12
Power Tools

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12.1
Introduction

Power tools are used in both on-the-job and off-the-job applications and have been a common part of our lives for many years. It is easy to forget about the hazards associated with their use. Understanding the potential hazards, recognizing those hazards, and managing those hazards are the key to the safe use of power tools. It is difficult to find exact statistics for the number of incidents and injuries that result from improper use of power tools, but the US National Safety Council (NSC) quoted numbers as high as 250 000 per year back in the 1980s (NSC, 1983) and as low as 125 000 serious injuries in the 2000s (NSC, 2001). Any incident is not acceptable, so it is necessary to provide information to users that will help them avoid all incidents. A list of general safe practices is a start to recognizing methods to control incidents. Brauer (1990) listed the following practices: ''Select the right tool for the job, know the hazards of the tool, use the tools correctly, maintain the tools, and store tools properly.'' Tool design, maintenance procedures, and training in proper use of the tools are some additional practices. The use of appropriate personal protective equipment (PPE) is another important consideration. The user must understand *from information in the tool user manual* what PPE is appropriate, must have it readily available, and must use it every time. The work environment is another consideration. The workplace must be in order with debris control, moisture control, and airborne materials controlled.

The following is a list of power tool precautions (OSHA, 2011; Power Tool Institute, 2011):

1) Never carry a tool by the cord or hose.
2) Never yank the cord or the hose to disconnect it from the receptacle.
3) Keep cords and hoses away from heat, oil, and sharp edges.
4) Disconnect tools when not in use, before servicing, and when changing accessories such as blades, bits, and cutters.
5) All observers should be kept at a safe distance away from the work area as defined by the tool operator manual.

Handbook of Loss Prevention Engineering, First Edition. Edited by J. M. Haight.

6) Secure work with clamps or a vise, freeing both hands to operate the tool.
7) Avoid accidental starting. The worker should hold a finger on the switch button while carrying a plugged-in tool.
8) Tools should be maintained with care. They should be kept sharp and clean for the best performance. Follow instructions in the user's manual for lubricating and changing accessories such as drill bits and blades.
9) Be sure to keep good footing and maintain good balance.
10) The proper apparel should be worn. Loose clothing, ties, or jewelry can become caught in moving parts.
11) All portable electric tools that are damaged must be removed from use and tagged "Do Not Use."
12) Keep the work area uncluttered and maintain adequate lighting. Cluttered and dimly lit work areas invite incidents.
13) Do not operate power tools if there is an explosive atmosphere or near flammable liquids, gases, or dust accumulations. Some power tools are capable of creating sparks, which could ignite dust, vapors, or mists.
14) Bystanders such as children and visitors must keep at a suitable distance when power tools are being used. The potential distractions could result in you losing control.
15) Grounded tools (with three-pronged plugs) are to be plugged into a properly grounded receptacle. Never remove the grounding prong or modify the plug. Avoid using adapter plugs.
16) Double insulated tools have a two-pronged polarized plug (with one blade wider than the other). Do not modify the plug in any way or force it into the receptacle backwards.
17) Make sure AC-only rated tools are not connected to a DC power supply.
18) Store battery packs away from metal objects such as paper clips, coins, keys, nails, and screws. The battery terminals could be shorted together, causing burns or fires and discharging the battery.
19) When using a corded power tool, do not touch grounded surfaces such as pipes, radiators, ranges, and refrigerators. If there were a ground fault in the tool, there is risk of shock if your body is grounded.
20) If there is a potential for damp locations, utilize a ground fault circuit interrupter (GFCI). If the work area does not have a permanent GFCI on the receptacle, use a plug-in GFCI. Wear insulated gloves and footwear.
21) Do not use or leave power tools in the rain or wet conditions.
22) Do not abuse the electrical cord by carrying the tool by its cord or pulling on the cord to unplug it. Firmly grasp the plug to remove it from a receptacle. Protect the electrical cord from chemicals, heat, oil, sharp edges, or moving parts. Tag the tool and replace a damaged cord immediately.
23) Always hold the tool by the gripping surfaces.
24) When using a power tool outside, use an extension cord marked for outdoor use. These cords are made for outdoor use.
25) Extension cords with three-pronged grounding plugs must be plugged into an appropriate three-pronged receptacle.

26) Take damaged or worn cords out of service immediately and replace them.
27) The wire gauge and length of the extension cord must be able to handle the tool electrical load. Check the National Electrical Code (NEC) NFPA 70 for acceptable combinations of length and size based on the current draw (A) of the tool taken from its nameplate.
28) The tool operator's manual must be read and understand along with the tool labels and the instructions packaged with all accessories before beginning the job.
29) Watch what you are doing when using power tools and use common sense. Stop working if something or someone distracts you when using a power tool.
30) Do not operate power tools when you are fatigued or under the influence of drugs, alcohol, or strong medication.
31) Never wear gloves, loose clothes, or jewelry and contain long hair, as these could become entangled in the moving parts of power tools.
32) Keep your power tool handles dry and free from oil and grease and other chemicals to improve your grip.
33) The power tool's switch must be off before plugging the tool cord or hose in or inserting a battery pack.
34) Remove chuck or adjusting keys and wrenches prior to tool operation.
35) Keep a firm footing and balance before starting the job with power tools.
36) Use all appropriate safety equipment. This could include eye protection, a dust mask, non-skid safety shoes, hard hat, or hearing protection. Refer to the operator's manual for the specific eye protection recommended. Protective clothing may also be required.
37) Disconnect power to the power tool before changing accessories or performing maintenance.
38) Hands must be kept away from rotating or moving parts.
39) Do not use the power tool accessories for jobs they were not designed to do.
40) Secure and support the work piece with clamps and on a stable work surface. Holding the work by hand or against your body must be avoided.
41) Make sure all power tool guards are in place and functioning as designed.
42) Use the power tool designed for the job. It will perform the task more efficiently and more safely.
43) Do not rely on strength to perform an operation. If you must use excessive force you may be using the wrong accessory or the tool may be dull.
44) Accessories recommended by the power tool manufacturer are the only ones safe to use. A mismatched tool may become hazardous when used on the wrong power tool.
45) Avoid touching the drill bit, blade, cutter, or other accessory and the work piece immediately after operation: they could be very hot, have a sharp burr, and may result in a cut or burn.
46) Dust collection devices provided with the power tool must be used to control dust and reduce the risk of dust-related exposures.
47) If the on and off switch is malfunctioning, the power tool must be taken out of service and the switch repaired.

