhaustion. Individuals with heat exhaustion sweat, but their body cannot maintain the correct body temperature because of the amount of heat. In a person suffering from heat exhaustion, the body increases its heart rate and strengthens blood circulation. Individuals suffering from heat exhaustion may feel disoriented, feel dizzy, feel fatigued, have a headache, or have flu-like symptoms. The skin has a normal temperature but also has a damp and clammy feeling. Generally, the individual needs to rest, cool down, and drink plenty of liquids.

Heat stroke is the most serious heat-related health problem. Heat stroke occurs when the body stops adjusting to the hot temperature and sweat glands shut down. Symptoms of heat stroke include confusion, collapse, unconsciousness, dry mottled skin, and skin that is warm or hot to the touch. A heat stroke victim can die quickly. Immediate medical attention is required. An individual suffering from heat stroke should be moved to a cool area and cool water should be used to cool the individual.

Harrington Hoists Inc.

Carts should be used to safely move objects that are heavy or oddly shaped.

Personal Protective Equipment

Personal protective equipment (PPE) is designed to protect technicians from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards. PPE includes safety glasses, hard hats, leather gloves, steel-toe work boots, earplugs, ear muffs, welding helmets and fire-resistant clothing (used for welding operations), and dust masks. **See Figure 1-4.** PPE regulations are listed in OSHA 29 CFR 1910 Subpart G—*Occupational Health and Environmental Control* and OSHA 29 CFR 1910 Subpart I—*Personal Protective Equipment,* which also references various standards for each type. For example, appropriate protective helmets are worn in areas with overhead hazards, and safety shoes with steel toes are worn to provide protection from falling objects.

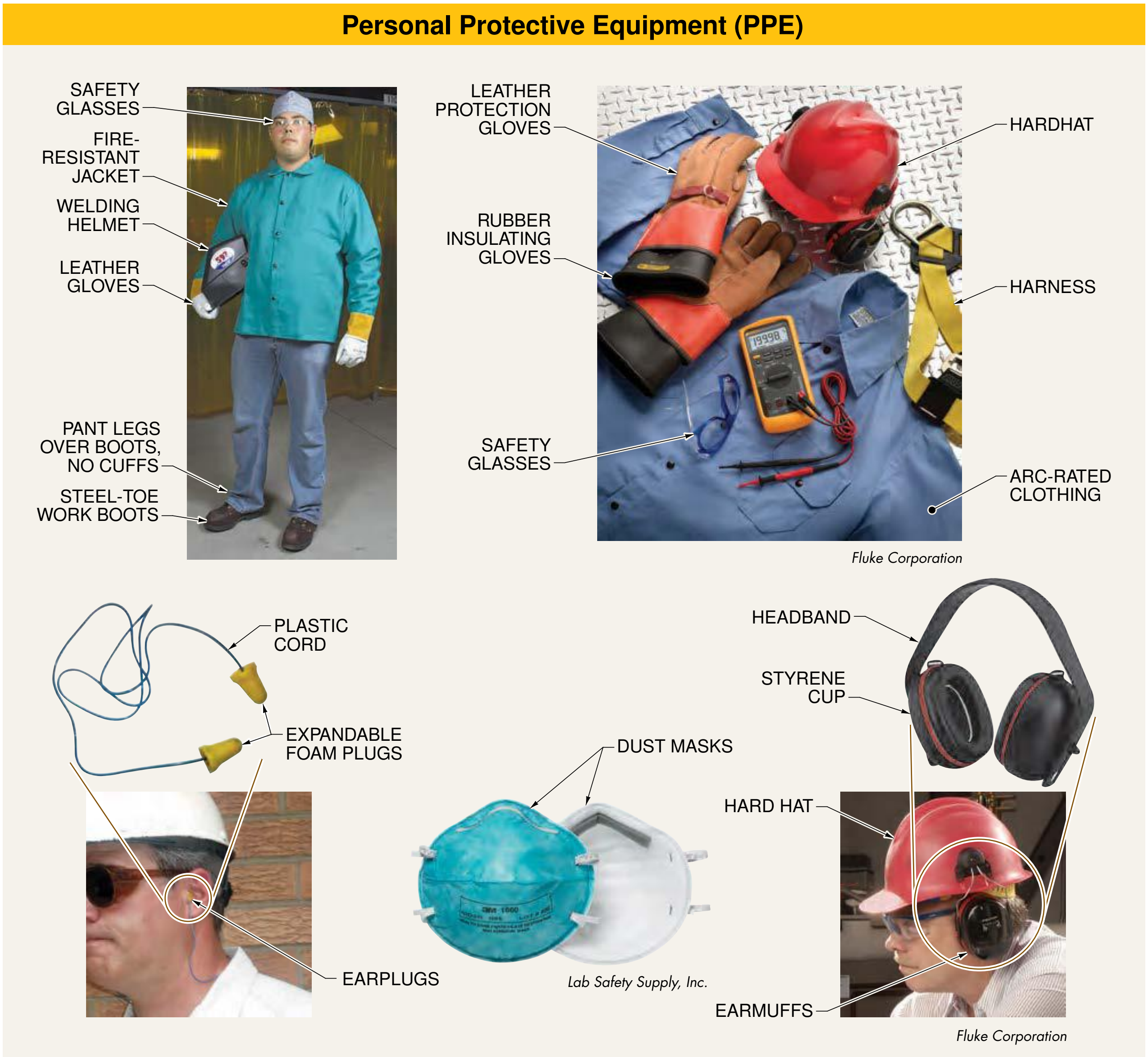


Figure 1-4. PPE is designed to protect technicians from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards.

Eye and Face Protection. PPE such as safety glasses with side shields, face shields, and goggles can protect technicians from the hazards of flying fragments, chips, hot sparks, optical radiation, splashes from molten metals, particles, sand, dirt, mists, dusts, and glare. OSHA 29 CFR 1910.133—*Eye and Face Protection* is designed to prevent or lessen the severity of injuries to technician's eyes and face. **See Figure 1-5.**

Eye protection must be maintained to provide protection and clear visibility. Pitted or scratched lenses should be replaced because they impair vision and are more likely to break. Eye protection should be cleaned and disinfected regularly. When not in use, eye protection should be kept in cases that keep them clean and prevent scratches.

If debris or chemicals get in the eyes or face, emergency eyewash and shower stations must be available to quickly flush the area with clean water. Requirements for these safety devices are listed in ANSI/ISEA Standard Z358.1, *Emergency Eyewash and Shower Equipment.*

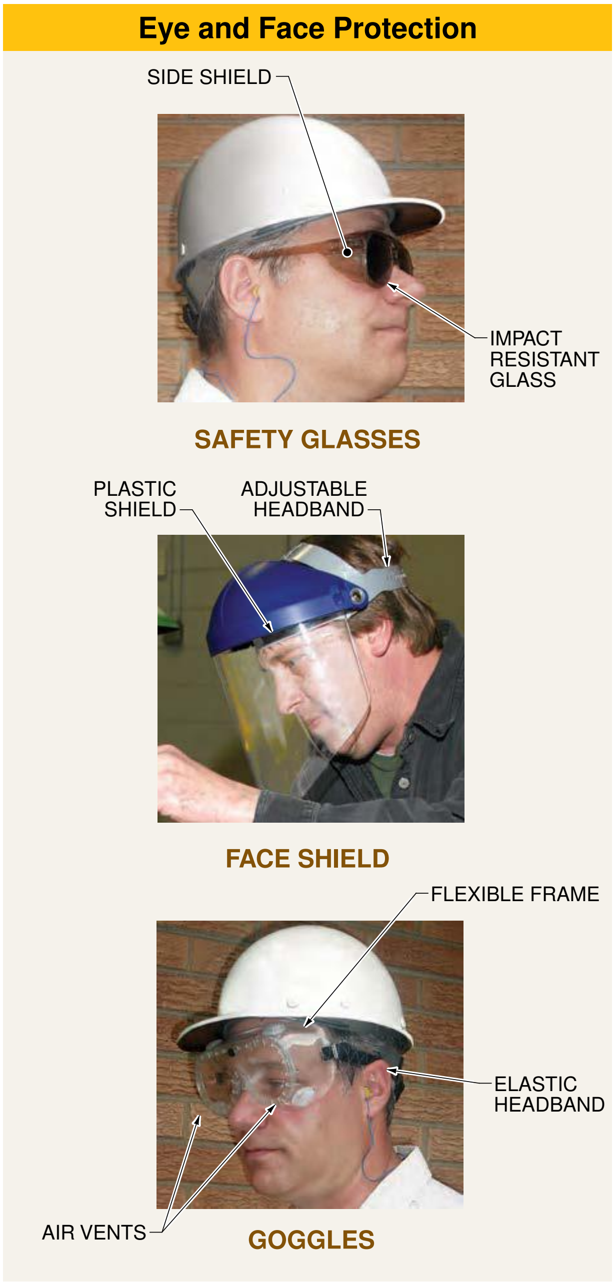


Figure 1-5. Eye and face protection must be worn to prevent injuries caused by flying particles, chemical splashes, dust and dirt, or optical radiation.

Dust may be present in the workplace during cutting, sanding, and buffing operations. Working in a dusty environment can cause eye injuries and present additional hazards to contact lens wearers. Either eyecup or cover-type safety goggles should be worn when dust is present. Safety goggles are the only effective type of eye protection from nuisance dust because they create a protective seal around the eyes.

The majority of impact injuries result from flying or falling objects or sparks striking the eye. Most of these objects are smaller than a pinhead and can cause serious injury such as punctures, abrasions, and contusions. While working in a hazardous area where the technician is exposed to flying objects, fragments, and particles, primary protective devices such as safety glasses with side shields or goggles must be worn. Secondary protective devices such as face shields are required in conjunction with primary protective devices during severe exposure to impact hazards.

Heat injuries may occur to the eye and face when technicians are exposed to high temperatures, splashes of molten metal, or hot sparks. Eye protection from heat is vital when workplace operations involve pouring, casting, hot dipping, furnace operations, and other similar activities. Burns to eye and face tissue are the main concern when working with heat hazards. Working with heat hazards requires eye protection such as goggles or safety glasses with special-purpose lenses and side shields. However, many heat hazard exposures require the use of a face shield in addition to safety glasses or goggles. When selecting PPE, consider the source and intensity of the heat and the type of splashes that may occur in the workplace.

A large percentage of eye injuries are caused by direct contact with chemicals. These injuries often result from an inappropriate choice of PPE that allows a chemical substance to enter from around or under protective eye equipment. Serious and irreversible damage can occur when chemicals contact the eyes in the form of splashes, mists, vapors, or fumes. When working with or around chemicals, the locations of emergency eyewash stations and how to access them with restricted vision must be known.

Welding operations create intense concentrations of heat, ultraviolet, infrared, and reflected light radiation. Eye and face protection are essential for technicians performing welding operations. Ultraviolet and infrared radiation produced by arc welding and cutting may cause flash burn, which is a burn to the eyes. Arc radiation can also cause burns to the face. The effects depend on the radiant energy wavelengths, intensity, and amount of exposure. Technicians performing welding operation must wear a suitable helmet with the proper filter plate shade number and safety glasses when arc welding or cutting. They must also take appropriate safety precautions when oxyfuel welding and cutting by wearing goggles or a face shield with the appropriate shade number.

Technicians performing welding operations should always be alert for welding arcs that can pose hazards to others near the welding operation. Technicians and visitors should use appropriate eye protection at all times when near welding operations. Other plant personnel can be protected by welding screens, curtains, or by remaining an adequate distance from the operation.

In arc welding and cutting, the filter plate shade number should be matched to the type of process and the welding current. In oxyfuel welding and cutting, the filter plate should be matched to the thickness of the material. When selecting filter lenses, a shade that is too dark to see the welding zone is selected. Lighter shades are then selected until one allows a sufficient view of the welding zone without going below the minimum protective shade. Standards for eye and face protection are specified in OSHA 29 CFR 1910.133(a)(5)—*Eye and Face Protection*.

Head Protection. Hard hats (protective helmets) provide protection from head impact, penetration injuries, and electrical injuries such as those caused by falling or flying objects, fixed objects, or contact with electrical conductors. Hard hats protect technicians by resisting penetration and absorbing the blow of an impact. Hard hat standards are identified by type and class for protection against specific hazardous conditions. **See Figure 1-6.** Standards for hard hats are specified in ANSI/ISEA Z89.1, *American National Standard for Industrial Head Protection*. Also, OSHA regulations require that technicians cover and protect long hair to prevent it from getting caught in machine parts such as belts and chains.

Foot and Leg Protection. Maintenance technicians perform many tasks that require handling objects that could injure a foot if dropped. Safety shoes with reinforced steel toes provide protection against injuries caused by compression and impact. Some safety shoes have protective metal insoles and metatarsal guards for protection from punctures from below, such as stepping on nails. Additional foot guards or toe guards may be used over existing work shoes.

Specialized safety shoes are available for certain situations, such as metal-free shoes for electrical work or shoes with soles that prevent slips on wet or oily surfaces. Rubber boots may be required in wet or chemically corrosive environments. Standards for protective footwear are specified in ASTM F2413, *Standard Specification for Performance Requirements for Foot Protection.*

Hard Hats

Type	Impact Protection
I	Impacts from top
II	Impacts from top and side
Class	**Use**
G	General service, limited voltage protection
E	Utility service, high voltage protection
C	Special service, no voltage protection

Figure 1-6. Hard hats are identified by type and class for protection against specific hazards.

In addition to foot guards and safety shoes, leggings made from leather, aluminized rayon, or other appropriate materials can help prevent injuries. These leggings protect technicians from hazards such as falling or rolling objects, sharp objects, wet and slippery surfaces, molten metals, hot surfaces, and electrical hazards.

Hearing Protection. When a technician is exposed to harmful sounds, such as sounds that are excessively loud or loud sounds over a long period of time, structures within the inner ear can be damaged. Inner ear damage is termed noise-induced hearing loss (NIHL). NIHL can be caused by a one-time exposure to a loud sound or by repeated exposure to sounds at various loudness levels over an extended period of time. The loudness of sound is measured in decibels. **See Figure 1-7.** An individual exposed to a sound level of 110 dB for longer than 30 min risks permanent hearing loss. No more than 2 hr of unprotected exposure to a sound level of 100 dB is recommended per OSHA 29 CFR 1926.52 (D)(1)—*Occupational Noise Exposure*.

Noise Level Exposure

Decibel Level of Various Sounds

130	Jet engine on ground
120	Reciprocating aircraft engine on ground
110	Punch press or pneumatic riveter
100	Maximum street noise
90	Loud shout
80	Diesel truck engine
74	Normal street noise
70	Barking dog or diesel locomotive
60	Average city office or conversational speech
50	Average city residence
40	Quiet office or average country residence
30	Turning page of newspaper
20	Rustle of leaves in breeze
10	Human heartbeat
0	Threshold of hearing

OSHA Noise Exposure Limitations

Sound Level*	Duration Permitted†
90	8
92	6
95	4
97	3
100	2
110	0.5
115	0.25

* in dBA
† in hr

Figure 1-7. Hearing protection must be worn when noise levels exceed the time-weighted permissible exposures.

Wearing earplugs or earmuffs can help prevent hearing damage. An *earplug* is a compressible device inserted into the ear canal to reduce the level of noise reaching the eardrum. Exposure to high noise levels can cause irreversible hearing loss or impairment as well as physical and psychological stress. Earplugs made from foam, waxed cotton, or fiberglass wool are self-forming and usually fit into the ear well. Also available are individually molded or preformed earplugs. Earplugs must be cleaned regularly or replaced if they cannot be cleaned.

An *earmuff* is a device worn over the ears to reduce the level of noise reaching the eardrum. A tight seal around the earmuff is required for proper protection. To protect electrical technicians, some earmuffs have no metal parts. Electronic earmuffs can reduce certain sound frequencies while still allowing voices to be heard. Earmuffs must be washed and dried daily according to manufacturer's instructions.

Hand Protection. Hand injuries account for approximately one-third of all disabling job-related injuries each year. Over 80% of these injuries are caused by pinch points. Pinch point injuries vary from bruises, cuts, and fractures to amputations. Common sources of pinch points include rotating equipment that has meshing gear teeth, chains and sprockets, rollers, belts, and pulleys. **See Figure 1-8.** About 20% of pinch point injuries become infected.

Pinch points must be identified and properly guarded and technicians must be aware of their existence and potential danger. Any machinery being serviced should be properly locked out and tagged. Machines should never be repaired, cleaned, or adjusted while in motion or energized.

Approved hand protection, such as work gloves, can be useful in preventing cuts, bruises, and abrasions resulting from handling rough materials or sharp objects. The correct gloves must be worn for the application. Wearing the wrong type of glove for an application may cause the glove and hand to be caught in moving parts or machinery. Certain gloves can also be effective in minimizing hand infections such as dermatitis.

Technicians exposed to harmful substances through skin absorption, severe cuts or lacerations, severe abrasions, chemical burns, thermal burns, or harmful temperature extremes require hand protection. Rings and jewelry should not be worn while working on machinery.

Safety Tip

PPE specifically designed for use when working on or near energized electrical circuits and equipment is available. This equipment includes fire-resistant clothing, rubberized gloves with leather protectors, insulated mats for working/standing on concrete surfaces, and work boots or shoes with insulated soles.

Body Protection. In some cases, technicians must shield most or all of their bodies against hazards in the workplace, such as exposure to heat, radiation, hot metals, scalding liquids, body fluids, hazardous materials or waste, and other hazards. In addition to fire-resistant wool and fire-resistant cotton, materials used in whole-body PPE include rubber, leather, synthetics, and plastic.

