



Hand and Power Tool Safety

Hand and power tools can be very hazardous in construction and have the potential for causing severe injuries when used or maintained improperly. Special attention toward hand and power tool safety is necessary in order to reduce or eliminate these hazards. This course is designed to present to employees and employers a summary of the basic safety procedures and safeguards associated with hand and portable power tools.

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OSHAcademy Course 810 Study Guide

[Hand and Power Tool Safety]

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Contact OSHAcademy to arrange for use as a training document.

This study guide is designed to be reviewed off-line as a tool for preparation to successfully complete OSHAcademy Course ###.

Read each module, answer the quiz questions, and submit the quiz questions online through the course webpage. You can print the post-quiz response screen which will contain the correct answers to the questions.

The final exam will consist of questions developed from the course content and module quizzes.

We hope you enjoy the course and if you have any questions, feel free to email or call:

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Course Introduction

Hand and power tools are a common part of our everyday lives and are present in nearly every industry. These tools help us easily perform tasks that otherwise would be difficult or impossible. However, these simple tools can be hazardous and have the potential for causing severe injuries when used or maintained improperly. Special attention toward hand and power tool safety is necessary in order to reduce or eliminate these hazards.

Hand and power tool hazards are addressed in specific standards for the general industry, shipyard employment, marine terminals, longshoring, and the construction industry.

This course is designed to present to employees and employers a summary of the basic safety procedures and safeguards associated with hand and portable power tools.

The material in this course is based on the standards of the Occupational Safety and Health Administration. However, this course should not be considered as a substitute for the full safety and health standards for the general industry (published in Title 29 Code of Federal Regulations (CFR), Part 1910, Subpart P), or for the construction industry (published in 29 CFR Part 1926, Subpart I).

Employers and employees in the 26 states and territories with OSHA-approved state safety and health plans should check with their state agency. Their state may be enforcing standards and other procedures that, while “at least as effective as” federal standards, are not always identical to the federal requirements.

Module 1: Recognizing Hazards

Introduction

This first module looks at the various hazards associated with working with tools and identifies ways to prevent worker injury through proper use of tools and personal protective equipment.

The employer is ultimately responsible for the safe condition of tools and equipment used by employees. Employers should never issue or permit the use of unsafe hand and power tools.

Employees should be trained in the proper use and handling of tools and equipment.

Workers should also be able to recognize the hazards associated with the different types of tools and the safety precautions necessary.

Five basic safety rules can help prevent hazards associated with the use of hand and power tools:

1. Keep all tools in good condition with regular maintenance.
2. Use the right tool for the job.
3. Examine each tool for damage before use and do not use damaged tools.
4. Operate tools according to the manufacturers' instructions.
5. Provide and properly use the right personal protective equipment.

Employees and employers should work together to establish safe working procedures. If an employee encounters a hazardous situation, it should be brought immediately to the attention of the proper individual—which is usually the supervisor—immediately for hazard abatement.

Ergonomics

Some tools are advertised as “ergonomic” or designed with ergonomic features. A tool becomes “ergonomic” only when it fits the task you are performing, and it fits your hand without causing awkward postures, harmful contact pressures, or other safety and health risks.

If you use a tool that does not fit your hand—or use the tool in a way it was not intended—you might develop an injury, such as carpal tunnel syndrome, tendonitis, or muscle strain.

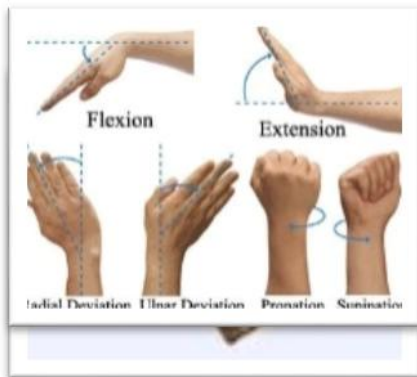
These injuries do not happen because of a single event, such as a fall. Instead, they result from repetitive movements that are performed over time or for a long period.

Unsafe practices may result in damage to muscles, tendons, nerves, ligaments, joints, cartilage, spinal discs, or blood vessels. Below are some ergonomic issues to consider when using hand and power tools.

Neutral Position - When working with hand tools, it is good practice and maintain a neutral (handshake) wrist position. Remember, bend the tool, not the wrist.



Flexion and Extension - Design tasks and select tools to reduce extreme flexion or deviation of the wrist.



Power Grip - The hand grip that provides maximum hand power for high force tasks. All the fingers wrap around the handle.

Contact Pressure - Pressure from a hard surface, point, or edge on any part of the body.



Pinch Grip - The hand grip that provides control for precision and accuracy. The tool is gripped between the thumb and the fingertips.



What is the Best Tool?

The best tool does the following:

- fits the job you are doing
- fits the work space available
- reduces the force you need to apply
- fits your hand
- can be used in a comfortable work position
- does not require you to raise or extend the elbows (heavy tools)

Conditions that Cause Hand and Wrist Illnesses

The following are some of the conditions that can cause hand and wrist illnesses:

- frequent or repetitive movement of the hand or wrist (usually associated with awkward wrist angulations)
- inappropriate tool and equipment design
- vibrating knives and saws
- poor work station design and arrangement
- cold environments

Symptoms of Hand and Wrist Illnesses

You may have a problem if you have any of these symptoms:

- tingling
- swelling in the joints
- decreased ability to move
- decreased grip strength

- pain from movement, pressure, or exposure to cold or vibration
- continual muscle fatigue
- sore muscles
- numbness
- change in the skin color of your hands or fingertips

These symptoms may not appear immediately because they develop over weeks, months or years. By then, the damage may be serious. Take action before you notice any symptoms. (Source: CAL-OSHA)

Trigger Finger

“Trigger-finger” happens when one of your fingers or your thumb catches in a bent position. The finger or thumb may straighten with a snap.

It’s caused by the narrowing of the tendon sheath when repetitive gripping actions are performed. Tendons in the finger joints can swell due to overuse, “locking” the finger into a fixed position.

To avoid this condition, choose tools with triggers that allow two or three fingers to activate the tool.

For a better understanding of this condition, look at this [short video](#) on Trigger Finger.

Vibration White-Finger Syndrome

White-Finger Syndrome, which is also called Hand-Arm Vibration Syndrome (HAVS), is caused by excessive vibration when using tools that can cause reduced blood circulation to the fingers. To help prevent this condition, use anti-vibration gloves.