48) Before using the power tool, verify that the moving parts are not misaligned, binding, or broken. Any damaged tools must be fixed before being put into service. Follow a maintenance schedule for the power tool based on guidelines provided by the manufacturer.
49) Keep blades and bits sharp and clean and verify that they are not damaged prior to use.
50) Service or maintenance on the power tool must be performed by properly trained repair personnel. Repairs by unqualified personnel could result in a risk of injury due to improper re-assembly where wiring and springs may not be secured correctly.
51) Follow the power tool operator's manual instructions regarding maintenance. Using unauthorized parts and failing to follow the maintenance instructions could create a risk of electrical shock or other injury.
52) Follow the operator's manual when cleaning and lubricating the power tool. Some cleaning agents may damage parts or otherwise lead to future malfunctions.
53) Labels and nameplates on the power tool carry important safety information for the user. The manufacturer can provide replacement labeling and safety decals if they are illegible or missing.
54) Remove power source from power tools before clearing jams or blockages. Jams or blockages should be cleared with a tool designed for that purpose and not the operator's hand.
55) Keep tools out of reach of those not authorized to use them. Store power tools in secure places to reduce the chance of unauthorized use and avoid the possibility of being struck by passersby.
56) When traveling, carry tools in a proper carrying case to prevent the unit from accidentally turning on and to protect the tool from damage. Power tools should not be packed in luggage with personal articles when flying.
57) When working on a ladder, aerial lift, scaffold, or other high places, do not reach out too far.
58) Never reach over power tools while they are operating to avoid possible injury.
59) Keep cords and hoses properly secured and out of the way so they do not become a tripping hazard or result in a tool being pulled to the floor or out of the hands of the operator.
60) Use a battery-operated tool only with the battery pack specified for that unit. Charge the battery for the time limit stated in the operator's manual. Some batteries need to be removed from the charger when fully charged. Check the operator's manual for the specific charging instructions for the particular battery.
61) When charging batteries only use the charger specified for that particular battery pack.
62) Never disassemble the battery pack. Do not incinerate the battery even if worn out or damaged. Follow the operator's manual on the proper disposal procedure for the battery pack.

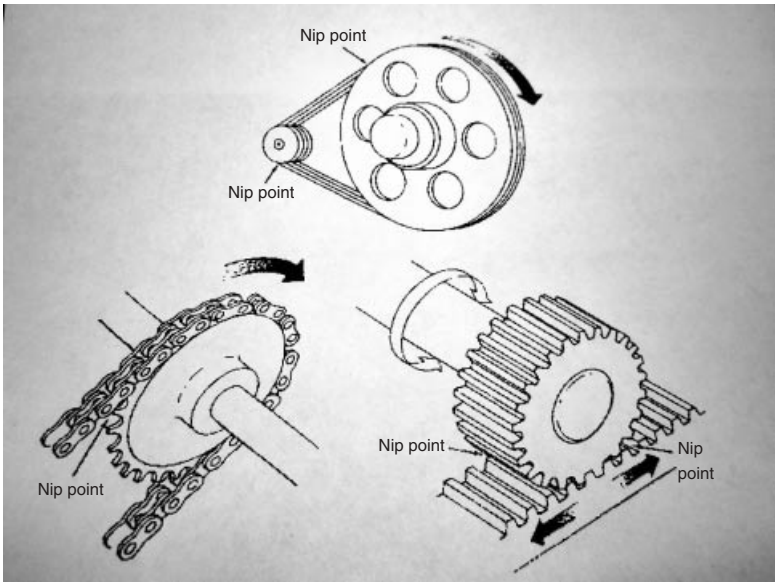

Figure 12.1 Examples of hazards that may need guarding (illustration provided by the author).

63) Never stick anything into the ventilation holes on a battery charger and charge within the stated temperature range for that battery. Disconnect the battery charger from the power supply when not in use. Allow the charger to cool between charges (Terratek, 2010).

The following sections outline some general concerns for consideration when designing, building, and using power tools (OSHA, 2002).

12.2 Guards

The hazardous moving parts of power tools need to incorporate some type of safeguarding (Figure 12.1). If employees can make contact with hazardous devices then those devices must be guarded. Examples are pulleys, gears, belts, drums, sprockets, chains, spindles, fly wheels, and other reciprocating, rotating, in-running or moving parts of equipment. Guards must be provided to protect operators and others from the point of operation, rotating parts, in-running nip points, and flying sparks and chips. The guards must be in place while the tool is being used. Portable circular saws must be guarded. The upper portion under the handle must have a fixed guard. The lower guard is a spring-controlled guard that rides up over the wood while cutting is taking place and springs back into place when the blade clears the wood (OSHA, 2002).

12.3
Safety Switches

The following hand-held powered tools must be equipped with a momentary contact ''on–off'' control switch: drills, tappers, fastener drivers, horizontal, vertical, and angle grinders with wheels with diameter larger than 2 in, disc and belt sanders, reciprocating saws, saber saws, and other similar tools. These tools also may be equipped with lock-on control provided that turnoff can be accomplished by a single motion of the same finger or fingers that turn it on. The following hand-held powered tools may be equipped with only a positive ''on–off'' control switch: routers, planers, laminate trimmers, nibblers, shears, scroll saws, and jigsaws with blade shanks $^1/_4$ in or less. Other hand-held powered tools such as circular saws having a blade greater than 2 in, chain saws, and percussion tools without positive accessory holding means must be equipped with a constant-pressure switch that will shut off the power when the pressure is released (OSHA, 2002).

