Chapter 1

Shop Safety and Practices

Objectives

After studying this chapter, you will be able to:

- ✓ List the types of PPE used for working on heavy equipment.
- ✓ Explain steps (actions) for being prepared for emergencies.
- ✓ Describe the different types of hazards associated with working with fluids and pneumatics.
- ✓ Demonstrate safe methods for working on heavy equipment systems.
- ✓ Explain the purpose of a job hazard analysis.
- ✓ Explain the different classifications of workplace accidents.
- ✓ List multiple safety factors related to heavy equipment.
- ✓ List risks associated with operating heavy equipment.
- ✓ Lists the risks associated with welding.
- ✓ List the risks associated working with oxygen and acetylene gases.

Working around and with heavy equipment exposes personnel to the potential for injury on a daily basis. It is the employer's responsibility to provide a workplace that is free from hazards that could cause physical harm and to ensure employees comply with industry safety standards. These same safety standards also require employees to comply with all safety standards, rules, and regulations. This chapter reviews many basic safe practices and the personal protective equipment, emergency preparedness, basic first aid, and machine safety that are essential to heavy equipment technicians. See **Figure 1-1**.

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Figure 1-1. The undercarriages were removed from this Challenger rubber track tractor. The undercarriages weigh several thousand pounds. The 40,000-pound tractor also had to be lifted. Excellent planning must take place to ensure that the task can be completed safely.

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Figure 1-2. Eye and face protection includes safety glasses and face shields, many of which are designed for specific tasks. A—Safety glasses. B—Hard hat, earmuffs, and face shield.

Personal Protective Equipment (PPE)

Depending on the country in which you are working, you must adhere to the government's regulating authority for safe workplaces. The ***Occupational Safety and Health Administration (OSHA)*** is the United States federal agency that is responsible for ensuring that employees have a safe work environment. OSHA's regulations carry the force of law, and companies can be fined for failing to follow them. Technicians working at mining sites often must follow a stricter set of rules. The ***Mine Safety and Health Administration (MSHA)*** is the United States federal agency responsible for ensuring mine site safety.

OSHA regulations require employers to provide workers with ***personal protective equipment (PPE)***, consisting of equipment and clothing that is designed to protect the employees from potential injuries or illnesses. Common PPE includes eye protection, gloves, hard hats, boots, and hearing protection. Construction sites may require safety vests. The employer is also responsible for training the workers for proper use of PPE.

Eye Protection

Eye protection is one of the most important pieces of PPE to be worn by technicians. Safety glasses should be equipped with side shields to prevent eye injury from flying debris and fluid being sprayed from multiple angles. Regular sunglasses and prescription eyeglasses are not approved eye PPE because they do not have impact-resistant lenses or side shields. Personnel with prescription eyeglasses may acquire prescription safety glasses or wear approved PPE, such as safety goggles or a face shield, over the traditional eyeglasses. See **Figure 1-2**.

Clothing

PPE includes task-appropriate clothing. Many companies require their technicians to wear long pants, safety vests, and prohibit long hair and any loose-fitting clothing, as these could become caught in operating components. Some technicians wear coveralls. Technicians may choose to wear nitrile gloves to avoid prolonged exposure to oils and chemicals. However, gloves do not protect personnel from fluid injection injuries, which will be discussed later in this chapter.

Warning

In order to fully concentrate on the job, technicians should not listen to music on headphones.

Hearing Protection

Diesel-powered, off-highway equipment can produce harmful noise, which can cause hearing loss with prolonged exposure. Noise generated by running machinery is one of the negative attributes of working on heavy equipment. Some systems, such as hydrostatic transmissions, generate considerably more noise than electric drive or manual transmissions when the machine is driving under a heavy load.

Hearing protection is required by OSHA when the workplace noise level reaches certain levels. The maximum permissible noise level without hearing protection ranges from 85 decibels to 140 decibels, depending on the frequency of the noise. Many employers adopt

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more stringent safety guidelines, requiring employees to wear hearing protection at lower noise levels. Hearing protection can consist of earplugs or earmuffs. See **Figure 1-3**.

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Figure 1-3. Hearing protection devices have noise reduction ratings (NRR) that indicate the amount of protection they provide from various decibel levels. A—Earplugs. B—Earmuffs.

Hard Hats

Technicians are frequently tasked with traveling to construction job sites and mine sites. Both OSHA and MSHA require hard hats to be worn on the job site to provide protection from falling objects. Technicians have been denied access or evicted from job sites for failing to follow OSHA and MSHA hard hat regulations.

There are two types of hard hats, Type I and Type II. Type I hard hats reduce the force from only the top of the head and Type II hard hats reduce the force of impact from the top as well as the side of the head. Companies may also use a hard hat color code to easily identify personnel on the worksite. See **Figure 1-4**.

Foot Protection

Most companies require their technicians to wear boots on the job for foot protection. OSHA regulations specify that employee's feet be protected from falling objects, rolling objects, and sole piercings. MSHA's protective footwear regulation does not specifically require steel-toe boots, but most mine sites require their employees to wear steel-toe boots.

Emergency Preparedness

Due to the sheer size and power of the equipment, heavy equipment technicians work in an environment that inherently has risks. Technicians must be prepared for emergencies. Before stepping into the shop, technicians should know where safety equipment is located and how to use it. Technicians who disregard this rule are placing themselves and those around them at risk.

Hard Hat Industrial Classes	
Class G hard hats	Provide impact and penetration resistance along with limited voltage protection (up to 2200 volts).
Class E hard hats	Provide the highest level of protection against electrical hazards, with high-voltage shock and burn protection (up to 20,000 volts). They also provide protection from impact and penetration hazards by flying/falling objects.
Class C hard hats	Provide lightweight comfort and impact protection but offer no protection from electrical hazards.

Optional Color Code				
Yellow	**Blue**	**Gray**	**White**	**Green**
General laborers Earthmoving equipment operators	Electrical workers Technical advisers	Site visitors General laborers	Supervisors Visitors Engineers Architects	New or probationary employees Inspectors

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Figure 1-4. Hard hat classes are based on the level of protection they provide from impact and electrical hazards. Although color coding is not standardized nor required, many companies choose to use specific colors for people who are working on or visiting a site.

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Case Study
Job Experience Provides Emergency Preparedness

A good example of emergency preparedness was reported by an instructor after his students experienced a fire while working in the shop. The instructor learned about the incident after a prepared student had quickly extinguished the fire. The student had been in the US Navy and worked aboard a submarine. Starting in boot camp, sailors learn that they have two jobs. The first job is a firefighter. The other job, such as electronics technician, welder, or avionics technician, truly is secondary to firefighting. This sailor had been properly educated to know where the fire extinguishing equipment was located and how to use it. A person in the middle of the ocean does not have the luxury of calling the fire department. Heavy equipment technicians can also be tasked with working in remote locations and must be prepared for the worst-case scenario with little or no help from others.

Fire Suppression

Fire extinguishers are rated based on the class(es) of fire they put out. Class A fires are fueled by combustible solids, such as wood, paper, or cardboard. Class B fires are fueled by combustible gases, oils, and greases. Class C fires are electrical fires. Class D fires are caused by the ignition of combustible metals. Some fire extinguishers are rated to extinguish more than one type of fire. For example, ABC fire extinguishers can extinguish Class A, Class B, and Class C fires. The ABC fire extinguisher is the type most commonly used by heavy equipment technicians. See **Figure 1-5**.

Warning

Using the wrong class of fire extinguisher on a fire can make the situation worse. For example, if an extinguisher rated for only Class A fires is used on a Class B fire, it could spread the fire. The same extinguisher used on a Class C fire could result in electric shock.

Each fire extinguisher must be inspected to ensure that it is fully charged. If the extinguisher is charged and ready for use, the extinguisher's gauge needle will point to the green section of the gauge. Fire extinguishers must also have an inspection tag indicating the most recent inspection date. The tag lists the date and the initials of the inspector. See **Figure 1-6A**.

Warning

Fire extinguishers expire and will not operate as designed after their expiration date.

While working in a shop, technicians need to know the location of fire extinguishers, fire exits, and fire alarm switches, **Figure 1-6B**. Responsible employers train their employees in safe practices and may test personnel on their emergency preparedness.

Onboard Systems

A machine may be equipped with a rubber grommet or port that serves as a fire extinguisher receptacle. See **Figure 1-7**. In the event of a fire, the fire extinguisher hose is pressed through the center of the port, and the extinguisher is operated. The port allows

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Fire Classifications

Class	Description	Requires	New Symbol	Old Symbol
A	Ordinary Combustibles (Materials such as wood, paper, and textiles)	Cooling/quenching		A
B	Flammable Liquids (Liquids such as grease, gasoline, oils, and paints)	Blanketing or smothering		B
C	Electrical Equipment (Wiring, computers, switches and any other energized electrical equipment)	A nonconducting agent		C
D	Combustible Metals (Flammable metals such as magnesium and lithium)	Blanketing or smothering		D

Fire Extinguishers

Type	Description	Typically Approved for Use On	Not for Use On
Pressurized Water	Water under pressure	A	B C D
Carbon Dioxide (CO_2)	Carbon dioxide (CO_2) gas under pressure	B C	A D
Foam	Aqueous film-forming foam (AFFF) or film-forming fluoroprotein (FFFP)	A B	C D
Dry Chemical, Multipurpose Type	Typically contains ammonium phosphate	A B C	D
Dry Chemical, BC Type	May contain sodium bicarbonate or potassium bicarbonate	B C	A D
Dry Powder	May contain sodium chloride, sodium carbonate, copper, or graphite	D	A B C

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Figure 1-5. Fire and fire extinguisher classification charts.