Look at this humorous [Napo video](#). It’s a good example of tool selection to help prevent injuries from vibrating tools.

Personal Protective Equipment

Safety equipment typically used with hand and power tools include safety glasses, safety shields, respirators, safety-toed shoes, high-top shoes, hard hats, bump caps, leather gloves, leather aprons, and coveralls. It’s very important to follow the safety measures below:

- You should wear approved, industrial-quality eye protection at all times. Safety glasses should have the ANSI Z87.1 logo on them to assure they are industrial quality.
- When handling carpentry materials, wear a hard hat or bump cap to protect your head.

Clothing and Grooming

Wear proper clothing. This varies depending on the type of hand or power tool you are working with.

- Work clothing should not be loose, baggy, or highly flammable.
- To protect against burns, wear clothing such as coveralls, high-top shoes, leather aprons and leather gloves.
- Remove all paper from pockets and wear cuffless pants.
- When working with heavy metals, wear hard-toed shoes with non-skid soles.
- Avoid wearing synthetic clothing because it has a low flashpoint which can result in severe burns.
- Do not wear jewelry. It can get caught in moving parts.

Work Area and Tool Condition

Keep work area and tools clean. Dirty, greasy, and oily tools and floors can cause accidents.

- Clean and put away all unneeded tools and materials.
- Workplace floors must be kept as clean and dry as possible to prevent accidental slips with or around dangerous hand tools.
- Clean up spills and scraps from the floor and equipment.
- Keep paths to exits clear. If conditions are dusty, use a respirator.

Keep cutting-edge tools sharp. Dull cutting-edge tools are dangerous as they require excessive pressure and hammering to make them cut.

- When cutting, always cut away from the body.

- Before using any cutting tool, remove nails or other objects that might destroy the tool's cutting edge.

Focus

A lack of attention to the work being performed can result in serious injuries. Loud talking as well as pushing, running, and scuffling while working with hand tools can also cause serious accidents. Be sure to do the following:

- Keep your mind on your work.
- Avoid horseplay and loud talk.
- Be alert and work defensively.

Module 1 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

- 1. Who is ultimately responsible for the safe condition of tools and equipment used in the workplace?**
 - a. The employee
 - b. The employer
 - c. The safety manager
 - d. The supervisor

- 2. Which of the following is a tool that fits the task you are performing without causing awkward postures, harmful contact pressures, or other safety and health risks?**
 - a. An ergonomic tool
 - b. A manufactured tool
 - c. An approved tool
 - d. An OSHA-approved tool

- 3. When choosing tools, the best tool is one that _____.**
 - a. has an OSHA-approved stamp
 - b. does not require the use of your arms
 - c. fits the time available to get the job done
 - d. reduces the force you need to apply

- 4. Which of the following is not a factor in causing hand and wrist illnesses?**
 - a. Cold
 - b. Vibration
 - c. Humidity
 - d. Repetitive movement

- 5. Excessive vibration of the hand while using tools over time may cause _____.**
 - a. trigger finger
 - b. white-finger syndrome
 - c. neuropathy of the hand

- d. Napo's syndrome

Module 2: Hand Tool Safety

Introduction

Tools that are manually powered are called hand tools. Hand tools include anything from axes to wrenches. Common hand tools include: Tin snips, hatchets, screw drivers, hammers, pliers, anvils, wrenches, files, rasps, saws, punches, chisels, planes, hand-held boring tools, and pop rivet guns.

Wrong Tool for the Job

The greatest hazards posed by hand tools result from misuse and improper maintenance.

Some examples include the following:

- If a chisel is used as a screwdriver, the tip of the chisel may break and fly off, hitting the user or other employees.
- If a wooden handle on a tool, such as a hammer or an axe, is loose, splintered, or cracked, the head of the tool may fly off and strike the user or other employees.
- If the jaws of a wrench are sprung, the wrench might slip.
- If impact tools such as chisels, wedges, or drift pins have mushroomed heads, the heads might shatter on impact, sending sharp fragments flying toward the user or other employees.

Selecting the Right Tool for the Job

Before you select a tool, think about the job you will be doing. Tools are designed for specific purposes.

Using a tool for something other than its intended purpose often damages the tool and could cause you pain, discomfort, or injury. You reduce your chances of being injured when you select a tool that fits the job you will be doing. Examples include the following:

- A job requiring cutting, pinching and gripping will require hand tools like pliers, snips and cutters.
- A job requiring you to strike something will require a hammer.

- A job requiring you to drive or turn something will require screw or nut drivers and wrenches.

Tips for Selecting Hand Tools

Over time, exposure to awkward postures or harmful contact pressures can contribute to an injury. You can reduce your risk of injury if you select hand tools that fit your hand and the job you are doing. Below are some tips from the Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH).

Single-Handle Tools

Tube-like tools measured by handle length and diameter. The diameter is the length of a straight line through the center of the handle.

- For single-handle tools used for precision tasks, select a tool with a handle diameter of 1/4 inch to 1/2 inch.
- For single-handle tools used for power tasks, select a tool that feels comfortable with a handle diameter in the range of 1 1/4 inches to 2 inches. You can increase the diameter by adding a sleeve to the handle.

Double-Handle Tools

Double-handle Tools are measured by handle length and grip span. The grip span is the distance between the thumb and fingers when the tool jaws are open or closed.

- For double-handle tools (plier-like) used for power tasks, select a tool with a grip span that is at least 2 inches when fully closed and no more than 3 1/2 inches when fully open. Consider using a clamp, a grip, or locking pliers when continuous force is required.
- For double-handle tools used for precision tasks, select a tool with a grip span that is no less than 1 inch when fully closed and no more than 3 inches when fully open.
- For double-handled pinching, gripping, or cutting tools, select a tool with handles that are spring-loaded to return the handles to the open position.

Edges and Surfaces

It's important to consider the edges and surfaces of the handles of tools you want to use. Be sure to check the following:

- Select a tool without sharp edges or finger grooves on the handle.
- Select a tool that is coated with soft material.

Handles

Select a tool with an angle that allows you to work with a straight wrist.