12.4
Electric Tools

People using electric tools must be aware of the dangers, the most serious being electrocution. The primary hazards of electric-powered tools are burns and slight shocks, which can lead to injuries and even heart failure. Under certain conditions, even a small amount of current can result in fibrillation of the heart and eventual death. A shock also can result in the user falling from an elevated work surface such as a ladder or scaffold due to the sudden contraction of muscles. To protect the user from shock, tools must either have a three-wire cord with ground and be grounded, be double insulated, or be powered by a low-voltage isolation transformer which reduces the line voltage to 12 V at the tool. Three-wire cords contain two current-carrying conductors and a grounding conductor. One end of the grounding conductor connects to the tool's metal housing. The other end is grounded through a prong on the plug. Whenever an adapter is used to accommodate a two-hole receptacle, the adapter wire must be attached to a known ground. The third prong grounding lug should never be removed from the plug. Double insulation is more convenient where the user and the tools are protected in two ways: by normal insulation on the wires inside, and by a housing that cannot conduct electricity to the operator in the event of a malfunction. The following are some general practices that should be adopted when using electric tools: electric tools should be operated within their design limitations; gloves and safety footwear are recommended during use of electric tools but glove use must be evaluated to assure it is not a hazard with the tool; when not in use, tools should be stored in a secure, dry place; corded electric tools should not be used in damp or wet locations; and work areas should be well lit. In the construction industry, employees who use electric tools must be protected by GFCIs or an assured equipment-grounding conductor program

whereby the integrity of the equipment grounding is verified on a periodic basis and documented (OSHA, 2002).

12.5
Powered Abrasive Wheel Tools

Powered abrasive grinding, cutting, polishing, and wire buffing wheels create special safety problems because they may throw off flying fragments. Before an abrasive wheel is mounted, it should be inspected closely and be sound or ring tested by the operator to be sure that the wheel is free from cracks or other defects. To test, wheels should be tapped gently with a light non-metallic instrument. If they sound cracked or dead, they could fly apart in operation and so must not be used. A sound and undamaged wheel will give a clear metallic tone or ring. Some newer types of wheels must be tested with an ultrasonic test instrument to detect any damage to wheel integrity. To prevent the wheel from cracking, the user should be sure that it fits freely on the spindle. The spindle nut must be tightened enough to hold the wheel in place, without distorting the flange. Follow the manufacturer's recommendations. Care must be taken to assure that the spindle wheel will not exceed the abrasive wheel specifications for maximum speed. Owing to the possibility of a wheel disintegrating (exploding) during start-up, the employee should never stand directly in front of the wheel as it accelerates to full operating speed. Portable grinding tools need to be equipped with safety guards to protect workers not only from the moving wheel surface, but also from flying fragments in case of breakage. The guards should cover the spindle, nut, flange, and at least 75% of the wheel diameter. When using a powered grinder, always use proper eye protection, turn off the power when not in use, let the wheel come to a stop before laying the tool down, and never clamp a hand-held grinder in a vise (OSHA, 2002).

12.6
Liquid Fuel 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 also give off dangerous exhaust gases. 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. 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 fuel-powered tools are used inside a closed area, effective ventilation and/or proper respirators such as atmosphere-supplying respirators must be utilized to avoid breathing carbon monoxide. Monitoring of the atmosphere can provide a warning of the levels of carbon monoxide being encountered. Fire extinguishers must also be available in the area (OSHA, 2002).

12.7
Pneumatic Tools

Pneumatic tools are powered by compressed air and include chippers, drills, hammers, impact wrenches, and sanders. Several dangers may be encountered in the use of pneumatic tools, the main one being the risk of being hit by one of the tool's attachments or by some kind of fastener that the worker is using with the tool. Eye protection is required and face protection is recommended for employees working with pneumatic tools. Substantial clothing should also be worn to cushion any errant tool to the body. Noise is another hazard, and working with noisy tools such as jackhammers requires proper, effective use of hearing protection. When using pneumatic tools, employees must check to see that they are fastened securely to the hose to prevent them from becoming disconnected. A short wire or positive locking device attaching the air hose to the tool will serve as an added safeguard. If the diameter of an air hose is more than $^1/_2$ in, a safety excess flow valve must be installed at the source of the air supply to reduce pressure in case of hose failure. In general, the same precautions should be taken 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. A safety clip or retainer must be installed to prevent attachments, such as chisels on a chipping hammer, from being unintentionally shot from the barrel. Pneumatic tools that shoot nails, rivets, staples, or similar fasteners and operate at pressures more than 100 lb in^{-2} (psi) must be equipped with a special device to keep fasteners from being ejected, unless the muzzle is pressed against the work surface. Screens must be set up to protect nearby workers from being struck by flying fragments from chippers, riveting guns, staplers, nailers, or air drills. A compressed air gun should never be pointed towards anyone. Users should never dead end it against themselves or anyone else. A chip guard must be used when compressed air is used for cleaning. 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 should also be used. Airless spray guns that atomize paints and fluids at pressures of $\geq$1000 psi must be equipped with automatic or visible manual safety devices that will prevent pulling the trigger until the safety device is manually released (OSHA, 2002).

12.8
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 fluids involves all hydraulic fluids used for the insulated sections of derrick trucks and aerial lifters, and hydraulic tools

Figure 12.2 Portable hand-held circular saw (photograph provided by the author).

that are used on or around energized lines. This hydraulic fluid should be of the insulating type. The manufacturer's recommended safe operating pressure for hoses, valves, pipes, filters, and other fittings must not be exceeded. Hoses that are operated under high pressure must be inspected for small leaks that could inject hydraulic fluid into a worker's body with dangerous or fatal consequences (OSHA, 2002).

Some considerations for managing the use of the tools such as purchase, training, maintenance, and storage are outlined in the following. Power tools have duty cycle considerations affecting tool life and reducing downtime due to tool failure. Tools that will be used frequently must have a duty cycle to match the expected use. They will cost more but will last longer and provide a better quality output. Heavy duty tools are often called industrial duty tools and provide a longer service life and reduce operator effort in their use (Kurtz, Welchel, and Hagan, 2001). The organization will need to train the operators, maintenance, and managers on the proper use of the tools. This can be done internally, in external classes through the tool suppliers, in vocational schools, or using an online supplier of training explaining the fundamentals, latest technology, and proper use of the tools (TPC Training Systems, 2011). The organization must put in place a distribution, inspection, and maintenance program to assure the best use of the tools. A storage and distribution program can help keep the tools in good condition or assure they are rapidly repaired and maintained so they are available when needed. This is an important function because it helps assure that the proper tool is used and when tools are damaged they will receive critical maintenance by trained repair people and not by the operator, who may not be adequately trained. A regular cleaning program will improve the tool life and improve operator confidence in following established procedures because the proper tool will be clean and available in working order when it is needed (Walton, 1961; Kurtz, Welchel, and Hagan, 2001).

