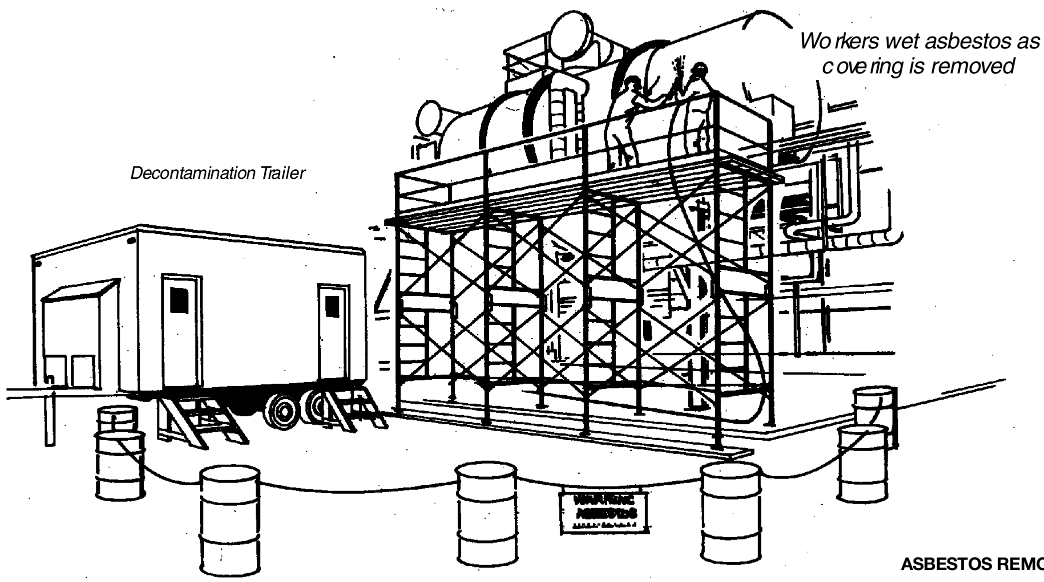


ASBESTOS REMOVAL

Table 9.1

APPROXIMATE WEIGHTS OF BUILDING MATERIALS

Material	Metric Unit Weight	Imperial Unit Weight
Aluminum	2643 kg/cu m	165 lb/cu ft
Iron (Wrought)	7769 kg/cu m	485 lb/cu ft
Steel	7849 kg/cu m	490 lb/cu ft
Nickel	8730 kg/cu m	545 lb/cu ft
Glass (plate)	2563 kg/cu m	160 lb/cu ft
Lumber (dry)		
Cedar (white)	352 kg/cu m	22 lb/cu ft
Douglas Fir	513 kg/cu m	32 lb/cu ft
Maple	689 kg/cu m	43 lb/cu ft
Red Oak	657 kg/cu m	41 lb/cu ft
Spruce	433 kg/cu m	27 lb/cu ft
Concrete	2403 kg/cu m	150 lb/cu ft
Granite	2803 kg/cu m	175 lb/cu ft
Brick	1922 – 2243 kg/cu m	120 – 140 lb/cu ft
Limestone, Marble	2643 kg/cu m	165 lb/cu ft
Sandstone	2082 kg/cu m	130 lb/cu ft
Steel Pipe (standard)		
1" I.D.	2.49 kg/m	1.68 lb/ft
2" I.D.	5.43 kg/m	3.65 lb/ft
3" I.D.	11.27 kg/m	7.58 lb/ft
4" I.D.	16.05 kg/m	10.79 lb/ft
Copper Pipe		
1" I.D.	2.71 kg/m	1.82 lb/ft
2" I.D.	6.28 kg/m	4.22 lb/ft
3" I.D.	13.02 kg/m	8.75 lb/ft
4" I.D.	19.20 kg/m	12.90 lb/ft
Aluminum Pipe (standard)		
1" I.D.	0.86 kg/m	0.58 lb/ft
1-1/2" I.D.	2.40 kg/m	1.61 lb/ft
2" I.D.	3.08 kg/m	2.07 lb/ft
3" I.D.	4.57 kg/m	3.07 lb/ft
Drywall (1/2" thick)	10.25 kg/m^2	2.10 lb/ft^2

many serious falls from scaffolds. You need an orderly work area to work safely on scaffolds.

9.6 Exposure to Hazardous Material

Frequently scaffolds are erected for work involving hazardous substances: e.g., refurbishing structures painted with lead-based paint. If you are sandblasting painted surfaces, lead can accumulate on planks and other components. Workers carrying out these activities must use appropriate personal protective equipment. The scaffold worker who has to dismantle the scaffold can also be at risk from the lead residue. Under these conditions you should do the following.

1. Clean components that are likely to be contaminated by lead dust, preferably by washing with a hose before dismantling begins.
2. Cap scaffolding frames and standards as the scaffold is being erected to prevent lead dust from accumulating inside and being subsequently released during the dismantling process.
3. If it is not possible to wash down the scaffolding before dismantling, then scaffold workers should wear properly fitting N100 filtering facepiece respirators while dismantling. The scaffold should then be washed before it is removed from the site.
4. Proper attention to personal hygiene is critical when dealing with lead. Workers must be instructed not to eat, drink, or smoke without washing their hands. A sign or notice indicating this should be conspicuous.
5. Workers should be provided with separate “clean” and “dirty” areas. Use the dirty area for changing out of contaminated clothing and the clean area for changing into uncontaminated clothing and eating. Washing facilities with clean water, soap, and individual towels should separate the two areas.
6. Scaffold workers should inform their physician if they are exposed to lead. The physician may want to monitor the level of lead in the person’s blood to see if it is within normal parameters.

5 ELEVATING WORK PLATFORMS

Basic Types

There are two basic types of elevating work platforms—boom and scissor. Both types come in

- *on-slab models* for use on smooth hard surfaces such as concrete or pavement
- *rough-terrain models* for use on firm level surfaces such as graded and compacted soil or gravel.

Both types share three major components: base, lifting mechanism, and platform assembly.

Scissor-Type Machines

These are raised and lowered by hydraulic pistons and an expanding scissor mechanism. Platforms are available in various configurations with different capabilities for extension and movement. Some have extendable platforms or platforms that can rotate. Extendable platforms should be retracted before raising or lowering the device. Typical machines are illustrated in Figure 1.1.

On-slab units

- not designed for uneven or sloping ground
- normally have solid rubber tires
- generally powered by rechargeable DC battery
- some powered by internal combustion engine, either gasoline or propane
- most have “pothole protection”—a metal plate lowered close to the ground to afford some protection against inadvertent movement into depressions or debris.

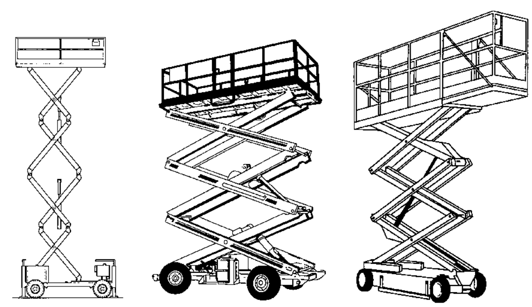


Figure 1.1: Scissor-type powered platforms

Rough-terrain units

- similar in design to on-slab machines
- built to handle rigorous off-slab challenges
- normally have wider wheel bases, larger wheels, and pneumatic tires
- some fitted with outriggers for extra stability
- usually powered by internal combustion engines, gasoline, diesel, or propane
- DC units also available but not common
- lifting mechanism is hydraulic.

Scissor-type machines range in capacity from 500 to several thousand pounds. They are available with platform heights often reaching 15 metres (50 feet) and beyond.

> Scissor-type machines must be set up on stable level ground, even with outriggers deployed. A slight imbalance or instability is amplified when the machine is raised.

Figure 1.2 shows one example of controls. Although fixed to the platform, the controls are moveable from one side of the platform to the other. This enables the operator to see the path of travel.

The controls must be oriented correctly so that the operator does not inadvertently move the machine in the wrong direction. Many machines have colour-coded directional arrows on the chassis to aid the operator in moving the machine.

Controls

1. Emergency stop button
2. Choke
3. Glowplugs (diesel engines only)
4. Stop/start switch
5. Run/idle switch
6. Lift up/down switch
7. Drive high range/low range switch
8. Forward/reverse joystick
9. Left/right steer switch
10. Traversing deck out/in switch
11. Outriggers up/down switch

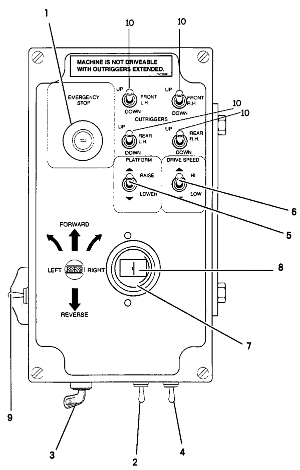


Figure 1.2: Example of controls on scissor-type platforms

Self-Propelled Boom-Supported Platforms

- normally fitted with rough-terrain undercarriages
- some smaller on-slab units
- platforms have lifting capacity of about 227 kg (500 pounds) or two workers
- lack capacity of scissor-type machines; not intended for lifting materials
- usually powered by an internal combustion engine, gasoline, diesel, or propane.

Booms

- telescopic, articulating, or combination of both
- raised and extended by hydraulic cylinders
- can reach up to 45 metres (150 feet)
- can extend well beyond the wheelbase.

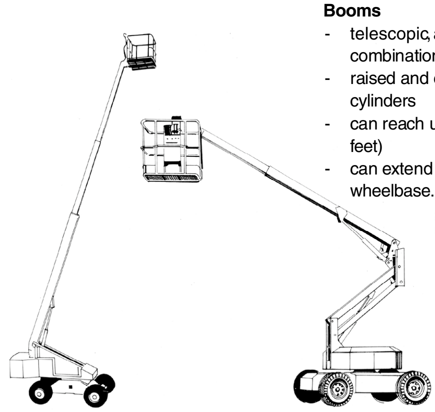


Figure 1.3: Boom-type powered platforms

Figure 1.4 shows one example of controls for a boom machine. Although controls are fixed in position, the operator may become disoriented by machine rotation and must remain aware of the direction of movement. Many machines have colour-coded directional arrows to help the operator move the machine in the right direction.

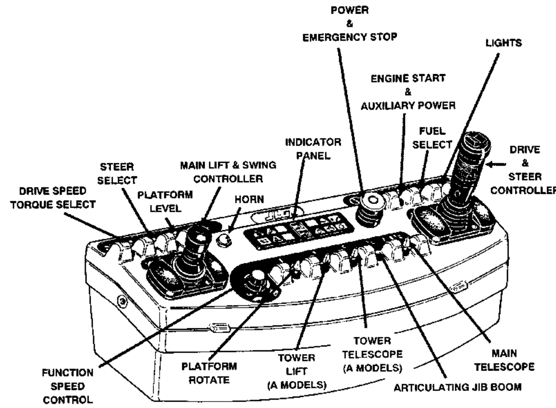


Figure 1.4: Example of boom-machine controls

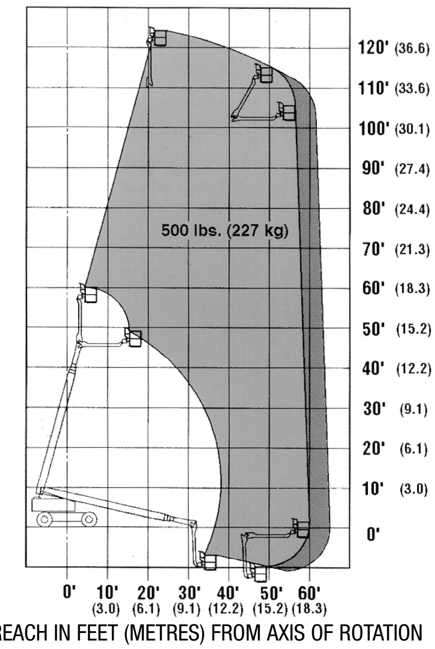


Figure 1.5: Reach chart for a 120-foot (36-metre) machine

As with mobile cranes, stability decreases with length of boom and boom angle as the centre of gravity moves in relation to the platform position. The machine will overturn if the centre of gravity moves outside the machine's base.

Machines come with load charts that show safe operating configurations. Machines with booms long enough to cause overturning at low boom angles are required to have radius-limiting interlocks to prevent operation in unstable configurations.

The reach chart shown in Figure 1.5 indicates the safe operating configurations for a machine with 36 metres (120 feet) of reach operating on a level surface.

The reach diagram in Figure 1.6 shows the safe operating envelope for a 10-metre boom machine.

Notice that the machine does not achieve its maximum height directly overhead. Nor does it achieve its maximum reach at ground level.

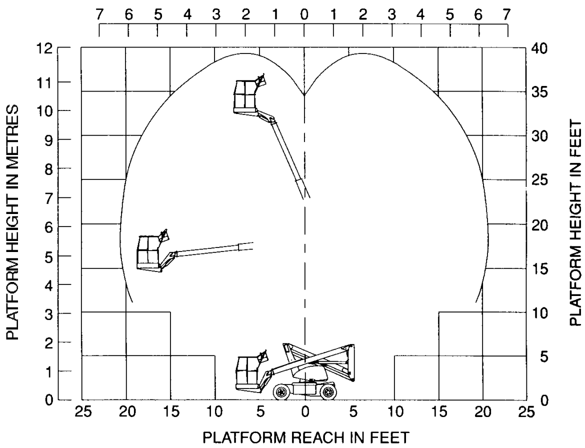


Figure 1.6: Reach diagram for a 10-metre articulating boom platform

Users must be familiar with the operating range of the individual make and model they are using. This knowledge is essential in order to position the machine correctly and reach the work location safely.

Non-Self-Propelled or Push-Arounds

As the name indicates, these units are not self-propelled and must be transported from one location to another with an independent power source or manually in the case of the smaller devices.

The machines are intended primarily for use on smooth, level, hard surfaces or on-slab conditions. Some trailer-mounted units are available.

Many of these devices can fold up to pass through a standard door and can be transported by pick-up truck. As a result they are suitable for maintenance or renovation work.

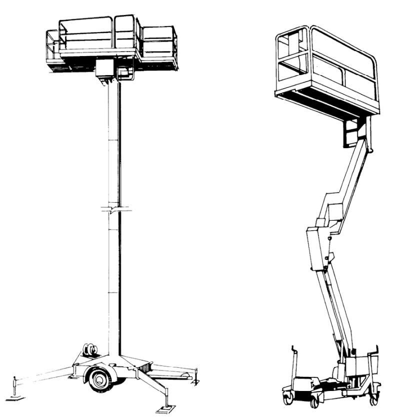


Figure 1.7: Push-around powered platforms

Push-Arounds

- Raising mechanism normally powered by gasoline or propane engine or by electric motors, either AC or DC
- normally raised and lowered by hydraulic cylinders
- platform capacities vary from 300 to 1000 pounds or more but are generally less than 500 pounds
- devices with capacity less than 500 pounds are **not recommended** for construction—better suited to maintenance activities
- platforms don't usually exceed 11 metres (36 feet) in height
- as platform is raised, risk of overturning increases
- extra care required when operating at maximum height.

Selection

Elevating work platforms are designed for different uses. It is essential to select the right machine for the job.

Typical Mistakes

- ✓ using an on-slab machine on rough terrain
- ✓ using a unit undersized with respect to height, reach, and lifting capacity
- ✓ lifting large materials that overhang the platform
- ✓ using a scissor lift where the reach of a boom-type machine is needed
- ✓ extending the platform with planks, ladders, or other devices because the machine can't reach the required height.

Factors to Consider

Capacity – Does the machine have the lifting capacity, the reach, and the height to complete the task?

Surface conditions – Are the surface conditions hard or soft, sloped or level? Will the ground have an effect on the type of machine selected?

Platform size and configuration – Do you need a regular or extendable platform? Is rotation required? Are there space restrictions to consider?

Mobility – Is a boom type better suited than a scissor lift to the task at hand?

Material to be lifted – Will the machine be able to lift the size and weight of material required for the job?

Access – Will the machine be able to travel around the workplace safely? Are there obstructions or depressions that will restrict the use of certain machines?

Operator skill or training – Are the people on site competent to operate the machine? If a propane-powered engine is used, has the operator received propane training?

Work environment – If the work is to be done indoors or in a poorly ventilated area, will an electrically powered machine be required?

Basic Hazards

The following are some basic hazards.

Machine tipping or overturning
Many factors cause instability—sudden stops, depressions, drop-offs, overreaching, overloading, etc. Overturning and tipping result in many fatalities and injuries.

Overriding safety features
Disarming features such as the tilt or level warning and the deadman switch can prevent operators from knowing when they are in a dangerous situation. Overriding the deadman switch has resulted in a fatality; so has malfunction of the tilt warning.

Overhead powerline contact
Contacting overhead wires can cause electrocution. This can happen with any type of machine—and with the loads carried by or overhanging the machine.

Makeshift extensions
When the machine can't reach the working height desired, don't compensate by using scaffold planks, ladders, blocks of wood, or other makeshift arrangements. Such practices lead to falls and machine instability.

Overloading the platform
EWPs overloaded or loaded unevenly can become unstable and fail. Boom-type machines are especially sensitive to overloading. Always stay within the operating range specified by the manufacturer.

Failure to cordon off
- EWPs have been struck by other construction equipment or oncoming traffic when the work area is not properly marked or cordoned off.
- Workers have been injured when they inadvertently entered an unmarked area and were struck by falling material, tools, or debris.
- In unmarked areas, workers have also been injured by swinging booms and pinched by scissor mechanisms.

Accidental contact
Many EWPs have blind spots. Moving the machine or platform may cause contact with workers or with obstacles. Use a designated signaller on the ground to guide the operator when the path of travel isn't clear or access is tight.

Improper maintenance or modifications
EWPs should be maintained by competent workers in accordance with manufacturer's instructions. No modifications should be made to the machine without the manufacturer's approval.

Improper blocking during maintenance
Failing to block, or improperly blocking the machine, boom, or platform can cause serious crushing injuries and property damage.

Improper access
Don't enter or leave the platform by climbing the scissors or the boom. Don't use extension ladders to gain access. Ladders exert lateral loads on the platform that can cause overturning. For the safest access, lower the machine completely.

Moving with platform raised
Lower the platform before moving the machine unless 1) the machine is designed to move with platform raised and 2) the supporting surface is smooth and level. Slight dips and drops are amplified when the platform is raised and can cause the machine to overturn.

Improper refuelling
Take care when refuelling. Gasoline, for instance, should be kept in approved containers and dispensed to prevent spills and sparking.

Pinch points
Clothing, fingers, and hands can get caught in scissor mechanisms. As platforms are raised, machines may sway. Workers can be pinched between guardrails and the structure. Position the platform so that work takes place above guardrail height.

Regulations and Responsibilities

The construction regulation (Ontario Regulation 213/91) includes the following requirements:

- Elevating work platforms must be engineered and tested to meet the relevant standard for that equipment [section 144(1)(a)]. Standards include
  - o CSA B354.1: non-self-propelled elevating work platforms
  - o CSA B354.2: self-propelled elevating work platforms
  - o CSA B354.4: boom-type elevating work platforms.
- The devices must be checked each day before use by a trained worker [section 144(3)(b)].
- The owner or supplier must keep a log of all inspections, tests, repairs, modifications, and maintenance [section 145(2)].
- The log must be kept up to date and include names and signatures of persons who performed inspections and other work [section 145(3)].
- A maintenance and inspection tag must be attached near the operator's station and include the date of the last maintenance and inspection and the name and signature of the person who performed the work [section 145(3)].
- Workers must be given oral and written instruction before using the platform for the first time. Instruction must include items to be checked daily before use [section 147].
- All workers on the platform must wear a full body harness or a safety belt attached to the platform while the platform is being moved [section 148(e)].

The health and safety responsibilities of all parties on a construction site are outlined in the "green book"—the *Occupational Health and Safety Act and Regulations for Construction Projects*.

Because elevating work platforms are often rented from an equipment supplier, there is confusion as to the responsibilities of the parties involved. Generally, the responsibilities can be summarized in the following way.

The owner or supplier must ensure that the machine

- is in good condition
- complies with regulations
- is maintained in good condition
- conforms to the appropriate CSA Standard
- includes the correct load rating charts if required.

The employer and supervisor on the project must

- ensure that the operator is competent
- ensure that the machine has the correct load rating capacity for the job
- maintain the equipment and all its protective devices
- maintain a log book for each platform
- ensure that workers use appropriate personal protective equipment
- keep the manufacturer's operating manual on site
- train workers on each class of equipment being used.

The worker or operator of the equipment must

- receive adequate training to be fully competent
- only operate the machine when competent
- operate the machine in a safe manner and as

prescribed by the manufacturer and the company's health and safety policy
- inspect the equipment daily before use
- perform function tests before use
- report any defects to the supervisor
- read, understand, and obey the manufacturer's safety rules, including the operating manual and warning decals.

When a defect is reported to the supervisor, the equipment must be taken out of service until the repairs are completed and the equipment is inspected and approved for use.

Stability and Tipping

In general, EWPs are well manufactured and are safe to use within their specific limitations. As with any equipment or tool, there are do's and don'ts to follow.

One of the most dangerous hazards in operating EWPs is tipping over. This can be caused by one or several of the following factors:

- sudden movement of the unit or parts of the unit when elevated
- sudden stopping when elevated
- overloading or uneven loading of the platform
- travelling or operating on a slope or uneven terrain
- changing the weight distribution of the machine by replacing parts with others of a different weight or adding attachments not approved by the manufacturer
- holes or drop-offs in the floor surface causing one wheel to drop suddenly
- operating the equipment in windy conditions (refer to the operator's manual for safe operating conditions).

It is important that users understand what makes a platform stable and what causes it to overturn. To understand stability, one must understand the concept of centre of gravity, tipping axis (or tipping point), and forces that shift the centre of gravity.

Stability is resistance against tipping over. Stability depends on the location of the centre of gravity in relation to the tipping axis.

Centre of Gravity

Every object has a centre of gravity. It is the point where the object's weight would be evenly distributed or balanced. If a support is placed under that point, the object would be perfectly balanced.

The centre of gravity is usually located where the mass is mostly concentrated. However, the location doesn't always remain the same. Any action that changes the machine's configuration—such as raising the platform, extending the boom, or travelling on a slope—can change the location of the centre of gravity.

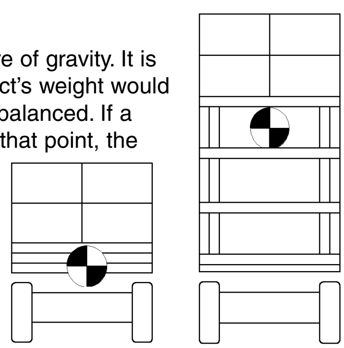


Figure 4.1 Centre of gravity on scissor lifts

Figure 4.1 shows how raising a scissor-type platform affects the centre of gravity.

Tipping Axis and Area of Stability

When an EWP turns over, it tips around an axis or point. This is called the tipping axis or tipping point. EWPs typically have four tipping axes – front, back, left, and right.

Each EWP has its own area of stability. This varies from platform to platform and from model to model. In most cases, the area of stability is bound by the four tipping axes (or the four tires or outriggers). The platform is stable as long as the centre of gravity remains inside the area of stability. This is the key to safe operation.

Figure 4.2 shows how lowering the boom angle affects the centre of gravity. In this example the centre of gravity moves towards the platform but remains inside the area of stability.

When the centre of gravity shifts beyond the area of stability, the machine will tip over. Some factors that can cause a shift beyond the stability area are overloading, moving on excessively sloped ground, a sudden drop of one wheel, and shock loading.

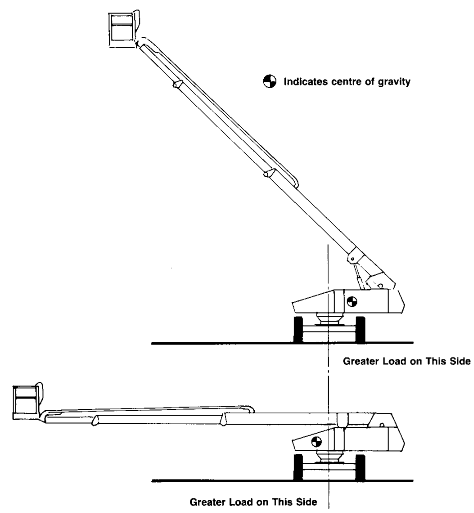


Figure 4.2: Centre of gravity for a boom-supported machine

Raising the platform also raises the EWP's centre of gravity. When a scissor lift is situated on a slope, and the platform is raised, the platform's centre of gravity will move toward the tipping axis. If the centre of gravity moves beyond the tipping axis, the platform will overturn.

Boom-supported EWPs work in the same way. When the boom is extended outward, the centre of gravity moves outwards towards the tipping axis. The EWP will overturn if the boom is extended such that the centre of gravity moves beyond the axis. Boom-type machines have an interlocking system that prevents the machine from moving into an unstable configuration.

Factors Affecting Stability

Dynamic Forces

Dynamic forces are forces generated by movement or change of movement. For example, applying the brakes suddenly or travelling too fast around corners can cause instability – as in a car or van. Sudden stops while raising or lowering the platform can also cause instability.

Travelling

Travelling the platform over rough or uneven ground can also cause instability. Figure 4.3 shows how a tire dropping 100 mm can cause the boom to sway 600 mm. It is important to lower the platform fully or to retract telescoping sections while travelling, particularly on uneven surfaces.

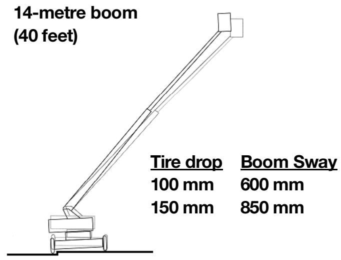


Figure 4.3: Effect of uneven ground on boom sway

Equipment Inspection

All components which bear directly on the safe operation of the EWP and can change from day to day must be inspected daily. Inspection is mostly visual – done in a quick but thorough manner.

Users must check the operator's manual for a complete list of pre-operational checks.

Minimum Requirements

Before climbing into the platform, check

- ✓ Tires for proper pressure and wheels for loose or missing lug nuts
- ✓ Steer cylinder, linkage, and tie rods for loose or missing parts, damage, and leaks
- ✓ Hydraulic hoses, lift cylinder(s), and connections for leaks or loose connections (for example, a small pool of hydraulic fluid)
- ✓ Fuel supply – adequate fuel, filler cap in place, no damage, leaks, or spills
- ✓ Hydraulic oil for leaks and fluid level, battery for fluid level and state of charge
- ✓ Proper connection of all quick-disconnect hoses
- ✓ Structural components for damage, broken parts, cracks in welds, including scissor arms, outrigger arms, and pads
- ✓ Ladder or steps for damage and debris (ladder must be firmly secured to the platform and relatively free of grease, mud and dirt)
- ✓ Beacon and warning lights for missing and defective lenses or caps
- ✓ Ground controls (manual and powered)—including emergency stop switch and platform lower/lift switch—for proper function and damaged and missing control sticks/switches
- ✓ Decals and warning signs to make sure they're clean, legible, and conspicuous.

On the platform, check

- ✓ Platform assembly for loose and missing parts, missing or loose lock pins and bolts
- ✓ Platform floor for structural damage, holes, or cracked welds and any dirt, grease, or oil that can create a hazard
- ✓ Operator's manual to make sure it's in place
- ✓ Extendable platform deck for ease of extension/retraction and proper function of locking position of platform
- ✓ Guardrails to make sure they're in place
- ✓ Access gate for ease of movement, missing parts, latch, and locking capabilities
- ✓ All fall protection anchorage points
- ✓ All control mechanisms for broken or missing parts
- ✓ All emergency controls for proper function—stopping, descending, master OFF switch
- ✓ All safety devices such as tilt and motion alarms for malfunction
- ✓ Swivels for freedom of rotation
- ✓ Scissors for smooth movement up and down
- ✓ Brakes for stopping capabilities
- ✓ Horn for proper function.

Manuals, Signs, and Decals

Section 144(8) of the construction regulation (Ontario Regulation 213/91) specifies the signs that are required on an EWP.

Signs clearly visible to the operator at the controls must indicate

- the rated working load
- all limiting operating conditions, including the use of outriggers, stabilizers, and extendable axles
- the specific firm level surface conditions required for use in the elevated position
- such warnings as may be specified by the manufacturer
- other than for a boom-type elevating work platform, the direction of machine movement for each operating control
- the name and number of the National Standards of Canada standard to which the platform was designed and
- the name and address of the owner.

In addition to the above, the CSA standards for EWPs require the following signs:

- the make, model, serial number, and manufacturer's name and address
- the maximum platform height
- the maximum travel height, if not equal to the maximum platform height

- the nominal voltage rating of the batteries, if battery-powered
- a warning to study the operating manual before using the equipment
- a notice outlining the required inspections
- diagrams or description of the various configurations in which the platform can be used
- the capacity in each configuration
- a statement as to whether or not the platform is insulated
- warnings against replacing, without the manufacturer's consent, components critical to the machine's stability—for example, batteries or ballasted tires with lighter weight components (the minimum weights of such components must be specified).

Many of these signs are vital to the operation of the machine and the protection of workers. All signs and decals must be kept clear of dust and grease so they can be easily read. Torn or damaged signs must be replaced. A typical warning sign is shown in Figure 5.1.

Figure 5.1

CSA standards also require that the manufacturer provide a manual containing the following information:

- description, specifications, and capacities of the platform
- the operating pressure of the hydraulic or pneumatic system that is part of the work platform
- instructions regarding operation and maintenance, including recommended daily, weekly, and monthly inspection checklists
- information on replacement parts.

The manual must be stored on the platform in a weather-proof storage container.

Safe Practices

Specific Requirements

For the specific EWP they will use, operators must be familiar with

- the manufacturer's operating manual
- the manufacturer's warning and caution signs on the machine
- the location of all emergency controls and emergency procedures
- the daily maintenance checks to perform.

General Guidelines

- Always check for overhead powerlines before moving the machine or operating the platform. The limits of approach from overhead powerlines must be observed. If work must be done within these limits make arrangements with the owner of the utility to have the powerline de-energized. Allow for movement or sway of the lines as well as the platform. Be aware of overhanging tools or equipment.

Voltage Rating of Powerline	*Minimum Distance*
750 to 150,000 volts	3 metres (10 feet)
150,001 to 250,000 volts	4.5 metres (15 feet)
over 250,000 volts	6 metres (20 feet)

- Wear a full body harness and tie off to a designated tie-off point while the machine is moving.
- Do not leave the machine unattended without locking it or otherwise preventing unauthorized use.
- Don't load the platform above its rated working load (RWL). Wherever possible, keep the load below 2/3 of the RWL.
- Make sure that all controls are clearly labeled with action and direction.
- Keep guardrails in good condition and ensure that the gate is securely closed before moving the platform.
- Shut off power and insert the required blocking before maintenance or servicing.
- Deploy stabilizers or outriggers according to the manufacturer's instructions.
- Don't remove guardrails while the platform is raised.
- Position the boom in the direction of travel where possible.
- Keep ground personnel away from the machine and out from under the platform.
- Don't access the platform by walking on the boom.
- Don't try to push or move the machine by telescoping the boom.
- Do not use the machine as a ground for welding.
- Don't use a boom-supported platform as a crane.
- Don't operate the equipment in windy conditions. For safe wind speeds refer to the operator's manual for the specific make and model you are using.
- Do not place the boom or platform against any structure to steady either the platform or the structure.
- Secure loads and tools on the platform so that machine movement won't dislodge them.
- Make sure that extension cords are long enough for the full platform height and won't get pinched or severed by the scissor mechanism.
- Use three-point contact and proper climbing techniques when mounting or dismounting from the machine (Figure 6.1).

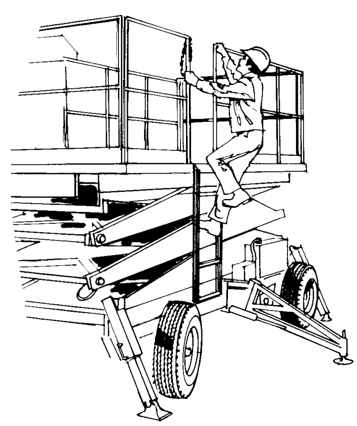


Figure 6.1: Three-point contact

Never operate equipment on which you have not been trained or which you are not comfortable operating. The safety of you and others on site depends on the competent, knowledgeable operation of equipment.

Work Area Inspection

Before operating the EWP, check the work area for

- ✓ drop-offs or holes in the ground
- ✓ slopes
- ✓ bumps or floor obstructions
- ✓ debris
- ✓ overhead obstructions
- ✓ overhead wires, powerlines, or other electrical conductors
- ✓ hazardous atmospheres
- ✓ adequate operating surface—ground or floor
- ✓ sufficient ground or floor support to withstand all forces imposed by the platform in every operating configuration
- ✓ wind and weather conditions.

6 SUSPENDED ACCESS EQUIPMENT

CONTENTS

1 INTRODUCTION

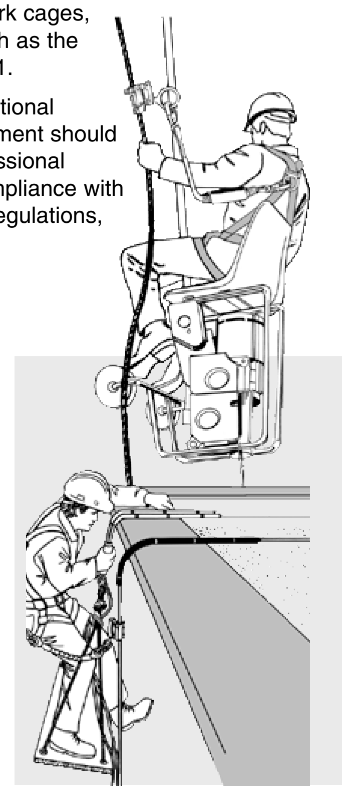
Suspended access equipment of various kinds has been used in construction and restoration for many years. With the increase in high-rise construction there has been a corresponding increase in the number and diversity of applications for this equipment. Unfortunately, there has also been an increase in the number of injuries and fatalities.

In an average year, two fatalities and over 100 lost-time injuries are connected with suspended access equipment in Ontario construction and window cleaning.

This chapter covers the main types of suspended access equipment used in construction, restoration, and maintenance work. It explains the fundamental requirements for set-up, rigging, and use; the necessary provisions for fall arrest; and the importance of assessing each job carefully in order to select the equipment most suitable for safe, efficient operation.

2 EQUIPMENT TYPES, LIMITATIONS, AND APPLICATIONS

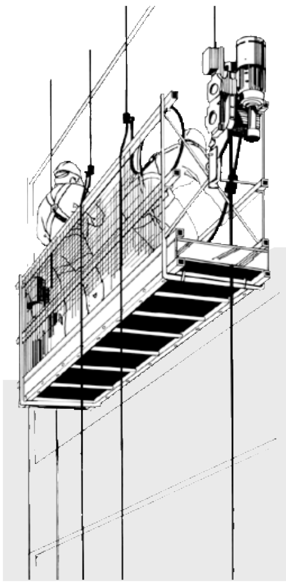
Equipment discussed in this section is restricted to factory-built stages, work cages, and bosun's chairs such as the types shown in Figure 1.

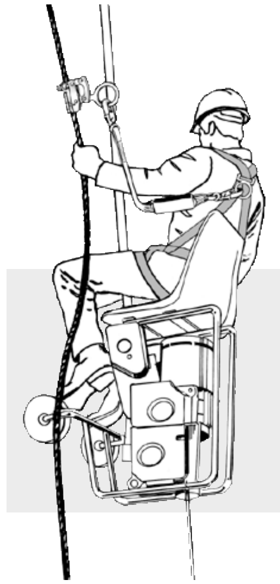


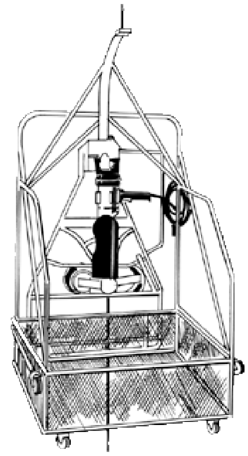
Unusual or non-conventional arrangements of equipment should be reviewed by a professional engineer to ensure compliance with applicable standards, regulations, and good practice. In some cases, the services of a professional engineer are required under the Construction Regulation (Ontario Reg. 213/91).

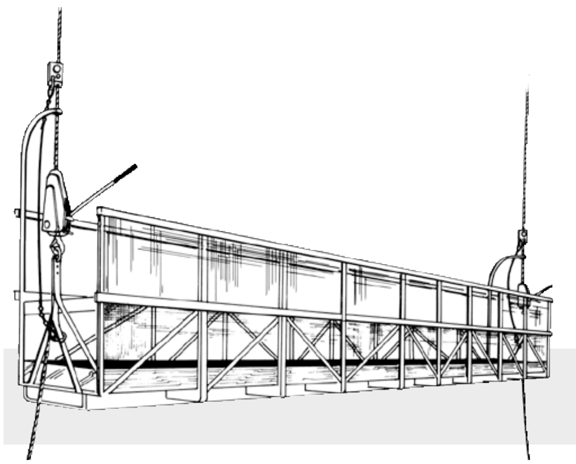
2.1 Special Requirements

Tiered stages and setups where the suspended platform and associated suspended equipment weigh more than 525 kilograms (1,157 lb.) must be designed by a professional engineer.









A copy of the design drawings must be kept on the project. In addition, a professional engineer must inspect the suspended scaffold before use and confirm in writing that it has been erected in accordance with the drawings.

2.2 Manual Traction Climber Equipped Stage (Figure 2)

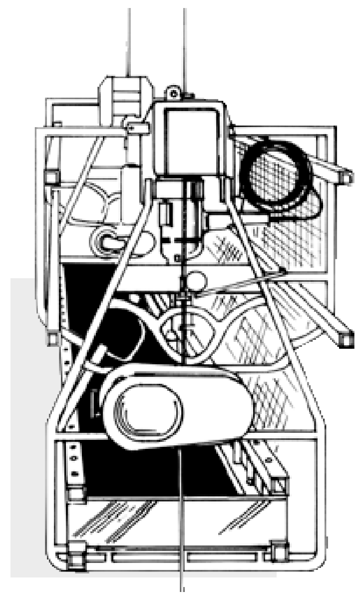
For many years this was the predominant type of suspended access equipment in the industry. More recently it has been replaced by various types of powered climbers, especially where considerable movement is required or heights are greater than 100 feet.

This type of equipment is, however, quite suitable for moderate heights where the stage will remain in approximately the same position a reasonable period of time and where only limited climbing is required.

2.3 Drill-Powered Traction Climber Equipped Stage (Figure 3)

The climbers on these devices are powered by specially designed electric drills. One advantage is that they operate on a 120-volt power supply. This eliminates the requirement for special 220-volt wiring commonly required on larger powered climbers. A disadvantage is that the rate of climb is somewhat slower than for other types of powered climbers.

Drills powering the climbers can be easily removed and stored when not in use, eliminating some of the weather damage and vandalism that occur when other climbing devices are left outdoors.



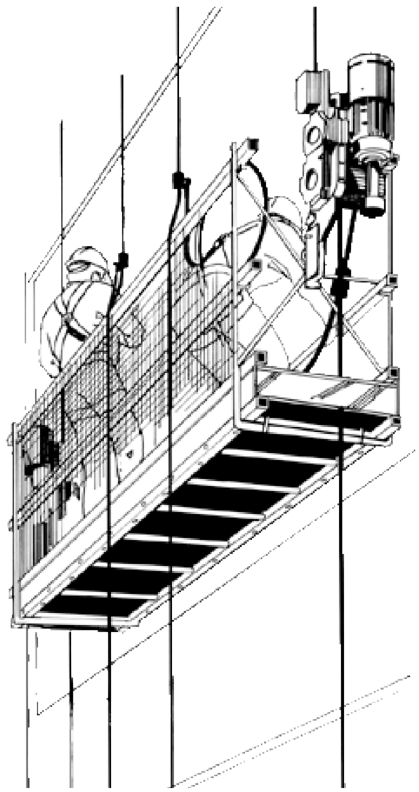
2.4 Powered Traction Climber Equipped Stage (Figure 4)

This is the most common type of powered climber in use today. Its fast rate of climb makes it ideal where vertical distances are large or frequent movement is required. Usually powered by a 220-volt power source, the unit may require installation of a temporary electrical supply depending on location.

Because of the relatively fast rate of ascent and descent (up to 35 ft/min), operators must take care that the stage does not catch on obstructions such as architectural features and overload the suspension system. This caution, of course, applies to all devices but is most important where climbers operate at greater speeds.

2.5 Powered Drum Hoist Climber Equipped Stage (Figure 5)

This equipment is common in the industry today. One advantage is that the suspension lines are wound up on the drum of a hoist rather than extending to the ground. This keeps the free ends of suspension lines from crossing, catching on the building, entangling, or



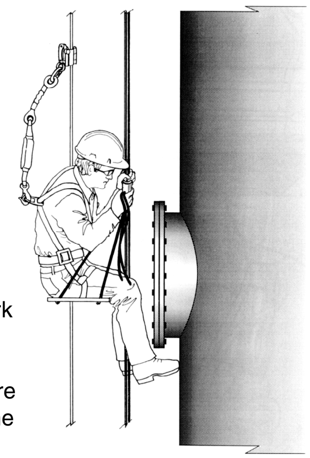
otherwise hindering safe operation. This feature improves the safety of the equipment. Although not common, other types of climbers can be equipped with a reel to provide the same feature.

2.6 Bosun's Chair

Bosun's (or boatswain's) chairs were used for centuries on ships.

Originally equipped with a rope fall, the chairs required considerable physical effort to be raised and lowered.

Today with descent control devices or powered climbers, bosun's chairs can be used for various purposes in construction, repair, maintenance, and inspection (Figure 6).



In some cases, it may be safer and more efficient to use work cages equipped with powered climbers.

Whether equipped with a descent control device or power climber, all bosun's chairs must use wire rope support cables if

- the distance from the fixed support to the work platform will exceed 90 metres (295 feet)
- corrosive substances are used in the vicinity of the support cables, or
- grinding or flame-cutting devices are used in the vicinity of the support cables.

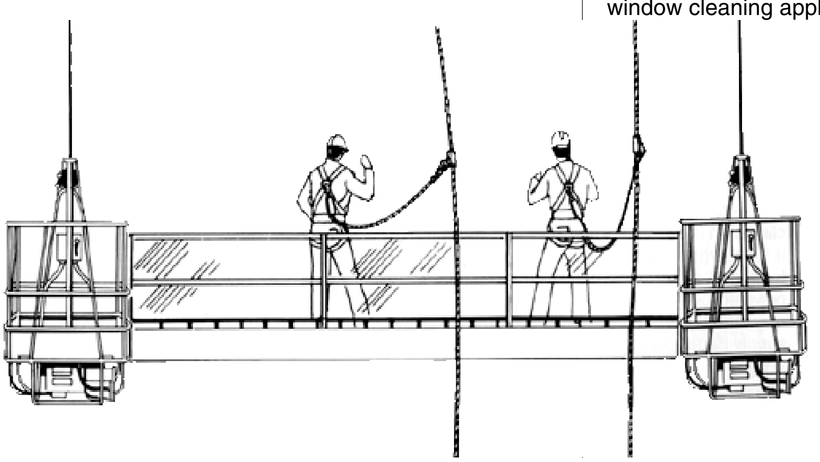
As with all suspended access equipment, a fall-arrest system (Figure 7) is essential with a bosun's chair. The system must be used at all times when a person is getting on, working from, or getting off the chair.

For more information on fall arrest, refer to Section 5.

2.7 Bosun's Chair with Descent Control Device (Figure 8)

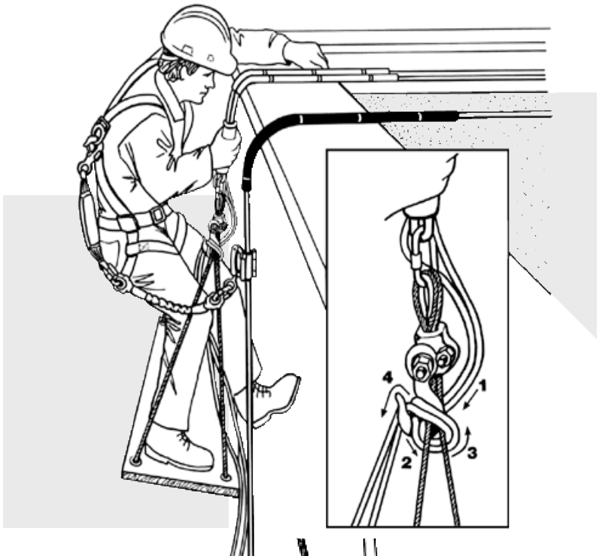
This arrangement is commonly used in the window cleaning trade. It is very useful in situations where workers must progressively descend from one level to another. It cannot be used to climb. The main advantage of descent control devices is that they are light to carry or move and simple to rig.

It is standard practice for such devices to be reeved with two suspension lines. The reason is that the ropes are easily damaged and the second suspension line provides added safety. A secondsuspension line is mandatory for window cleaning applications.



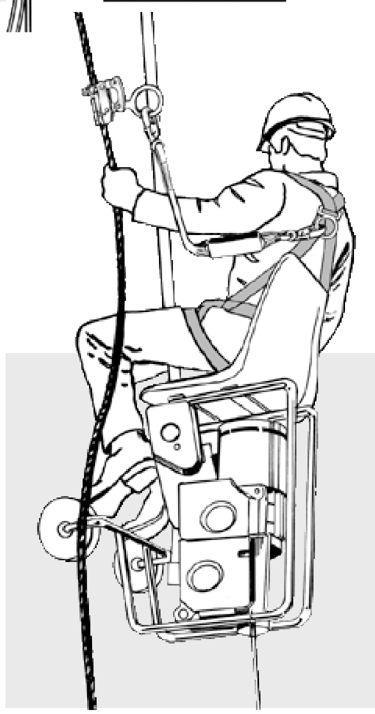
2.8 Bosun's Chair with Powered Climber (Figure 9)

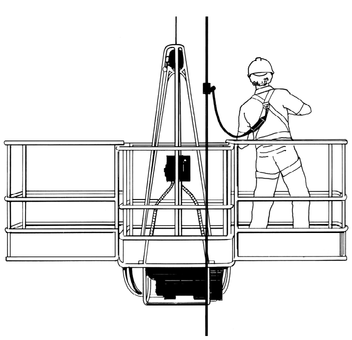
These devices are fitted with a seat attached to a powered climber unit. They are often used for work which requires a considerable amount of travel in restricted areas where powered work cages would be cumbersome. They are compact in size and generally lighter than work cages. Inspection work is a typical application for these devices.

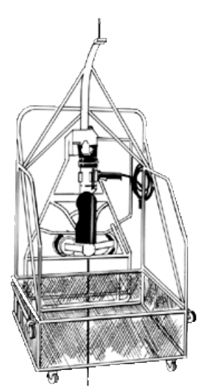


2.9 Work Cage with Powered Climber (Figure 10)

In construction, work cages are often used in place of bosun's chairs for both safety and efficiency. These devices are usually equipped with powered climbers similar to those used for stages. Some of the devices fold up for easy transport. Others may be equipped with platform extensions providing a wider working area.







3 COMPONENTS AND RIGGING

3.1 Planning and Selection of Equipment

When starting a new job on an unfamiliar site, always inspect the roof and work area before deciding on the equipment
required.

The following are some of the points to check during inspection.

- ❑ Building height—you need this to determine the length of suspension lines and lifelines.
- ❑ Location, type, and capacity of permanent roof anchors.
- ❑ If there are no permanent anchors, what provisions are required to adequately anchor support cables as well as travel-restraint and fall-arrest system?
- ❑ Area available for set-up.
- ❑ Location of any electrical hazards.
- ❑ Roof capacity—is it capable of supporting all of the required equipment?
- ❑ Is there a parapet wall? Has it been designed to accommodate a parapet clamp outrigger system or will outrigger beams have to be set up on stands above the wall elevation to protect it from damage?
- ❑ How much overhang will be required for outrigger beams?

Once you have determined these and other site-specific conditions, select the suspended access equipment and fall-arrest system that will best accommodate the job.

Always ensure that the proposed set-up and equipment will meet the requirements of the Construction Regulation (O. Reg. 213/91) under the *Occupational Health and Safety Act.*

3.2 Platforms

Platforms of various types are illustrated in Figures 3, 4, and 5. Load ratings of platforms and platform combinations are available from manufacturers. Typical platforms have 500-lb. or 750-lb. ratings. The platform must be capable of supporting all loads to which it is likely to be subjected without exceeding the manufacturer's rated working load. The load includes air or water hoses and similar equipment suspended from the stage. We strongly recommend that only stages rated for 750 lb. or greater be used on construction projects.

Each platfo rm should be equipped with

- an adequate guardrail system that includes
  - a securely attached top rail between 0.9 metres (36 inches) and 1.1 metres (43 inches) above the work platform
  - a securely attached mid-rail
  - toeboards
- wire mesh
- a skid-resistant platform
- adequately sized, securely attached stirrups.

On many platforms, the front guardrail (closest to the building face) can be lowered to accommodate the work being done.

It's good practice to use front guardrails in the fully raised position at all times. You must use them when the stage is more than 75 mm (3 inches) from the building facade. If the stage is less than 75 mm from the facade and properly secured to the face of the structure, you can lower the front guardrails.

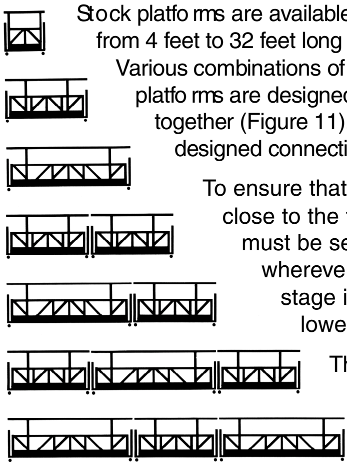
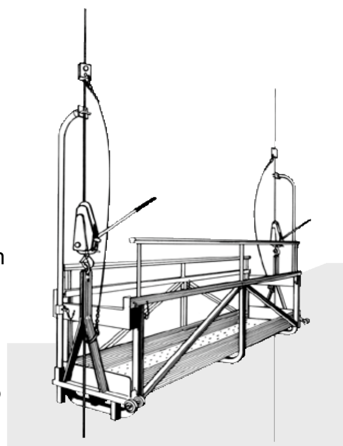


Figure 11
Typical Platform Modules

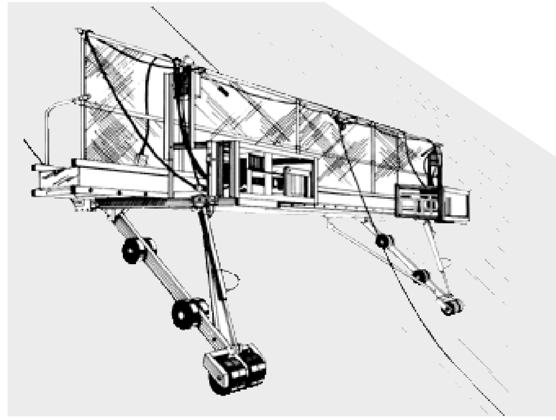
Stock platforms are available from most suppliers from 4 feet to 32 feet long in increments of 2 feet. Various combinations of shorter modular platforms are designed to be connected together (Figure 11). Use only manufacturer-designed connection methods.

To ensure that the stage remains close to the facade during work, it must be secured to the building wherever possible, unless the stage is being raised or lowered.

The wire mesh [38 mm x 38 mm ($1\frac{1}{2}$" x $1\frac{1}{2}$")] should be in good condition and fastened in position to cover the area from top rail to toeboard. This will prevent debris and tools from falling off the platform and injuring personnel below.



Various platform accessories are available from suppliers to improve safety and operation. For example, guides or wire rope stabilizers attached to the stirrups (Figure 12) will reduce platform sway. Ground castors on the bottom of the platform (Figure 13) facilitate horizontal movement. Bumper or guide rollers attached to the front of the platform provide clearance around small obstacles and protect the building face from the platform. Special adjustable roller or castor systems are available for



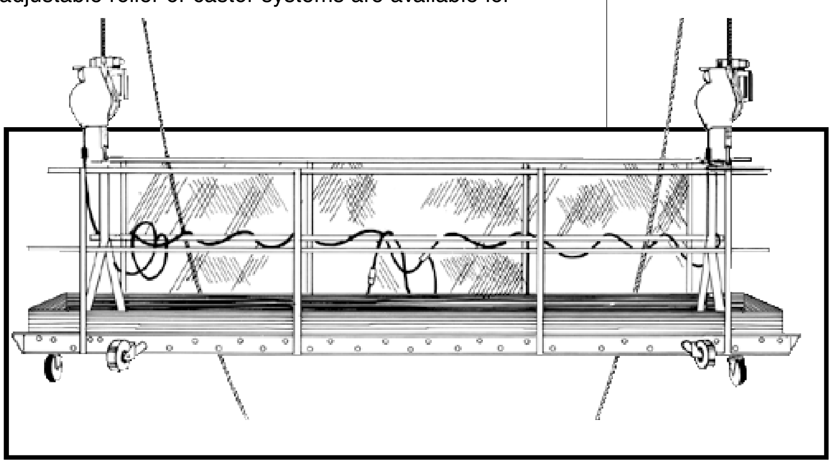
platforms used on sloping surfaces (Figure 14). This type of set-up should only be used with the advice of the supplier and in accordance with manufacturers' recommendations.

Stirrups must be securely attached to the platform. This is usually done with a threaded rod or bolts. These should be equipped in turn with lock nuts or drilled and fitted with locking pins.

A suspended stage must be anchored to the building wherever possible, unless the stage is being raised or lowered. Newer buildings are equipped with mullion guides. Devices attached to the stage slide up and down the guides to reduce lateral movement. Mullion guides are usually not found on older buildings or buildings under construction.

Most platform structures are manufactured from aluminum components for strength, light weight, and easy handling. However, aluminum platforms are not recommended where caustic or acidic materials and fumes may be encountered. In these instances special provisions must be made to protect the platform from the particular hazardous substance. Where aluminum platforms are exposed to caustic or acidic conditions, they should be rinsed off with clean water regularly and inspected regularly for signs of degradation or damage. Aluminum stages may be given a protective coating.

Components of the platform such as the main structure, handrails, and stirrups should be inspected regularly and any damage promptly repaired. Only competent persons should repair the platform structure. Welding repairs should be done only by a certified welder with the manufacturer's approval using proper equipment and procedures. Connector bolts, brackets, and shackles should be checked for wear and torque regularly and often.