Pinch Point Sources

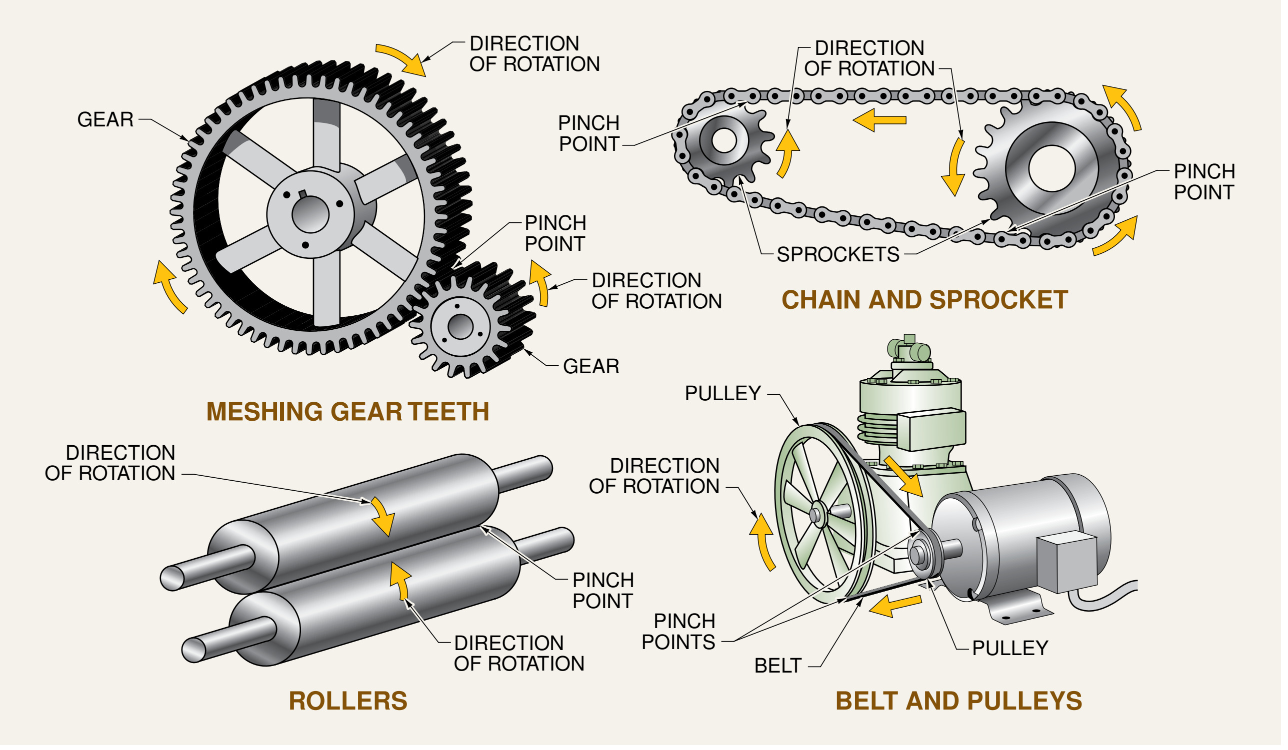


Figure 1-8. Common sources of pinch points include rotating equipment that has meshing gear teeth, chains and sprockets, rollers, belts, and pulleys.

Respiratory Protection. When engineering controls are not feasible, technicians must use appropriate respirators to protect against adverse health effects caused by breathing air contaminated with harmful dust, fog, fumes, mist, gas, smoke, spray, or vapor. A *respirator* is a device that protects the wearer from inhaling airborne contaminants. A respirator is selected based on the type of material or chemical hazard to which a technician is exposed. **See Figure 1-9.** Respirator selection should be made according to NIOSH 87-108, *Respirator Decision Logic* and ANSI/AIHA Z88.2, *Respiratory Protection.*

Respirators generally cover the nose and mouth or the entire face or head and help prevent respiratory illness and injury. A proper fit is essential for respirators to be effective. Respirators must be selected by qualified personnel. Improper use and/or selection of a respirator may result in serious injury or death. Required respirators must be NIOSH approved and medical evaluation and training must be provided before use.

PPE Selection. The PPE selected must ensure a level of protection greater than the minimum level required to protect a technician from the hazard. Careful consideration must be given to comfort and fit. PPE must fit properly to be effective and must be comfortable to enable prolonged use. If the protective gear does not fit, it may not adequately protect the technician. When protective gear is uncomfortable it is hard to concentrate on the job and it may tempt technicians to remove it. Defective or damaged PPE shall not be used.

PPE alone should not be relied on to provide protection against hazards. PPE should be used in conjunction with guards, engineering controls, and sound manufacturing practices.

Confined Spaces

A *confined space* is a space large enough for an individual to physically enter and perform assigned work but has limited or restricted means for entry and exit and is not designed for continuous occupancy. Confined spaces include storage tanks, process vessels, boilers, ventilation or exhaust ducts, sewers, underground utility vaults, pipelines, and open top spaces more than 4′ in depth such as pits and ditches.

Respirators		
Air-Purifying		
Respirator		Description
	Disposable particulates mask	Low profile, lightweight, designed for limited use. Low-cost protection against dusts, mists, and fumes (not for mists containing gases, vapors, or nonabsorbed contaminants). Completely disposable. No cleaning or spare parts required.
	Reusable half-mask respirator	Lightweight, easy to maintain, very little restriction of movement or vision. Uses replaceable cartridges and filters. Limited number of parts. Protects against chemical hazards such as dust, fumes, mists, and vapors.
	Reusable full-face respirator	Offers greater eye and face protection than half-mask. Uses replaceable cartridges and filters. Easy to maintain (no intricate parts). Protects against chemical hazards such as dust, fumes, mists, and vapors.
	Powered air-purifying respirator (PAPR)	Cooler, less exhausting for worker. Provides easier breathing for higher productivity. Uses cartridges or filters. Face- or belt-mounted with a battery for power. Includes air blower that pulls air through the cartridges and filters into the face piece.
Supplied-Air		
	Airline respirator	Uses outside air source to keep worker cooler and offers greater protection than an air-purifying respirator. Available in two styles: constant flow and pressure demand. Uses Grade D air supply from ambient air pump, plant compressor, or bottled air. Not for use in IDLH (immediately dangerous to life or health) situations or where the oxygen content is less than 19.5%.
	Self-contained breathing apparatus (SCBA)	Provides greatest protection available. Pressurized bottle of air is carried on worker's back. For use in oxygen-deficient atmospheres, IDLH, and emergency situations. Available in two different types of cylinders: aluminum and composite. Provides good mobility with few restrictions because air source is carried on back.
	Emergency escape breathing apparatus (EEBA)	For use in escape situations only. IDLH and oxygen deficiency. Service life depends on a 5 min to 10 min bottle of air. Not designed for rescue use.

Color Code for Cartridges/Canisters	
Contaminant	Color Assigned
Acid gases only	White
Organic vapors only	Black
Ammonia gas	Green
Acid gases and organic vapors	Yellow
Radioactive materials (except tritium and noble gases)	Purple
Dust, fumes, and mists (other than radioactive materials)	Orange
Other gases and vapors (not listed above)	Olive

North by Honeywell

Figure 1-9. Respirators are selected for the specific contaminants and concentrations present in a hazard area.

Confined-Space Hazards. Confined spaces are particularly susceptible to containing oxygen-deficient, toxic, or explosive atmospheres. Oxygen deficiency is caused by the displacement of oxygen by leaking gases or vapors, combustion or oxidation processes, oxygen absorbed by the vessel or stored products, and/or consumption by bacteria. Oxygen-deficient air can result in injury or death. **See Figure 1-10.** Common toxic gases include hydrogen sulfide, natural gas, and carbon monoxide. Toxic gases are released by cleaning solvents, chemical reactions, heated materials, and other sources.

Potential Effects of Oxygen-Deficient Atmospheres*

Oxygen Content†	Effects and Symptoms‡
19.5	Minimum permissible oxygen level
16 – 19.5	Decreased ability to work strenuously. May impair condition and induce early symptoms in persons with coronary, pulmonary, or circulatory problems
12 – 14	Respiration exertion and pulse increase. Impaired coordination, perception, and judgment
10 – 11	Respiration further increases in rate and depth, poor judgement, lips turn blue
8 – 9	Mental failure, fainting, unconsciousness, ashen face, blue lips, nausea, and vomiting
6 – 7	Eight min, 100% fatal; 6 min, 50% fatal; 4 to 5 min, recovery with treatment
4 – 5	Coma in 40 seconds, convulsions, respiration ceases, death

* Values are approximate and vary with state of health and physical activities
† % by volume
‡ at atmospheric pressure

Figure 1-10. Oxygen-deficient atmospheres in confined spaces can be life threatening.

Combustible atmospheres are commonly caused by gases such as methane, carbon monoxide, and hydrogen sulfide. An increase in the oxygen level above the normal 21% increases the explosive potential of combustible gases. Finely ground materials, including carbon, grain, fibers, metals, and plastics, can also cause explosive atmospheres.

The *explosive range* is the difference between the lower explosive limit and the upper explosive limit of combustible gases. **See Figure 1-11.** The *lower explosive limit (LEL)* is the lowest concentration (air-fuel mixture) at which a gas can ignite. Concentrations below this limit are too lean to burn. The *upper explosive limit (UEL)* is the highest concentration (air-fuel mixture) at which a gas can ignite. Concentrations above this limit are too rich to burn.

Combustible Atmospheres

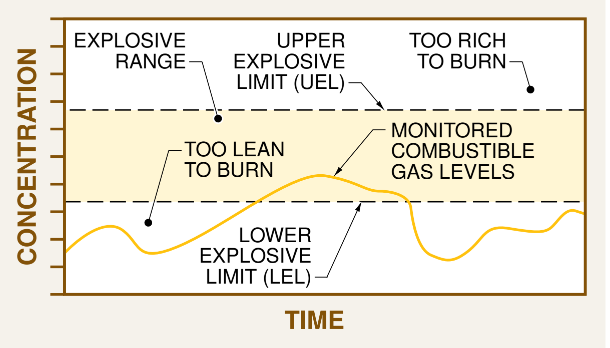


Figure 1-11. Atmospheres are potentially explosive when the concentration of a combustible gas is within a certain range.

Combustible gases at any concentration are a concern. Lean mixtures can collect in areas and reach combustible levels. Also, lean mixtures may still be toxic. Rich mixtures can be diluted with air and become combustible. Detection instruments are set to sense the presence of combustible gases at levels that forewarn technicians of potentially hazardous combustible atmospheres before the LEL is reached. **See Figure 1-12.**

Warning: Confined-space procedures vary for each facility. For maximum safety, always refer to specific facility procedures and applicable federal, state, and local regulations.

Confined-Space Permits. A *permit-required confined space* is a confined space that has specific health and safety hazards capable of causing death or serious physical harm. Permit-required confined spaces are spaces that have the potential to contain a hazardous atmosphere; contain a material that has the potential for engulfing an entrant; have an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or a floor that slopes downward and tapers into a smaller cross-section; or contain any other recognized safety or health hazard.

OSHA 29 CFR 1910.146—*Permit-Required Confined Spaces,* contains the requirements for practices and procedures to protect individuals from the hazards of permit-required confined spaces. **See Figure 1-13.**

Confined-Space Atmosphere Testing

Mine Safety Appliances Co.

Figure 1-12. Confined spaces must be tested for oxygen level and air contaminants before entering.

Even if a confined space does not initially require a permit, individuals must be aware that the condition can change with tasks such as welding, painting, or solvent use within the confined space. Employers must evaluate the workplace to determine if spaces are permit-required confined spaces. If confined spaces exist in the workplace, the employer must inform individuals of their existence and location and of the danger they pose. This is accomplished by posting danger signs or by other equally effective means. In addition, the employer must develop a written permit-required confined-space program that specifies entry procedures, hazard identification, access restriction, hazard control, and monitoring of the space during entry.

Permit-Required Confined Spaces

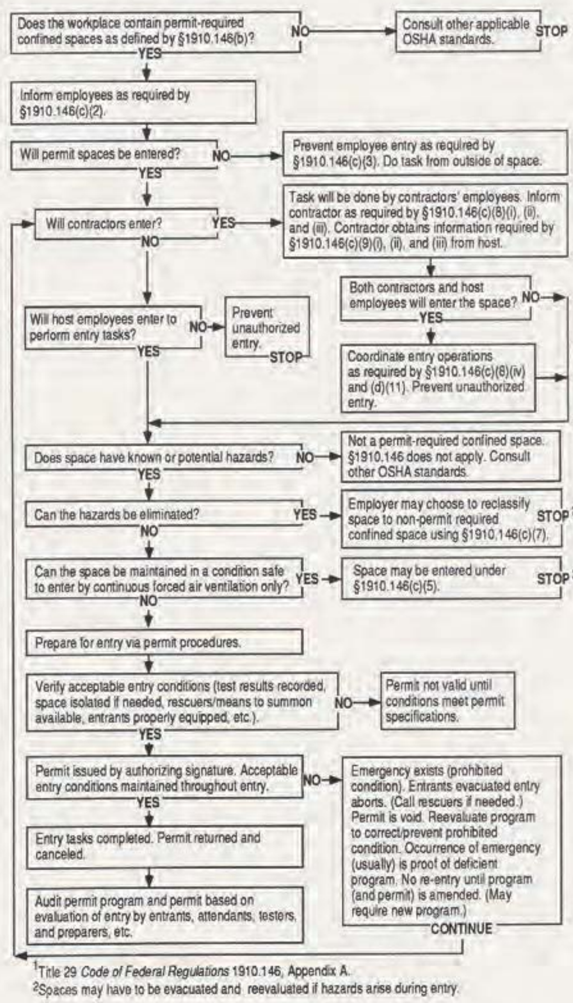


Figure 1-13. Procedures for entering a confined space must follow established OSHA safety standards.

Entry-Permit Procedures. An entry permit must be posted at confined-space entrances or otherwise made available to entrants before entering a permit-required confined space. The permit is signed by the entry supervisor and verifies that preentry preparations have been completed and that the space is safe to enter. **See Figure 1-14.** A permit-required confined space must be isolated before entry. This prevents hazardous energy and materials from entering the space. Plant procedures for lockout/tagout of permit-required confined spaces must be followed. A plant may develop its own confined space permit, but OSHA requires that certain checklist items be included.

Confined-space Entry Permits

ENTRY PERMIT

✓ CONFINED SPACE ✓ HAZARDOUS AREA

PERMIT VALID FOR 8 HOURS ONLY. ALL COPIES OF PERMIT WILL REMAIN AT JOB SITE UNTIL JOB IS COMPLETED

SITE LOCATION and DESCRIPTION Bunker Fuel Oil Tank #2

PURPOSE OF ENTRY Routine Maintenance/Inspection

SUPERVISOR(S) in charge of crews. Type of Crew Phone #

Michael Green Maintenance Shift II - x5924

* BOLD DENOTES MINIMUM REQUIREMENTS TO BE COMPLETED AND REVIEWED PRIOR TO ENTRY*

REQUIREMENTS COMPLETED	DATE	TIME	REQUIREMENTS COMPLETED	DATE	TIME
Lock Out/De-energize/Try-out	10/2	09:00	**Full Body Harness w/"D" ring**	10/4	08:00
Line(s) Broken-Capped-Blanked	10/2	11:00	**Emergency Escape Retrieval Equip**	10/4	08:00
Purge-Flush and Vent	10/3	09:00	**Lifelines**	10/4	08:00
Ventilation	10/3	10:00	Fire Extinguishers	10/4	08:00
Secure Area (Post and Flag)	10/2	08:00	Lighting (Explosion Proof)	10/4	08:00
Breathing Apparatus	10/4	08:00	Protective Clothing	10/4	08:00
Resuscitator - Inhalator	10/4	08:00	Respirator(s) (Air Purifying)	10/4	08:00
Standby Safety Personnel	10/4	08:00	Burning and Welding Permit	N/A	N/A

Note: Items that do not apply enter N/A in the blank.

** RECORD CONTINUOUS MONITORING RESULTS EVERY 2 HOURS

CONTINUOUS MONITORING** TEST(S) TO BE TAKEN	Permissible Entry Level		10/4							
PERCENT OF OXYGEN	**19.5% to 23.5%**		20.5	20.6	20.7	20.5	20.5			
LOWER FLAMMABLE LIMIT	**Under 10%**		5	5	5	5	6			
CARBON MONOXIDE	**+35 PPM**		0	0	0	0	0			
Aromatic Hydrocarbon	+ 1 PPM	* 5PPM	2	1	2	1	1			
Hydrogen Cyanide	(Skin)	* 4PPM	N/A							
Hydrogen Sulfide	+10 PPM	*15PPM	N/A							
Sulfur Dioxide	+2 PPM	* 5PPM	3	2	2	2	2			
Ammonia		* 35PPM	N/A							

* Short-term exposure limit:Employee can work in the area up to 15 minutes.

+ 8 hr. Time Weighted Avg.:Employee can work in area 8 hrs (longer with appropriate respiratory protection).

REMARKS:

GAS TESTER NAME & CHECK #	INSTRUMENT(S) USED	MODEL &/OR TYPE	SERIAL &/OR UNIT #
Marty James	Combination Gas Meter	Industrial Scientific	15A

SAFETY STANDBY PERSON IS REQUIRED FOR ALL CONFINED SPACE WORK

SAFETY STANDBY PERSON(S)	CHECK #	NAME OF SAFETY STANDBY PERSON(S)	CHECK #
Kate Washington	3312		
Tony Linder	3318		

SUPERVISOR AUTHORIZING ENTRY
ALL ABOVE CONDITIONS SATISFIED

AMBULANCE 2800 FIRE 2900
Safety 4901 Gas Coordinator 4529/5387

Figure 1-14. A confined-space entry permit documents preparations, procedures, periodic monitoring, and required equipment.