A

B *Goodheart-Willcox Publisher*

Figure 1-6. Fire extinguishers must be inspected regularly. A—The gauge indicates that this extinguisher is fully charged and ready for use. The tag lists the date the extinguisher was inspected as well as the inspector's initials. B—Fire extinguishers and fire alarms are often located near an entryway. The fire extinguisher shown here is rated for Class A, B, and C fires.

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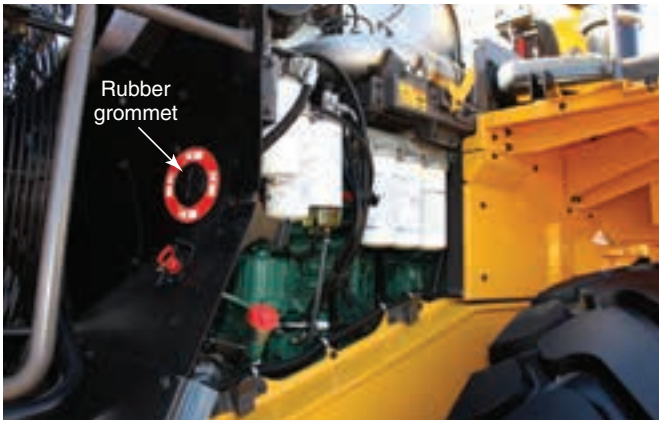

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Figure 1-7. The rubber grommet on this Volvo wheel loader is a receptacle through which a fire extinguisher's nozzle can be inserted before the extinguisher is operated. This design allows the engine compartment to remain closed to limit the intake of outside air. In this photo the engine compartment door has been opened, exposing the engine's filters.

A

B

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Figure 1-8. A—This D10T Caterpillar dozer has a factory-installed, onboard fire suppression system.
B—This underground mining loader has a button that is used to manually deploy an onboard fire suppression system.

the agent to be deployed with the engine compartment closed, which prevents a rush of outside air (containing oxygen) that could cause the fire to flare. Always review and follow the manufacturer's literature for using the extinguishing port.

The most expensive off-highway machines and underground mining machines commonly use onboard fire-suppression systems. Extra care must be taken when servicing machines with onboard systems. These systems use inert gases, such as nitrogen, and chemical agents to smother a fire. See **Figure 1-8A**.

Onboard systems may be automatically triggered by a heat-sensitive wire or sensor or manually actuated by an operator, **Figure 1-8B**. Inadvertently deploying a system can be costly as well as dangerous for the technician. The deployment of the extinguishing agent could eliminate the technician's oxygen supply if he or she is working in a confined area, such as an engine compartment.

Combustibles in the Shop

Technicians frequently use tools that discharge high amounts of heat, such as welders, plasma cutters, and torches. Excessive heat must be kept away from hydraulic cylinders, hoses, steel lines, accumulators, and other hydraulic components. In addition to components on machines, heat must be kept away from fluids and containers that are not part of the machine, such as chemicals, fuels, lubricants, and aerosol cans. In addition, all combustible fluids and chemicals should be properly stored in a flammable safety storage cabinet when not in use.

Hydraulic Oil

Although hydraulic oil is not highly volatile, it can ignite if it is heated to its flash point. Typical hydraulic oil flash points range from 338°F to 590°F (170°C to 310°C). Unfortunately, technicians have lost their lives due to machine fires. A diesel engine's exhaust, especially the turbocharger, is a source of heat that can cause oil from a ruptured hose to quickly ignite.

Safety Data Sheet (SDS)

Technicians work with a wide variety of chemicals and products, such as hydraulic oils, greases, engine oils, and cleaners. ***Safety data sheets (SDS)*** are printed materials that provide end users important information regarding products. An SDS includes information on the effects of skin or eye exposure, ingestion, and inhalation as well as the actions that should be taken for each type of exposure. Employees must know the location of the data sheets and be able to quickly access that information in case of an emergency. The categories of information provided in an SDS are listed in **Figure 1-9**.

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Product and company identification	Physical and chemical properties
Emergency phone number	Stability and reactivity
Composition information on ingredients	Toxicological information
Hazards identification	Ecological information
First-aid measures	Disposal considerations
Firefighting measures	Transport information
Accidental release measures	Regulatory information
Handling and storage	Other information specific to the chemical/material
Exposure controls and personal protection	

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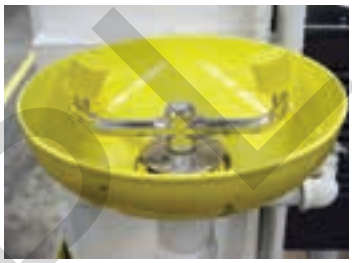
Figure 1-9. A—An unobstructed view of the location of safety data sheets in a shop. It is helpful to review the information included in the SDS before working with hazardous materials. B—All safety data sheets include critical information for each of these categories.

First-Aid Stations

Knowing the locations of a first-aid kit, an eyewash station, and a safety shower will also assist a technician in being prepared for an emergency. Technicians working in a new environment should familiarize themselves with the workplace and note the location of all first-aid and safety equipment. See **Figure 1-10.** It is also recommended that a basic first-aid kit be kept on heavy equipment machines.



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C *jirapong/Shutterstock.com*

Figure 1-10. Know the location of eyewash stations and safety showers. A—This eyewash station is tied into the building's plumbing. B—This station is self-contained and can be installed where there is no plumbing. C—Many shops are equipped with a safety shower.

First Aid

Unfortunately, accidents do occur. Many heavy equipment personnel work long distances from metropolitan areas. Technicians can save lives by receiving first-aid and cardiopulmonary resuscitation (CPR) training. ***First aid*** involves treating an injured person at the job site, where the injury occurred, to help sustain their life until medical personnel can arrive. ***Cardiopulmonary resuscitation (CPR)*** is the use of manual chest compressions and breathing into the patient's mouth when an individual's heart stops beating or he or she quits breathing. Many shops and job sites have an ***automated external defibrillator (AED)*** that can be used in the event a person's heart stops beating. Today's defibrillators provide audible instruction on how to install and properly use the AED. However, personnel should be prepared by becoming CPR certified, which includes learning the proper use of AEDs.

Fluid Hazards

Heavy equipment machines use pressurized hydraulic and fuel systems that pose serious risks. Technicians are at risk of injuries, such as burns and fluid injection, any time they work with pressurized fluids. ***Fluid injection*** occurs when pressurized fluid penetrates the skin, most commonly caused by a burst hose. Untrained and careless technicians are at risk of receiving serious burns, having a limb amputated or worse yet, losing their lives.

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Fluid-Injection Injuries

Hydraulic system pressures can exceed 7000 psi (482 bar) and some fuel system pressures can exceed 35,000 psi (2413 bar). It has been medically noted that it only takes a pressure of 7 atmospheres (or 100 psi) for fluid to puncture the skin. It has also been reported that a high-pressure oil leak can cause fluid to spray at a velocity of 300 meters per second (671 mph).

Although fluid-injection injuries are rare, the injection injury itself is a very small pinhole to the skin, so small that it is easily overlooked. Some patients have reported that the injury did not initially cause intense pain, leading many patients to delay seeking medical attention. If medical attention is delayed, swelling and pain will increase.

Patients need to quickly seek the care of a surgeon. The two immediate treatments consist of surgical decompression and debridement (the removal of damaged tissue). The severity of the injury is affected by multiple factors: the quantity of fluid injected, the pressure and velocity of the injected fluid, the toxicity of the fluid, and the amount of time before medical attention is obtained.

Patients with injection injuries can mistake the cause of their injury to be something as small as a nick to the hand. This oversight allows the fluid to cause further damage to the skin, which can lead to gangrene if not properly treated. Forty percent of all fluid injection injuries result in some form of amputation, and amputation is required nearly 100% of the time if the patient does not receive prompt medical care. Injuries resulting from system pressures of 7000 psi (482 bar) and higher result in amputation nearly 100% of the time. Even if the limb can be saved, patients typically lose some or all function of the limb.

For these reasons technicians should never use their hands for trying to locate hard-to-find leaks. Some manufacturers recommend using cardboard for locating a pinhole leak. The most common cause for injection injuries is a ruptured hose. Technicians should avoid handling pressurized fluid conductors because they are unable to predict when a hose might burst.

Pinhole leaks emit a fine mist making it difficult to identify which hose is leaking. Placing cardboard between two hoses can help identify the leaking hose and save time and money by indicating the correct hose to replace.