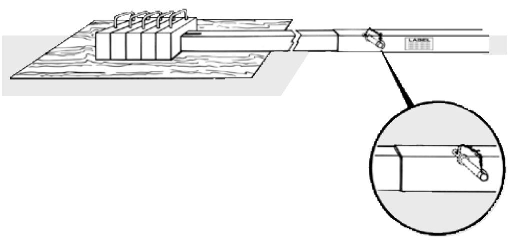
3.3 Outrigger Beams

Various types of outrigger beams are in common use. Most beams are steel while others are aluminum. They have two or sometimes three sectional components to keep them light and portable.

The outrigger beam should be rated to withstand four times the maximum load applied without exceeding its ultimate unit stress. These beams are not indestructible, however, and should be used only in accordance with the manufacturer's or supplier's table of counterweights and allowable projections beyond the fulcrum for various suspension line loads. Adequate legible instructions for the use of counterweights must be affixed to the outrigger beam.

It must be understood that **outrigger beams have maximum allowable projections beyond the fulcrum due to strength limitations.** Consult the manufacturer or supplier if this information is not provided on the equipment.

Sectional outrigger beams must have a means of preventing pins from loosening and falling out (Figure 15). Otherwise, pins can work loose with movement of the stage and action of the climbers.



Beams should be free of any damage, dings or kinks since these can reduce structural capacity considerably.

3.4 Counterweights

Counterweights range from 50 to 60 lb. each. Only manufactured counterweights compatible with the outrigger beam should be used. The counterweights should have a means of being secured in place on the beam. An adequate number of counterweights should be available to provide the counterweight capacity required for the beam projection beyond the fulcrum, as discussed in Section 4.3.

3.5 Wire Rope

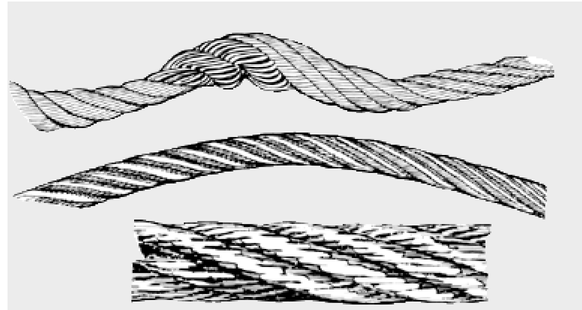
For suspension lines on any type of climbing equipment use only wire rope of the type, size, construction, and grade recommended by the manufacturer of the climbing unit. The minimum size of steel wire rope used for climbing devices on suspended access equipment is 7.8 mm (5/16 inch) diameter.

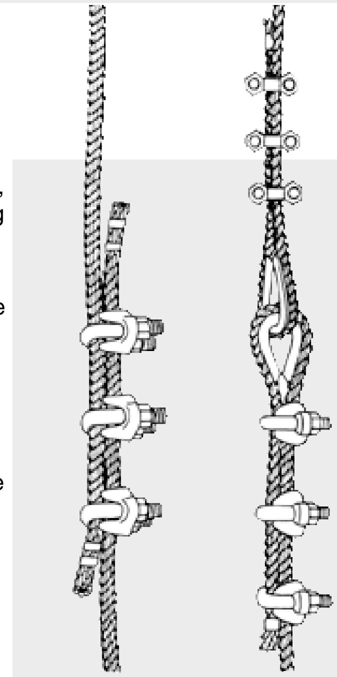
Take care to ensure that the solid core wire rope intended for some traction climbers is not replaced by fibre core wire rope. The compressibility of the fibre core can cause the rope to slip through the traction climber. Manual traction climbers use a wire rope of relatively stiff construction (usually 6 x 17). Powered climbers use a more pliable wire rope construction (usually 6 x 19 or 6 x 31).

Wire ropes should be free of kinks, birdcaging, excessive wear, broken wires, flat spots, or other defects (Figure 16).

When brazing the end of wire ropes, cut the core back 3 or 4 inches short to allow for movement in the rope and easier threading through the climber.

Wire ropes may be used as static lines or tieback lines for outrigger beams. In either case, the wire rope must be properly secured to adequate anchorage.





The use of secondary safety devices commonly known as "block stops" simplifies the installation of wire rope tiebacks. These devices must be installed, used, inspected, and maintained according to manufacturer's instructions.

Cable clips used with wire rope tiebacks or static lines should be the right size and number, torqued up tightly, and correctly installed (Figure 17).

Cable clips must never be used on fibre or synthetic rope unless the procedure is authorized by the rope manufacturer.

Table 1 specifies the number of cable clips required for various types and sizes of wire rope commonly used for tiebacks and static lines. Although U-bolt clips are the most common, double saddle clips (sometimes called J-clips or fist grips) do not flatten the wire rope and are more appropriate to this application.

Note: Cable clips are not recommended for use on suspension lines. Loops in suspension lines should have thimbles and be either spliced or secured with a mechanically swaged fitting.

Table 1

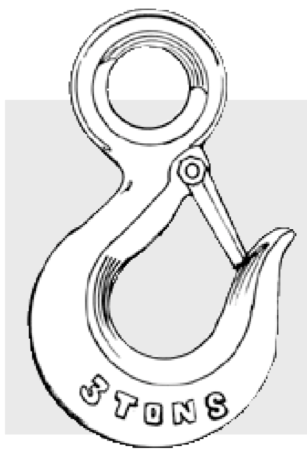
Wire ropes used with suspended access equipment must have a safety factor of 10 against failure (the manufacturer's catalogue breaking strength). This applies to all wire ropes used in rigging the equipment, including suspension lines and tiebacks.

Wire rope suspension lines supporting a stage used for electric welding must be protected from the danger of welding current passing through them. This can be done by using an insulated thimble on the suspension line/outrigger beam connections and covering the climber and suspension lines in the vicinity of the stage with an insulating material such as a rubber blanket. The ground connection for the material being welded should be as close as possible to the welding zone. The deck and rails of the stage should be covered with insulating rubber and the stage should have rubber bumpers.

3.6 Rigging Hardware

Rigging hardware for use with suspended access equipment should be capable of supporting at least 10 times the maximum load to which it may be subjected. This applies to all hooks, shackles, rings, bolts, slings, chains, wire rope, and splices.

Figure 18
Forged Alloy Hook with Stamped Capacity



Shackles and hooks should be forged alloy steel (Figure 18). The capacity of these devices for normal hoisting purposes is usually based on a safety factor of 5 and should be stamped on the device. For use with suspended access equipment, this capacity must be divided by two to ensure a safety factor of 10.

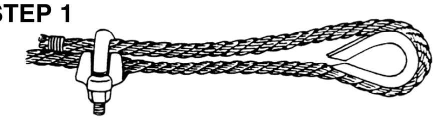
3.7 Manual Traction Climbers

The mechanical action of these devices is similar to hand-over-hand pulling on a rope. While one mechanism pulls, the other changes position to pull in turn. The jaws of the device grip the wire without damaging it. They are self-locking. As the load increases, their grip increases—the greater the load the tighter the grip.

Lifting capacity varies with the size of the device. Check the manufacturer's literature to ensure that the capacity is adequate for the load. A maximum load rating for pulling and maximum load rating for hoisting will usually be specified in the literature. Use the load rating for **hoisting**.

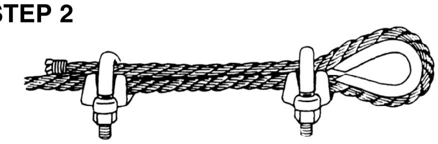
Only the size, type, construction, and grade of wire rope specified by the manufacturer should be used with these climbers. Maintenance is usually limited to daily inspection and periodic cleaning. Field personnel should not try to repair these devices. Repairs should be left to an authorized dealer with factory trained personnel.

STEP 1



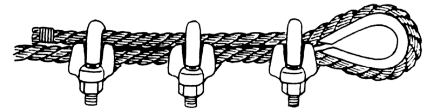
APPLY FIRST CLIP – one base width from dead end of wire rope – U-Bolt over dead end – live end rests in clip saddle. Tighten nuts evenly to recommended torque.

STEP 2



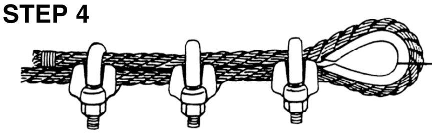
APPLY SECOND CLIP – as close to loop as possible – U-Bolt over dead end – turn nuts firmly but DO NOT TIGHTEN.

STEP 3



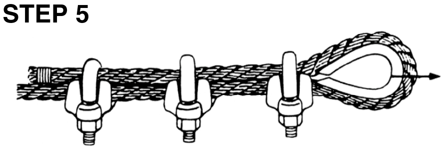
APPLY ALL OTHER CLIPS – Space equally between first two and 6 -7 rope diameters apart.

STEP 4



APPLY tension and tighten all nuts to recommended torque.

STEP 5

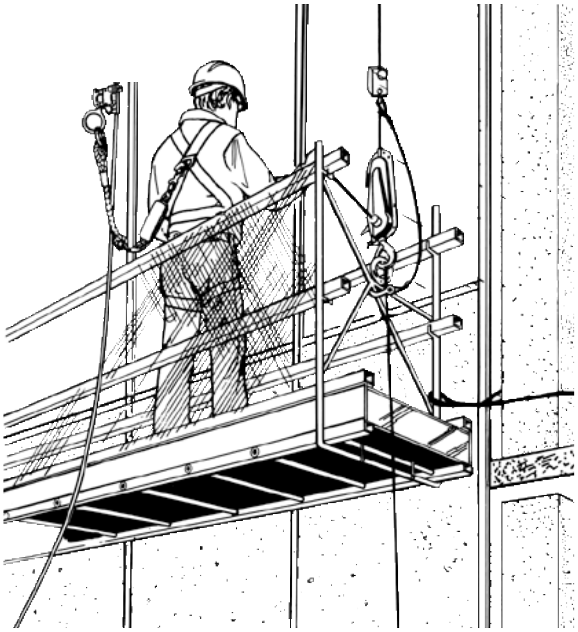


CHECK nut torque after rope has been in operation.

3.8 Secondary Safety Devices

A secondary safety device is a wire rope grabbing device that provides protection in case the wire rope connection or primary hoisting system fails. Figure 19 illustrates how the device is mounted on each wire rope above the hoist with a whip or sling connected to the stirrup of the stage. These devices may also be a fixed component on powered climbers.

As these devices advance on the wire rope their jaws open slightly to let the rope pass through. When a sharp downward pull is exerted, the jaws automatically close on the rope and grip it with a degree of tightness determined by the load.



3.9 Powered Climbers

Powered climbers come in a variety of sizes with different climbing speeds, power requirements, and safety devices. The majority are powered by electricity. Some operate at 115 volts, 60 Hertz, while others operate at 220 volts, 60 Hertz. Air- and hydraulic-powered systems are also available.

Most powered climbers have automatic overspeed brakes for situations where descent takes place too quickly. Most also have a manual system for lowering the stage in case of power failure or other emergency. Workers using the stage should be fully instructed in the operation and purpose of these devices.

Manufacturers usually list a safe working load either on the device or in their literature. Along with this information the climbing speed will usually be noted. Climber lifting capacities range from 304 to 1,134 kg (750 to 2,500 lb.) and climbing speeds vary from 0.178 to 0.76 metres per second (15 to 35 ft/min). You must not exceed the rated working load of either of the two climbers on your stage. To ensure that you are not overloading the climbers, take the combined total of

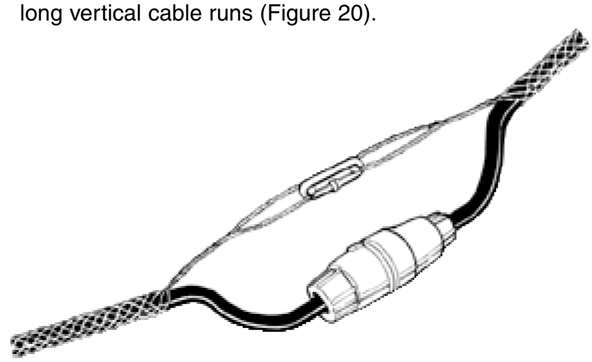
a) half of the weight of the stage, motors, climbers, and power cables
plus
b) the full weight of all the people, working materials, tools, equipment, and anything else that the stage may carry.

This combined total must not exceed the manufacturer's rated working load of each of your climbers taken alone.

Before selecting an electrically powered climbing device for a particular application, determine what circuits are available at the site. If circuits do not meet the voltage and amperage required, temporary wiring will be necessary to accommodate the climbers. Where the wiring runs are long, voltage drops may be so large that a portable step-up transformer is needed to maintain current levels so that the motor will not overheat.

Also consider the amount of climbing necessary for the job. Climbing speeds vary with the size of the climber. Small climbers carrying loads up near their safe working load limits over large distances may overheat and automatically cut off power. Workers should be advised why such situations can occur. It is usually because of improper climber selection, an inadequate circuit for the supply of power, or a cable too small for the length of run.

Power supply cables or cords must have wire heavy enough to minimize voltage drop in the line. Most supply cable is either 10 or 12 gauge 3 wire cab tire (neoprene rubber protected) depending on size of climber motors and length of run. Twist-lock outdoor male and female connectors should be used. "Sock" supporting devices should be used to relieve the strain on connections for long vertical cable runs (Figure 20).



3.10 Lifelines

Vertical lifelines must meet or exceed the requirements for performance, durability, impact strength, and elasticity specified in the current version of CAN/CSA Z259.2.

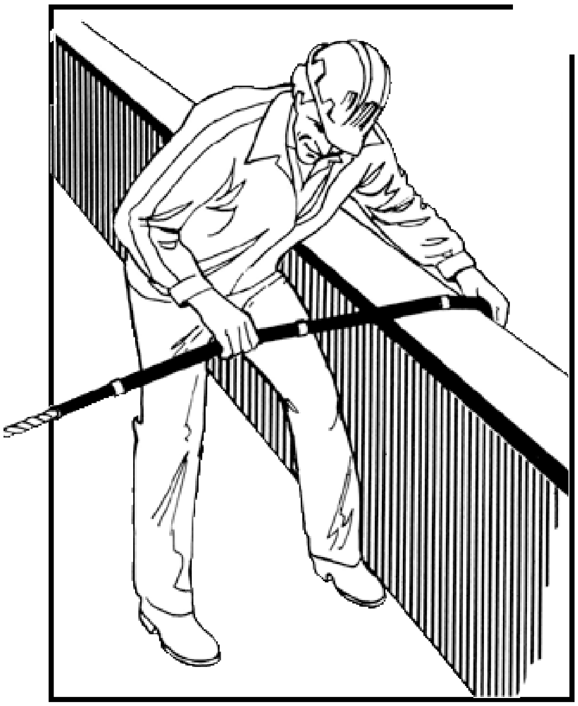
There must be an individual lifeline for each worker on a stage, platform, or chair. Each lifeline must have a separate anchor. Do not attach lifelines to the same anchor point as outrigger beam tiebacks.

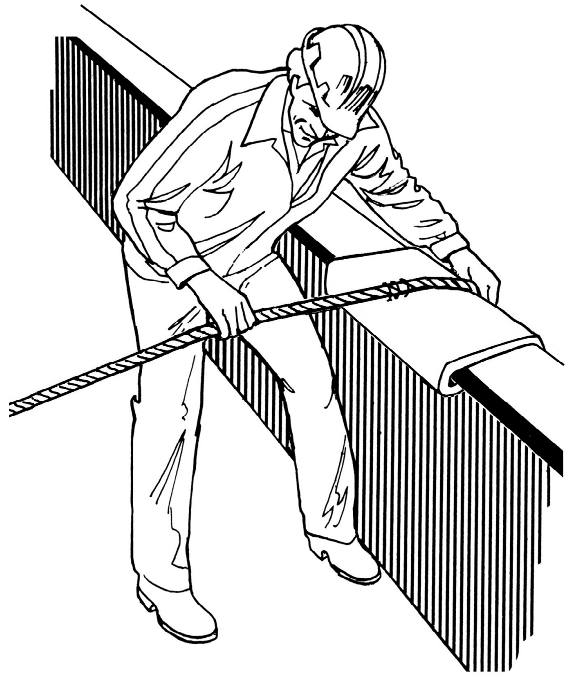
Each lifeline must be long enough to reach the ground or a working level where a worker can exit from the equipment onto a solid, flat, level surface. Each lifeline must also have a means of preventing a rope grab from running off the end of the rope.

Before each use, lifelines should be inspected for damage from abrasion and chafing. When in use they should be protected from such damage.

Protection is necessary where lifelines are tied or anchored and where they extend over a wall, roof, or structural framing, as illustrated in Figure 21. Provide for protection when preparing for the job.

Lifelines must never be used to raise or lower material and equipment. When work is done, lifelines must be lowered to the ground, not dropped or thrown from the roof.





3.11 Fall-Arrest Equipment

Full body harnesses (not safety belts) must be used for all applications involving suspended access equipment. These devices transfer fall-arrest loads to the lower parts of the body such as thighs and buttocks instead of the mid-torso area containing a number of vital organs. The thighs and buttocks are not only more capable of sustaining the fall-arrest loads, but can also more comfortably and safely support the person awaiting rescue.

Lanyards must meet or exceed the requirements of the current version of CAN/CSA-Z259. It is recommended that lanyards be fitted with locking snap hooks (Figure 22) or be spliced to rope grabs. Following this recommendation will reduce the risk of rollout (see section 5.5).

Shock absorbers must be used in any fall-arrest system. Shock absorbers should be manufactured to CSA Standard Z259.11-M92 and carry the CSA label. Shock absorbers may be attached to harnesses and lanyards with locking snap hooks in D-rings. It should be noted that shock absorbers can add as much as 1.2 metres (4 feet) to the fall distance before the fall is arrested.

Fibre rope lifelines are not recommended where caustic or acidic solutions or sprays will be used, as in building cleaning, or where sparks from welding or cutting can cause damage. In such situations use wire rope lifelines. When using a wire rope lifeline, a shock absorber, connected between the “D” ring of the full body harness and the lanyard, or an integrated shock absorbing lanyard, must always be used to keep the forces on the body resulting from a fall arrest within acceptable and safe limits.

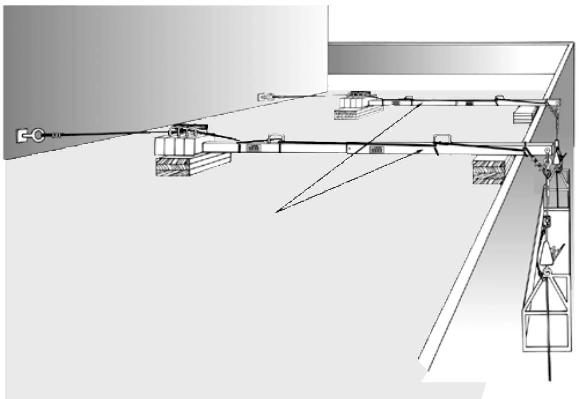
In addition, wire rope lifelines should be insulated whenever electric welding is taking place.

4 SET-UP AND OPERATION

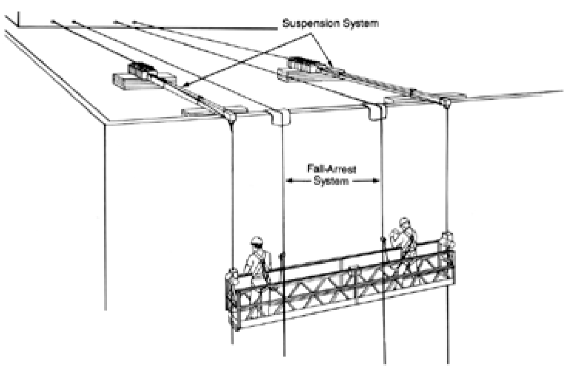
4.1 Two Independent Means of Support

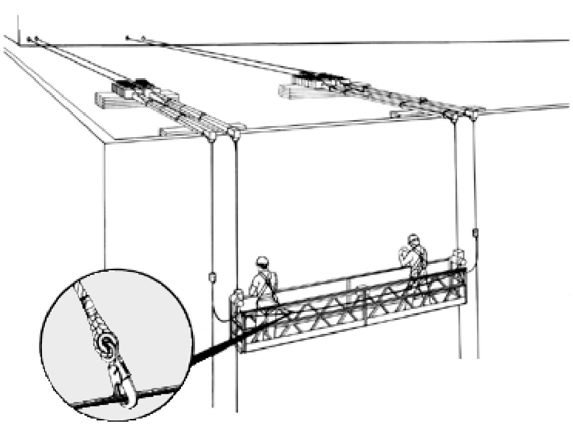
A fundamental concept in the use of suspended access equipment is that there must be two independent means of support for workers on the equipment.

One independent means of support is the suspension system of the stage or bosun's chair (Figure 23). This usually consists of climbers, suspension lines, outrigger beams and counterweights or parapet clamps, and tiebacks secured to adequate anchorage.



The second independent means of support for a typical two-point suspension single stage is a fall-arrest system (Figure 24). This consists of a full body harness, lanyard, rope grab, and lifeline secured to adequate anchorage.

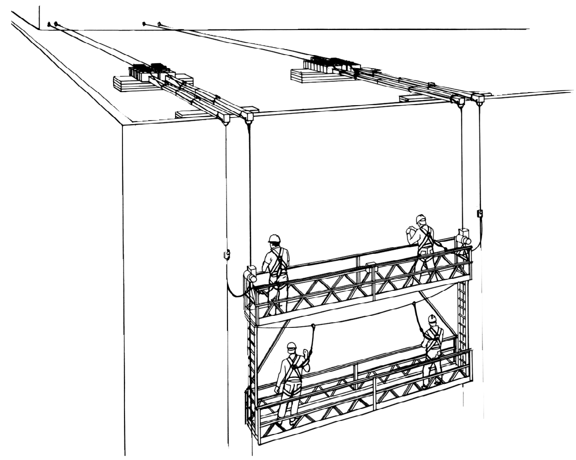




An alternative method for providing a second independent means of support is a second complete and independent suspension system (Figure 25). In this case, the worker should tie off directly to one of the stirrups or to a properly designed horizontal lifeline securely fastened to both stirrups.

This type of secondary suspension system must be designed by a professional engineer.

In practice two complete suspension systems are not used unless the application involves a tiered stage (Figure 26). In this case workers on the lower stage could not adequately be protected by a lifeline if the upper stage were to fall. Therefore the arrangement must be supported by two independent support systems. Workers on the lower stage must tie off to the stage they are on or the one above. Workers on the upper stage may tie off to the stage they are on or a lifeline.



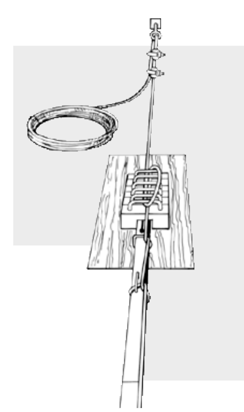
Tiered stages must not be used unless the system is designed for the specific application by a professional engineer familiar with this type of equipment. The system must be rigged according to the design. Drawings of the design should be kept on-site for easy reference and inspection. In addition, the rigging should be checked by a professional engineer before the first drop is made.

4.2 Outrigger Beams, Counterweights, and Tiebacks

Outrigger beams may be used for either stages or bosun's chairs. Procedures for both are essentially the same and in both cases the instructions on counterweight requirements and overhang limitations must be affixed to the outrigger beam being used.

Beams must be

- counterweighted to maintain a 4-to-1 safety factor against overturning or failure
- tied back to adequate anchorage as shown in Figure 27
- firmly attached to the counterweights
- free of damage, dings, or kinks
- light enough to be manually handled and transported.



4.3 Loads and 4-to-1 Safety Factor

The dynamic loads involved and the unforgiving nature of suspended equipment require that the outrigger beam/ counterweight arrangement must have a safety factor of 4 against overturning.

This means that the tipping tendency holding the beam from overtu rning must be at least 4 times the tipping tendency created by the suspension line load acting on the beam.

4.3.1 Suspension Line Load with Powered Climbers

For both suspended stages and bosun's chairs operated by powered climbers, the line load used to calculate the number of counterweights is the same as the manufacturer's rated capacity of the climber. The information plate on the climber should provide this information. The rated capacity must match the load limit information on the outrigger beams.

Powered climbers operating at speeds up to 35 feet per minute can load up ve ry quickly if the stage or chair gets caught on an obstruction. In this situation the line load will reach the capacity of the climber before it automatically cuts out.

4.3.2 Suspension Line Load with Manual Climbers

Stages and bosun's chairs with manual climbers do not move nearly as quickly as powered climbers so there is no need to consider the capacity of the climber as the maximum possible suspension line load. We recommend the following criteria for establishing these loads on manually powered systems.

Two-point Suspended Stages: Calculate the weight of people, tools, and material expected to be on or suspended from the stage plus the weight of the stage, suspension lines, and climbers. Consider this load to be at least 1,000 lb. Then take 1,000 lb. or the total weight of the suspended system— whichever is **greater**—as the suspension line load for calculation purposes. Consider this the load on **each** suspension line.

For example, if a stage weighs 200 lb., 2 workers weigh 400 lb., and climbers and other gear weigh 200 lb., the total load is 800 lb. In this case we recommend that each suspension line be rigged for 1,000 lb. of line load. If the load had been 1,200 lb. we would recommend rigging for a suspension line load of 1,200 lb. **after checking with the supplier to ensure that the equipment is capable of taking such a load.**

Bosun's Chairs: Calculate the weight of the person, tools, materials, chair, suspension line and climber, but not less than 350 lb. The greater value then becomes the suspension line load for calculation purposes.

4.3.3 Calculation of Counterweight Load

Each outrigger beam should have an information label attached to it. This label will state the number of counterweights you need for a given loading and overhang situation. This information applies only to that beam, and to the counterweights provided by the manufacturer for use with that particular system. If the label is missing, you must not attempt to calculate the number of counterweights needed unless you know all the characteristics of that beam and of the counterweights being used.

The first operation in calculating the proper counterweight load is determining the appropriate suspension line load as discussed in 4.3.1 and 4.3.2.

For calculating the proper counterweight load, Figure 28a describes a formula for people with a good understanding of mathematics and the "law of the lever."

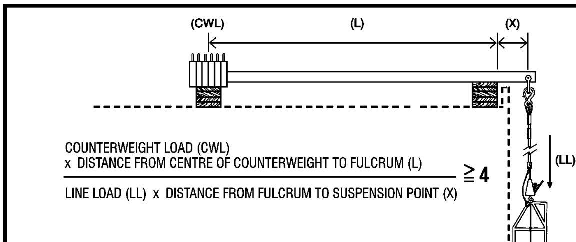


Figure 28(a)

We can also look at the problem in terms of what we have "wo rking **against** us" versus what we need "working **for** us."

What we have working against us are the suspension line load and its distance from what we call the "fulcrum" or the tipping point. What we have working for us are the counterweights and the distance from the tipping point to the centre of the weights (Figure 28b).

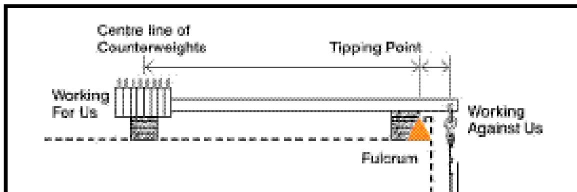


Figure 28(b)

Because of dynamic loads and the unforgiving nature of the equipment, we need to build in a safety factor. The safety factor is 4. We need 4 times as much for us as we have against us (Figure 28c).

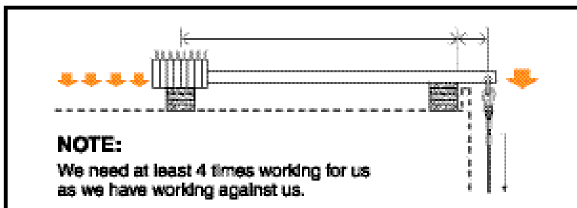


Figure 28(c)

A dynamic load is greater than a static or stationary load. We have all caught something dropped to us. The article is heavier when we catch it than when we simply hold it. The increase is due to the article moving. Its load when moving is called the dynamic load. This is one more reason why we need a safety factor.

The law of the lever says that the "tipping effect" or "moment" is equal to the load multiplied by the length of the lever. We have all used a pry bar to move heavy objects. The longer the bar the easier it is to move the heavy object, or the heavier the person on the bar the easier it is to move the object. This concept and the safety factor of 4 form the basis for our calculation.

If we assume our line load is 1,000 lb. and the suspension point is located 1 foot beyond the outrigger beam's tipping point [Figure 28(d)], then the tipping force (moment) is:

1,000 lb. x 1 foot = 1,000 lb. ft.

To resist this tipping force of 1,000 lb. ft and at the same time ensure a built-in safety factor of 4, we need to have 4 times this value, that is, 4,000 lb. ft., working for us.

If overall beam length is 12 feet, then the section working for us to resist tipping force extends from the tipping point to the far end, that is,

12 feet – 1 foot = 11 feet.

However, in our calculation we can only consider the distance from the fulcrum or tipping point to the centre of the counterweights.

Let's assume that there are 400 lb. of 50 lb. counterweights each 1/2 foot in width. In Figure 28d you can see that the lever arm from the fulcrum to the **centre** of the counterweights can only be 11 ft. – 2 ft. = 9 ft. What we have working for us is: 400 lb. x 9 ft. = 3,600 lb. ft.

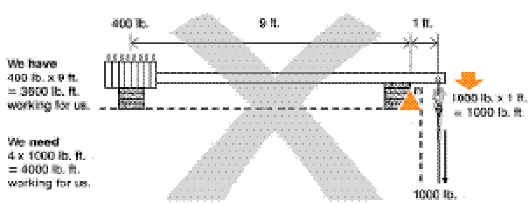


Figure 28(d) Inadequate Arrangement

This is less than the 4,000 lb. ft. we require. We will have to change something. We cannot change the suspension line load but we can change some of the other conditions.

If we reduce the distance that the suspension point extends out from the tipping point to 9 inches (.75 ft.) the value of what we have working against us is:

1,000 lb. x .75 ft. = 750 lb. ft.

What we now need working for us is:

4 x 750 = 3,000 lb. ft.

If we keep the same number of counterweights, the lever arm working for us becomes 9.25 feet long. It gained 3 inches (0.25 feet) when the other side was reduced 3 inches (Figure 28e). We now have:

400 lb. x 9.25 ft. = 3,700 lb. ft.

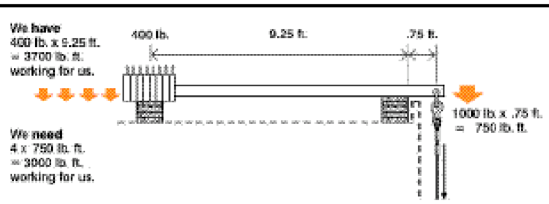


Figure 28(e) Adequate Arrangement

This would be satisfactory since 3,700 lb.ft. exceeds what we actually need (3,000 lb. ft.). See what a difference a few inches can make in this calculation!

Remember—the load line must remain vertical. This affects whether or not the beam projection can be reduced and by how much.

Another approach is to add more counterweights. If we add two more, our counterweights total 500 lb. However, our lever arm is reduced by 6 inches since the centre of the counterweights has shifted.

What we have working against us is still the same:

1,000 lb. x 1 ft. = 1,000 lb. ft.

What we need working for us is still:

4 x 1,000 lb. ft. = 4,000 lb. ft.

What we have working for us is:

500 lb. x 8.5 ft. = 4,250 lb. ft.

Again, this would be satisfactory. We have more working for us than we actually need (Figure 28f).

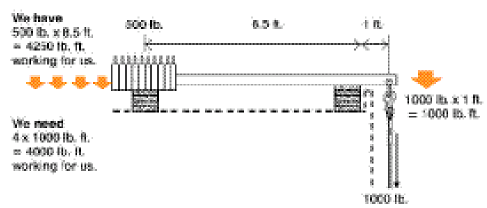
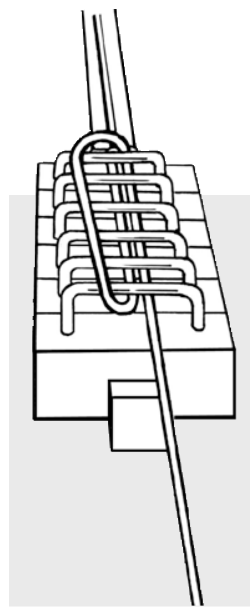


Figure 28(f) Adequate Arrangement

Before deciding whether or not to add more counterweights, keep in mind that every manufactured steel outrigger beam has a defined limit to the number of counterweights that can be placed and secured on it. This limit should be indicated on the beam label.

4.4 Counterweights

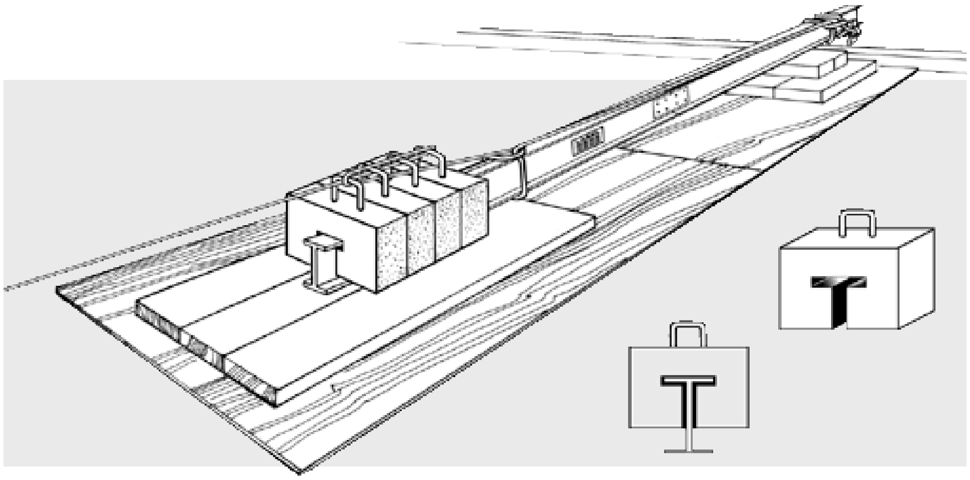
Counterweights vary in size and design from manufacturer to manufacturer. This is the main reason why one manufacturer's tables for counterweights cannot be used with another manufacturer's equipment.



Counterweights should be securely attached to the outrigger beam so that the vibration or movement of the beam will not dislodge or move them. Typical counterweight securing systems are shown in Figures 29 and 30.

4.5 Roof Loads

Counterweights can overload roofs of light material such as metal roof deck. Most roofs are designed for the weight of the roof plus the design snow load which may range between 45 and 80 lb. per sq/ft. for areas in Ontario. Loads exerted by counterweights can be considerably greater than this and should be spread over a larger area by using plywood or planks (Figure 30). This also helps to reduce damage to built-up bituminous roofing.



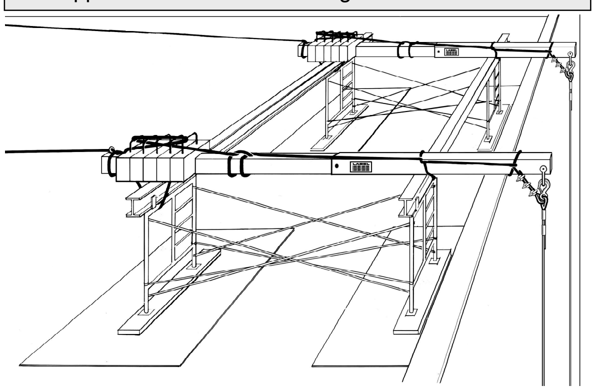
It is especially important to spread the loads on scaffold legs or the special support structure over a large area of the roof. Otherwise damage to the roofing material and possibly the deck itself may occur. Note planks and plywood under scaffold legs in Figure 31.

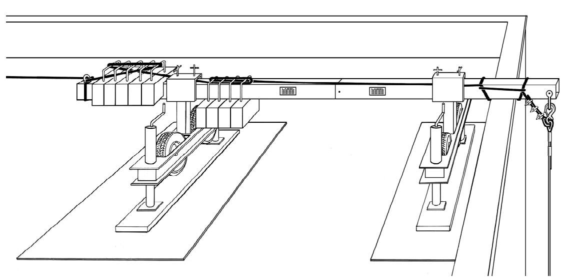
A scaffold system, or other specialized manufactured support system used to raise outrigger beams above the level of the parapet wall, must be designed by a professional engineer. A copy of the design drawings must be used to erect and inspect the system according to the engineer's design and must be kept on site as long as the system is in place.

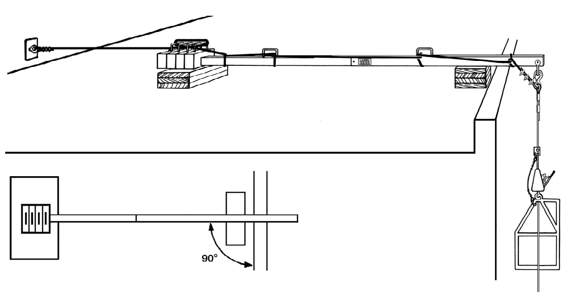
4.6 Parapet Walls

Parapet walls often present an obstruction to outrigger beams that must be overcome by the use of scaffolding or a special support structure (Figures 31 and 32).

> **Note:** The fulcrum is the point supported by the scaffold or support structure—**not** the edge of the roof.







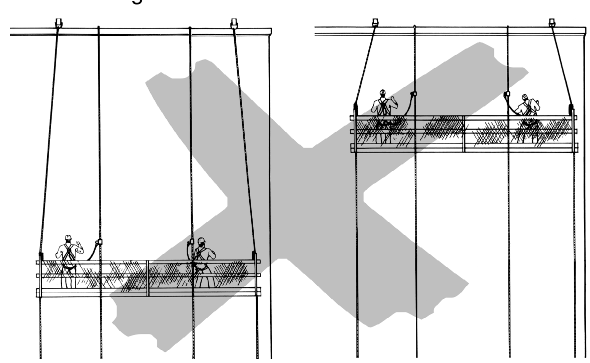
4.7 Outrigger Beams

Outrigger beams should be placed at right angles to the edge of the roof wherever possible (Figure 33).

If it's not possible to set up outrigger beams at right angles to the edge, the beams must be adequately secured or braced to resist any lateral movement while the system is in use.

Suspension points on the beams must be the same distance apart as stirrups on the stage. Position beams to ensure that spacing is the same. Failure to do so has resulted in many serious accidents.

Figure 34 illustrates what happens when the proper distance between outrigger beams is not maintained. The difficulty becomes serious as the stage nears the roof. At this point, sideways forces can move the outrigger beam, often causing a serious accident.



The pins on sectional outrigger beams must be properly installed and secured (Figure 15).

Wiring the pin in position or securing the nut on the pin with a cotter pin is also important. If the pin is not

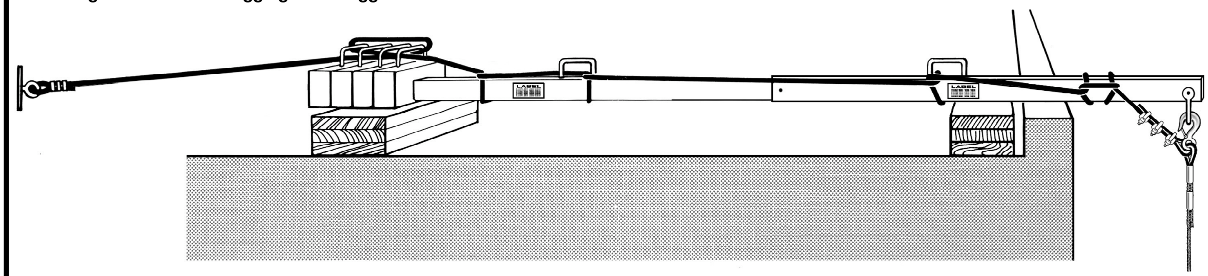


Figure 35 Tieback Rigging on Outrigger Beam

secured, vibration can easily dislodge it and make the beam come apart. This is especially important where manual climbers are used because the uneven jacking action of the climbers can apply intermittent loads to the beam and easily shake out a loose pin. This requirement also applies to shackle pins and eyebolts used on outrigger beam systems.

4.8 Tiebacks

Tiebacks should extend from the thimble of the suspension line back along the outrigger beam, with at least one half-hitch tied around the beam through the handles on each section. Tiebacks should then loop around the counterweight handles if they are so equipped, and then extend on back to an adequate anchorage (Figure 35).

Wire ropes are recommended for tiebacks with all suspended access systems. Fibre rope tiebacks are considered suitable for stages equipped with manual traction climbers. If fibre rope tiebacks are used, they should be 3/4-inch diameter polypropylene. Tiebacks for bosun's chairs should be 5/8 inch diameter polypropylene rope. Other manufactured rope that equals or exceeds the impact resistance, elasticity, and UV protection of 16-millimetre (5/8 inch) diameter polypropylene rope can also be used. Nylon is not recommended because it stretches too much and manila rope is not recommended because it is much more subject to deterioration.

Wire rope used for tiebacks should be at least equal in size to the wire rope used for the climber. After wire rope has been used for tiebacks it should not be used for suspension line because of damage and deformation from cable clips, bends, and hitches.

Wire ropes should be fastened with cable clips in the correct manner (Figure 17) and recommended number (Table 1). Polypropylene rope should have either a spliced loop and thimble with a safety hook or shackle or be tied using a round turn and half-hitches (Figure 36) or a triple bowline knot (Figure 37). Knots may reduce the safe working load of the ropes depending on the means of securing and are therefore a less desirable alternative. Protect fibre rope from sharp bends. Figure 38 shows one method.

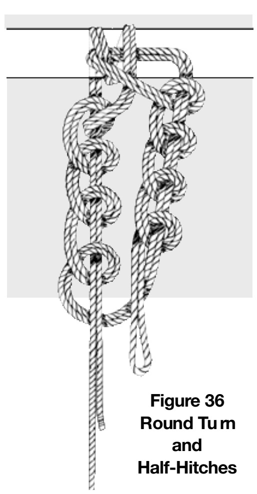
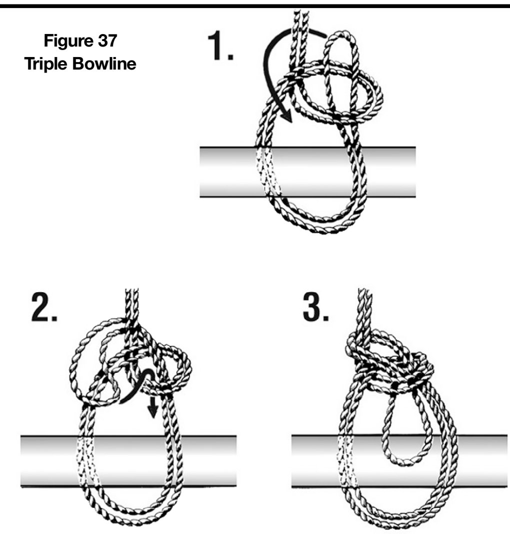


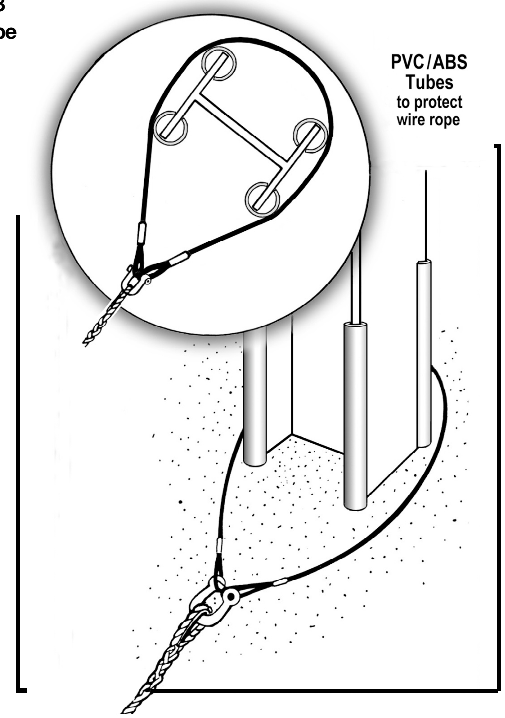
Figure 36 Round Turn and Half-Hitches

Figure 37 Triple Bowline



Where scaffolds are used for support structures, the tieback line should also be looped around the top of the scaffold (Figure 31).

Figure 38 Wire Rope Sling to Protect Fibre Rope



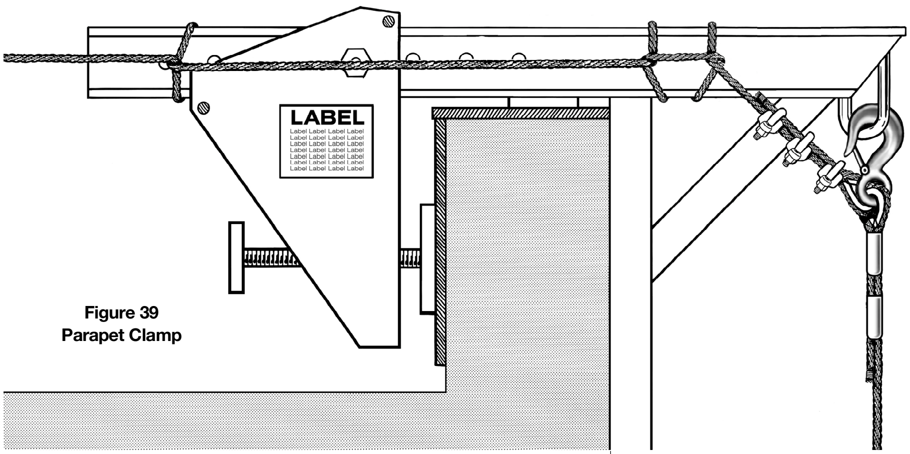


Figure 39
Parapet Clamp

A fundamental concept in the use of any type of fall protection system is that it must be fully rigged, in place, properly adjusted, and worn by all workers

- while they are setting up and taking down the suspension equipment and working within 2 metres (6 feet) of the perimeter edge;
- while they are getting on and off the suspended access equipment; and
- at all times while they are on the equipment.

4.9 Adequate Anchorage for Tiebacks

Adequate anchorage for tiebacks includes

- the base of large HVAC units
- columns on intermediate building floors or stub columns on roofs
- designed tieback systems such as eye bolts and rings
- large pipe anchorage systems (12-inch diameter or greater)
- large masonry chimneys
- roof structures such as mechanical rooms
- parapet clamps attached to reinforced concrete parapet walls **on the other side of the building**.

Never tie back to

- roof vents or "stink pipes"
- roof hatches
- small pipes and ducts
- metal chimneys
- TV antennas
- stair or balcony railings.

4.10 Parapet Clamps (Figure 39)

Where parapet walls are constructed of **reinforced** concrete or **reinforced** masonry, parapet clamps may be used. Before using any type of parapet clamp, obtain confirmation from the owner of the project that the parapet has been constructed with sufficient strength and performance characteristics to support the intended clamp.

Clamps must always be installed according to the manufacturer's drawings and written instructions. Ensure that clamps are securely fastened to the parapet wall and tied back to an adequate anchorage in a manner similar to tiebacks for standard outrigger beams.

5 FALL PROTECTION

A fundamental concept in the use of the suspended access equipment is that **there must be two independent means of support for each worker using the equipment**.

The first means of support is the access equipment itself. The second is provided by an appropriate fall protection system consisting of a full body harness, lanyard, shock absorber, rope grabbing device, and lifeline, as illustrated in Figure 40.

5.1 Fall Protection Planning

The pre-job inspection must determine not only the suspended access equipment to be used but also the proposed fall protection system.

When assessing fall protection requirements, check the following points.

- ❑ Is there a parapet wall higher than 1 metre (3 feet) around the roof perimeter?
- ❑ Are engineered anchors installed on the roof? How many are there? Where are they located? How far are they from the set-up area?

- ❑ If there are no engineered anchors, are any existing structures big and strong enough to serve as anchors? An adequate anchor should be capable of supporting the weight of a small car (about 3,600 pounds).
- ❑ Are there any sharp edges requiring lifelines to be protected?

Fall protection planning must include

- type of fall protection equipment to be used
- type, length, and number of lifelines required
- travel restraint or warning barriers to be used when setting up or dismantling the suspended access system on the roof
- fall protection procedures to follow while setting up, getting on, getting off, working from, and dismantling the suspended access equipment.

Finally, all horizontal and vertical work surfaces where the suspended access equipment will be assembled, operated, and dismantled must be evaluated to determine escape, rescue, and other emergency procedures in the event of mechanical failure or breakdown.

5.1.1 Fall-Arrest Rescue Planning

Before any fall-arrest equipment is used on a construction project, the employer is legally required to have in place a written procedure outlining how to rescue a worker involved in a fall arrest. This procedure is in addition to those required by law to cover general emergency response on a project.

A worker hanging in harness after a fall arrest must be rescued and brought to a stable work surface, platform, or ground within 30 minutes. Left suspended for more than 30 minutes, the worker may experience increasing discomfort, nausea, dizziness, and fainting. If left suspended for a prolonged period of time, the worker may have heart and breathing difficulties and may even die.

To ensure timely, effective rescue, an employer may create generic procedures to cover all potential fall rescue requirements for the company's typical work.

The employer must then

- provide staff training in the procedures
- ensure that the procedures are reviewed and modified as necessary to meet specific job conditions
- provide staff training in these modified, site-specific procedures.

Use the following checklist to prepare rescue procedures for workers involved in fall arrest.

- ❑ Is there a safe practical means of self-rescue? Can a worker involved in fall arrest reach a work platform, ground, or other safe place? Is any special equipment or training necessary for self-rescue?
- ❑ How will the worker communicate his or her predicament to other workers?
- ❑ What is the procedure when workers see a co-worker hung up in fall arrest? Who should be notified and how? What information needs to be conveyed? What should be done before help arrives?
- ❑ In an arrested fall from the highest point on the project, can the worker be reached by ground? Is there an adequate ladder or other device for rescue? Where is the equipment stored and who has access to it?
- ❑ Can a suspended worker be rescued from a level above or below? Is access unobstructed? Is a key necessary? Is there a way of quickly removing a window or other feature to reach the worker?
- ❑ If a suspended worker can't be reached from ground, another level, or a work platform, what specialized rescue equipment is needed? Are workers trained to use this equipment?
- ❑ What procedures are in place to rescue a suspended worker who is unconscious, injured, or otherwise unable to assist rescuers?
- ❑ What service, private or public, is available to aid in high-reach rescue? Has the service been notified and supplied with project information such as location, access, size, height, and available anchorage? Is the phone number of the service posted where everyone can see it? Have employees been advised to contact the service when high-reach rescue is needed?

5.2 Fall Protection Systems

There are two main types of fall protection systems:

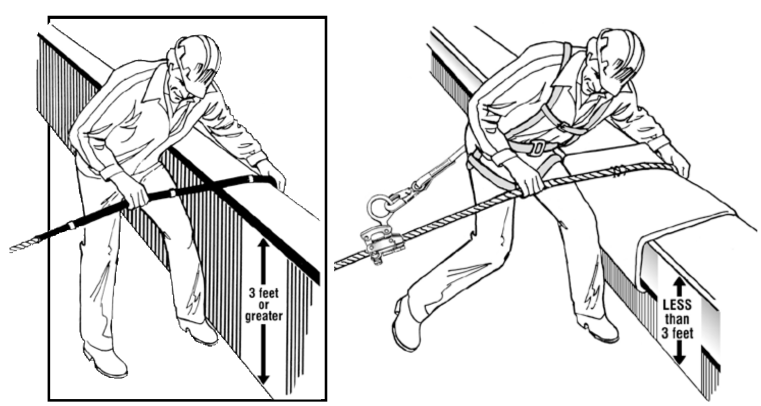
1) fall prevention
2) fall arrest.

5.2.1 Fall Prevention Systems

Fall prevention is a system that prevents a worker from gaining access to a known fall hazard. A guardrail is one example.

Fall prevention is primarily used around areas on the roof where workers set up or take down the suspension system. It can also be used to protect personnel working on balconies or similar structures.

A parapet wall 0.9 metres (3 feet) high or higher surrounding a roof provides fall prevention. This is equivalent to having a guardrail around the perimeter. Workers can work near the edge of the roof without additional protection as long as they don't reach over or beyond the parapet wall. Otherwise they must wear appropriate fall protection equipment and be properly tied off (Figure 41).



A bump line or warning barrier can be set up 2 metres (6 feet) from any perimeter edge. Inside this cordoned-off area, workers do not require fall protection equipment. The barrier acts as a physical boundary by keeping unprotected workers away from the perimeter.

Where no bump or warning line is used, or where the work requires workers to be less than 2 metres (6 feet) from the edge, a travel-restraint system is required. This has all the same components as a fall-arrest system—full body harness, shock absorber, lanyard, rope grab, and adequately anchored lifeline (see 5.2.2). The difference between the two systems is how they are used.

The lifeline in a travel-restraint system must have a positive stopping device or knot tied in it to prevent the rope grab from travelling beyond that point. The device or knot must be positioned so that the distance back to the anchor point, plus the combined length of the rope grab, lanyard, and D-ring on the harness, is less than the distance from the anchor point to the edge of the work surface. With the system arranged in this way, a worker falling toward the edge will be stopped before going over the edge.

5.2.2 Fall-Arrest Systems

Workers getting on, getting off, or working from suspended access equipment must wear a fall-arrest system and be properly tied off to an adequately anchored lifeline. This also applies to workers working on balconies or similar structures without other means of fall protection.

A fall-arrest system must include

- a f**ull body harness** that meets or exceeds the current CSA standard
- a **shock absorber** that meets or exceeds the current CSA standard and is attached to the D-ring on the harness
- a **lanyard** that meets or exceeds the current CSA standard and is connected to the free end of the shock absorber and properly connected to the connecting ring of a rope grab
- a r**ope grab** properly attached to an adequate vertical lifeline
- a **vertical lifeline** that meets or exceeds the current CSA standard and is properly secured to an adequate anchor
- an independent **anchor** which has been designed by a professional engineer for that purpose or which a competent worker can reasonably consider strong enough to support the weight of a small car (about 3,600 pounds).

In cases where the second means of support consists of a second, properly designed, fully rigged, and complete suspension system, workers can tie off directly to the suspended access equipment, as per design specifications for that particular system.

5.2.3 Fall Protection Training

Employers must ensure that any worker who may use a fall protection system is properly trained in its use and given adequate oral and written instructions by a competent person.