- Tools with bent handles are better than those with straight handles when the force is applied horizontally (in the same direction as your straight forearm and **wrist**).
- Tools with straight handles are better than those with bent handles when the force is applied **vertically**.
- For tasks requiring high force, select a tool with a handle length longer than the widest part of your hand—usually 4 inches to 6 inches.
- Prevent contact pressure by making sure the end of the handle does not press on the nerves and blood vessels in the palm of your hand. If the handle is too short, the end will press against the palm of your hand and may cause an injury.
- Select a tool that has a non-slip surface for a better grip. Adding a sleeve to the tool improves the surface texture of the handle. To prevent tool slippage within the sleeve, make sure that the sleeve fits snugly during use. Remember, a sleeve always increases the diameter or the grip span of the handle.

Proper Tool Use

Be sure to follow these general rules when using hand tools:

- Inspect tools before using.
- Avoid using damaged tools.
- Tools that appear to be damaged or have broken handles should be marked unsafe.
- Do not use damaged or defective tools until they have been repaired.

Always use proper-sized tools and equipment for the job. Use each tool only for the job for which it was intended. Forcing a small tool to do the job of a large one may result in injury or tool damage. Follow these guidelines:

- Never use a screw driver to see if electrical circuits are hot.
- Never use a machinist's hammer in place of a carpenter's hammer.
- Do not strike a hardened steel surface, such as an anvil, with a steel hammer because a small piece of steel may break off and injure someone.
- Be sure wrenches fit properly.
- Never use pliers in place of a wrench.
- Never strike wrenches with hammers or use wrenches as hammers.
- Pull on wrenches. Do not push.
- When sawing, secure the material in the saw vise.
- Watch your fingers. Take special care when hammering so that you strike the object, not your fingers.

Tool Replacement and Storage

To make sure tools remain in good condition, follow these guidelines when replacing and storing tools:

- Carry and store all hand and power tools properly.
- Carry all sharp-edge tools and chisels with the cutting edge down.
- Do not carry sharp tools in a pocket.
- Store all sharp-edge cutting tools with the sharp edges down.
- Grip and hold tools so that they do not slip and hit someone.
- Do not wear gloves if they are bulky and make gripping tools difficult.
- Keep other employees away from the work when using saw blades, knives, or other tools.
- Keep tools away from aisle areas and away from other employees.

- Knives and scissors must be sharp.
- Remove cracked saw blades from service.
- Replace wrenches when jaws are sprung to the point that slippage occurs.
- Replace tools with mushroomed heads, such as impact tools such as drift pins, wedges, and chisels.
- Replace all tools with splintered wooden handles.
- Do not store iron or steel hand tools that may produce sparks around flammable substances.
- Store only spark-resistant tools made of non-ferrous materials where flammable gases, highly volatile liquids, and other explosive substances are stored.

Module 2 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

- 1. Which of the following causes the greatest hazards posed by hand tools?**
 - a. Poor quality
 - b. Misuse and improper maintenance
 - c. Lack of training
 - d. Unavailability of tools

- 2. For double-handled pinching, gripping, or cutting tools, select a tool with handles that are _____.**
 - a. spring-loaded
 - b. sharpened
 - c. longer than the wrist
 - d. equipped with a stop

- 3. When a task requires high force, which of the following tool handles would be best?**
 - a. A handle shorter than the widest part of your hand
 - b. A handle longer than the narrowest part of your hand
 - c. A handle longer than the widest part of your hand
 - d. A handle shorter than the narrowest part of your hand

- 4. What should you do with a hand tool that has a broken handle?**
 - a. Wrap the handle with duct tape
 - b. Reduce the amount of force used
 - c. Continue using the tool with added care
 - d. Mark it as unsafe and get it repaired

- 5. Which of the following is not listed as an unsafe work practice when using hand tools?**
 - a. Using a screw driver to see if electrical circuits are hot
 - b. Using duct tape to improve the grip on a handle
 - c. Using pliers in place of a wrench
 - d. Using a wrench as a hammer

Module 3: Power Tool Safety

Introduction

Because power tools are so common in construction, workers are constantly exposed to a variety of hazards. The very tool that makes their job easy and efficient may one day be the cause of a tragic accident. It is good to be reminded of good-sense safety practices.

Which Power Tools Cause the Most Hand Injuries?

Considering how often they are used at construction sites, powered hand tools cause relatively few hand injuries in the industry. In 2012, hand injury claims amounted to only about 4.5 percent of all injury claims accepted for the industry.

It should not come as too much of a surprise that saws, drills, and nail guns account for most of the injuries (67 percent). However, let's look at the top 10 most dangerous portable power tools:

1. saws (except chainsaws)
2. drills
3. nail guns
4. jackhammers
5. hand grinders
6. chainsaws
7. hand tools not otherwise classified
8. sprayers-paint
9. hammers
10. impact wrenches

(Source: OR-OSHA)

Guards

The exposed moving parts of power tools need to be safe-guarded. Belts, gears, shafts, pulleys, sprockets, spindles, drums, flywheels, chains, or other reciprocating, rotating, or moving parts of equipment must be guarded.

Machine guards, as appropriate, must be provided to protect the operator and others from the following:

- point of operation
- in-running nip points
- rotating parts
- flying chips and sparks

Safety guards must never be removed when a tool is being used.

Follow these rules when using circular saws:

- Portable circular saws with a blade greater than 2 inches (5.08 centimeters) in diameter must be equipped at all times with guards.
- An upper guard must cover the entire blade of the saw.
- A retractable lower guard must cover the teeth of the saw, except where it makes contact with the work material.
- The lower guard must automatically return to the covering position when the tool is withdrawn from the work material.

Grooming

Protect your hair, scalp, and head. Pull back long hair in a band or a cap to keep it from getting caught in tools or moving parts. Be extremely careful with long hair when using a drill or drill press.

Operating Controls and Switches

Power tools must be fitted with safety switches; they are extremely hazardous when used improperly. The types of power tools are determined by their power source: electric, pneumatic, liquid fuel, hydraulic, and powder-actuated.

Constant-Pressure Switches and Controls

The following hand-held power tools must be equipped with a constant-pressure switch or control that shuts off the power when pressure is released:

- drills
- tappers
- fastener drivers
- horizontal, vertical, and angle grinders with wheels more than 2 inches (5.08 centimeters) in diameter
- disc sanders with discs greater than 2 inches (5.08 centimeters)
- belt sanders
- reciprocating saws
- saber saws
- scroll saws, and jigsaws with blade shanks greater than 1/4-inch (0.63 centimeters) wide
- circular saws having a blade diameter greater than 2 inches (5.08 centimeters)
- chain saws
- percussion tools with no means of holding accessories securely
- other similar tools

These tools also may be equipped with a “lock-on” control, if it allows the worker to also shut off the control in a single motion using the same finger or fingers.