Warning

Numerous service manuals specify unsafe test procedures, such as checking flow by holding a hose in a 5-gallon bucket, putting a technician at risk for fluid injection and burn injuries. As a result, it is possible for veteran supervisors to unknowingly recommend unsafe practices. Always refer to the most current and safest test procedures. The following is a list of safe practices that should always be followed when working with hydraulic systems. The list is not all-inclusive and your employer or instructor may have additional precautions that you must follow.

- *Never* connect or disconnect plumbing to a system under pressure.
- Do *not* handle hoses, gauges or components that are under pressure. It takes only 100 psi to cause a fluid injection injury and common hydraulic operating temperatures will cause severe burns if you come in contact with the fluid.
- Shut off and depressurize systems *before* working on them.
- Use flowmeters to measure flow.
- Use pressure gauges to measure pressure.
- *Never* apply heat to a fluid line or fluid component, including accumulators.
- *Never* use a makeshift device to load a hydraulic actuator.

Technicians, operators, and customers frequently take shortcuts that endanger themselves and others. The old saying is that hindsight is 20/20. If a person only knew when something was going to cause harm, they would have taken preventive measures. Many personnel work with machinery without a healthy respect of the potential risks and with little expectation that something can go wrong. As a result, they can become complacent, rush through procedures, and take shortcuts, putting themselves and others at serious risk.

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Note

Many manufacturers put fluorescent dye in the oil and use a black light to locate hard-to-find leaks.

Because of the rarity of fluid injections, it is necessary for technicians to be prepared in the event of an injury. The International Fluid Power Society (IFPS) provides its members a reminder card that can be carried on their person to remind them of the five things to share with the emergency room personnel:

- Type of fluid.
- Quantity of fluid injected.
- The fluid pressure.
- How far the fluid injury has spread.
- The amount of time since the injury.

Technicians should also have fast and easy access to the fluid's SDS so that the data sheet can be provided to the surgeon as well.

Burns

During a hot summer day, hydraulic operating temperatures can exceed 200°F (93°C). Malfunctioning hydraulic systems can overheat, causing the oil temperatures to exceed 300°F (149°C). In the event of a hose failure, a technician can receive serious burns. Burns are categorized as first-degree, second-degree, third-degree, and fourth-degree depending on their severity.

- First-degree burns are the least severe and only affect the outer layer of skin. These burns are often treated with cool running water. These burns appear red and may cause swelling.
- A second-degree burn affects the two outer layers of the skin and must be treated by medical personnel to prevent infection and reduce the victim's pain. The burn will look red, splotchy, and blistered and may cause disfigurement.
- Third-degree burns penetrate through the first two layers of the skin and reach the inner hypodermis layer and require *immediate* medical attention. The victim's skin is usually charred black or dry and white. Do *not* apply an ointment or ice.
- Fourth-degree burns are even more severe, resulting in damage to deeper tissue, nerves, muscle, and bones. They require expert medical treatment. Patients lose feeling in the burn area due to the nerve damage.

Warning

In the event of a fire, remember to "stop, drop, and roll." If helping someone on fire, use a blanket to smother the fire and call 911.

Pneumatic Hazards

Heavy equipment technicians work with compressed air systems, known as ***pneumatic systems***. See **Figure 1-11**. Some machines are equipped with air compressors that provide air pressure for suspension or brake systems. Shops are also equipped with air compressors that supply air pressure for pneumatic tools. Although compressed air systems are essential tools and may not appear hazardous, careless use of compressed air poses dangers to personnel including eye and lung injuries.

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Figure 1-11. Repair shops use large air compressors for powering tools.

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- Eye injuries may be caused by particles and other flying debris that has been stirred up by compressed air when it is used to clean an area. In addition, as little as 12 psi can force an eye out of its socket.
- Lung injuries may occur when fine dust particles and other debris are stirred up and inhaled. Direct inhalation of compressed air can cause the lungs, intestines, or stomach to burst.

Case Study
Treating Fluid-Injection Injuries

A technician was working on the header float system of a self-propelled windrower. The system had a relief pressure of 2100 psi (145 bar), but a pressure sensor was reading 3800 psi (262 bar). To determine if the pressure sensor was malfunctioning, a diagnostic test port was going to be installed in the circuit to directly measure the circuit's pressure.

The technician shut off the machine and followed the service manual's procedure for depleting the pressure in the circuit. Note that the circuit did have an accumulator. The circuit was bled by manually pressing a bypass valve multiple times.

A wrench was used to crack the fitting on a 1/4" hydraulic hose. Approximately a half gallon of oil leaked from the cracked hydraulic line. After oil quit draining from the hose, the technician began to remove the hose by hand. Keep in mind that the oil had quit draining and the attached hose end was quite loose, with no tension on the fitting.

The technician used his hand to back off the remaining threads on the loose fitting, and this is when things went awry. A tremendous amount of fluid under high pressure blew out of the hose, injecting fluid into the technician's fingers. One finger had approximately a half square inch of skin removed by the force of the hydraulic fluid. An inch-long blister immediately formed on his middle finger and the technician was completely covered in oil.

He covered his bleeding fingers and traveled 40 minutes to the hospital. He chose the hospital that was 40 minutes away because it was a little larger facility. He assumed the doctors at the larger facility would have more experience with this type of injury.

When he arrived at the hospital, oil was still oozing out of his fingers. The doctor soaked his hand and treated the wound as a common hand injury. The technician was unsettled by the lack of concern shown by the doctor. The technician attempted to give the doctor the number for the manufacturer's 24-hour medical hotline so she could consult with them regarding the injury. The emergency room doctor advised the technician that she had gone to medical school, and that the problem was just a common hand injury. After soaking and wrapping the fingers, the doctor sent the technician home, stating that he might feel some tingling, numbness, and soreness.

The technician still felt uneasy about the course of treatment he had received and called the medical hotline. The hotline attendant advised the technician regarding hydraulic fluid injuries, what symptoms might occur, and what information to provide the medical personnel, which included the oil's SDS.

Approximately two hours after he left the emergency room, his finger and the blister on it began to swell quite large, his fingers tingled, his arm went numb, and he suddenly felt as if he had the flu, causing him to vomit violently.

The technician called the manufacturer's medical hotline again, and was advised to go to a different hospital. The hotline attendant spoke to the emergency room's physician's assistant who then called the state's university hospital and consulted with a hand surgeon.

The medical staff was unable to find a puncture wound on the fingers. They took an X-ray of the hand to investigate the extent of the damage. They lanced the blister on the finger and drained four cubic centimeters of oil from the technician's finger. The hand immediately began to feel better. They brushed the wound to clean away the remaining hydraulic oil. Unfortunately, the medical staff was advised to not administer local anesthesia because it would interfere with the treatment.

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- Internal bodily injury, such as an ***embolism***, may occur if air bubbles penetrate the skin and enter the bloodstream. An embolism can block a blood vessel and cause a stroke or heart attack and result in death.

Cleaning with Compressed Air

Compressed air can be very useful for cleaning dust and other debris from hard-to-reach places or around intricate machinery. In the United States, OSHA requires that compressed air be less than 30 psi if it is being used for cleaning and that proper PPE be used for protection. In some Canadian locations, it is against the law to use compressed air for cleaning certain items, such as benches, machinery, and clothing. Tool manufacturers offer OSHA-approved air nozzles that limit the pressure to less than 30 psi.

Alternatives to Compressed Air

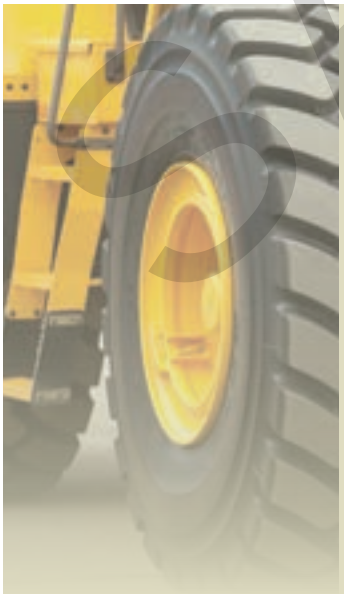
Some employers do not allow the use of compressed air for cleaning due to the hazards presented and instead use vacuum cleaners with proper filtration. Another alternative for cleaning up materials that do not pose an inhalation risk is to sweep.

Safe Practices

Accidents can be costly to both the employee and the company. An injured technician may require substantial recovery time, which can cause personal hardship and cost the company thousands of dollars in worker compensation. The machine availability may also be reduced while the technician is recovering. Responsible employers enforce a safety-first environment and properly train employees before allowing them to work on any machinery. To further encourage safe practices, many companies offer safety bonuses to employees or shops for working consecutive weeks or months without a reportable incident or injury.

Know the System

It is important to gain an understanding of a system before working on a machine. Although heavy equipment machines have many similarities, they also have many differences. A technician can reduce the chance of damage and injury by reviewing the manufacturer's manual and studying the system components before beginning a job.



Case Study
Working On-Site

A customer requests some assistance with a tractor. The tractor's transmission clutch was replaced, and after the new clutch was installed, the hydraulic three-point hitch began malfunctioning. The hydraulic hitch is now jerky, sluggish, and sometimes will not lift a bale of hay. The technician has no familiarity with the tractor. If the technician is limited to taking only one item to the tractor, what should the one-and-only item be?