Some examples of power tools are presented below.

12.8.1 Portable Hand-Held Circular Saw

The term applies to an electric circular saw weighing up to 10–12 lb (4.5–5.4 kg) (Bies, 1989) (Figure 12.2). It is used primarily to cut wood in its various forms but

with different types of properly designed blades can cut many other materials. The base of the saw is adjustable both in depth of cut and in angle of cut. The blade may be mounted directly to the motor shaft or through a set of worm gears to provide more blade torque for jobs requiring the extra torque for job efficiency. There are multiple handle arrangements to improve the operator's control of the saw in various modes, and some have laser lights to help guide the saw through a cut accurately. There is a track system available where the saw is mounted to a sliding frame that allows the operator to move the saw across a large piece of lumber and avoid having to move the heavy lumber through the saw and maintain a straight cut without binding the blade. The most frequent blade diameter is $7^1/_4$ in (185 mm) with either a high speed steel or a tungsten carbide-tipped cutting edge. Specialized saws are available with smaller blades for unique uses. When selecting a saw for the job, consider the duty cycle to assure that the saw selected will stand up to the level of use being experienced. This will provide some assurance of job quality throughout the tool life. In addition, a tool inspection and maintenance program must be in place to verify that the tool is always ready to do the job intended and will not become a hazard due to some unforeseen defect. The training program should include information included in the user's manual and a reporting process whereby the operator takes action if trouble is encountered during the tool's use, including reporting of the issue encountered and taking the saw out of service if the concern is serious. When using a circular saw, the operator must wear impact-resistant safety glasses, a dust mask when encountering dusty cuts, and hearing protection. Gloves and safety shoes with gripping soles are also important, and loose clothing, jewelry, and long uncontained hair that could get caught during the cutting operation should be avoided.

The following is a list of issues that need to be considered when planning on using a portable hand-held circular saw:

1) Make sure that the blade is the right size and is at the right speed for the saw and that the blade is clean and sharp. Never use a damaged blade that may be cracked, bent, or warped – these conditions may cause injury and property damage. Follow the manufacturer's recommended sequence for mounting the blade using the proper washers and spring washers. Tighten the blade screw securely in a clockwise fashion.
2) Support large panels in such a manner as to prevent the panel bending where the cut is occurring. Use a rip fence or straight edge to help make large cuts smoothly and avoid binding of the blade.
3) Check the blade guards for proper operation prior to each use – there may have been a small particle that has rendered the guard inoperable. Use the lower blade guard handle to move the guard manually to verify its proper operation. The depth and angle adjusting nuts must be tight before use.
4) The work piece must be secured with some type of clamping process. Check that the power cord is not in the path of the cut. To avoid kickback, take the proper precautions as the cut is planned. The blade depth should be no more than $^1/_8 - ^1/_4$ in greater than the thickness of the work piece. Make sure the

Figure 12.3 Portable angle grinder (photograph provided by the author).

saw base or shoe is resting on the clamped portion of the work piece so that when the end of the cut is reached the cut-off piece will not be supporting any of the saw's weight. Use both hands on the saw handles and start the blade up to full speed before making contact with the work piece. If the saw binds in the work piece, release the switch and allow the blade to stop rotating before removing it from the work piece. To restart the cut, set the blade in the kerf and make sure that the blade is free to rotate before restarting the cut.

5) When finished with the cut, allow the blade to come to a stop before setting it down. It may be necessary to use a respirator to control dust exposure and hearing protection must be used to control noise levels. Safety goggles must also be utilized to avoid dust particles getting into the eyes.
6) Other unusual uses must be applied following the information given in the operator's manual provided by the manufacturer with the power tool. Rip cut, bevel cut, and pocket cut are some examples of other uses (Craftsman, 1996; Hoerner and Bettis, 1998; Dodds, 2005; Harbor Freight Drillmaster, 2006).

12.8.2 Portable Angle Grinder

The motor, which may be electric, gasoline, or compressed air drives a head with a set of gears to achieve the right angle position (Figure 12.3). Various types of abrasive discs are attached to the head along with a guard and side handle to help maintain better control of the tool during use. Typical disc sizes range from 4 to 12 in (100–300 mm) (Bies, 1989) and can be used in metalworking, construction, and emergency rescue by fire and rescue teams. The various types of discs include polishing, grinding, sanding, and wire brush wheels. The thinner sanding disc usually have some kind of plastic or rubber backing disc to help provide uniform pressure while using the disc. There are a large variety of grinder combinations available, some with more powerful motors and size of the disc for the job. One important consideration is to make sure that the recommended disc rotation speed is equal to or less than the no-load spindle speed to avoid the disc flying apart and causing injury and damage. Small precision grinders are generally air operated to

keep the size and weight down. Noise is always a consideration and the operator must plan on using some type of adequate hearing protection.

The following issues need to be considered:

1) Review the operator manual supplied with the tool prior to use to become aware of any unique requirements for the tool.
2) Before using an angle grinder, it should be inspected to be sure that it is in good condition, the disc is properly attached and does not have damage or cracks, and the guard is properly attached.
3) Wear appropriate PPE for the job; it should include safety goggles and hearing protection, and, depending on the material being ground, may require a dust mask.
4) Accessories must be properly attached with the supplied hardware in the proper sequence to prevent damage to the accessory and the tool. Only use accessories designed for the unit – makeshift accessories may fly apart and injure the operator or damage the tool. Use any specially supplied holding tools when assembling the accessories to assure proper tightness of fasteners. When first starting the tool after attaching a new accessory, let the unit run for a minute or so to determine that the unit is operating normally. Move the tool with the sanding or grinding medium slowly to the material being worked to avoid damage to the tool, media, and work piece. Make the cut slowly and do not try to make the cut too deep, which could potentially jam the tool or grinding wheel. The work piece must be secured so that it cannot be thrown and cause injury or damage.
5) Make sure the grinder is not too heavy to control while performing the task; if the unit is large and heavy, a balancing holder may be required to offset some of the weight.
6) Position the tool so that the open end of the guards faces away from the operator in case the wheel should shatter or the work piece should become dislodged. Keep the power cord out of the way of the accessory tool to avoid damaging the cord and possibly electrifying the tool and work piece. Be aware of spark generation which may require getting a burning permit before starting to avoid causing a fire.
7) When using a cut-off wheel, let it stop in the part being cut if there is a need to stop. When returning to complete the cut, bring the wheel up to speed before inserting it back into the cut and re-enter slowly.
8) It is important to use the supplied side handle to keep firm control of the grinder when making the various cuts and avoid damage to the tool and work piece.
9) If the tool is air powered, make sure that the speed control device is operable – check the speed with a tachometer after maintenance has been performed. It is important that the speed be known so that the accessories can be matched to the speed of the unit. The tag on the tool should have the speed (rpm) listed – if the tachometer reading does not match the tag, then the unit must be taken out of service and repaired.

Figure 12.4 Portable drill/driver (photograph provided by the author).

10) Keep debris away from cooling holes in the tool's housing to allow the tool to cool properly. Conductive debris can cause malfunction of the unit and possibly create a short.
11) If the unit is supplied with brushes, they may need to be changed. The maintenance department would be expected to perform this task (Harbor Freight Chicago Electric, 2011; Kidd, 2011).

12.8.3 Portable Drill/Driver

This is a motorized tool that can be fitted with drill bits or driver bits with screw driver tips or nut driver tips (Figure 12.4). Some examples are the corded electric drill, cordless battery-driven drill, and rotary hammer drill. There are larger drills (augers) used to dig post holes that are powered with small internal combustion engines. The drills can also be driven with compressed air. Most of these drills have a pistol grip, but there are special right-angle and straight-body drills for specialized applications. There are highly specialized drills for the medical and dental industry and also the space flight zero gravity environment. Rotary hammer drills are used to drill into concrete or masonry and utilize a hammering action through special bits to break up the material. Many of the cordless drill models use a keyless chuck for quick drill/driver changes and an adjustable clutch to control the tool's torque to allow driving fasteners without damaging the fastener or the material being driven into, and may have a variable-speed trigger to aid in starting fasteners. Some drills have a small LED light to illuminate the area where the drill or driver is working and this feature is a useful aid when working in tight areas where lighting is at a premium. Some models have a bubble level to help make sure the drill is going into the material at a right-angle. Batteries may discharge quickly when doing a lot of work so it is important to invest in the quick charge variety so that batteries can be taken out quickly and recharged to keep the job moving. Nickel–cadmium batteries have some disadvantages, including disposal issues, limited life, and a tendency to self-discharge. Lithium ion batteries are quicker to charge, light weight, and have a longer life coupled with a shorter charging time. However, they are more expensive

than the alternatives, have reduced performance in cold conditions and cannot be recharged as frequently as the nickel–cadmium or nickel–metal hydride (NiMH) batteries.

The following issues should be addressed:

1) Make sure that the drill bit is designed for the material being worked and that the bit is sharp. Also verify that the drill has the capacity to handle the drill bit being used.
2) The drill trigger or control switch should be in its locked position while changing or adjusting the drill bits.
3) When inserting the drill bit into the drill, check to make sure that it is straight and not sideways. Tighten the check jaws so that the bit is firmly grasped. If the jaws are keyless, grasp with the hands and tighten; if the chuck uses a chuck wrench, tighten at all locations around the chuck to assure a secure bit.
4) If the drill has an adjustable torque clutch, make sure it is set for the task to be performed. Generally, the harder the job the higher is the number to be used on the torque ring.
5) Some materials should be center punched before beginning so that there is a starting point for the drill point. Starting with a slower speed on variable-speed units can help keep the bit centered on the starting point. The material being worked must be secured so that it does not rotate when the drill starts cutting and breaks through. Be prepared for the bit to grab, especially when drilling metal. Do not force the bit into the material: apply steady pressure as the job progresses. If the bit stalls in the material, stop the drill and determine the reason for the stall. Do not use the drill to enlarge the hole by using side pressure – use a larger bit to achieve the desired opening size. A second piece of scrap material clamped to the bottom of the primary material may help reduce the possibility of the bit grabbing when it breaks through the primary material. If a large hole is being drilled, a pilot drill hole can make the job work much better.
6) Use an auxiliary handle if supplied to help control the drill as it progresses through the material. Along with a proper stance, the drilling operation will be lea likely to cause problems for the operator, especially when breaking through the material being drilled.
7) If the bit becomes jammed in the work piece, stop the drill and remove the drill. It is not acceptable to try to force the drill through the bind by starting and stopping the drill unit. The bit may become damaged and the drill may twist and injure the operator.
8) When using the drill to drive fasteners, select the right tool for the job and set the torque clutch for the fastener and material being worked on. Take advantage of the variable-speed control to get the fastener started and keep steady pressure on the tool so that it does not ''walk'' out of the fastener. Choose a fastener that is compatible with the material holding the fastener and prepare the material to receive the fastener in the most efficient manner without damaging the material or the fastener. An example is a Torx head

Figure 12.5 Portable sander (photograph provided by the author).

versus a Phillips head fastener (Craftsman, 2002; Terratek, 2010; Kidd, 2011; Harbor Freight Chicago, 2007).

12.8.4 Portable Sanders

These are portable tools that can be used to smooth surfaces for various reasons. They consist of some type of driver with a sanding head attached (Figure 12.5). The driver rapidly moves the sanding medium in various directions to smooth or abrade the surface being worked. The surface generally is wood or metal but could be drywall, plastic, and even glass. The driver and sanding head are designed to achieve the desired results such as orbital sander, straight-line sander, random orbit sander, detail sander, flap sander, belt sander, and disc sander. The unit should have a means of attaching a dust collection vacuum to help control the dust that is generated when sanding. A sanding device such as orbital sander that is sized for the job being performed should be chosen for optimum efficiency and reduced fatigue for the operator. This unit hooked to a dust collection unit is a good fit for finishing drywalls, allowing access around fixtures and in corners.