Training should include, but not be limited to,

- basic inspection, care, and maintenance of personal fall protection equipment
- proper methods of assembling, putting on, and adjusting equipment
- how to protect, handle, and secure lifelines
- safe versus unsafe anchor points
- procedures for tying off
- explanation of all work procedures that require fall protection
- explanation of company policy regarding mandatory use of fall protection on the job.

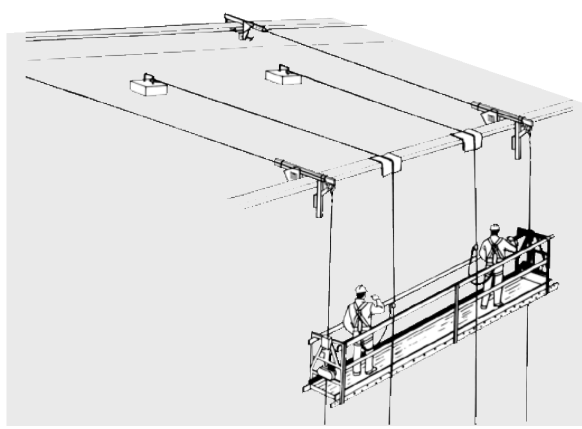
Employers must keep written records of all employees trained in fall protection.

5.3 Lifelines

Each lifeline must be tied back to an adequate anchorage. In practice, adequate anchorage is usually a matter of judgment rather than calculated capacity. As a rule of thumb, the anchorage should be capable of sustaining the weight of a small car.

On new construction, lifelines usually can be secured to exposed structural components such as beams or columns. On existing buildings adequate anchorage includes the points itemized in section 4.9.

Each lifeline must be tied off to an adequate anchor point separate and independent from the anchor points used for other lifelines and for tiebacks (Figure 42). Where there aren't enough independent anchor points to meet this requirement, an anchoring system must be designed by a professional engineer.



5.4 Protection for Lifelines

Lifelines must be protected from abrasion or chafing and from sharp corners which can break the lines under heavy shock loads.

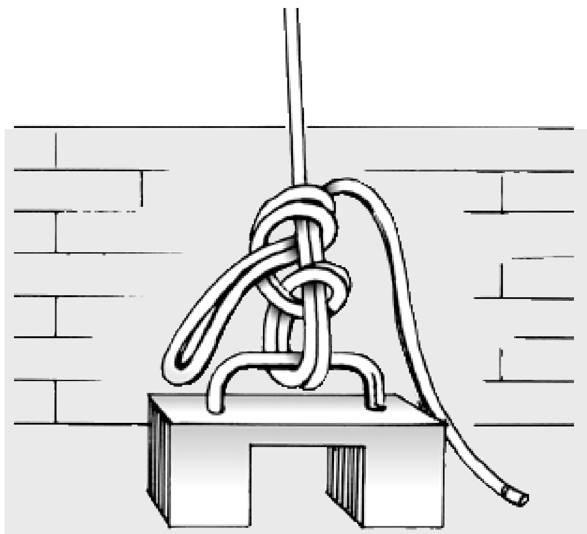
A spliced eye and thimble, complete with a safety hook, is the recommended connection device. However, where the rope must be tied to the anchorage it is recommended that the rope be doubled back and tied with either a round turn and half-hitches (Figure 36) or a triple bowline knot (Figure 37).

Although tying to the anchorage with knots is necessary in some situations, it is not recommended where the spliced eye and safety hook can be used. Knots may reduce the load-carrying capacity of the rope significantly.

Lifelines must also be protected from abrasion where they pass over a parapet wall or the edge of a roof. A rubber hose clamped to the lifeline to hold it in position is an effective means of providing protection. Rubber mats or carpeting also provide protection but should be fixed to the lifeline or be wide enough to allow for considerable shifting of the lifeline because of wind or worker movement below (Figure 21).

The lifelines should be reasonably taut. Loose coils on the roof should be lined out. Lifeline anchors should be perpendicular to the roof edge at the point where the lifelines drop over. The anchor point should be a reasonable distance from the roof edge—preferably 3 metres (10 feet) or more. This will allow the rope to absorb more energy in the event of a fall arrest at the roof edge.

Lifelines must also be protected from entanglement in traffic on the ground below or in construction equipment such as tower cranes. This can be done by tying the lifeline to the structure at ground level or weighting it down with counterweights (Figure 43). Always allow enough slack for the movement of workers on the stage.



5.5 Lanyards and Rope Grabs

Lanyards should be attached to the lifeline by a rope grab. The rope grab should meet the requirements of CSA Standard Z259.2M-1998.

Rope grabs and lanyards should be attached by a locking snap hook, a karabiner looped through a spliced loop and thimble, or a loop and thimble spliced into the rope grab ring. These methods will prevent “roll-out.”

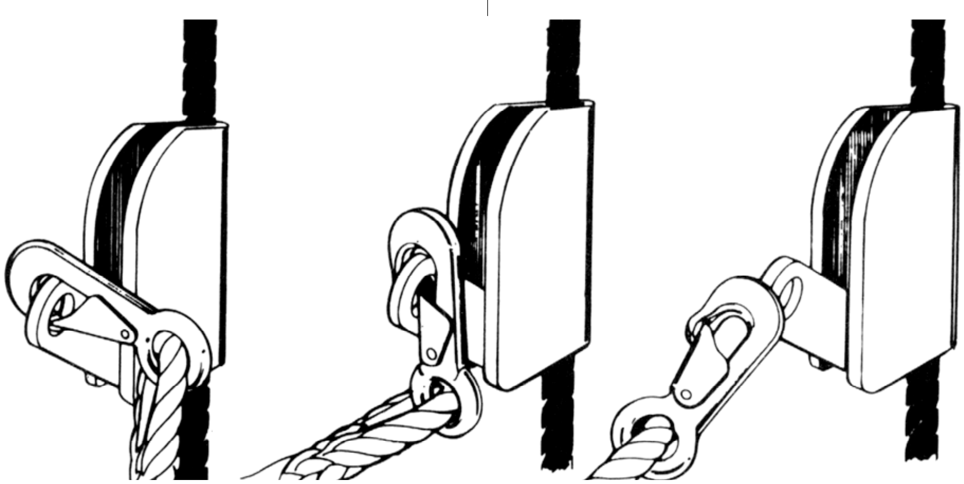
Roll-out can occur when a regular snap hook attached to a small ring in the connection system releases itself under load (Figure 44). Small rings are sometimes found on older rope grabs.

5.6 Full Body Harness

With suspended access equipment, it is a legal requirement in Ontario to wear a full body harness—not a safety belt. The harness absorbs fall-arrest loads at the thighs and buttocks rather than the upper abdomen and chest where many of the body’s vital organs are located.

Lanyards should be attached to shock absorbers which should, in turn, be attached to the full body harness. The attachment should be a locking snap hook or a spliced hook loop and thimble. Looping a splice around a D-ring is **not** recommended.

The fall-arrest system must be in place and properly rigged, with attachments suitably adjusted, **before** the worker gets on the suspended access equipment. The worker must wear the fall-arrest system and be properly tied off at all times when getting on, using, or getting off the suspended access equipment.



6 Checklists

The following list identifies points which should be checked before anyone uses suspended access equipment.

- ❑ Operator knowledgeable and competent to operate the equipment involved?
- ❑ All required components available, properly rigged, and in good condition?
- ❑ Failsafe devices such as rope grabs, secondary safety devices, and overspeed controls installed and operating?
- ❑ Power supplies for climbers adequate, grounded, and secured?
- ❑ All tiebacks for outrigger beams, parapet clamps, and lifelines properly secured to adequate anchorage capable of supporting 10 times the applied load?
- ❑ Adequate number of counterweights securely attached to outrigger beams?
- ❑ Fibre ropes protected from chafing and abrasion?
- ❑ Emergency rescue arrangements planned, prepared, and communicated to everyone involved?
- ❑ Access to and from the work area planned and arranged?

The answer to each of these questions should be yes.

SUSPENDED ACCESS EQUIPMENT DAILY CHECKLIST WEEK ENDING ______

Planning Checklist Items

Jobsite ______	Location ______	Contact ______	Position ______	Log Book ______
Competent Person ______	Roof Sketch ______	Access ______	Control ______	Storage ______
Equipment Requirements ______	Personnel Req'd ______	Training Req'd ______	WHMIS ______	Work Plan ______
Public Protection ______	Hoarding/Barricade ______	Signage ______	Inspection ______	Building Height ______
Type of Work ______	Restoration ______	Caulking ______	Cleaning ______	Other ______
Building Height ______	Obstructions ______	Landing Area ______	Anchorage ______	Adjacent Powerlines ______

Support Checklist Items

BEAMS	**M**	**T**	**W**	**Th**	**F**	**SWINGSTAGES**	**M**	**T**	**W**	**Th**	**F**	**FALL-ARREST SYSTEM**	
Length of Overhang						Power Cable & Yoke						Daily or Frequent Checks	
Number of Weights						110v Box						Separate Anchor Point	
Connecting Pins, Lock Wire						Support Cables						Knot	
Support Cable & Hooks						Cradles/Stirrups						6 Feet from Edge	
Parapet Clamps						Motor Mounts						CSA Rope Grab	
Beam Supports						Motor Daily Checks						CSA Lanyard	
Beam Label						Overspeed Check						CSA Shock Absorber	
TIEBACKS						**GROUND CHECK**						CSA Body Harness	
Through Thimble						Fence/Barricades						Lifeline	
Through Handles						Free of Garbage						Rope Protection	
Through Weights						Equipment Secured						Locking Snap Hooks	
Block/Drop Stops						Cladding/Hoarding						Trained in Using	
Wire Rope Clips						Walkthrough Scaffolding						Line Ground Protection	
Clevises/Shackles						**SCAFFOLDING**						Lines Perpendicular	
Anchoring Points						Lock Pins							
Knots						Vertical Braces							
Clear Path to Edge						Horizontal Braces							
Edge Protection						Guardrails							
POWER CABLE						Planks							
Tied Back						Base Plates							
Edge Protection						Tie-Off							
Plugs Secure & Dry						Access Ladder							
						HOUSEKEEPING							
						Cleanup							
						Storage							

7 RIGGING

Tradespeople who are not professional riggers must nonetheless rig loads at times on the job. Carpenters, for instance, are often involved not only in handling but in hoisting and landing material. When in doubt about rigging, consult an experienced rigger or a professional engineer. Information in this chapter covers only the basics of rigging.

Inspection

Use this checklist to inspect rigging components regularly and before each lift.

Manila Rope

Manila rope is not recommended for construction use and is illegal for lifelines and lanyards.

Dusty residue when twisted open	Wear from inside out. Overloading. If extensive, replace rope.
Broken strands, fraying, spongy texture	Replace rope.
Wet	Strength could be reduced.
Frozen	Thaw and dry at room temperature.
Mildew, dry rot	Replace rope.
Dry and brittle	Do not oil. Wash with cold water and hang in coils to dry.

Polypropylene and Nylon Rope

Chalky exterior appearance	Overexposed to sunlight (UV) rays. Possibly left unprotected outside. Do not use. Discard.
Dusty residue when twisted open	Worn from inside out. If extensive, replace.
Frayed exterior	Abraded by sharp edges. Strength could be reduced.
Broken strands	Destroy and discard.
Cold or frozen	Thaw, dry at room temperature before use.
Size reduction	Usually indicates overloading and excessive wear. Use caution. Reduce capacity accordingly.

Wire Rope (Figure 87)

Rusty, lack of lubrication	Apply light, clean oil. Do not use engine oil.
Excessive outside wear	Used over rough surfaces, with misaligned or wrong sheave sizes. Reduce load capacity according to wear. If outside diameter wire is more than 1/3 worn away, the rope must be replaced.
Broken wires	Up to six allowed in one rope lay, OR three in one strand in one rope lay, with no more than one at an attached fitting. Otherwise, destroy and replace rope.
Crushed, jammed, or flattened strands	Replace rope.
Bulges in rope	Replace, especially non-rotating types.
Gaps between strands	Replace rope.
Core protrusion	Replace rope.
Heat damage, torch burns, or electric arc strikes	Replace rope.
Frozen rope	Do not use. Avoid sudden loading of cold rope.
Kinks, bird-caging	Replace rope. Destroy defective rope.

Polypropylene and Nylon Web Slings

Chalky exterior appearance	Overexposed to sunlight (UV) rays. Should be checked by manufacturer.
Frayed exterior	Could have been shock-loaded or abraded. Inspect very carefully for signs of damage.
Breaks, tears, or patches	Destroy. Do not use.
Frozen	Thaw and dry at room temperature before use.
Oil contaminated	Destroy.

Wire Rope Slings

Broken wires	Up to six allowed in one rope lay or three in one strand in one rope lay with no more than one at an attached fitting. Otherwise, destroy and replace rope.
Kinks, bird-caging	Replace and destroy.
Crushed and jammed strands	Replace and destroy.
Core protrusion	Replace and destroy.
Bulges in rope	Replace and destroy.
Gaps between strands	Replace and destroy.
Wire rope clips	Check proper installation and tightness before each lift. Remember, wire rope stretches when loaded, which may cause clips to loosen.
Attached fittings	Check for broken wires. Replace and destroy if one or more are broken.
Frozen	Do not use. Avoid sudden loading of cold ropes to prevent failure.

Sharp bends	Avoid sharp corners. Use pads such as old carpet, rubber hose, or soft wood to prevent damage.

Chain Slings

Use only alloy steel for overhead lifting.

Elongated or stretched links	Return to manufacturer for repair.
Failure to hang straight	Return to manufacturer for repair.
Bent, twisted, or cracked links	Return to manufacturer for repair.
Gouges, chips, or scores	Ground out and reduce capacity according to amount of material removed.

Chain repairs are best left to the manufacturer. Chain beyond repair should be cut with torch into short pieces.

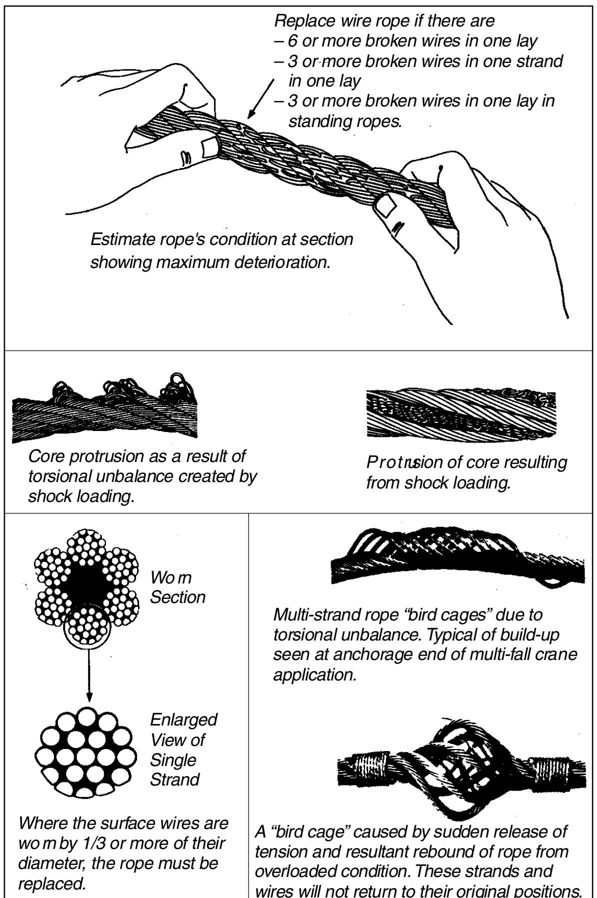


Figure 87 — Wire Rope Inspection

Hardware

Know what hardware to use, how to use it, and how its working load limits (WLLs) compare with the rope or chain used with it.

All fittings must be of adequate strength for the application. Only forged alloy steel load-rated hardware should be used for overhead lifting. Load-rated hardware is stamped with its WLL (Figure 88).

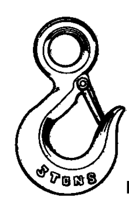


Figure 88

Inspect hardware regularly and before each lift. Telltale signs include
– wear
– cracks
– severe corrosion
– deformation/bends
– mismatched parts
– obvious damage.

Any of these signs indicates a weakened component that should be replaced for safety. Figure 89 shows what to check for on a hook.

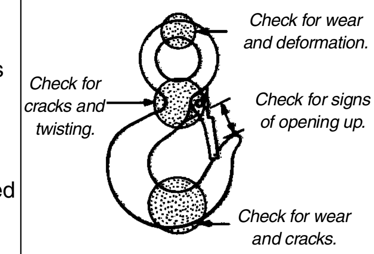
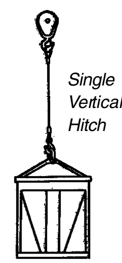


Figure 89
Hook Inspection Areas

Sling Configurations

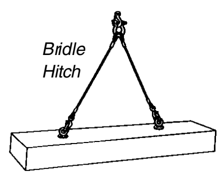
The term "sling" includes a wide variety of configurations for all fibre ropes, wire ropes, chains, and webs. The most commonly used types in construction are explained here.

Single Vertical Hitch

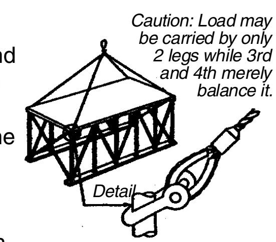


The total weight of the load is carried by a single leg. This configuration must not be used for lifting loose material, long material, or anything difficult to balance. This hitch provides absolutely no control over the load because it permits rotation.

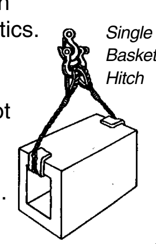
Bridle Hitch



Two, three, or four single hitches can be used together to form a bridle hitch. They provide excellent stability when the load is distributed equally among the legs, when the hook is directly over the centre of gravity of the load, and the load is raised level. The leg length may need adjustment with turnbuckles to distribute the load.

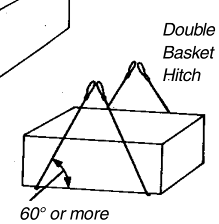


Single Basket Hitch



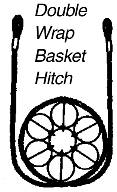
This hitch is ideal for loads with inherent stabilizing characteristics. The load is automatically equalized, with each leg supporting half the load. Do not use on loads that are difficult to balance because the load can tilt and slip out of the sling.

Double Basket Hitch



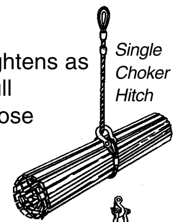
Consists of two single basket hitches passed under the load. The legs of the hitches must be kept far enough apart to provide balance without opening excessive sling angles.

Double Wrap Basket Hitch



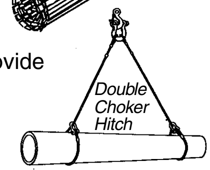
A basket hitch that is wrapped completely around the load. This method is excellent for handling loose materials, pipes, rods, or smooth cylindrical loads because the rope or chain exerts a full 360-degree contact with load and tends to draw it together.

Single Choker Hitch



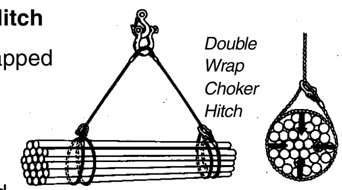
This forms a noose in the rope and tightens as the load is lifted. It does not provide full contact and must not be used to lift loose bundles or loads difficult to balance.

Double Choker Hitch



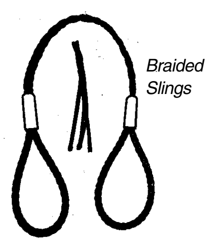
Consists of two single chokers attached to the load and spread to provide load stability. Does not grip the load completely but can balance the load. Can be used for handling loose bundles.

Double Wrap Choker Hitch



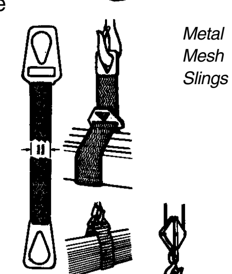
The rope or chain is wrapped completely around the load before being hooked into the vertical part of the sling. Makes full contact with load and tends to draw it together. If the double wrap choker is incorrectly made and the two eyes are placed on the crane hook, the supporting legs of the sling may not be equal in length and the load may be carried by one leg only. Do not run the sling through the hook, permitting an unbalanced load to tip.

Braided Slings



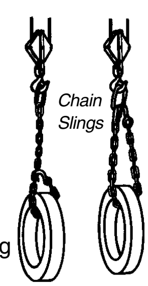
Fabricated from six or eight small diameter ropes braided together to form a single rope that provides a large bearing surface, tremendous strength, and flexibility in all directions. They are very easy to handle and almost impossible to kink. Especially useful for basket hitches where low bearing pressure is desirable or where the bend is extremely sharp.

Metal (Wire or Chain) Mesh Slings



Well adapted for use where loads are abrasive, hot, or tend to cut fabric or wire rope slings.

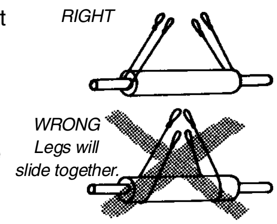
Chain Slings



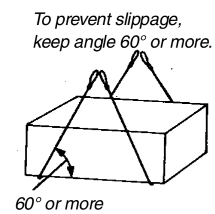
Made for abrasion and high temperature resistance. The only chain suitable for lifting is grade 80 or 100 alloy steel chain. Grade 80 chain is marked with an 8, 80, or 800. Grade 100 is marked with a 10, 100, or 1000. The chain must be embossed with this grade marking every 3 feet or 20 links, whichever is shorter – although some manufacturers mark every link. Chain must be padded on sharp corners to prevent bending stresses.

Wire Rope Slings

The use of wire rope slings for lifting materials provides several advantages over other types of slings. While not as strong as chain, it has good flexibility with minimum weight. Outer wires breaking warn of failure and allow time to react. Properly fabricated wire rope slings are very safe for general construction use.



On smooth surfaces, the basket hitch should be snubbed against a step or change of contour to prevent the rope from slipping as the load is applied. The angle between the load and the sling should be approximately 60 degrees or greater to avoid slippage.



On wooden boxes or crates, the rope will dig into the wood sufficiently to prevent slippage. On other rectangular loads, the rope should be protected by guards or load protectors at the edges to prevent kinking.

Loads should not be allowed to turn or slide along the rope during a lift. The sling or the load may become scuffed or damaged. Use a double choker if the load must turn.

Hooking Up

- Avoid sharp bends, pinching, and kinks in rigging equipment. Thimbles should be used at all times in sling eyes.
- Never wrap a wire rope sling completely around a hook. The tight radius will damage the sling.
- Make sure the load is balanced in the hook. Eccentric loading can reduce capacity dangerously.
- Never point-load a hook unless it is designed and rated for such use (Figure 91).
- Never wrap the crane hoist rope around the load. Attach the load to the hook by slings or other rigging devices adequate for the load.
- Avoid bending the eye section of wire rope slings around corners. The bend will weaken the splice or swaging.
- Avoid bending wire rope slings near any attached fitting.
- Understand the effect of sling angle on sling load (Figure 92) and pull angle on beam load (Figure 93).

Rig the load with its centre of gravity directly below the hook to ensure stability. The crane hook should be brought over the load's centre of gravity before the lift is started. Crane hook and load line should be vertical before lifting. Weights of common materials are listed in Tables 7-11.

Caution: This table is for illustration and comparison only. Check manufacturers' ratings for the WLLs of the specific slings you use.

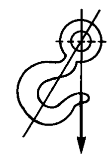
WIRE ROPE SLINGS 6 x 19 Classification Group, Improved Plow Steel, Fibre Core						
Rope Diameter (Inches)	MAXIMUM WORKING LOAD LIMITS - POUNDS (Design Factor = 5)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined		
				60°	45°	30°
3/16	600	450	1,200	1,050	850	600
1/4	1,100	825	2,200	1,900	1,550	1,100
5/16	1,650	1,250	3,300	2,850	2,350	1,650
3/8	2.400	1,800	4,800	4,150	3,400	2,400
7/16	3,200	2,400	6,400	5,550	4,500	3,200
1/2	4,400	3,300	8,800	7,600	6,200	4,400
9/16	5,300	4,000	10,600	9,200	7,500	5,300
5/8	6,600	4,950	13,200	11,400	9,350	6,600
3/4	9,500	7,100	19,000	16,500	13,400	9,500
7/8	12,800	9,600	25,600	22,200	18,100	12,800
1	16,700	12,500	33,400	28,900	23,600	16,700
1-1/8	21,200	15,900	42,400	36,700	30,000	21,200
1-1/4	26,200	19,700	52,400	45,400	37,000	26,200
1-3/8	32,400	24,300	64,800	56,100	45,800	32,400
1-1/2	38,400	28,800	76,800	66,500	54,300	38,400
1-5/8	45,200	33,900	90,400	78,300	63,900	45,200
1-3/4	52,000	39,000	104,000	90,000	73,500	52,000
1-7/8	60,800	45,600	121,600	105,300	86,000	60,800
2	67,600	50,700	135,200	117,100	95,600	67,600
2-1/4	84,000	63,000	168,000	145,500	118,800	84,000
2-1/2	104,000	78,000	208,000	180,100	147,000	104,000
2-3/4	122,000	91,500	244,000	211,300	172,500	122,000
				If used with Choker Hitch multiply above values by 3/4.		
Notes: Table values are for slings with eyes and thimbles in both ends, Flemish Spliced Eyes and mechanical sleeves. Eyes formed by cable clips – reduce loads by 20%.						

Caution: This table is for illustration and comparison only. Check manufacturers' ratings for the WLLs of the specific slings you use.

NYLON WEB SLINGS 6800 lb/in Material						
Web Width (Inches)	MAXIMUM WORKING LOAD LIMITS - POUNDS (Design Factor = 5) (Eye & Eye, Twisted Eye, Triangle Fittings, Choker Fittings)					
	Single Vertical Hitch	Single Choker Hitch	Single Basket Hitch (Vertical Legs)	2-Leg Bridle Hitch & Single Basket Hitch With Legs Inclined (Sling Angle)		
				60°	45°	30°
1	1,100	825	2,200	1,905	1,555	1,100
2	2,200	1,650	4,400	3,810	3,110	2,200
3	3,300	2,475	6,600	5,715	4,665	3,300
4	4,400	3,300	8,800	7,620	6,220	4,400
5	5,500	4,125	11,000	9,525	7,775	5,500
6	6,600	4,950	13,200	11,430	9,330	6,600
				If used with Choker Hitch multiply above values by 3/4.		

1. For working load limits of endless or grommet slings, multiply above values by 2.
2. Values have been adjusted to reflect fabrication efficiency (FE) using formulas and tables developed by the Web Sling Association. This accounts for strength loss due to stitching and manufacture.
3. All web slings must carry a load rating tag as specified in OH&S Regulations.

Figure 91
Point Loading



Capacity Severely Reduced

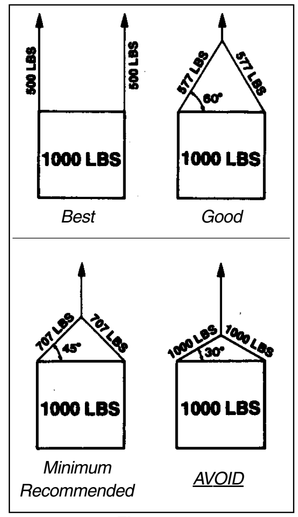


Figure 92
Effect of Sling Angle on Sling Load

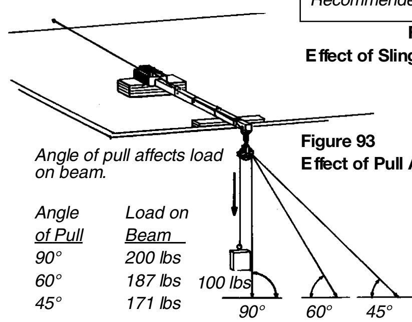
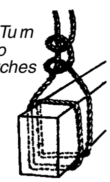


Figure 93
Effect of Pull Angle on Beam Load

Basic Knots and Hitches



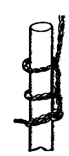
Round Turn and Two Half Hitches

Every worker should be able to tie the basic knots and hitches that are useful in everyday work.

Round Turn and Two Half Hitches

Used to secure loads to be hoisted horizontally. Two are usually required because the load can slide out if lifted vertically.

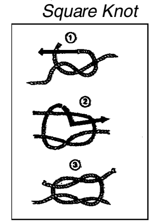
Timber Hitch and Two Half Hitches



Timber Hitch and Two Half Hitches

A good way to secure a scaffold plank for hoisting vertically. The timber hitch grips the load.

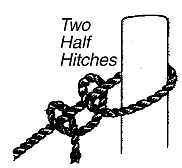
Reef or Square Knot



Reef or Square Knot

Can be used for tying two ropes of the same diameter together. It is unsuitable for wet or slippery ropes and should be used with caution since it unties easily when either free end is jerked. Both live and dead ends of the rope must come out of the loops at the same side.

Two Half Hitches



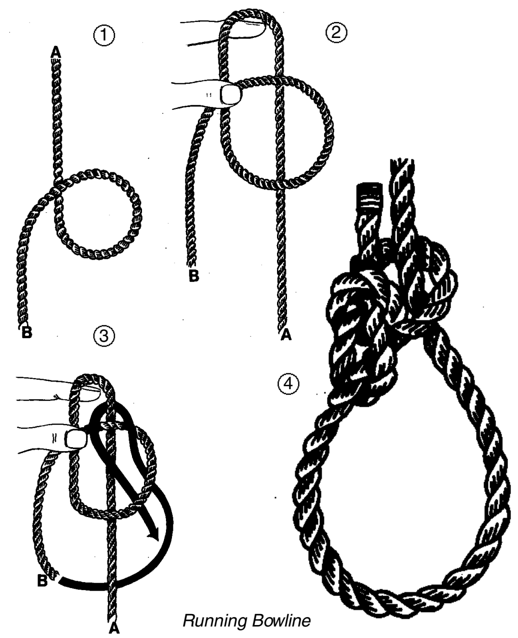
Two Half Hitches

Two half hitches, which can be quickly tied, are reliable and can be put to almost any general use.

Running Bowline

The running bowline is mainly used for hanging objects with ropes of different diameters. The weight of the object determines the tension necessary for the knot to grip.

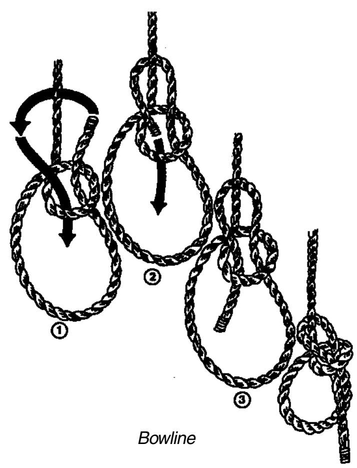
Make an overhand loop with the end of the rope held toward you (1). Hold the loop with your thumb and fingers and bring the standing part of the rope back so that it lies behind the loop (2). Take the end of the rope in behind the standing part, bring it up, and feed it through the loop (3). Pass it behind the standing part at the top of the loop and bring it back down through the loop (4).



Running Bowline

Bowline

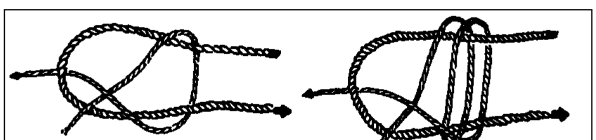
Never jams or slips when properly tied. It is a universal knot if properly tied and untied. Two interlocking bowlines can be used to join two ropes together. Single bowlines can be used for hoisting or hitching directly around a ring or post.



Bowline

Sheet Bend

Can be used for tying ropes of light or medium size.


Single Sheet Bend *Double Sheet Bend*

WEIGHTS OF MATERIALS (Based On Volume)

Material	Approximate Weight Lbs. Per Cubic Foot	Material	Approximate Weight Lbs. Per Cubic Foot
METALS		**TIMBER, AIR-DRY**	
Aluminum	165	Cedar	22
Brass	535	Fir, Douglas, seasoned	34
Bronze	500	Fir, Douglas, seasoned	40
Copper	560	Fir, Douglas, wet	50
Iron	480	Fir, Douglas, glue laminated	34
Lead	710	Hemlock	30
Steel	480	Pine	30
Tin	460	Poplar	30
MASONRY		Spruce	28
Ashlar masonry	140-160	**LIQUIDS**	
Brick masonry, soft	110	Alcohol, pure	49
Brick masonry, common (about 3 tons per thousand)	125	Gasoline	42
		Oils	58
Brick masonry, pressed	140	Water	62
Clay tile masonry, average	60	**EARTH**	
Rubble masonry	130-155	Earth, wet	100
Concrete, cinder, taydite	100-110	Earth, dry (about 2050 lbs.) per cu. yd.)	75
Concrete, slag	130		
Concrete, stone	144	Sand and gravel, wet	120
Concrete, stone, reinforced (4050 lbs. per cu. yd.)	150	Sand and gravel, dry	105
		River sand (about 3240 lbs. per cu. yd.)	120
ICE AND SNOW			
Ice	56	**VARIOUS BUILDING MATERIALS**	
Snow, dry, fresh fallen	8		
Snow, dry, packed	12-25	Cement, portland, loose	94
Snow, wet	27-40	Cement, portland, set	183
MISCELLANEOUS		Lime, gypsum, loose	53-64
Asphalt	80	Mortar, cement-time, set	103
Tar	75	Crushed rock (about 2565 lbs. per cu. yd.)	90-110
Glass	160		

Table 7

DRYWALL WEIGHTS

	8'	10'	12'
Non-Fire Rated			
1/2"	58 lbs.	72 lbs.	86 lbs.
5/8"	74 lbs.	92 lbs.	110 lbs.
Fire-Rated			
1/2"	64 lbs.	80 lbs.	96 lbs.
5/8"	77 lbs.	96 lbs.	115 lbs.

Table 8

STEEL STUDS AND TRIMS – WEIGHTS

		Pcs./Bdl.	Lbs. (per 1,000 Lin. Ft.)
STUD SIZE–.018 THICKNESS			
1 5/8	All Lengths	10	290
2 1/2	All Lengths	10	340
3 5/8	All Lengths	10	415
6 (.020)	All Lengths	10	625
TRACK SIZES–.018 THICKNESS			
1 5/8	Regular Leg	10	240
2 1/2	Regular Leg	10	295
3 5/8	Regular Leg	10	365
6 (.020)	Regular Leg	10	570
1 5/8	2 Leg	12	365
2 1/2	2 Leg	6	415
3 5/8	2 Leg	6	470
DRYWALL FURRING CHANNEL			
Electro-Galvanized		10	300
DRYWALL CORNER BEAD			
1 1/4 x 1 1/4		Various	120
RESILIENT CHANNEL			
Electro-Galvanized		20	210
DRYWALL TRIMS			
1/2 Door & Windows L.		20	100
5/8 Door & Window L.		20	100
3/8 Casing Bead J.		20	110
1/2 Casing Bead J.		20	120
5/8 Casing Bead J.		20	130
DRYWALL ANGLE			
1 x 2 Drywall Angle		10	200

Table 9

WEIGHTS OF MATERIALS (Based On Surface Area)

Material	Approximate Weight Lbs. Per Square Foot	Material	Approximate Weight Lbs. Per Square Foot
CEILINGS		**FLOORING**	
(Per Inch of Thickness)		(Per Inch of Thickness)	
Plaster board	5	Hardwood	5
Acoustic and fire resistive tile	2	Sheathing	2.5
Plaster, gypsum-sand	8	Plywood, fir	3
Plaster, light aggregate	4	Wood block, treated	4
Plaster, cement sand	12	Concrete, finish or fill	12
ROOFING		Mastic base	12
Three-ply felt and gravel	5.5	Mortar base	10
Five-ply felt and gravel	6.5	Terrazzo	12.5
Three-ply felt, no gravel	3	Tile, vinyl 1/8 inch	1.5
Five-ply felt, no gravel	4	Tile, linoleum 3/16 inch	1
Shingles, wood	2	Tile, cork, per 1/16 inch	0.5
Shingles, asbestos	3	Tile, rubber or asphalt 3/16 inch	2
Shingles, asphalt	2.5	Tile, ceramic or quarry 3/4 inch	11
Shingles, 1/4 inch slate	10	Carpeting	2
Shingles, tile	14	**DECKS AND SLABS**	
PARTITIONS		Steel roof deck 1 1/2" - 14 ga.	5
Steel partitions	4	- 16 ga.	4
Solid 2" gypsum-sand plaster	20	- 18 ga.	3
Solid 2" gypsum-light agg. plaster	12	- 20 ga.	2.5
Metal studs, metal lath, 3/4"		- 22 ga.	2
plaster both sides	18	Steel cellular deck 1 1/2" - 12/12 ga.	11
Metal or wood studs, plaster		- 14/14 ga.	8
board and 1/2" plaster both sides	18	- 16/16 ga.	6.5
Plaster 1/2"	4	- 18/18 ga.	5
Hollow clay tile 2 inch	13	- 20/20 ga.	3.5
3 inch	16	Steel cellular deck 3" - 12/12 ga.	12.5
4 inch	18	- 14/14 ga.	9.5
5 inch	20	- 16/16 ga.	7.5
6 inch	25	- 18/18 ga.	6
Hollow slag concrete block 4 in	24	- 20/20 ga.	4.5
6 in	35	Concrete, reinforced, per inch	12.5
Hollow gypsum block 3 inch	10	Concrete, gypsum, per inch	5
4 inch	13	Concrete, lightweight, per inch	5-10
5 inch	15.5	**MISCELLANEOUS**	
6 inch	16.5	Windows, glass, frame	8
Solid gypsum block 2 inch	9.5	Skylight, glass, frame	12
3 inch	13	Corrugated asbestos 1/4 inch	3.5
MASONRY WALLS		Glass, plate 1/4 inch	3.5
(Per 4 Inch of Thickness)		Glass, common	1.5
Brick	40	Plastic sheet 1/4 inch	1.5
Glass brick	20	Corrugated steel sheet, balv.	
Hollow concrete block	30	- 12 ga.	5.5
Hollow slag concrete block	24	- 14 ga.	4
Hollow cinder concrete block	20	- 16 ga.	3
Hollow haydite block	22	- 18 ga.	2.5
Stone, average	55	- 20 ga.	2
Bearing hollow clay tile	23	- 22 ga.	1.5
		Wood Joists - 16" ctrs. 2 x 12	3.5
		2 x 10	3
		2 x 8	2.5
		Steel plate (per inch of thickness)	40

Table 10

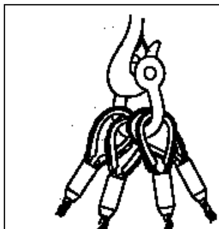
SUSPENDED CEILING GRID SYSTEMS–WEIGHTS

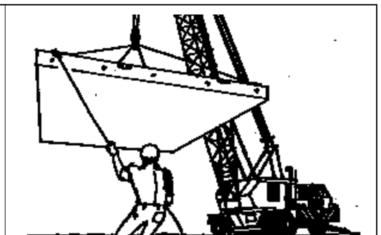
Systems	**Qty./Ctn. (Lin. Ft.)**	**Lbs./Ctn. (Lbs.)**
NON-FIRE RATED GRID SYSTEM		
1 1/2 x 144" Main Runner	240	58
1 x 48" Cross Tee	300	55
1 x 24" Cross Tee	150	28
1 x 30" Cross Tee	187.5	35
1 x 20" Cross Tee	125	23
1 x 12" Cross Tee	75	14
FIRE-RATED GRID SYSTEM		
1 1/2 x 144" Main Runner	240	70
1 1/2 x 48" Cross Tee	240	70
1 1/2" x 24" Cross Tee	120	35
WALL MOULDINGS		
Wall Mould 3/4 x 15/16 x 120"	400	49
Reveal Mould 3/4 x 3/4 x 1/2 x 3/4 x 120"	200	36
ACCESSORIES		
Hold-Down Clips (for 5/8" tile)	500 pcs.	3
BASKETWEAVE & CONVENTIONAL 5' x 5' MODULE – NON RATED		
1 1/2 x 120" Main Member	200	49
1 1/2 x 60" Cross Tee	250	61
Wall Mould 3/4 x 15/16 x 120"	400	57
THIN LINE GRID SYSTEM – NON-RATED		
Main Runner 1 1/2 x 144"	300	65
Cross Tee 1 1/2 x 48"	300	65
Cross Tee 1 1/2 x 24"	150	33
Wall Mould 15/16 x 9/16 x 120"	500	62
Reveal Mould 1 x 3/8 x 3/8 x 9/16 x 120"	300	48
Main Runner 1 1/12 x 144"	300	65
Cross Tee 1 1/2 x 48"	300	65
Cross Tee 1 1/2 x 24"	150	33
Wall Mount 15/16 x 9/16 x 120"	500	62

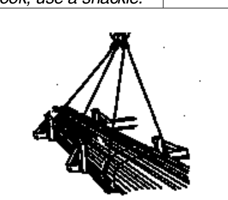
Table 11

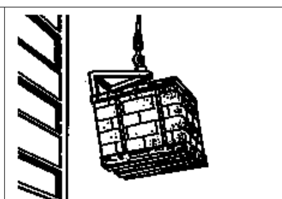
HAND SIGNALS FOR HOISTING OPERATIONS

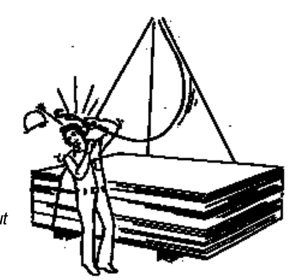
Rigging Safety Tips


With two or more slings on a hook, use a shackle.


Use tag lines for control.

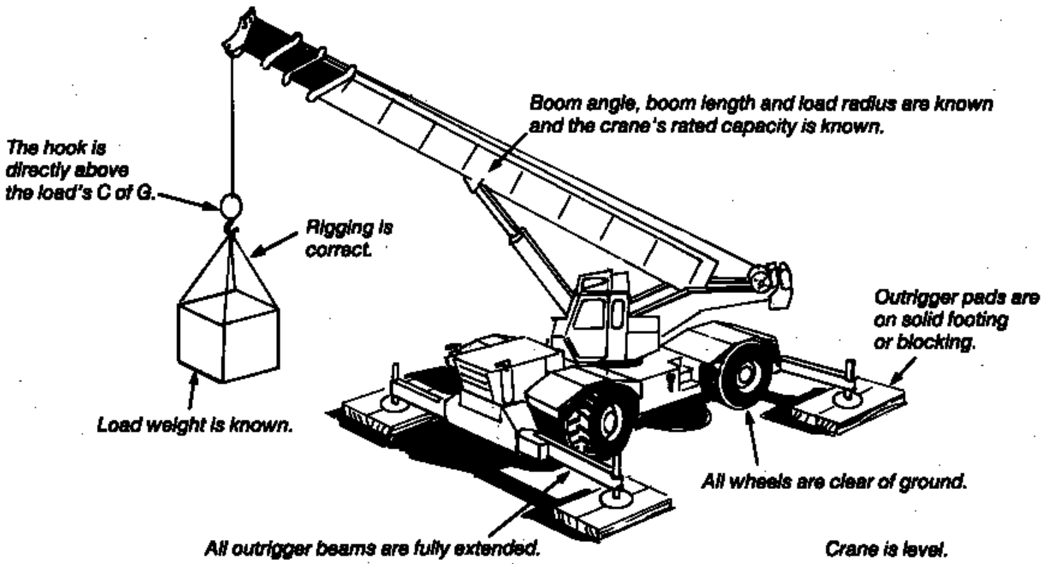

Block loose loads before unhooking.


Make sure loads are secure.

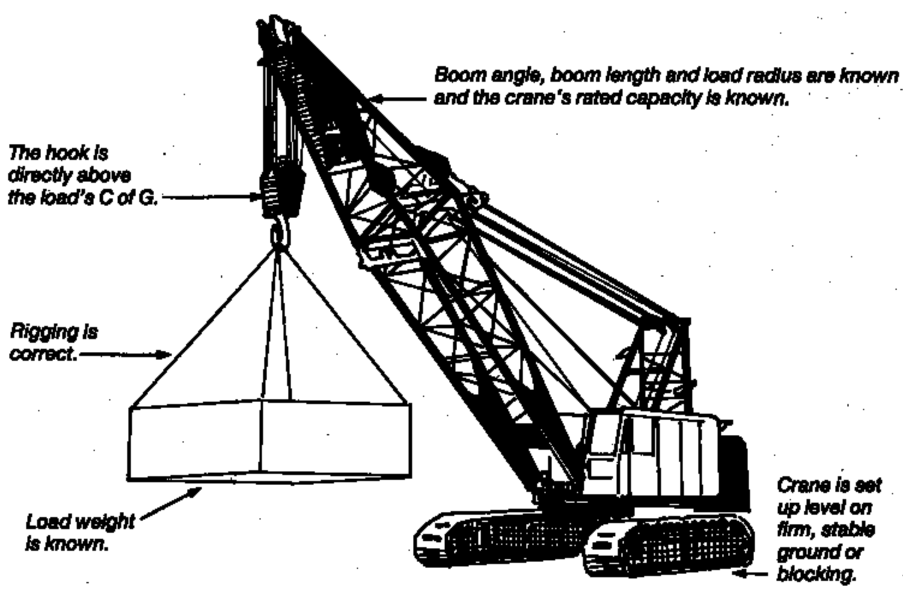

Stay back when slings are pulled out from under loads.

A crane is properly set up for lifting when the following conditions are met.

For Cranes Operating "On Outriggers"



For Crawler-Mounted Cranes or When Lifting "On Rubber"



Hazards

1 HOUSEKEEPING

Many injuries result from poor housekeeping, improper storage of materials, and cluttered work areas. To maintain a clean, hazard-free workplace, all groups – management, supervision, and workers – must cooperate.

General

Regulations for safe housekeeping require

- daily jobsite cleanup program
- disposal of rubbish
- individual cleanup duties for all workers
- materials piled, stacked, or otherwise stored to prevent tipping and collapsing
- materials stored away from overhead powerlines
- work and travel areas kept tidy, well-lit, and ventilated (Figure 8)
- signs posted to warn workers of hazardous areas.

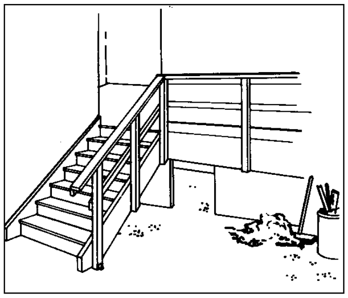


Figure 8
Keep stairs and landings clear and well-lit.

The basics of good housekeeping are shown in Figure 9.

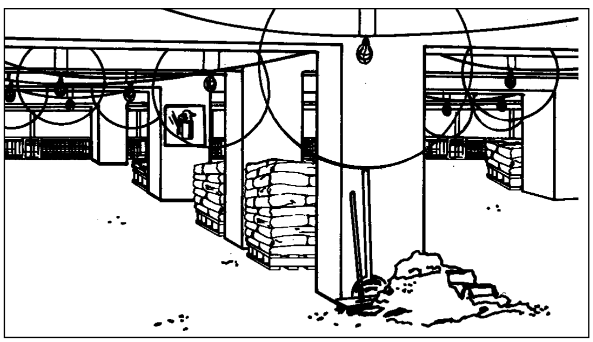


Figure 9
Good housekeeping means clear traffic and work areas, out-of-the-way storage, adequate illumination, and cleanup of debris.

Specific

- Gather up and remove debris as often as required to keep work and travel areas orderly.
- Keep equipment and the areas around equipment clear of scrap and waste.
- Keep stairways, passageways, and gangways free of material, supplies, and obstructions at all times.
- Secure loose or light materials stored on roof or on open floors to prevent them being blown by the wind.
- Pick up, store, or dispose of tools, material, or debris which may cause tripping or other hazards.
- Before handling used lumber, remove or bend over protruding nails and chip away hardened concrete.
- Wear eye protection when there is any risk of eye injury.
- Do not permit rubbish to fall freely from any level of the project. Lower it by means of a chute or other approved devices (Figure 10).
- Do not throw materials or tools from one level to another.
- Do not lower or raise any tool or equipment by its own cord or supply hose.
- When guardrails must be removed to land, unload, or handle material, wear fall-arrest equipment (Figure 11). The area must also be roped off with warning signs posted.

In shops it is relatively easy to maintain a clean work area. Barriers and warning lines can also be set up to isolate table saws and other equipment.

On construction sites, arrangements are more difficult. Equipment often sits in basements, on decks, or in corners with insufficient working space and sometimes it's open to the weather. The footing may simply consist of a piece of plywood.

Around table saws and similar equipment, keep the immediate area clear of scrap to avoid tripping hazards and provide sound footing.

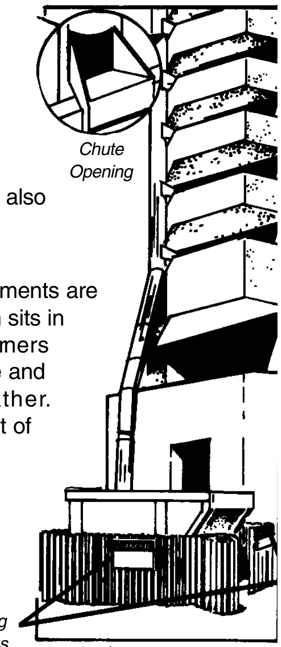


Figure 10

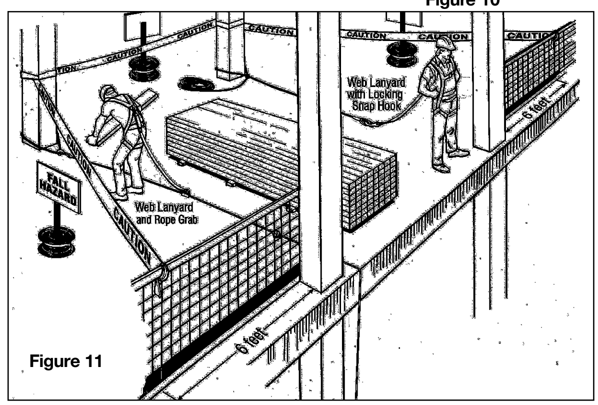


Figure 11

Airborne wood dust can be a respiratory hazard, causing problems ranging from simple irritation of the eyes, nose, and throat to more serious health effects. Dust collectors should be installed in shops to remove sawdust from air and equipment. Wood dust is also very flammable.

In construction, saws and other tools are often operated in the open air where dust presents no hazard. However, dust masks or respirators should be worn whenever ventilation is inadequate.

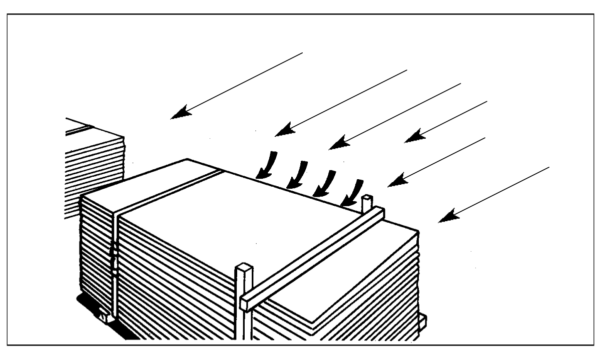


Figure 12
Secure material against the wind.
After removing material, resecure pile.

Storage

Storage areas should be at least 1.8 metres (6 feet) from roof or floor openings, excavations, or any open edges where material may fall off (Figure 12).

Near openings, arrange material so that it cannot roll or slide in the direction of the opening.

Flammable Materials

- Use copper grounding straps to keep static electricity from building up in containers, racks, flooring, and other surfaces (Figure 13).
- Store fuel only in containers approved by the Canadian Standards Association (CSA) or Underwriters' Laboratories of Canada (ULC).
- Ensure that electric fixtures and switches are explosion-proof where flammable materials are stored.
- See Figure 14 for pointers on safe storage.

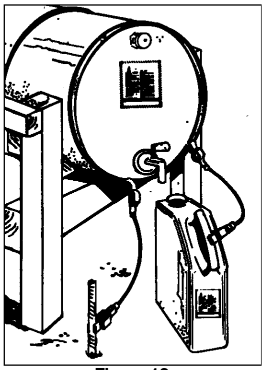


Figure 13
Dispensing and receiving containers should both be grounded.

Hazardous Chemicals

- Refer to material safety data sheets (MSDSs) for specific information on each product.
- Follow manufacturer's recommendations for storage.
- Observe all restrictions concerning heat, moisture, vibration, impact, sparks, and safe working distance.
- Post warning signs where required.
- Have equipment ready to clean up spills quickly.

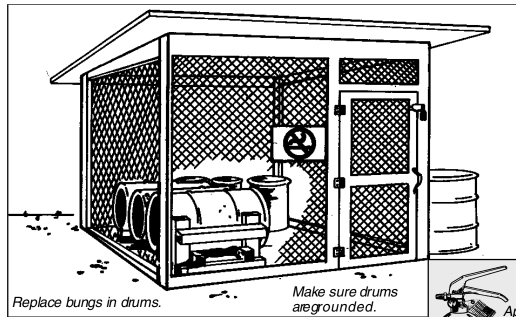


Figure 14
Storage of Flammable Liquids

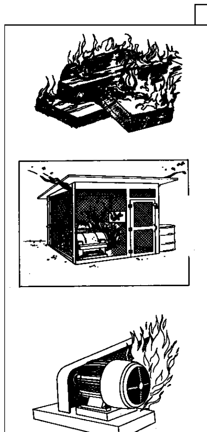
- To keep them separate for special handling and disposal later, store empty chemical containers in secure area away from full containers.

Bags and Sacks

- Do not pile bagged material more than 10 bags high unless the face of the pile is supported by the walls of a storage bin or enclosure.
- Do not move piles more than 10 bags high unless fully banded or wrapped.
- Cross-pile bags and sacks for added stability. Pile only to a safe and convenient height for loading and unloading.

Compressed Gas Cylinders

- Store and move cylinders in the upright position. Secure cylinders upright with chains or rope.
- Lock up cylinders to prevent vandalism and theft.
- Wherever possible, store cylinders in a secure area outdoors.



A

Class "A" Extinguishers

For fires in ordinary combustible materials such as wood, paper, and textiles where a quenching, cooling effect is required.

B

Class "B" Extinguishers

For flammable liquid and gas fires, such as oil, gasoline, paint and grease where oxygen exclusion or flame interruption is essential.

C

Class "C" Extinguishers

For fires involving electrical wiring and equipment where the non-conductivity of the extinguishing agent is crucial.

This type of extinguisher should be present wherever functional testing and system energizing take place.

D

Class "D" Extinguishers

For fires in combustible metals such as sodium, magnesium, and potassium.