Checklist items required by OSHA include the permit date, time, expiration, supervisor name, results of atmospheric testing both prior to entry and periodically during work, the applicable safety equipment, and communication and rescue procedures. Standby personnel, commonly referred to as a "hole watch," must remain just outside a confined space while technicians are inside. Hole watch personnel are responsible for periodically testing and recording the atmospheric conditions, monitoring the technicians inside the space, and assisting rescue personnel in the event of an emergency. The duration of entry permits must not exceed the time required to complete a task. The entry supervisor must terminate entry and cancel permits when a task has been completed or when new conditions exist. All canceled entry permits must be filed for at least one year.

Training is required for all personnel who are required to work in or around permit-required confined spaces. A certificate of training includes the technician's name, the signature or initials of the trainer, and the dates of training. The certificate must be available for inspection by authorized personnel.

Fall-Arrest Systems

A personal fall-arrest system is used to arrest (stop) a technician in a fall from a working level. Personal fall-arrest systems may be used, and are many times required for use, with equipment such as aerial lifts. Proper personal fall-arrest systems must be used when working at heights greater than 10′. Personal fall-arrest systems consist of an anchorage point, connectors, and a body harness and may include a lanyard, lifeline, deceleration device, or combinations of these devices. **See Figure 1-15.**

An anchorage point provides a secure point of attachment for lifelines, lanyards, or other deceleration devices. Anchorage points for personal fall-arrest systems must be independent of any anchorage point used to support or suspend platforms and must be capable of supporting 5000 lb minimum per person attached to the anchorage point or at least twice the anticipated load. Anchorage points must be designed and installed under the supervision of a qualified person. A qualified person can be a safety engineer or a supervising technician.

Personal Fall-Arrest Systems

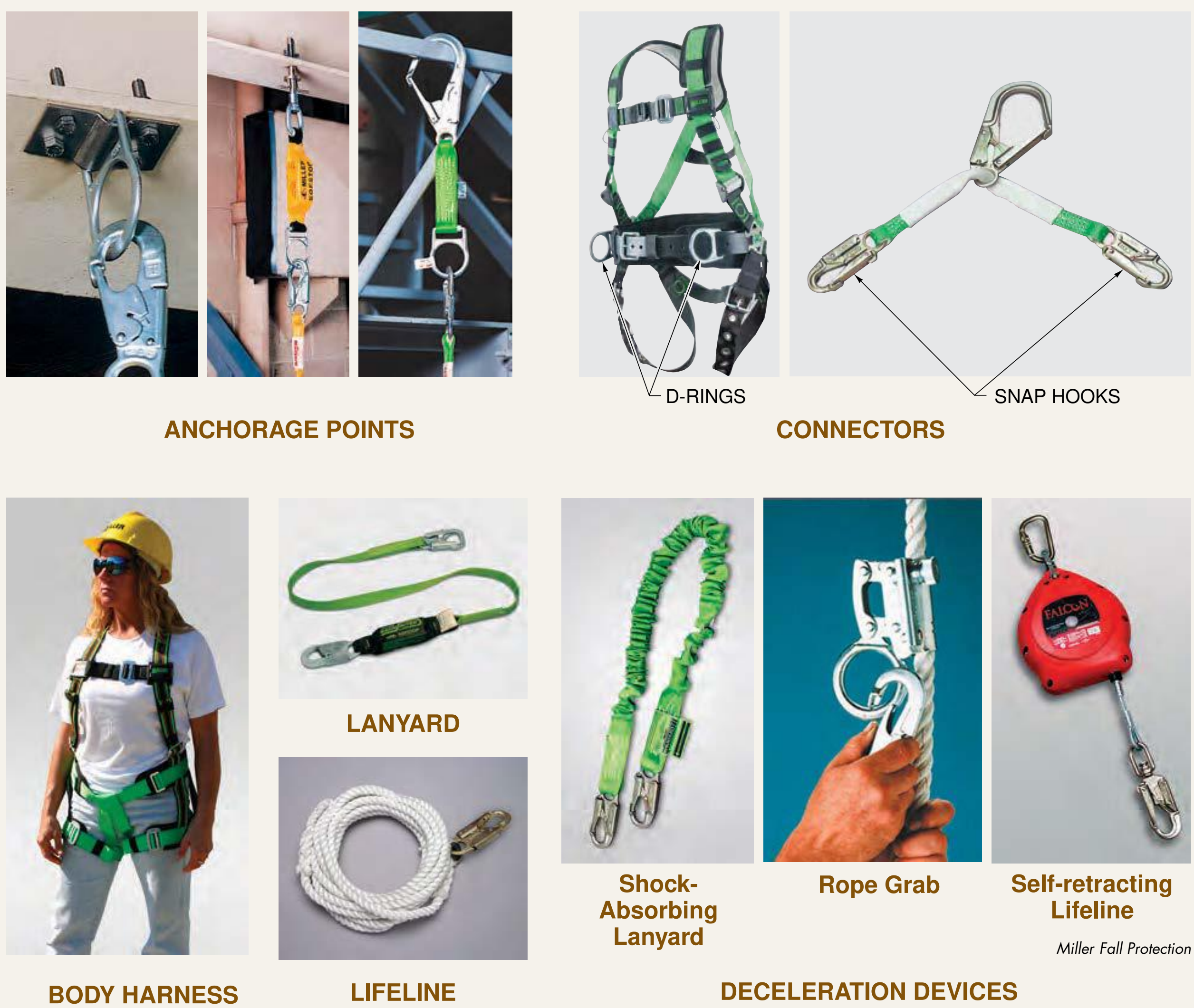


Figure 1-15. Personal fall-arrest systems must be utilized when working at heights greater than 10′ when other means of fall protection are not provided.

Connectors such as D-rings and snap hooks must have a minimum tensile strength of 5000 lb and must be proof-tested to a minimum tensile load of 3600 lb. Connectors are normally attached to other personal fall-arrest system components such as anchorage points, body harnesses, lifelines, and lanyards. Only locking-type snap hooks are permitted to be used for personal fall-arrest systems. Snap hooks can be attached directly to webbing, rope or wire rope, a D-ring, each other, and horizontal lifelines.

When worn properly, body harnesses protect internal body organs, the spine, and other bones in a fall. The attachment point of a body harness should be located in the center of the back near shoulder level or above the technician's head. Body harnesses should be inspected before each use to ensure that they will properly support a technician in case of a fall.

The harness webbing should be inspected for wear, such as frayed edges, broken fibers, burns, and chemical damage. D-rings and buckles should be inspected for distortion, cracks, breaks, and sharp edges. Grommets on body harnesses should be inspected to ensure they are tight.

Harnesses must fit snugly and be securely attached to a lanyard. A *lanyard* is a flexible line of rope, wire rope, or strap that generally has a connector at each end for connecting a body harness to a deceleration device, lifeline, or anchorage point. A deceleration device dissipates a substantial amount of energy during a fall arrest or limits the energy imposed on a technician during a fall arrest. Common deceleration devices include rope grabs, shock-absorbing lanyards, and self-retracting lifelines or lanyards.

A *rope grab* is a device that clamps securely to a rope. A rope grab automatically engages a vertical or horizontal lifeline by friction to arrest the fall while allowing freedom of movement. A lanyard or lifeline is attached between the body harness and rope grab.

A shock-absorbing lanyard has a specially woven, shock-absorbing inner core that reduces fall arrest forces. The outer shell of the lanyard serves as the secondary lanyard. Lifelines are anchored above the work area, offering a free-fall path, and must be strong enough to support the force of a fall. Vertical lifelines are connected to a fixed anchor at the upper end that is independent of a work platform such as a scaffold. Vertical lifelines must never have more than one technician attached per line.

A self-retracting lifeline is a type of vertical lifeline. A self-retracting lifeline contains a line that can be slowly extracted from or retracted onto its drum under slight tension during normal technician movement. When a fall occurs, the drum automatically locks, arresting the fall. Horizontal lifelines are connected to fixed anchors at both ends. Technicians attach their lanyard to a D-ring on the lifeline, allowing them to freely move horizontally along the lifeline.

A lifeline must be properly terminated (anchored) to prevent the safety sleeve or ring from sliding off its end. The path of a fall must be visualized when anchoring a lifeline. Obstacles below and in the fall path can be deadly.

Personal Fall-Arrest System Requirements. When a personal fall-arrest system is used for fall protection, the system must be able to do the following:

- It must limit the maximum arresting force to 1800 lb when used with a body harness.
- It must be rigged so the technician can neither fall more than 6′ nor contact any lower level. **See Figure 1-16.**
- It must bring a technician to a complete stop and limit the maximum deceleration distance a technician falls to 3′-6″. *Deceleration distance* is the additional vertical distance a falling technician travels, excluding lifeline elongation and free-fall distance, before stopping, from the point at which the deceleration device begins to operate. The deceleration distance is measured as the distance between the location of a technician's body harness attachment point at the moment of activation of the deceleration device during a fall and the location of that attachment point after the technician comes to a full stop.
- It must have sufficient strength to withstand twice the potential energy impact of a technician free-falling a distance of 6′ or the free-fall distance permitted by the system, whichever is less. The *free-fall distance* is the vertical distance between the fall-arrest attachment point on the body harness before the fall and the attachment point when the personal fall-arrest system applies force to arrest the fall.

Safety Nets. A *safety net* is a net made of rope or webbing for catching and protecting a falling technician. A safety net must be used anywhere a technician is 25′ or more above the ground, water, machinery, or other solid surfaces when the technician is not otherwise protected by fall-arrest equipment or scaffold guardrails. **See Figure 1-17.** Safety nets must also be used when public traffic or other technicians are permitted underneath a work area that is not otherwise protected from falling objects.

Estimated Fall Distance

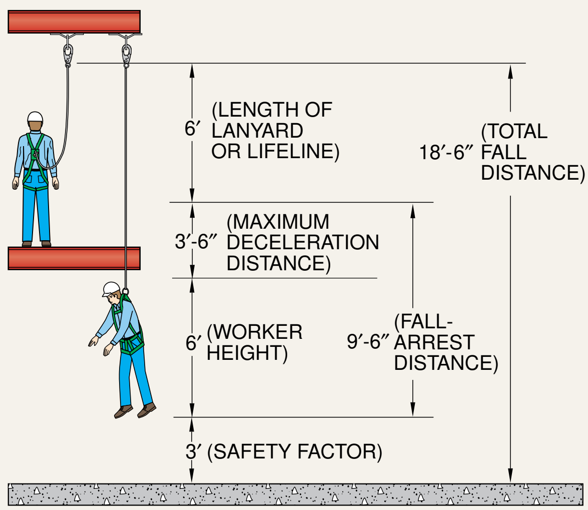


Figure 1-16. Always determine the estimated fall distance when selecting the proper personal fall-arrest system.

Safety Nets

The Sinco Group, Inc.

Figure 1-17. A safety net must be installed whenever a worker is 25′ or more above the ground, water, machinery, or other solid surfaces when technicians are not otherwise protected by fall-protection equipment or guardrails.

Review

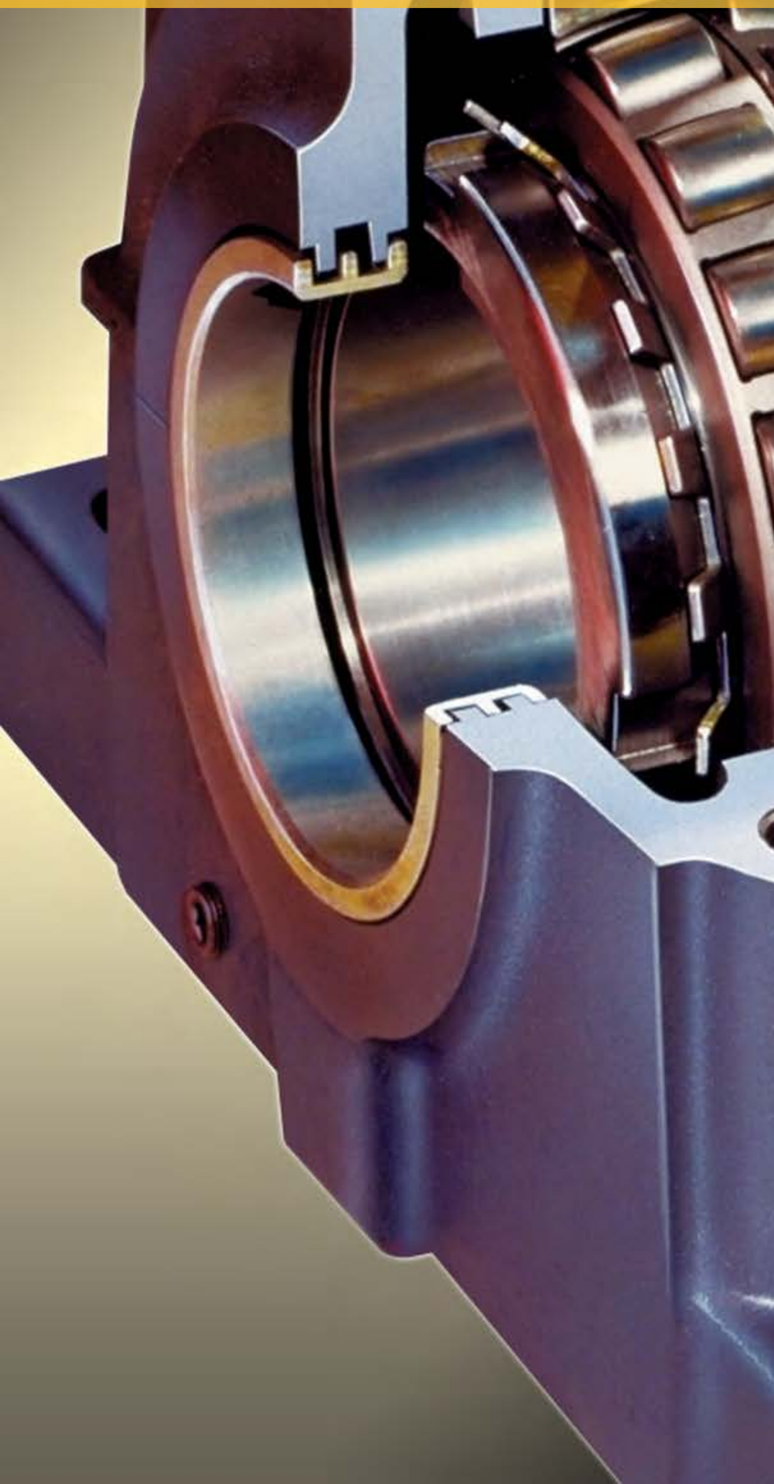
1. What are the two main causes of injuries in the workplace?
2. What is first aid?
3. What is a Good Samaritan law?
4. What is the most visible result of an injury?
5. List the causes of burns.
6. List the steps to follow when assisting a choking victim.
7. What are the two main causes of slips and falls in the workplace?
8. What causes a large percentage of eye injuries?
9. What is the most common work-related disease?
10. What type of PPE should be worn to prevent hearing damage?
11. Explain how a respirator is selected.
12. Explain the difference between the lower explosive limit (LEL) and upper explosive limit (UEL).
13. Where must a confined-space entry-permit be placed?
14. What is the minimum working height that requires the use of a personal fall-arrest system?
15. Define safety net.

Digital Resources

ATPeResources.com/Quicklinks
Access Code 462409

CHAPTER 2

TOOLS AND TOOL SAFETY



When an industrial or mechanical technician performs work, the proper tools and equipment must be selected for each operation. The tools and equipment must be organized and readily available for use. Types of tools include hand tools, power tools, and test tools. To avoid injury and prevent damage to a tool, technicians should consult the operator's manual for proper operation and use before performing any work.

Milwaukee Electric Tool Corp.

Chapter Objectives

- List the different types of tools used for noncutting operations.
- List the different types of tools used for cutting operations.
- Explain the tasks that usually require the use of power tools.
- Describe the test tools used to measure and record quantities involving electrical current, motion, distance, speed, and temperature.
- Compare contact and noncontact temperature test tools.
- Explain safety precautions to follow when working with hand tools, power tools, and test tools.
- Describe the different types of ladders and their uses.
- Describe the different types of scaffolds and their uses.
- Explain the use of safety nets.
- Explain safety precautions to follow when working with ladders and scaffolds.

Key Terms

- hammer
- wrench
- screwdriver
- pliers
- punch
- vise
- screw extractor
- mechanical puller
- file
- tap
- chisel
- handsaw
- power drill
- circular saw
- reciprocating saw
- metal ladder
- fiberglass ladder

TOOLS

Various hand, power, and test tools are used by industrial and mechanical technicians for the maintenance, troubleshooting, and installation of different types of equipment. Different tools are designed for the efficient and safe completion of a specific job. Proper use of tools is required for safe and efficient work.

Specialized hammers are used for industrial operations such as removing slag from weld lines.

Hand Tools

Industrial and mechanical technicians use hand tools for twisting, turning, bending, cutting, stripping, attaching, pulling, and securing operations. Noncutting operations require the use of tools such as hammers, wrenches, screwdrivers, pliers, punches, vises, tape rules, screw extractors, and mechanical pullers for gears and bearings. Cutting operations require the use of tools such as files, taps and dies, chisels, wire stripper/crimper/cutters, handsaws, and hacksaws.

Hammers. A *hammer* is a striking or splitting tool with a hardened head fastened perpendicular to a handle. Common types of hammers used in industrial and mechanical applications include claw, ball peen, engineer's, and sledge. **See Figure 2-1.** A claw hammer is used to drive nails. A claw hammer can also be used to remove nails previously driven into a surface. Ball peen hammers of the proper size are designed for striking chisels and punches. Ball peen hammers can also be used for riveting, shaping, and straightening unhardened metal. Engineer's hammers are double-faced hammers used for driving large-size chisels, cold punches, rock drills, and hardened nails. Medium-size sledgehammers (5 lb to 8 lb) are used for driving stakes and other heavy-duty pounding.

Figure 2-1. Common types of hammers used in industrial and mechanical applications include claw, ball peen, engineer's, and sledge.