Inexperienced technicians often recommend taking a service manual, a pressure gauge, a flowmeter, a bucket of oil, or even an experienced technician. However, it is surprising that inexperienced technicians very seldom mention the single most important item to bring, *safety glasses*! In this real case scenario, the hydraulic system spewed oil in the face of the technician. Fortunately, the one-and-only item that was brought to the tractor was the pair of safety glasses that technician was wearing. Technicians must work with the expectancy that the hydraulic system could fail and must be prepared for when that failure occurs.

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Note

Technicians working on-site must be aware of potential dangers specific to the site. For example, the silage (wet chopped crop that ferments) kept in farm silos is kept from spoiling by a lack of oxygen. Due to the fermentation process and enclosed area, toxic gases, such as nitrogen dioxide and carbon dioxide, may build up in the work area and create breathing hazards that require respiration equipment for protection.

Before Beginning a Job

Before a technician begins a job, he or she must ensure the worksite, whether it is on-site or in the shop, is safe and the machine that will be worked on has been disabled. One manufacturer recommends that the machine or implement be lowered to the ground, the engine shut off, and the ignition key removed. Most manufacturers recommend disconnecting the battery's negative cable before completing any substantial work on the machine. This practice ensures that someone will not crank the engine while a technician is in a dangerous position. This practice also prevents machine and equipment damage. For example, disabling the machine might prevent a pump failure by not allowing an engine to crank while the reservoir is empty. A technician may also install a safety tag in the cab that clearly states "Do not operate." The tag should include the name of the technician, the date, and time.

Lock-Out, Tag-Out (LOTO)

If a technician is diagnosing or repairing an electrically powered machine on-site, such as in a mine, he or she must follow a lock-out, tag-out procedure. The machine's power must be shut off and a lock and tag must be installed to prevent power from being restored to the machine. The tag may include the date and time as well as the technician's name. After the required service is completed, the lock and tag are removed. See **Figure 1-12**.

Safety Shields and Guards

The agricultural, construction, and mining industries have all spent tremendous amounts of energy to develop safe practices to ensure people are protected from rotating shafts, belts, gears, pumps, motors, and other moving or heated components. Manufacturers also install safety guards and panels on machinery to protect personnel from injury. Unfortunately, people are injured or killed each year while working carelessly around machines from which the safety guards have been removed. If the safety guards must be removed to access a component, the technician must exercise extreme caution and replace the safety guard before performing running tests. The evening television news and morning newspapers are an unfortunate place to be reminded about the consequences of not working safely around machines or disregarding safety shields and guards. Many technicians personally know someone who has been injured while working on a machine without safety guards or shields. Do not allow yourself to become a statistic by taking unnecessary shortcuts.

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Figure 1-12. Typical tag and lock used for lock-out procedures.

Note

Guards on European agricultural equipment require a tool for removal, such as a screwdriver to unlatch a cam lock.

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Power Take-Off (PTO)

One component that is especially important to have guarded is the agricultural ***power take-off (PTO)***. A PTO provides a mechanical power source to drive implements, such as a baler, mower, grinder, or posthole digger. PTO shafts rotate at high speeds with a high torque and can be very dangerous. PTOs are essential to agricultural work but are also one of the primary causes of injury and death in the agricultural industry. PTOs have factory-installed safety guards and shields to minimize the risk of entanglement in the shaft. Do *not* operate machinery connected to a PTO if the safety guards are not in place. See **Figure 1-13**.

The PTO's shaft contains a lock on the coupler. It must also be fully functional to prevent the shaft from coming uncoupled during operation. Chapter 4, *Agricultural Equipment Identification*, provides more information on agricultural PTOs.

Exhaust Ventilation

An engine's exhaust fumes contain carbon monoxide, which can cause sickness or death. Whenever a machine is running in the shop, the shop's exhaust ventilation system must be turned on and connected to the machine's exhaust pipe. Exhaust ventilation systems vary and each technician working in a shop should be trained to properly connect and use the shop's system. See **Figure 1-14**. Some shops have additional exhaust fans to aid in exhausting fumes and heat generated by running engines. Regular inspection and maintenance should be performed on the system to ensure it is working properly.

Overhead Shop Doors

Overhead shop doors with high clearance are used to allow machines to enter and exit the shop. These doors should be *fully opened* or *fully closed* at all times to prevent a driver from hitting and damaging the door and machine and potentially injuring the driver or nearby personnel.

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Figure 1-13. The PTO should have a telescoping cover that keeps objects from getting tangled in the PTO shaft. The cover is normally chained so that it remains stationary while the driveshaft spins.

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Figure 1-14. This shop uses a retractable overhead duct system that is attached to a high-volume fan that draws the exhaust fumes out of the shop.

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Figure 1-15. Fall protection allows technicians to work at elevated heights and prevents injuries caused by falls. A—A technician is strapped into a full-body harness. B—A shock-absorbing lanyard is used to secure the harness to an anchor point on the machine.

Fall Protection

One common regulation that technicians must follow is the need for fall protection. ***Fall protection*** is achieved with a full-body harness and a shock-absorbing lanyard that is securely attached to a secure anchor point. In the event that a technician slips or falls, the harness prevents the technician from falling to the ground. See **Figure 1-15**. Fall protection is required when working at elevated heights. The minimum height is dependent on the industry but most require protection for employees working at any height above 4′, 5′, or 6′.

Note

The full-body harness and shock-absorbing lanyard is sometimes called a *fall-arrest system*. Dealerships and repair shops are often designed with fall protection in mind and provide secure places for workers to attach their fall protection harness.

Job Hazard Analysis (JHA)

Some employers require employees to conduct a ***job hazard analysis (JHA)*** before performing any task. The JHA helps determine potential risks related to the job, tools, and surrounding environment in order to reduce these risks. The JHA form provides space for the technician to write the tasks that will be performed and the potential hazards that will be encountered during the job. Information that may be recorded on a JHA includes the following:

- The name of the employee conducting the JHA.
- A description of the task to be completed.
- The level of risk: low, moderate, high.
- A sequential plan for completing the job.
- The proper PPE required for the task.
- The types of risks on the job (falls, contact with electrical or gas utility lines, working alone, pinch points, and slip hazards).
- List of risks related to manual labor, such as lifting, repeated motion, vibration, and transporting components or tools.
- List of potential hazards and actions that will be taken to prevent the potential injuries.
- Rating of the chances of injury and the plan to lower the odds.
- A reviewer's name and signature.

Tracking Accidents

As a means of ensuring companies maintain safe workplaces, OSHA has strict guidelines for recording and reporting occupational injuries and illness that must be followed for complete compliance. OSHA requires companies to report ***recordable accidents*** or ***incidents*** when the accident results in any of the following:

- Fatality.
- Loss of consciousness.
- Illness or injury that requires extended care by a physician and/or hospitalization.

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- Absence from future workdays.
- The employee's work being limited.

In addition to complying with OSHA mandates, many employers keep more detailed records to record both recordable and nonrecordable accidents. An employer may define a ***nonrecordable accident*** as one in which the employee sees a physician but receives only minor care, such as a temporary bandage. The terms *loss-time accident* and *non-loss time accident* may be used to indicate whether the accident resulted in the employee's absence for a period of time. Employers can use these detailed records to help improve their safety program through careful examination of causes and employee preparedness.

Machine Safety

Most accidents that occur when working with heavy machinery can be attributed to personnel performing unsafe acts. These ***unsafe acts*** occur when workers willingly choose to take unnecessary risks. It takes training and a conscientious effort to maintain a safe machine work environment. With proper training and discipline, accidents can be greatly reduced or prevented, enabling personnel to remain safe and on the job. The following sections describe many of the safe practices heavy equipment technicians should know and use while on the job.

Wheel Chocks

Wheel chocks are wedge-shaped blocks that are inserted in the front and rear of a machine's tire when the machine is not in service, being unloaded, or being serviced. See **Figure 1-16A**. The wheel chocks prevent the vehicle or trailer from moving in the event that the brake mechanism fails. OSHA requires that the parking brake be set and the rear tires of any commercial motor vehicle (CMV) be chocked before being unloaded. MSHA requires machines to be chocked if they are parked on a surface that is not level. Many employers require the use of wheel chocks on *all* machines, including service trucks. Wheel chocks are typically stored on the machine for easy access. See **Figure 1-16B**.

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B NelliGal/Shutterstock.com

Figure 1-16. A—Wheel chocks are made of different types of material, such as plastic, wood, rubber, or steel. B—The front bumper of this haul truck has a place to hang the truck's wheel chocks.

Caution

Only use legitimate wheel chocks designed to prevent the machine from rolling. Rocks or any other makeshift devices are *not* approved wheel chocks.

Entering and Exiting Machines

Technicians frequently enter and exit machines during repair or maintenance procedures. Most machines require technicians to climb steps or a stepladder to enter the operator's cab. While climbing up or down the stairs/steps, personnel must always face toward the stairs and use three points of contact. The ***three points of contact*** can be two hands and one foot or two feet and one hand. See

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Figure 1-17. Using three points of contact helps minimize the risks that are associated with entering and exiting the machine, such as slick steps or having a boot becoming lodged in the crevice of a step. Falls from ladders or stairs can cause serious injury, and personnel should never climb facing away from the steps or using only two points of contact while clinging onto tools, supplies, files, or a book.