Positive “On-Off”, Constant Pressure, and “Lock-On” Controls

The following hand-held power tools must be equipped with either a positive “on-off” control switch, a constant pressure switch or a “lock-on” control:

- disc sanders with discs 2 inches (5.08 centimeters) or less in diameter
- grinders with wheels 2 inches (5.08 centimeters) or less in diameter
- platen sanders, routers, planers, laminate trimmers, nibblers, shears, and scroll saws
- jigsaws, saber and scroll saws with blade shanks a nominal 1/4-inch (6.35 millimeters) or less in diameter

It is recommended that the constant-pressure control switch be regarded as the preferred device.

Portable Tool Use with Extension Cords

In construction, extension cords suffer a lot of wear and tear. Most often, the damage is only to the insulation, exposing energized conductors. When a person handling the damaged cord contacts the exposed wires while holding a metal tool case or contacting a conductive surface, serious electrical shock can result, causing a fall, physical injury, or **death**.

Extension Cords—Who Can Repair Them?

When a worker at a construction site inspects an extension cord and determines that it needs to be repaired, who can repair it?

Anyone who is qualified can do the repair. The worker does not have to be a licensed electrician to repair a typical extension cord. However, he or she must have the knowledge and skills to repair the cord correctly, understand the hazards involved in making the repair, and be able to describe what could happen if the repair is done wrong. The employer is responsible for determining if the person is qualified. The basis for the determination is normally from the electrical industry perspective. (Source: OR-OSHA)

Grounding

The term "ground" refers to a conductive body, usually the earth. "Grounding" a tool or electrical system means intentionally creating a low-resistance path to the earth. When properly done, current from a short or from lightning follows this path, thus preventing the

buildup of voltages that would otherwise result in electrical shock, injury and even death. View this [animation](#) to see what happens when grounding is improper.

Under certain conditions, even a small amount of electric current can result in fibrillation of the heart and death. An electric shock also can cause the user to fall off a ladder or other elevated work surface and be injured due to the fall.

To protect the worker from shock and burns at work, make sure electrical powered tools have a three-wire cord with a ground. They must also be:

- plugged into a grounded receptacle
- double insulated
- powered by a low-voltage isolation transformer

Three-wire cords contain two current-carrying conductors and a grounding conductor. Any time an adapter is used to accommodate a two-hole receptacle, the adapter wire must be attached to a known ground. The third prong must never be removed from the plug.

Ground-Fault Circuit Interrupters (GFCI)

Since neither insulation nor grounding protects you from these conditions, use other protective measures. One acceptable method is a ground-fault circuit interrupter (GFCI).

A ground-fault circuit interrupter (GFCI), is a fast-acting circuit breaker designed to shut off electric power in the event of a ground-fault within as little as $1/40$ of a second. It works by comparing the amount of current *going to* and *returning from the* equipment along the circuit conductors. When the amount *going* differs from the amount *returning* by approximately 5 [milliamperes](#), the GFCI interrupts the current.

-) **Receptacle Type** - The Receptacle Type incorporates a GFCI device within one or more receptacle outlets. Such devices are becoming popular because of their low cost.
-) **Portable Type** - Portable Type GFCIs come in several styles, all designed for easy transport. Some are designed to plug into existing non-GFCI outlets, or connect with a cord and plug arrangement. The portable type also incorporates a no-voltage release device that will disconnect power to the outlets if any supply conductor is open. Units approved for outdoor use will be in enclosures suitable for the environment. If exposed to rain, they must be listed as waterproof.

-) **Cord-Connected Type** - The Cord-Connected Type of GFCI is an attachment plug incorporating the GFCI module. It protects the cord and any equipment attached to the cord. The attachment plug has a non-standard appearance with test and reset buttons. Like the portable type, it incorporates a no-voltage release device that will disconnect power to the load if any supply conductor is open. Because GFCIs are so complex, they require testing on a regular basis. Test permanently wired devices monthly, and portable-type GFCIs before each use. All GFCIs have a built-in test circuit, with test and reset buttons, which triggers an artificial ground-fault to verify protection. Ground-fault protection, such as GFCIs provide, is required by OSHA in *addition* to (not as a substitute for) general grounding requirements.

For more information on power tool operation see the [Professional Power Tool Guide](#) website.

Module 3 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

- 1. Which of the following power tools cause the most injuries on the job?**
 - a. Drills
 - b. Saws
 - c. Nail guns
 - d. Grinders

- 2. Which of the following hazards is controlled by using guards on tools?**
 - a. Flying material
 - b. Splashing
 - c. Excessive air pressure
 - d. Too much noise

- 3. Which of the following is the recommended control switch device for powered tools?**
 - a. Positive on-off control switch
 - b. Lock-on control switch
 - c. Instant-release switch
 - d. Constant-pressure control switch

- 4. Which of the following is true concerning the use of the third prong on a plug?**
 - a. Third prongs may be removed to adapt to a two-prong plug
 - b. Third prongs are used in place of a ground wire
 - c. Third prongs must never be removed
 - d. Third prongs are required on all powered tools

- 5. Permanently wired Ground Fault Circuit Interrupters (GFCI) should be tested at least _____.**
 - a. daily
 - b. weekly
 - c. monthly
 - d. annually

Module 4: Electrical Powered Tools

Introduction

The invention of portable electric power tools benefits industry and workers in almost every field. Greater speed, increased production, reduced effort to perform tasks, and—in most cases—greater accuracy are the advantages these tools provide.

However, portable power tools also have hazards. Serious injuries can occur if you do not take precautions.

What are Electrical Power Tools?

Electric power tools include grinders, drill presses, band saws, jig saws, circular saws, belt sanders, electric drills, table saws, radial arm saws, jointers, and paint spray guns.

Employees using electric tools must be aware of several dangers. Among the most serious hazards are electrical burns, shock, and heart failure.

Double-Insulated Tools

Hand-held tools manufactured with non-metallic cases are called double-insulated. If approved, they do not require grounding under the National Electrical Code. Although this design method reduces the risk of grounding deficiencies, a shock hazard can still exist.