Wrenches. A *wrench* is a hand tool with jaws at one or both ends that is designed to turn bolts, nuts, or pipes. Common wrenches used for industrial and mechanical applications include socket, adjustable, Allen (hex key), combination, and pipe. **See Figure 2-2.** Socket wrenches are used to tighten a variety of items, such as hex-head lag screws, bolts, and various electrical connectors. Adjustable wrenches are used to tighten items such as various-size hex-head lag screws, bolts, and large conduit couplings. Allen wrenches are used for tightening hex-head bolts. A combination wrench is a hand tool with an open-end wrench on one end and a closed-end box wrench on the other. Pipe wrenches can be straight, offset, strap, or chain. Pipe wrenches are used to tighten and loosen pipes and large conduit.

When using wrenches, a pipe extension or other form of "cheater" should never be used to increase the leverage of the wrench. A wrench is selected with an opening that corresponds to the size of the nut to be turned. A wrench with too large an opening for the workpiece can spread the jaws of an open-end wrench and batter the points of a box or socket wrench. Care should be taken in selecting inch wrenches for inch fasteners and metric wrenches for metric fasteners. It is a good practice to pull on a wrench handle before use. The safest wrench that can be used is a box or socket wrench because wrenches of these types cannot slip and injure a technician. A straight handle is better than an offset handle if conditions permit.

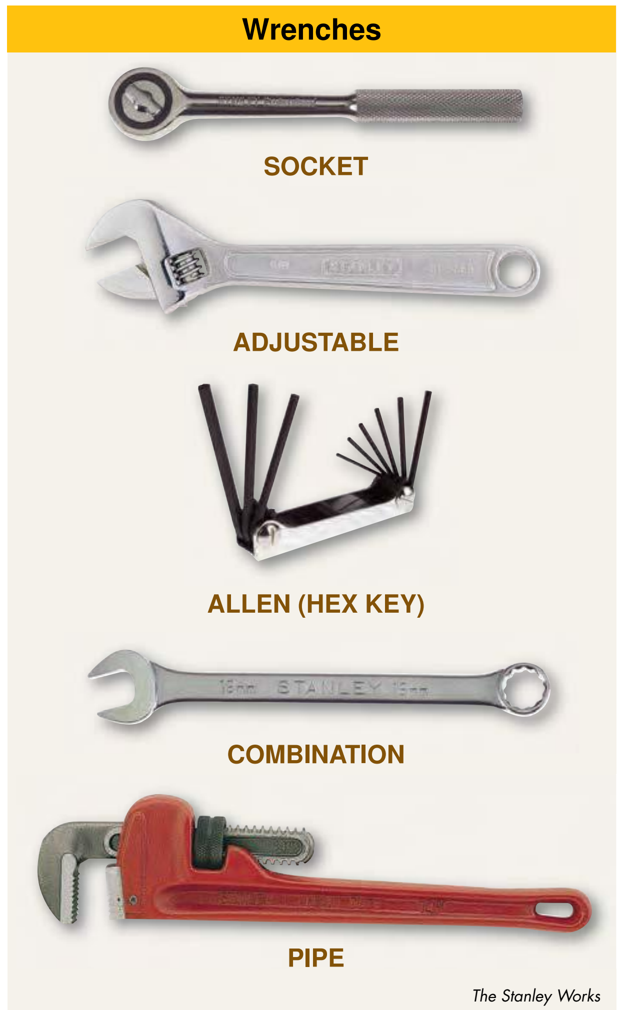


Figure 2-2. Wrenches have jaws at one or both ends and are designed to turn bolts, nuts, or pipes.

Tech Tip

To help reduce worker fatigue and provide uniform torque, many types of wrenches used in industrial applications are available with electric or pneumatic power.

Screwdrivers. A *screwdriver* is a hand tool with a tip designed to fit into a screw head for fastening operations. Industrial and mechanical technicians use screwdrivers in most installation, troubleshooting, and maintenance activities to secure and remove various threaded fasteners. Various types of screwdrivers are available, but the two main types of screwdrivers are the flat head and Phillips. Flat head and Phillips screwdrivers are available as standard and offset. Offset screwdrivers are also available as a combination with a Phillips head and a flat head. A screw-holding attachment can be used with standard screwdrivers. **See Figure 2-3.**

Figure 2-3. Different types of screwdrivers are used for various turning operations.

Tech Tip

Hand tools such as hammers, screwdrivers, scrapers, wrenches, chisels, pry bars, and wire brushes are available as nonsparking designs for use in areas where flammable vapors or dust may be present. Nonsparking hand tools are typically composed of brass, beryllium copper, bronze, bronze alloys, or copper alloys.

Standard screwdrivers are used for the installation and removal of threaded fasteners. Offset screwdrivers provide a means for reaching difficult screws. A screw-holding screwdriver is used to hold screws in place when working in tight spots. Once started, the screw is released and tightened with a standard screwdriver. Screwdrivers are available with square shanks to which a wrench can be applied for the removal of stubborn screws. Screwdrivers can also have a thin shank to reach and drive screws in deep, counterbored holes.

When using a screwdriver, verify that the tip fits the slot of the screw snugly and does not project beyond the screw head. A screwdriver should never be used as a cold chisel or punch. A screwdriver should not be used near energized electrical wires and should never be exposed to excessive heat. A worn tip should be redressed with a file to regain a good, straight edge. A screwdriver that has a worn or broken handle should be discarded.

Pliers. *Pliers* are a hand tool with opposing jaws for gripping and/or cutting. Industrial and mechanical technicians use pliers for various gripping, turning, cutting, positioning, and bending operations. Common pliers include slip-joint, tongue-and-groove, long nose, locking, diagonal-cutting, lineman's, end-cutting, and self-adjusting pliers. **See Figure 2-4.**

Slip-joint pliers are used to tighten box connectors, lock nuts, and small-size conduit couplings. Tongue-and-groove pliers are used for a wide range of applications involving gripping, turning, and bending. Locking pliers (such as Vise-Grip™ pliers) are used to lock onto a workpiece. Locking pliers can be adjusted to lock at any size with any desired amount of pressure. The adjustable jaws of tongue-and-groove pliers enable adjustment to a wide range of sizes. Long nose pliers are used for bending and cutting wire and positioning small components. Diagonal-cutting pliers are used for cutting cables and wires that are too difficult to cut with side-cutting pliers.

Figure 2-4. Pliers are used by industrial and mechanical technicians for turning, bending, and cutting operations.

Lineman's pliers are used for cutting cable, removing knockouts, twisting wire, and deburring metal pipe. End-cutting pliers are used for cutting wire, nails, rivets, etc., close to the workpiece. Self-adjusting pliers work in the same manner as slip-joint pliers but automatically adjust to the size of the workpiece and lock in place.

Punches. A *punch* is a hand tool with a pointed or blunt tip for marking or making holes or driving objects when struck by a hammer. Care should be used in selecting the proper punch for each operation. Punches include prick, center, solid, pin, and spring-loaded punches. **See Figure 2-5.**

The Stanley Works

Figure 2-5. A punch is a hand tool with a pointed or blunt tip for marking or making holes or driving objects when struck by a hammer.

A *prick punch* is a sharp, pointed steel shaft struck with a hammer to mark centerpoints or punch holes in light-gauge metal. Prick punches are made of tool steel and have a tapered point ground to an included angle of approximately 30°. Prick punches are used for making small dents or indentations and/or establishing points for dividers and trammel points.

Reed Manufacturing Co.

Copper vise-jaw caps can be used to protect vise jaws and surfaces of workpieces from scratching or marring.

A *center punch* is a steel hand tool with one end formed to a conical point of approximately 90°. It is used to make small indentations in hard surfaces, such as metal, by striking the surface with a hammer to establish a centerpoint for drilling a hole. Center punches are similar in design to prick punches, except that the tapered point is ground to an angle of approximately 90°. Center punches are manufactured in various sizes and are available in sets of various sizes. Neither prick punches nor center punches should be used to punch holes. Punches of these types are intended for establishing points only.

A *solid punch* is a hand tool with a blunt, circular end, which is used to punch small holes in light-gauge metal. Solid punches are also available in sets of various sizes. A *pin punch* is a punch used for removing pins from parallel holes. Pin punches are used for removing pins such as roll pins or dowel pins. Pin punches are not tapered like most punches, but are slightly smaller in diameter than the fractional hole they enter. The face of the pin punch is flat to ensure a solid seat against the pin being removed. A *spring-loaded punch* is a punch that is equipped with a spring. A spring-loaded punch can mark an object without the use of a hammer. When pushing down on the punch, the spring activates the punch to make the desired mark on the object. The spring tension can be adjusted by turning an adjustment knob located near the top of the punch.

Vises. A *vise* is a portable or stationary clamping device used to firmly hold work in place. Vises are used for holding work during inspection, assembly, forming, welding, and machining processes. Vises usually consist of a screw, lever, or cam mechanism that closes and holds two or more jaws around a workpiece. Although there are various types of vises, the most common types of vises used for mechanical work include pipe vises, bench vises, and machine vises. **See Figure 2-6.**

A *pipe vise* is a vise that has a hinge at one end and a hook at the opposite end. This allows the vise to be opened so that the pipe does not need to be inserted through the vise jaws to be worked on. A yoke pipe vise is bolted to a workbench. A clamp kit vise is a vise that contains a clamp for mounting. A clamp kit vise can be temporarily mounted for light-duty work without drilling holes. Yoke vises and chain pipe vises are available in portable workbench models.

A *bench vise* is a vise that can be attached to a bench top. Bench vises are the most common type of vise and can be used for most industrial and mechanical applications. A *machine vise* is vise made with high-grade body castings and ground-steel jaw plates. Machine vises are designed for heavier industrial processes such as milling, drilling, shaping, and grinding. Vises should adhere to the International Standards Organization (ISO) and The American National Standards Institute (ANSI) standards.

Vises

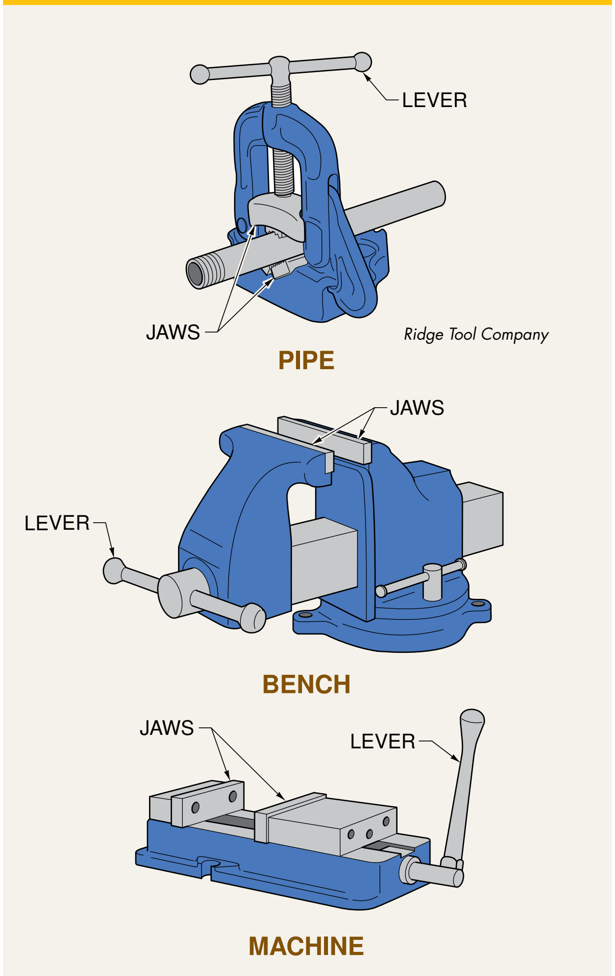


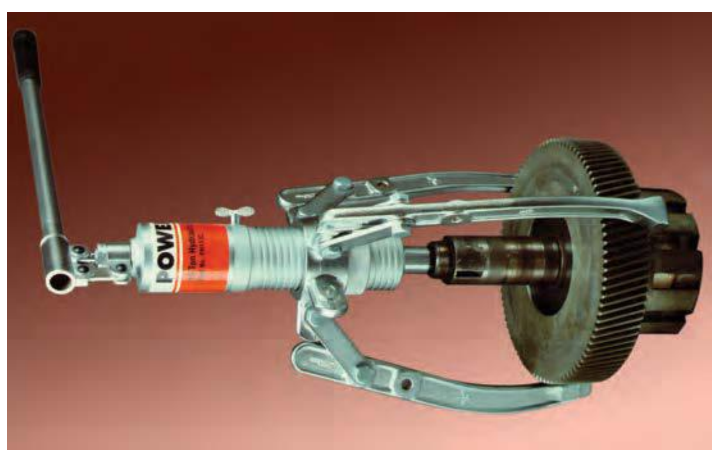
Figure 2-6. Common types of vises used in industrial mechanics include pipe vises, bench vises, and machine vises.

Screw Extractors. A *screw extractor* is a tool used to remove studs, bolts, or screws broken below or near the surface of a workpiece. Some screw extractors resemble reverse-threaded screws, while others resemble square tapered rods with chiseled edges. Screw extractors are available for most screw sizes. Screw extractors require the use of penetrating oil to assist in the removal of the broken screw. *Penetrating oil* is an industrial lubricant used to clean and loosen frozen parts. When penetrating oil is applied to a frozen or stuck part, it must be allowed to soak into the work area for several minutes. The size of hole depends on the broken bolt or screw size and extractor size. For example, the screw extractor hole size for a $\frac{3}{8}''$ screw requires a $\frac{1}{4}''$ hole for a reverse-threaded extractor and a $\frac{15}{64}''$ hole for a square extractor. Usually, the required hole size is stamped on the screw extractor. Removing a broken bolt or screw with a screw extractor is completed by applying the procedure:

1. Drill a small pilot hole in the center of the broken bolt or screw. **See Figure 2-7.**
2. Drill a second, larger extractor hole into the pilot hole.
3. Apply penetrating oil and use hammer to tap proper-size screw extractor into drilled hole.
4. Rotate the extractor counterclockwise for a broken bolt or screw with a right-hand thread (clockwise for a left-hand thread) and remove broken bolt or screw.

Note: Most screw threads used in industrial and mechanical equipment are right-handed.

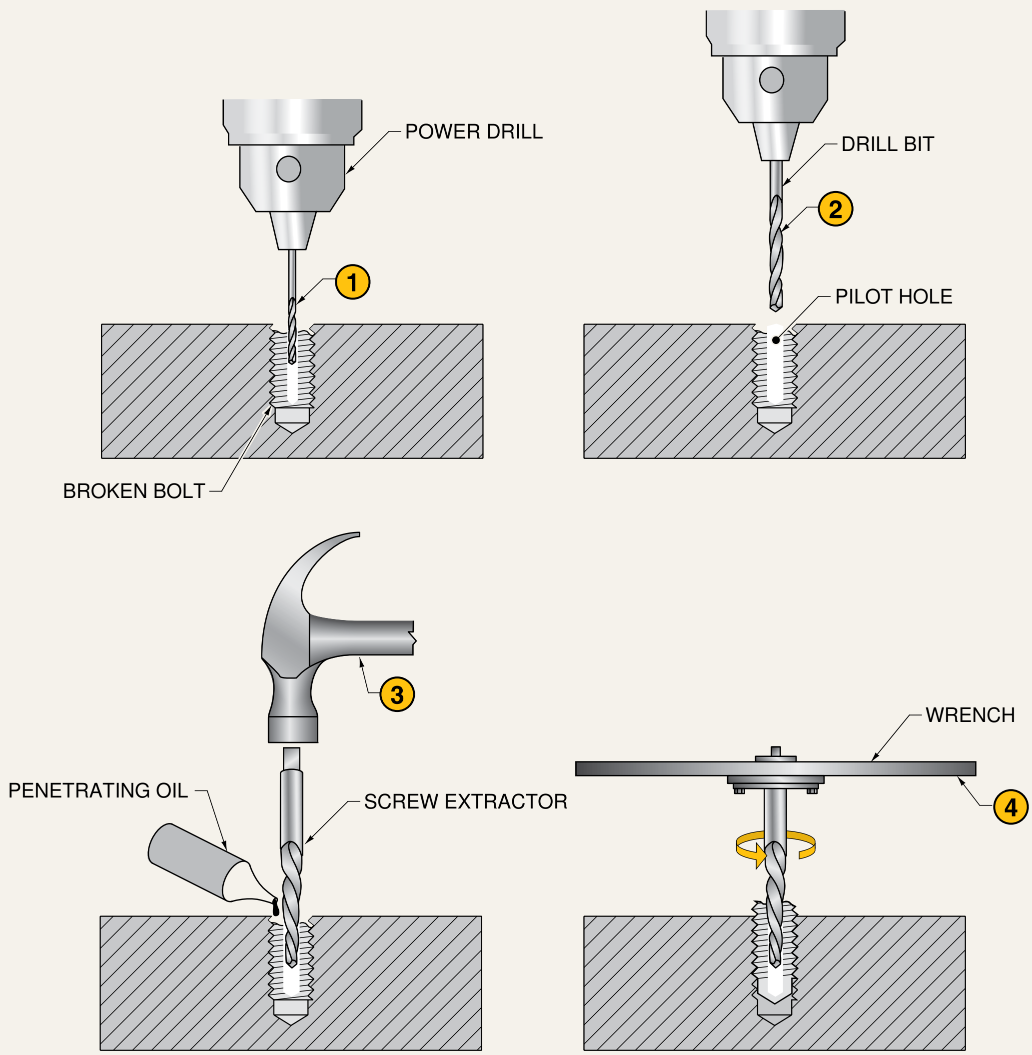
Mechanical Pullers. A *mechanical puller* is a tool used to remove fitted machine parts. Fitted machine parts include parts such as sprockets, gears, pulleys, and bearings. Prying and hammering to remove a fitted machine part can damage both the fitted machine part and the matching machine part. The three basic types of pullers used for most applications are external pullers, internal pullers, and press pullers. **See Figure 2-8.** For a straight pull, a mechanical puller must be aligned with the shaft of the object to be removed. Each jaw must be parallel with the forcing screw. An off-center pull can bind parts, causing damage to equipment and harm to the user. As the forcing screw is rotated, the jaws pull the object to be removed.