Some additional requirements and/or recommendations are as follows:

1) Use some type of appropriate device to hold the work piece securely while the sanding operation is being performed, such as ''C'' clamps or adjustable wood clamps. When sanding on metal, make sure that the potential sparks generated do not ignite nearby combustible materials. When using a dust control system, make sure that it can safely handle combustible dusts. Do not use the system when sanding on metal, which could create a spark stream and lead to fire. Make sure that the sandpaper has holes that line up with the dust control portion of the sander.
2) On orbital sanders, the sandpaper is attached to the sander with a system of hooks and loops on the backing pad. Make sure that the sandpaper holes line up with exhaust collection holes on the backing pad before hooking the loops.
3) Start the unit before making contact with the work piece to be sure the sandpaper is adequately secured to the backing pad. Make contact with the work

piece gently and move the unit in the direction of the grain when sanding wood. Choose a grade of sandpaper that best meets the level of material removal – a coarser grit for heavy material removal and lighter grit for fine sanding. Depending on the aggressiveness of the removal process and the quality of the sandpaper, check for the optimum time to replace the sandpaper to achieve the most efficient use and best surface finish.

4) When using a belt sander, have the right sized belt for the unit and adjust the tension lever to hold the belt in place. Observe the moving belt and use the tension adjuster to center the belt on the unit. Hook up the dust control bag or vacuum hose. When starting the job, hold the unit with both hands, start the unit, and allow the rear of the unit to make contact with the work piece first. Move the unit back and forth in the direction of the wood grain and overlap slightly the previous track until fully sanded. Change the grit of the belt to achieve a smoother finish. When removing the unit from the work piece, let the unit stop completely before setting it down.
5) On a disk sander, make sure that the speed limit of the accessory sanding or polishing pad is greater than the maximum no-load speed of the driver. When sanding, avoid putting too much pressure on the unit and let the sandpaper abrade the material. If it is metal, be aware of any spark field and keep it clear of combustible materials. When using the sander with a polishing head, start the unit with the polishing bonnet against the work piece to control the bonnet and keep it from possibly flying off the unit. When waxing, apply the wax to the pad, not the surface being waxed, to avoid the wax being thrown off by the spinning wax head.
6) When attaching sandpaper to a finishing sander, follow the operator instructions on how to open and close the sandpaper clamps and obtain the proper tension on the paper.
7) The sequence when doing a wood sanding project is to start with a belt sander for the heavy work, move to an orbital for the intermediate stock removal and finally a finish sander to obtain the smooth finish desired. This is the most efficient way and to avoid overheating or damaging units when taking too much stock off the work piece, an example being starting with an 80 grade coarse sandpaper, moving up to the finer grades of finishing sandpaper, and at the same time considering the grain direction to obtain the best finish in line with the wood grain (Hoerner and Bettis, 1998; Dodds, 2005; Harbor Freight Chicago Electric, 2003, 2005).

12.8.5 Reciprocating Saws

This versatile saw can be used to cut wood, pipe, plastic, and metal (Figure 12.6). Proper blade selection is important when preparing to use the device. It can be used in any direction and the approximate 1 in stroke length generally has multiple speeds and can be cord or battery powered. It is especially useful for making openings in existing surfaces for insertion of some addition such as a window,

Figure 12.6 Reciprocating saw (photograph provided by the author).

duct, or access port. It also comes in handy for minor demolition and repairs of old buildings, for example, where pieces of deteriorated material need to be removed. With the proper blade it can also be used for pruning trees and shrubs. Manufacturers have designed an array of units that have characteristics for almost any job. Choose the unit or units that best fit the tasks that are most frequently undertaken. These units have the ability to plunge cut or start their own hole, but it is important to read the instructions to avoid injury and damage to the unit. Choosing a double insulated model will provide some additional protection in case a live wire should be encountered when cutting into an existing wall or during demolition work. It is not perceived as a precision device, but with careful use and proper clamping reasonably precise cuts can be made. The cutting action is from the bottom to top so the finish side of material should be face down for the cleanest look. This tool has aggressive action, so where it is expected to be used there needs to be an adequate area for footing and forethought in placement of utilities behind the wall, for example. This tool can be used to cut holes in walls for installation of electrical and plumbing fixtures. Cutting the hole for a sink in a countertop is an example.

Some additional requirements and/or recommendations are outlined below:

1) It is important to use a blade that is matched to the work and to be sure that the blade is sharp. The method of attaching the blade to the saw must be followed to prevent injury and equipment damage. Read the blade attachment instructions for the particular unit being used. Use the shortest blade that will cut the material to reduce the potential for blade breakage.
2) When making a plunge cut or starting a hole, rest the shoe on the material with the blade parallel to the surface, start the unit and slowly rotate the blade into the material until it penetrates the surface and the shoe is flat against the material. It is not recommended to plunge cut metal: drill a hole large enough for the blade to fit. Move the blade in the desired direction with sufficient pressure to cut smoothly and not overload the unit.
3) When beginning a job, if the unit is corded be sure that the cord is out of the way of the cut and is long enough to avoid snagging. When withdrawing from a cut, let the blade come to a stop before attempting to pull the blade out. Smaller pieces must be securely clamped down before sawing – be sure the

Figure 12.7 Electric impact wrench (photograph provided by the author).

projected saw cut line does not cut through the clamping mechanism. When cutting light sheet metal or plastic, the material can be sandwiched between wooden panels to reduce the chance of vibration and damage to the material being cut.

4) Be aware of your body parts when using the saw and make sure that contact is not made. The saw blades are sharp and may be hot from a vigorous cut. When completing a cut, let the unit come to a complete stop before the saw is laid down. When finished, the blade should be removed and the unit cleaned up before it is stored in a proper storage case.
5) Before using a reciprocating saw, the operator's manual should be read and understood. All appropriate PPE must be used. Any hazardous materials that are cut may require special PPE for controlling the unique hazard being encountered. Examples include safety goggles, hearing protection, and gloves to help control vibration (Craftsman, 1999; Burch, 2008).