How to Use the Extinguisher

Aim the extinguisher at the base of the fire to extinguish the flames at their source.

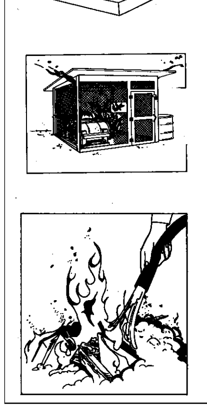


Figure 15

- Keep full cylinders apart from empty cylinders.
- Store cylinders of different gases separately.
- Keep cylinders away from heat sources.
- When heating with propane, keep 45-kilogram (100 lb.) cylinders at least 3 metres (10 feet) away from heaters; keep larger tanks at least 7.6 metres (25 feet) away.

Lumber

- Stack on level sills.
- Stack reusable lumber according to size and length. Remove nails during stacking.
- Support lumber at every 1.3 metre (4-foot) span.
- Cross-pile or cross-strip when the pile will be more than 1.3 metres (4 feet) high.

Fire Protection

Housekeeping includes fire prevention and fire protection. Workers must be trained to use fire extinguishers properly.

Fire extinguishers must be

- accessible
- regularly inspected
- promptly refilled after use.

Extinguishers must be provided

- where flammable materials are stored, handled, or used
- where temporary oil- or gas-fired equipment is being used
- where welding or open-flame cutting is being done
- on each storey of an enclosed building being constructed or renovated
- in shops, for at least every 300 square metres of floor area.

Fire extinguishers are classified according to their capacity to fight specific types of fires (Figure 15).

Workers must be trained to use fire extinguishers properly.

For most operations, a 4A40BC extinguisher is adequate.

Extinguishers have a very short duration of discharge – usually less than 60 seconds. Be sure to aim at the base of the fire.

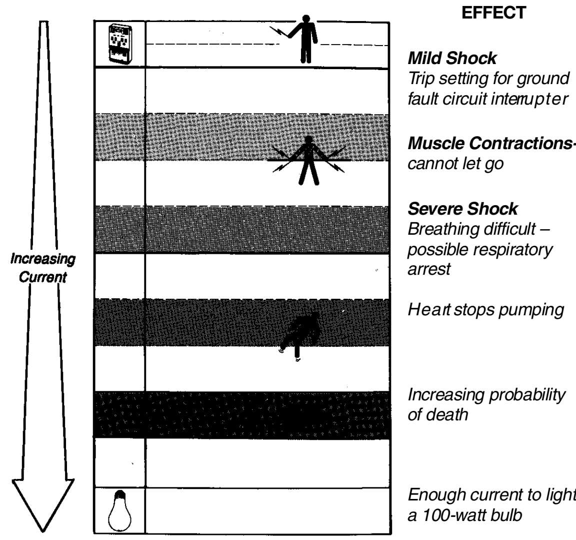
2 ELECTRICITY

Most tradespeople tend to take electricity for granted as a steady, reliable source of power for a wide variety of tools, equipment, and operations. But familiarity can create a false sense of security. Remember that electricity is ***always*** a potential source of danger.

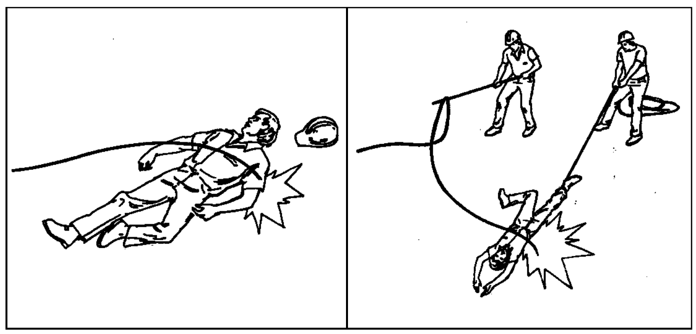
> The basic rule is straightforward: Consider all electrical wires and equipment live until they are tested and proven otherwise.

Shock

The passage of electricity through the body is called shock. Effects can range from a tingling sensation to death. A shock that may not be enough to kill or even injure can nonetheless startle a worker and cause a fall from a ladder or work platform.



Procedure for Unbroken Contact



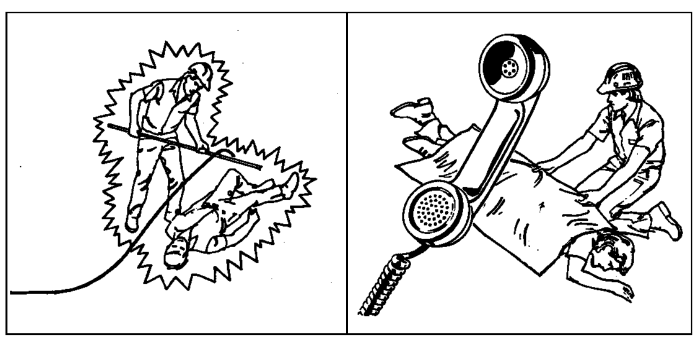
1. In some electrical accidents, the injured or unconscious person remains in contact with the live wire or equipment.

Rescue should only be attempted after power has been turned off.

2. In some cases of low voltage, when power cannot be turned off, break contact if possible. Use a dry board, rubber hose, or dry polypropylene rope to move either the injured person or the line.

An object can sometimes be thrown to separate the injured person from the wire.

If you don't know the voltage, treat it as **high**.



3. WARNING. Even with dry wood or rubber, touching the injured person can be dangerous. High voltage can jump a considerable gap and objects that are normally insulators may become conductors.

Only electrical personnel specially trained and equipped to use special live-line tools can attempt rescue safely.

4. Call emergency services — in most cases, ambulance, fire department, and utility.

WARNING. Give first aid only after the injured person is free of contact.

Figure 1

Burns are the most common shock-related injury. Electricity can cause severe burns at points of entry and exit. The damage is often more serious than it looks. Although entry and exit wounds may be small, bone and muscle can be extensively burned in between.

Shock can also cause irregular beating of the heart (fibrillation) leading to respiratory failure and cardiac arrest.

Get medical help as soon as possible after electrical contact.

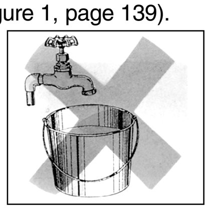
The effect of electric shock on the body is determined by three main factors:

1) how much current is flowing through the body (measured in amperes and determined by voltage and resistance)
2) the path of current through the body
3) how long the body is in the circuit.

Table 12 shows generally how degree of injury relates to amount of current passing through a body for a few seconds.

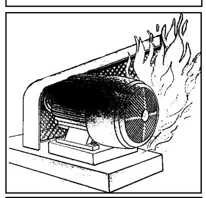
In addition to emergency procedures (page 1) and artificial respiration (page 15), workers should know what to do in the event of unbroken electrical contact (Figure 1, page 139).

Electrical Fires



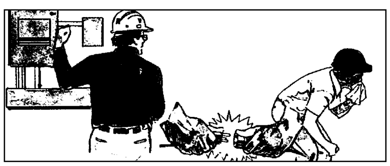
Never put water on fires in live electrical equipment or wiring.

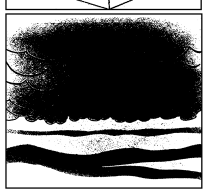
Water is a conductor and increases the risk of flash, arc, and electrocution.

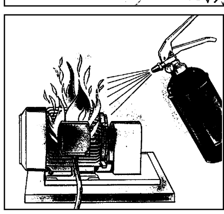


An electrical fire in a confined space can rapidly deplete oxygen and may release toxic fumes. If possible, switch off power.

Avoid inhaling fumes and vacate the area at once.







If necessary, breathe through a damp cloth and stay close to the floor.

Use a Class C fire extinguisher. Intended for electrical fires, this type employs a non-conductive extinguishing agent.

An ABC fire extinguisher may also be used on an electrical fire.

Report fires immediately.

Wiring or equipment involved in a fire must be inspected by the electrical utility inspector before being reactivated.

Every worker who may be required to use a fire extinguisher must be trained in its use.

Powerlines

- Contact utility to locate all underground and overhead services before starting work. Determine voltage. Mark underground lines on all drawings. Post warning signs along their route.

Voltage Rating of Powerline	Minimum Distance
750 to 150,000 volts	3 metres (10')
150,001 to 250,000 volts	4.5 metres (15')
over 250,000 volts	6 metres (20')

- Have powerlines moved, insulated, or de-energized where necessary.
- Avoid storing material or equipment under powerlines. If it must be stored there, hang warning flags and signs to prevent other workers from using hoisting equipment to move or lift it.
- With backhoes, cranes, and similar equipment near powerlines, use a signaller to warn the operator when any part of the equipment or load approaches the minimum allowable distances.
- Before moving ladders, rolling scaffolds, or elevating work platforms, always check for overhead wires. Death and injury have been caused by electrical contact with access equipment (Figure 2).

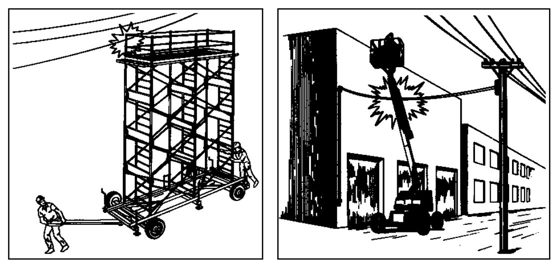


Figure 2

Temporary Lighting

- Avoid contact with the wires strung for temporary lighting. Frequent relocation of circuits can loosen connections, break insulation, and create other hazards.
- Beware of tripping and shock hazards from stringers overhead and underfoot (Figure 3).
- Do not use temporary lighting circuits as extension cords. If a fuse blows, it can be dangerous to find your way to the panel in the dark.
- Take care that exposed wires do not contact steel door frames in the final stages of work, when temporary lines often pass through doors that may be accidentally closed on them (Figure 4).
- Replace missing or burned-out bulbs to maintain required levels of illumination in stairwells, basements, halls, and other areas. Bulbs must be caged.
- Do not modify manufactured stringers.

Panels

- Temporary panel boards (Figure 5) must be securely mounted, protected from weather and water, accessible to workers, and kept clear of obstructions.
- Use only fuses or breakers of the recommended amperage.
- Follow regulated procedures for lockout and tagging. Section 188 of the Construction Regulation specifies conditions and controls.

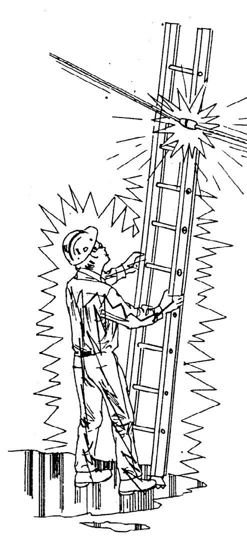


Figure 3

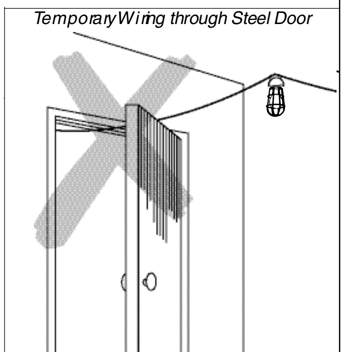


Figure 4

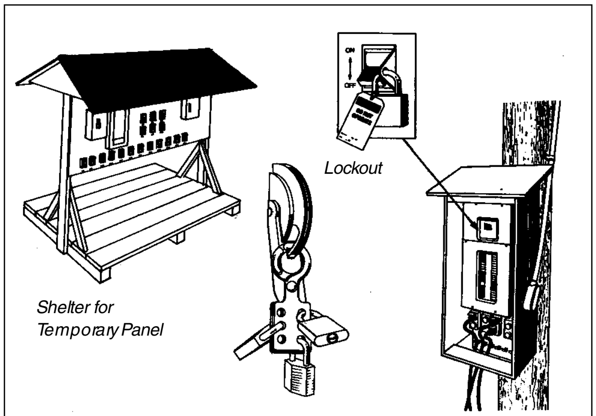
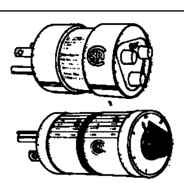


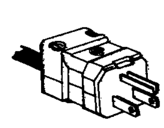
Figure 5

Cords and Plugs

- Never cut off, bend back, or cheat the ground pin on three-prong plugs.
- Make sure that plugs and cords are in good condition.
- Make sure that extension cords are the right gauge for the job to prevent overheating, voltage drops, and tool burnout.
- Check extension cords and outlets with a circuit-tester (Figure 6) before use.
- Use cords fitted with deadfront plugs (Figure 7). These present less risk of shock and shortcircuit than open front plugs.
- Do not use extension or tool cords that are defective or have been improperly repaired.
- Do not wire plugs into outlets. Disconnecting will take too long in an emergency.



Circuit Testers - Figure 6



Deadfront Plug - Figure 7

- Protect cords from traffic. Protect bulbs with cages (Figure 8).

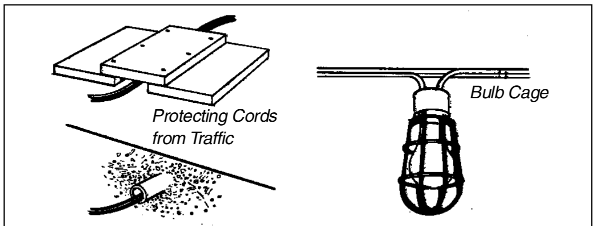


Figure 8

Tools

- Use only tools that are grounded or double-insulated (see symbol at right). Make sure the casings of double-insulated tools are not cracked or broken.
- Always use a ground fault circuit interrupter (GFCI) with any portable electric tool operated outdoors or in wet locations (Figure 9). This is required by the Construction Regulation, Section 192. GFCIs detect current leaking to ground from the tool or cord and shut off power before injury or damage can occur. Only type A GFCIs are designed to trip at about 5 milliamperes (5 thousandths of an ampere), offering adequate protection to workers.

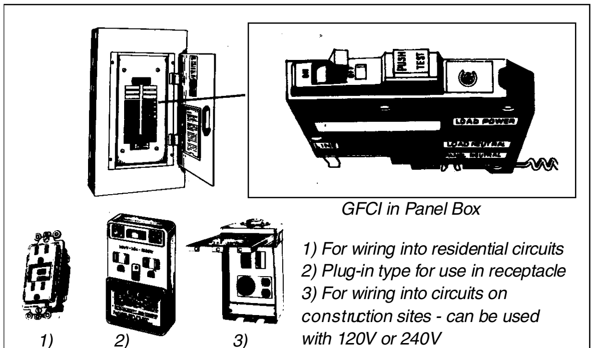


Figure 9 - Ground Fault Circuit Interrupters

- Use hand tools with insulated handles and grips. Whenever required, wear protective equipment—safety goggles, insulated gloves, shock-resistant footwear (Figure 10).

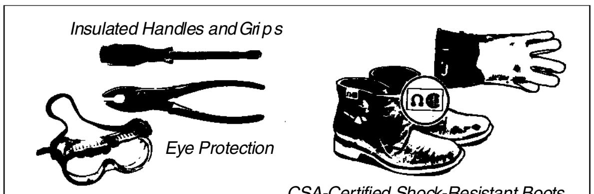


Figure 10

- Do not hold water pipes or other grounded conductors when using electric tools. A defect in tool or cord will make you part of the circuit, causing shock, a fall off your ladder, or, at worst, electrocution.
- Before drilling, hammering, or cutting with hand or power tools, check for electrical wires or equipment behind walls, above ceilings, and under floors.
- Keep cords out of the path of electric tools and equipment.

- Before making adjustments or changing attachments, disconnect electric tools from the power source. Switching off the tool may not be enough to prevent accidental startup.
- Never bypass broken switches on tools or equipment by plugging and unplugging the cord. Shutting off power will take too long in an emergency.
- Any shock or tingle, no matter how slight, means that the tool or equipment should be checked and repaired if necessary.
- Never use metal or metal-reinforced ladders near live wires or equipment. Use wooden or fibreglass ladders.

3 BACKING UP

Reversing vehicles and equipment on construction projects pose a serious problem for personnel on foot.

Fatal accidents resulting from workers being backed over by dump trucks and other equipment occur all too frequently.

Anyone on foot in the vicinity of reversing vehicles and equipment is at risk. More then 20 deaths have occurred on construction sites over a ten-year period as a result of reversing vehicles.

Blind Spots

The main problem with reversing vehicles and equipment is the driver or operator's restricted view.

Around dump trucks and heavy equipment such as bulldozers and graders there are blind spots where the operator has no view or only a very limited view.

The operator may not see someone standing in these blind spots. Anyone kneeling or bending over in these areas would be even harder to see.

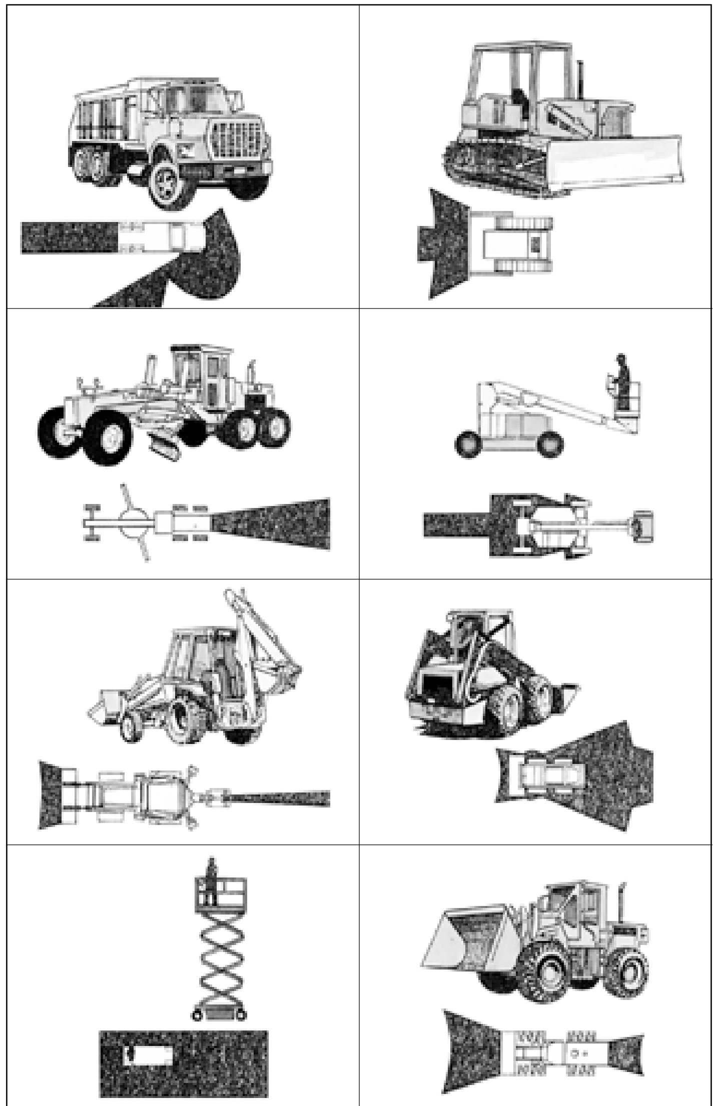


Figure 1 – Dark areas indicate operator blind spots.

Consequently the driver or operator must rely on mirrors or signallers to back up without running over someone or into something. Figure 1 shows the blind spots for common types of construction equipment.

Accident Prevention

To prevent injuries and deaths caused by vehicles and equipment backing up, there are four basic approaches:

1) site planning
2) signallers
3) training
4) electronic devices.

Site planning

Wherever possible, site planners should arrange for drive-through operations to reduce the need for vehicles to back up (Figure 2).

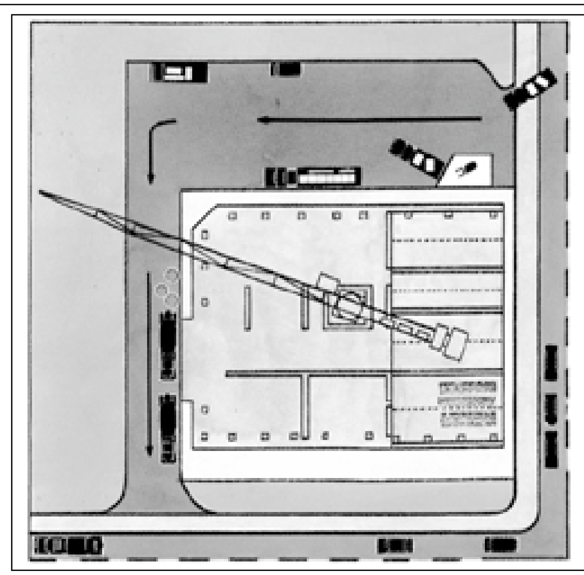


Figure 2

Foot traffic should be minimized where trucks and equipment operate in congested areas such as excavations. Where feasible, a barricade can help to

Figure 3

protect workers: for example, by keeping excavation work separate from forming operations (Figure 3).

The hazards of reversing vehicles can also be reduced through separate access for workers on foot. Where possible, for instance, a scaffold stair system should be provided for worker access to deep excavations.

Near loading and unloading areas, pedestrian walkways can be roped off or barricaded.

Signallers

On some projects, you cannot avoid having reversing vehicles or equipment on site. Often, they must share an area with other vehicles and operating equipment – as well as workers on foot.

You must have a signaller or spotter when

a) a vehicle or equipment operator's view of the intended path of travel is obstructed
b) a person could be endangered by the operation of the vehicle or equipment, or by its load.

A signaller must be a competent worker and must not have any other duties to fulfill while acting as a signaller.

Before a worker can act as a signaller, the employer must ensure that the worker has been given adequate oral and written instructions in a language that he or she understands. The employer must keep, on site, a copy of the written instructions and a record of the training.

A signaller must wear a garment – usually a nylon vest – that is fluorescent or bright orange, with 2 vertical 5-centimetre-wide yellow stripes on the front and 2 similar stripes forming a diagonal "X" pattern on the back. These stripes must be retro-reflective and fluorescent. The vest must have an adjustable fit and have a front and side tear-away feature.

If a signaller has to work during the night, he or she must wear retro-reflective silver stripes around each arm and leg.

The signaller must maintain clear view of the path that the vehicle, machine, or load will be travelling and must be able to watch those parts of the vehicle, equipment, or load that the operator cannot see. The signaller must maintain clear and continuous visual contact with the operator at all times while the vehicle or equipment is moving (Figure 5), and must be able to communicate with the operator using clearly understood, standard hand signals (Figure 6). The signaller must warn other workers on foot of the approaching vehicle or equipment, and must alert the operator to any hazards along the route.

Training

Instruction for drivers, operators, signallers, and workers on foot is essential to reduce the hazards created by reversing vehicles and equipment.

For example, all construction personnel must be made familiar with blind spots – the areas around every vehicle that are partly or completely invisible to the operator or driver, even with the help of mirrors (Figure 1).

Specific training can then focus on the following points.

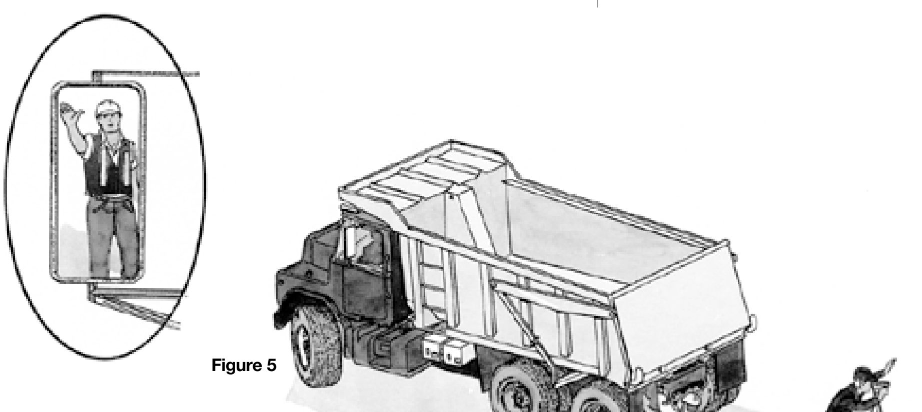


Figure 5

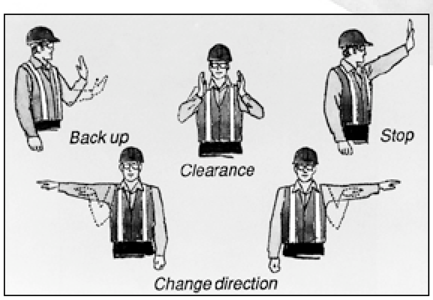


Figure 6

Workers on Foot

- Know how to work safely around trucks and operating equipment.
- Understand the effect of blind spots (Figure 7).
- Avoid entering or standing in blind spots.
- **Make eye contact with the driver or operator before approaching equipment.**
- Signal intentions to the driver or operator.
- When possible, use separate access rather than vehicle ramps to enter and exit the site.
- Avoid standing and talking near vehicle paths, grading operations, and other activities where heavy equipment is moving back and forth.

Figure 7 - *This illustration shows how some personnel on foot are visible to the dri ver while others are not. The driver cannot see the dark figures because they are passing through blind spots at the front and rear of the truck.*

Drivers and Operators

- Always obey the signaller or spotter. If more than one person is signalling, stop your vehicle and determine which one to obey.
- If possible, remain in the cab in areas where other equipment is likely to be backing up.
- Make sure that all mirrors are intact, functional, and properly adjusted for the best view.
- Blow the horn twice before backing up.
- When no spotter is present, get out and quickly walk around your vehicle. If the way is clear, back up at once (Figure 8).
- Stop the vehicle when a spotter, worker, or anyone else disappears from view.

Figure 8

Signallers

- Stay alert to recognize and deal with dangerous situations.
- Know and use the standard signals for on-site traffic (Figure 6).
- Wear a reflective fluorescent or bright orange vest and a bright hard hat for high visibility.
- Use a signalling device such as a bullhorn in congested excavation areas.
- Understand the maneuvering limitations of vehicles and equipment.
- Know driver and operator blind spots.
- Stand where you can see and be seen by the driver or operator.
- Make eye contact with driver or operator before signalling or changing location.

Electronic Equipment

Since 2000, automatic audible alarms that signal when a vehicle is being operated in reverse have been required on dump trucks.

Alarms offer the greatest benefit when traffic is limited to only one or two vehicles. The warning effect of the alarm is greatly reduced, however, when it simply becomes part of the background noise on-site.

This is a common shortcoming with devices that sound continuously when the transmission is put in reverse, especially in areas where several vehicles are operating at once.

Newer devices using a type of radar to sense objects or people within a pre-set radius appear to be more effective but are not readily available or widely used.

Other technologies such as infrared or heat sensors and closed-circuit television are limited by the effects of vibration, dust, and dirt – conditions all too common on construction sites.

4 TRAFFIC CONTROL

Attention: Supervisors

Traffic control persons (TCPs) must be given written and oral instructions regarding their duties. This section is designed to help you meet the requirement for written instructions set out in Section 69(4) of the Construction Regulation.

A worker who is required to direct vehicular traffic,

(a) shall be a competent worker;
(b) shall not perform any other work while directing vehicular traffic;
(c) shall be positioned in such a way that he or she is endangered as little as possible by vehicular traffic; and
(d) shall be given adequate written and oral instructions, in a language that he or she understands, with respect to directing vehicular traffic, and those instructions shall include a description of the signals that are to be used.

In addition, the written instructions must be kept on the project.

What are the objectives of traffic control?

- To protect construction workers and the motoring public by regulating traffic flow.
- To stop traffic whenever required by the progress of work. Otherwise to keep traffic moving at reduced speeds to avoid tie-ups and delays.
- To allow construction to proceed safely and efficiently.
- To ensure that public traffic has priority over construction equipment.

What equipment do I need?

Personal

- Hard hat that meets regulated requirements.
- Safety boots, CSA-certified, Grade 1 (green triangular CSA patch outside, green rectangular label inside).
- Garment, usually a vest, covering upper body and meeting these requirements:
    - fluorescent or bright orange in colour
    - two vertical yellow stripes 5cm wide on front, covering at least 500cm^2
    - two diagonal yellow stripes 5cm wide on back, in an X pattern, covering at least 570cm^2
    - stripes retro-reflective and fluorescent
    - vests to have adjustable fit, and a side and front tear-away feature on vests made of nylon.

Sign

A sign used to direct traffic must be

- octagonal in shape, 450mm wide, and mounted on a pole 1.2m long
- made of material with at least the rigidity of plywood 6mm thick
- high-intensity retro-reflective red on one side, with STOP printed in high-intensity retro-reflective white 150mm high
- on the other side, high-intensity retro-reflective micro-prismatic fluorescent chartreuse, with a black diamond-shaped border at least 317mm x 317mm, with SLOW printed in black 120mm high.

We recommend that garments comply with CSA standard Z96-02.

After Dark

Section 69.1(4) of the Construction Regulation requires that you wear retro-reflective silver stripes encircling each arm and leg, or equivalent side visibility-enhancing stripes with a minimum area of 50cm^2 per side.

The following measures are recommended:

- Wear a hard hat with reflective tape.
- Use a flashlight with a red cone attachment as well as the sign and carry spare batteries.
- Place flashing amber lights ahead of your post.
- Stand in a lighted area under temporary or street lighting, or illuminated by light from a parked vehicle (stand fully in the light without creating a silhouette).

What are the requirements of a good traffic control person?

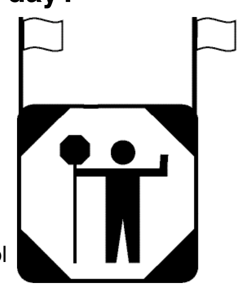
- Sound health, good vision and hearing, mental and physical alertness.
- Mature judgment and a pleasant manner.
- A good eye for speed and distance to gauge oncoming traffic.
- Preferably a driver's licence.
- The ability to give motorists simple directions, explain hazards, and answer questions.
- Liking, understanding, and respect for the responsibilities of the job.

How do I prepare for each job?

Before starting work, make sure that you know

- the type of construction you will be involved with – paving, installing pipe, grading, cut and fill, etc.
- the type of equipment to be used, such as scrapers, trucks, compactors, and graders
- how the equipment will be operating – for instance, crossing the road, along the shoulder, in culverts, or on a bridge
- whether you will have to protect workers settling up components of the traffic control system such as signs, delineators, cones, and barriers
- any special conditions of the contract governing road use (for instance, many contracts forbid work during urban rush hours)
- how public traffic will flow – for example, along a two-lane highway, around curves or hills, by detour or on a road narrowed to a single lane. This last is a very common situation and requires two traffic control persons to ensure that vehicles do not move in opposing directions at the same time (page 146). In some cases, where the two cannot see one another, a third is necessary to keep both in view and relay instructions (see "Positioning of Traffic Control Persons," page 146).

What should I check each day?



- Make sure that the STOP-SLOW sign is clean, undamaged and meets height and size requirements.
- Place the TRAFFIC CONTROL PERSON AHEAD sign at an appropriate distance to afford motorists adequate warning.
- Remove or cover all traffic control signs at quitting time or when traffic control is temporarily suspended.
- Arrange with the supervisor for meal, coffee, and toilet breaks.

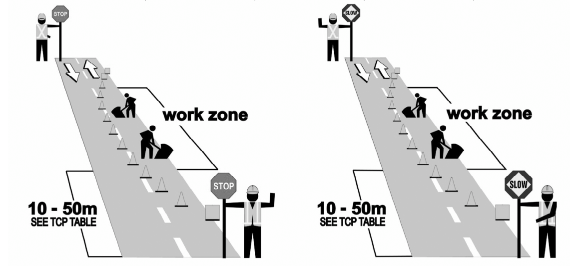
Where should I stand?

- Stand the correct distance from the work area. Refer to TCP Table on the following page.
- Do not stand on the travelled portion of roadway and always face oncoming traffic.
- Be alert at all times. Be aware of construction traffic around you and oncoming traffic on the roadway.
- Stand alone. Don't allow a group to gather around you.

- Stand at your post. Sitting is hazardous because your visibility is reduced and the ability of a motorist to see you is reduced.

TCP TABLE

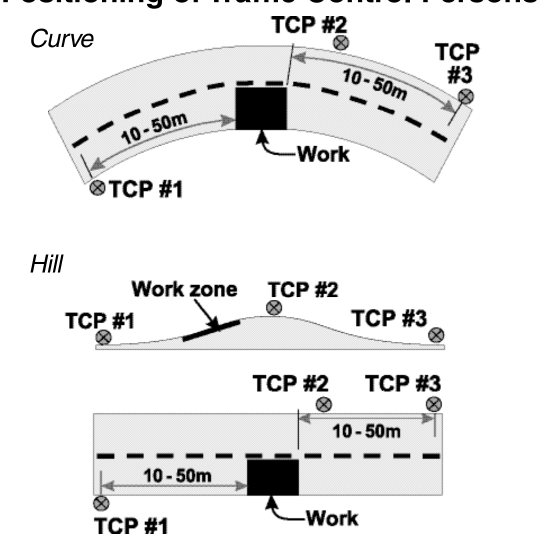
POSTED SPEED	60 km/h OR LESS, ONE LANE OR REDUCED TO ONE LANE IN EACH DIRECTION		70 km/h TO 90 km/h, ONE LANE OR REDUCED TO ONE LANE IN EACH DIRECTION	
TRAFFIC VOLUME	LOW	HIGH	LOW	HIGH
DISTANCE OF TCP FROM WORK ZONE	10 – 15 m	20 – 30 m	30 – 40 m	40 – 50 m



Typical Arrangement on Two-lane Roadway

- Adjust distances to suit road, weather and speed conditions. Remember these points:
  - Traffic must have room to react to your directions to stop (a vehicle can take at least twice the stopping distance on wet or icy roads).
  - Stand where you can see and be seen by approaching traffic for at least 150 metres (500 feet).
  - Avoid the danger of being backed over or hit by your own equipment.
- Hills and curves call for three TCPs or some other means of communication. The job of the TCP in the middle is to relay signals between the other two.

Positioning of Traffic Control Persons



Note: On curves and hills, three TCPs or some other means of communication are required.
The duty of TCP #2 is to relay signals between TCP #1 and #3.

- Once you have been assigned a traffic control position by your supervisor, look over the area for methods of escape – a place to get to in order to avoid being injured by a vehicle heading your way, if for some reason the driver has disregarded your signals.

  If this should happen, protect yourself by moving out of the path of the vehicle and then warn the crew.

Where am I not allowed to direct traffic?

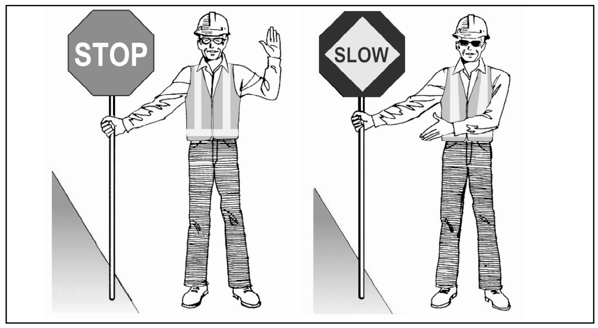
Section 69 of Ontario Regulation 213/91 specifies that:

A worker shall not direct vehicular traffic for more than one lane in the same direction. s. 69(2)

A worker shall not direct vehicular traffic if the normal posted speed limit of the public way is more than 90 kilometres per hour. s. 69(3)

How should I signal?

- Use the STOP-SLOW sign and your arms as shown below.



- Hold your sign firmly in full view of oncoming traffic.
- Give the motorist plenty of warning. Don't show the STOP sign when the motorist is too close. The average stopping distance for a vehicle travelling at 50 kilometres per hour (30 miles per hour) is 45 metres (150 feet). Higher speeds require more stopping distance.
- When showing the SLOW sign, avoid bringing traffic to a complete halt. When motorists have slowed down, signal them to keep moving slowly.
- When showing the STOP sign, use firm hand signals and indicate where you want traffic to stop. When the first vehicle stops, step into the centre of the road so the second vehicle can see you.
- Before moving traffic from a stopped position, make sure the opposing traffic has stopped and that the last opposing vehicle has passed your post. Then turn your sign and step back on the shoulder of the road.
- Stay alert, keep your eyes on approaching traffic, make your hand signals crisp and positive.
- Coordinate your effort with nearby traffic signals to avoid unnecessary delays, tie-ups, and confusion.
- Do not use flags to control traffic.
- In some situations, two-way traffic may be allowed through the wo rk zone at reduced speed, with a traffic control person assigned to each direction. Since motorists can be confused or misled by seeing the STOP side of the sign used in the opposite lane, the signs must be modified. The STOP side must be covered to conceal its distinctive shape and command. This should prevent drivers from stopping unexpectedly.

How can I improve safety for myself and others?

- Don't be distracted by talking to fellow workers or passing pedestrians. If you must talk to motorists, stay at your post and keep the conversation brief.

- When using two-way radios to communicate with another traffic control person, take the following precautions:
  - Establish clear voice signals for each situation and stick to them.
  - Be crisp and positive in your speech.
  - Test the units **before** starting your shift and carry spare batteries.
  - Avoid unnecessary chit-chat.
  - Don't use two-way radios in blasting zones.
- When two traffic control persons are working together, you should always be able to see each other in order to coordinate your STOP-SLOW signs. Signals between you should be understood. If you change your sign from STOP to SLOW or vice-versa, you must signal the other person by moving the sign up and down or sideways. This will ensure that traffic control is coordinated. Two-way radios are the best way of communicating.

  When you can't see the other traffic control person, a third should be assigned to keep you both in view.

What are my rights under the law?

Additional requirements for traffic control are spelled out in the ***Ontario Traffic Manual***, *Book 7: Temporary Conditions*, available through the Ministry of Transportation.

The information applies to traffic control by any persons or agencies performing construction, maintenance, or utility work on roadways in Ontario.

The Construction Regulation under the *Occupational Health and Safety Act* makes it mandatory that traffic control persons be protected from hazards. This includes not only personal protective clothing and equipment but measures and devices to guard against the dangers of vehicular traffic. Safety should receive prime consideration in planning for traffic control. Regulations under the *Occupational Health and Safety Act* are enforced by the Ministry of Labour.

Traffic control persons have no authority under the *Highway Traffic Act* and are not law enforcement officers. If problems arise, follow these steps.

- Report dangerous motorists to your supervisor.
- Keep a pad and pencil to jot down violators' licence numbers.
- Ask your supervisor for assistance from police in difficult or unusual traffic situations.
- Never restrain a motorist forcibly or take out your anger on any vehicle.
- Always be alert to emergency services. Ambulance, police, and fire vehicles have priority over all other traffic.

Remember

- Always face traffic.
- Plan an escape route.
- Wear personal protective clothing.
- Maintain proper communication with other traffic control persons.
- Stay alert at all times.
- Be courteous.

Traffic control is a demanding job, often a thankless job, but always an important job. How well you succeed will depend largely on your attitude.

5 MOUNTING AND DISMOUNTING

Each year, workers are hurt while getting on or off trucks, backhoes, and other construction equipment. Learn the safe way to mount and dismount.

Three-point contact

When getting on or off equipment, you need three points of constant contact with the machine. That means one hand and two feet, or two hands and one foot – **at all times.**

Anything less, and you're risking a fall.

Three-point contact forms a triangle of anchor points which changes in form while you mount or dismount (Figure 1). You have the most stability when the centre of this triangle is close to your centre of gravity. Your weight should be evenly distributed among the three contact points. This means that you should avoid sideways movement because it can put you off balance.

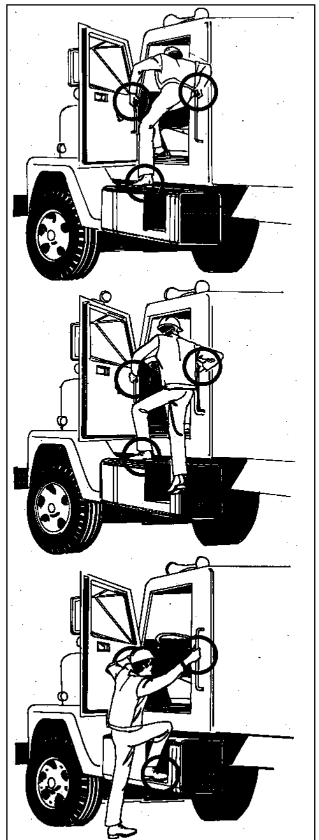


Figure 1

Remember

- ✓ always face in towards the machine or ladder
- ✓ mount and dismount only when the equipment is standing still
- ✓ break three-point contact only when you reach the ground, the cab of the vehicle, or a stable platform
- ✓ take your time
- ✓ take extra care in wet, snowy, icy, or other dangerous weather conditions
- ✓ avoid wearing loose or torn clothing that can catch on the equipment
- ✓ get on or off at the safest access position (normally designed by the manufacturer)
- ✓ where necessary, retrofit equipment to provide safe access.

The Construction Regulation states that construction equipment must have a means of access to the operator's station that will not endanger the operator, and must have skid-resistant walking, climbing, and work surfaces.

Ensure that your equipment complies with the law. And keep runningboards, treads, steps, footholds, and platforms clear of mud, ice, snow, grease, debris, and other hazards. Housekeeping keeps you and your co-workers safe!

6 TRENCHING

This chapter covers

- Background
- Causes of cave-ins
- Protection against cave-ins
- Other hazards and safeguards
- Emergency procedures
- Underground utilities
- Soil types

Background

Fatalities

A significant number of deaths and injuries in sewer and watermain work are directly related to trenching.

Trenching fatalities are mainly caused by cave-ins. Death occurs by suffocation or crushing when a worker is buried by falling soil.

Injuries

The following are the main causes of lost-time injuries in the sewer and watermain industry:

- material falling into the trench
- slips and falls as workers climb on and off equipment
- unloading pipe
- handling and placing frames and covers for manholes and catch basins
- handling and placing pipe and other materials
- being struck by moving equipment
- falls as workers climb in or out of an excavation
- falling over equipment or excavated material
- falling into the trench
- exposure to toxic, irritating, or flammable gases.

Again, many of these injuries are directly related to trenching.

Regulations

Supervisors and workers in the sewer and watermain industry must be familiar with the "Excavations" section of the Construction Regulation under the *Occupational Health and Safety Act.*

It is important to understand, for instance, the terms "trench" and "excavation." Simply stated, an excavation is a hole left in the ground as the result of removing material. A trench is an excavation in which the depth exceeds the width (Figure 1).

Difference between excavation and trench

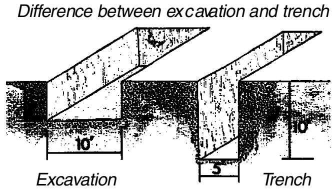


Figure 1

The "Excavations" section identifies the various types of soils and specifies the type of shoring and timbering to be used for each.

The Regulation also spells out the requirements for trench support systems that must be designed by a professional engineer.

Causes of Cave-Ins

Soil properties often vary widely from the top to the bottom and along the length of a trench.

Many factors such as cracks, water, vibration, weather, and previous excavation can affect trench stability (Figure 2). Time is also a critical factor. Some trenches will remain open for a long period, then suddenly collapse for no apparent reason.

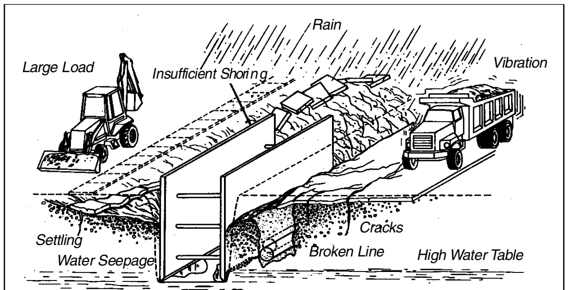


Figure 2 - Many factors affect trench stability.

Figure 3 shows the typical causes of cave-ins.

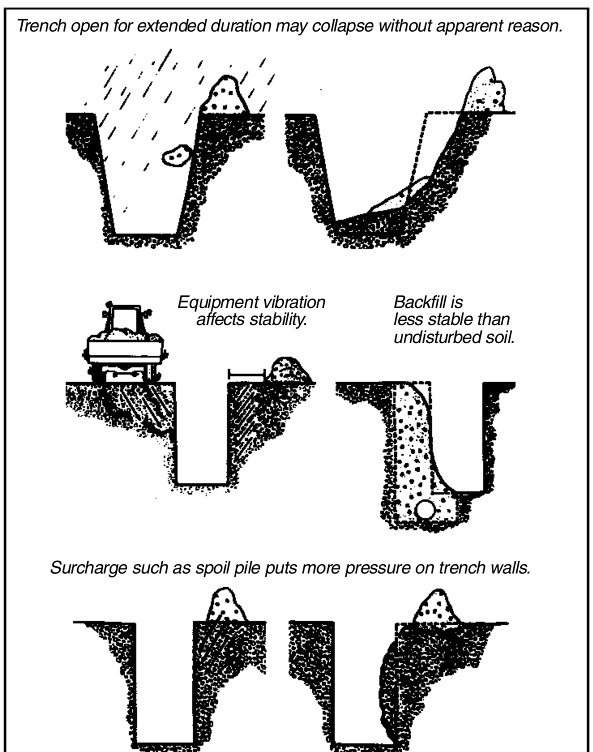


Figure 3

The main factors affecting trench stability are soil type, moisture, vibration, surcharge, previous excavation, existing foundations, and weather.

Soil Type

The type of soil determines the strength and stability of trench walls.

Identifying soil types requires knowledge, skill, and experience. Even hard soil may contain faults in seams or layers that make it unstable when excavated.

The foreman or supervisor must be knowledgeable about soil types found on a project and plan protection accordingly. This knowledge must include an awareness that soil types and conditions can change over very short distances. It is not unusual for soil to change completely within 50 metres or for soil to become saturated with moisture over even smaller distances.

While many people classify soil as good, mediocre, and bad, the Construction Regulation sets out four soil types.

Type 1 It is hard to drive a pick into Type 1 soil. Hence, it is often described as "hard ground to dig". In fact, the material is so hard, it is close to rock.

When excavated, the sides of the excavation appear smooth and shiny. The sides will remain vertical with no water released from the trench wall.

If exposed to sunlight for several days, the walls of Type 1 soil will lose their shiny appearance but remain intact without cracking and crumbling.

If exposed to rain or wet weather, Type 1 soil may break down along the edges of the excavation.

Typical Type 1 soils include "hardpan," consolidated clay, and some glacial tills.

Type 2 A pick can be driven into Type 2 soil relatively easily. It can easily be excavated by a backhoe or hand-excavated with some difficulty.

In Type 2 soil, the sides of a trench will remain vertical for a short period of time (perhaps several hours) with no apparent tension cracks. However, if the walls are left exposed to air and sunlight, tension cracks will appear as the soil starts to dry. The soil will begin cracking and splaying into the trench.

Typical Type 2 soils are silty clay and less dense tills.

Type 3 Much of the Type 3 soil encountered in construction is previously excavated material. Type 3 soil can be excavated without difficulty using a hydraulic backhoe.

When dry, Type 3 soil will flow through fingers and form a conical pile on the ground. Dry Type 3 soil will not stand vertically and the sides of the excavation will cave in to a natural slope of about 1 to 1 depending on moisture.

Wet Type 3 soil will yield water when vibrated by hand. When wet, this soil will stand vertically for a short period. It dries quickly, however, with the vibration during excavation causing chunks or solid slabs to slide into the trench.

All backfilled or previously disturbed material should be treated as Type 3. Other typical Type 3 soil includes sand, granular materials, and silty or wet clays.

Type 4 Type 4 soil can be excavated with no difficulty using a hydraulic backhoe. The material will flow very easily and must be supported and contained to be excavated to any significant depth.

With its high moisture content, Type 4 soil is very sensitive to vibration and other disturbances which cause the material to flow.

Typical Type 4 material includes muskeg or other organic deposits with high moisture content, quicksand, silty clays with high moisture content, and leta clays. Leta clays are very sensitive to disturbance of any kind.

Moisture Content

The amount of moisture in the soil has a great effect on soil strength.

Once a trench is dug, the sides of the open excavation are exposed to the air. Moisture content of the soil begins to change almost immediately and the strength of the walls may be affected.

The longer an excavation is open to the air, the greater the risk of cave-in.

Vibration

Vibration from various sources can affect trench stability.

Often trench walls are subject to vibration from vehicular traffic or from construction operations such as earth moving, compaction, pile driving, and blasting. These can all contribute to the collapse of trench walls.

Surcharge

A surcharge is an excessive load or weight that can affect trench stability.

For instance, excavated soil piled next to the trench can exert pressure on the walls. Placement of spoil piles is therefore important. Spoil should be kept as far as practical from the edge of the trench. Mobile equipment and other material stored close to the trench also add a surcharge that will affect trench stability.

One metre from the edge to the toe of the spoil pile is the minimum requirement (Figure 4). The distance should be greater for deeper trenches.

Move spoil pile farther back for deep trenches

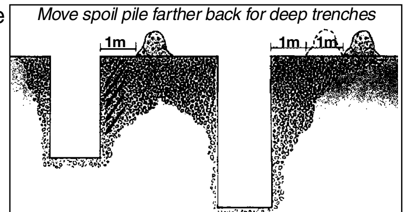


Figure 4

Previous Excavation

Old utility trenches either crossing or running parallel to the new trench can affect the strength and stability (Figure 5).

Old utilities are surrounded by backfilled soil which is usually less stable than undisturbed soil.

Figure 5

Soil around and between these old excavations can be very unstable. At best it is considered Type 3 soil – loose, soft, and low in internal strength. In some unusual circumstances it may be Type 4 – wet, muddy, and unable to support itself.

This kind of soil will not stand up unless it is sloped or shored.

Existing Foundations

Around most trenches and excavations there is a failure zone where surcharges, changes in soil condition, or other disruptions can cause collapse.

Existing foundations are surrounded by backfill and may add a surcharge load to the pressure on the trench wall.

Figure 6

When the foundation of a building adjacent to the trench or excavation extends into this failure zone, the result can be a cave-in (Figure 6). Soil in this situation is usually considered Type 3.

Weather

Rain, melting snow, thawing earth, and overflow from adjacent streams, storm drains, and sewers all produce changes in soil conditions. In fact, water from any source can reduce soil cohesion (Figure 7).

Moisture affects stability, especially where heavy rainfall has occurred

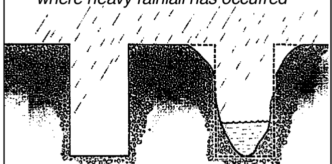


Figure 7

Don't make frozen soil an excuse for heavier loading or reduced shoring. Frost extends to a limited depth only.

Protection Against Cave-Ins

There are three basic methods of protecting workers against trench cave-ins:

- sloping
- trench boxes
- shoring

Most fatal cave-ins occur on small jobs of short duration such as service connections and excavations for drains and wells. Too often people think that these jobs are not hazardous enough to require safeguards against collapse.

Unless the walls are solid rock, never enter a trench deeper than 1.2 metres (4 feet) unless it is properly sloped, shored, or protected by a trench box.

Sloping

One way to ensure that a trench will not collapse is to slope the walls.

Where space and other requirements permit sloping, the angle of slope depends on soil conditions (Figures 8, 9 and 10).

For Type 1 and 2 soils, cut trench walls back at an angle of 1 to 1 (45 degrees). That's one metre back for each metre up. Walls should be sloped to within 1.2 metres (4 feet) of the trench bottom (Figure 8).

GOOD SOIL — Type 1 & 2 Soil

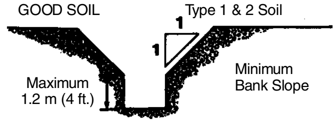


Figure 8

FAIRLY GOOD SOIL — Type 3 Soil

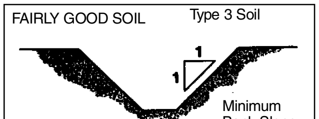


Figure 9

BAD SOIL — Type 4 Soil

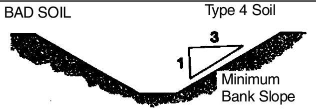


Figure 10

For Type 3 soil, cut walls back at a gradient of 1 to 1 from the trench bottom (Figure 9).

For Type 4 soil, slope the walls at 1 to 3. That's 3 metres back for every 1 metre up from the trench bottom (Figure 10).

Although sloping can reduce the risk of cave-in, the angle must be sufficient to prevent spoil not only from sliding back but from exerting too much pressure on the trench wall (Figure 11).

Spoil piles can exert too much pressure on sloped trench wall.

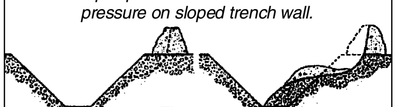


Figure 11

Sloping is commonly used with shoring or trench boxes to cut back any soil above the protected zone. It is also good practice to cut a bench at the top of the shoring or trench (Figure 12).

It is good practice to cut a bench at top of shoring

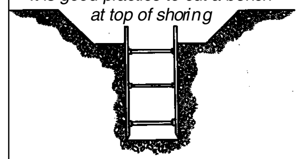


Figure 12

Cut back unshored top position with a 1 to 1 slope

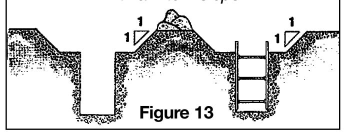


Figure 13

If sloping is to be used above a trench box, the top portion of the cut should first be sloped 1 to 1. Then the box should be lowered into the trench (Figure 13).

Trench Boxes

Trench boxes are not usually intended to shore up or otherwise support trench walls. They are meant to protect workers in case of a cave-in. They are capable of supporting trench walls if the space between the box and the trench wall is backfilled and compacted.

Design drawings and specifications for trench boxes must be signed and sealed by the professional engineer who designed the system and must be kept on site by the constructor.

Boxes are normally placed in an excavated but unshored trench and used to protect personnel. A properly designed trench box is capable of withstanding the maximum lateral load expected at a given depth in a particular soil condition.

As long as workers are in the trench they should remain inside the box and leave only when the box is being moved. A ladder must be set up in the trench box at all times.

Excavation should be done so that the space between the trench box and the excavation is minimized (Figure 14). The two reasons for this are

1) allowing closer access to the top of the box
2) limiting soil movement in case of a cave-in.

Keep space between trench box and excavation as small as possible.

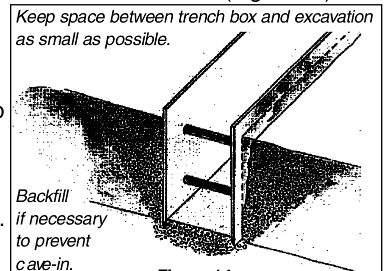


Figure 14

Shoring

Shoring is a system which “shores” up or supports trench walls to prevent movement of soil, underground utilities, roadways, and foundations.