Power Team, Division of SPX Corporation

Mechanical pullers are available with hand pumps for removal of medium-size gears and bearings.

Screw Extractors – Broken Bolt Removal Procedure



1. DRILL SMALL PILOT HOLE IN CENTER OF BROKEN BOLT
2. DRILL LARGER EXTRACTOR HOLE INTO PILOT HOLE
3. APPLY PENETRATING OIL AND USE HAMMER TO TAP PROPER SIZE SCREW EXTRACTOR INTO DRILLED HOLE
4. USE WRENCH TO ROTATE SCREW EXTRACTOR AND REMOVE BROKEN BOLT

Figure 2-7. Screw extractors are used to remove broken bolts and screws from equipment without causing damage to screw threads or equipment.

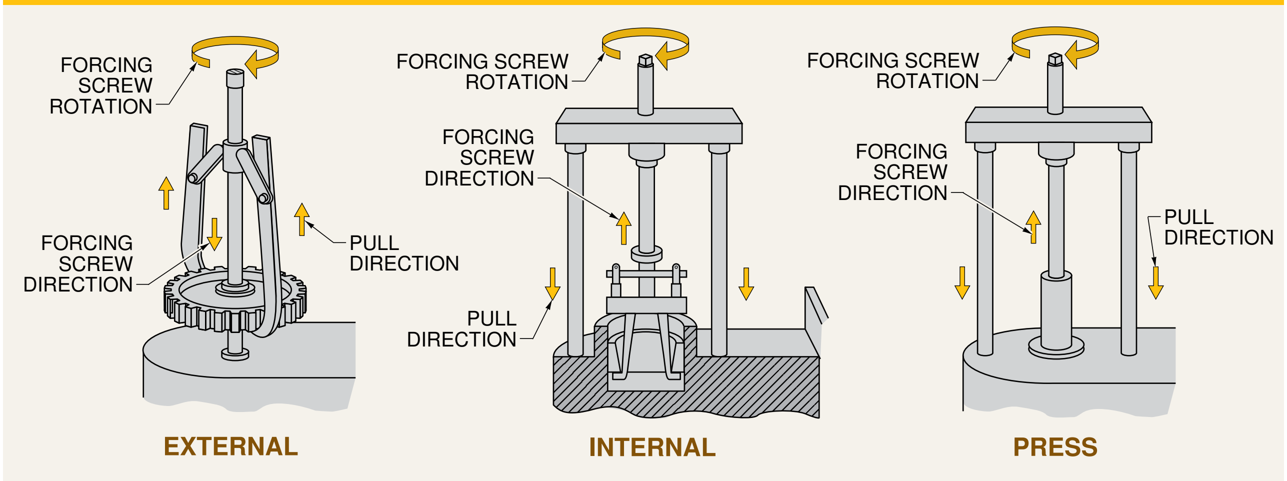


Figure 2-8. Mechanical pullers are used to remove fitted machine parts such as sprockets, gears, pulleys, and bearings.

Safety Tip

To avoid injuries to hands and feet, leather gloves and steel-toe with metatarsal protection safety shoes should be worn when removing gears and bearings with mechanical pullers.

Each type of puller has a forcing screw, puller arms (jaws), and a yoke (supporting arms). Pullers are available with either two or three puller arms. A three-arm puller offers smoother pulls, gives greater support, and is self-centering. An external puller is sometimes referred to as a universal gear puller, although it pulls more than gears. An external puller has a set of jaws that grip the back of the object from around the outside diameter.

Internal pullers are used to remove objects such as bearings or bushings from a bore. Internal pullers have a set of jaws that grip from the back by entering the inside of the object to be removed. Internal pullers have legs that mount on the stationary part while the forcing screw pulls the object to be removed. Most internal puller sets have interchangeable jaws for specific applications. For example, larger jaws can be attached to achieve greater coverage for removing bushings without breaking them.

Press pullers are used to remove shafts from within a bore. In most applications, a hole must be drilled and tapped in the center of the shaft to be removed to accommodate the assembly of the force screw. Press pullers have legs, which mount on the stationary part as the forcing screw is screwed into the end of the shaft. As the forcing screw is rotated, a pulling motion is applied to the shaft.

Files. A *file* is an abrasive tool with single or double rows of fine teeth cut into the surface. Files are used to remove burrs from sheets of metal, to square the ends of band iron, to straighten uneven edges, and for various other operations that require removing a small amount of metal. File parts include the point, edge, face, heel, and tang. File cutting faces can be single cut or double cut. **See Figure 2-9.** Single-cut files have a single set of teeth cut at an angle of 65° to 85°. Double-cut files have two sets of teeth crossing each other. Double-cut files are used for rough filing since they remove material faster than single-cut files. File handles are usually made of wood and are designed to fit the hollow of the hand. A metal ferrule on the end of the handle prevents it from splitting. The most common types of files used for industrial and mechanical projects include flat, mill, three square, round, square, half-round, and knife. **See Figure 2-10.**

Files are used to remove burrs and rough spots from metal workpieces.

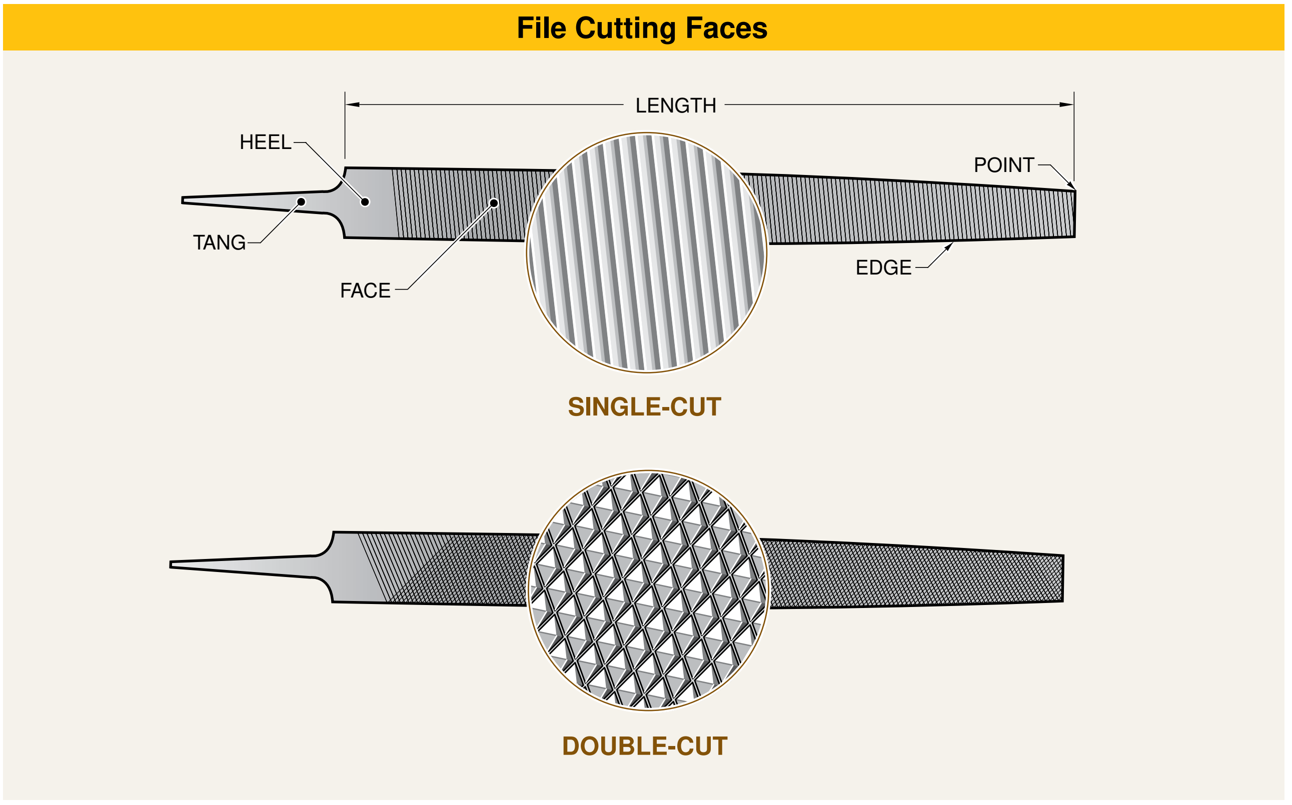


Figure 2-9. File cutting faces can be single cut or double cut.

A *flat file* is a file that is used to file flat surfaces as well as for other operations that require a fast-cutting file. A *mill file* is an all-purpose, single-cut file especially adapted for finish filing. A *knife file* is a file with a blade cross-section tapering from a square to a pointed edge. A knife file is used to smooth areas enclosed by an acute angle. It is suited for finishing sharp corners of grooves and slots where other files cannot fit. A *three-square file (three-cornered file)* is a file that has angles of 60° and is used for filing internal angles, clearing out corners, etc. A file card or brush with a scorer is used to remove particles that clog files.

Taps. A *tap* is a tool used to cut internal threads in a predrilled hole. Taps have a helical design, and are self-feeding once engaged into the material to be tapped (cut). Taps are used with a tap wrench to "pull" the tap into a workpiece. Taps are used to cut female threads into a rigid metal or plastic workpiece. The most common types of taps used for industrial or mechanical applications are the taper tap, plug tap, and bottom tap. **See Figure 2-11.**

A *taper tap* is a tap with a long, gradual taper that allows the tap to start easily. Taper taps are used for threading small-diameter holes and alloy steels because they cause less breakage. The taper also allows for a gradual cutting action, which keeps the tap square with a drilled hole.

A *plug tap* is a tap that is used after a taper tap to start a true and straight thread. Plug taps (intermediate taps) are used for through tapping and are used as the second tap in bottom tapping. Plug taps have good cutting capabilities due to their slight starting taper.

A *bottom tap* is a tap designed to cut threads at the bottom portion of a hole. Bottom tapshould not be used for cutting threads in an unthreaded hole. A lack of a taper at the cutting edge greatly lessens the starting capability of a bottom tap.

Tech Tip

When working with files, it is important that the object being filed is held firmly or in a vise so there is no movement. Movement of the object can cause the teeth of the file to cut down the object in an unsatisfactory way or even damage the file.

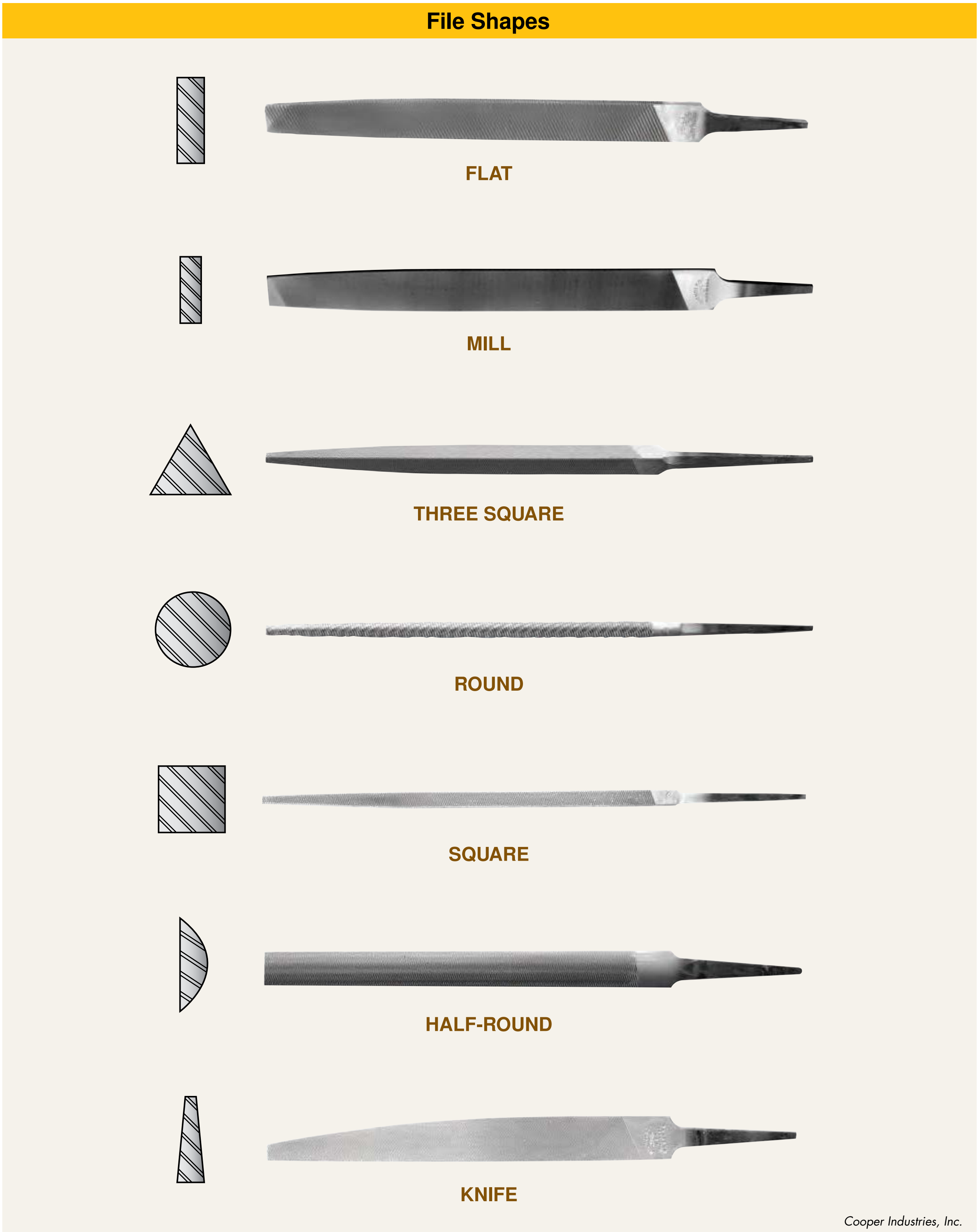


Figure 2-10. Different files are used for various metalworking applications.

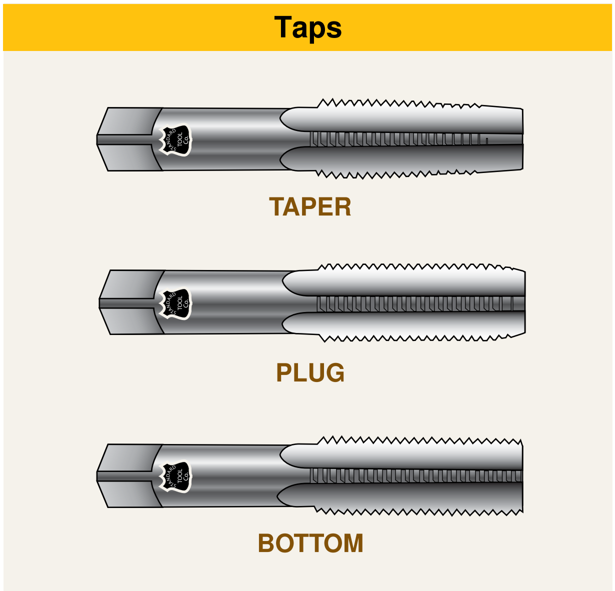


Figure 2-11. Taps have a helical design, and are self-feeding once engaged into the material to be tapped (cut).

Cutting metal with taps requires the use of proper cutting fluids to reduce friction and to achieve cleanly formed threads. Friction due to improper use can cause cutting edges of taps to chip, break, or shatter. A properly tapped hole begins with a properly drilled hole and is completed by determining the number of threads per inch and diameter of the finished tapped hole. A tap-drill size chart can be used for this determination. **See Appendix.** When a tap-drill size chart is not available, tap-drill size is determined by applying the formula:

$$TD = MD - \frac{1}{N}$$

where
TD = tap-drill size
MD = major diameter
N = number of threads per inch

For example, what is the tap-drill size for a ¼″-20 threaded hole?

$$TD = MD - \frac{1}{N}$$

$$TD = 0.250 - \frac{1}{20}$$

$$TD = 0.250 - 0.050$$

$$TD = \mathbf{0.200''}$$

Checking the drill sizes on a drill index indicates that the tap drill for a ¼″-20 hole is a number 7 drill (0.201″). Tapping a hole with a taper tap is completed by applying the procedure:

1. Drill a hole perpendicular to the work surface. **See Figure 2-12.**
2. Place a taper tap in a tap wrench ("T" handle wrench).
3. Hold tap wrench square to the surface and start cutting action by applying cutting fluid and turning the tap clockwise.
4. After about two turns, back off the tap about a half-turn to break away metal turning chips.
5. Repeat steps 3 and 4 until hole is tapped to specifications.

Note: To prevent loading the hole with metal chips and cutting fluid, it may be necessary to periodically remove the tap to clean out the chips.

Dies. A *die* is a tool used to cut external threads on round rods. Dies are available in a variety of designs and are usually made from carbon tool steel or high-speed steel. Different types of dies are available for producing either English or metric threads. The most common types of dies are round or hexagonal, and are typically available as single piece design. **See Figure 2-13.** Dies are placed in a diestock (handle) for hand threading. The depth of the thread cuts can be adjusted with one or more adjustment screws in the die or die holder. Dies have a side with a 45° chamfer to prevent die-tooth breakage and to allow for a gentle cutting start. Dies have holes adjacent to the cutting threads to allow for the removal of metal turning chips.