12.8.6
Impact Wrench – Air and Electric

These devices (Figure 12.7) are designed to remove and install nuts and bolts without the reaction torque that would result if it were a direct drive motor. The units create noise levels that must be considered. They can be very helpful in loosening nuts and bolts that have been in place for some time. The hammering action helps to break them loose whereas a regular wrench might round off or otherwise damage the fastener. The heavy duty tools are generally air operated, but light duty units can be cord operated or use a battery pack. When designing equipment where this tool is expected to be used, there must be adequate clearance to allow the tool to make proper contact with the fastener being removed.

There are some additional requirements and/or recommendations:

1) Impact wrenches require specially made tools that are designed to withstand the impacts without premature failure. Check the tools prior to use for any damage that might result in injury or damage to the work piece. Air-operated wrenches should not be operated unless the socket is in contact with the nut or

Figure 12.8 Electric saber saw (photograph provided by the author).

bolt being tightened/loosened because the socket can become dislodged from the wrench and cause injury or damage.

2) When using air-operated wrenches, make sure that the air supply is of sufficient pressure and flow rate to operate the wrench adequately. Only use air from an air compressor not from gas storage bottles. Hoses and connections should be leak free and compatible.
3) When using the wrench to loosen a stuck fastener, use short bursts of the unit and reverse the direction of the unit to help work the fastener loose. Always let the unit stop rotating before engaging the reversing lever. The work piece must be secured before using the impact wrench to retain control of the work piece. When loosening lug nuts on a vehicle, break them loose only until the weight of the vehicle has been removed.
4) When using an electric wrench, keep the cord out of the way so that it does not become entangled around the driver. The battery pack should not be installed until the unit is ready to be used. Only make torque change adjustments on the wrench when the power has been removed to avoid damage to the mechanism.
5) Before using an impact wrench, read and understand the operator's manual. Utilize all PPE that is recommended for the job and any other that may be appropriate if unusual conditions are encountered. When finished using the device, disconnect the power supply, remove the driver sockets, and clean and store the unit in an appropriate storage case (Hoerner and Bettis, 1998; Burch, 2008).

12.8.7 Jigsaw/Saber Saw

These devices (Figure 12.8) have many uses but probably do the best work in cutting circles or curves. The devices can have up to a 1 in stroke and are cord and battery powered. Many features are available, depending on the job requirements. The base can be adjusted for an angular cut and there are quick-change blade systems and adjustable orbital blade cutting action. Some units have blade speed adjustments. The type of blade used is dictated by the work to be accomplished.

These units can start a hole similar to the reciprocating saw. Different materials will call for different blades and also the number of teeth per inch for specific conditions. A good rule of thumb is that at least two teeth should be in contact with the material being worked at any one time. A thin, fine tooth blade is best for curves, for example. There are attachments available to aid in cutting circles and also other aids to help in freehand cutting.

Some additional requirements and/or recommendations are the following:

1) Before beginning to attach or remove the blade or change other adjustments, be sure that the unit is unplugged or the battery pack has been removed. As with all saws, a sharp blade is important to a good cut and avoiding operator injury and work piece damage. Be certain that the blade is not bent or otherwise damaged before starting the cut. The blade and all other adjusting devices must be secure before starting the unit.
2) Care must be used with the lock-on type of switch. It must be off before supplying power to the unit and should be disengaged before pulling the saw out of the work piece. When beginning the cut, let the unit reach the operating speed and then slowly advance the blade into the work piece following the mark of where the cut is desired. Do not force the saw but let the blade action do the work, but do keep pressure down on the unit to keep it from jumping on the work piece. For plunge cutting, review the instructions supplied with the saw for the proper procedure.
3) The base can be adjusted for angular cuts and to cut up to a wall or front edge of a work piece. The base adjustments must be made with power sources disengaged.
4) If the saw must be removed in the middle of a cut, allow the blade to come to a stop and then remove the unit. When restarting in the same cut, insert the blade into the cut and put pressure down on the saw before engaging the power switch.
5) Before beginning to use a saber saw, read and understand the operator's manual. Utilize any PPE that is recommended for the unit by the manual and any other PPE that might be dictated by unusual job conditions being encountered. When the job is completed, remove the power supply, remove the blade, and clean and store the saw in a storage case (Hoerner and Bettis, 1998; Harbor Freight Drillmaster, 2001).

12.8.8 Multifunction Power Tool

This is a relatively new device (Figure 12.9) that oscillates at up to 20 000 strokes per minute and with an appropriate attachment can be used to cut, scrape, and sand materials such as wood, metal, plastic, drywall, and ceramic tiles, among others. The devices are available as corded and cordless and some have variable-speed oscillations. The units are light weight and provide a lot of flexibility to the operator with a need that meets the capability of the device. This tool is most appropriate for smaller

Figure 12.9 Multifunction power tool (photograph provided by the author).

jobs such as maintenance functions rather than basic construction jobs. Modifications to existing jobs represent another use, such as adding a deadbolt lock to a door.

Some additional requirements and/or recommendations are summarized below:

1) When attaching the array of attachments available for this device, either have the cord unplugged or have the battery pack removed.
2) The attachments can be mounted in many positions on the main spindle. Determine the best direction for the job being attempted and make sure that the spindle tabs are in the holes on the attachment before tightening the spindle bolt or cap screw.
3) The device should be allowed to reach full operating speed before it makes contact with the work piece. Apply sufficient pressure to make the attachment do its job but do not put excessive pressure on the unit to avoid damage to the unit and the work piece and heat buildup. The material and attachment combination must be considered to determine the optimum pressure. Be aware of nails or other fasteners so as to avoid making contact with the attachment unless the fastener is the target of the task.
4) Before using this device, read and understand the operator's manual supplied with the unit. Wear appropriate PPE based on the manufacturer's recommendations and the materials being worked with. Some materials may require additional PPE. Examples of PPE are safety goggles, gloves for vibration, and dust mask or respirator that is matched to the various materials being worked (Harbor Freight Chicago Electric, 2009).

12.8.9 Heat Gun

A heat gun (Figure 12.10) can emit from 500 to 1100° F of flameless heat that can be use for the removal of paint and floor tiles, soften materials such as putty or caulking, thaw frozen pipes, bend plastic pipe and sheets, and shrink the shrink tubing available for securing wiring and wiring connections. The units get hot, so it is important to observe the areas of the gun where the heat is concentrated. There is an array of tools available to help in the removal process.