Shoring should not be confused with trench boxes. A trench box provides worker safety but gives little or no support to trench walls or existing structures such as foundations and manholes.

The two types of shoring most commonly used are timber and hydraulic. Both consist of posts, wales, struts, and sheathing.

Figures 15 and 16 identify components, dimensions, and other requirements for timber shoring in some typical trenches.

“Hydraulic shoring” means prefabricated strut and/or wale systems in aluminum or steel. Strictly speaking, these may

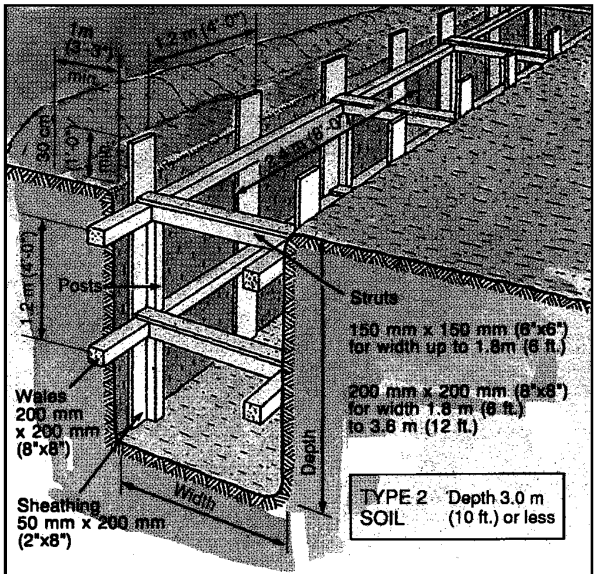


Figure 15

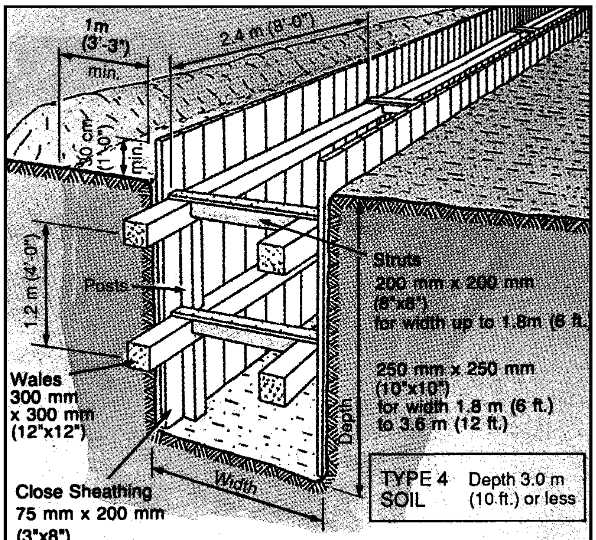


Figure 16

not operate hydraulically. Some are air-operated or manually jacked. Design drawings and specifications for prefabricated shoring systems must be kept on site.

One major advantage of hydraulic shoring over some applications of timber shoring is safety during installation. Workers do not have to enter the trench to install the system. Installation can be done from the top of the trench.

Most hydraulic systems are

- light enough to be installed by one worker
- gauge-regulated to ensure even distribution of pressure along the trench line
- able to “pre-load” trench walls, thereby using the soil's natural cohesion to prevent movement.
- easily adapted to suit various trench depths and widths.

Wherever possible, shoring should be installed as excavation proceeds. If there is a delay between digging and shoring, no one must be allowed to enter the unprotected trench.

All shoring should be installed from the top down and removed from the bottom up.

Access/Egress

Whether protected by sloping, boxes, or shoring, trenches must be provided with ladders so that workers can enter and exit safely (Figure 17).

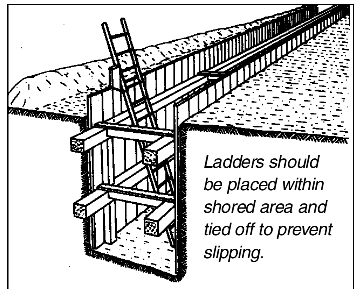


Figure 17

Ladders must

- be placed within the area protected by the shoring or trench box
- be securely tied off at the top
- extend above the shoring or box by at least 1 metre (3 feet)
- be inspected regularly for damage.

Ladders should be placed as close as possible to the area where personnel are working and never more than 7.5 metres (25 feet) away.

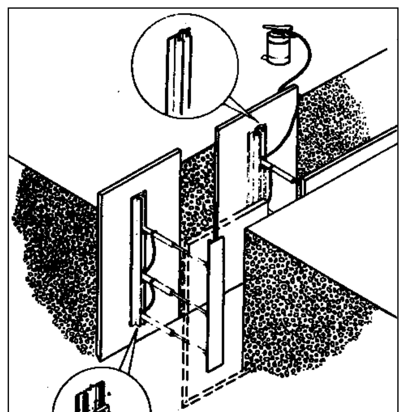
Anyone climbing up or down must always face the ladder and maintain 3-point contact. This means that two hands and one foot or two feet and one hand must be on the ladder at all times.

Maintaining 3-point contact means hands must be free for climbing. Tools and materials should not be carried up or down ladders. Pumps, small compactors, and other equipment should be lifted and lowered by methods that prevent injury from overexertion and falling objects.

Inspection

Inspection is everyone's responsibility. Whatever the protective system, it should be inspected regularly.

Check hydraulic shoring for leaks in hoses and cylinders, bent bases, broken or cracked nipples, and other damaged or defective parts (Figure 18).



Check hydraulic shoring for leaks. – Figure 18

Check timber shoring before installation. Discard damaged or defective lumber. After installation, inspect wales for signs of crushing. Crushing indicates structural inadequacy and calls for more struts (Figure 19).

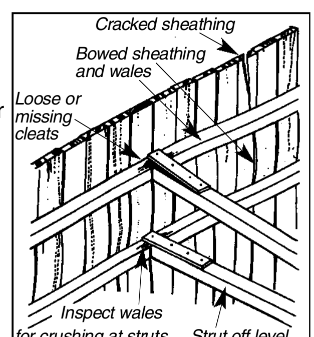


Figure 19

Inspect trench boxes for structural damage, cracks in welds, and other defects (Figure 20). During use,

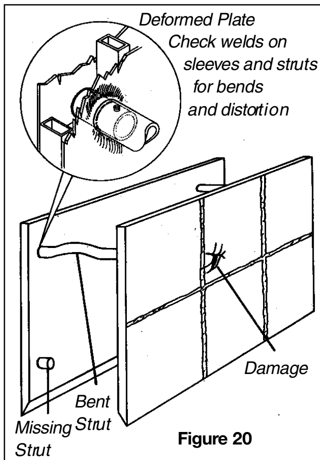


Figure 20

check the box regularly and often to make sure that it is not shifting or settling much more on one side than the other. If it is, leave the trench and ask the supervisor to check for stability.

Check ground surface for tension cracks which may develop parallel to the trench at a distance one-half to three-quarters of the trench depth (Figure 21). If cracks are detected, alert the crew and check all protective systems carefully.

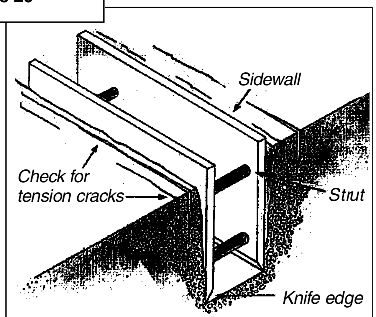


Figure 21

Check areas adjacent to shoring where water may have entered the trench. A combination of water flow and granular soils can lead to undermining of the trench wall. Such conditions have caused fatalities.

Finally, make sure that tools, equipment, material, and spoil are kept at least 1 metre (3 feet) back from the edge of the trench to prevent falling objects from striking workers.

Summary

Sloping, trench boxes, and shoring are meant to protect workers from the hazards of cave-ins.

The method chosen must meet the specific requirements of the job at hand. Depending on application, one method may be better suited to certain conditions than another.

Whatever the system, inspect it regularly to make sure that it remains sound and reliable.

Remember: Never enter a trench more than 1.2 metres (4 feet) deep unless it is sloped, shored, or protected by a trench box.

Other Hazards and Safeguards

The risk of cave-in is not the only hazard in trenching. Injuries and deaths are also related to six other major areas:

- personal protective equipment
- utilities underground and overhead
- materials handling and housekeeping
- heavy equipment
- traffic control
- confined spaces.

Personal Protective Equipment

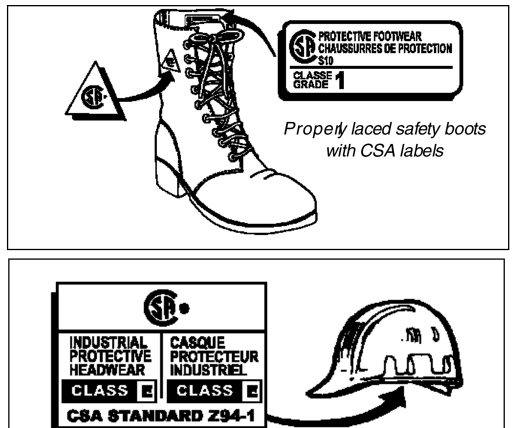
Personal protective equipment is an important defence against certain types of injury.

Injuries from falling and flying objects, for instance, can be reduced by wearing hard hats and eye protection.

Everyone on a construction project must wear Grade 1 safety boots certified by the Canadian Standards Association (CSA) as indicated by the CSA logo on a green triangular patch (Figure 22).

Under the wet, muddy conditions often encountered in trenching, you may also require rubber safety boots displaying the same CSA logo on a green triangular patch.

It is mandatory for everyone on a construction project to wear head protection in the form of a hard hat that complies with the current Construction Regulation.



Properly laced safety boots with CSA labels

CSA label, stamped into the shell, indicating Class E hard hat.

Figure 22

Eye protection is strongly recommended to prevent injuries from construction operations such as chipping and drilling and site conditions such as dust.

Personnel exposed for long periods to noisy equipment should wear hearing protection.

Work in confined spaces such as manholes and valve chambers may require respiratory protection against hazardous atmospheres.

Contact the Construction Safety Association of Ontario for more information on eye, hearing, and respiratory protection.

Underground Utilities

Locates

Services such as gas, electrical, telephone, and water lines must be located by the utility before excavation begins.

The contractor responsible for the work must contact the owners of any underground utilities that may be in that location or phone Ontario One Call. Request locates for all the underground utilities in the area where excavation will be taking place.

The service locate provided by the utility owner should indicate, using labelled stakes, flags, and/or paint marks, the centre line of the underground utility in the vicinity of the proposed excavation.

The excavator should not work outside of the area covered by the locate stakeout information without obtaining an additional stakeout.

Existing utility lines may require support.

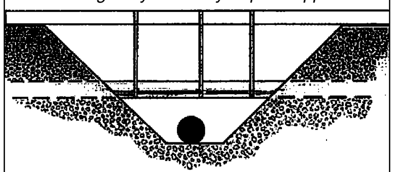
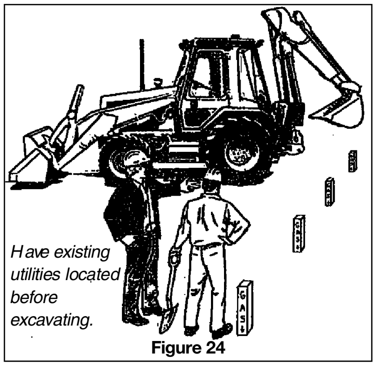


Figure 23

Locate stakeout accuracy should be considered to be 1 metre on either side of the surface centre line locate unless the locate instructions specifically indicate other boundary limits.

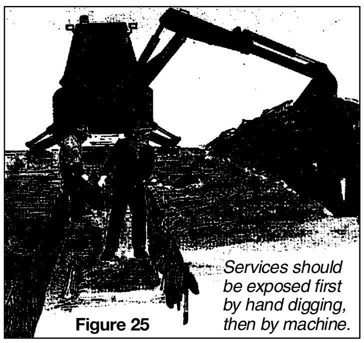


Have existing utilities located before excavating.

Figure 24

Where the underground utility cannot be located within the locate stakeout limits, the utility owner should be contacted to assist with the locate.

Mechanical excavation equipment should not be used within the boundary limits of the locate without first digging a hole or holes using the procedure below to determine the underground utility's exact centre line and elevation.



Services should be exposed first by hand digging, then by machine.

Figure 25

Test holes should, in general, be excavated by one of the following methods:

(a) machine excavation immediately outside the boundary limits and then hand digging laterally until the underground utility is found; or

(b) (i) hand excavation perpendicular to the centre line of the locate in cuts of at least 1 foot in depth;
(ii) mechanical equipment can then be used carefully to widen the hand-dug trench to within one foot of the depth of the hand-dug excavation;
(iii) repeat steps (i) and (ii) until the utility is located;

or

(c) a hydro-excavation system – acceptable to the owner of the utility – which uses high-pressure water to break up the cover material and a vacuum system to remove it can be used to locate the underground utility.

Centre line locates should be provided and test holes dug where a representative of the utility identifies

(a) alignment changes
(b) changes in elevation.

Where an underground utility may need support or where it may shift because of disturbance of surrounding soil due to excavation, guidelines for excavation and support should be obtained from the owner of the utility (Figure 23).

Breaks

Breaks in electrical, gas, and water services can cause serious injuries, even deaths. Hitting an underground electrical line can result in electrocution while hitting a gas line can cause an explosion. A broken water line can release a sudden rush of water, washing out support systems and causing a cave-in.

Cutting telephone lines can create a serious problem if emergency calls for police, fire, or ambulance are required.

In the event of gas line contact, call the gas company immediately. The company will check the line and close down the supply if necessary.

If a leak is suspected, people in the immediate area should be told to evacuate. Where service to a building or home has been struck, people inside should be advised to leave doors and windows open; shut off appliances, furnaces, and other sources of ignition; and vacate the premises until the gas company declares it safe to return.

Construction personnel should take two precautions.

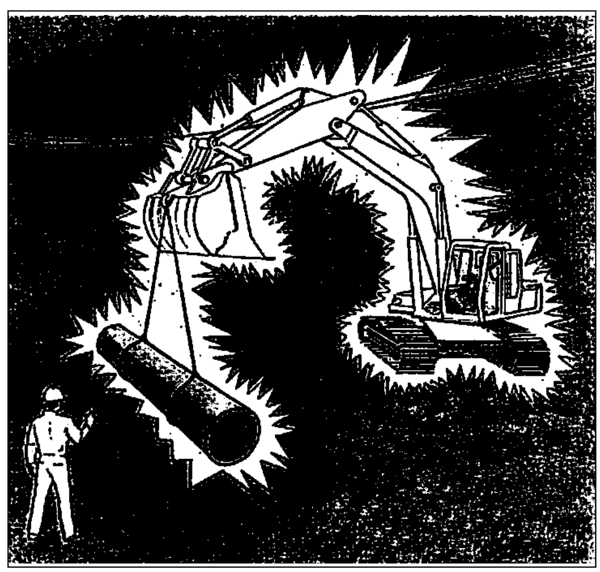
1) Put out smoking materials and shut off other sources of ignition such as engines and equipment.
2) Leave the trench immediately. Gas can collect there.

Overhead Powerlines

Equipment such as an excavator or backhoe must not be moved closer than one boom length to an overhead powerline of more than 750 volts unless a signaller is stationed to warn the operator when any part of the machine, boom, or load approaches the minimum distance specified in the regulations.

If equipment touches a high-voltage line, the operator should take the following precautions.

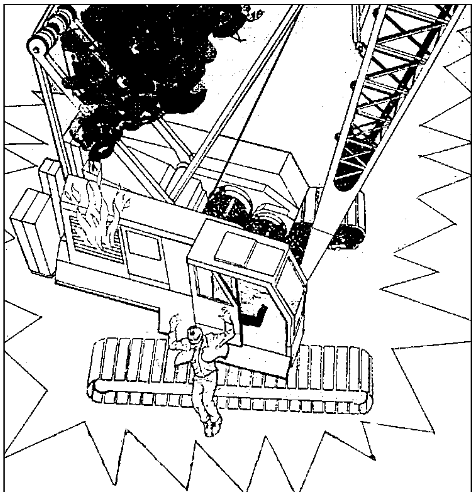
1) Stay on the machine. Don't touch equipment and ground at same time. Touching anything in contact with the ground could be fatal.
2) Keep others away. Warn them not to touch the load, load lines, boom, bucket, or any other part of the equipment (Figure 26).



3) Get someone to call the local utility to shut off power.
4) If possible, break contact by moving the machine clear of the wires.

> ***Warning:* Beware of time relays. Even after breakers are tripped by line damage, relays may be triggered to restore power.**

5) Otherwise do not move the machine until the utility shuts down the line and confirms that power is off.
6) If an emergency such as fire forces you to leave the machine, **jump** clear (Figure 27). Never step down. If part of your body contacts the ground while another part touches the machine, current will travel through you.



If an emergency forces you to leave the machine, jump clear with feet together and shuffle away — never step down.

Figure 27

7) Jump with feet together and shuffle away in small steps. Don't take big steps. With voltage differential across the ground, one foot may be in a higher voltage area than the other. The difference can kill you (Figure 28).

Voltage differential across the ground can injure or kill you.

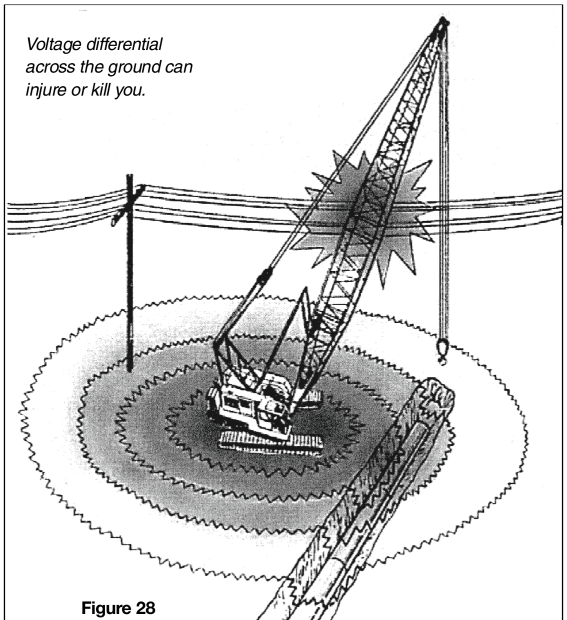


Figure 28

Special precautions are required for casualties in contact with live powe rlines or equipment.

1) Never touch the casualty or anything in contact with the casualty.
2) If possible, break contact. Use a dry board, rubber hose, or dry polypropylene rope to move either the casualty or the line. An object can sometimes be thrown to separate the casualty from the wire.

> ***Warning:* Touching the casualty, even with dry wood or rubber, can be dangerous. With high voltage lines, objects that are normally insulators can become conductors.**

3) Call emergency services – in most cases ambulance, fire department, and utility.
4) Provide first aid once the casualty is free of contact. If the casualty is not breathing, begin artificial respiration immediately (mouth-to-mouth is most efficient) or CPR. Apply cold water to burns and cover with clean dressing.

Materials Handling

Many lost-time injuries in trenching involve materials handling. Moving rock and soil, lifting pipe and manhole sections, laying down bedding material, or lowering pumps and compactors into the trench can all be hazardous.

Pipe

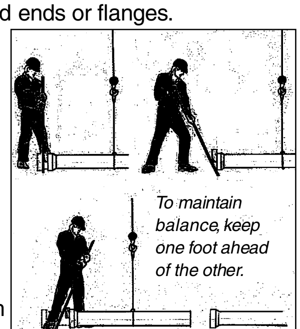
Trucks should always be on level ground when pipe is unloaded. Pipe should be chocked or staked before tie-downs are released. These measures will reduce the risk of sections rolling off the truck.

Plastic and small diameter pipe is often banded with metal straps. Take care cutting the straps. They are under tension and can fly back and hit you.

Personnel often injure fingers and hands when laying and joining sections of pipe. While sections are suspended from hoisting equipment, keep hands away from slings or chokers in tension. When guiding and pushing sections together by hand, never curl fingers around ends or flanges.

As pipe is placed along the trench, each section should be blocked or set so that it cannot roll and cause injury.

Back injuries can occur when small-diameter pipe is being homed into position (Figure 29). The worker pushing the bar should place his feet directly in front of the pipe with one foot ahead of the other.



To maintain balance, keep one foot ahead of the other.

Figure 29

Large-diameter pipe should be placed with pipe pullers (Figure 30).

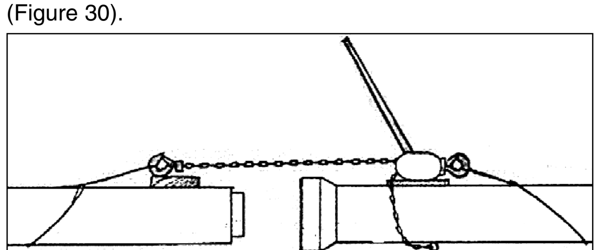


Figure 30

Bedding material

Personnel shovelling bedding material in the trench are usually working in a confined area where footing is muddy and uneven.

The result can be overexertion or slips and falls leading to back and other injuries. Mechanical equipment can significantly reduce this hazard. For instance, bedding material can be put in the excavator bucket with a front-end loader, then spread evenly along the trench bottom.

Rigging

Rigging is essential to safe, efficient materials handling since pipe, manhole sections, and equipment are lowered into the trench by cranes or other hoisting devices.

Rigging these loads properly can prevent injury.

Inspect slings and rigging hardware regularly and replace any damaged or worn devices.

Nylon web slings – Damage is usually easy to spot: cuts, holes, tears, worn or distorted fittings, frayed material, broken stitching, heat burns. Damaged web slings should be replaced.

Wire rope slings – Inspect for broken wires, worn or cracked fittings, loose seizings and splices, flatening, and corrosion. Knots or kinks indicate that wire rope slings are permanently damaged and should not be used.

Damage most often occurs around thimbles and fittings. Don't leave wire rope lying on the ground for any length of time in damp or wet conditions.

Eyes in wire rope slings should be fitted with thimbles. To make an eye with clips, put the U-bolt section on the dead or short end of the rope and the saddle on the live or long end (Figure 31). Remember – never saddle a dead horse.

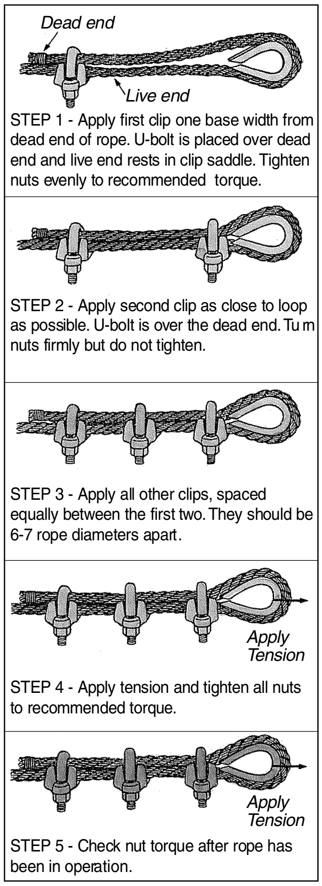


Figure 31

At least three clips are required for wire rope up to 5/8" diameter, and four are required for wire rope greater than 5/8" up to and including 7/8" diameter.

Avoid binding the eye section of wire rope slings around corners. The bend will weaken the splice or swaging.

When using choker hitches, do not force the eye down towards the load once tension is applied.

Chain Slings – Inspect for elongated links. A badly stretched link tends to close up (Figure 32).

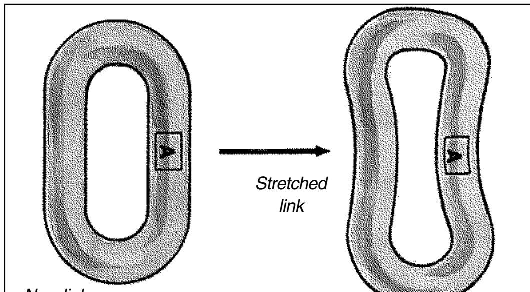


Figure 32

Look for bent, twisted, or damaged links that can result when chain has been used to lift a load with unprotected sharp edges.

Inspect for cracks. Although sometimes hard to detect, cracks always indicate that the chain should be removed from service. Also look for gouges, chips, cuts, dents, peen marks, and corrosive wear at points where links bear on each other.

Rigging Tips

- Wherever possible, lower loads on adequate blockage to prevent damage to slings.
- Keep hands away from pinch points when slack is being taken up.
- Stand clear while the load is being lifted and lowered or when slings are being pulled out from under it.
- Use tag lines to control swinging, swaying, or other unwanted movement of the load.

Housekeeping

Accident prevention depends on proper housekeeping at ground level and in the trench.

At the top of the trench, sections of pipe, unused tools and timber, piles of spoil, and other material must be kept at least 1 metre (3 feet) away from the edge.

The slips and falls common on excavation projects can be reduced by cleaning up scrap and debris. Trenches should also be kept as dry as possible. Pumps may be required.

Ladders should be placed within shored area and tied off to prevent slipping.

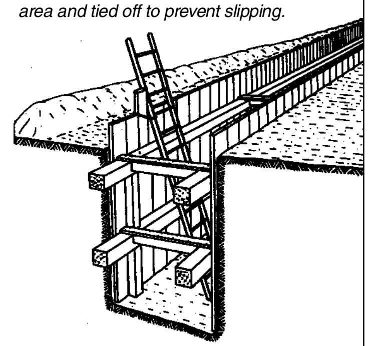


Figure 33

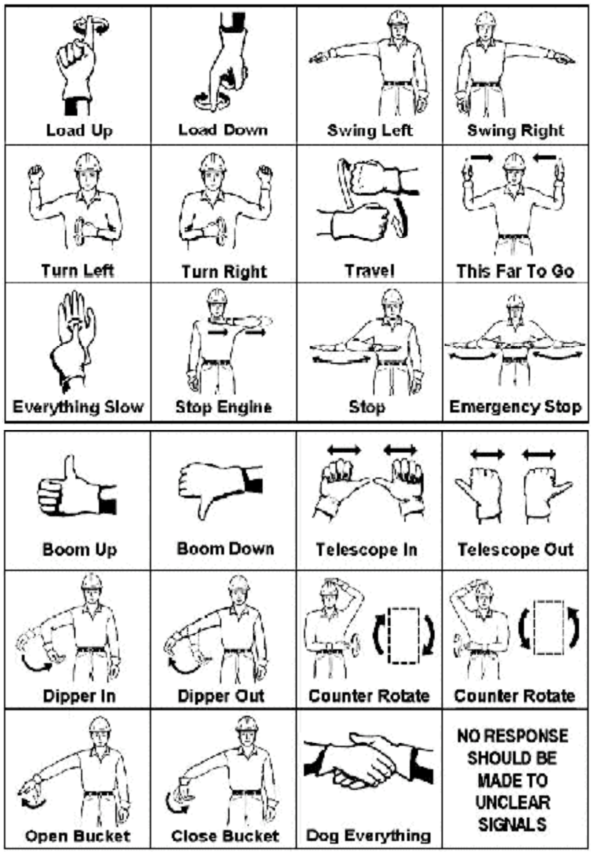
Proper housekeeping is especially important around ladders. The base and foot of the ladder should be free of garbage and puddles. Ladders should be tied off at the top, placed in protected areas, and inspected regularly for damage (Figure 33).

Heavy Equipment

Excavators, backhoes, and other heavy equipment can cause injuries and fatalities to operators and personnel on foot.

Excavator Handsignals

Communicate clearly with your co-workers. Use the following handsignals.



Operators

Improperly climbing on and off equipment has caused injuries to operators for many years. The best prevention is to maintain 3-point contact (Figure 34).

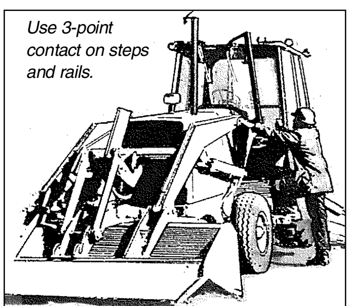


Figure 34

Equipment should be fitted with steps, grabs, and rails that are repaired or replaced when damaged.

Operators have also suffered serious injuries when equipment upsets because of soil failure near excavations (Figure 35), improper loading on floats, or inadvertently backing into excavations.

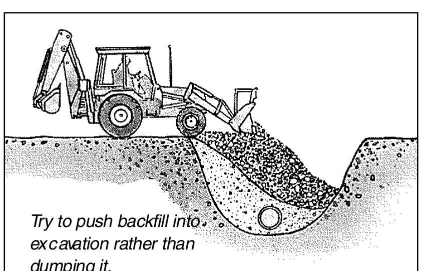


Figure 35

Moving Equipment

Signallers are required by law

- if the operator's view of the intended path of travel is obstructed, or
- if a person could be endangered by the moving equipment or its load.

Back-up alarms are required on dump trucks and recommended for all moving equipment. Where vehicles have to operate in reverse, warning signs must be conspicuously posted.

Ground Rules for Truck Drivers

- Understand and obey the signaller at all times.
- Remain in the cab where possible.
- Ensure that mirrors are clean, functional, and properly adjusted.
- Do a circle check after being away from the truck for any length of time (walk around the truck to ensure the area is clear before moving).
- Stop immediately when a signaller, worker, or anyone else disappears from view.

Workers on Foot

Personnel on foot are frequently stuck by machine attachments such as excavator buckets and bulldozer blades when they stand or work too close to operating equipment, especially during unloading and excavation.

Workers on foot are also injured and killed by equipment backing up.

Ground Rules for Workers on Foot

- Beware of common operator blind spots (See page 142).
- Stay alert to the location of equipment around you.
- Avoid entering or standing in blind spots.
- **Always remain visible to the operator. Make eye contact to ensure that you are seen.**
- Never stand behind a backing vehicle.
- Remember – The operator may be able to see you while you are standing but not when you kneel down or bend over.

Signallers

In heavily travelled or congested work areas, a signaller may be necessary to direct equipment and prevent injuries and deaths caused by vehicles backing up.

Ground Rules for Signallers

- Wear a fluorescent or bright orange safety vest.
- Use standard hand signals (Figure 37).
- Stand where you can see and be seen.
- Stay in full view of the operator and the intended path of travel.
- Know where the operator's blind spots are.
- Warn other workers to stay clear of equipment.

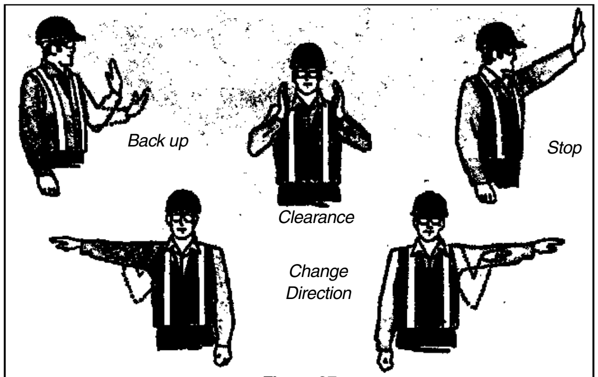


Figure 37

Traffic Control

On trenching projects along public roadways, the construction crew must be protected from traffic. Regulations specify the following methods for protecting personnel:

- traffic control persons (TCPs) using signs (Figure 38)
- warning signs
- barriers
- lane control devices
- flashing lights or flares.

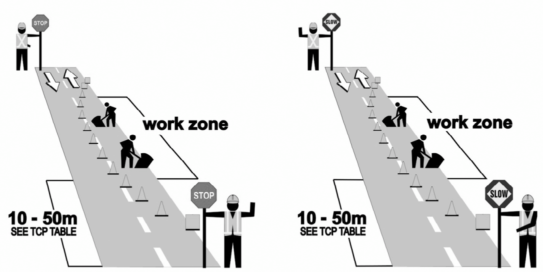


Figure 38

Supervisors must train TCPs on site and explain the nature of the project, where construction equipment will be operating, and how public traffic will flow. TCPs must wear a fluorescent or bright orange safety vest.

Training must also include the proper use of the STOP/SLOW sign, where to stand, how to signal, and communication with other TCPs. (See Traffic Control, pg. 144)

After presenting this information, the supervisors must give TCPs written instructions in a language they can understand.

Confined Spaces

A confined space is a workplace where entry and exit are limited and, because of its construction, location, contents, or the work being done there, a hazardous atmosphere may occur. (See Confined Spaces, chapter 7.)

In the sewer and watermain industry, confined spaces can be locations such as trenches, excavations, manholes, valve chambers, pump stations, and catch basins. The atmosphere in these spaces may be

- toxic
- oxygen-deficient
- oxygen-enriched
- explosive.

Sewage not only smells bad but can create dangerous atmospheres. Decaying waste releases hazardous gases such as hydrogen sulfide and methane. The bacteria in sewage are not only a source of infection but can also consume oxygen and leave the atmosphere oxygen-deficient.

Other sources of contamination can include

- fumes from welding or patching compounds
- chemicals from waste disposal sites
- engine exhaust
- propane or other explosive gases that are heavier than air and collect in the bottom of the trench
- leaks from underground storage tanks
- decomposing material in landfill sites.

Protecting the health and safety of personnel starts with some basic steps.

- A competent worker must test a confined space to determine whether it is hazard-free before a worker enters, and continue testing to ensure that it remains hazard-free.
- Where tests indicate safe air quality, workers may be allowed to enter the confined space.
- Where tests indicate a hazardous level of fumes, vapours, gases, or oxygen, entry must not be allowed until the space has been adequately ventilated and subsequent tests indicate that the air is safe to breathe.
- Where possible, mechanical venting should be continued in any confined space containing hazardous levels of fumes, vapours, gases, or oxygen, even after venting has corrected the hazard. The space must also be continuously monitored while personnel are working there.
- In situations where ventilation has removed a hazard, workers entering the space should still wear rescue harnesses attached to individual lifelines. A worker should also be posted at the entrance prepared, equipped, and trained to provide rescue in an emergency. For rescue situations, workers entering the space should wear supplied-air respirators (Figure 40).

Self-contained breathing apparatus (SCBA)

Figure 40

Hydrostatic Testing

Hydrostatic testing involves entry into a confined space such as a manhole or valve chamber. The procedures listed above should be followed.

Testing new lines can be very hazardous if components break or plugs let go. For that reason, additional precautions are required.

When testing watermains, ensure that all lines, elbows, and valves are supported and equipped with thrust blocks. Otherwise the line could come apart under test pressure.

Arrange watermain testing so that lines are pressurized when no one is in the manhole or valve chamber.

For sewer line testing, all requirements for entering confined spaces apply.

Ensure that plugs are secure. No one should be in a manhole when the upstream line is being filled. Plugs that are not properly installed can let go, causing injury and letting a manhole fill quickly, depending on the size of the line.

Flooding is another reason why no one should be in a manhole without a rescue harness and a worker outside ready and prepared for an emergency.

Emergency Procedures

General

Emergency telephone numbers – ambulance, fire, police, local utilities, senior management, Ministry of Labour – should be posted in the field office for quick reference.

If someone is seriously injured, take the following steps.

1) Protect the area from hazards.
2) Prevent further injury to the casualty.
3) Administer first aid.
4) Call an ambulance or rescue unit.
5) Have someone direct the ambulance or rescue unit to the accident scene.

All projects must have a person qualified and certified to provide first aid.

Cave-ins

It is natural to try to rescue casualties caught or buried by a cave-in. But care must be taken to prevent injury and death to rescuers, whether from a further cave-in or other hazards.

The following procedures may be suitable, depending on conditions.

1) To get down to the casualty, use a tarpaulin, fencing, plywood, or similar material that can cover the ground and will ride up over any further cave-in.
2) Sometimes a further cave-in can be prevented by placing a backhoe bucket against the suspected area or excavating it.
3) Rescue workers should enter the trench with ropes and wear rescue harnesses if possible.
4) To prevent further injury, remove the casualty by stretcher whenever possible. Tarps or ladders can be used as a makeshift stretcher.
5) Stabilize the casualty.

Breathing – Ensure that the casualty is breathing. If not, open the airway and start artificial respiration immediately. Mouth-to-mouth is the most efficient method.

Bleeding – Control external bleeding by applying direct pressure, placing the casualty in a comfortable position, and elevating the injured part if possible.

Unconsciousness – This is a priority because it may lead to breathing problems. An unconscious person may suffocate when left lying face up. If injuries permit, unconscious persons who must be left unattended should be placed in the recovery position (Figure 41).

Recovery position

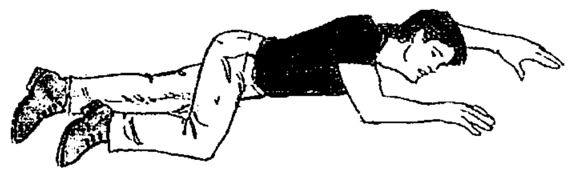


Figure 41

7 CONFINED SPACES

Introduction

Construction workers are frequently required to work in confined spaces.

Confined spaces can be described as places

a) where entry and exit are limited by location, design, or construction, and
b) where hazardous airborne contaminants **may** be present or **may** accumulate, or where there **may** be too little or too much oxygen.

Because construction projects are not limited to new buildings alone, confined spaces may be encountered in various locales. The following table describes typical confined spaces and the most common hazards found there. Also see Figure 2.

EXAMPLES OF CONFINED SPACES	COMMON HAZARDS
Chemical and Petrochemical Projects Tanks, vessels, pipes, sumps, pits, any area where a worker cannot readily escape from a toxic or explosive atmosphere; any area where toxic, explosive, or oxygen-deficient atmospheres may be encountered.	Toxic and explosive gases, vapours and fumes; physical hazards of cramped entry and exit, narrow passages, and chemical spills.
Sewage Handling Systems Settling tanks, sewers, manholes, pumping areas, digesters.	Toxic and/or explosive atmospheres such as hydrogen sulphide and methane; oxygen deficiencies.
Heavy Industrial Projects Sumps, pits, roasters, digesters, mixers, bins, flues, ducts, conveyors, elevators, bag houses.	Wide range of hazards depending on processes and materials involved.
General Construction Vaults, basements, caissons, unventilated rooms, tunnels.	Toxic materials such as gases and fumes from temporary heaters in low-lying areas; refrigerants; high-voltage transmission equipment; physical hazards involving poor lighting and cramped working conditions.
Water Treatment Plants Settling tanks, holding tanks, equipment and wells below floor level.	Chlorine and fluorine gases; also possibly methane produced by decaying debris removed from lake and river water.

Hazard Recognition

All too often the hazards of working in confined spaces are not recognized until it is too late.

For example,
- four workers died from hydrogen sulphide poisoning in a sewage holding tank
- a worker was killed by carbon monoxide gas from a gasoline powered pump used to drain a pit
- a worker was caught in a mixing tank which was inadvertently started while he was inside
- two workers using gasoline as a solvent in the basement of a house were seriously injured when the gasoline vapour ignited.

Confined spaces can harbour a number of hazards which may pose serious threats to workers. The hazards can be divided into two distinct categories – physical hazards and dangerous atmospheres.

Physical Hazards

These hazards may cause accidental injury or increase the possibility or severity of such injuries.

Examples of physical hazards:
- noise
- temperature
- radiation: e.g., welding, x-rays
- cramped working spaces
- reactive or corrosive residues
- poor access or exit
- rotating or moving equipment
- electrical hazards
- uncontrolled movement of liquids and solids
- vibration

Physical hazards often involve a greater risk and severity of potential injury inside a confined space than outside. For instance, electrical flashover can be less dangerous in a large electrical room with clear exits than in a vault or manhole where the avenue of escape is severely limited. Similarly, a fire in a confined space can be far more dangerous than a fire in an open work area.

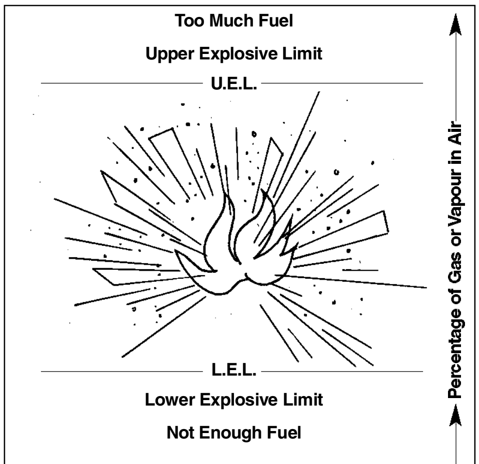
Dangerous Atmospheres

Three kinds of dangerous atmospheres may be present in confined spaces:

1) explosive
2) oxygen-enriched or oxygen-deficient
3) toxic.

The dangerous atmosphere may be due to existing conditions or may be created by the work being done inside the confined space (e.g., welding, using solvents). In some cases, removing sludge or scale can release trapped pockets of gas or vapour and create a dangerous atmosphere. Moreover, dangerous atmospheres often exist together. For instance, an explosive atmosphere may also be toxic or cause an oxygen deficiency.

Explosive Atmospheres – Explosive atmospheres are those in which a flammable gas or vapour is present in quantities between the Lower Explosive Limit (L.E.L.) and the Upper Explosive Limit (U.E.L.). These limits define the "Explosive Range" which varies from one substance to another.

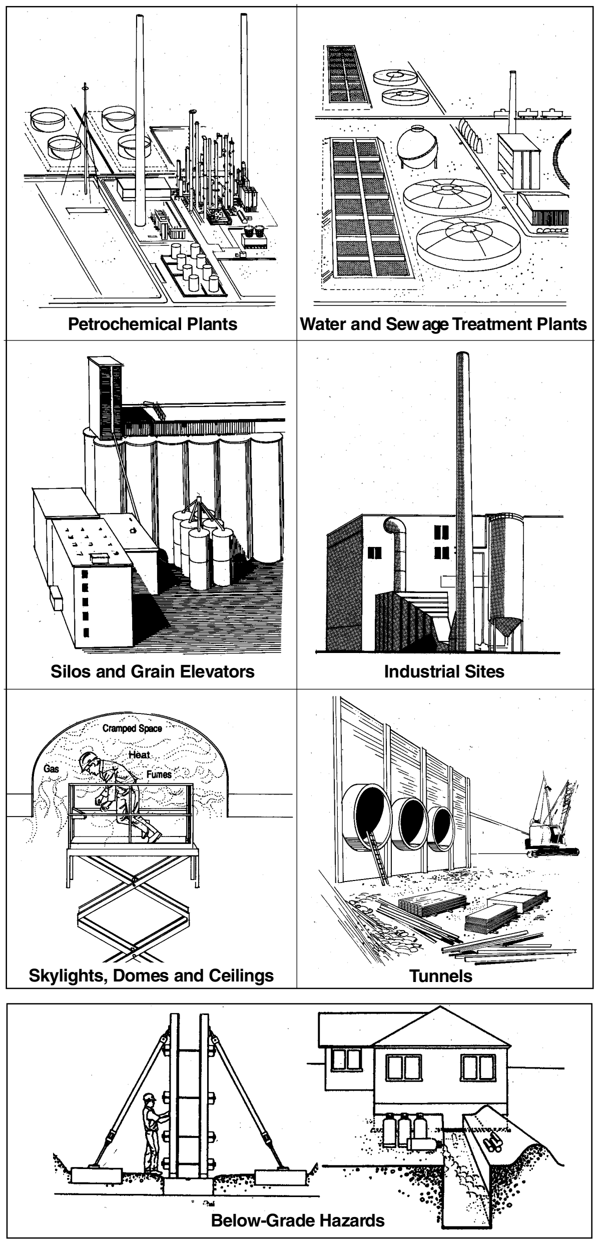


EXPLOSIVE RANGE
Figure 1

The L.E.L. is the lowest, and the U.E.L. the highest concentration of gas or vapour that will support combustion.

For example, gasoline has an L.E.L. of 1.4% and a U.E.L. of 7.6%. Below 1.4% there is not enough fuel to burn, while above 7.6% there is too much fuel and not enough oxygen to burn (Figure 1).

Typical Locations of Confined Spaces - Figure 2



The most common explosive or combustible gas likely to be encountered in sewers and other underground structures is methane or "natural gas" produced by decaying garbage and sewage.

Other explosive gases and vapours may be present in confined spaces depending on previous contents or accidental spills and leaks (e.g., leaking fuel storage tanks near service stations).

Explosive ranges for common gases and vapours are listed in Table 1. These values must be considered when selecting and operating gas-testing equipment.

TABLE 1
Explosive Range for Common Gases and Vapours

Gas/Vapour	Lower Explosive Limit %	Upper Explosive Limit %
Acetone	2.6	12.8
Ammonia	16.0	25.0
Benzene	1.3	7.1
Ethyl Alcohol	3.3	19.0
Gasoline	1.4	7.6
Hexane	1.1	7.5
Hydrogen Sulphide	4.0	44.0
Methane	5.3	14.0
Methyl Alcohol	7.3	36.0
Propane	2.4	9.5
Toluene	1.2	7.1
Xylene	1.1	7.0

In grain elevators, feed mills and some industrial settings such as bag houses, explosive quantities of **dust** may be present. The most common explosive dust is grain or flour dust and several explosions in grain elevators have occurred in recent years. This factor should be specifically addressed in any work in these settings. Refer to "Construction and Maintenance Work in Grain Storage, Handling and Processing Facilities" (IB002), available from the Construction Safety Association of Ontario.

Oxygen-enriched and Oxygen-deficient Atmospheres – Normal outside air contains about 21% oxygen. If the concentration of oxygen exceeds 23% it is considered "enriched". The primary concern with oxygen-enriched atmospheres is the increased flammability of materials. Things that would only smoulder in normal air will burn vigorously in oxygen-enriched atmospheres.

Oxygen-enriched atmospheres are fairly rare in construction and usually associated with pure oxygen escaping from leaking or ruptured oxyacetylene hoses or, on projects in existing plants, from an oxygen line in an industrial or manufacturing process.

Oxygen deficiencies on the other hand are fairly common. They may result from bacterial action which uses up oxygen or from chemical reactions such as rusting or combustion. Oxygen may also be displaced by another gas or vapour (e.g., nitrogen used to purge tanks, pipe, and vessels). Table 2 lists the effects of oxygen deficiency.

TABLE 2

Oxygen Concentration	Effect
Less than 18%	Loss of judgment and coordination
Less than 15%	Loss of consciousness
Less than 12%	Sudden collapse and loss of consciousness

Toxic Atmospheres – Toxic atmospheres form the third and most diverse group of dangerous atmospheres. A recent study listed over 54,000 known or suspected toxic materials in regular use in North America. For construction in an industrial setting, any of these substances may be encountered depending on the processes and materials involved. Those likeliest to be found in construction include hydrogen sulphide, carbon monoxide, sulphur dioxide, chlorine, and ammonia.

Hydrogen Sulphide (H_2S) is generated by the decomposition of garbage and sewage. It is also found in many oil refineries since most crude oil in Canada has some H_2S dissolved in it. H_2S is very toxic. A single breath at a concentration of about 500-700 ppm* can be instantly fatal. At very low concentrations, H_2S has the characteristic odour of rotten eggs. However, at about 100 ppm it can deaden your sense of smell and create the false impression that no further problem exists. H_2S can be found in sewers, sewage treatment plants, refineries, and pulp mills.

Carbon Monoxide (CO) is a ve ry common toxic gas. It has no odour or taste and is clear and colourless. Carbon monoxide poisoning can be ve ry subtle and may cause drowsiness and collapse followed by death. The major sources of CO in construction are gasoline, propane, and diesel engines. Also suspect CO in steel mills where blast furnaces use CO produced in coking operations.

Sulphur Dioxide (SO_2) is a very irritating and corrosive gas with a strong sulphur-like odour which may be found in pulp and paper mills and also in oil refineries.

Chlorine (Cl_2) is another irritating and highly corrosive gas with a bleach-like odour used as a disinfectant in water and sewage treatment plants and a wide variety of other industrial settings.

Ammonia (NH_3) is a fairly common chemical used as a refrigerant and in making fertilizer, synthetic fibres, plastics, and dyes.

Hundreds of other toxic materials may be encountered in factories, chemical plants, and similar industrial settings. The best way to obtain information regarding the presence or absence of toxic materials is to discuss the proposed work with the client and ask for the information.

Flammable Products

When using flammable materials in a confined space, take precautions:

- Provide adequate ventilation.
- Control sparks and other potential ignition sources.
- Extinguish all pilot lights.
- Have fire extinguishers handy.

Contact cement is one example of a product with fire or explosion potential when used in a small room with poor ventilation, such as a bathroom. Deaths have occurred from explosion and fire when workers finished work and switched off the light in a room where solvent vapours from contact cement or adhesives had accumulated.

Below-Grade Hazards

Workers erecting and bracing forms below grade must often work in areas where movement is restricted. They must be aware of hazards underfoot and overhead. Someone should be topside to pass down material and watch for hazards. Trenches, basements, and low-lying areas may also become hazardous from leaking gases heavier than air, such as propane.

Skylights, Domes, and Ceilings

Drywall workers are sometimes required to work within the confines of newly installed skylights where lighter-than-air gases and fumes may accumulate. Workers should be aware of this hazard. At the first sign of discomfort or disorientation they should leave the area until it has been ventilated.

The air quality in stairwells and close to ceiling lines will often reflect any pollution in the rest of the building or structure. Workers feeling light-headed or experiencing headaches may be inhaling these pollutants. Drowsiness or disorientation can lead to falls. Again, leave the area until it has been ventilated.

Tunnels and Utility Spaces

These confined spaces may present physical or atmospheric hazards. Many utilities are routed through tunnels or spaces below ground where hazardous atmospheres may collect from containers or operations above, or be created by leaks in utilities such as gas and oil.

Shafts

Work to be done in shafts must be carefully planned. Because the work may be of short duration and require only a temporary platform, these jobs are often not given proper attention. But shafts can present various physical and atmospheric hazards against which safeguards must be planned and carried out.

The same requirements that apply to exterior work platforms apply to platforms used inside shafts, tanks, and similar structures, including the regulations regarding suspended access equipment.

Because of the natural draw in shafts, airborne contaminants can be carried through quickly and in large volumes, with fatal results.

Other Spaces

In addition to the locales already described, beware of apparently harmless areas that can become hazardous because of the products being used there or the work being done (Figure 118). Basements, halls, and small rooms can be dangerous when lack of ventilation and hazardous materials or operations combine to create atmospheric hazards.

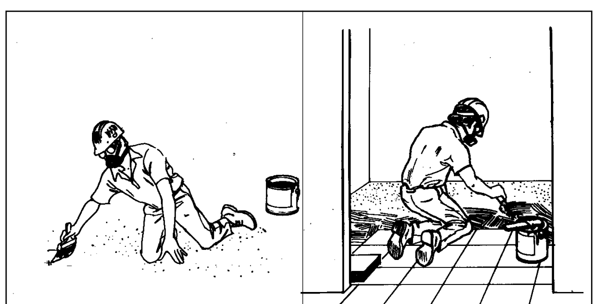


Figure 118

*ppm = parts per million – a measure of the concentration of gas or vapour (1% = 10,000 ppm)

Heating

Heating in confined areas, particularly with propane, involves special hazards and safeguards. Propane is heavier than air and can collect in low-lying areas such as trenches, basements, and shaft bottoms. Propane can also be absorbed into clothing. Workers must therefore use extreme caution in the event of leakage or flame-out.

When propane is burned to fuel heaters and other equipment, it uses up oxygen and releases carbon monoxide and nitrogen oxides. To keep these gases at acceptable levels and to ensure enough oxygen for breathing, adequate ventilation must be provided and maintained.

- Store and secure cylinders upright at all times. Do not store propane indoors or near other fuel storage areas.
- Store cylinders away from buildings, preferably in a separate compound where there is no danger of them being struck by falling material or moving equipment. A compound can be constructed from snowfence and T-bars. The barrier provides a means of tying the cylinders upright as well as controlling stock.
- Keep valves fully open to prevent freeze-up.
- Secure cylinders at least 10 feet (3 metres) from the heater (Figure 119).
- Fuel-fired heating devices must not be used in a confined or enclosed space unless there is enough air for combustion and adequate ventilation.
- Protect heaters from damage and overturning.
- Vent exhaust from heaters outside the building or structure.
- Protect fuel supply lines and steam piping for temporary heat from damage.
- Keep a 4A40BC fire extinguisher available wherever propane fuel is being used.

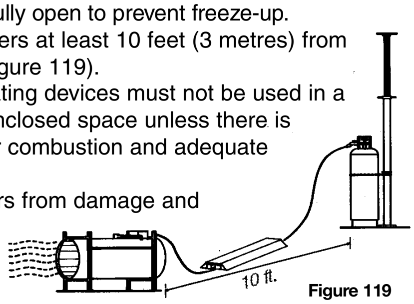


Figure 119

Hazard Evaluation

Once a hazard has been identified it should be evaluated to determine its impact on the job at hand. Physical hazards are generally easier and simpler to address than dangerous atmospheres.

Physical Hazards

Access – This can be examined before entry by checking drawings, by prior knowledge, or simply by inspection from outside the space.

Cramped Conditions – Plan the work so that required tools, equipment, and materials can be used safely and efficiently in the confined space.

Temperature – The likelihood of encountering dangerous temperatures can be determined by checking with plant personnel.

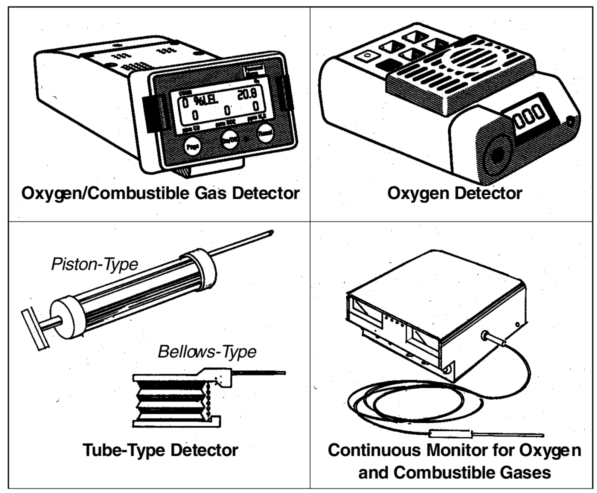
Moving Equipment – Before entry, identify any moving or rotating equipment (e.g., conveyors, mixers, augers) which could become activated by stored pressure, accidental contact, or gravity action. Check with plant personnel and review drawings, plans and specifications.

Reactive and Corrosive Residues – In some instances materials left in the space may pose a hazard. This can be determined by checking with plant personnel.

Electrical Hazards – Live electrical work poses a risk in any setting but the hazard in a manhole or vault can be much more serious. Any exposed conductors or energized apparatus should be identified before entry. The presence of water in confined spaces may pose an additional electrocution hazard around energized conductors – check the space before entry. Have a pump readily available.