When adjusting a die, the die can shatter if the adjusted opening is too large. If the adjusted opening is too small, the die can damage the workpiece and cause thread breakage. Dies without an adjustment screw are preset by the manufacturer and generally do not require adjustment. Hexagonal dies are used for tough cutting and are designed with thicker cross sections than round dies to permit cleaning and rethreading of threads (thread chasing). Hexagonal dies used for rethreading purposes are not to be used for cutting new threads on un-threaded material. Cutting external threads by hand with a single-piece die is completed by applying the procedure:

1. Place die in diestock.
2. Place the 45° starting chamfer side of the die on end of workpiece to be threaded.
3. Align die squarely with the starting point of the workpiece.

4. Apply cutting fluid, and rotate die clockwise (counterclockwise for left-hand threads). Cutting fluid is used to disperse heat and assist in the formation and removal of metal chips.
5. Apply equal pressure to both sides of the die to verify a straight cut.
6. Repeat steps 4 and 5 until workpiece is threaded to specifications.

Note: To prevent chipped die threads, avoid turning the die completely against the shoulder (bottom) of the workpiece.

Chisels. A *chisel* is a hand tool with a cutting edge on one end that is used to shape, dress, or work wood, metal, or stone. Chisels are commonly driven with a mallet or hammer. Chisel types used for industrial and mechanical applications include flat cold, cape, round nose, and diamond point. **See Figure 2-14.** A *flat cold chisel* is a chisel with a tempered cutting edge to maintain durability. A flat cold chisel is typically used for cutting sheet metal, rivets, and bolts, and in chipping operations. A *cape chisel* is a chisel with a thin, tapered face and a narrow cutting edge. Cape chisels are used for cutting slots, grooves, and keyways in deep corners of metal. A *round-nose chisel* is a chisel that has a round nose and is used for roughing out the concave surfaces of corners. Round-nose chisels are also used for cutting grooves. A *diamond-point chisel* is a chisel with a V-shaped blade that is less than 180°. Diamond-point chisels are used for cutting V-shaped grooves, for chipping corners, and sometimes for removing bolts where the heads have broken off.

Tech Tip

Powered tapping tools are available to help reduce worker fatigue and increase tapping accuracy for projects that require a high number of tapped products. Powered tapping machines include electric tap guns, power drill attachments, and hand tappers that can be attached to a workbench.

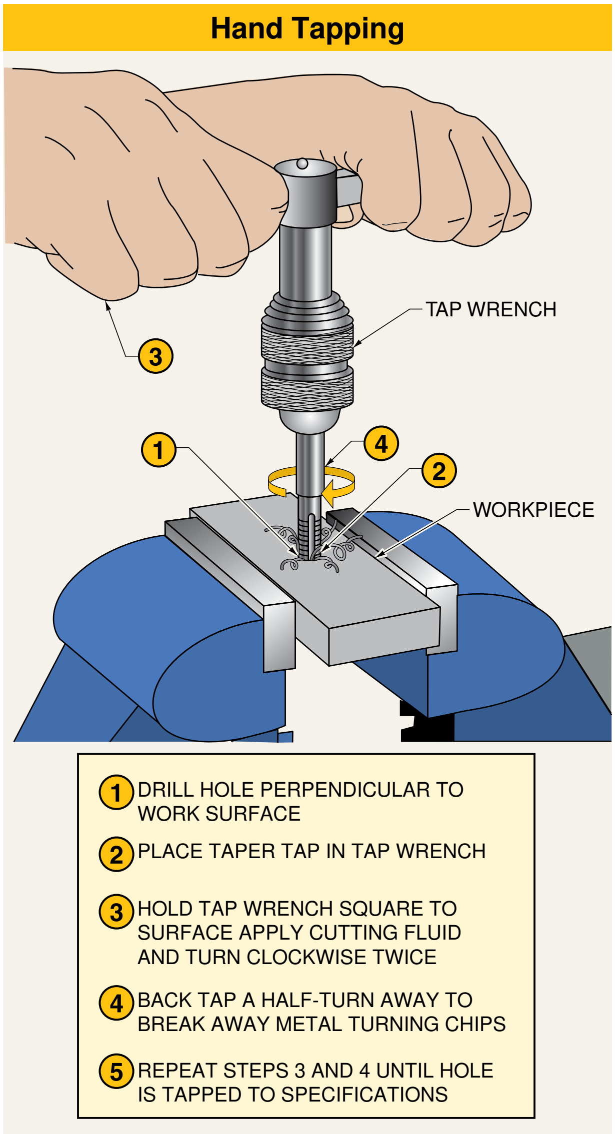


Figure 2-12. Hand tapping is performed by holding a tap square to a predrilled hole and turning in a clockwise motion.

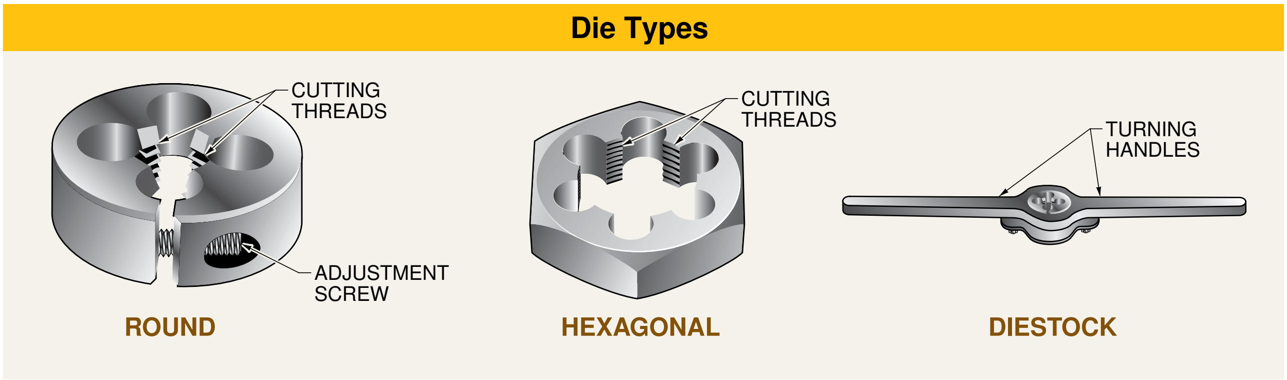


Figure 2-13. Each type of die has features designed for specific threading applications.

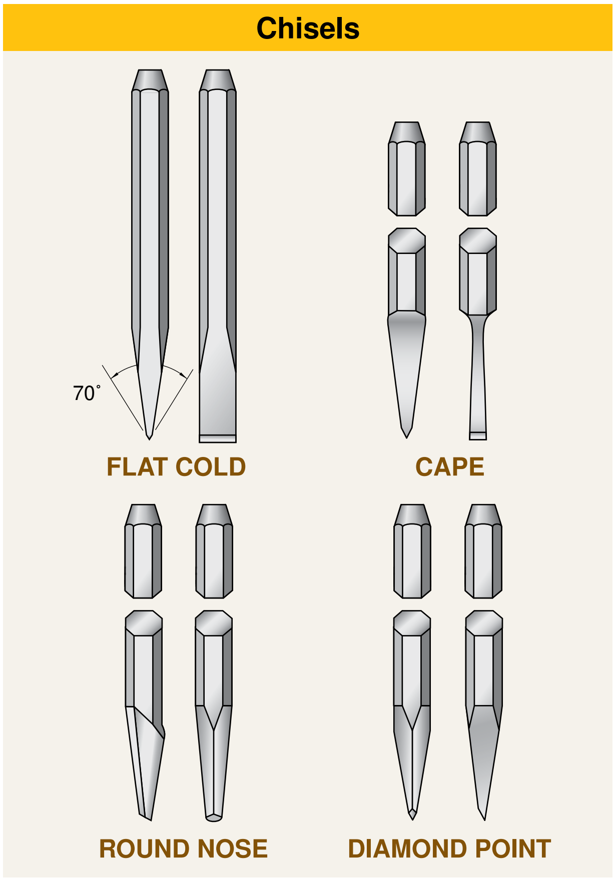


Figure 2-14. Chisel types used for industrial and mechanical applications include flat cold, cape, round nose, and diamond point.

Wire Stripper/Crimper/Cutters. A *wire stripper/crimper/cutter* is a tool used for the removal of insulation from small-diameter wire. Most wire strippers strip stranded wire from American Wire Gauge (AWG) size 22 to AWG size 10 and solid wire from AWG size 18 to AWG size 8. A wire stripper/crimper/cutter is also used to crimp wire connection terminals from AWG size 22 to AWG size 10. Most modern models are also designed with a wire cutter in the nose of the tool and a small-diameter bolt cutter near the handle. Most stripper/crimper/cutters shear bolts ranging from size 4-40 to size 10-32. Wire strippers are also available without the crimper and bolt-shear functions and are smaller and easier to handle than a stripper/crimper/cutter. **See Figure 2-15.**

Figure 2-15. Wire stripper/crimper/cutters are used for removing insulation from and cutting small-diameter wire.

Handsaws. A *handsaw* is a woodcutting hand tool consisting of a straight, toothed blade attached to a handle. The blade is moved back and forth against wood to produce cutting action. The main parts of a handsaw are the blade (including the toe and heel of the blade), teeth, back, and handle. **See Figure 2-16.** Although the basic construction of all types of handsaws is similar, there are differences in the length and shape of the blade and the number and shape of the teeth. Most handsaws have a straight back, but skewback saws (curved-back saws) are also available.

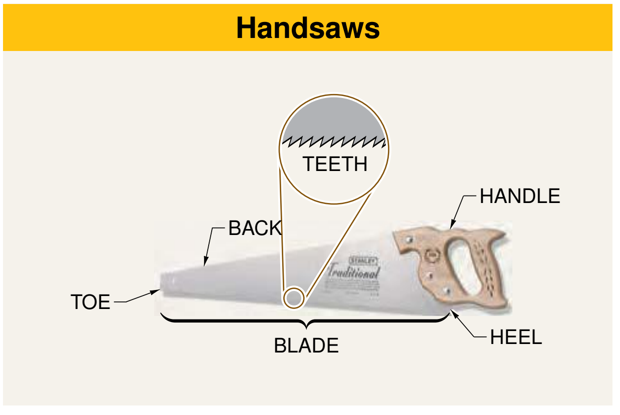


Figure 2-16. The main parts of a handsaw are the blade (including the toe and heel of the blade), teeth, back, and handle.

The cut made by a handsaw is wider than the thickness of a saw blade to allow the blade to move freely through the material being cut. If the saw blade cannot move freely, the wood fibers pressing against the blade cause the saw to bind, making the cutting action difficult. Handsaw teeth are alternately bent from side to side, which provides a wider cut than the blade thickness (kerf).

High-quality handsaw blades are tapered from the blade top to the blade bottom. The top portion of the blade is thinner than the blade at the cutting edge, requiring less set in the teeth. A handsaw usually has a number printed on its blade indicating the number of teeth or points per inch. The lower the number, the larger the teeth, and the rougher the cut that is made. For example, an 8-point saw has larger teeth than an 11-point saw and produces a rougher cut than an 11-point saw. **See Figure 2-17.** When using a handsaw, position the workpiece face up to avoid splintering on the face. The back of the workpiece splinters due to the cutting action of the blade.

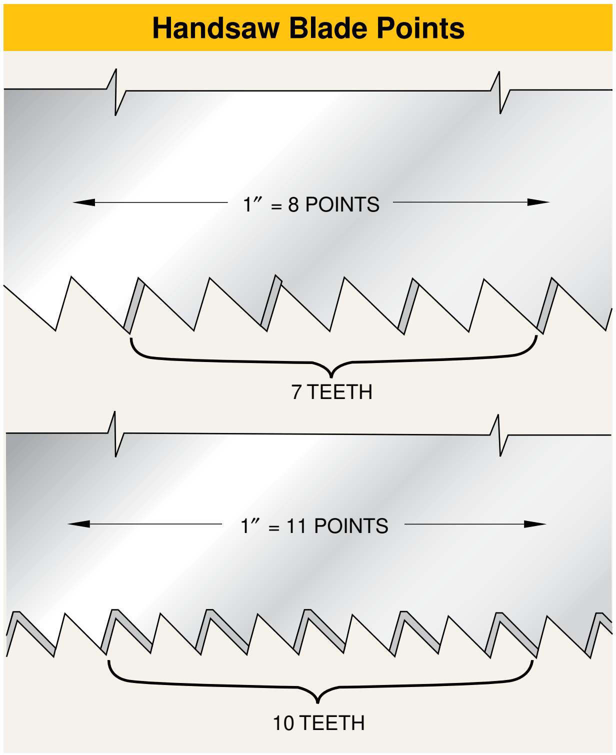


Figure 2-17. An 8-point saw has larger teeth than an 11-point saw and produces a rougher cut than an 11-point saw.

The two types of cuts that can be made are cross cuts and rip cuts. A *cross cut* is a cut that is made against the direction of the wood grain and is made with full, even strokes at about a 45° angle. A *rip cut* is a cut that is made with the direction of the wood grain and is made with full, even strokes at about a 60° angle. Cutting material by hand with a handsaw is completed by applying the procedure:

1. Wear safety glasses or a face shield.
2. Choose a handsaw of the proper size and shape for the material to be cut.
3. Check the material to be cut for objects that can buckle or damage the saw, such as nails, screws, staples, and knots.
4. Hold the material to be cut firmly against a support such as a table, vise, or bench.
5. Hold the handsaw beside the desired cut location with the thumb upright on the saw handle while applying pressure against the blade.
6. Carefully and slowly start the cut by pulling the blade upward until the blade creates a starting cut.
7. With a partial cut made, set handsaw to proper cutting angle. Sawing is accomplished with pressure applied on the down stroke only.

Note: If the material being cut is long, a wedge can be used to spread the material apart to prevent blade bind and to assist in blade cleaning.

Hacksaws. A *hacksaw* is a metal-cutting hand tool with an adjustable steel frame for holding various lengths and types of blades. Blades are inserted with the teeth pointing away from the handle. Hacksaws can be straight handle or pistol-grip handle. **See Figure 2-18.** A straight-handle hacksaw is usually preferred for fine work. Either type of frame is adjustable for various blade lengths. Tension is applied to the blade to make it taut by means of a wing nut on the pistol-grip frame or by turning a threaded handle on the straight-handle hacksaw. Hacksaws are used to cut workpieces such as metal pipe, PVC pipe, conduit, small-diameter metal rods, rigid plastics, bolts, and nails.

Power Tools

While much of the work performed by industrial and mechanical technicians can be completed with hand tools, many tasks require the use of power tools. Tasks that usually require the use of power tools include drilling, cutting, and sawing. Most power tools can operate with either an AC power source or a DC power source (battery). Power tools that operate with a DC power source are also known as cordless tools. Cordless tools are used because of their mobility but typically do not have as much power as power tools that operate on AC power. Another disadvantage of cordless tools is that their batteries can become run down before the project is completed.

Projects that require a large amount of drilling, cutting, or sawing typically require the use of a tool powered by an AC power source. The most common power tools used by industrial and mechanical technicians include drills, circular saws, and reciprocating saws.

Hacksaws

Figure 2-18. Common hacksaw designs are straight handle and pistol-grip handle.

Power Drills. A *power drill* is a power-driven rotary tool used with a bit with cutting edges for boring holes in materials such as wood, metal, or plastic. Some types of power drills, such as hammer drills, can drill at speeds up to 3000 rpm and simultaneously hammer into the material at up to 50,000 blows per minute. Hammer drills are used by industrial and mechanical technicians to drill holes in concrete walls, floors, and ceilings. Power drills can also be retrofitted with different types of attachments for operations such as screwing, grinding, and buffing. **See Figure 2-19.**

Circular Saws. A *circular saw* is a handheld or table -mounted power saw with teeth around the circumference of a circular blade that is rotated at high speed on a central axis or shaft. Circular saws are primarily used to cut wood but can also be used to cut certain types of plastic and metal. Circular saws are used to cut lumber or wood panels to length and width. A circular saw blade turns in a counterclockwise direction, cutting the material from the underside through the top. Circular saws are equally efficient for crosscutting and ripping lumber and panel products, and can be adjusted to cut angles ranging from 45° to 90°. The size of a circular saw is based on the largest-diameter blade that can be properly installed. Circular saw blade diameters range from 4½″ to 12″, with 7¼″-, 7½″-, or 8¼″-diameter blades being the most commonly used. A variety of saw blades are available for different operations required for cutting wood and other materials.

Power Drills

Figure 2-19. Power drills can be fitted with different types of attachments for operations such as screwing, grinding, and buffing.

Portable Band Saw. A *portable band saw* is a handheld power saw that has a flexible metal saw blade that forms a continuous loop around two parallel pulleys. Portable band saws use a continuous cutting action to slice through metals. These saws are used in the field to cut all-thread rod, strut channel, pipe, and other metal components. They come in both corded and cordless versions.

Most portable band saws have two speeds. The lower speed is used when cutting hard materials, and the higher speed is used when cutting soft materials. Portable band saws should be held firmly with both hands, and at least three teeth should be kept in the cut. When using a portable band saw, it is important to let the blade do the cutting and to not put too much pressure on the material with the blade. Excessive pressure can cause the blade to bind or break, leading to tool damage or worker injury.

Portable band saw blades are available in several pitches (teeth per inch). Using a blade with the correct pitch for the material being cut will extend the blade life.

The size, shape, and material being cut should be considered when selecting the proper blade. Soft materials require coarse pitch blades, and hard materials require fine pitch blades. Furthermore, thick materials require coarse pitch blades, and thin materials require fine pitch blades. **See Figure 2-20.**

Reciprocating Saws. A *reciprocating saw* is a multipurpose cutting tool in which the blade reciprocates (moves back and forth) to create the cutting action. Reciprocating saw blades can be plunged directly into walls, floors, ceilings, and other resilient material. Reciprocating saws operate at 1700 to 2800 strokes per minute (at no load) and are used by industrial and mechanical technicians to make cuts into finished walls, ceilings, floors, and any other rigid materials. **See Figure 2-21.** Reciprocating saws can also be retrofitted with different types of saw blades for cutting small-diameter plastic or metal pipes, rods, and tubing.