Implement Locks

A technician may use an implement lock to hold an implement in place while accessing a component that would otherwise be blocked. For example, a tractor's loader might need to be raised to gain access to a front engine component that is blocked when the loader is in the lowered position. An ***implement lock*** typically consists of a steel brace that is inserted over a hydraulic cylinder's rod. The steel brace, locked between the machine frame and the cylinder, prevents the hydraulic cylinder from moving and locks the implement in place. See **Figure 1-18**. Implement locks are also included on most cabs and on other implements, such as on the header or feeder lift cylinder on a combine. See **Figure 1-19**.

Warning

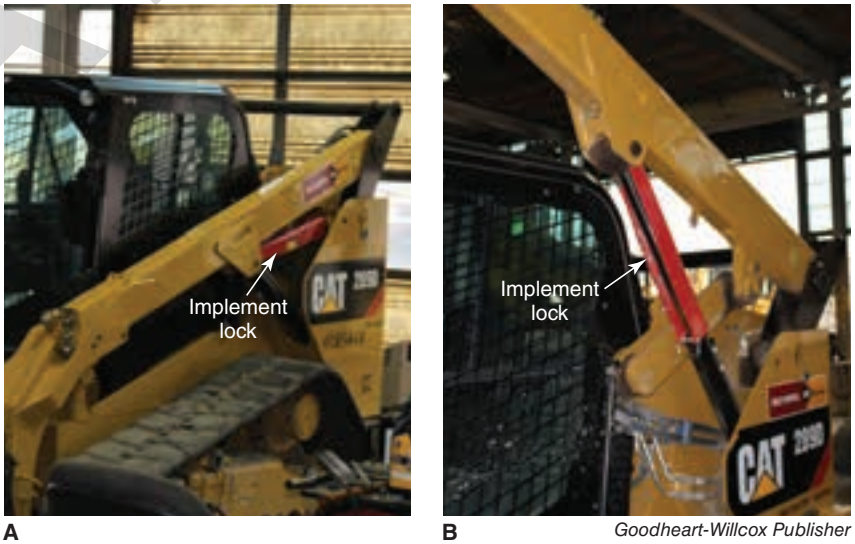
Never work below an unsupported component, implement, or machine. A technician who takes shortcuts and fails to properly secure a machine or component may be severely injured or even lose his or her life. Working below a suspended load that is being held only by fluid pressure is essentially betting your life on the strength of a hydraulic hose or a hydraulic-cylinder's seal. If the hose or seal ruptures, the implement will lower and potentially crush anyone below it.

Note

Many construction machines use an implement hydraulic lockout lever or switch. See **Figure 1-20.** When the hydraulic lockout has been actuated, it typically blocks pilot oil pressure from the directional control valves to prevent the valves from operating.

Scott A. Frangos/Shutterstock.com

Figure 1-17. This operator is using three points of contact, two feet and one hand.



A B Goodheart-Willcox Publisher

Figure 1-18. Loaders commonly have an implement lock. A—Notice the loader frame is in a lowered position and the red implement lock is in its stored position. B—The implement lock has been placed over the loader's lift cylinder rod and is preventing the loader from lowering.

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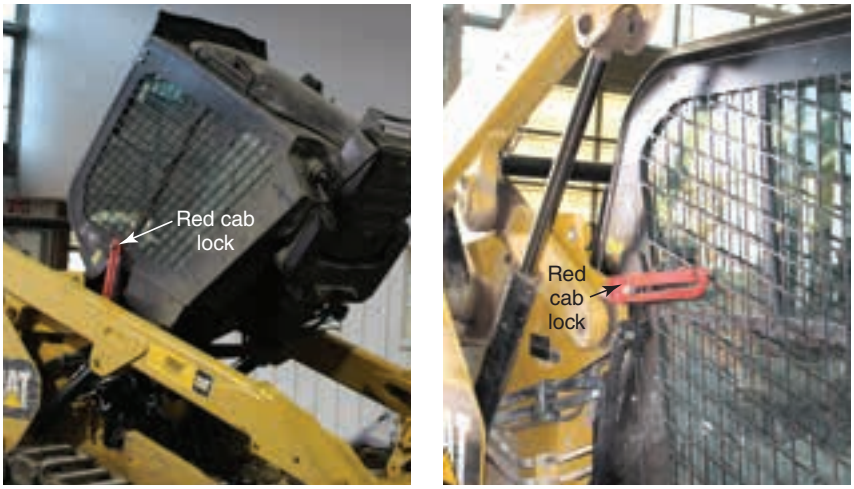

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Figure 1-19. The loader's cab can be raised to service the machine. A—The red cab lock is used to prevent the operator's cab from lowering. B—The red cab lock is placed in a horizontal position when it is not bracing the lifted cab.

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Figure 1-20. The excavator's hydraulic lockout lever has been lifted to the lockout position. The hydraulic controls are disabled in this position.

Articulation Steering Locks

Several mobile machines steer by means of a center articulation joint that allows the front and rear frame to pivot in the middle of the machine. Examples of machines that use articulated steering are four-wheel drive agricultural tractors, wheel loaders, motor graders, and haul trucks. As the steering wheel is turned, it causes the steering cylinders to pivot the machine's articulation joint to steer the tractor. It is very dangerous for personnel to be near a tractor's articulation joint when the tractor is running. One bump of the steering wheel could cause the tractor to steer, causing a fatality or serious injury. Articulated tractors have steering locks that lock the front and rear frame together to prevent the tractor from articulating. See **Figure 1-21**.

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Figure 1-21. The red brace is the articulation steering lock. It is shown in its stored position. When the left pin is removed, the brace can be rotated and aligned with the hole on the right side frame. When the brace is locked in place across the joint, the loader will not articulate.

Dump Bed Locks

Dump trucks also use locks to hold the bed in a raised position to provide safe access to the powertrain. The locks are designed to prevent the hydraulic bed dump cylinders from retracting. The rigid-frame dump truck in **Figure 1-22** uses two pins to lock the dump bed in a raised position.

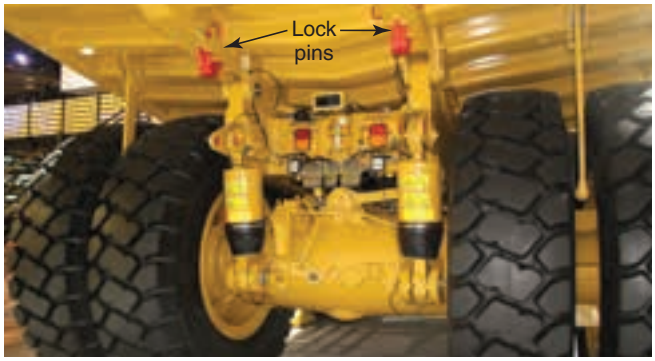

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Figure 1-22. This Caterpillar 777G dump truck has two lock pins that are used to lock the bed in a raised position. When the bed is fully raised, the pins are inserted through the two holes above the suspension cylinders to lock the bed in a raised position.

Rollover Protective Structure (ROPS)

Most mobile machines are equipped with a ***rollover protective structure (ROPS)***. The ROPS is a safety device designed to prevent the machine from crushing the operator if the machine rolls over. To be effective, a machine's ROPS must be used in conjunction with the machine's seat belt. Fatalities often occur when the unsecured operator panics during a rollover and attempts to jump out of the machine or falls out of the seat and into the machine's path.

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Some structures are as simple as a U-shaped bar bolted to the machine's frame, **Figure 1-23A**. This design is also known as a two-post ROPS because of the two attaching posts. Some large riding lawn mowers, compact utility tractors, and compactors have a foldable ROPS that allows the tractor to be driven into a low-clearance storage facility. See **Figure 1-23B**. Tractors operated on steep slopes or near cliffs have a higher risk for rolling over and may be equipped with a full ROPS that extends past the operator's cab to the front of the tractor. See **Figure 1-23C**. Full ROPS are also used in forestry applications. In rare cases, machines designed to operate only on flat surfaces at low travel speeds may not be equipped with an ROPS, **Figure 1-23D**.

Many ROPS are designed as an integral part of a machine's cab. It is critical that the ROPS not be modified in any way. Modifications made by drilling, cutting, shortening, lengthening, or welding will compromise the system's integrity.

Warning

An ROPS may be removed from a machine to allow highway bridge clearance during transport. The ROPS should not be removed before the machine is loaded on a trailer and it should be installed before unloading the machine from the trailer to prevent injuries or fatalities from a rollover that occurs during loading or unloading.