Hazardous Liquids and Solids – Sludge, scale, and other material may not be completely removed from confined spaces. Use inspection ports, dipsticks, and the knowledge of plant personnel to evaluate such hazards. In some silos and storage facilities a crust of hardened material may form on top and fall onto workers below or break when someone steps on it.

Gas Detection Equipment - Figure 3



Dangerous Atmospheres

Atmospheric evaluation requires the use of some specific instruments (Figure 3). Atmospheres should be evaluated before each entry and preferably continuously while work is under way.

The main points to consider in evaluating dangerous atmospheres include

a) selecting the appropriate type of detection equipment
b) calibration, maintenance, and use of the equipment in accordance with the manufacturer's recommendations
c) checking for oxygen content, combustible or explosive gases and vapours, and toxic gases and vapours
d) proper interpretation of the results obtained by the equipment.

- ❑ The first thing to check for is oxygen content. This is important since most of the subsequent tests require adequate oxygen for a valid result. An oxygen analyzer or oxygen meter must be used. Available in a wide variety of models, these devices contain sensing cells designed to detect and measure oxygen. The meter should be calibrated according to manufacturer's recommendations before each use.

Where possible, the probe should be inserted through an inspection port or other opening before removing large doors or covers. Make sure that as much of the space as possible is tested, including the bottom, so that layers or pockets of bad air are not missed (Figure 4).

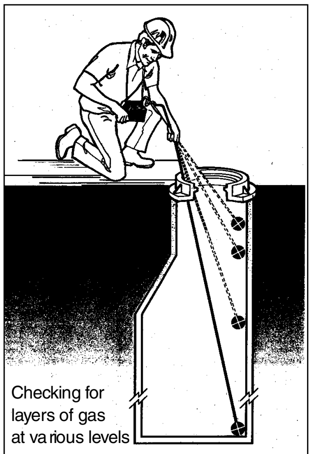


Figure 4

Some newer devices automatically detect the oxygen content as well as toxic and combustible concentrations. With these instruments the order of testing is not as critical.

CAUTION: Know the limitations of your specific equipment. Consult the manufacturer's instructions for proper use.

Results of the tests should be recorded on the work permit or checklist.

If the oxygen (0_2) content is less than 18% or more than 23% the space is too hazardous for entry without using the procedures described below under "Hazard Controls."

❑ If the 0_2 level is OK, test for explosive atmospheres.

An explosive gas/vapour meter, also referred to as a combustible gas detector, is required. As with oxygen detectors, various models are available for detecting explosive quantities of gas and vapour.

The basic method of detecting flammable or explosive gases and vapours is by measuring the change in temperature of a heated filament in the detection cell. With older models the presence of combustible gases causes an increase in the temperature of the filament which is then related to its increased resistance. New devices generally use a more sensitive cell where the presence of a flammable gas or vapour causes a decrease in resistance.

Regardless of type, the explosive gas detector should be calibrated in accordance with the manufacturer's instructions. Several different calibration gases are available. Methane is used most frequently since it is a common gas found in many places. However, it is possible to get devices calibrated for propane, hexane, heptane, or almost any other combustible gas. Once the device has been properly calibrated, insert the probe, or in some cases, the entire detector into the confined space and sample the air. The result obtained with these devices is expressed as a percentage of the lower explosive limit (L.E.L.) for the calibration gas used. As with the oxygen test, the results must be recorded.

If the meter goes off scale and then returns to zero, the space likely contains a concentration of gas or vapour which exceeds the upper explosive limit (U.E.L.) Test the atmosphere again and carefully monitor the action of the read-out. If it goes off scale again and returns to zero, the space should be considered too dangerous to enter.

Between 0% and 10% of the L.E.L., only cold work can be done. (Cold work is work which does not involve welding and cutting or the use of tools or equipment which can produce a spark or other source of ignition.)

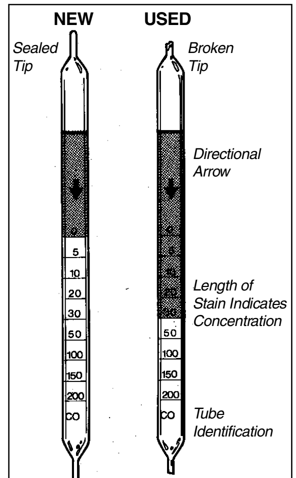
If the reading is 10%-50% of the L.E.L., only cleaning and inspection work may be done and even then only with the use of explosion-proof equipment.

Other options are discussed under "Hazard Controls" below.

WARNING Combustible gas detectors should not be used to assess toxic atmospheres since most do not respond to low concentrations. For example, H_2S is flammable from 4.3% to 44%. It is Immediately Dangerous to Life or Health (IDLH) at 100 parts per million (.01%) and would not be detected at this concentration by most combustible gas detectors. Most other toxic gases which are also flammable are dangerous in concentrations well below the L.E.L.

❑ The next thing to check for is the presence of toxic gases and vapours. Essentially three types of toxic gas detectors are available.

1) The first is the colour-changing tube type. A sample of air is drawn through a glass tube filled with crystals that change colour if certain gases or vapours are present (Figure 5). These devices are the simplest, cheapest, and most versatile way of checking for toxic gases and vapours. However, they are very specific and will react only to certain gases or vapours. Therefore you must first know what gas or vapour is likely to be present in order to select the appropriate tube. They are only considered accurate to within ±25% of the indicated value and are not suited for continuous monitoring.



Colour-changing tube
Figure 5

The concentration is read by looking at the length of stain in the tube. Always check to make sure the change is the right colour. If the gas or vapour to be detected is supposed to turn the crystals green and the stain is black, there may be some other gas or vapour present. Check the instructions regarding other colour changes and any interfering gases or vapours.

The pump should be checked for leaks before use. For details consult the manufacturer's instructions.

2) The second type of toxic gas detector uses specific electrochemical reactions to detect specific gases. The most common gases specified are H_2S, CO, and Cl_2, although dozens of others can be specified.

Electrochemical devices can be used as continuous monitors. It is important, however, to know the limitations of the specific equipment, especially at low temperatures.

3) The third type of toxic gas detector uses a very sensitive element to detect a wide variety of gases or vapours that are combustible as well as toxic. These

instruments employ a single solid-state broad-range sensor. While the devices cannot detect every toxic gas, they can provide protection from a far wider range than chemically specific devices can.

An added advantage is that this third type of detector can also be used as a continuous monitor

WARNING Many toxic gases and vapours are combustible. However, some are not combustible and therefore cannot be detected by this method.

REMEMBER
Never trust your senses to determine whether the atmosphere in a confined space is safe.
You cannot see or smell many toxic gases and vapours.
You cannot determine by your senses the level of oxygen present.

Results of any toxic gas checks should be recorded on the permit or checklist. If the concentration is below acceptable limits the confined space may be entered, providing the oxygen and explosive tests are OK. If the concentration is higher than the acceptable limit, other controls will be needed.

If measurements are within acceptable limits, but are approaching hazardous levels, the decision to proceed should be based on an assessment of the source of the problem, the likelihood of change and the prevailing conditions at the scene. In doubtful cases, it is advisable to implement the appropriate controls discussed in the following section.

Always test for the three dangerous atmospheres:

- too much or too little oxygen
- combustible or explosive gases or vapours
- toxic gases or vapours.

All three types of dangerous atmospheres must be evaluated before entry. Users of gas detectors must receive training in the operation, calibration, and maintenance of the devices. Most manufacturers can provide necessary training materials.

Hazard Controls

Any confined space hazard that can be identified can be controlled.

The key points to address in controlling confined space hazards include

- prevention of unwanted movement
- provision of safe access
- adequate lighting
- isolation of material handling facilities such as conveyors and piping
- isolation of electrical, hydraulic, or pneumatic power supplies
- ventilation or other controls for dangerous atmospheres
- blocking of equipment that can move because of gravity, such as conveyors and elevators
- availability of emergency equipment and procedures.

Physical Hazards

Physical hazards such as poor access and inadequate lighting can be corrected with minimal expenditures of time and materials.

If the work is so critical that emergency repairs have to be conducted in a poorly lit dangerous atmosphere, low-voltage explosion-proof lighting should be used.

Equipment that moves in any way or rotates must be isolated by locking out and/or tagging the controls and power supplies. With pneumatic or hydraulic equipment the power source should be isolated and supply lines depressurized. Components which may still be pressurized after the supply lines have been bled should be depressurized – for instance, hydraulic cylinders. Pipes carrying solids and liquids to or from a confined space must be disconnected and drained or have blank flanges inserted. Where the pipe cannot be blanked off or disconnected the valve may be closed, chained, locked and tagged, provided that this type of control has been explained to all workers in the area and the importance of the tagging and locking procedure has been demonstrated. **Simply closing valves is not generally acceptable**. With conveyors and other equipment, blocking may be necessary to prevent movement caused by gravity.

Reactive or corrosive residues should, where practical, be neutralized before entry. Often this is not possible since the work to be done consists of cleaning and removing such residues in the form of sludge and scale. In this case, suitable protective clothing such as chemically-resistant suits, gloves, and boots as well as respirators may be needed. Such requirements can usually be determined before entry.

Electrical equipment in the space should be shut down, locked out, and grounded where practical. In the case of live line work in the confined space, special attention to standard procedures is necessary. A minor mistake in a manhole can be disastrous. Because cramped working conditions can make accidental contact with an energized conductor more likely, non-conductive equipment may be necessary. Gloves, mats, and other insulating equipment may be required depending upon the type of work to be done. Capacitors or other components which may store a charge should be discharged and/or grounded.

Hazardous liquids and solids should be removed before any workers enter. If this is not practical, protective clothing resistant to the specific chemicals should be worn. This must be selected by a knowledgeable person since protective clothing suitable for one material can be attacked and dissolved by others. For example, polyvinyl chloride (PVC) plastic is resistant to most acids, but it can be softened or penetrated by many common solvents such as benzene, toluene, and xylene.

Dangerous Atmospheres

Dangerous atmospheres can be controlled through two methods.

1) **Ventilation**

This is the first and most effective method. The space can be made safe by blowing enough fresh air in or by removing or suction-venting the “bad air” and allowing

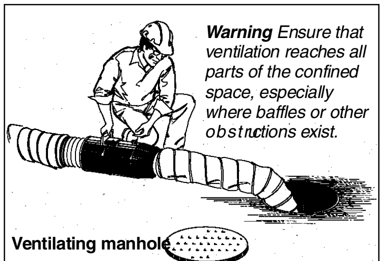


Figure 6

clean air in. Studies have shown that the best results are obtained by blowing fresh air into a space close to the bottom. **Check the efficiency of ventilation by re-testing the atmosphere with the gas detection equipment before entry.**

Where ventilation is used to improve the air in a confined space, ensure that the toxic or flammable gases or vapours removed from the space do not pose a risk to other workers — "bad air" should not be discharged into another work area. In cases where the concentration of explosive gas or vapour is higher than the U.E.L., ventilation will bring it down through the Explosive Range. This is one reason why only "explosion-proof" fans should be used. These may be specially designed fans operated by electricity or compressed air. Some pneumatic air movers may also be suitable.

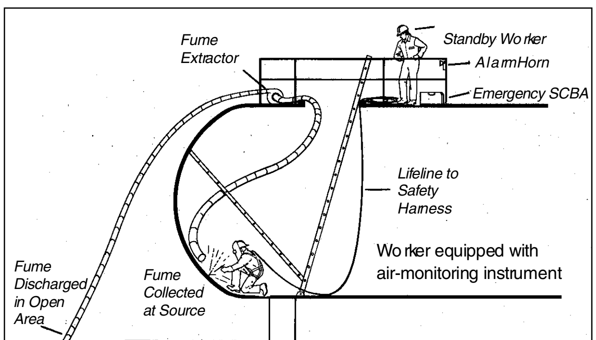
For entry into manholes, portable fans can be used. These usually provide around 750-1,000 cubic feet per minute.

A typical manhole 10 feet deep and 5 feet wide contains 196 cubic feet. Blowing in 750 cubic feet per minute should provide an air change every 15 seconds and easily dilute or displace most dangerous atmospheres.

Fans capable of moving 5,000 cubic feet per minute are available for use in larger tanks and vessels.

In situations where additional toxic or explosive gases or vapours may be generated (e.g., by disturbing sludge and scale) this type of ventilation may not be adequate.

Requirements must be evaluated by someone who understands the risks associated with the work being done. In the case of welding or other work which generates a **localized** source of toxic gas, fume, or vapour, an exhaust ventilator can be used to draw out and discharge the hazard in an open area (Figure 7).



Suction Venting of Localized Hazard

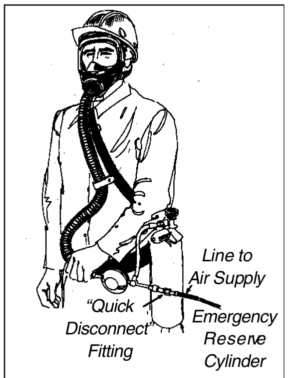
Figure 7

2) **Respiratory Protective Equipment**

The second method of controlling exposures to dangerous atmospheres is respiratory protective equipment. This should be used where ventilation is impractical or inadequate. Certain basic rules apply to the equipment.

First of all, the proper type of respirator must be used.

Oxygen-deficient atmospheres require the use of supplied-air respirators – either airline types with emergency reserves or SCBA (Self-Contained Breathing Apparatus) as in Figures 8 and 9.



Combination Airline/SCBA Unit

Figure 8

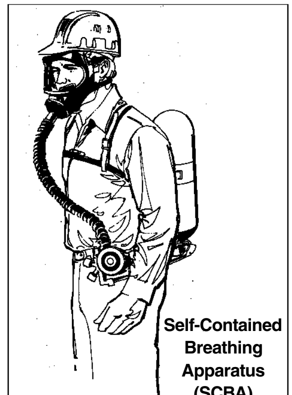


Figure 9

With toxic atmospheres, supplied-air respirators must be used if the concentration of the gas or vapour exceeds the level considered to be Immediately Dangerous to Life or Health (IDLH) or if the concentration is unknown.

Where the level of toxic gas or vapour is above the TLV-TWA®* but below the IDLH level, air-purifying respirators may be used provided the exposure conditions do not exceed the unit's limitations. This can only be determined by someone who knows the equipment and understands the hazards.

Workers required to wear respirators must be instructed in the proper fitting and maintenance of the devices used. For more information on respiratory protection, refer to the chapter on personal protective equipment.

Explosive Atmospheres

In the case of explosive atmospheres, other control factors should be assessed. If the concentration is greater than 50% of the Lower Explosive Limit the space **must not be entered** for any reason, even with respiratory protection.

If the concentration is less than 10% of the Lower Explosive Limit, "cold work" may be done but respirators may be needed. (Cold work is work which does not involve welding and cutting or the use of tools or equipment which can produce a spark or other source of ignition.)

Permits and Checklists

Permits and checklists are valuable tools for planning, evaluating and controlling confined space entries.

A checklist can itemize the different hazards and evaluation/ control steps for specific site entries. Permits involve a more formal system in which the checklist is approved by someone having authority over work in a particular area.

For instance, in many industrial settings, such as refineries, comprehensive entry permit systems are used. The operator of the area "permits" or allows work providing that certain conditions are met or certain specified practices and

*TLV-TWA® or "Threshold Limit Value-Time Weighted Average" is a registered trademark of the American Conference of Governmental Industrial Hygienists. It is used to denote the acceptable airborne concentrations below which nearly all workers may be exposed for eight hours a day and a 40-hour work week without adverse effect.

tools are used. The need for these provisions is geared to the safety of other workers as well as those directly involved in the confined space entry. For example, valves, lines, and pumps which are isolated or locked out could cause a problem for other plant personnel who are not aware of the shutdown.

Entry and work permits should be understood by everyone involved in the job. Any questions regarding the requirements and limitations of the permit should be addressed before entry. Any doubts about the permit should be discussed with the issuer of the permit.

For the majority of confined space entries in construction there is no management system which controls or "permits" work to be done, so an industrial type of permit system is not directly applicable. However, a permit in the form of an entry checklist can be easily generated and effectively used. In this case, permission to enter is decided by the supervisor, competent person, or individual workers.

Typical Entry Checklist

- ☐ date and time of entry
- ☐ location and description of space
- ☐ name of worker conducting tests
- ☐ gas check results
  - O_2
  - explosive
  - toxic (specify each gas checked for, e.g., H_2S, Cl_2, etc.)
- ☐ gas detectors used (make, model, or company designation)
- ☐ description of work to be done
- ☐ tags and lockouts required (specify locations and type)
- ☐ emergency equipment available (fire extinguisher, safety harness, rope, first aid kit).

In addition to this entry checklist, an equipment checklist should be made up to ensure that required tools and equipment are available. A checklist for emergency repair equipment may also be necessary.

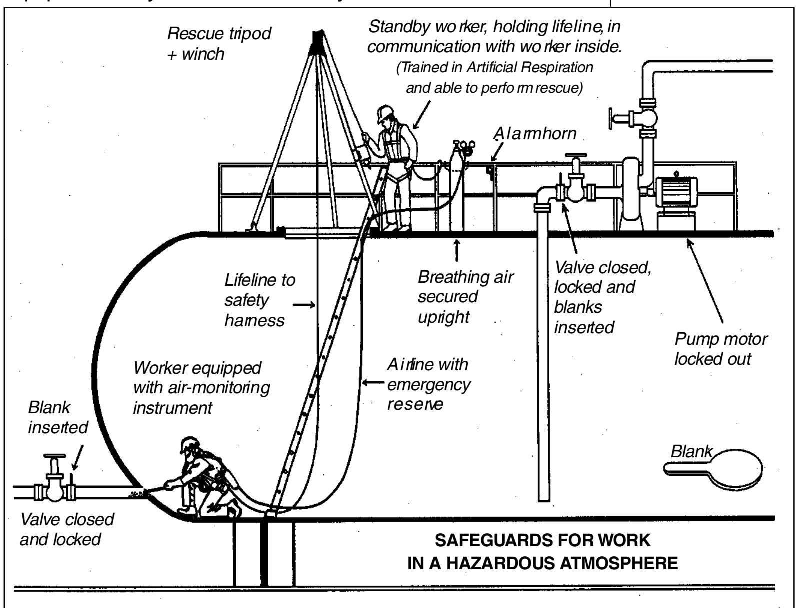


Figure 10

Basic Equipment Checklist

- ☐ safety harness and rope (one for each worker required to enter the space)
- ☐ temporary lighting
  - flashlights (preferably explosion-proof)
  - 100 volt lighting (preferably explosion-proof) or a low-voltage DC system
- ☐ gas detection equipment
  - preferred model: continuous monitor with pre-set alarm
  - 0_2 plus explosive gas/vapour
  - specific toxic gas detector (with detector tubes for suspected gases or vapours) or broad range toxic gas detector
- ☐ fire extinguisher (4A40BC rated)

Additional Equipment Checklist (as required)

Emergency repair kit (for use when venitlation may not be adequate, where repairs are urgent, and where toxic atmosphere may exist)

- ☐ explosion-proof lighting
- ☐ explosion-proof tools
- ☐ fans or blowers plus ducting
- ☐ self-contained breathing apparatus (with extra air cylinders) or airline with SCBA
- ☐ impervious clothing and gloves

An example of a checklist/permit for manhole entry is shown on the next page.

A "standard" kit will depend upon the type of work normally undertaken by the work crew as well as the urgency of completion and the degree of hazard expected.

Rescue Training

Removing an injured or unconscious person from a confined space is easier said than done.

Procedures for entry should be aimed at preventing problems rather than dealing with their results. However, even with the best planned and executed entry there is a chance of a sudden change in conditions due to some factors which have been recognized earlier but for which no "absolute" protection exists, such as the failure of a respirator, the introduction of a new hazard, or collapse from heart attack or illness. In such cases you need a rescue plan that has been practiced and works.

The first concern of rescuers should be to protect themselves. **Rescuers are no good to the victim if they also become victims**. Many cases of multiple fatalities involve would-be rescuers overcome because of inadequate preparation.

Where practical, the rescue should be done from outside the space. For instance, the rescuer stays out of the confined space and removes the

CONFINED SPACE ENTRY CHECKLIST

LOCATION AND DESCRIPTION	**DATE**
SUPERVISOR	**TIME**

WORKERS ENTERING (list names)

REASON FOR ENTERING (describe work to be done)

AIR TEST RESULTS

Time					
Oxygen					
Explosive/Combustible					
Toxic (specify)					
Tested by					

EQUIPMENT USED ______________________________

TAGS AND LOCKOUTS REQUIRED (specify type and location)

NOTES

COMPLETED BY

____

overcome worker by using the rope and harness. This is not as easy as it sounds. Pulling a 200-lb. person unconscious or limp from a manhole 12-feet deep is difficult. This problem can be aggravated when the victim is trapped or becomes entangled in some obstruction. Equipment designed for this purpose should be available at the site. Tripod-type arrangements and mountain-climbing-type gear are commercially available.

The standby or “safety person” positioned at the entrance to the space should have a horn, whistle, or radio to summon help if needed. Entering a confined space without a backup can be fatal.

Systematic Entry

Confined space entries present so many different possible hazards that the best way of ensuring safety is to address each problem systematically.

1) Determine the likelihood of a dangerous atmosphere caused by the contents of the space, the work to be done, and the activities or processes conducted nearby.
2) Review the drawings, specifications and notes to determine the physical hazards to be dealt with – for example, equipment to lock out, lighting requirements, and access.
3) Review the work to be done taking into account the tools and materials needed as well as the possibility of a dangerous atmosphere generated by the work itself.
4) Review emergency procedures and communications with the standby worker.
5) Check the safety equipment needed:
   - safety harnesses and rope
   - gas detectors
   - ventilator
   - fire extinguisher
   - first aid kit
   - gloves
   - respirators
   - other protective equipment
   - alarms, communications, etc.
6) Get “local knowledge” of any special toxic gases to be checked for (e.g., in or adjacent to refineries and industrial settings).
7) Check for dangerous atmospheres at the scene (oxygen content, explosive gases, and toxic gases) and record levels.
8) If readings are OK proceed with the work.
9) If readings indicate problems, implement controls. Call the office and get assistance, or ventilate and check the atmosphere again.
10) If gas checks are OK after ventilation, proceed with the work but continually test the atmosphere.

In some cases, the cause of the dangerous atmosphere may be a leak or failure in an industrial process. Check the source, if possible, and notify the office. The fire department should be notified if the atmosphere is explosive or toxic since other workers or the public may be at risk.

For more information on procedures and equipment regarding confined spaces, contact the Construction Safety Association of Ontario.

8 ASBESTOS

The requirements for handling, working with, removing, and disposing of asbestos and asbestos-containing products are spelled out in *Asbestos on Construction Projects and in Buildings and Repair Operations* (Ontario Regulation 838).

What is Asbestos?

Asbestos is a naturally occurring material once used widely in the construction industry. Its strength, ability to withstand high temperatures, and resistance to many chemicals made it useful in hundreds of applications. But early widespread use of asbestos has left a potentially dangerous legacy.

Before any work begins with asbestos, the Ministry of Labour must be notified.

The improper handling of asbestos-containing products may release harmful amounts of fibre. When inhaled, asbestos has been shown to cause the following diseases

– asbestosis
– lung cancer
– mesothelioma (cancer of the lining of the chest and/or abdomen).

Where Can Asbestos Be Found?

Most structures built between 1930 and 1975 will contain products having substantial amounts of asbestos.

ASBESTOS PRODUCTS IN CONSTRUCTION			
Product	**Residential**	**Commercial/ Institutional**	**Industrial**
Sprayed-On Fireproofing		XX*	
Pipe and Boiler Insulation	X	X	XX
Loose Fill Insulation			X
Asbestos Cement Products	X	X	X
Acoustical Plaster		X	
Acoustical Tiles	X	XX	
Vinyl Asbestos	X	X	
Gaskets		X	XX
Roofing Felts		X	X
Asphalt/Asbestos Limpet Spray			X
Drywall Joint-Filling Compound	X	X	
Coatings and Mastics	X	X	X

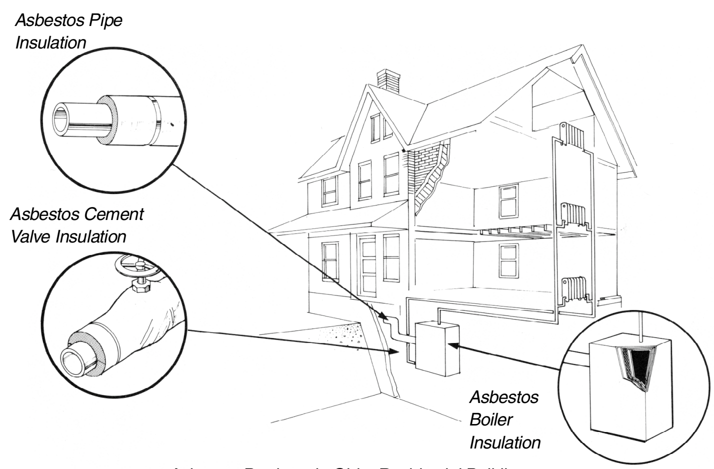
*Denotes extensive use

If you have any concerns about material that you believe may be asbestos, play it safe and have it checked **before** work is started.

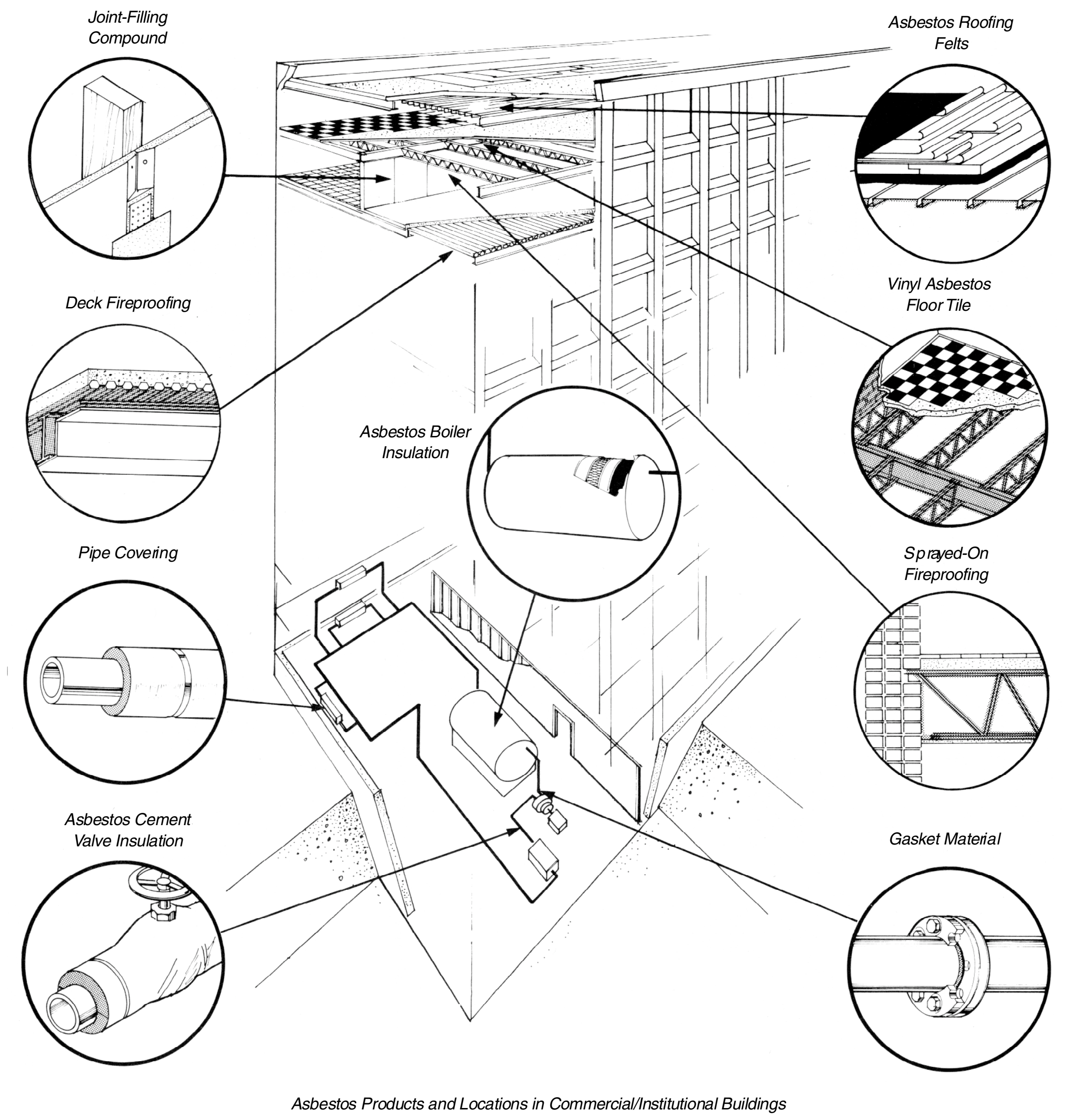
Workers in the carpentry, drywall, resilient flooring, and acoustic and interior systems trades may encounter asbestos in

– light fixtures
– light troughs
– soffits
– transite tile over stairways
– soffits of plazas
– ceiling tile
– 2' x 2' porous tile
– exterior cladding
– insulation
– pre-1975 drywall joint compound
– caulking materials
– gaskets and packings.

Remember, sanding creates fine airborne dust which may stay airborne for 24 hours or longer. Air movements created by heating and air-conditioning systems will spread these airborne particles throughout the building unless the work area is sealed off.



Asbestos Products in Older Residential Buildings



Asbestos Products and Locations in Commercial/Institutional Buildings

Friable and Non-Friable

Two classes of asbestos products were widely used in the past. The first includes materials easily crumbled or loose in composition. These are referred to as "friable."

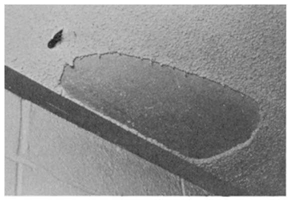
The second type includes materials much more durable because they are held together by a binder such as cement, vinyl, or asphalt. These products are termed "non-friable."

Friable material was widely used to fireproof steel structures. It can be found on beams, columns, trusses, hoists, and steel pan floors. Sprayed material was also used as a decorative finish and as acoustical insulation on ceilings.

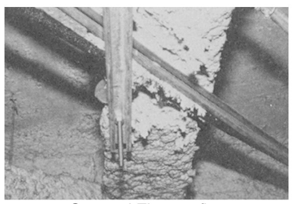
The material can be loose, fluffy, and lumpy in texture or, if more gypsum was used, it may be quite hard and durable.

Friable Materials

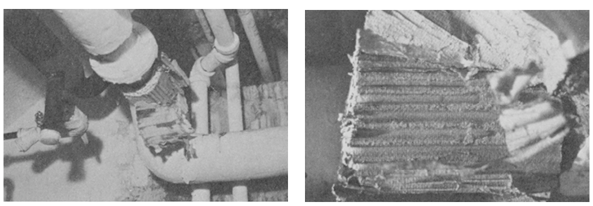
Approved Fireproofing



Acoustical Coating

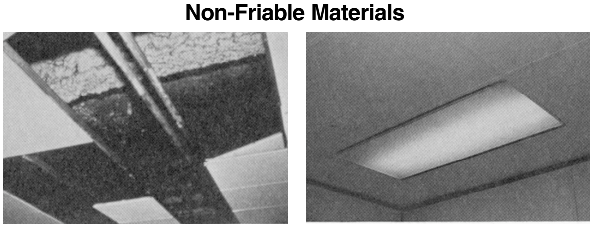


Sprayed Fireproofing

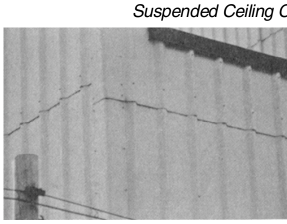


Air-Cell Pipe Insulation

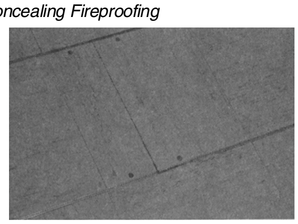
Non-Friable Materials



Suspended Ceiling Concealing Fireproofing



Asbestos-Cement Siding

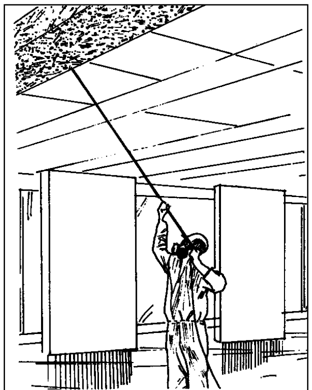


Vinyl Asbestos Floor Tile

Encapsulation and Removal

In dealing with asbestos that may be encountered in applications such as fireproofing and cement, the decision whether to encapsulate or remove the material rests with the client/owner.

Many owners of asbestos-containing buildings have decided to reduce the risk of exposure to asbestos. The procedure is normally either removal or encapsulation. Encapsulation means spraying an approved sealant onto or into the material to prevent the release of fibres into the air in the building.



Spraying Asbestos Ceiling Material with Amended Water Before Wet Removal

Removal of asbestos is a more permanent solution to the problem. Most removal projects employ the **wet removal** method. Water and a wetting agent are sprayed onto the asbestos. This effectively reduces the quantity of fibres released when the material is removed.

Dry removal is normally done only when wet removal is impractical – for instance in computer rooms or other areas where there is a chance of water damage to delicate equipment. Dry removal causes excessively high concentrations of asbestos fibres (in excess of 100 fibres per cubic centimetre) and may contaminate other previously "clean" areas.

Dry removal projects should include extensive filtered exhaust systems to create a slight negative pressure in the work area. This will reduce the chance of spreading asbestos fibres.

Another solution is to enclose the asbestos with a physical barrier such as drywall. This is normally done where the area is not going to be entered frequently or altered later.

Precautions to prevent the spread of asbestos fibres during installation of the enclosure should be the same as those taken for encapsulation and removal.

Types

Five factors determine whether, under Ontario law, an asbestos operation is Type 1, Type 2, or Type 3. The factors are

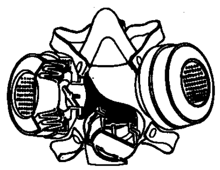
– nature of asbestos material
– nature of work activity
– applicability of alternate controls
– duration of exposure
– risk to bystanders.

These five factors can be used to categorize the proposed operation into one of three types.

Type 1 – generally presents little hazard to workers or bystanders (for example, hand removal of vinyl asbestos tile).

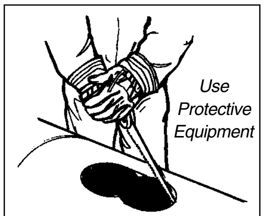
Type 2 – may create exposure exceeding acceptable limits but work is of short duration (for example, removing six square inches of asbestos fireproofing to attach a new pipe hanger).

Type 3 – major exposures, exceeding acceptable limits, involving frequent or prolonged exposure, and posing serious risks to both workers and to bystanders (for example, full-scale removal of asbestos fireproofing in an occupied building).

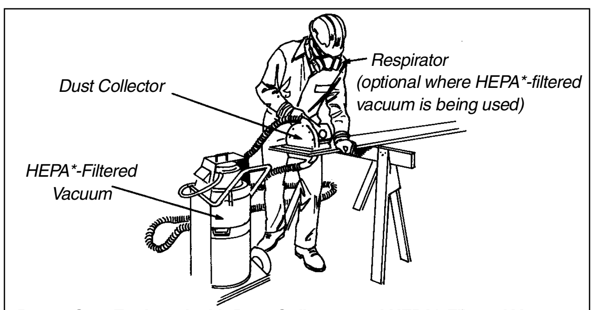
Respirators for Different Types of Asbestos Operations	
 *Half-Face Mask (N, R, or P100)*	For Type 1 or Type 2 operations
 *Powered Air-Purifying Respirator (Tight-fitting, full-face, with HEPA* filters)*	For Type 3 wet removal of chrysotile or crocidolite or power cutting asbestos cement products
 *Combination Airline/SCBA (Self-Contained Breathing Apparatus) Unit – Positive-pressure full-face mask*	For Type 3 dry removal of asbestos (any species) and wet removal of amosite Workers using these respirators must be trained in their proper care, fitting, maintenance, and operation.

Type 1 Operations

Installing or removing manufactured products containing asbestos (for example, vinyl asbestos tile, acoustic tile, gaskets, seals, packings, brake pads and linings, clutch facings, and asbestos cement products).



Type 1: Sawing Asbestos Cement Pipe

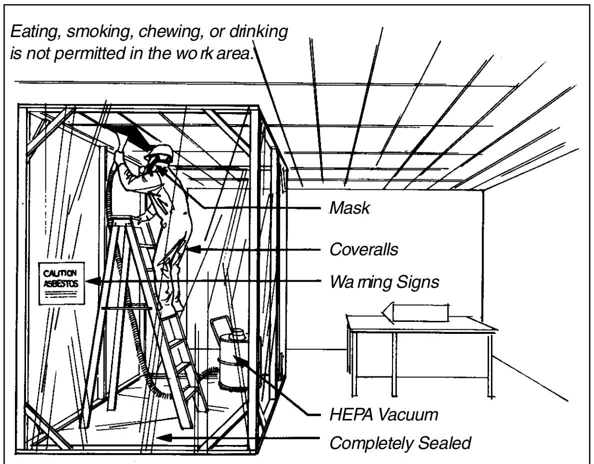


Power Saw Equipped with Dust Collector and HEPA*-Filtered Vacuum

Type 2 Operations

An example of a Type 2 operation is removing all or part of a false ceiling in buildings which contain sprayed asbestos fireproofing where there is a strong likelihood of asbestos dust resting on top of the ceiling because the fireproofing is damaged or deteriorating.

*HEPA = High Efficiency Particulate Air



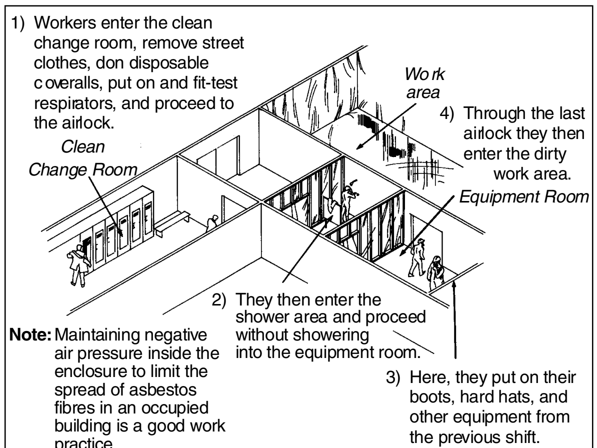
Type 2: Enclosure for Ceiling Work

For details on enclosure, refer to *Asbestos on Construction Projects and in Buildings and Repair Operations* (Ontario Regulation 838).

Type 3 Operations

The following operations involve serious potential exposure to asbestos dust and accordingly are subject to the most stringent precautions:

- removing or encapsulating asbestos insulation or fireproofing (other than minor Type 2 operations)
- cleaning or removing air-handling equipment in buildings with sprayed asbestos fireproofing
- repairs, alterations, or demolition of kilns, metallurgical furnaces, and other installations where asbestos refractory materials are present
- repair, alteration, or demolition of buildings which are or were used to manufacture asbestos products
- cutting, grinding, or abrading asbestos products with power tools not equipped with dust collectors and HEPA-filtered vacuums.



Typical Entry/Decontamination Layout

Asbestos Waste Management

The off-site handling and disposal of asbestos waste is governed by the *Environmental Protection Act.* Regulations regarding the transportation of dangerous goods under either Transport Canada (federal) or the Ontario Ministry of Transportation may also apply.

Some municipalities may not accept asbestos waste at landfill operations. Contractors are urged to check with local authorities for the nearest disposal site and with the district office of the Ministry of the Environment.

Worker Placing Asbestos Waste in Container
Note plastic bag inside drum.

Other Methods

Contractors who wish to use methods and equipment other than those described in this chapter must submit their proposals in writing to the Ministry of Labour for review and written approval **before the work begins**.

9 WATER AND ICE

Construction over and around water and ice presents special dangers. Precautions specifically developed for such construction must be taken before work begins.

This chapter outlines general safeguards that must be followed whenever personnel are required to work over water or on ice, including construction on bridges, wharves, dams, locks, and breakwaters.

Guardrails

The requirements for guardrails specified in this manual and in Section 26 of the Construction Regulation apply to work stations over water or ice.

Ramps

Ramps must be

– at least 46 centimetres (18 inches) wide
– not sloped more than 1 in 3 (20 degrees) and
– where slope exceeds 1 in 8 (6 degrees), have cleats 19 x 38 millimetres (1 inch by 2 inches) secured at regular intervals not more than 50 centimetres (20 inches) apart.

When a ramp is used for equipment such as wheelbarrows and a worker may fall from the ramp a distance of 1.2 metres (4 feet) or more — or may fall any distance into water — the ramp must be provided with guardrails (Figure 122).

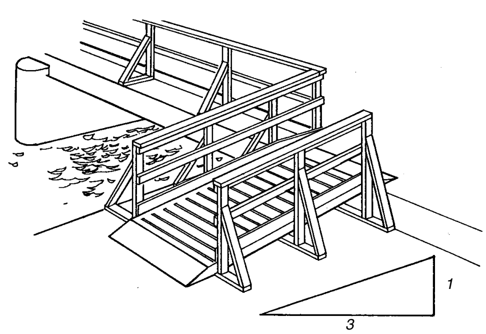


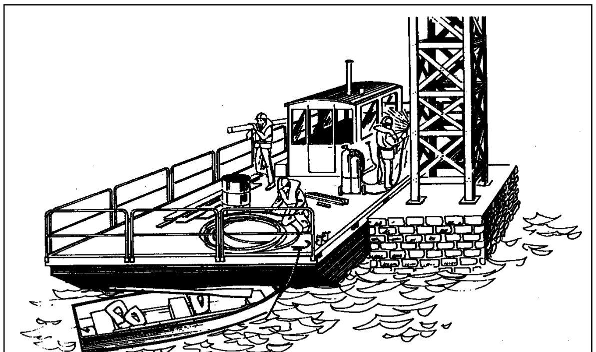
Figure 122

Floating Work Platforms

When used on a construction project, rafts, scows, and similar vessels are considered work platforms. As such, they are subject to certain requirements.

- Guardrails must be provided along open edges. The guardrails may be removed at the working side of the platform, provided workers are protected by alternate measures of fall protection.
- Workers on floating platforms must wear lifejackets. A lifejacket provides enough buoyancy to keep the wearer's head above water, face up, without effort by the wearer.
- Appropriate rescue measures must be prepared.

In addition, the positioning and securing of vessels used as work platforms should be supervised and undertaken by experienced personnel.



Fall-Arrest Systems

The requirements specified in Chapter 6 of this manual apply to work over water or ice.

Safety Nets

Safety nets may be necessary when structural design, loading access, worker mobility, or other factors make guardrails and fall-arrest systems impractical (Figure 123).

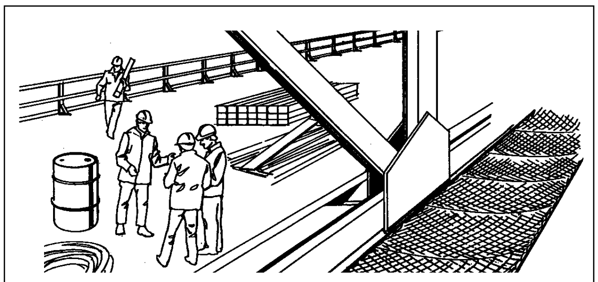


Figure 123

Safety nets must be

- designed, tested, and installed in accordance with ANSI Standard 10.11-1989, *Personnel and Debris Nets for Construction and Demolition Operations*
- installed by a competent worker
- inspected and tested by a professional engineer or competent person under the engineer's supervision before the net is put into service.

The engineer must document the inspection and testing of the safety net and sign and seal the document. A copy of the document must be kept at the project while the safety net is in service.

Lifejackets and PFDs

A PFD is a personal flotation device.

A **lifejacket** is a PFD that provides buoyancy adequate to keep the wearer's head above water, face up, without effort by the wearer.

Other PFDs do not provide this protection. Some provide flotation only.

Lifejackets must be worn by workers exposed to the danger of drowning in water deep enough for the lifejacket to be effective. Workers must use an approved lifejacket when travelling on water or while at a project over or adjacent to water.

For boating to and from the worksite, boats must be equipped with one approved lifejacket for each person on board.

“Approved” refers to approval by Transport Canada (look for the Transport Canada label).

Rescue

Where personnel are exposed to the risk of drowning, at least two workers **trained to perform** rescue operations must be available for a rescue operation. A seaworthy boat must also be available and furnished with the following rescue equipment (minimum):

– a ring buoy attached to 15 metres (50 feet) of polypropylene rope 9.5 millimetres (3/8 inch) in diameter
– a boat hook
– lifejackets for each person in the rescue crew.

Where a manually-operated boat is not suitable or where the water is likely to be rough or swift, the rescue boat must be power-driven. The engine should be started and checked daily.

Rescue equipment such as boats must be stored on or near the project, ready for use.

Where there is a current in the water, a single length of line must be extended across the water downstream from all work locations and be fitted with buoys or similar floating objects that are capable of providing support for a person in the water. The line must be securely fastened at each end to adequate anchorage.

An alarm system must be installed and maintained to alert workers to the need for an emergency rescue.

All of these requirements are illustrated in Figure 125.

Transporting Workers by Boat

When navigating any Canadian waterway, boats and other floating vessels must comply with the requirements of the *Canada Shipping Act*. Refer specifically to the *Small Vessel Regulations* (Section 16.02) and *Collision Regulations* under the Act.

Commonly, boats used for construction operations are not longer than 6 metres (19’8”). Boats in this class must be equipped with at least

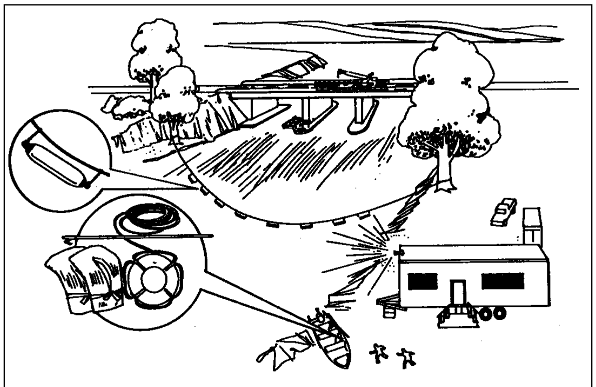


Figure 125

– one approved lifejacket for each person on board
– one paddle or an anchor with at least 15m of cable, rope, or chain
– one bailer or one manual pump
– one Class 5BC fire extinguisher if the craft has an inboard engine, fixed fuel tank, or fuel-burning appliance
– one sound signalling device.

All powerboats require some navigation lights if operated after sunset or before sunrise. For appropriate regulations, consult the *Safe Boating Guide* published by the Canadian Coast Guard, or the *Canada Shipping Act – Small Vessel Regulations* and applicable standards set out in the *Collision Regulations* under the Act.

Ice Testing

Work, travel, and parking on frozen bodies of water should be avoided whenever possible and be done only as a last resort. The ice **must** be tested before any workers or vehicles are allowed onto the surface. Loads that may safely travel on ice may not necessarily be left on ice for extended periods of time. This applies especially to parked vehicles.

Before testing, learn as much as possible about ice conditions from local residents. Testing requires at least two persons on foot proceeding with caution. Each person must wear an approved lifejacket or, preferably, an approved floatable survival suit that protects against hypothermia.

For ice testing, a survival suit or lifejacket is required because a person falling into frigid water may lose consciousness and the suit or lifejacket will keep the person's face out of the water.

Members of the ice-testing crew should stay about 10 metres (30 feet) apart. The lead member must wear a safety harness attached to a polypropylene rescue rope 9.5 millimetres (3/8 inch) thick, at least 20 metres (65 feet) long, and held by the trailing crew member (Figure 127).

Clear blue ice is the most desirable for strength. White or opaque ice forms from wet snow and has a higher air content. It is less dense and therefore weaker than clear blue ice. Grey ice indicates the presence of water from thawing and should not be trusted as a load-bearing surface.

The lead crew member should cut test holes every 8 metres (25 feet) or so. If ice is less than 10 centimetres (4 inches) thick, the lead and trailing crew members should vacate the area immediately.

Figure 127

The biggest uncertainty about the load-bearing capacity of ice is the natural variation in thickness and quality that can occur over a given area. Currents and springs can cause variations in thickness without changing the overall surface appearance of the ice. Considerable variation in ice thickness can occur where rivers have significant currents or high banks. Similar situations occur in lakes at the inlet and outlet of rivers.

Only the thickness of continuously frozen ice should be used to determine bearing capacity. The basis for capacity should be the **minimum** thickness measured.

In addition to testing for thickness, crews should check ice for cracking.

Ice thickness (Figure 128) is determined by the full thickness of clear blue ice plus half the thickness of any white, continuously frozen ice (source: *Safety Guide for Operations Over Ice*, Treasury Board of Canada).

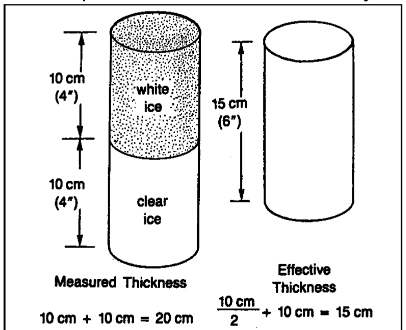


Figure 128

For repeated work or travel over ice, the surface must be tested regularly to ensure continued safety. Ice must also be tested regularly near currents or eddies and around permanent structures like abutments.

Bearing Capacity of Ice

Where heavy equipment such as cranes or structures such as concrete fo rms are to be placed on ice for extended periods, ask an experienced consultant for advice on bea ring capacity, load methods, and inspection procedures. With professional advice it is possible to increase bea ring capacity considerably. But careful control is required over surface operations, loading procedures, and ice monitoring.

In other cases, refer to Graph 1 for allowable **moving** loads on various thicknesses of clear blue ice. Remember: the graph is **not** to be used for loads parked, stored, or otherwise left stationary for long periods of time.

Certain types of cracking can affect the bearing capacity of ice. For a single dry crack wider than 2.5 centimetres (1 inch), reduce loads by one third; for intersecting cracks of this size, reduce loads by two thirds. Dry cracks can be repaired by filling in with water or slush.

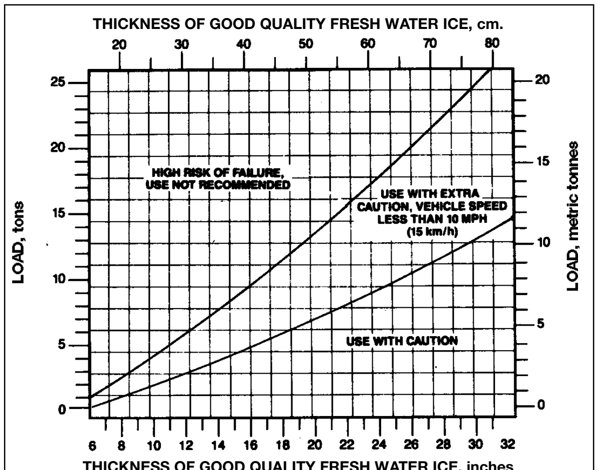
A wet crack indicates penetration through the ice to water below. Bearing capacity can be dangerously lowered. For a single wet crack, reduce loads by three quarters. Most wet cracks refreeze as strong as the original ice. A core sample should be taken to determine the depth of healing.

Other Considerations

- Ice roads must be at least 40 centimetres (16 inches) thick along their entire length and should be clearly marked.
- Ice roads should not be built up more than 10 centimetres (4 inches) in one day and must not be used or reflooded until the top layer has completely frozen.
- While an ice road is in use it must be checked daily for thickness, cracks, thawing, and other conditions.
- All rescue equipment listed earlier in this chapter must be readily available.
- A life ring attached to 20 metres (65 feet) of polypropylene rescue rope 9.5 millimetres (3/8 inch) thick must be kept within 35 metres (115 feet) of the wo rk area.
- A warm place such as a truck cab or hut must be provided and made known to personnel near the worksite.

For more information on the bearing capacity of ice, see *Safety Guide for Operations Over Ice*, by the Treasury Board of Canada.

Recommended Bearing Capacity Based on Experience — Moving Loads Only



The allowable load should be reduced by one half for operations on white opaque ice.

Graph 1 Courtesy Treasury Board of Canada

Ice thickness versus ice strength

This table provides the safe load for a given ice thickness of

- fresh ice (lake and river ice) and
- sea ice (St. Lawrence River, Gulf of St. Lawrence, etc.)

SAFE LOAD	OPERATION	FRESH ICE	SEA ICE
One person	at rest	8 cm	13 cm
0.4 ton	moving slowly	10 cm	18 cm
10 ton tracked vehicle	moving slowly	43 cm	66 cm
13 ton aircraft	parked	61 cm	102 cm

Table provided by the National Research Council of Canada.

Tools and Techniques

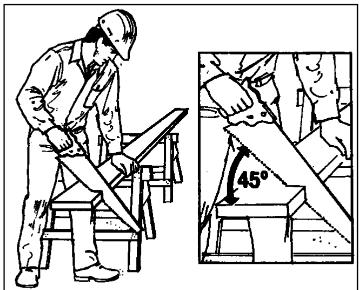
1 HAND TOOLS

Injuries with hand tools are not often serious but they do involve lost time. Common causes include using the wrong tool, using the right tool improperly, haste, and lack of training or experience.

Hand Saws

Select the right saw for the job.

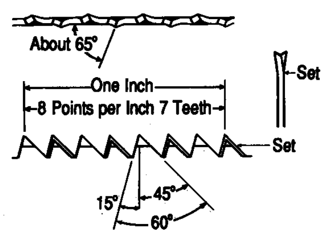
A 9 point is not meant for crosscutting hardwood. It can jump up and severely cut the worker's hand or thumb.



The approved method of crosscutting.

For this kind of work the right choice is an 11 point (+). When starting a cut, keep your thumb up high to guide the saw and avoid injury.

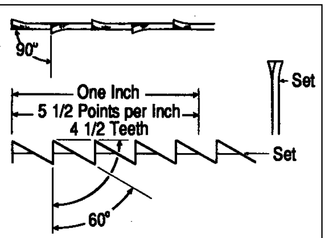
The side and tooth-edge views of a typical crosscut saw. This saw is used for cutting across the grain and has a different cutting action than that of the ripsaw. The crosscut saw cuts on both the forward and backward strokes.