Portable Band Saws

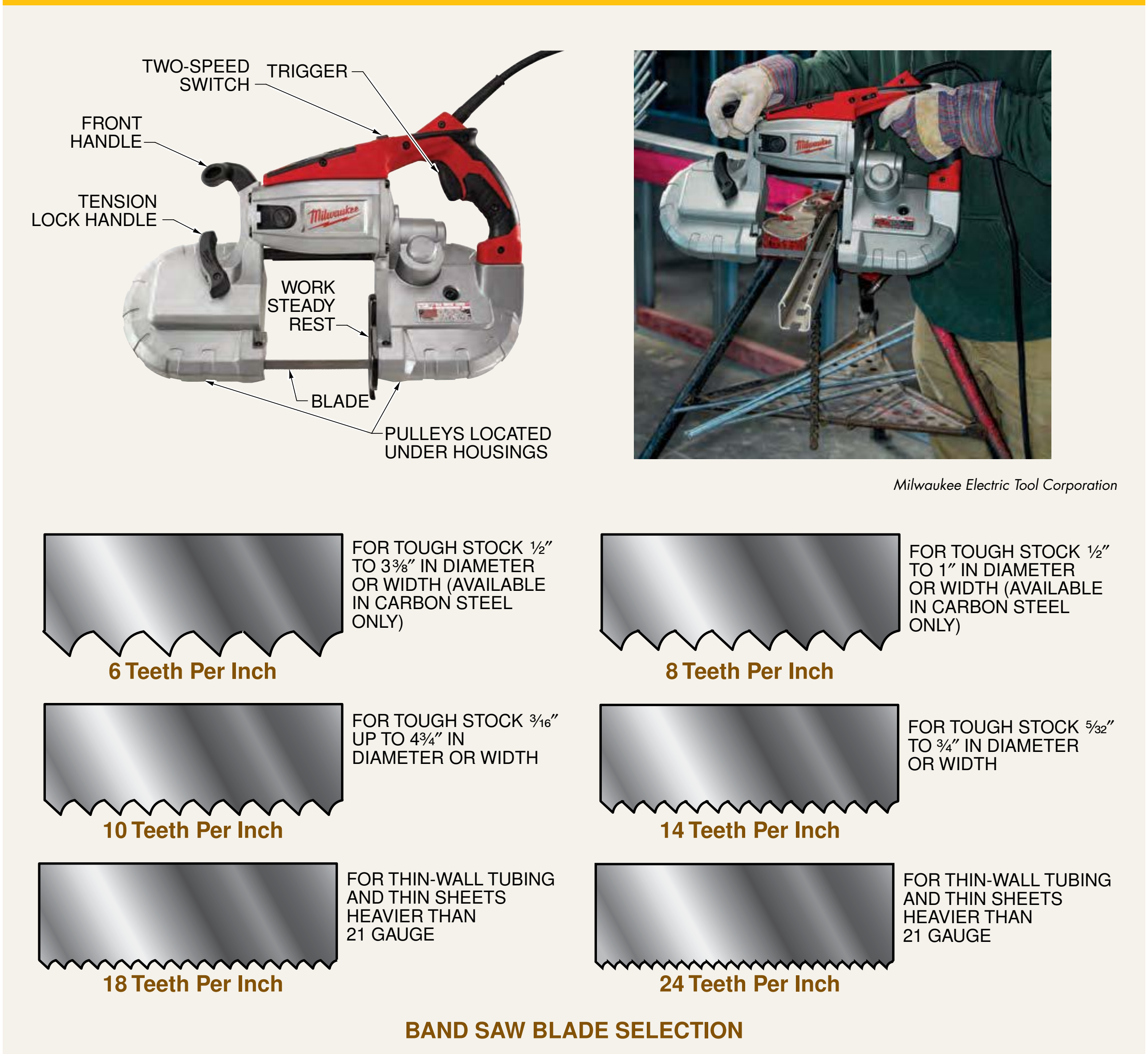


Figure 2-20. Portable band saws use a continuous cutting action to slice through metals.

Reciprocating Saws

Milwaukee Electric Tool Corp.

Figure 2-21. Reciprocating saws are used by industrial and mechanical technicians to make cuts into finished walls, ceilings, and floors.

Test Tools

Industrial and mechanical technicians use various types of test tools when performing work. Many test tools are used to measure and record quantities involving electrical current, motion, distance, speed, and temperature. During tests, components can provide signals or responses that technicians can use while troubleshooting or recordkeeping.

Types of test tools include multimeters, flowmeters, tachometers, stroboscopes, and stethoscopes. Most test tools are designed to measure and display a particular quantity with the greatest amount of accuracy. The accuracy of a measurement is always within manufacturer specified limits.

Multimeters. A *multimeter* is a portable test tool that is capable of measuring two or more electrical quantities. Multimeters are either analog or digital.

An *analog multimeter* is a meter that can measure two or more electrical quantities and display the measured quantities along calibrated scales using a needle. Most analog multimeters have several calibrated scales which correspond to different selector switch settings (AC, DC, or R) and jack usage (mA jack or 10 A jack). **See Figure 2-22.**

It is important to use the correct scale when reading an analog multimeter. The most common quantities measured with analog multimeters are voltage, resistance, and current. Many analog multimeters also include scales and ranges for measuring decibels and checking batteries. The decibel scale is a scale that indicates the comparison, or ratio, of two or more signal powers or voltages. The battery tester function allows the multimeter to display the charged condition (25%, 50%, 75%, or 100%) of a battery being tested.

A *digital multimeter (DMM)* is a meter that can measure two or more electrical quantities and display the measured quantities as numerical values. **See Figure 2-23.** Basic DMMs can be used to measure voltage, current, and resistance. Advanced DMMs include special functions, such as functions for measuring capacitance and temperature. The main advantages of a DMM over an analog multimeter are both the ability to record measurements as well as a digital display that is easier to read than a needle and scale.

Flowmeters. A *flowmeter* is a test tool that measures the flow of a fluid within a system. **See Figure 2-24.** Flowmeters obtain measurements as flow rates (the amount of fluid passing a point per unit of time). Flow rate units include the following:

- Gas—cubic feet per minute (cfm) or cubic feet per hour (cfh)
- Liquid—gallons per minute (gpm), cubic feet per second (cfs), or cubic feet per minute (cfm)

Flow can be measured directly with an in-line fixed flowmeter, or it can be closely approximated with a noncontact flowmeter. In-line fixed flowmeters are more accurate but may create problems by interfering with the flow of less viscous fluids, such as powders and slurries.

Noncontact flowmeters provide a close approximation (often within ±2.0%) of fluid flow. Noncontact flowmeters are ideal for testing or troubleshooting a system in which the indication of fluid flow is more important than the exact amount of fluid flow. Noncontact flowmeters operate through the use of a transducer sensor that allows a measurement of the flow inside a pipe. The displayed measurement is a velocity (ft/sec), but that velocity can be converted to a flow rate (gpm) by referring to manufacturer charts. The conversion can also be performed automatically by the flowmeter if it includes the required software.

Tachometers. A *tachometer* is a test tool that measures the speed of a moving object. Speed measurements can be taken using contact tachometers, photo tachometers, strobe tachometers, or laser tachometers. The type of tachometer used for an application depends on the units of measurement required and expected results. Rotating speeds are displayed in revolutions per minute (rpm), and linear speeds are displayed in feet per minute (ft/min, fpm) or meters per minute (m/min, mpm).

Analog Multimeters

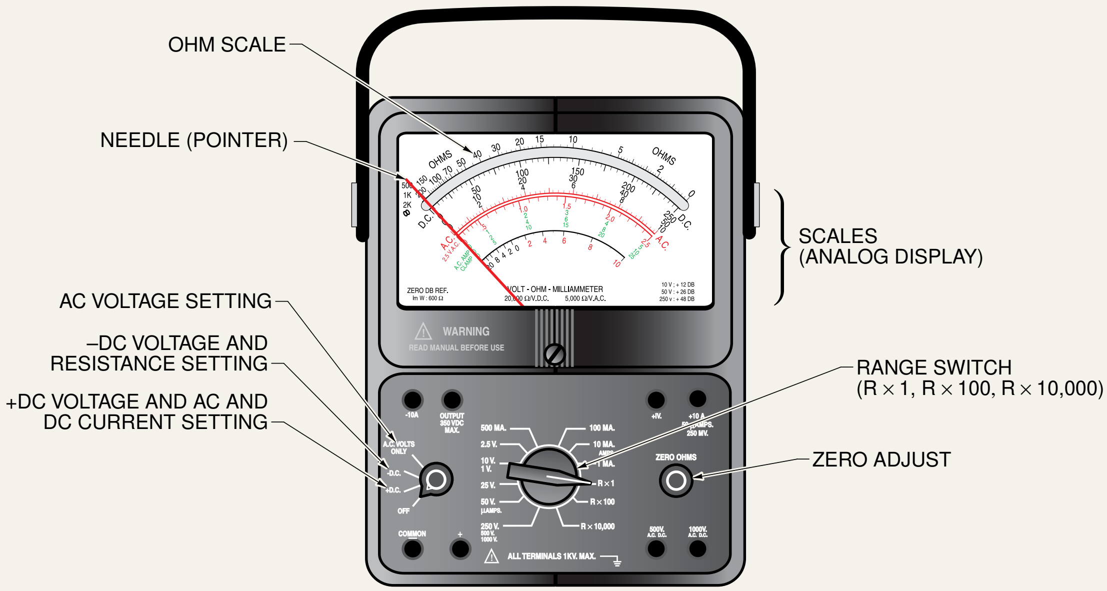


Figure 2-22. Analog multimeters can measure two or more electrical quantities and display the measured quantities along calibrated scales using a needle.

Digital Multimeters (DMMs)

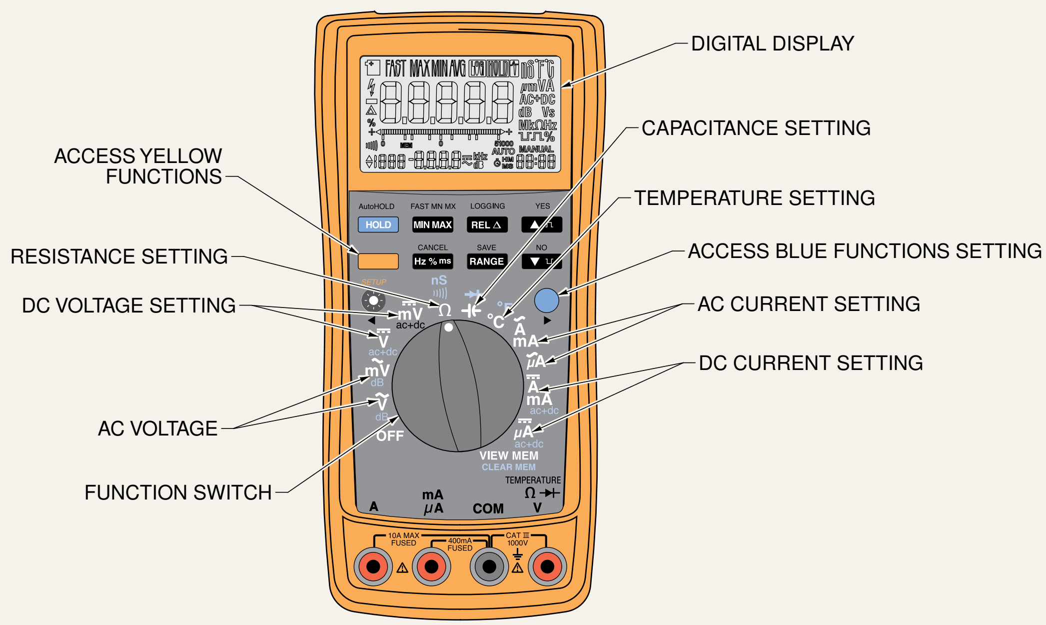


Figure 2-23. DMMs can measure two or more electrical quantities and display the measured quantities as numerical values.

A *contact tachometer* is a test tool that measures the rotational or linear speed of an object through direct contact with the object. **See Figure 2-25.** Contact tachometers are used to measure the rotational speed of objects such as motor shafts, gears, belts, and pulleys, as well as linear speeds of moving conveyors and press webs. Contact tachometers measure speeds from 0.1 rpm to about 25,000 rpm.

Flowmeters

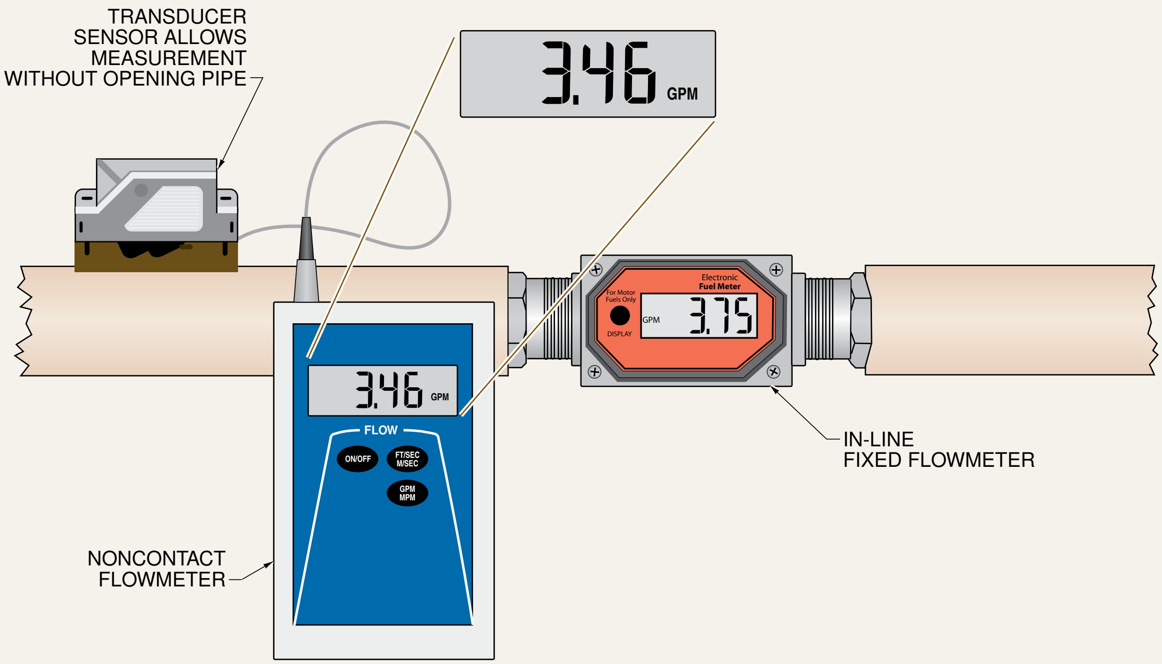


Figure 2-24. Fluid flow can be measured directly with an in-line fixed flowmeter or can be closely approximated with a noncontact flowmeter.

Contact Tachometers

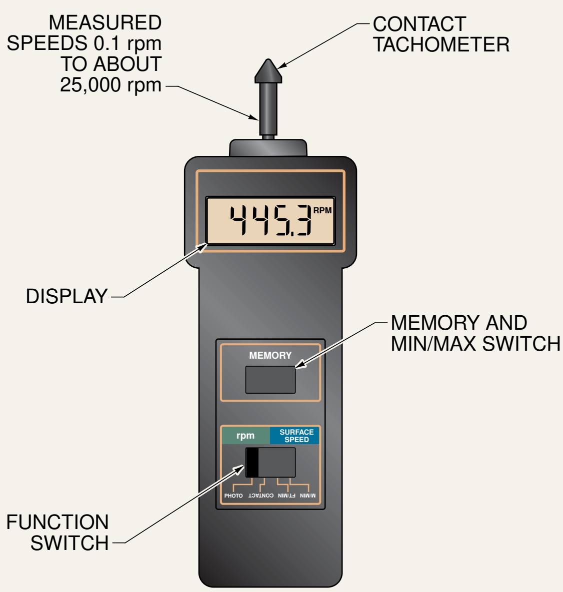


Figure 2-25. Contact tachometers measure the rotational or linear speed of an object, such as a motor shaft or gear, through direct contact with the object.

A *photo tachometer* is a test tool that uses light beams to measure the rotational speed of an object. **See Figure 2-26.** A photo tachometer measures speed by focusing a light beam on a reflective area or a piece of reflective tape on a rotating object and counting the number of reflections per minute. A photo tachometer is used in applications in which the rotating object cannot be reached or touched. It can measure speeds from 1 rpm to about 100,000 rpm, but it cannot measure linear speeds.

A *strobe tachometer*, similar to a photo tachometer, is a test tool that measures the rotational speed of an object by use of a flashing (strobe) light. Strobe tachometers are used to test shaft speeds for motors or pumps; abnormal vibrations; and alignment of components such as cams, shafts, couplings, and gears.

A *laser tachometer* is a test tool that uses a laser light to measure the rotational speed of an object. **See Figure 2-27.** A laser tachometer measures speed by focusing a laser light beam on a reflective area or a piece of reflective tape on a rotating object and counting the number of reflections per minute. Laser tachometers work well in areas of high ambient light because red laser light is easier to see than the white light emitted by photo tachometers.