A *Logoboom/Shutterstock.com*

B *Goodheart-Willcox Publisher*

C *Goodheart-Willcox Publisher*

D *TFoxFoto/Shutterstock.com*

Figure 1-23. Different types of rollover protective structures are used on different machines. A—This compact utility tractor's ROPS consists of a simple U-shaped bar. Large bolts fasten the ROPS to each side of the tractor's frame. B—A foldable ROPS enables a machine to enter areas with low clearance. The ROPS on this compactor is folded. C—This dozer is equipped with a full ROPS that extends from the operator's cab to the front of the machine. D—Pavers are examples of machines that have little risk of rolling over because they work on flat surfaces and travel at slow speeds and typically do not have an ROPS.

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Seat Belts

As mentioned, an ROPS will not protect an operator unless the operator is wearing a seat belt or operator restraint system. OSHA and MSHA require the use of seat belts and specify that seat belts follow the Society of Automotive Engineers (SAE) seat belt regulations (J386 for off-road machines and J1194 for agricultural wheeled tractors). The seat belt must be clearly marked with the year it was made, the manufacturer's name, and the model number. The seat belt should be replaced if it is worn, frayed, cracked, or any part of the restraint is not working. Some manufacturers also specify that seat belts more than five years old or that have been on the machine more than three years should be replaced.

Note

One large contractor places signs in their machines and trucks that state "seat belts are a condition of employment," meaning that "no seat belt" equals "no job."

Falling Object Protective Structure (FOPS)

Machines used on sites or for jobs where the operator is at risk from falling objects are typically equipped with both an ROPS and a ***falling object protective structure (FOPS)***. An FOPS is commonly used on rigid-frame haul trucks. See **Figure 1-24**. The cabs on haul trucks are at risk from falling objects when excavators, loaders, and shovels load the trucks. The FOPS and ROPS may be designed into the same structure.

Stay out of Compartments

Machinery and surrounding compartments impose great risk to personnel. In a combine for example, the separator housing can have multiple large drive belts and the grain tank can have spinning augers. Personnel must always stay out of compartments while the machine is operating or they risk severe injury or death.

Machine Operation Safety

Technicians may have to operate or move machinery during a service or repair job and must be fully aware of safe practices associated with machine operation. The following material includes some basic safety practices to be used when operating heavy equipment.

Know the Machine's Capacities and Limitations

One key component to machinery safety is knowing the machine's capacities, including the machine's operating weight and its work-load limitations. For example, if the machine's operating weight is 40,000 lb (20 tons) it should not be transported over a bridge that is rated at 16 tons (32,000 lb). Another example would be driving a tractor with a full loader. It is very easy to tip a tractor when operating with a full load in the bucket and traveling at moderate speeds. Operating loads and static tipping loads for loaders are explained in Chapter 3, *Construction Equipment Identification*.

Jose Luis Stephens/Shutterstock.com

Figure 1-24. The truck bed serves as the FOPS in a rigid haul truck application.

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Machine Blind Spots

Many mobile machines, such as skid steers, haul trucks, and combines, have poor rear visibility. The lack of rear visibility creates a blind spot which makes it difficult to back up, especially in close quarters. This blind spot also creates risk for any person who is located at the rear of the machine. For this reason, all personnel working in close proximity to the machine must ensure that the machine's operator is aware of their presence and can clearly see them as he or she backs up the machine. A spotter may be used to guide the operator. A ***spotter*** is a person that is in direct radio communication with the machine operator.

Overhead Power Lines

Overhead power lines exert extremely high voltage and pose serious risks to heavy equipment operating in their vicinity. Most overhead power lines have no protective insulation and any machine contact can cause serious damage to the machine and severe injury or death to personnel. Some mobile machines, such as cranes, telehandlers, forklifts and personnel lifts, are at a greater risk of contacting power lines due to their height. Agricultural machines, such as combines or cotton pickers, may also be tall enough to make contact with low overhead power lines. Extreme care should be taken when operating machines near power lines. Spotters should be used to help guide the operator.

Starting a Machine

All heavy equipment machines should be started only when the operator is seated in the driver's seat with the transmission in neutral and the parking brake applied. Oftentimes, an operator working in the field may attempt to start a machine by using a tool to jump across the starter solenoid's terminals while standing on the ground. This unsafe practice is more common with farmers who are often working miles from their workshop and do not have access to the proper tools. Unfortunately, people are often severely injured or killed when the engine starts and the tractor, which may have been left in gear, begins moving and runs them over. Even if the engine does not start, it is possible that the starter is strong enough to propel the tractor while it is cranking and cause injury. Some manufacturers offer kits that cover the starter's solenoid to prevent personnel from attempting to start the machine from the ground. **Figure 1-25A** shows an older starter solenoid with the connectors exposed and **Figure 1-25B** shows a late model tractor with the starter wires covered.

It is also important to ensure that the engine is shut off, the parking brake is applied, and the implements are lowered to the ground before exiting the machine. Some manufacturers have additional safeguards listed in the service literature that are to be used when turning off and exiting a machine.

A B *Goodheart-Willcox Publisher*

Figure 1-25. Shorting the terminals on a starter solenoid will engage the starter. A—Old tractor starters often have exposed solenoid connections. B—On late-model tractors, the connections are covered to prevent personnel from bypassing the starter switch. Warning stickers are also used to remind personnel of the risk involved with starting a tractor at the starter's solenoid.

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No Riders

Personnel should never allow riders or passengers on machines that are equipped with only one operator seat. The second person could easily fall and get hurt or accidentally actuate controls due to the confined space in the cab. Additionally, the operator restraint and ROPS in a single-seat cab is designed for a single operator's protection.

Some larger agricultural tractors and combines are equipped with a small second seat in the operator's cab. The seat is sometimes called a buddy seat. See **Figure 1-26**. Manufacturers often stipulate that the seat is only there for the purpose of training operators how to properly operate the machine.

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Figure 1-26. Combines and large agricultural tractors may be equipped with a second seat, often called a buddy seat.

Towing Large Implements

Manufacturers often specify a minimum amount of tractor horsepower needed to tow implements. The minimum amount of horsepower specified is typically based solely on the size and weight of the machine needed to safely tow the implement. Towing implements with an undersized tractor will damage the tractor and increase the risk of an accident and injury. *Never* tow implements with an undersized tractor.

Welding Safety

Heavy equipment technicians are often required to weld broken or damaged components. ***Welding*** is the process of using heat to fuse two pieces of metal. Welding poses a wide range of safety and health risks, including exposure to toxic fumes, burns, eye damage, electric shock, and noise. While many important safety practices are included in this chapter, it is essential for technicians to read and comply with owner's manuals, product safety labels, and all applicable industry standards. Technicians must also read and understand *Safety in Welding, Cutting, and Allied Processes* (ANSI Z49.1). This publication is the industry standard for establishing safe welding practices.

Welding PPE

Proper welding PPE is required to avoid injury from the risks associated with welding. Although there are some variations in PPE depending on the type of welding and the location of the work, all welding requires a helmet and face shield, gloves, jacket or apron, flame-resistant pants, and boots. See **Figure 1-27**. Some types of welding also require a respirator or hearing protection.

- Welding helmets are equipped with a protective lens to protect the welder's eyes from intense ultraviolet (UV) and infrared (IR) radiation emitted during welding. The lenses are rated from 2 to 14, and the rating needed is based on the type of welding and amperage being used. The helmet also protects the welder's face from hot spatter.
- Welding gloves are heat-resistant and have a flame-retardant lining. The gloves protect hands and forearms from heat, electrical shock, UV and IR radiation, hot spatter, and abrasion. Thicker gloves can have better insulation, but are less flexible. The gloves must be regularly inspected for tears and holes.

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Figure 1-27. It is imperative for technicians to wear the proper PPE when welding.

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- Welding jackets and aprons protect the body from heat, fire, UV and IR radiation, and welding spatter.
- A welder's pants must be flame-resistant. The pants must have no tears, holes, or cuffs. Welding chaps may also be worn over pants for additional protection.
- Steel-toe boots with rubber soles are commonly worn in a welding environment. Some welders place covers over their boots to further protect their feet.
- The welding environment is often noisy and may require ear protection. Earplugs may be worn comfortably with a welding helmet.
- Respirators can be worn to protect from inhalation dangers, such as airborne particulates, toxic fumes, and smoke. The type of respirator that should be used varies by situation and the type of welding being performed.

Welding jobs often need to be done on-site and care must be taken to ensure the area is safe and any additional safety precautions needed are taken. Welders may also have to work in awkward positions to reach damaged components, and additional care must be taken to ensure the welding can be performed safely.

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Figure 1-28. Flammables must be stored in a flammable safety storage cabinet.

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Figure 1-29. The acetylene working pressure gauge redlines at 15 psi.

Oxygen and Acetylene

Many heavy equipment technicians choose to weld with an oxyacetylene system because it is very portable and highly versatile. The torch can be used for heating, soldering, brazing, welding, and cutting steel. It may also be used to remove oxidation from fasteners and expand metal for an easier press fit. Oxyacetylene welding requires a mixture of oxygen and acetylene. When the mixture of oxygen and acetylene burns, the resulting flame can reach a temperature of 5700°F. Welding temperatures are high enough to melt the base metal. Technicians who may need to perform welding repairs should be properly trained to transport, use, and store welding equipment before they attempt any welding repairs.