For cutting softwood, select a 9 point (-). The teeth will remove sawdust easily and keep the saw from binding and bucking.

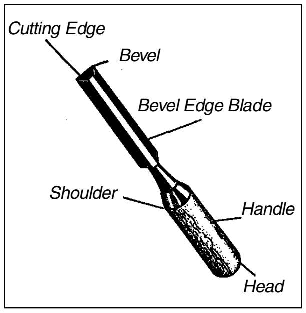
Ripping requires a ripsaw. Check the illustrations for the differences in teeth and action between rip and crosscut saws.

The side and tooth-edge views of a typical ripsaw. This saw is used for cutting with the grain. Cutting is done only on the forward stroke.



Wood Chisels

Most injuries with this tool can be prevented by keeping the hand that holds the work ***behind***, not in front of, the chisel.



A dull or incorrectly sharpened chisel is difficult to control and tedious to work with.

Chisels not in use or stored in a toolbox should have protective caps.

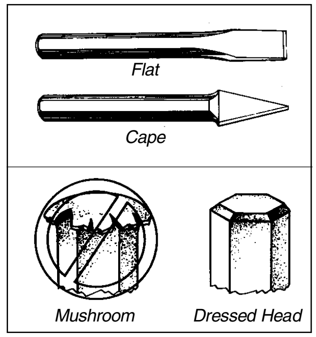
Wood chisels are tempered to be very hard. The metal is brittle and will shatter easily against hard surfaces.

Never use a chisel for prying.

Repeatedly striking the chisel with the palm of your hand may lead to repetitive strain injury.

With chisels and other struck tools, ***always wear eye protection***. Gloves are recommended to help prevent cuts and bruises.

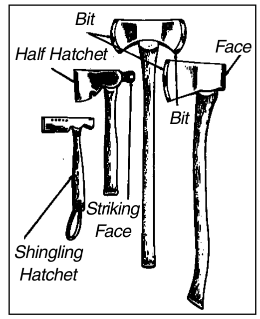
Cold Chisels



Cold chisels are used to cut or shape soft metals as well as concrete and brick.

In time the struck end will mushroom. This should be ground off. Don't use chisels with mushroomed heads. Fragments can fly off and cause injury.

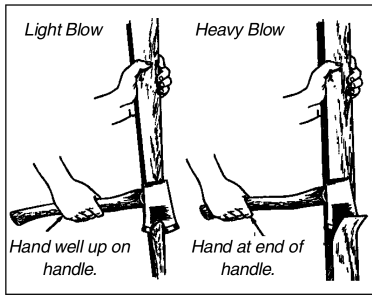
Axes and Hatchets



In construction, axes are mainly used for making stakes or wedges and splitting or shaping rough timbers.

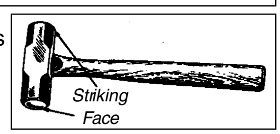
Unless it has a striking face, don't use the hatchet as a hammer. The head or the wooden handle can crack and break.

Hatchets with striking faces are meant only for driving common nails, not for striking chisels, punches, drills, or other hardened metal tools.



Grasp the handle of the hand axe approximately halfway between the ends to strike a light blow and at the end of the handle to obtain the necessary swing for a heavy blow.

Never use an axe or hatchet as a wedge or chisel and strike it with a hammer.



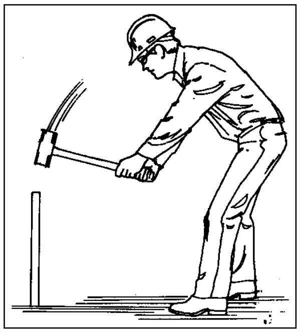
Most carpenters prefer a hatchet with a solid or tubular steel handle and a hammer head with a slot for pulling nails.

Sledgehammers

Sledgehammers are useful for drifting heavy timbers and installing and dismantling formwork. They can knock heavy panels into place and drive stakes in the ground for bracing.

Sledgehammers can also be used to drive thick tongue-and-groove planking tightly together. Use a block of scrap wood to prevent damage to the planks.

The main hazard is the weight of the head. Once the hammer is in motion it's almost impossible to stop the swing. Serious bruises and broken bones have been caused by sledgehammers off-target and out of control.



Hammer On Target

Missing the target with the head and hitting the handle instead can weaken the stem. Another swing can send the head flying.

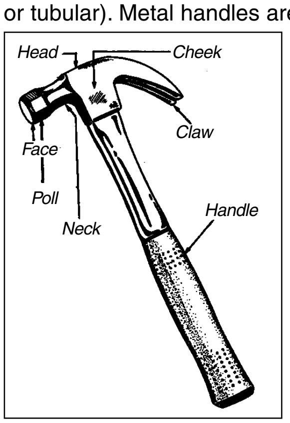
Always check handle and head. Make sure head is secure and tight. Replace damaged handles.

As with any striking or struck tool, always wear eye protection.

Swinging a sledgehammer is hard work. Avoid working to the point of fatigue. Make sure you have the strength to maintain aim and control.

Claw Hammers

These are available in many shapes, weights, and sizes for various purposes. Handles can be wood or steel (solid or tubular). Metal handles are usually covered with shock-absorbing material.



Caution: Repeated use of a hammer may lead to musculoskeletal injury, strain, or carpal tunnel syndrome. Exercising to warm up, as well as to develop and maintain overall muscle condition, may help to reduce the risk of strain or injury.

Start with a good quality hammer of medium weight (16 ounces) with a grip suited to the size of your hand.

Rest your arm occasionally to avoid tendinitis. Avoid overexertion in pulling out nails. Use a crow bar or nail puller when necessary.

When nailing, start with one “soft” hit, that is, with fingers holding the nail. Then let go and drive the nail in the rest of the way.

Strike with the hammer face at right angles to the nailhead. Glancing blows can lead to flying nails. Clean the face on sandpaper to remove glue and gum.

Don't use nail hammers on concrete, steel chisels, hardened steel-cut nails, or masonry nails.

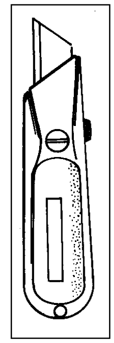
Discard any hammer with a dented, chipped, or mushroomed striking face or with claws broken, deformed, or nicked inside the nail slot.

Utility Knives

Utility knives cause more cuts than any other sharp-edged cutting tool in construction.

Use knives with retractable blades only.

Always cut away from your body, especially away from your free hand. When you're done with the knife, retract the blade at once. A blade left exposed is dangerous, particularly in a toolbox.

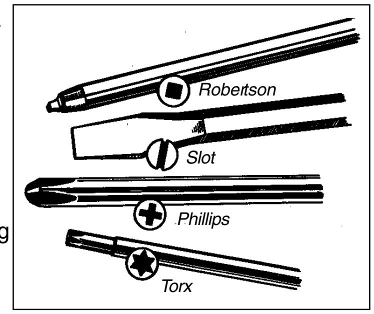


Screwdrivers

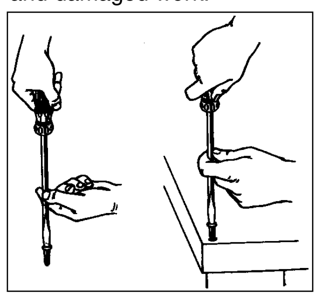
More than any other tool, the screwdriver is used for jobs it was never meant to do.

Screwdrivers are not intended for prying, scraping, chiselling, scoring, or punching holes.

The most common abuse of the screwdriver is using one that doesn't fit or match the fastener. That means using a screwdriver too big or too small for the screw or not matched to the screw head.



The results are cuts and punctures from slipping screwdrivers, eye injuries from flying fragments of pried or struck screwdrivers, and damaged work.

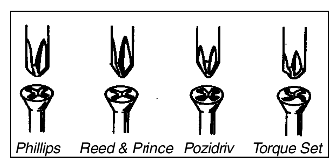


Always make a pilot hole before driving a screw.

Start with one or two “soft” turns, that is, with the fingers of your free hand on the screw. Engage one or two threads, make sure the screw is going in straight, then take your fingers away.

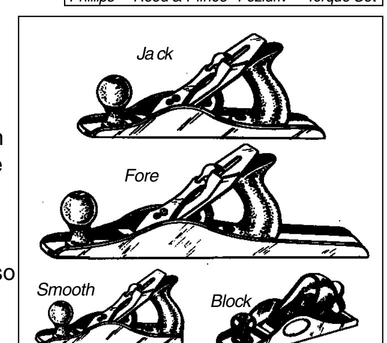
You can put your fingers on the shank to help guide and hold the screwdriver. But the main action is on the handle, which should be large enough to allow enough grip and torque to drive the screw. Power drivers present obvious advantages when screws must be frequently or repeatedly driven.

Note: All cross-point screws are not designed to be driven by a Phillips screwdriver. Phillips screws and drivers are only one type among several crosspoint systems. They are ***not*** interchangeable.



Hand Planes

Hazards include the risk of crush and scrape injuries when the hand holding the plane strikes the work or objects nearby. Cuts and sliver injuries are also common.



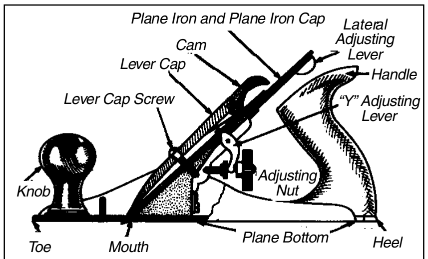
Various types of planes used by woodworkers.

The hand plane requires some strength and elbow grease to use properly. The hazards of overexertion and tendinitis can be aggravated by using a dull iron or too short a plane.

Use the plane suited to the job and keep the iron sharp.

For long surfaces like door edges, use a fore plane 18" long and 2 3/8" wide or a jointer plane 24" long and 2 5/8" wide.

For shorter surfaces, use a jack plane 15" long and 2 3/8" wide or a smoothing plane 10" long and 2 3/8" wide.



Typical smoothing plane.

Remember that sharp tools require less effort and reduce the risk of fatigue, overexertion, and back strain.

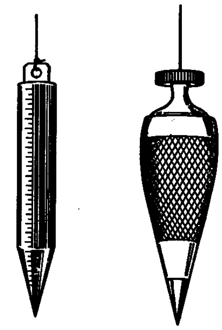
Work can also be easier with a door jack (page 182) and supports on your work bench.

Plumb Bobs

The weight of a mercury-filled plumb bob will surprise you. Designed for use in windy conditions, the bob has considerable weight in proportion to its surface area.

The weight and point of the bob can make it dangerous. Ensure that all is clear below when you lower the bob.

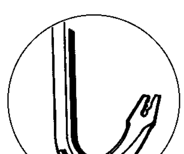
Don't let it fall out of your pocket, apron, or tool bag. The same goes for the standard solid bob.


Solid Plumb Bob

Crow Bars

Any steel bar 25-150 cm long and sharpened at one end is often called a crow bar.

The tools include pry bars, pinch bars, and wrecking bars. Shorter ones usually have a curved claw for pulling nails and a sharp, angled end for prying.



Nail Pulling

Pulling out nails can be easier with a crow bar than a claw hammer.

In some cases, a nail-puller does the job best. Keep the hand holding the claw well away from the striking handle.


Nail-Puller

Lifting

Loads levered, lifted, or shifted by bars can land on fingers and toes.

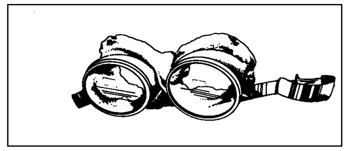
- Make sure to clear the area and maintain control of the load.
- Have enough rollers and blocking ready.
- Never – not even for a split second – put fingers or toes under the load.

General

Try to avoid prying, pulling, wedging, or lifting at sharp angles or overhead.

Wherever possible, keep the bar at right angles to the work.

Wear eye protection and, where necessary, face protection.



2 POWER TOOLS — DRILLS, PLANES, ROUTERS

Safety Basics

- Make sure that electric tools are properly grounded or double-insulated.
- Never remove or tamper with safety devices.
- Study the manufacturer's instructions before operating any new or unfamiliar electric tool.
- Regulations require that ground fault circuit interrupters (GFCIs) be used with any portable electric tool operated outdoors or in wet locations.
- Before making adjustments or changing attachments, always disconnect the tool from the power source.
- When operating electric tools, always wear eye protection.
- When operating tools in confined spaces or for prolonged periods, wear hearing protection.
- Make sure that the tool is held firmly and the material properly secured before turning on the tool.

Drills

Types

With suitable attachments, the drill can be used for disk sanding, sawing holes, driving screws, and grinding. However, when such applications are repeatedly or continuously required, tools specifically designed for the work should be used.

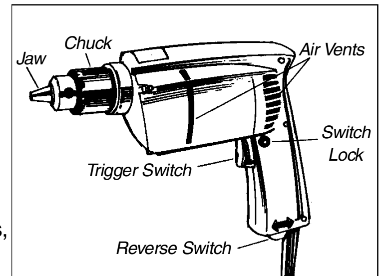


Figure 129 — Light Duty Drill

Trim carpenters will generally select a 1/4 or 3/8 inch trigger-controlled variable speed drill (Figure 129). Simply by increasing pressure on the trigger, the operator can change drill speed from 0 to 2,000 rpm.

Carpenters working in heavy structural construction such as bridges, trusses, and waterfront piers will usually select the slower but more powerful one- or two-speed reversible 1/2 or 3/4 inch drill (Figure 130a).

Size of the drill is determined by the maximum opening of the chuck. For instance, a 3/8 inch drill will take only bits or attachments with a shank up to 3/8 inch wide.

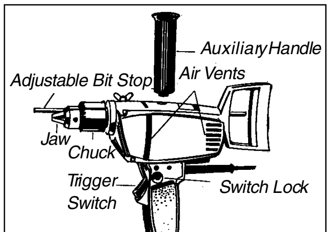


Figure 130a
Heavy-Duty Drill

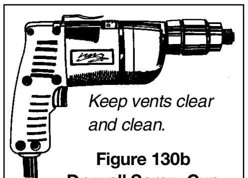


Figure 130b
Drywall Screw Gun

For dry wall screws, a drywall screw gun (Figure 130b) should be used. The driving bit should be replaced when worn. Select a gun that can hang from your tool belt so it does not have to be continuously hand-held.

Attachments

Attachments such as speed-reducing screwdrivers, disk sanders, and buffers (Figure 131) can help prevent fatigue and undue muscle strain. A right-angle drive attachment (Figure 132) is very useful in tight corners and other hard-to-reach places.

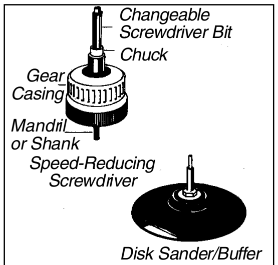


Figure 131 — Drill Attachments

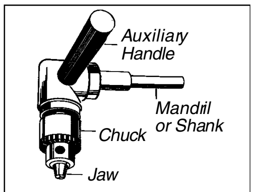


Figure 132
Right-Angle Drive Attachment

Cutting and drilling attachments must be kept sharp to avoid overloading the motor. Operators should not crowd or push the tool beyond capacity. Such handling can burn out the motor, ruin the material, and injure the operator in the event of a kickback.

Some attachments, such as hole saws, spade bits, and screwdrivers (Figure 133), require considerable control by the operator. If the operator does not feed the attachment slowly and carefully into the material, the drill can suddenly stop and severely twist or break the operator's arm. Stock should be clamped or otherwise secured to prevent it from moving. This will also enable the operator to control the tool with both hands and absorb sudden twists or stops caused by obstructions such as knots or hidden nails.

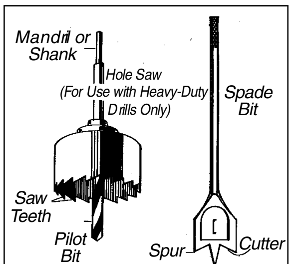


Figure 133 — Drill Attachments

Operators must restrain the drill just before the bit or cutting attachment emerges through the material, especially when oversized spade bits are used. Sides of the bit often become hooked on the ragged edge of the nearly completed hole and make the drill come to a sudden stop that can wrench the operator's arm.

At the first sign of the bit breaking through the material, the operator should withdraw the drill and complete the work from the other side. This will produce a cleaner job and prevent the material from cracking or splintering.

The same result can be obtained by clamping a back-up piece to the material and drilling into that.

Select the bit or attachment suitable to the size of the drill and the work to be done. To operate safely and efficiently, the shanks of bits and attachments must turn true.

Make sure that the bit or attachment is properly seated and tightened in the chuck.

Some operations require the use of an impact or hammer drill. For instance, drilling large holes in concrete or rock with a carboloy bit should be done with an impact drill (Figure 134).

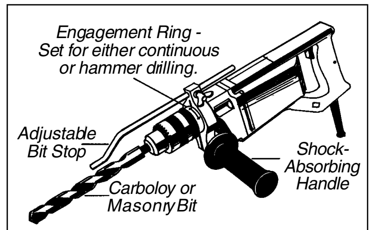


Figure 134 — Impact or Hammer Drill

Follow manufacturer's instructions when selecting and using a bit or attachment, especially with drills or work unfamiliar to you.

Working with Small Pieces

Drilling into small pieces of material may look harmless, but if the pieces are not clamped down and supported, they can spin with the bit before the hole is completed.

If a small piece starts to twist or spin with the drill, the operator can be injured. Small work pieces should be properly secured and supported. Never try to drill with one hand and hold a small piece of material with the other.

Drilling from Ladders

Standing on a ladder to drill holes in walls and ceilings (Figure 135) can be hazardous. The top and bottom of the ladder must be secured to prevent the ladder from slipping or sliding when the operator puts pressure on the drill.

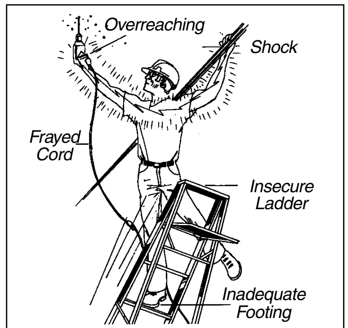


Figure 135 — Drilling and Ladder Hazards

When drilling from a ladder, never reach out to either side. Overreaching can cause the ladder to slide or tip.

Never stand on the top step or paint shelf of a stepladder. Stand at least two steps down from the top. When working from an extension ladder, stand no higher than the fourth rung from the top.

When drilling from a ladder, never support yourself by holding onto a pipe or any other grounded object. Electric current can travel from the hand holding the drill through your heart to the hand holding the pipe.

A minor shock can make you lose your balance. A major shock can badly burn or even kill you.

Operation

Always plug in the drill with the switch **OFF**.

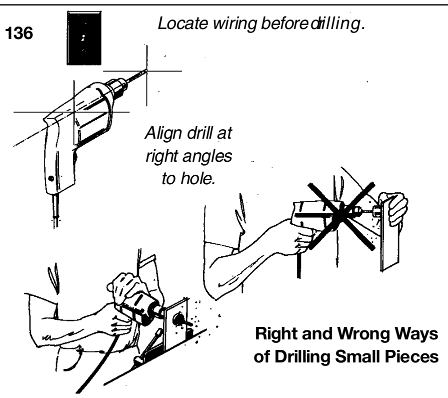
Before starting to drill, turn on the tool for a moment to make sure that the shank of the bit or attachment is centred and running true.

Punch a layout hole or drill a pilot hole in the material so that the bit won't slip or slide when your start drilling. A pilot hole is particularly important for drilling into hard material such as concrete or metal.

With the drill **OFF**, put the point of the bit in the pilot hole or punched layout hole.

Hold the drill firmly in one hand or, if necessary, in both hands at the correct drilling angle (Figure 136).

Figure 136



Right and Wrong Ways of Drilling Small Pieces

Turn on the switch and feed the drill into the material with the pressure and control required by the size of the drill and the type of material.

Don't try to enlarge a hole by reaming it out with the sides of the bit. Switch to a larger bit.

While drilling deep holes, especially with a twist bit, withdraw the drill several times with the motor running to clear the cuttings.

Never support material on your knee while drilling. Material should be firmly supported on a bench or other work surface for drilling.

Unplug the drill and remove the bit as soon as you have finished that phase of your work.

When drilling into floors, ceilings, and walls, beware of plumbing and especially of wiring.

Large rotary and hammer drills can generate extreme torque and must be handled with caution.

Remember that the longer you work, the heavier the drill feels, particularly when working overhead. Take a breather now and then to relax your arms and shoulders.

Drilling Timbers

When drilling timbers with a self-feeding auger bit (Figure 137), do not underestimate the physical pressure required to maintain control of the tool. Such work calls for a heavy-duty, low-rpm drill, 1/2 or 3/4 inch in size.

Thread angle determines how fast the bit will feed through the material.

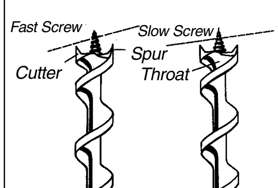


Figure 137
Self-Feeding Auger Bits

Never attempt to drill heavy timbers by yourself, especially when working on a scaffold or other work platform. If the self-feeding auger bit digs into a hidden knot or other obstruction, the sudden torque can twist or wrench your arm and throw you off balance.

Other Materials

The main hazard in drilling materials other than wood is leaning too heavily on the tool. This can not only overload and burn out the motor but also cause injury if you are thrown off balance by the drill suddenly twisting or stopping.

Always use a drill powerful enough for the job and a bit or attachment suited to the size of the drill and the nature of the work. As at other times, punching a layout hole or drilling a pilot hole can make the job safer and more efficient.

A drill press stand (Figure 138) is ideal for drilling holes in metal accurately and safely. Small pieces can be clamped in a vise and bolted to he table. This prevents the workpiece from spinning when the drill penetrates the metal.

A drill press can also be used for cutting large holes in wood with a hole saw or speed bit. The stability of the press and the operator's control over cutting speed eliminate sudden torque.

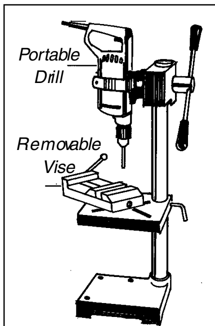


Figure 138 — Drill Press

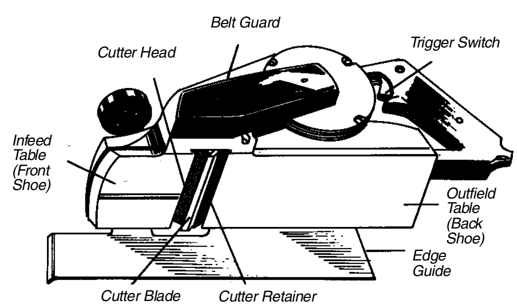
Planes

Available in various types and sizes, electric planes are generally operated in similar ways. Adjustments between models may differ, however, depending on specific features.

Planes may be equipped with

- outfeed tables (back shoes) that are either fixed or movable
- infeed tables (front shoes) that move straight up and down or move up and down on an angle to keep the gap between cutter head and table as small as possible
- cutter heads with two or more straight blades (also called knives or cutter blades)
- cutter heads with two curved blades.

Never operate an electric plane while wearing a scarf, open jacket, or other loose clothing. Always wear eye protection and practice good housekeeping.



Standard Power Plane

Standard Plane

- Hold with both hands to avoid contact with cutter blades.
- Always keep both hands on the plane until motor stops.

- Use the edge guide to direct the plane along the desired cut. Never try to guide the plane with your fingers. If the plane runs into an obstruction or starts to vibrate, your fingers can slide into the unprotected cutter head.

Block Plane (Electric)

Designed for use on small surfaces, the block plane is necessarily operated with only one hand. Though convenient and useful, it is more dangerous than the larger, standard plane.

Operators tend to support the work with one hand while operating the block plane with the other. Any unexpected twist or movement can force the plane or the material to kick back and injure the operator. Keep your free hand well out of the way, in case the plane slips accidentally.

Maintaining Blades

- Avoid striking staples, nails, sand, or other foreign objects. The first step in operation is to make sure the work is free of obstructions.
- Keep blades in good condition and sharp. A sharp blade is safer to use than a dull blade that has to be held down and forced. A dull blade tends to float over the work and can bounce off, injuring the operator.
- Restore blades to original sharpness on a fine grit oilstone. Unless nicked or cracked, blades can be resharpened several times.

Changing Blades

Raising or replacing cutter blades takes time and patience. Blades must be the same weight and seated at the same height to prevent the cutter head from vibrating. Any deviation can cause the head to run off balance. Blades can fly out, inuring the operator or fellow workers.

Replacing cutter blades involves two steps: removing and installing.

Removing Blades

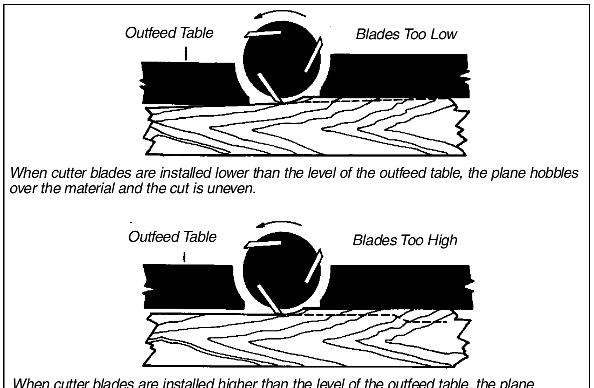
1) Disconnect the plane from the power source.
2) Turn the plane upside down and secure it in a fixed position.
3) Hold the cylinder head stationary by tapping a softwood wedge between the cutter head and the bearing (some tools are equipped with a locking device for this).
4) Loosen all the screws and lift out one blade and throat piece.
5) Turn the cutter head and repeat this procedure with other blades.
6) If necessary, clean parts thoroughly with recommended solvent.

Installing Blades

1) Replace one throat piece and blade.
2) Tighten the two end screws lightly.
3) Take a hardwood straight edge and use the outfeed table (back shoe) as a gauge. Raise or lower the blade until both ends are level with the outfeed table at the blade's highest point of revolution.
4) Tighten up the remaining screws.
5) Set the rest of the blades in the same way.
6) Turn the cylinder head and make sure that all blades are the same height.
7) Tighten up all the screws.
8) Double-check the height of all blades. Tightening can sometimes shift the set.
9) Double-check all the screws.
10) Turn the tool right side up and plug it in.
11) Hold the tool in both hands with the cutter blades facing away from you and switch it on.

Operation

- Always disconnect the plane from the power source before adjusting or changing blades or the cutter head.
- Make sure that blades at their highest point of revolution are exactly flush with the outfeed table for safe, efficient operation (Figure 139).



When cutter blades are installed lower than the level of the outfeed table, the plane hobbles over the material and the cut is uneven.

When cutter blades are installed higher than the level of the outfeed table, the plane gouges the material.

Figure 139

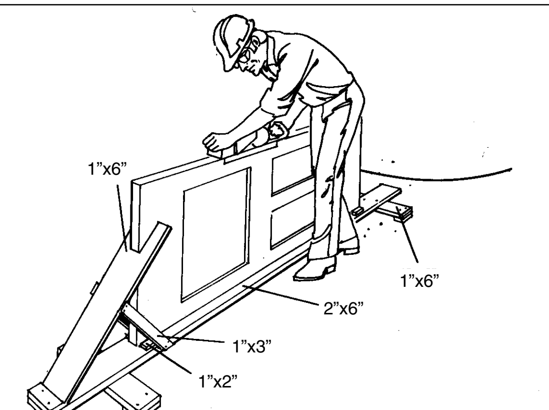


Figure 140 — Door Jack

- Support work securely for safety and accuracy.
- When planing doors and large pieces of plywood, use a jack (Figure 140) to secure material and keep edges clear of dirt and grit.
- When using an electric block plane, clamp or fasten the workpiece whenever possible. Keep your free hand well away from plane and material.
- When using the standard power plane, adjust the edge guide to provide desired guidance.
- Adjust depth of cut to suit the type and width of wood to be planed.
- To start a cut, rest the infeed table (front shoe) firmly on the material with cutter head slightly behind the edge of the material. After finishing a cut, hold both hands on the plane until motor stops.

Routers

With special guides and bits, the portable electric router can be used to cut dadoes, grooves, mortises, dovetail joints, moldings, and internal or external curves. Carpenters find routers especially useful for mortising stair stringers and recessing hinges and lockplates on doors.

The router motor operates at very high speed (up to 25,000 rpm) and turns clockwise. Components are shown in Figure 141.

> ***WARNING*** The speed and power of the router require that it be operated with both hands.

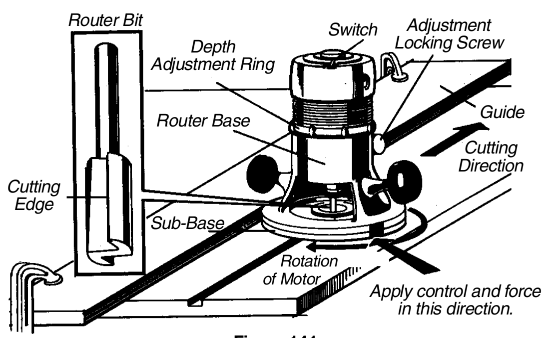


Figure 141
Router Parts and Operation

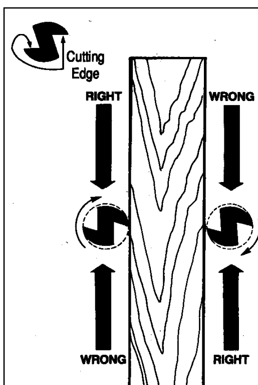
When starting a router with a trigger switch in the handle, keep both hands on the tool to absorb the counterclockwise starting torque.

When starting a router with a toggle switch on top of the motor, hold the router firmly with one hand and switch on power with the other, then put both hands on the tool for control and accuracy.

Always wear eye protection. You may also need hearing protection.

Operation

- Always support and secure the work in a fixed position by mechanical means such as a vise or clamps. Never try to hold the work down with your hand or knee. Never rely on a second person to hold the material. Human grip is no match for the torque and kickback that a router can generate.
- Make sure that the bit is securely mounted in the chuck and the base is tight.
- Set the base on the work, template, or guide and make sure that the bit can rotate freely before switching on the motor.



For work along edges such as bevelling, the cutting edge of the bit must contact the material to the left of the cutting direction.

Figure 142

- For work along edges such as bevels and moldings, make sure that the cutting edge of the router bit contacts the material to the ***left*** of the cutting direction (Figure 142). Otherwise the router will kick back or fly away from you.

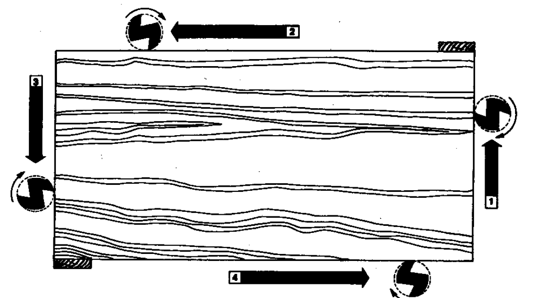


Figure 143

- When routing outside edges, guide the router around the work counterclockwise (Figure 143). Splinters left at corners by routing ***across*** the grain will be removed by the next pass ***with*** the grain.
- Feed the router bit into the material at a firm but controllable speed. There is no rule on how fast to cut. When working with softwood, the router can sometimes be moved as fast as it can go. Cutting may be very slow, however, with hardwood, knotty or twisted wood, and larger bits.
- Listen to the motor. When the router is fed into the material too slowly, the motor makes a high-pitched whine. Push too hard and the motor makes a low growling noise. Forcing the tool can cause burnout or kickback. Cutting through knots may cause slowdown or kickback.
- When the type of wood or size of bit requires going slow, make two or more passes to prevent the router from burning out or kicking back.
- If you're not sure about depth of cut or how many passes to make, test the router on a piece of scrap similar to the work.
- When the cut is complete, switch off power and keep both hands on the router until the motor stops. In lifting the tool from the work, avoid contact with the bit.

3 POWER TOOLS — SAWS

The saws covered in this chapter are

– circular	– quick-cut
– sabre	– table
– chain	– radial arm
– chop	

Basic Saw Safety

- Wear protective clothing and equipment (see chapter on Personal Protective Equipment). Eye protection is essential.
- Where saws are used in confined spaces or for prolonged periods, wear hearing protection.
- Where ventilation is inadequate, wear a dust mask for protection against dust. Over time, exposure to dust from particle board and other materials may cause respiratory problems.

- With electric saws operated outdoors or in wet locations, you must use a ground fault circuit interrupter.
- Never wear loose clothing, neck chains, scarves, or anything else that can get caught in the saw.
- Leave safety devices in place and intact on the saw. Never remove, modify, or defeat guards. Keep your free hand away from blade (Figure 144).

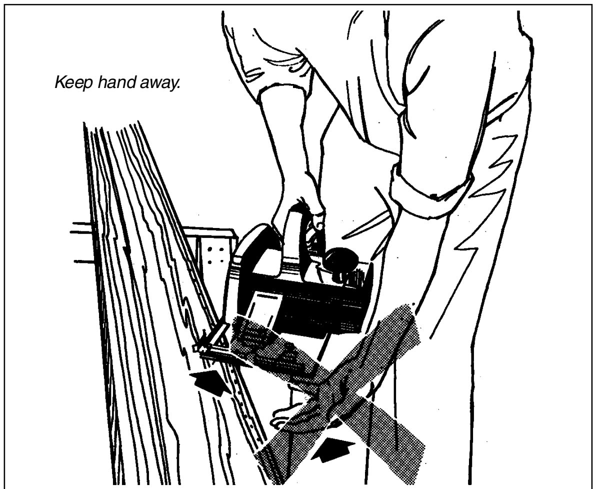
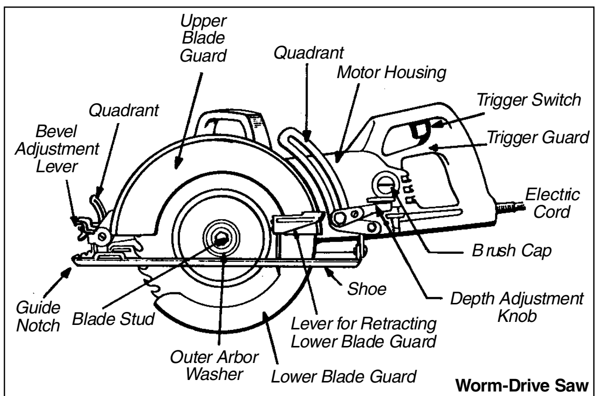
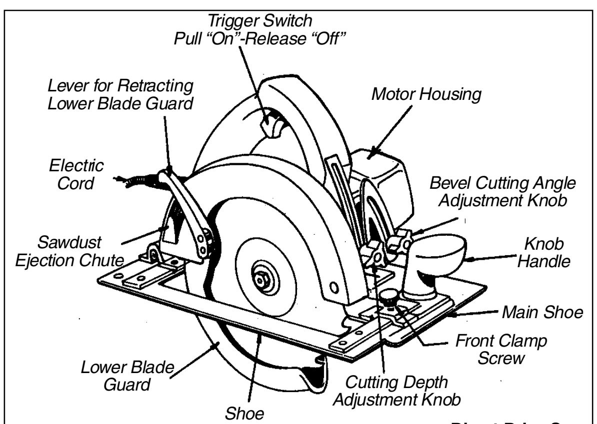


Figure 144

- Always change and adjust blades with the power OFF. Disconnect electric saws from the power source before making changes or adjustments.



Worm-Drive Saw



Direct-Drive Saw

Circular Handsaws

The two models most often used on construction sites are illustrated. The main difference between the two lies in the drive action. The worm-drive saw has gears arranged so that the blade runs parallel to the motor shaft. The direct-drive saw has the blade at a right angle to the motor shaft.

The worm-drive saw periodically requires special gear oil to keep the inner gears lubricated. This requirement is usually eliminated in the direct-drive saw, which has sealed bearings and gears.

Both saws must be inspected regularly for defects, and operated and maintained in accordance with manufacturers’ recommendations.

Check for

– damaged cord	– loose blade
– faulty guards	– defective trigger
– chipped or missing teeth	– cracked or damaged casing

Safety Features

Sawdust Ejection Chute

This feature prevents sawdust from collecting in front of the saw and obscuring the cutting line. The operator can continue cutting without having to stop the saw and clear away sawdust.

Clutch

Some worm-drive saws are equipped with a clutch to prevent kickback. Kickback occurs when a saw meets resistance and violently backs out of the work. The clutch action allows the blade shaft to continue turning when the blade meets resistance. The blade stud and friction washer can be adjusted to provide kickback protection for cutting different materials. Check friction washers for wear.

Brake

An electric brake on some circular saws stops the blade from coasting once the switch is released. This greatly reduces the danger of accidental contact.

Trigger Safety

On some light-duty saws a latch prevents the operator from accidentally starting the motor. The trigger on the inside of the handle cannot be pressed without first pressing a latch on the outside of the handle. On heavy-duty saws a bar under the trigger switch helps to prevent accidental starting.

Blades

Blades should be sharpened or changed frequently to prolong saw life, increase production, and reduce operator fatigue. The teeth on a dull or abused blade will turn blue from overheating. Cutting will create a burning smell. Such blades should be discarded or reconditioned.

Before changing or adjusting blades, disconnect the saw from the power source.

Take care to choose the right blade for the job. Blades are available in a variety of styles and tooth sizes.

Combination blades (rip and crosscut) are the most widely used.

Ensure that arbor diameter and blade diameter are right for the saw.

Because all lumber is not new, make sure it is clean and free of nails, concrete, and other foreign objects. This precaution not only prolongs blade life but may also prevent serious injury.

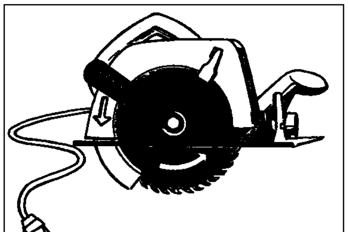


Figure 145

Take special care to ensure that blades are installed in the proper rotational direction (Figure 145). Remember that electrical circular handsaws cut with an upward motion. The teeth visible between the upper and lower guard should be pointing toward the front of the saw. Most models have a directional arrow on both blade and guard to serve as a guide.

Blade Guards

Never operate an electric saw with the lower guard tied or wedged open. The saw may kick back and cut you, or another worker may pick up the saw and – not knowing that the guard is pinned back – get hurt.

Accidents have also occurred when the operator forgot that the blade was exposed and put the saw on the floor. The blade, still in motion, forced the saw to move, cutting anything in its path.

Make sure that the lower guard returns to its proper position after a cut. Never operate a saw with a defective guard-retracting lever.

On most saws the lower guard is spring-loaded and correct tension in the spring will automatically close the guard. However, a spring weakened by use and wear can allow the guard to remain open after cutting. This creates a potential for injury if the operator inadvertently rests a still turning blade against his leg after finishing a cut. Always maintain complete control of the saw until the blade stops turning. The guard may also be slow to return after 45° cuts.

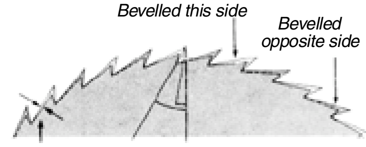
Choosing the Proper Blade

For safety, saw operators must understand the different designs and uses of blades (Figure 146). Blades unsuited for the job can be as hazardous as dull blades. For instance, a saw fitted with the wrong blade for the job can run hot so quickly that blade tension changes and creates a wobbly motion. The saw may kick back dangerously before the operator can switch it off.

Resharpened blades can be substantially reduced in diameter – for instance, from nine to eight inches. Make sure that the blade diameter and arbor diameter are right for the saw.

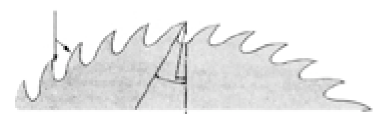
Carbide-Tipped Blades – Take special care not to strike metal when using a carbide-tipped blade. The carbide tips can come loose and fly off, ruining the blade and injuring the operator. Inspect the blade regularly for cracked or missing tips.

Crosscut Blade — The bevelled sharp-pointed teeth are designed to cut the crossgrain in wood. Size and bevel of the teeth are important factors in cutting different woods.

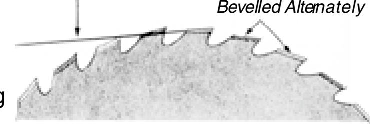


Softwood requires bigger teeth to carry off the sawdust. Hardwood requires fine teeth with many cutting edges. Note the different angles and edges needed for cutting hardwood and softwood.

Ripsaw Blade — The flat sharp teeth are designed to cut the long grain in wood. They are neither bevelled nor needle-pointed. Needle-pointed teeth would get clogged and the blade would become overheated. Never use a ripsaw blade for crosscutting or for cutting plywood. The material can jam and overheat the blade or splinter in long slivers that may seriously injure the operator.



Combination Blade This blade combines features of the crosscut and ripsaw blades. It can be used for crosscutting and ripping, or for cutting plywood. Carpenters on construction sites prefer the combination blade for rough woodwork such as stud walls and formwork because they don't have to change blades. The teeth are alternately bevelled and have a straight front. The heel of each tooth is not lower than the heel of the tooth on either side of it.



Standard Combination or Mitre Blade This is mainly used by trim carpenters. It includes teeth for crosscutting, raker teeth for ripping, and deep gullets for carrying off sawdust. The blade can be used for cutting both hardwood and softwood and for mitring.

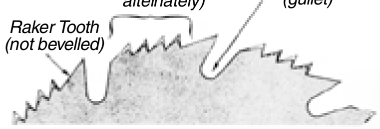


Figure 146

Changing, Adjusting, and Setting Blades

When changing blades, take the following precautions.

1. Disconnect the saw from the power source.
2. Place the saw blade on a piece of scrap lumber and press down until the teeth dig into the wood (Figure 147). This prevents the blade from turning when the locking nut is loosened or tightened. Some machines are provided with a mechanical locking device.
3. Make sure that keys and adjusting wrenches are removed before operating the saw.

Proper adjustment of cutting depth keeps blade friction to a minimum, removes sawdust from the cut, and results in cool cutting.

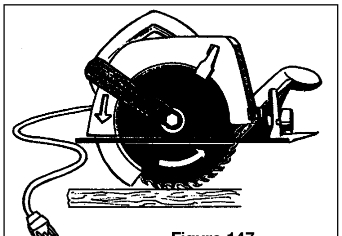


Figure 147

The blade should project the depth of one full tooth below the material to be cut (Figure 148). When using carbide-tipped blades or mitre blades let only half a tooth project below the material. If the blade is to run freely in the kerf (saw cut), teeth must be set properly, that is, bent alternately (Figure 149). The setting of teeth differs from one type of blade to another. Finer-toothed blades require less set than rougher-toothed blades. Generally, teeth should be alternately bent 1/2 times the thickness of the blade.

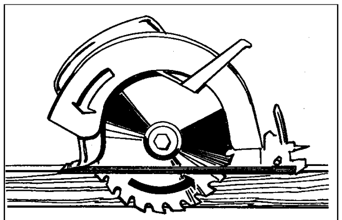


Figure 148

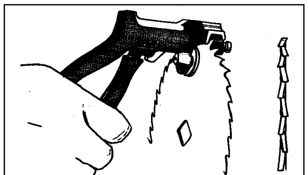


Figure 149

Sharp blades with properly set teeth will reduce the chance of wood binding. They will also prevent the saw from overheating and kicking back.

Cutting

Place the material to be cut on a rigid support such as a bench or two or more sawhorses. Make sure that the blade will clear the supporting surface and the power cord. The wide part of the saw shoe should rest on the supported side of the cut if possible.

Plywood is one of the most difficult materials to cut with any type of saw. The overall size of the sheet and the internal stresses released by cutting are the main causes of difficulty. Large sheets should be supported in at least three places, with one support next to the cut.

Short pieces of material should not be held by hand. Use some form of clamping to hold the material down when cutting it (Figure 150).

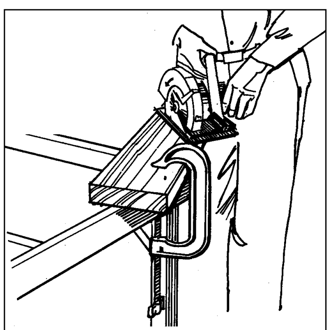


Figure 150

> **NEVER** use your foot or leg to support the material being cut. Too many operators have been seriously injured by this careless act.

The material to be cut should be placed with its good side down, if possible. Because the blade cuts upward into the material, any splintering will be on the side which is uppermost.

Use just enough force to let the blade cut without labouring. Hardness and toughness can vary in the same piece of material, and a knotty or wet section can put a heavier load on the saw. When this happens, reduce pressure to keep the speed of the blade constant. Forcing the saw beyond its capacity will result in rough and inaccurate cuts. It will also overheat the motor and the saw blade.

Take the saw to the material. Never place the saw in a fixed, upside-down position and feed material into it. Use a table saw instead.

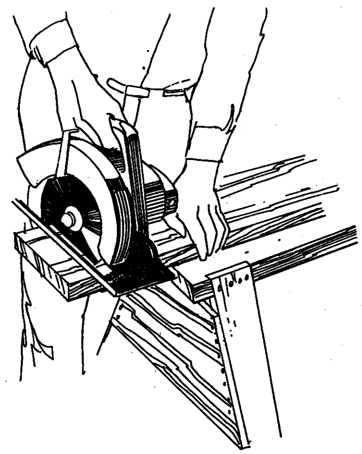
If the cut gets off line, don't force the saw back onto line. Withdraw the blade and either start over on the same line or begin on a new line.

If cutting right-handed, keep the cord on that side of your body. Stand to one side of the cutting line. **Never reach under the material being cut.**

Always keep your free hand on the long side of the lumber and clear of the saw. Maintain a firm, well-balanced stance, particularly when working on uneven footing.

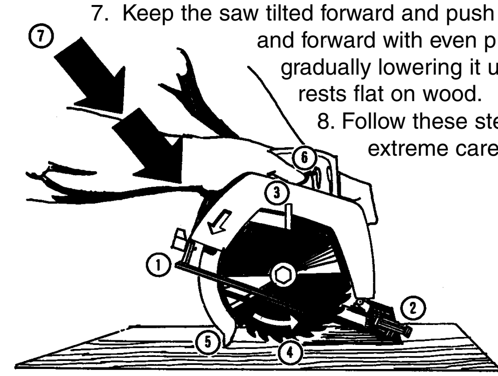
> Plywood, wet lumber, and lumber with a twisted grain tend to tighten around a blade and may cause kickback. Kickback occurs when an electric saw stalls suddenly and jerks back toward the operator. The momentarily exposed blade may cause severe injury.

Use extreme caution and don't relax your grip on the saw.



Pocket Cutting

1. Tilt saw forward.
2. Rest front of shoe on wood.
3. Retract lower guard.
4. Lower saw until front teeth almost touch wood.
5. Release guard to rest on wood.
6. Switch on the saw.
7. Keep the saw tilted forward and push it down and forward with even pressure, gradually lowering it until shoe rests flat on wood.
8. Follow these steps with extreme care.



Sabre Saws

The sabre saw, or portable jigsaw (Figure 151), is designed for cutting external or internal contours. The saw should not be used for continuous or heavy cutting that can be done more safely and efficiently with a circular saw.

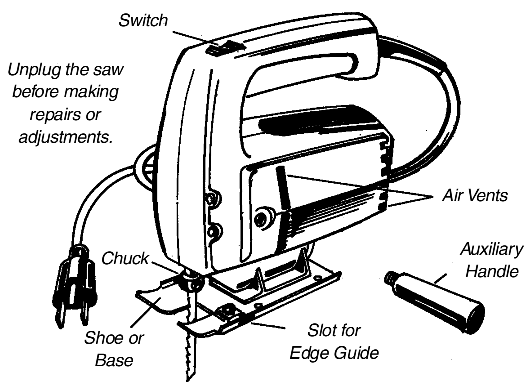


Figure 151 —Sabre Saw

The stroke of the sabre saw is about 1/2 inch for the light-duty model and about 3/4 inch for the heavy duty model. The one-speed saw operates at approximately 2,500 strokes per minute. The variable-speed saw can operate from one to 2,500 strokes per minute.

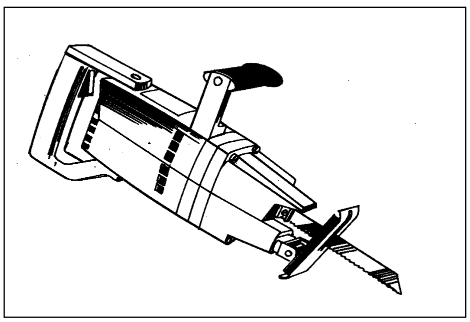
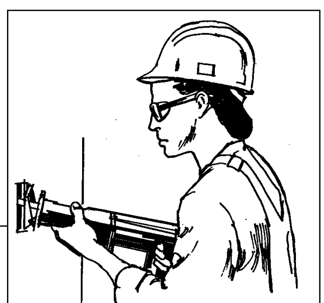
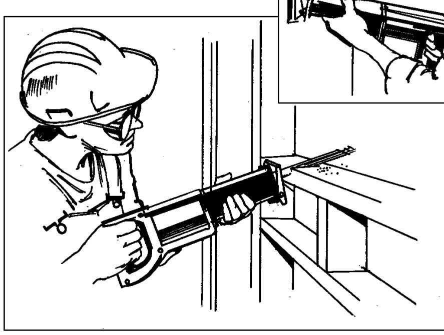


Figure 152
Reciprocating Saw



Use caution when cutting through walls. Beware of electrical wiring and other services in or behind the wall.



The reciprocating saw (Figure 152) is a heavier type of sabre saw with a larger and more rugged blade. The tool is often used by drywall and acoustical workers to cut holes in ceilings and walls. Equipped with a small swivel base, the saw can be used in corners or free-hand in hard-to-reach places. The reciprocating saw must be held with both hands to absorb vibration and to avoid accidental contact.

Eye protection is a must. You may also need respiratory protection.

Choosing the Proper Blade

Various blades, ranging from 7 to 32 teeth per inch, are available for cutting different materials. For the rough cutting of stock such as softwood and composition board, a blade with 7 teeth per inch will cut the fastest. For all-round work with most types of wood, a blade with 10 teeth per inch is satisfactory.

Cutting

The sabre saw cuts on the upstroke. Splintering will therefore occur on the top side of the material being cut. Consequently, the good side should be facing down. The degree of splintering depends on the type of blade, the vibration of the material, and the feed of the saw.

To avoid vibration, the material should be clamped or otherwise secured and supported as close to the cutting line as possible. If the material vibrates excessively or shifts during cutting, the saw can run out of control, damaging the blade and injuring the operator.

- Before starting a cut make sure that the saw will not contact clamps, the vise, workbench, or other support.
- Never reach under the material being cut.
- Never lay down the saw until the motor has stopped.
- Do not try to cut curves so tight that the blade will twist and break.
- Always hold the base or shoe of the saw in firm contact with the material being cut.

WARNING When sawing into floors, ceiling, or walls, always check for plumbing and wiring.

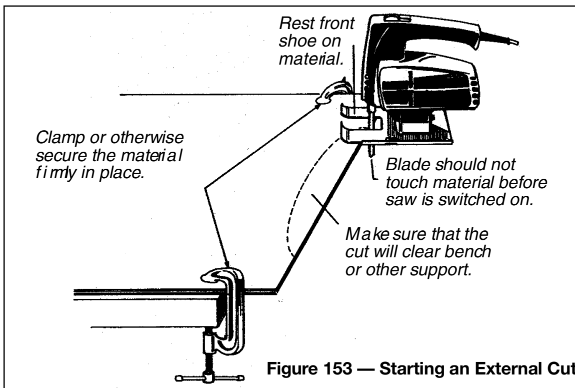


Figure 153 — Starting an External Cut

External Cut (Figure 153)

To start an external cut (from the outside in), place the front of the shoe on the material. Make sure that the blade is not in contact with the material or the saw will stall when the motor starts.

Hold the saw firmly and switch it on. Feed the blade slowly into the material and maintain an even pressure. When the cut is complete, do not lay down the saw until the motor has stopped.

Inside Cuts (Figure 154)

To start an inside cut (pocket cut), first drill a lead hole slightly larger than the saw blade. With the saw switched off, insert the blade into the hole until the shoe rests firmly on the material. Do not let the blade touch the material until the saw has been switched on.

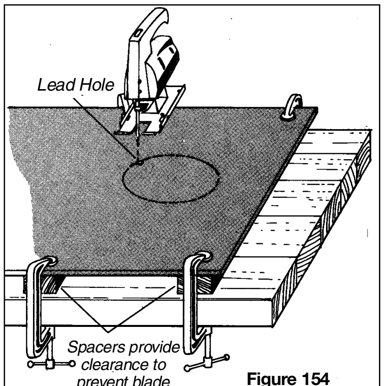


Figure 154
Starting an Inside Cut

It is possible to start an inside cut without drilling a lead hole first — but only when it's absolutely necessary. To do this, rest the front edge of the shoe on the material with the saw tipped backward. Keep the blade out of contact with the material.

Switch on the saw and slowly feed the blade into the material while lowering the back edge of the shoe. When the shoe rests flat on the material and the blade is completely through, proceed with the cut. Any deviation from this procedure can cause the blade to break and injure the operator or workers nearby.

Never try to insert a blade into, or withdraw a blade from, a cut or a lead hole while the motor is running.

Never reach under the material being cut.

Chainsaws

Each year in Ontario, construction workers are injured while using chainsaws. Generally the injuries result from two types of accidents:

1) the operator makes accidental contact with the revolving chain

2) the operator is struck by the object being cut, usually a tree or heavy limb.

Many of these injuries are serious.

While the chainsaw is relatively easy to operate, it can be lethal. As with all high-speed cutting tools, it demands the full attention of even the trained and experienced operator.

Requirements

Chainsaws can be powered by electric motors (Figure 155) or gasoline engines (Figure 156).

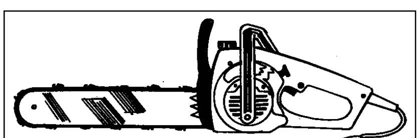


Figure 155 — Electric Chainsaw

Both saws are designed to provide fast cutting action with a minimum of binding in the cut, even though wood may be sap-filled or wet. Both afford about the same performance in terms of horsepower and they are equipped with similar controls and safety devices.

Regulations require that chainsaws used in construction must be equipped with a chain brake. Make sure that the saw is equipped with a chain brake mechanism, and not simply a hand guard, which is similar in appearance.