Double-insulated tools are often used in areas where there is considerable moisture or wetness. Although the user is insulated from the electrical wiring components, water can still enter the tool's housing. Ordinary water is a conductor of electricity. If water contacts the energized parts inside the housing, it provides a path to the outside, bypassing the double insulation. When a person holding a hand tool under these conditions contacts another conductive surface, an electric shock occurs.

If a power tool, even when double-insulated, is dropped into water, the employee should resist the initial human response to grab for the equipment without first disconnecting the power source.

Best Practices

When using electrical power tools, the general practices discussed below are important and should be followed.

Personal Protective Equipment (PPE) and Clothing

- Wear PPE that is proper for the type of work being done.
- Do not wear gloves when operating a grinder.
- Do not wear loose-fitting clothes or jewelry that can get caught in moving parts.
- Do not roll up long sleeves. If you wear long sleeves, be sure they are properly buttoned.
- Do not wear flammable clothes.
- Wear safety-toed shoes to protect your feet and toes.
- Protect your eyes, face, head, and scalp. Only wear ANSI-approved industrial-quality safety glasses or safety shields.
- Pull back long hair in a band or a cap to keep it from getting caught in moving parts.
- If necessary, use a proper dust, half-face or full-face respirator.

Operation

- Avoid distractions. Keep your mind on your work. Talking, running, pushing, and scuffling can lead to accidents.
- Work only at operating speed. Do not use a power tool before it has reached operating speed or while it is coming to a stop.
- Do not force a tool by applying too much pressure.
- Use both hands. Use both hands to hold and guide material being sawed.
- Stand in a safe location. Position yourself to avoid being hit if the tool kicks back.
- Do not allow wires, chords, or other objects that could get caught in equipment.
- Do not stand directly behind the equipment.
- Keep safety guards in place and proper working order.

- Do not use blades that are cracked or kinked.
- Keep saw blades sharp and set properly.
- Know the switch location so you can turn off the tool quickly.

Before Operation

- Be familiar with the tool by reading the operator's manual. Know tool applications and limitations before you begin to use it.
- Do not use tools that are or appear to be in disrepair.
- Keep the work area clean.
- Keep the floor free of scraps and oil.
- Remove nails, staples, and loose knots before sawing.
- Protect the electrical cord. Keep the power cord out of the line of the cut. Serious shock may result if the cord is cut.
- Make sure there is proper ventilation when using pneumatic tools producing hazardous vapors in confined areas.

After Operation

Never force an object into moving parts to stop the machine.

Do not abruptly stop moving parts. After power has been turned off, allow it to coast to a full stop before laying it down.

Do not leave the machine running unattended.

Make sure all moving parts have come to a complete stop before making tool adjustments.

Always clean power tools and make sure they are in good repair before putting them away.

Watch these two WorkSafeBC videos on Circular Saw Safety: [Video 1](#) [Video 2](#)

Module 4 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

- 1. What is the best type of electrical power tool for use in areas where there is considerable moisture or wetness?**
 - a. Insulated tools
 - b. Double-insulated tools
 - c. Single-insulated tools
 - d. Non-insulated tools

- 2. What should a worker do if a double-insulated tool is dropped into a puddle of water?**
 - a. Go ahead and pick it up, and wipe it off
 - b. Wait at least 15 seconds to pick it up
 - c. Turn off power to the tool and then pick it up
 - d. Pick it up and then turn off power to dry it out

- 3. You notice a worker is wearing gloves while operating a grinder. What should you tell the worker?**
 - a. Don't tell the worker anything as he's fine
 - b. Tell the worker to wear only synthetic gloves
 - c. Tell the worker he should wear only one glove
 - d. Tell the worker to take the gloves off

- 4. You notice a worker placing a circular saw on the ground next to his feet immediately after use. What should you tell the worker?**
 - a. Allow the saw to coast to a full stop before placing on the ground
 - b. Place the saw on a surface other than the ground
 - c. Nothing, the worker is safe
 - d. Place the saw a little farther away from the feet

5. What should you do when using pneumatic tools producing hazardous vapors in confined areas?

- a. Ensure to monitor humidity within the space
- b. Be sure to wear ear plugs
- c. Make sure there is proper ventilation
- d. Avoid producing static electricity

Module 5: Portable Abrasive Wheel and Pneumatic Tools

Portable Abrasive Wheel Tools

One of the most common tools found in any shop, the portable grinder is incredibly useful for grinding and finishing material of all shapes and sizes.

The hazards associated with portable grinders are similar to those of pedestal or bench grinders. The rotating abrasive stone can cause severe abrasions and cuts. There's also the potential for the abrasive stone to shatter and kickback from the spindle end. Other hazards such as flying fragments and sparks are present during grinding.

When using a powered grinder:

- Always use eye or face protection.
- Turn off the power when not in use.
- Never clamp a hand-held grinder in a vise.

Guards

Portable grinders usually come with the manufacturer's safety guard covering most of the wheel.

Exposure to the wheel should not exceed a maximum angle of 180 degrees, and the top half must be enclosed at all times. The guard should be mounted so it maintains proper alignment with the wheel.

Abrasive wheel tools must be equipped with guards that:

1. Cover the spindle end, nut, and flange projections.
2. Maintain proper alignment with the wheel.
3. Do not exceed the strength of the fastenings.

Vertical "right angle" grinders should have a 180-degree guard between the operator and wheel. The guard should be adjusted so that pieces of a broken wheel will be deflected away from the operator.

Cup wheel grinders should be guarded as described above or with special "revolving cup guards," which mount behind the wheel and turn with it.

Wheels

All abrasive wheels must be inspected and “ring-tested” before mounting to ensure that they are free from cracks or other defects. The spindle speed of the machine also must be checked before mounting the wheel to ensure it does not exceed the maximum operating speed marked on the wheel. Always follow the manufacturer’s recommendations.

Check out this [Workbench Grinder Wheel Explodes](#) video.

To test the wheel, do the following:

- Gently tap the wheel with a light, non-metallic instrument.
- If the wheels sound cracked or dead, they must not be used because they could fly apart in operation.
- A stable and undamaged wheel, when tapped, will give a clear metallic tone or ring.

To prevent an abrasive wheel from cracking, it must fit freely on the spindle.

- The spindle nut must be tightened enough to hold the wheel in place without distorting the flange.
- Always follow the manufacturer’s recommendations.
- Ensure that the spindle speed of the machine will not exceed the maximum operating speed marked on the wheel.