Warning

Inspect your work area for combustible materials, such as aerosol cans, oils, fuel, and chemicals, before welding. When not in use, all combustibles must be stored in a steel flammable material storage cabinet that meets local fire code. See **Figure 1-28.**

Acetylene Gas Safety

Acetylene gas is a very unstable and highly flammable gas. An acetylene cylinder's internal design contains a porous mass that is saturated with liquid acetone. The acetone is used to absorb the acetylene gas to improve its stability. Acetylene must only be stored in these specially designed cylinders.

When an acetylene regulator is being adjusted, the working pressure must never exceed 15 psi. The acetylene regulator working pressure gauge should have a red warning area on the scale beyond 15 psi. See **Figure 1-29**. Never use

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acetylene gas at working pressures above 15 psi. Acetylene cylinders are charged up to 250 psi, but the acetylene cylinder has a porous mass that is saturated with liquid acetone to keep the acetylene stable.

Acetylene gas should not be drawn out of the cylinder at a rate of more than one seventh of the cylinder volume per hour. For example, if the acetylene cylinder's volume equaled 210 cubic feet, the maximum withdraw rate must not exceed 30 cubic feet per hour; otherwise acetone will begin to be withdrawn from the cylinder. The acetylene gas is the fuel source for the torch.

Oxygen Gas Safety

The second gas used in oxyacetylene torches is compressed oxygen. Pure oxygen is not, by itself, a flammable gas. However, it is an oxidizing gas that accelerates the burning of combustibles, causing them to burn faster and hotter. This accelerant characteristic is one of the safety concerns for working with compressed oxygen. Due to the explosive potential of oil exposed to oxygen, never allow oil to mix with compressed oxygen. Oxygen is heavier than atmospheric air and can temporarily pool on the ground while it is mixing back into the atmosphere. This can accelerate the combustion of any flammable materials in the oxygen-rich area.

Oxygen cylinders store compressed oxygen at pressures up to 2100 psi. See **Figure 1-30**. The cylinders must be handled with care. If the cylinder valves are broken, the cylinders can become lethal projectiles. If the cylinder valve is opened carelessly, the pressurized gas presents the same hazards as a pneumatic system.

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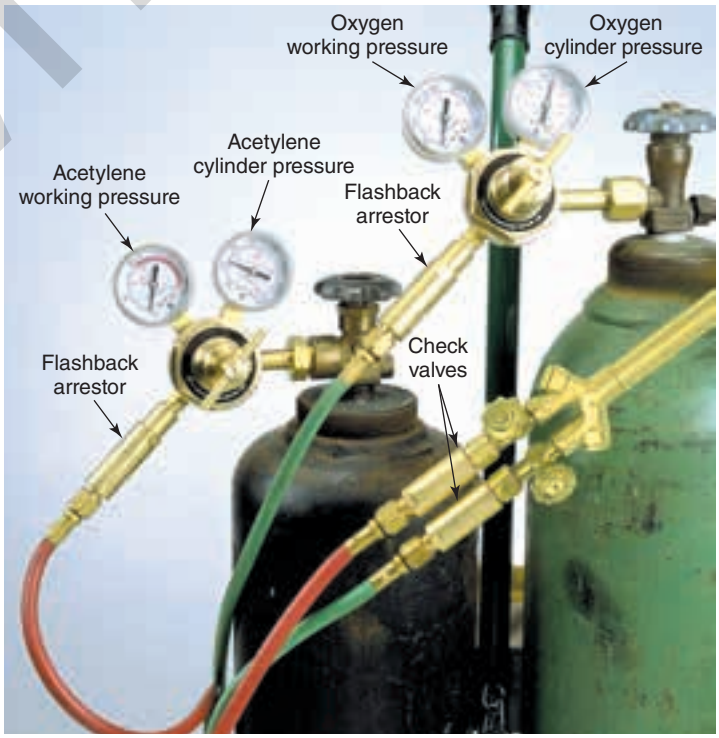
Figure 1-30. Oxygen cylinders can be charged up to 2100 psi. The gauge on the right shows the cylinder pressure of the gas. The gauge on the left shows the working pressure of the gas.

Safety Devices

Oxyacetylene torches can ***backfire***, which is the result of the flame traveling back through the torch tip, resulting in a single loud pop which extinguishes the torch's flame. Backfires can occur if the gas pressure is too low, if the torch tip contacts the heated metal, or if the tip is obstructed. If the popping noise turns into a whistle, then the backfire has become a ***flashback***, which is the flame traveling back through the torch head. If the flashback were allowed to continue traveling backward, it could cause the hoses and cylinders to violently explode. Flashback travels at twice the speed of sound, which does not allow a person enough time to shut off the cylinders. Some oxyacetylene torches use two check valves to prevent the reverse flow of gas and/or two flashback arrestors to quench a flashback, preventing the flame from traveling backward. See **Figure 1-31**.



Thermadyne Industries, Inc.

Figure 1-31. This image shows oxygen and acetylene regulators properly attached to the cylinders.

Check Valve

The ***check valve*** contains a spring that presses against a poppet-style check valve, which stops the reverse flow of gas. The check valves are often installed on the torch before the hoses, one for oxygen and one for acetylene. The check valves cannot stop a flame from traveling backward, but they do prevent reverse flow of gas.

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Flashback Arrestor

A ***flashback arrestor*** is a safety device designed to quench a flame, preventing a flame from traveling back into the hose or regulator. Flashback arrestors are installed on a welding outfit either in place of or in combination with check valves. They are normally physically longer than the check valves. Like check valves, flashback arrestors prevent the reverse gas flow. However, they also have an element that extinguishes any flame that reaches it. A flashback arrestor is placed between each hose and the torch or between each hose and regulator. Today, flashback arrestors are commonly included with the torch. An old torch might have neither check valves nor flashback arrestors.

Cylinders

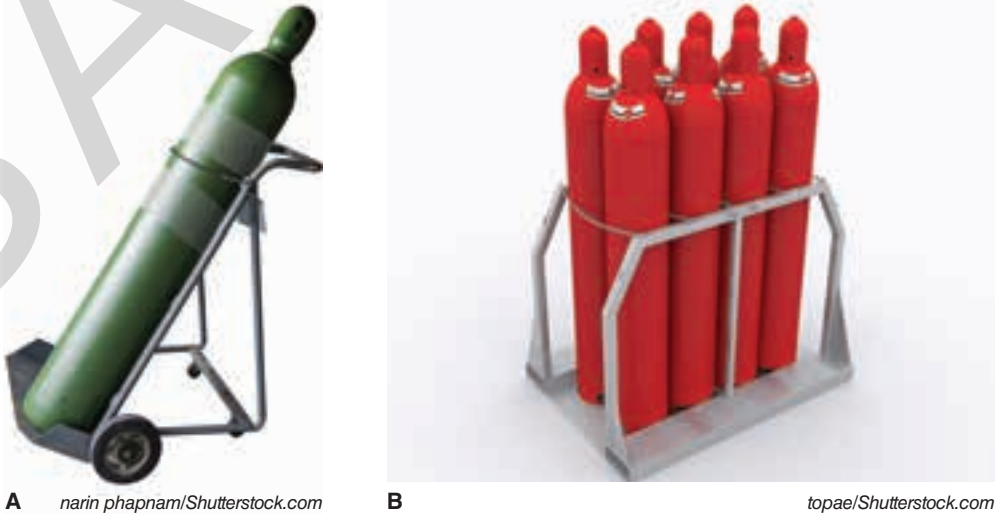
Gas cylinders may also be equipped with safety devices to prevent the rupture of the cylinders if the cylinder pressure increases. Cylinder pressures can rise if they are exposed to heat, such as a fire.

Oxygen and nitrogen cylinders are equipped with a ***burst*** or ***rupture disk***, which is designed to rupture at a specified pressure. This allows the gas to be emitted out of the tank at a controlled rate, reducing the pressure in the cylinder and preventing it from exploding. The disk will not reclose once the cylinder's pressure drops below the rupture setting. The disk acts as a pressure fuse.

Acetylene cylinders may be equipped with a ***fusible plug*** filled with a metal alloy that will melt at a specific temperature. Once the metal alloy melts, it allows the cylinder to release the acetylene gas at a controlled rate. Again, this safety feature releases built-up pressure to prevent the cylinder from exploding.

Cylinder Storage and Transport

When the gas cylinders are not in use, they must be stored properly. Removable protective caps should be installed and the cylinders must be secured with restraining chains or straps. See **Figure 1-32**. Acetylene cylinders must always be stored and used in an upright position. If the acetylene tank is placed in a horizontal position, it must be allowed to sit in an upright position for the same length of time it was lying horizontal before it can be used. This ensures the acetylene and acetone have not separated. Preferably, the tank should sit for at least 24 hours in an upright position before its use.



A *narin phapnam/Shutterstock.com* **B** *topae/Shutterstock.com*

Figure 1-32. Gas cylinders must be properly secured when not in use. A—This oxygen cylinder is secured to its cart with a chain, and the protective cap is installed. B—These acetylene cylinders are secured to a steel pallet with chains. The cylinders have their protective caps installed as well.