Photo Tachometers

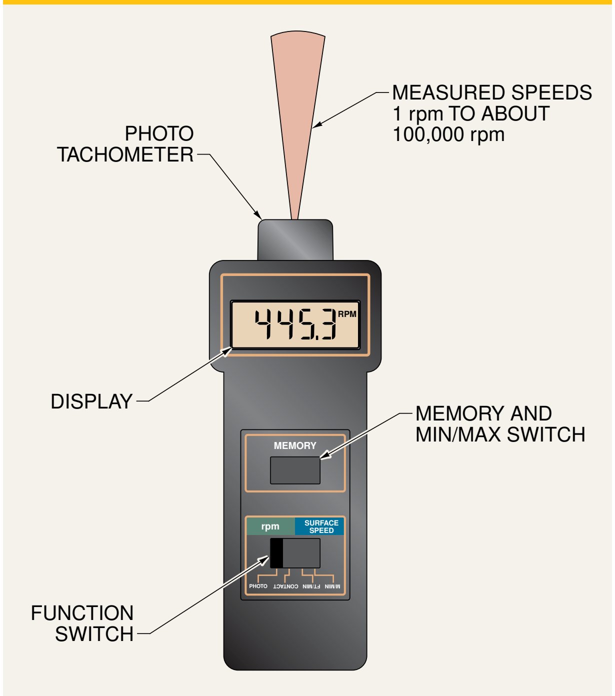


Figure 2-26. Photo tachometers use light beams to measure the speed of rotating objects.

Laser Tachometers

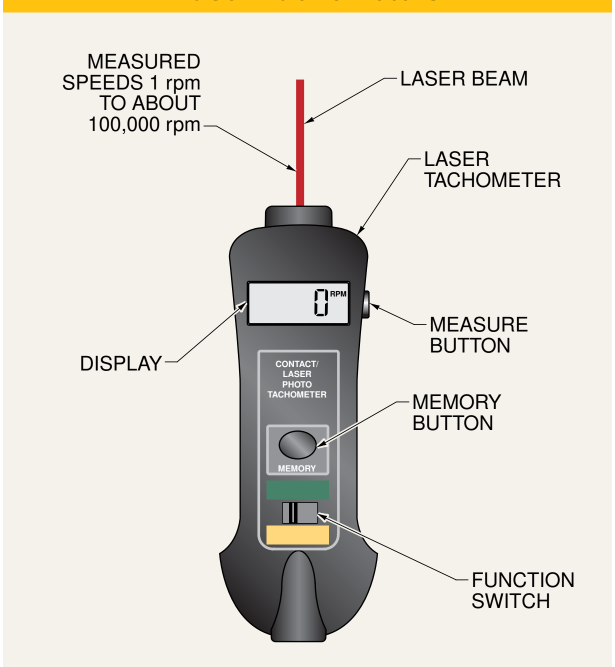


Figure 2-27. Laser tachometers can be used to measure the rotational speed of objects in hard-to-reach areas.

Laser tachometers can also be used to make speed measurements in hard-to-reach or dangerous areas. Because a laser light is a concentrated beam, laser tachometers are better than photo tachometers when making measurements in confined areas. Similar to photo tachometers, laser tachometers measure speeds from 1 rpm to about 100,000 rpm.

Stroboscopes. A *stroboscope* is a test tool that can capture a motionless image of a moving object for ease of inspection by use of a flashing light, or strobe light. **See Figure 2-28.** Stroboscopes operate by using an electronic pulse generator to control microsecond flashes of light to illuminate a moving object. To capture a motionless image, the frequency of the stroboscope flash has to match the object's frequency of motion. When the frequencies match, the flash creates an image of the object that appears still, or frozen in place, which allows for inspection of the component during operation. Stroboscopes can help technicians inspect slippage between shafts, conditions of belts and gears, and the alignment of couplings at all operating speeds. Stroboscopes, like strobe tachometers, can also measure rotational speed in revolutions per minute.

Stroboscopes

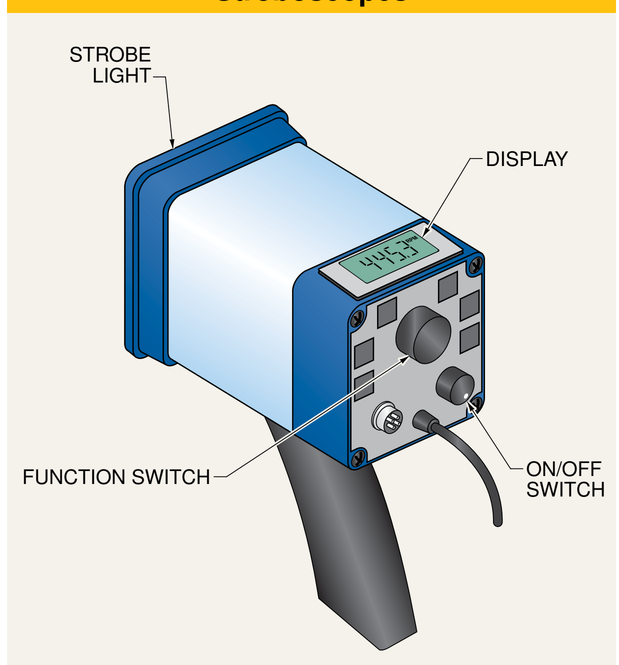


Figure 2-28. Stroboscopes capture motionless images of moving objects for ease of inspection by use of a flashing light, or strobe light.

CAUTION: Improper use of a stroboscope can cause serious harm due to the high frequency and brightness of the flashing light. The flashing light of a stroboscope can cause seizures or blackouts in personnel who are photosensitive or have an epileptic condition. Care should be taken so the strobe light does not enter the eye.

Stethoscopes. A *stethoscope* is a test tool used for detecting and locating abnormal noises within machines or equipment. Defective components, such as worn conveyor parts, degraded bearings, chipped gear teeth, and fluid leaks, often create abnormal noises. Stethoscopes can help locate defective components such as these by detecting the abnormal noises they generate. Abnormal noises made by moving components are significantly amplified with the use of a stethoscope. Environmental noise is reduced by using an insulated headset. **See Figure 2-29.**

Stethoscopes

Figure 2-29. Stethoscopes are used for detecting and locating abnormal noises within machines and components.

Industrial facilities generate various sounds that are not easily distinguishable or familiar. These sounds can even be problematic. By using an industrial stethoscope, unfamiliar sounds can be traced and located by an industrial technician. Once a sound is located, the technician can then start to further test and troubleshoot the component or machine.

Temperature Test Tools

Temperature test tools are used to measure the intensity of heat in certain types of equipment. Temperature measurements can be taken using contact or noncontact test tools. A *contact temperature probe* is a test tool that measures temperature at a single point through direct contact with the area being measured. Contact temperature probes use conduction to monitor temperature changes. A *noncontact temperature probe* is a test tool that measures temperature using convection or radiation.

There are many types of temperature test tools. The most common are thermocouples, change-of-state sensors, and infrared thermometers.

Thermocouples. A *thermocouple* is a device that produces electricity by heating two different metals that are joined together. Thermocouples are contact temperature probes. **See Figure 2-30.** Thermocouples have a wide temperature range from 328°F to over lll2°F.

Thermocouples are considered thermoelectric voltage devices and operate by producing voltage from the connection of two dissimilar metals (iron and constantan) as they are heated by the component being tested. The reaction at the junction of the two dissimilar metals produces a potential difference of a few millivolts (mV), normally about 1 mV to 50 mV. The amount of voltage produced by a thermocouple depends on the type of thermocouple used and its temperature. As the temperature rises, the output voltage of the thermocouple increases. The voltage produced by the thermocouple provides a temperature measurement when it is connected to a temperature meter or when voltage is converted into a temperature measurement.

Change-of-State Sensors. Change-of-state sensors, or phase-change temperature sensors, indicate the condition of equipment affected by a change in temperature. Change-of-state sensors are nonelectric devices available as labels, pellets, crayons, or liquid crystals. The most common are temperature-sensitive labels. **See Figure 2-31.**

Temperature-sensitive labels are labels that can be applied to certain devices to indicate temperature change. Temperature-sensitive labels are constructed of a temperature-sensitive material sealed behind a transparent heat-resistant material and in front of an adhesive backing. As the label is heated, the sensitive material dissolves and is absorbed by the adhesive backing, causing a color change. As a result, when a certain temperature is reached, the appearance of the label changes.

Thermocouples

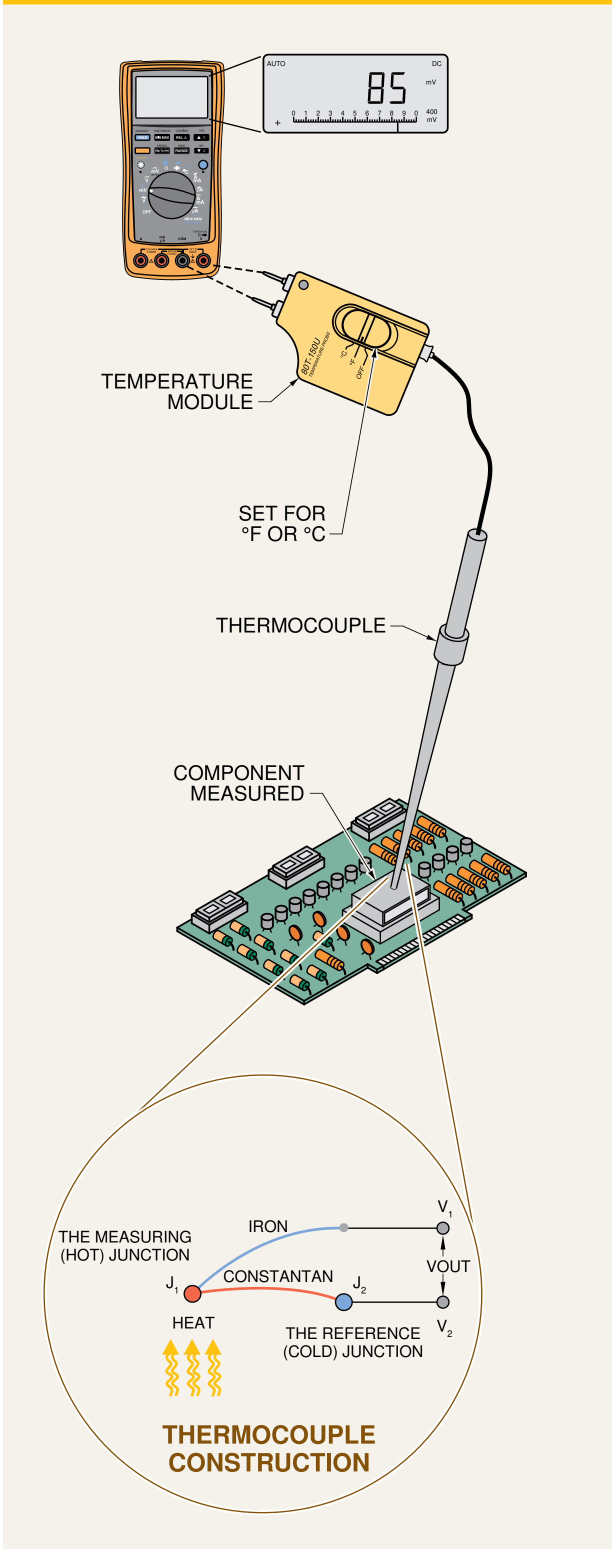


Figure 2-30. Thermocouples are used to measure temperatures at certain points of contact.

Temperature-Sensitive Labels

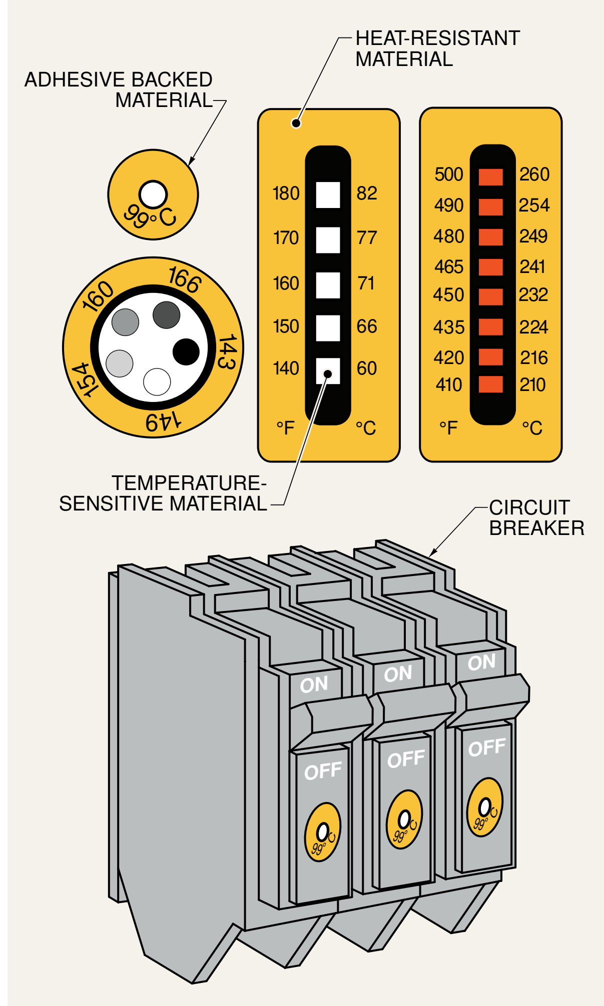


Figure 2-31. Change-of-state sensors are nonelectric sensors that are available as temperature-sensitive labels.

Normally, these labels contain white or yellowish dots that change to black when temperatures are exceeded. Once the color has changed, it remains for the remainder of the label's use. Temperature-sensitive labels can be applied to components such as circuit breakers or temperature-sensitive equipment that is monitored often.

Infrared Thermometers. All materials or components emit infrared radiation in proportion to their surface temperatures. The higher an object's temperature, the greater the amount of infrared radiation emitted. An *infrared thermometer* is a handheld device that detects infrared emissions to measure temperature. Infrared (IR) thermometers are commonly referred to as noncontact temperature probes. **See Figure 2-32.**

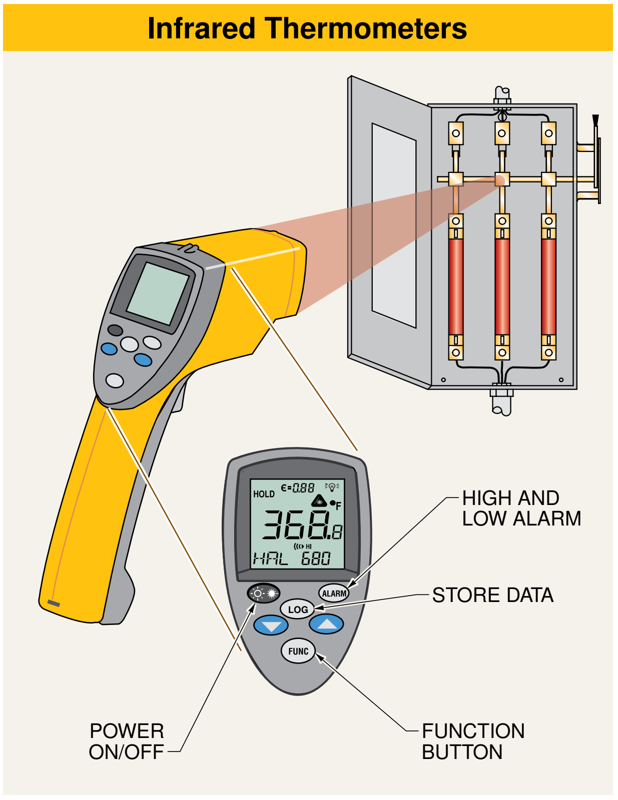


Figure 2-32. An infrared thermometer is used as an inspection tool to check for the presence of a component malfunction.

Infrared thermometers are used as inspection tools to check for the presence of component malfunctions or to establish a baseline temperature for monitored components. Baseline temperature readings of circuit components can be scheduled and recorded. Any change in a baseline temperature can warrant further investigation. Infrared thermometers are commonly used to take measurements of electrical distribution systems, motors, bearings, switching circuits, and any other equipment where excessive heat can cause detrimental effects during operation.

With recent advancements in technology, infrared thermometers can provide advantages that other leading test tools cannot. For example, IR thermometers can measure temperatures far below freezing to well over 2000°F. IR thermometers also have a fast response time, allowing for correct temperature measurements in fractions of a second. The temperature of equipment that is too difficult to reach or access is easily measured with a clear line of sight, clean optics, and no dust or smoke surrounding the equipment. And since they are noncontact temperature probes, IR thermometers are less likely to have adverse effects on equipment. The equipment is less likely to be damaged; there is less risk of contamination; and the temperature of the equipment is less likely to be changed by the thermometer.

TOOL SAFETY

Industrial and mechanical technicians must use hand tools, power tools, and test tools to successfully perform most tasks. To avoid personal injury and damage to the tools or equipment, proper safety precautions must be followed. A precaution that applies to hand, power, and test tools is the use of personal protective equipment. *Personal protective equipment (PPE)* is clothing and/or equipment worn by a technician to reduce the possibility of injury in the work area. The most common PPE used in industrial environments includes protective clothing, items worn for head protection, eye protection, hand protection, and foot protection. Additional PPE can include items worn for knee protection (knee pads), ear protection (ear plugs), and face protection (face shields). In addition to the use of PPE, separate precautions must be taken for hand tool, power tool, and test tool safety.

Hand Tool Safety

Hand tools are designed for specific purposes. Attempting to use a hand tool for a purpose other than what it is designed for or using it improperly can result in problems, such as incomplete projects, damaged or destroyed tools, damaged components, or injuries to workers.

According to the Bereau of Labor Statistics, the misuse of hand tools accounts for over 10% of all emergency room visits each year, many of which can develop into severe disabilities. For example, using a screwdriver on an unstable workpiece can result in tool slippage and possible injury. **See Figure 2-33.** Guidelines for safe use of hand tools include the following:

- Wear proper PPE.
- Dress for safety. When working with hand tools, wear long sleeves, work gloves, and heavy jeans.
- Pull tools rather than push them for greater control and balance.
- Never use a "cheater bar" or other device to increase leverage.
- Release stuck saws by pulling the saw toward the body.
- Fit screwdrivers snugly into the slot of a screw without extending over the edge.
- Work on a solid surface, such as a workbench.