An abrasive wheel may disintegrate or explode during start-up. To make sure you do not get injured during startup, do the following:

- Allow the tool to come up to operating speed prior to grinding or cutting.
- Never stand in the plane of rotation of the wheel as it accelerates to full operating speed.

Abrasive wheels must be supplied with sufficient power to maintain the spindle speed at safe levels under all conditions. Do not run a wheel or blade faster than its maximum rated capacity.

Watch these WorkSafeBC videos on Grinder Safety: [Video 1](#) [Video 2](#) Graphic!

Concrete Grinder and Cutters

Construction workers who perform concrete grinding and cutting may breathe dust that contains respirable crystalline silica (RCS).

Grinding/polishing: Dry grinding and polishing is the method most commonly used in the industry. A NIOSH study found that workers dry grinding concrete to smooth poured concrete surfaces were exposed to high levels of dust containing RCS, ranging from 35 to 55 times the NIOSH recommended exposure limit (REL). Wet polishing uses water to cool the diamond abrasives and eliminate grinding dust.

Concrete cutting is a process of controlled sawing, drilling and removing concrete. Skilled operators use special saws to cut concrete and asphalt. As with grinding, dry cutting is most often used. Careful selection of saw blades can help reduce exposure. Diamond saw blades produce less dust and require less water which make them better than abrasive saw blades to cut.

The concrete saw should have a local exhaust ventilation (LEV) system, which can capture the majority of dust emitted during the cutting operation. When operating, the operator should always wear personal protective equipment (PPE).

A local exhaust ventilation (LEV) system can be used to reduce the exposure to silica dust. The LEV system consists of a grinder equipped with a ventilation shroud, a length of flexible hose, and a portable electric vacuum cleaner that acts as a fan and dust collector for the ventilation system.

Real World Accident

An employee was using a grinder to grind a metal pin, when the pin became jammed and drawn into the space between the tool rest and the spinning grinding wheel. The employee's left index finger was also drawn into and against the abrasive wheel, and it was amputated. He was hospitalized. The distance between the tool rest and the abrasive wheel is not known. It is also not known whether the rest was secured in that position. At the time of the accident, the grinder's tongue guard was adjusted to a position 0.875 inches from the wheel. (Source: OSHA)

Pneumatic Tools

Pneumatic tools are powered by compressed air and include chippers, drills, hammers, and sanders.

There are several dangers associated with the use of pneumatic tools. First and foremost is the danger of getting hit by one of the tool's attachments or by some kind of fastener the worker is using with the tool. Be sure to know and comply with the following best practices when working with pneumatic tools:

- Check to see that the tools are fastened securely to the air hose to prevent them from becoming disconnected. A short wire or positive locking device attaching the air hose to the tool must also be used and will serve as an added safeguard.
- To reduce pressure in case of hose failure, make sure a safety excess flow valve is installed if an air hose is more than 1/2-inch (12.7 millimeters) in diameter.
- Take the same precautions with an air hose that are recommended for electric cords, because the hose is subject to the same kind of damage or accidental striking, and because it also presents tripping hazards.
- Install a safety clip or retainer to prevent attachments such as chisels on a chipping hammer from being ejected during tool operation.
- Eye protection is required. Head and face protection is also recommended for employees working with pneumatic tools.
- Screens must also be set up to protect nearby workers from being struck by flying fragments around chippers, riveting guns, staplers, or air drills.
- Compressed air guns should never be pointed toward anyone.
- Workers should never "dead-end," or block the tip of the air gun against themselves or anyone else. A chip guard must be used when compressed air is used for cleaning.
- Do not use compressed air to clean clothing. Cleaning clothing with compressed air can increase the oxygen level within clothing fabric to the point that the clothing becomes extremely flammable. The result may be a fatal injury due to burns.

Noise is another hazard associated with pneumatic tools. Working with noisy tools such as jackhammers requires proper, effective use of appropriate hearing protection.

See this informative video from Guardair Corporation: [Air Gun Safety in the Workplace](#).

Nail Guns

Nail guns are used every day on many construction jobs. They boost productivity but also cause tens of thousands of serious injuries each year. Injuries resulting from the use of nail guns hospitalize more construction workers than any other tool-related injury. When they do occur, these injuries are often not reported or given proper medical treatment. One study found that two out of five residential carpenter apprentices experienced a nail gun injury over a four-year period.

Watch this short video: [Keeping Them Safe – Nail Gun Safety](#).

General safety guidelines

- Review the owner's manual carefully with all operators.
- Observe each employee demonstrating safe operating procedures.
- Always wear safety glasses.
- Do not touch the trigger unless firing the tool against the work piece.
- Use extreme caution when using an air tool around other workers.
- Never point the tool at anyone. Treat the tool like a firearm and assume it's loaded.
- Disconnect the air hose before clearing a jam or making adjustments.
- Use manufacturer's specified pressures for the tool.
- Keep your free hand safely out of the way of the tool.
- Secure the hose when working on scaffolds to prevent the weight of the hose from dragging the tool off the scaffold if you set the tool down.

Trigger selection

Research has identified that the risk of a nail gun injury is twice as high when using a multi-shot contact trigger as when using a single-shot sequential trigger nailer.

Watch these short WorkSafeBC videos on Safe Handling of Nail Guns.

[Video 1](#) [Video 2](#) They're graphic!

Sequential mode and bump mode are the two basic trigger mechanisms used in pneumatic nailers and staplers. It is important to understand the differences between the two triggers in order to prevent injuries. To find out whether your nail gun is a sequential trigger or bump trigger model, fire a nail as usual and keep the trigger depressed. Lift the nail gun and carefully press its nose against the work surface again. If the gun fires a second nail, you have a bump trigger model. If the gun doesn't fire, you have the safer sequential trigger model.

- **Sequential mode trigger.** In the sequential mode, also known as a restrictive trigger or operating in the trigger fire mode, you must first press the nail gun firmly against the workpiece and then press the trigger. One nail is fired and you must release the trigger before you can begin the next nailing cycle.
- **Bump mode trigger.** In the bump mode trigger, also known as dual- action, bottom fire, or contact trip, you must press the trigger before you bring the nail gun into contact with the workpiece. Each time you press the nailer against the workpiece, a nail is fired and a nailing cycle begins. You must keep the trigger pulled while moving the tool along the work surface with a bouncing motion, depressing the safety element where you want to drive a nail or staple. By repeatedly "bumping" the nail gun against the workpiece, you can rapidly fire any number of nails. (Source: OR-OSHA)

Pneumatic tools that shoot nails, rivets, staples, or similar fasteners and operate at pressures more than 100 pounds per square inch (6,890 kPa) must be equipped with a special device to keep fasteners from being ejected, unless the muzzle is pressed against the work surface.