Figure 12.10 Electric heat gun (photograph provided by the author).

Some additional requirements and/or recommendations are as follows:

1) Before starting, examine the unit for any damage and check that any attachments such as heat concentrator cone are secure.
2) If stripping paint, for example, be sure that the area has been cleared of any flammable liquids or other flammable or combustible materials. Check behind areas to be stripped for any hidden flammables.
3) The work area should be cleared so that there is access to the work piece. Loose clothing can become involved with the heat, so avoid this when using a heat gun. If the gun has not been used for some time, the initial startup may result in smoke and odors being emitted – allow them to burn off. If the internal fan appears not to be working, the unit should be taken out of service and repaired as necessary.
4) Proper use of the gun to avoid damage to the work piece requires the operator to keep the gun moving and to adjust the distance from the work piece to get the job done with the least potential for damage. All openings on the gun must be kept open to prevent the unit from overheating.
5) When finished with the job, the gun should be temporarily stored in a position to allow it to cool to an acceptable level. Any attachments must be removed and the unit stored in a storage container.
6) Before attempting to use the heat gun, the operator's manual must be read and understood. All appropriate PPE must be available and used. Some materials being heated may emit gases or vapors that will require the operator to wear a proper respirator. This should be determined in the job planning process to avoid exposure to hazardous substances such as lead-based paints, crystalline silica, arsenic, and chromium (Harbor Freight Drill Master, 2007; Ace Hardware, 2012).

12.8.10 Portable Air Compressor

Portable air compressors (Figure 12.11) have many uses in small shops, auto repair shops, and home workshops. There are many models available to choose from that

Figure 12.11 Portable air compressor (photograph provided by the author).

best fit the anticipated use. They can be used to inflate toys and air mattresses, grind, run impact wrenches, nail/staple guns, and liquid spray guns, and inflate tires. Their advantage are their small size and relatively quiet operation. When choosing a unit, analyze the intended use and be sure that the air pressure and cubic feet per minute will adequately drive all the attachments anticipated. There are two-stage units, oil-less units, 120/240/480 V 50 and 60 cycle power requirements, and horizontal or vertical storage tanks. For home use, those with 6 horsepower or lower motors are available that run on a 120 V supply and have wheels and handles to aid in portability.

Some additional requirements and/or recommendations are set out below:

1) When making connections to the compressor air connection or other static adjustments, make sure that the power cord is removed from the power source. Do not use a compressor in a potentially explosive atmosphere – if spraying a flammable liquid, adequate ventilation must be used with the compressor outside the spray booth or 20 ft from the spray area. The compressor pump may become hot during use and the operator must avoid making contact with hot areas.
2) If the unit has an air storage tank, it should be drained daily to remove any moisture that has collected in the tank. The tank pressure switch is not to be tampered with; it is factory set to turn on the compressor at ~95 psi (6.5 bar) in the storage tank and turn the compressor off when the tank pressure reaches 125 psi. When moving the unit around, the air pressure must be bled off from the storage tank. The airline components must have a minimum working pressure of 150 psi or 150% of the maximum capable pressure of the unit, the greater of the two. The compressor oil should be maintained at the recommended level and checked on a daily basis.
3) These devices are not designed to provide breathing air. When moving units about, use the supplied handle and do not drag the unit by the air hose or electric cord. A regulator must be in the supply piping system along with a shutoff valve and any other device required by the tool being used. If the storage tank must be rapidly drained of air, the safety valve must be activated. When using the unit with a blow-off nozzle, it should be limited to less then 30 psi

Figure 12.12 Shop vacuum (photograph provided by the author).

dead head pressure and never placed against the operator's skin or anyone else's. A barrier must be in place around the blow gun exit to prevent debris from blowing back into the operator's face and body.

4) Before the air compressor is used, the operator's manual must be read and understood. Owing to the many jobs that can be accomplished with the air compressor, PPE requirements must be matched to the task being done. The operator's manual will give guidance on these requirements. If the unit is supplied with an automatic shutdown system and it activates, shut down the tools and let the unit cool before the reset button is activated. Before resetting the unit, determine the cause of overheating and establish the reason. The intake air filter must be periodically cleaned to assure top performance: consult the operator's manual for the frequency and procedure (Campbell Hausfeld, 1984; Burch, 2008; Kidd, 2011).

12.8.11 Shop Vacuum

Housekeeping is an important element of power tool use. The shop vacuum (Figure 12.12) is a device designed to help in the process of housekeeping. These units are wet/dry units and the debris being collected by the units does not pass through the vacuum motor system but directly into the collection tank or canister. A series of filters and check valves prevent the debris or liquid from going through the motor pump system. Many woodworking and grinding devices have vacuum hose connections that will connect to a shop vacuum for convenient use. There is an array of accessories designed to do almost any kind of clean-up encountered,

such as brushes, squeegees, crevice tools, and extension wands. The motor size and tank capacity should be considered for the job sizes anticipated. It is important to analyze the debris or liquid being vacuumed to be sure that it is compatible with the unit and is not contaminating the air outside the unit.

Some additional requirements and/or recommendations are as follows:

1) Before use, make sure that the unit is properly assembled and all safety devices supplied are in place. Make sure that the filter bag in place is adequate for the material being collected.
2) Do not use the unit to vacuum hazardous materials such as hot or burning debris, flammable/combustible materials, or toxic materials.
3) When using the unit for wet pick-up, the float ball will cause the motor noise level to rise and the unit must be shut off and the liquid drained out of the collection tank.
4) Before using the shop vacuum, read and understand the operator's manual. PPE is required for many of the operations being performed such as safety goggles and hearing protection (Dodds, 2005; Shop Vac, 2009).

12.9 Conclusion

The material covered in this chapter deals primarily with a sampling of portable power tools. The array of portable power tools is immense. The best advice for potential portable power tool users is to obtain, read, and understand the operator's manual supplied with the unit. Even though the operator may have previous experience with a device, it is important to review the operator's manual anyway. There may be running model changes, updates, and features added or refined that the operator should be aware of. The use of PPE cannot be overemphasized. Use the recommended PPE every time the power tool is used.

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