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Colors

Colored warning labels are used on compressed gas cylinders to identify the contents. Agencies, such as OSHA, the Department of Transportation (DOT), and the National Fire Protection Agency (NFPA) have established standard requirements for the colors and icons used. For example, the DOT placard for acetylene cylinders uses a red diamond label with a white flame. Oxygen cylinders are labeled with a yellow diamond label with a flame over a circle, indicating that oxygen is an oxidizing gas. The actual color of gas cylinders is not standardized. The acetylene torch hose is red and the oxygen hose is green.

Additional Oxyacetylene Gas Safety Tips

- For any given task, use only equipment designed for that task and the pressure ranges that will be used. This applies to regulators, hoses, cylinders, and torches.
- Wear appropriate PPE, including flame- and spark-resistant cotton clothing, eye and face protection, and gloves.
- Keep all PPE and welding equipment free of oil and grease.
- Never transfer acetylene into another storage cylinder.
- Work in well-ventilated areas to prevent the buildup of carbon monoxide and other dangerous fumes.

Electrical Shock

Although oxyacetylene does not require electricity, other types of welding use electricity to power welders (welding machines). The human body will easily conduct electricity when it is placed in its path and may result in a person's ***electrocution*** (death from electrical shock). To minimize the risk of electrocution, personnel can take preventive measures.

- Wear dry clothing and PPE.
- Ensure that you are dry and insulated from the metal and the ground.
- Do not allow your skin or anything wet to touch the electrode or its metal.
- Do not stand on wet surfaces.
- Do not touch the metal parts.
- Ensure cable insulation is in good condition.
- Shut off the welder when it is not in use.

Although electrocution can occur anywhere, technicians must take additional precautions when working on-site instead of in the shop. Technicians should evaluate the site and note any wet areas, power lines, and other electrical equipment in use before they begin working on a machine.

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Summary

- Technicians must be equipped and trained for proper use of personal protective equipment (PPE).
- Technicians must receive instruction on safe work practices.
- Safety data sheets (SDS) must be on hand for all chemicals and hazardous materials being used in the shop.
- Heavy equipment technicians often work alone in remote locations and need to be prepared for emergencies.
- All shop personnel should be aware of the location of the shop's first-aid stations.
- Pressurized fluids pose risks to personnel and machinery in the form of burns, fluid injection injuries, and machine fires.
- Compressed air systems pose risk to personnel in the form of eye, lung, and internal injuries.
- All safety guards and shields should be properly installed on machines to ensure the operator's safety while the machine is running.
- Exhaust ventilation systems must be on and properly connected when a machine is running in the shop.
- Fall protection will prevent a technician from falling to the ground when working at elevated heights.
- A job hazard analysis (JHA) should be performed before a job is begun.
- A recordable accident occurs when an injury results in a fatality, medical care or hospitalization is required, the employee must be absent from future workdays, or the employee's work is limited.
- Recordable accidents include incidents that result in fatalities, loss of consciousness, having to see a physician, missing work, and having work limitations. An example of a nonrecordable accident could involve seeing a physician, but receiving only a temporary bandage.
- Wheel chocks should be used when a machine is being unloaded or serviced and when it is parked on a slope.
- When entering or exiting a machine, always use three points of contact and face the machine.
- Never work below an unsupported implement. Always use implement locks to secure the implement.
- Articulated tractors have steering locks that lock the front and rear frames together to prevent the tractor from articulating.
- ROPS and seat belts protect operators in the event of a machine rollover.
- FOPS protect operators from falling objects.
- All heavy equipment machines should be started only when the operator is seated in the driver's seat with the transmission in neutral and the parking brake applied.
- Before towing an implement, ensure the tractor is large enough to handle the size of the implement.
- Welding poses a wide range of safety and health risks, including exposure to toxic fumes, burns, eye damage, electric shock, and noise. Proper PPE must always be worn.
- Oxyacetylene welding uses oxygen and unstable, highly flammable acetylene. The welding process generates heat that is high enough to melt metal.

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Technical Terms

acetylene gas
automated external defibrillator (AED)
backfire
burst disk
cardiopulmonary resuscitation (CPR)
check valve
electrocution
embolism
falling object protective structure (FOPS)
fall protection
first aid
flashback
flashback arrestor
fluid injection
fusible plug
implement lock
job hazard analysis (JHA)
Mine Safety and Health Administration (MSHA)
nonrecordable accident
Occupational Safety and Health Administration (OSHA)
personal protective equipment (PPE)
pneumatic system
power take-off (PTO)
recordable accident
recordable incident
rollover protective structure (ROPS)
rupture disk
safety data sheets (SDS)
spotter
three points of contact
unsafe acts
welding
wheel chocks

Review Questions

Answer the following questions using the information provided in this chapter.

Know and Understand

1. Of the following, _____ are approved PPE.
   A. contact lenses
   B. safety glasses
   C. sunglasses
   D. traditional prescription glasses
2. All of the following are examples of PPE, *EXCEPT*:
   A. safety glasses.
   B. hard hats.
   C. earplugs.
   D. neck braces.
3. All of the following present additional hazards when exposed to heat, *EXCEPT*:
   A. hydraulic cylinders.
   B. solder.
   C. gas cylinders.
   D. accumulators.
4. A technician's arm breaks out in a rash after rebuilding a hydraulic cylinder. Where should the technician look for information related to this problem?
   A. Service manual.
   B. Operator's manual.
   C. Training manual.
   D. Safety data sheet (SDS).
5. A hydraulic system operating at high system pressure can spray fluid up to _____.
   A. 60 mph
   B. 300 mph
   C. 670 mph
   D. 2000 meters per second
6. In the event of a fluid injection in a technician's hand, all of the following will affect the chances of potential amputation, *EXCEPT*:
   A. delay before receiving medical attention.
   B. quantity of fluid.
   C. the type of fluid.
   D. weather conditions.

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7. All of the following are used for fall protection, *EXCEPT*:
   A. netting.
   B. an anchor point.
   C. a body harness.
   D. a shock-absorbing lanyard.
8. Which of the following is a form completed by employees as a way to analyze risks prior to starting the job?
   A. FHA.
   B. JHA.
   C. SHA.
   D. NHA.
9. An accident occurred on the job. All of the following will result in a recordable accident, *EXCEPT*:
   A. receiving prescription medication.
   B. receiving stitches.
   C. receiving a temporary bandage.
   D. having to be reassigned to a light-duty job task.
10. How many points of contact should be maintained when entering or exiting a machine?
    A. One.
    B. Two.
    C. Three.
    D. Four.
11. A technician is exiting a tractor. Which way should he or she face while exiting?
    A. Toward the machine.
    B. Away from the machine.
    C. Depends on the type of machine.
    D. Does not matter.
12. Which of the following actions must be performed when a cab or implement must be lifted to service a component?
    A. Technicians are never permitted to work under a lifted cab or implement.
    B. Use a hydraulic cylinder to support the cab or implement.
    C. Use the manufacturer's safety support lock.
    D. The implement must be dismantled.
13. An implement lockout switch or lever normally prevents implement operation by eliminating _____.
    A. hydraulic pilot oil
    B. solenoid operational relay
    C. engine from cranking
    D. hydraulic oil from returning to the reservoir
14. All of the following machines are likely to use an ROPS, *EXCEPT*:
    A. a dozer operating on a steep incline.
    B. a dozer operating in a forestry application.
    C. an agricultural tractor operating on a steep slope.
    D. an asphalt paver laying pavement.
15. A haul truck bed can also serve as an _____.
    A. FOPS
    B. ROPS
    C. Both A and B.
    D. Neither A nor B.
16. When is it okay to start a tractor by jumping across a tractor's starter's solenoid terminals?
    A. If the transmission is in gear.
    B. When the park brake is released.
    C. When the service brake is released.
    D. Never. The machine should only be started from the operator's seat.

Apply and Analyze

17. OSHA stands for Occupational Safety and Health _____.
18. The _____ is required to provide PPE for employees.
19. The acronym *PPE* stands for personal protective _____.
20. According to some manufacturers, when checking for high-pressure hydraulic leaks, a technician should use a piece of _____.
21. The minimum fluid pressure that can cause oil to penetrate a human's skin is _____psi.
22. A Class_____ fire extinguisher is used to extinguish oil or grease fires.
23. A Class _____ fire extinguisher is used to extinguish electrical fires.
24. The most common cause of fluid injection injuries is a burst _____.
25. A(n) _____ degree burn affects only the outer layer of skin.
26. The acronym *ROPS* stands for rollover protective _____.
27. Some manufacturers recommend that seat belts that have been on a machine more than _____ years be replaced.
28. Welding helmets are equipped with a protective lens to protect the welder's eyes from intense _____ and infrared radiation emitted during welding.
29. Acetylene must never be used at a working pressure above _____ psi.

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Critical Thinking

30. Some manufacturers require a technician to run a machine and make adjustments, such as adjusting the null adjustment on a hydrostatic transmission, while measuring pressures. What are some steps a technician can take to avoid being injured while measuring flows, pressures, and making adjustments to a machine?

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Personnel should wear bright clothing or safety vests in addition to all other required PPE when working around heavy equipment.

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