To get more information read the Department of Labor's [Nail Gun Safety – A Guide for Construction Contractors](#) and the [CDC's Straight Talk About Nail-Gun Safety](#).

Jackhammers

Four potentially serious safety and health hazards exist when using pneumatic jackhammers:

- excessive noise
- excessive vibration
- exposure to dust
- being struck by flying objects

Use of heavy jackhammers can cause fatigue and strains. Heavy rubber grips reduce these effects by providing a secure handhold. Workers operating a jackhammer must wear safety

glasses and safety shoes that protect them against injury if the jackhammer slips or falls. A face shield also should be used.

Silica hazard. Construction workers are potentially exposed to hazardous dust containing respirable crystalline silica (RCS) when using jackhammers to break concrete pavement. NIOSH found that such exposures could be reduced by using a water-spray attachment. This low-flow, water-spray control suppressed and reduced dust exposures by 70%–90%. (Source: NIOSH)

Real World Accident

Two employees were using jackhammers to break up a 240-square-meter, 150-millimeter-thick concrete pad located in the center of a round condominium. The employees had used the jackhammers to break the concrete near a high voltage conduit line and were using hammers to break the concrete from around the conduit. One of the employees used a jackhammer to break the concrete over the conduit. The jackhammer slipped, and the employee lost his balance. He fell to the ground, and the jackhammer broke through the concrete and conduit and contacted the three-phase line. The bit of the jackhammer cut all three AWG #2 stranded copper conductors and causing an electrical fault. The ensuing electric arc burned the employee who had been using the jackhammer. The electrical fault also damaged the control cabinet in the fire pump room. The injured employee was treated at a hospital for burns to his face and released the same day.

Watch this short video: [Jackhammer Made Easy Tips](#).

Abrasive Blasting Tools

Abrasive blasting may have several hazards associated with it at any given time. Abrasive blasting is more commonly known as sandblasting since silica sand has been a commonly used material as the abrasive, although not the only one always used.

Abrasive blasting entails accelerating a grit of sand-sized particles with compressed air to provide a stream of high-velocity particles used to clean metal objects such as steel structures or provide a texture to poured concrete. This process typically produces a large amount of dust from the abrasive, anything on the substrate being abraded, and/or the substrate itself.

Safe Work Practices

Using good work practices workers will reduce the risk of exposure to toxic air contaminants and other safety and health hazards associated with abrasive blasting. Safe work practices include all of the following:

- use vacuums equipped with High Efficiency Particulate Air (HEPA) filters or wet methods when removing accumulated dust
- schedule blasting when the least number of people would be exposed
- perform blasting in a specified location that is as far away as possible from other employees
- stop other work and clearing people away while blasting is taking place
- cleaning up paint chips, dust, and used abrasive daily or as soon as possible after blasting has finished
- avoid blasting in windy conditions
- post warning signs to mark the boundaries of work areas contaminated with blasting dust and alerting employees to the hazard and any required PPE

Personal Hygiene

Employers must require that employees use proper personal hygiene practices. These practices are an important control measure for protecting employees from exposure to hazardous contaminants generated during abrasive blasting. Some contaminants, such as lead, are hazardous when inhaled or ingested. Others, such as beryllium, may be hazardous through inhalation and skin contact. Good personal hygiene practices to limit exposure to abrasive blasting dust include the following:

- Prohibit eating, drinking, using tobacco products, or applying cosmetics in abrasive blasting areas.
- Wash hands and face before eating, drinking, smoking, or applying cosmetics.
- Shower before leaving the worksite.
- Change into clean clothing before leaving the worksite.
- Park cars where they will not be contaminated with abrasive blasting dust.

Spray Guns

One of the most frequent types of spray operations is spray painting, with spray booths as a common engineering control used to protect workers. Spray booths serve two main purposes:

1. to protect the health of the painter
2. to reduce fire and explosion hazards

All spraying areas must be provided with mechanical ventilation adequate to remove flammable vapors, mists, or powders to a safe location and to confine and control combustible residues so that life is not endangered.

Mechanical ventilation must be kept in operation at all times while spraying operations are being conducted and for a sufficient time thereafter to allow vapors from drying coated articles and drying finishing material residue to be exhausted.

For more information on using a spray gun, watch this video: [How to Spray: Helpful Tips Before Using Your Paint Sprayer](#). Note the PPE being used while spraying.

Module 5 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

- 1. Which of the following portable tools is most likely going to expose workers to flying objects, abrasions, and cuts?**
 - a. Pneumatic paint sprayer
 - b. Portable grinder
 - c. Hydraulic jack
 - d. Floor buffer

- 2. Exposure to the grinder wheel should not exceed a maximum angle of ____.**
 - a. 90 degrees
 - b. 270 degrees
 - c. 180 degrees
 - d. 45 degrees

- 3. What is the most common hazard when using pneumatic tools?**
 - a. Being cut by high-pressure air stream
 - b. Exposure to excessive noise
 - c. Exposure to dust created by blowing air
 - d. Being hit by a tool attachment or fastener

- 4. Which of the following is not listed as a serious hazard when working with pneumatic jackhammers?**
 - a. Awkward posture
 - b. Excessive noise
 - c. Excessive vibration
 - d. Exposure to silica dust

- 5. What is a potentially fatal hazard associated with cleaning work clothes with compressed air?**
- a. Exposure to cold
 - b. Increased flammability
 - c. Excessive noise levels
 - d. Blowing dust into the air

Module 6: Fuel-Powered, Hydraulic, and Powder-Actuated Tools

Fuel-Powered Tools

Fuel-powered tools are usually operated with gasoline. The most serious hazard associated with the use of fuel-powered tools comes from fuel vapors that can burn or explode and give off dangerous exhaust fumes.

The worker must be careful to handle, transport, and store gas or fuel only in approved flammable liquid containers, according to proper procedures for flammable liquids.

Be sure to follow all of these precautions when working with fuel-powered tools:

- Before refilling a fuel-powered tool tank, the user must shut down the engine and allow it to cool to prevent accidental ignition of hazardous vapors.
- When a fuel-powered tool is used inside a closed area, effective ventilation and/or proper respirators such as atmosphere-supplying respirators must be utilized to avoid breathing carbon monoxide.
- Fire extinguishers must also be available in the area.

Hydraulic Power Tools

The fluid used in hydraulic power tools must be an approved fire-resistant fluid and must retain its operating characteristics at the most extreme temperatures to which it will be exposed.

The exception to fire-resistant fluid involves all hydraulic fluids used for the insulated sections of derrick trucks, aerial lifts, and hydraulic tools that are used on or around energized lines. This hydraulic fluid must be of the insulating type.

The manufacturer's recommended safe operating pressure for hoses, valves, pipes, filters, and other fittings must not be exceeded.

Jacks

All jacks including lever and ratchet jacks, screw jacks, and hydraulic jacks must have a stop indicator, and the stop limit must not be exceeded. Also, the manufacturer's load limit must be permanently marked in a prominent place on the jack, and the load limit must not be exceeded.

A jack should never be used to support a lifted load. Once the load has been lifted, it must immediately be blocked up. Put a block under the base of the jack when the foundation is not firm, and place a block between the jack cap and load if the cap might slip.

To set up a jack, make certain of the following:

- The base of the jack must rest on a firm, level surface.
- The jack must be correctly centered.
- The jack head must bear against a level surface.
- The lift force must be applied evenly.

Proper maintenance of jacks is essential for safety. All jacks must regularly be lubricated. In addition, each jack must be inspected according to the following schedule:

- When jacks are used continuously or intermittently at one site, they should be inspected at least once every six months.
- When jacks are sent out of the shop for special work, they should be inspected when sent out and inspected when returned.
- When jacks are subjected to abnormal loads or shocks, they should be inspected before use and immediately thereafter.

Powder-Actuated Tools

Powder-actuated tools, like “Hilti guns” or “Ramset guns”, operate like a loaded gun and must be treated with extreme caution. In fact, they are so dangerous that they must be operated only by specially trained employees.

Here is a good video on [Fastening basement walls to a concrete floor with a Ramset Gun](#).

Here is a video on operating the [Hilti Powdered Actuated Tools](#).

Powder-actuated fastening tools must be tested each day before loading to ensure that the safety devices are in proper working condition. Any tool found not to be in proper working order must be immediately removed from service until repairs are made.

When using powder-actuated tools, an employee must wear suitable ear, eye, and face protection. The user must select a powder level—high or low velocity—that is appropriate for the powder-actuated tool and necessary to do the work without excessive force.

The muzzle end of the tool must have a protective shield or guard centered perpendicular to and concentric with the barrel to confine any fragments or particles that are projected when

the tool is fired. A tool containing a high-velocity load must be designed not to fire unless it has this kind of safety device.

To prevent the tool from firing accidentally, three separate motions should be used for firing:

1. Bring the tool to the firing position
2. Press it against the target surface (wall).
3. Pull the trigger.

The tool must not be able to operate until it is pressed against the work surface with a force of at least 5 pounds (2.2 kg) greater than the total weight of the tool.

If a powder-actuated tool misfires, the user must hold the tool in the operating position for at least 30 seconds before trying to fire it again. If it still will not fire, the user must hold the tool in the operating position for another 30 seconds and then carefully remove the load in accordance with the manufacturer's instructions. This procedure will make the faulty cartridge less likely to explode. The bad cartridge should then be put in water immediately after removal. If the tool develops a defect during use, it should be tagged and must be taken out of service immediately until it is properly repaired.

Safety precautions that must be followed when using powder-actuated tools include the following:

- Do not use a tool in an explosive or flammable atmosphere.
- Inspect the tool before using it to determine that it is clean, that all moving parts operate freely, and that the barrel is free from obstructions and has the proper shield, guard, and attachments recommended by the manufacturer.
- Do not load the tool unless it is to be used immediately.
- When a tool develops a defect during use, immediately cease to use it and notify the supervisor.
- Do not leave a loaded tool unattended, especially where it would be available to unauthorized persons.
- Keep hands clear of the barrel end.

- Never point the tool at anyone.

When using powder-actuated tools to apply fasteners, several additional procedures must be followed:

- Do not fire fasteners into soft materials unless such materials are backed by a substance that will prevent the pin or fastener from passing completely through and creating a flying missile hazard on the opposite side.
- Do not drive fasteners into very hard or brittle materials such as cast iron, glazed tile, surface-hardened steel, glass block, live rock, face brick or hollow tile.
- Always use an alignment guide when shooting fasteners into existing holes.
- Do not drive a fastener into a spalled area caused by an unsatisfactory fastening.
- When using a high-velocity tool, do not drive fasteners more than 3 inches (7.62 centimeters) from an unsupported edge or corner of material such as brick or concrete.
- When using a high-velocity tool, do not place fasteners in steel any closer than 1/2-inch (1.27 centimeters) from an unsupported corner edge unless a special guard, fixture, or jig is used.

Check out this great [Ramset Powder Actuated Tool Licensing course](#).

Module 6 Quiz

Use this quiz to self-check your understanding of the module content. You can also go online and take this quiz within the module. The online quiz provides the correct answer once submitted.

- 1. The most serious hazard associated with the use of fuel-powered tools comes from _____.**
 - a. strains and sprains
 - b. fuel vapors
 - c. exposure to sharp edges
 - d. being struck by flying objects

- 2. Which of the following is a requirement for the fluid operating hydraulic power tools?**
 - a. It must be a fire-retardant
 - b. It must retain normal characteristics under all pressures
 - c. It must retain its operating characteristics at the most extreme temperatures
 - d. It must be UL approved

- 3. What is the next step once a load has been lifted using a hydraulic jack?**
 - a. The load must be weighed
 - b. A locking pin must be set properly
 - c. Hydraulic pressure should be bled
 - d. The load must be blocked up

- 4. A powder-actuated tool must not be able to operate until _____.**
 - a. it is pressed forcefully against the work surface
 - b. the trigger is cocked using the thumb
 - c. the safety level is released
 - d. the barrel receives adequate release

- 5. If a powder-actuated tool misfires, the user must hold the tool in the operating position for _____ before trying to fire it again.**
- a. up to 15 seconds
 - b. at least 30 seconds
 - c. at least 15 seconds
 - d. up to 30 seconds

Endnotes

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