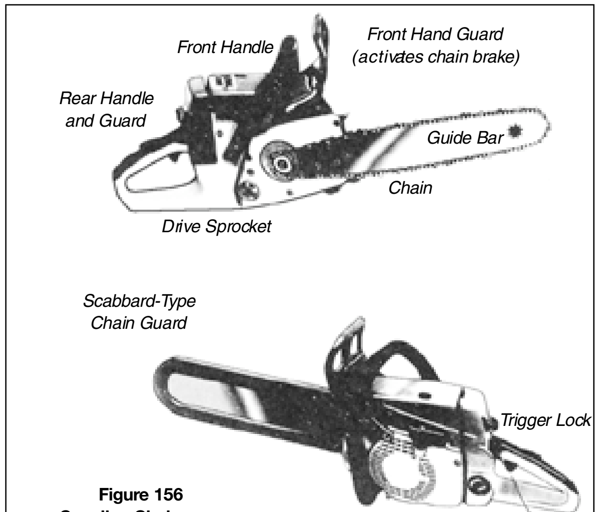


Figure 156
Gasoline Chainsaws

Regulations require that chainsaws used in construction must be equipped with “anti-kickback” chains. Called safety chains (Figure 157) by the manufacturers, these chains incorporate design features intended to minimize kickback while maintaining cutting performance.

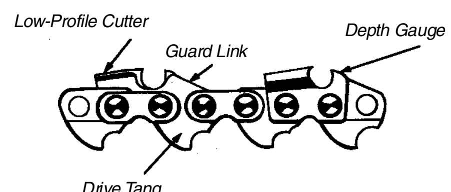


Figure 157
Safety Chain

Protective Clothing and Equipment

- Eye protection in the form of plastic goggles is recommended. A faceshield attached to the hard hat will not provide the total eye protection of close-fitting goggles.
- Leather gloves offer a good grip on the saw, protect the hands, and absorb some vibration. Gloves with ballistic nylon reinforcement on the back of the hand are recommended.
- Since most chainsaws develop a high decibel rating (between 95 and 115 dBA depending on age and condition), adequate hearing protection must be worn, especially during prolonged exposure.
- Trousers or chaps with sewn-in ballistic nylon pads provide excellent protection, particularly for the worker who regularly uses a chainsaw.

Kickback

Kickback describes the violent motion of the saw that can result when a rotating chain is unexpectedly interrupted. The cutting chain’s forward movement is halted and energy is transferred to the saw, throwing it back from the cut toward the operator.

The most common and probably most violent kickback occurs when contact is made in the "kickback zone" (Figure 158).

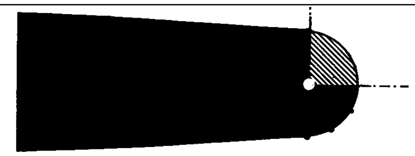


Figure 158 — Kickback Zone

Contact in this zone makes the chain bunch up and try to climb out of the track. This most often happens when the saw tip makes contact with something beyond the cutting area such as a tree branch, log, or the ground.

To minimize the risk of kickback

- use a low-profile safety chain
- run the saw at high rpm when cutting
- sharpen the chain to correct specifications
- set depth gauges to manufacturers' settings
- maintain correct chain tension
- hold the saw securely with both hands
- don't operate the saw when you are tired
- know where the bar tip is at all times
- don't allow the cut to close on the saw
- make sure the chain brake is functioning.

Starting

When starting, hold the saw firmly on the ground or other level support with the chain pointing away from your body and nearby obstructions. Use a quick, sharp motion on the starter pull (Figure 159). Never "drop start" the saw. This leaves only one hand to control a running saw and has resulted in leg cuts. Use the proper grip (Figure 160).

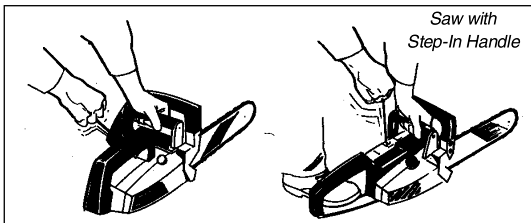


Figure 159 — Correct Starting Position

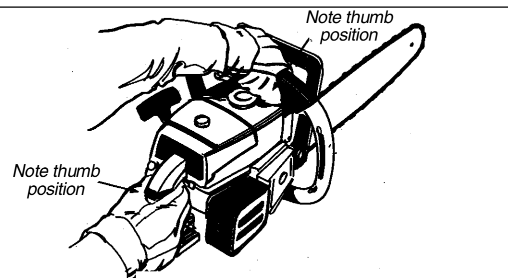
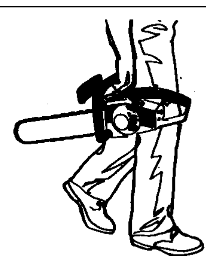


Figure 160 — Proper Grip

Before moving from place to place, shut off the saw and walk with the guide bar pointed backwards. A trip or a stumble with a running saw can cause serious injury.



Site Hazards

- Take extra care when making pocket cuts (Figure 161). Start the cut with the underside of the chain tip, then work the saw down and back to avoid contact with the kickback zone. Consider an alternative such as a sabre saw.

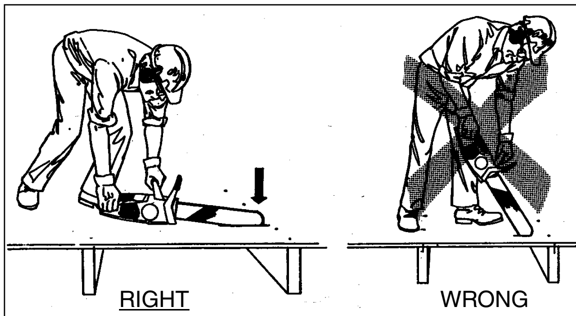


Figure 161 — Pocket Cuts

- Be particularly careful to avoid contact with nails, piping, and other metallic objects. This is especially important when making a pocket cut through framing lumber such as a subfloor or when cutting used lumber such as trench shoring, lagging, or blocking timbers.
- Use chainsaws to cut wood only. They are not designed to cut other materials.
- When using a chainsaw to trim rafter ends, take the following steps to avoid injury:
  – Cut down from the top of the rafter. Don't cut from underneath.
  – Use a harness, lanyard, and lifeline to prevent falls or work from a secure scaffold at eaves level.
  – The extension cord on an electric chainsaw should be secured on the roof above the operator with enough working slack. This will prevent the weight of a long cord from pulling the operator off balance.
  – Keep both hands firmly on the saw.

Maintenance

Well-maintained cutting components are essential for safe operation. A dull or improperly filed chain will increase the risk of kickback.

- Inspect and maintain your saw according to the manufacturer's recommendations regarding chain tension, wear, replacement, etc. Check for excessive chain wear and replace chain when required. Worn chains may break!
- Select the proper size files for sharpening the chain. Two files are necessary:
  1) a flat file for adjusting depth gauge
  2) a round file of uniform diameter for sharpening cutters and maintaining drive links.
- You must choose the correct round file for your chain to avoid damaging the cutters. Consult the owner's manual or the supplier to be sure of file size.
- A round file used in combination with a file holder or, better yet, a precision filing guide will give the best results (Figure 162).

Adjusting Chain Tension

- Follow the manufacturer's instructions on chain tension.

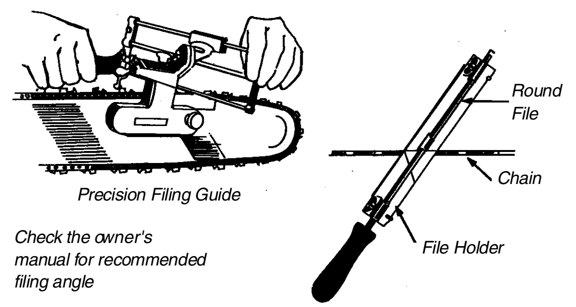


Figure 162 — Sharpening Tools

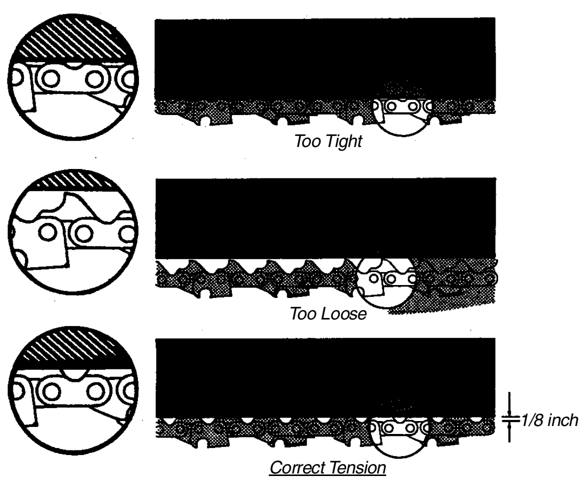


Figure 163 — No Noticeable Sag

- In general, the chain should move easily around the bar by hand without showing noticeable sag at the bottom (Figure 163).
- Be generous with chain lubricating oil. It is almost impossible to use too much. Most late model saws have automatic oilers. **But operators must still remember to fill the chain-oil reservoir.**

Chop Saws

Increasingly, carpenters and other trades are using chop saws to cut various materials (Figure 164). These portable saws offer quick, efficient, and economical cutting.

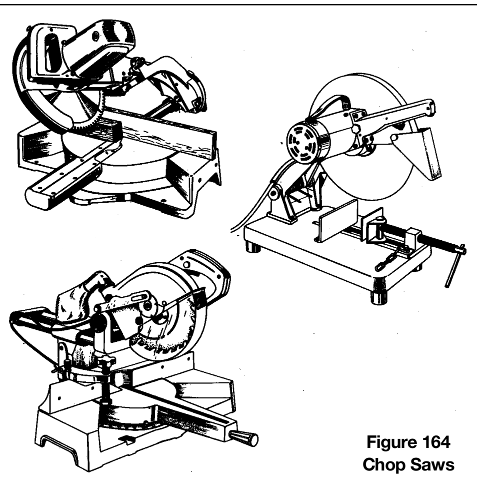


Figure 164
Chop Saws

Unfortunately, like all power equipment, chop saws pose serious hazards for the unwary or untrained operator. Follow **Basic Saw Safety** (page 183) and **Safety Basics** (page 179) as for other power saws.

Most of these saws are equipped with abrasive wheels for quick cutting through metal studs and other material.

- Select the proper abrasive cutting wheel for the material being cut. For metals, use aluminum oxide. For masonry, stone, and concrete, use silica carborundum.
- The rpm of the saw should not exceed the recommended rpm printed on the blade label.
- The centre hole on the blade must fit the mandril and be snugly fastened in place with the proper washer and lock nut.

Warning A loose or off-centre blade can shatter in use.

- Position material to be cut at 90 degrees to the blade. Support the other end to prevent the blade from binding.
- Do not rush cutting. Let the wheel cut without burning or jamming.
- When cutting is complete, let the blade stop before moving material.
- Maintain the saw in good repair with the blade guard in place and working smoothly. Tighten any loose parts and replace any broken or damaged ones.
- Don't try to adjust for length on downward cutting motion. Your hand could slide into the blade while it is spinning.
- With some large chop saws (Figure 165), additional precautions are required because of the tremendous torque the saws can develop.
- Beware of sparks landing on combustible material.

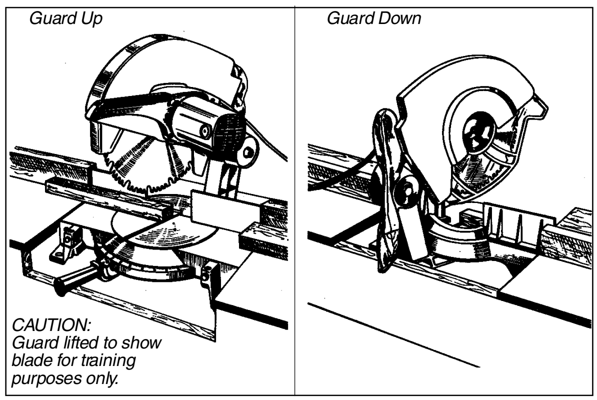


Figure 165 — Some large chop saws may require additional precautions.

Quick-Cut Saws

Hand-held portable circular cut-off saws are commonly known as “quick-cut saws” in construction (Figure 166). They are widely used for cutting concrete, masonry products, sheet metal products (both steel and aluminum), and light steel sections such as angles and channels.

Hazards

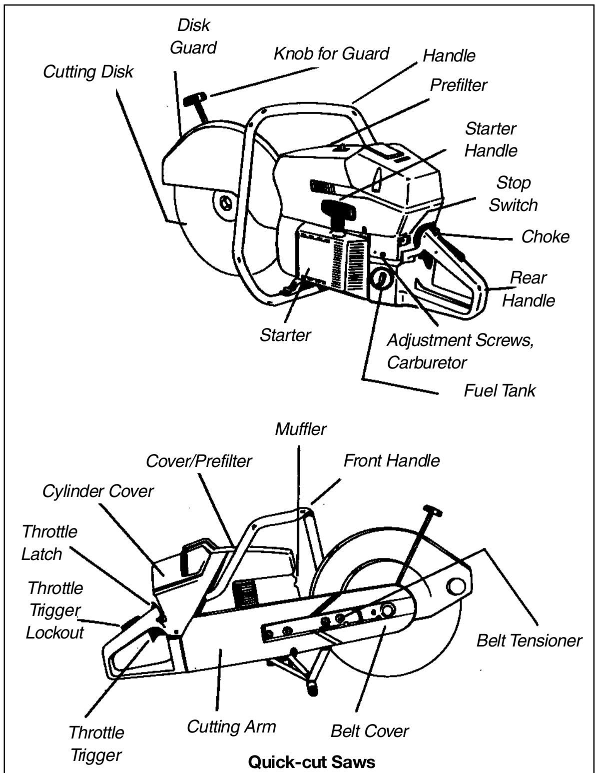
Quick-cut saws are high-powered compared to similar tools. Hazards include high-speed blade rotation, blade exposure during operation, and exhaust from the internal combustion engine (the usual power source).

The saws also create clouds of dust when dry-cutting masonry and showers of hot sparks when cutting metal products, especially steel.

These hazards can result in cuts, kickbacks, exposure to carbon monoxide fumes, exposure to dusts (silica from concrete and masonry products in particular), burns, flying particles hitting the eye, and other injuries from flying material when work is not secured for cutting or when blades fly apart.

These hazards can be controlled by

- operators trained to use quick-cut saws properly and to wear the right protective equipment such as eye, hearing, and respiratory protection as well as face shields and gloves
- saws kept in good working condition, equipped with proper blades or disks, and used with all guards in place
- work secured to keep it from shifting during cutting
- caution around sharp edges left by cuts.



Quick-cut Saws
Figure 166

Training

Operators should be instructed in the care, maintenance, and operation of quick-cut saws. They should read the operating manual, review the major points, and receive both oral and written instruction.

The operating manual should be available on the job, not only for instruction but for ready reference if something goes wrong with the saw or it must be used for work outside the operator's experience.

Time spent on instruction will reduce accidents and injuries as well as prolong the service life of the saw.

As a minimum the operator should be instructed in

- care of the saw
- installing disks and blades
- mixing fuel and fueling the saw
- starting the saw
- supporting and securing work to be cut
- proper cutting stance and grip
- proper cutting techniques for different material
- respiratory protection against dusts
- how to inspect and store abrasive disks.

Care

Quick-cut saws must be serviced and maintained in accordance with the manufacturers' instructions. Replacement parts should be those recommended by the manufacturer.

Cracked, broken, or worn parts should be replaced before the saw is used again. Guards and air-intakes should be cleaned regularly and often. Abrasive disks should be checked before installation and frequently during use. Correct any excessive blade vibration before trying to make a cut.

In confined areas, make sure that ventilation is adequate. Gasoline-driven saws release carbon monoxide gas — odourless, colourless, and highly toxic.

Starting

Most of the following procedures are for gasoline-powered quick-cut saws — the type most commonly used in construction.

- Use caution when preparing the oil/gasoline mixture and when fuelling the saw. No smoking or ignition sources should be allowed in the area where fuel is mixed or tanks are filled.
- Fill the tank outdoors in a well-ventilated space at least 3 metres from the area where the saw will be used. Spilled fuel should be wiped off the saw.
- Avoid fuelling the saw on or near formwork. Gasoline spills are a fire hazard. Use a funnel to avoid spills.
- Do not overfill the saw or run it without securing the fuel tank cap. Gasoline seeping from the tank can saturate your clothing and be ignited by sparks thrown off from metal cutting. The only cap to use is one supplied by the manufacturer.
- Check the saw for leaks. Sometimes vibration makes gas lines leak.
- Start the saw in an area clear of people and obstacles. Under no circumstances should anyone be standing in front of the saw as it starts or while it's running.
- Put the saw on a smooth hard surface for starting. The guard should be properly set for the type of cut beforehand.
- Assume a solid well-balanced stance. Do not wrap the starter cord around your hand — this can cause injury.
- Set one foot on the rear handle, put one hand on the top handle to lift the blade off the surface, and use the other hand to pull the starter cord (Figure 167).

Warning: Always shut off saw before fuelling.
Keep fuel container well clear of work area.

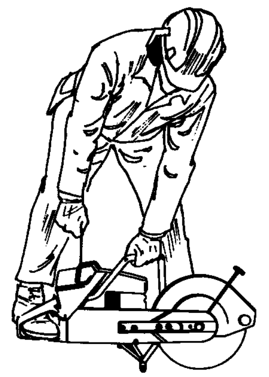


Figure 167 — Starting Position

- Once the saw is running, release the throttle and make sure the engine drops to idle without the disk or blade moving.
- Run the engine at full throttle and let the disk or blade run freely to make sure it turns on the arbor without wobbling or vibrating.

Support

One of the major hazards with quick-cut saws is failure to support and secure the work to be cut.

The saw is powerful enough to throw material around unless it is securely held and supported. Standing on material to hold it down is **not** recommended.

For repeated cuts of masonry or metal pieces, a jig is ideal for efficiency and safety. The jig should be designed and built to hold material in place after measurement without further manual contact (Figure 168).

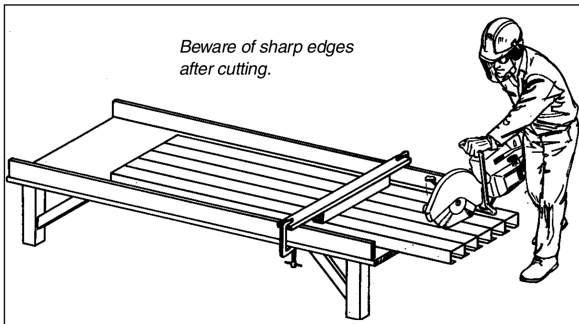


Figure 168 — Jig for Cutting

Stance and Grip

The quick-cut saw is a heavy, powerful tool that must be held by hand. Operators need a secure stance with legs apart for balance and support. The saw should be held at a comfortable, balanced location in front of the operator.

Grip the saw firmly with one hand on each handle. Hold your forward arm straight to keep the saw from kicking back or climbing out of the cut (Figure 169).

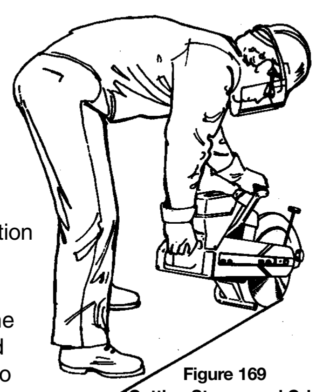


Figure 169
Cutting Stance and Grip

Cutting

Although skill in handling the quick-cut saw can only be learned through practice, some safety considerations and operating techniques must always be kept in mind, even by the most experienced operators.

Work should be supported so that the disk or blade will not bind in the cut. Support heavy materials on both sides of the cut so the cut piece will not drop or roll onto the operator's foot. Light materials can generally be allowed to fall. In all cases the cut should be as close as possible to the supporting surface (Figure 170).

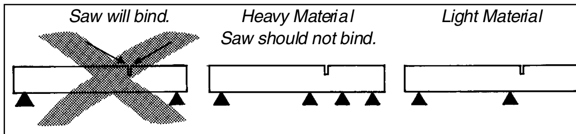


Figure 170 — Support for Different Cuts

Kickback and Pull-In

Kickback can happen extremely fast and with tremendous power. If the segment of the disk or blade shown in Figure 171 contacts the work, the disk or blade starts to climb out of the cut and can throw the saw up and back toward the operator with great force.

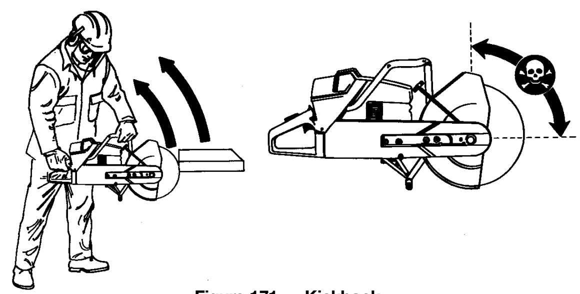


Figure 171 — Kickback

For cutting, keep the throttle wide open. Ease the blade down onto the cut line. Don't drop or jam the blade down hard. Move the saw slowly back and forth in the cut.

Hold the saw so that disk or blade is at right angles to the work and use only the cutting edge of the disk or blade (Figure 172). Never use the side of a disk for cutting. A worn disk will almost certainly shatter and may cause severe injury.

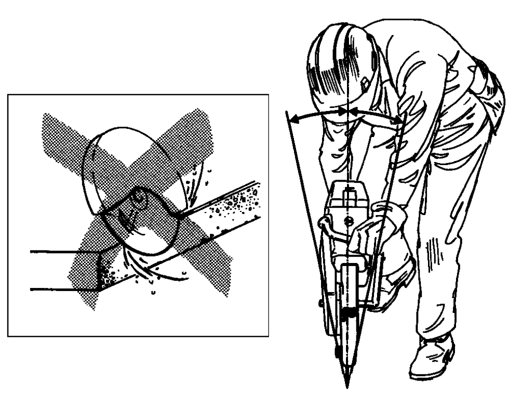


Figure 172 — Saw at Right Angles to Material

Beware of blade run-on. The blade may continue to rotate after the cut and run away with a saw set down too soon.

Don't force the saw to one side of the cut. This will bend the disk or blade and cause it to bind, possibly to break.

Water cooling is recommended for cutting masonry materials. It prolongs disk life and reduces dust exposure.

Keep pressure on the saw reasonably light. Although more pressure may be necessary for hard materials, it can cause an abrasive disk to chip or go "out of round." This in turn will make the saw vibrate. If lowering the feed pressure does not stop vibration, replace the disk.

Don't carry the saw any distance with the engine running. Stop the engine and carry the saw with the muffler away from you.

To avoid kickback, take the following steps:

- Secure and support the material at a comfortable position for cutting. Make sure that material will not move, shift, or pinch the blade or disk during cutting.
- Keep steady balance and solid footing when making a cut.
- Do not support the work on or against your foot or leg.
- Use both hands to control the saw. Maintain a firm grip with thumb and fingers encircling the handles.
- Never let the upper quarter segment of blade or disk contact the material.
- Run the saw at full throttle.
- Do not cut above chest height.
- When reentering a cut, do so without causing blade or disk to pinch.

Pull-in occurs when the lower part of the disk or blade is stopped suddenly – for instance, by a cut closing up and binding. The saw pitches forward and can pull the operator off balance.

Protective Equipment

In addition to the standard equipment mandatory on construction sites, operators of quick-cut saws should wear snug-fitting clothing, hearing protection, eye and face protection, and heavy-duty leather gloves (Figure 173).

The dry cutting of masonry or concrete products calls for respiratory protection as well. See the chapter on Personal Protective Equipment.

For general dust hazards, a half-mask cartridge respirator with NIOSH-approval for dust, mist, and fumes should provide adequate protection when properly fitted and worn by a cleanshaven person.

Disks and Blades

Disks and blades are available in three basic types:

– abrasive disks
– diamond-tipped blades
– carbide-tipped blades.

Use only the disks and blades compatible with your saw and rated for its maximum rpm. Blades or disks may fly apart if their rpm is not matched to saw rpm. If you have any doubts, consult the operating manual or a reputable supplier.

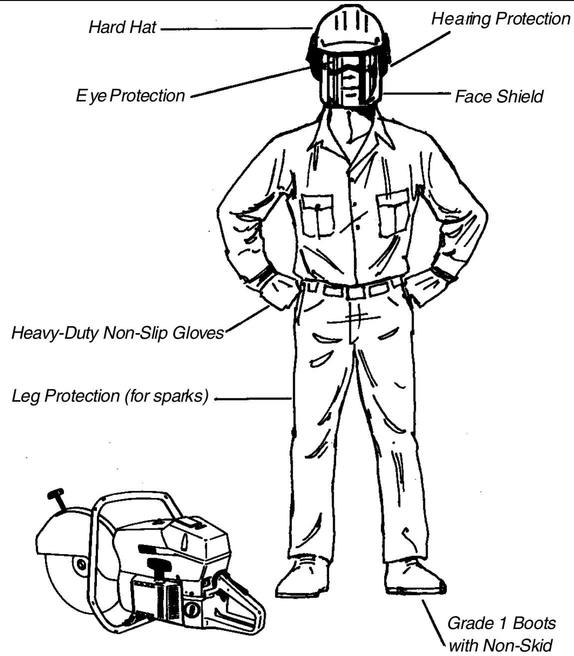


Figure 173 — Protective Equipment

Abrasive Disks — Types and Uses

Type	Uses	Materials
Concrete	All-around use, most economical for cutting concrete and masonry. **Water-cooling recommended to increase disk life and reduce dust.**	Concrete, stone, masonry products, cast iron, aluminum, copper, brass, cables, hard rubber, plastics.
Metal	Primarily for steel, not suited for masonry products. Water-cooling is not recommended with metal abrasive disks.	Steel, steel alloys, other hard metals such as cast iron.

Diamond Disks and Blades

Diamond disks are normally used with water cooling. They are now available for dry cutting, which may be necessary to avoid staining some masonry products.

When dry-cutting with a diamond blade, let the blade cool for 10-15 seconds every 40-60 seconds. This can be done simply by pulling the saw out of the cut.

Types and Uses

Type	Uses	Materials
Diamond Abrasive Disk	Cuts faster than other abrasive disks and creates less dust. **Water-cooling is absolutely necessary to prevent heat build-up that can make disk disintegrate.**	Stone, all masonry and concrete products. Not recommended for metals.
Dry-Cut Diamond Blade	Fast cuts, lots of dust, very expensive. Let blade cool for 10-15 seconds every 40-60 seconds. Continuous cutting will damage the blade.	Stone, all masonry and concrete products. Not recommended for metals.

Carbide-Tipped Blades

These blades must be used with care. If a carbide-tipped blade encounters material harder than what it is designed to cut, the tips may fly off.

A carbide-tipped blade used with a quick-cut saw **must** be designed for that purpose. It must also be used only to cut the materials specified by the manufacturer.

Inspection/Installation

Inspect disks and blades before installing them.

- Make sure that contact surfaces are flat, run true on the arbor, and are free of foreign material.
- Check that flanges are the correct size and not warped or sprung (Figure 174).

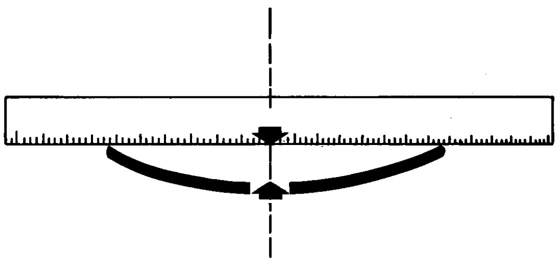


Figure 174 — Check disk for warping.

- Check the label to make sure that the disk or blade is approved for use on high-speed quick-cut saws and has a rated rpm suitable to the saw being used. A periodic service check may be necessary to ensure that the rpm still meets the manufacturer's requirement.
- Inspect the disk or blade for damage. Abrasive disks tapped lightly with a piece of wood should ring true. If the sound is dull or flat, the disk is damaged and should be discarded.
- Make sure that diamond or carbide tips are all in place. Do not use diamond or carbide-tipped blades or disks if any tips are missing.
- Do not drop abrasive disks. Discard any disk that has been dropped.
- Use the proper bushing on the arbor so that the disk runs true on the shaft without wobbling or vibrating.
- Discard badly worn disks that are uneven or “out of round.”

Table Saws

Types

The table saw most often used in construction is the 10-inch belt-driven tilting arbor saw. The dimension refers to the diameter of the saw blade recommended by the manufacturer.

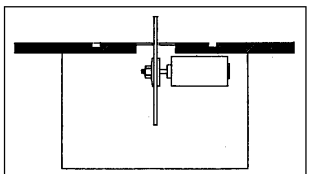


Figure 175 — Direct-Drive Table Saw

Although some saws are direct-drive (Figure 175), with the blade mounted right on the motor arbor, most are belt-driven (Figure 176).

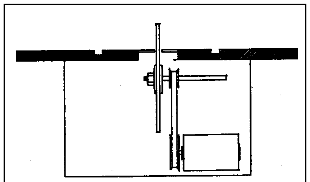


Figure 176 — Belt-Driven Table Saw

Both types are equipped with a fixed table top and an arbor that can be raised, lowered, or tilted to one side for cutting at different depths and angles.

Basket Guards

Basket guards may be fastened to the splitter or hinged to either side of the saw on an L-shaped or S-shaped arm (Figure 177).

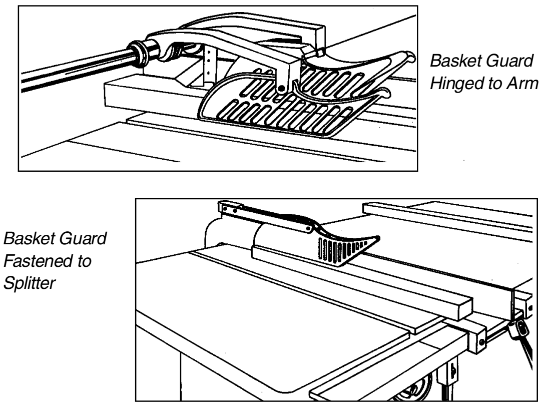


Figure 177 — Basket Guards

Basket guards can protect the operator from sawdust, splinters, and accidental contact with the blade. Keep the basket guard in place for normal operations such as straight and bevel ripping and mitre cutting. When the guard is removed to permit cutting of tenons, finger joints, rabbets, and similar work, use accessories such as feather boards, holding jigs, push sticks, and saw covers.

Figure 178 shows a split basket guard with a see-through cover. One side can be moved sideways for a blade tilted to 45 degrees. One side can be lifted up while the other remains as a protective cover.

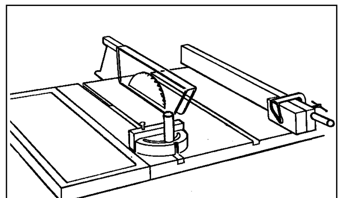


Figure 178
See-Through Plastic Basket Guard

Sheet metal baskets fastened to the splitter are less effective because the operator cannot see the saw blade.

Kickback

Kickback occurs when stock binds against the saw blade. The blade can fire the wood back at the operator with tremendous force, causing major injuries to abdomen, legs, and hands.

- Never stand directly behind the blade when cutting. Stand to one side. See that other workers stand clear as well.
- Make sure the rip fence is aligned for slightly more clearance behind the blade than in front. This will help prevent binding.
- Use a sharp blade with teeth properly set for the wood being cut. A dull or badly gummed blade will cause friction, overheating, and binding.
- Install a splitter to keep the kerf (cut) open behind the blade. Also effective are anti-kickback fingers attached to the splitter.

Splitters

Splitters prevent the kerf from closing directly behind the blade. Ideally, they should be slightly thinner than the saw blade and manufactured from high tensile steel.

Splitters are not always needed with carbide-tipped saw blades, whose relatively wide kerf may provide the desirable clearance. A wide kerf alone, however, is often not enough to keep some boards from closing behind the cut and binding against the blade.

In general, it is impossible to predict how a board will behave during ripping. It may remain straight, presenting no problems. On the other hand, the release of internal stresses may make the two ripped portions behind the blade either close up or spread apart.

Figure 179 shows a disappearing splitter with anti-kickback fingers. It can be pushed down when in the way of a workpiece and pulled up when necessary after the machine has been shut off.

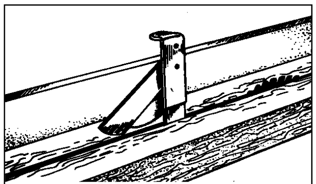


Figure 179 — Disappearing Splitter with Anti-Kickback Fingers

Roller Stand

Operators risk injury trying to maintain control over long pieces of stock singlehandedly, especially if the stock begins to bind on the blade and kick back.

A roller stand (Figure 180) provides the needed support. Adjust it to a height slightly lower than the saw table to allow for sagging of the material. Be sure to set up the stand so the roller axis is at 90 degrees to the blade. Otherwise, the roller could pull the stock off to one side and cause binding.

Whatever the design, a support stand should be standard equipment in every carpentry and millwork shop. It can be used as an extension to a workbench, jointer, or bandsaw and is especially important with the table saw.

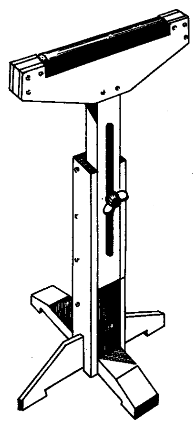


Figure 180 — Roller Stand

Extensions

Made of wood or metal, table top extensions installed behind and to both sides of the machine can make the cutting of large sheets of plywood and long stock safer and more efficient.

In most cases a space must be provided between extension and saw top for adjusting the basket guard and allowing scrap to fall clear.

Blades

Table saw blades are basically similar to those for circular saws.

The teeth on carbide-tipped, hollow-ground, and taper blades do not need setting (Figure 181).

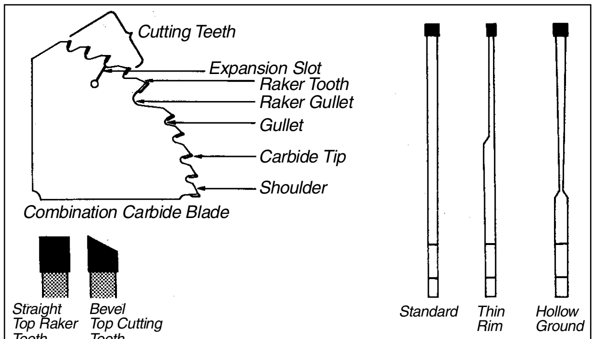


Figure 181 — Carbide-Tipped Blades

Blade Adjustment

Proper adjustment of cutting depth holds blade friction to a minimum, removes sawdust from the cut, and results in cool cutting.

Sharp blades with properly set teeth will keep the work from binding and the blade from overheating and kicking back.

The blade should project the depth of one full tooth above the material to be cut. When using carbide-tipped blades or mitre blades let only half a tooth project above the material.

Blade Speed

The right cutting speed is important. The blade should turn at the correct rpm to yield the recommended cutting speed.

When not in motion, saw blades, especially large blades, are usually not perfectly flat because of internal tensions. At the right operating speeds, however, the blades straighten out as a result of centrifugal force and cut smoothly at full capacity.

Blades running too fast or too slow tend to start wobbling either before or during a cut. If cutting continues, the blade will overheat and may cause kickback, damage the equipment, and injure the operator.

Rip Fence

The rip fence is used mainly to guide the stock and maintain correct width of cut. The fence on small saws is usually clamped down at both the front and back of the table by pushing down a lever or turning a knob. Adjust the fence slightly wider at the back to let the wood spread out behind the cut and reduce the risk of kickback.

Many carpenters add a piece of hardwood to the rip fence in order to rip thin pieces of wood and make dadoes and rabbets. The auxiliary fence can be set close to the cutters without the risk of contact between the blade and the steel fence.

Pushsticks

Narrow pieces can be cut safely and efficiently with the help of pushsticks (Figure 182), which should be painted or otherwise marked to prevent loss.

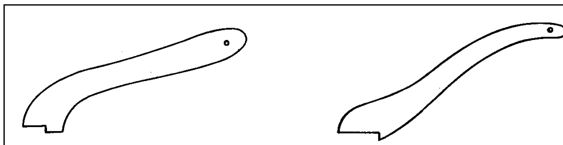


Figure 182 — Pushsticks

To rip narrow, short pieces, a push block is the right choice (Figure 183). The shoe holds the material down on the table while the heel moves the stock forward and keeps it from kicking back.

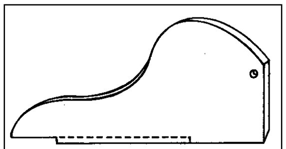


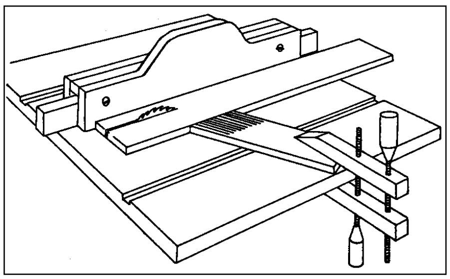
Figure 183 — Push Block

Different designs of pushsticks are required for cutting different kinds of stock.

The heel of the pushstick should be deep enough to prevent it from slipping and strong enough to feed the stock through the saw.

Feather Boards

You can also use one or two feather boards (Figure 184) to rip narrow stock safely. A feather board clamped immediately in front of the saw blade will provide side pressure to the stock without causing binding and kickback. Use a push block to feed stock all the way through.



Clamp feather board in front of saw blade.

Clamp second feather board to auxiliary rip fence.

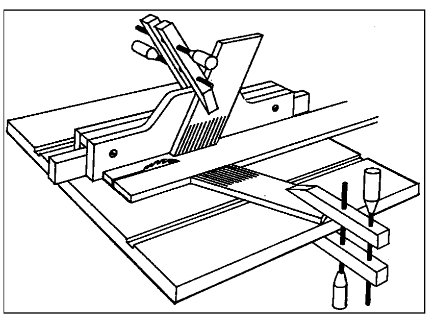


Figure 184 — Feather Boards

Operation

- Follow **Basic Saw Safety** (page 183).
- Keep the floor around the saw clear of scrap and sawdust to prevent slipping and tripping.
- Always stop the machine before making adjustments. Before making major adjustments, always disconnect the main power supply.
- Select a sharp blade suitable for the job.
- Use the safety devices such as pushsticks and feather boards recommended in this chapter.
- Make sure nobody stands in line with a revolving blade.
- Don't let anyone or anything distract you when you are operating the saw.
- Whenever possible, keep your fingers folded in a fist rather than extended as you feed work into the saw.
- Never reach around, over, or behind a running blade to control the stock.
- Follow the manufacturer's recommendations in matching the motor size to the saw. Underpowered saws can be unsafe.
- Table saws should be properly grounded. Check the power supply for ground and always use a ground fault circuit interrupter. This is mandatory for saws used outdoors or in wet locations.
- Table saws should be equipped with an on-off switch so power can be shut off quickly in an emergency.
- A magnetic starter switch is preferable to a mechanical toggle because it prevents the saw from starting up again unexpectedly after an interruption in power.
- When purchasing a new table saw, try to get one equipped with an electric brake. The brake stops blade rotation within seconds of the operator turning off the saw. The reduced risk of injury is worth the extra cost.
- Extension cords should be of sufficient wire gauge for the voltage and amperage required by the saw and for the length of the run.

Radial Arm Saws

The motor and blade of the radial arm saw are suspended above the table (Figure 185). Because the motor and blade assembly can be locked in different positions and can travel during the cut, the operator must pay special attention to keeping fingers and hands clear.

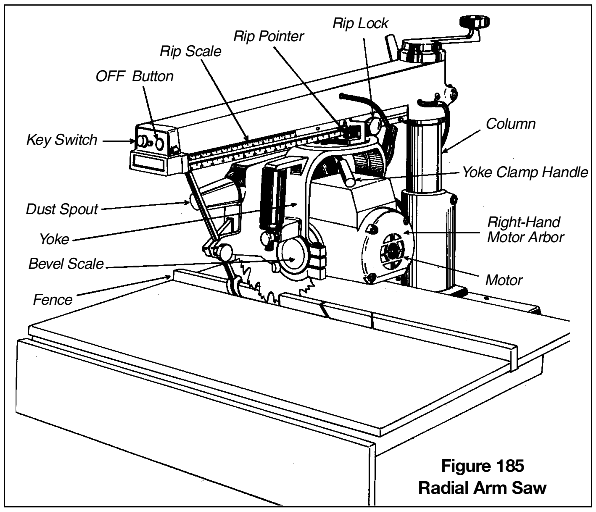


Figure 185
Radial Arm Saw

Injuries involving radial arm saws tend to be serious. By using appropriate guards and procedures, however, operators can safely use the saw for crosscuts, mitre cuts, ripping, and dadoes.

Set-Up

- The saw must be adequately powered for the work, especially for cutting thick hardwood.
- The saw should be installed in a well-lit area out of the way of traffic, with enough space to store and handle long lengths of wood. Locating the machine with its back to a wall or partition can help to keep flying pieces from hitting anyone.
- Where possible, mark the floor with yellow warning lines to keep other personnel back from the saw.
- Make sure all safety guards and devices are in place.
- Choose the right blade for the job. A sharp tungsten carbide combination blade is good for both crosscutting and ripping without frequent

resharpening. For information on blade types and uses, refer to earlier sections of this chapter.

General Procedures

- Follow **Basic Saw Safety** (page 183).
- If you don't have someone to help with long stock, use a roller stand or extension table to support the work.
- Always return the motor head to the column stop.
- When crosscutting or mitring, keep hands at least six inches away from the blade. **Do not adjust length of cut until the motor is back at column.**
- Slope the table top back slightly to keep the blade at the column, thereby preventing contact with stock being placed in position.
- Do not allow the blade to cut too quickly when crosscutting or mitring.
- Avoid drawing the blade completely out of the cut. The cut piece, whether large or small, often moves. When the saw is rolled back towards the column, the teeth can grab the piece and shoot it in any direction.
- Do not cut by pushing the saw away from you into the stock. The material can lift up and fly over the fence.

Ripping and Crosscutting

- For regular ripping, turn the motor away from the column to the in-rip position. Feed stock into the saw from the right side.
- To cut wide stock, change the saw to the out-rip position. Feed stock into the saw from the left side. Operators accustomed to in-ripping may find this set-up awkward. Remember – the blade must turn **up and toward** the person feeding the stock.
- Do not force the cut. Allow the blade through the wood at its own pace.
- **To avoid kickback, take the following precautions.**
  – Maintain proper alignment of blade with fence.
  – Adjust anti-kickback device (Figure 186) to 1/8 inch below the surface of stock being fed.

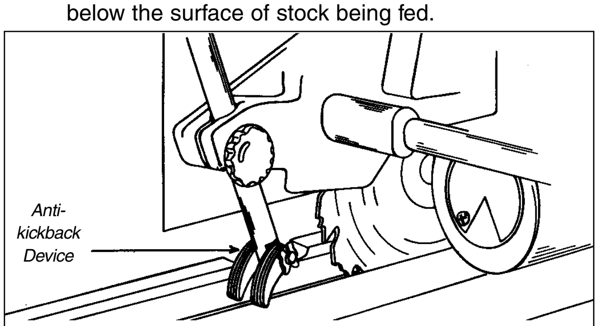


Figure 186

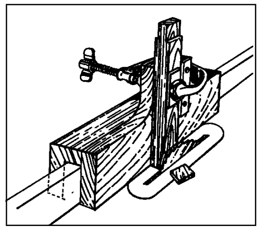
  – Use a sharp blade, free of gum deposits and with teeth properly set.
  – When binding occurs, stop saw and open kerf with a wedge.
  – After completing cut, remove stock from rotating blade to prevent overheating and possible kickback.
  – Always push stock all the way through past the blade.
  – Do not leave machine with motor running.
  – Use a push stick when ripping narrow pieces. Have suitably sized and shaped pushsticks for other jobs as well.

See information on pushsticks and feather boards under Table Saws, earlier in this chapter.

Jigs

The control provided by a well-made jig is essential for making irregular cuts safely and accurately.

Keep commonly used jigs (Figure 187) on hand. Jigs such as those for making stair and doorframe wedges and tapers are designed to carry stock past the blade with the saw locked in the rip position.



Tenoning Jig

Taper Jig

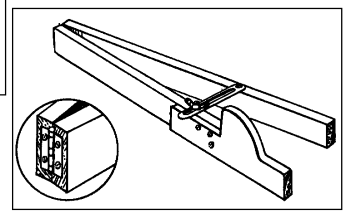


Figure 187 — Jigs

When you're drawing the saw into the stock, clamp or nail jigs to the table to prevent slipping.

Re-Sawing with Blade Horizontal

The rip fence on the radial arm saw is too low for supporting material to be re-sawn on edge. Therefore the material must be laid flat on the table and the motor must be turned so the blade is parallel to the table. The closeness of the arbor requires an auxiliary table top and fence to re-saw thin stock.

Because the kickback fence can't be used and controlling stock is sometimes difficult, re-sawing on the radial arm saw can be hazardous.

If no other equipment is available, rip the stock halfway through, then turn it around and complete the cut.

On the second cut, be sure to push the two halves well past the blade once they have been cut apart. Pushsticks and featherboards clamped to the table can reduce hazards.

Dadoes

A dado head is an essential tool for cutting grooves, rabbets, and dadoes. A groove is cut with the grain; a dado is cut across the grain; and a rabbet is a shoulder cut along the edge of a board.

The most common dado head consists of two outside cutters and several inside chippers between the outside cutters (Figure 188).

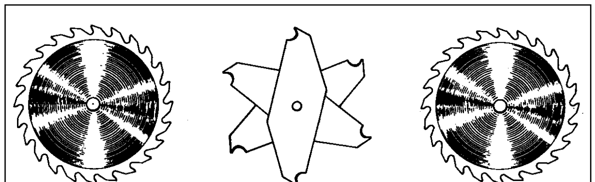


Figure 188
Dado Head Cutter Blades and Chippers

Another type is sometimes called a quick-set dado, consisting of four tapered washers and a blade. By rotating the locking washers, the blade will oscillate and cut a groove to the desired width.

Because of their small size, dado heads do not run at the peripheral feed speed on a big radial arm saw. As a result, the blade feeds itself too fast, either stopping the motor or lifting the work and throwing it back. To prevent this, **make several light passes**, lowering the dado head 1/8 to 1/4 inch each time.

Dado heads require guards for safety. Always make sure guards are in place before starting work.

Proper rotation of the teeth is **up and toward** you.

Other Accessories

Rotary accessories of various types are advertised as turning the radial arm saw into a multifunction machine. Operators should remember that the saw has its limitations. Possible problems include the following.

- Shaper heads run too slow for safe and smooth work.
- Grinding stones may run too fast or slow and are not recommended.
- Sanding drums tend to run too fast and may burn the wood.

4 POWER TOOLS — AIR

Many different types of tools are powered by compressed air. They are fast, powerful, and ideal for repetitive tasks such as the nailing of large areas of roof decking or chipping and breaking concrete. A compressor, powered by a combustion or electric motor, supplies the air for the tools.

Air-powered tools include

– jack hammers
– chipping hammers
– drills
– grinders
– sanders
– staplers
– framing nailers
– wrenches
– brad nailers
– winches
– air nozzles
– saws
– buffers
– impact tools
– sprayers.

- Run combustion engines outside or in a well-ventilated area to prevent the build-up of carbon monoxide gas. Always keep a fire extinguisher near flammable liquids.
- When moving compressors to another location, ask for help or use mechanical devices to prevent back injuries.
- Occasionally workers suffer eye injuries when compressed air is used to blow out formwork. Wear safety goggles and respiratory protection.
- Always secure hose connections with wire or safety clips to prevent the hose from whipping except when automatic cut-off couplers are used.
- Make sure hoses are clear of traffic and pose no tripping hazards.
- Replace worn-out absorption pads and springs. Too much vibration of the tool can damage nerves in fingers, hands, and other body parts. This is called “white finger disease” or Raynaud's Syndrome.
- Some tools have a high decibel rating – for instance, jack hammers and impact drills. To prevent hearing loss, always wear hearing protection.
- Never tamper with safety devices.
- Keep hands away from discharge area – on nailers in particular.
- Match the speed rating of saw blades, grinding wheels, cut-off wheels, etc. to tool speed. Too fast or too slow a rotation can damage the wheels, release fragments, and injure workers.
- Never use air to blow dust or dirt out of work clothes. Compressed air can enter the skin and bloodstream with deadly results.
- Turn off the pressure to hoses when the system is not in use.
- Turn off the air pressure when changing pneumatic tools or attachments.
- Never “kink” a hose to stop air flow.

Most air-powered tools need very little maintenance. At the end of the shift, put a teaspoon of oil in the air inlet and run the tool for a second or two to protect against rust.

Dust, moist air, and corrosive fumes can damage the equipment. An inline regulator filter and lubricator will extend tool life.

Before start-up, check the couplings and fittings, blow out the hose to remove moisture and dirt, and clean the nipple before connecting the tool. Set the air pressure according to the manufacturer's specifications and open gradually.

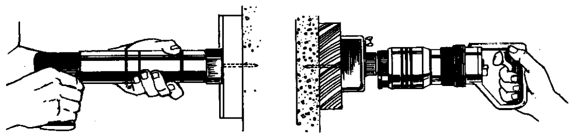
Compressed air can be dangerous. Hazards include

Air embolism	This is the most serious hazard, since it can lead to death. If compressed air from a hose or nozzle enters even a tiny cut on the skin, it can form a bubble in the bloodstream – with possibly fatal results.
Physical damage	Compressed air directed at the body can easily cause injuries – including damage to eyes and ear drums.
Flying particles	Compressed air at only 40 pounds per square inch can accelerate debris to well over 70 miles per hour when it is used to blow off dust, metal shavings, or wood chips. These particles then carry enough force to penetrate the skin.

WARNING: Make sure that air pressure is set at a suitable level for the tool or equipment being used. Before changing or adjusting pneumatic tools, turn off air pressure.

5 POWER TOOLS — EXPLOSIVE

Referred to as explosive-actuated or powder-actuated, these tools use a powder charge to fire a fastener into hard materials such as concrete, mild steel, and masonry. Used improperly, powder-actuated tools pose obvious hazards. The tools should be treated with the same respect as a firearm. Most jurisdictions – including Ontario – require that operators be trained before using the tools and carry proof of training on the job.



Hazards

Flying Particles – This is the major hazard. On impact, materials may break up, blow apart, or spall off. This often happens when fasteners are fired too close to a corner of masonry or concrete or when they strike materials such as glazed tile, hollow tile, or thin marble tile.

Ricochets – These usually result when the tool is not held at right angles to the base material, or the fastener hits a particularly hard material such as stone or hardened steel. Always check the base material to ensure that it can safely accept the fastening device.

Noise – Powder-actuated tools create an extreme pulse of sound when fired. Operators and others in the area should wear hearing protection – especially when the tool is operated in a confined space.

Sprains and Strains – These injuries usually result from using the tool repeatedly in awkward, cramped, or unbalanced positions. Operators should try to work from a balanced position on a solid surface.

Explosions – There is always the risk of explosion or fire when the tools are used in atmospheres contaminated by flammable vapour, mist, or dust. The work area must be ventilated – mechanically if necessary.

Blow-Through – When the base material does not offer enough resistance, the fastener may pass completely through and fly out the other side. This is particularly dangerous when fasteners penetrate walls, floors, or ceilings where others may be working. If necessary, areas behind, around, and under material should be kept clear of people.

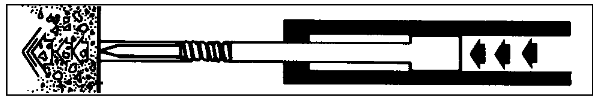
Protective Equipment

In addition to the standard personal protective equipment required on construction projects (see the Personal Protective Equipment chapter in this manual), the operator of a powder-actuated tool should wear hearing protection, eye protection, and a face shield. Heavy shirts and pants provide some protection against ricochets and flying fragments of material and fasteners.

Tool Types

High-Velocity — High-velocity powder-actuated tools use the expanding gases from the exploding cartridge to propel the fastener. The gases push directly against the fastener. These tools are rarely used in construction, except in special cases to penetrate thick steel or very hard material — they are usually used in military, salvage, or underwater applications. No one should operate high-velocity tools without special training.

Low-Velocity — Most powder-actuated tools used in construction are low-velocity. The expanding gases from the exploding cartridge push against a piston which in turn drives the fastener into the base material.



Many different low-velocity tools are available, from single-shot models to semi-automatic models using multiple cartridges in strip or disk holders. Some tools are specific to one size of fastener or type of cartridge. Most can be fitted with various pistons, base plates, spall stops, and protective shields for different jobs.

Pistons

Specialized pistons are available for different fasteners. Such pistons are designed for the fastener and should not be used with other types. Misusing a tool with a specialized piston can result in under- or over-driven fasteners or fasteners leaving the barrel misaligned, leading to ricochets. Some general-purpose tools can take various types of pistons.

Fasteners

Fasteners used with powder-actuated tools are made of special steel to penetrate materials without breaking or bending. Never use any kind of substitute for a properly manufactured fastener.

Generally pins and studs should not be used on hard, brittle, or glazed materials such as cast iron, marble, tiles, and most stone. The fastener will either fail to penetrate and ricochet or the base material will shatter.

Materials whose hardness or ductility is unknown should be tested first. Try to drive a pin into the material with a normal hammer. If the pin point is blunted or fails to penetrate at least 2 mm (1/16"), a powder-actuated tool should **not** be used.

Fasteners are invariably fitted with a plastic guide device. Its purpose is twofold. When the fastener is inserted into the barrel the guide keeps the fastener from dropping out. It also aligns the fastener inside the barrel so it will penetrate the base material at right angles.

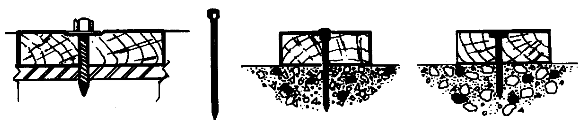
There are two basic types of fasteners – pins and studs.

Pins are fasteners designed to attach one material to another, such as wood to concrete. They resemble nails, but there the similarity stops. Ordinary nails cannot be used as fasteners in powder-actuated tools.

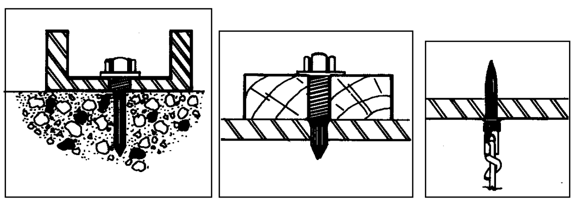
Head diameters for pins are available between 7 mm (1/4") and 9 mm (3/8"). Lengths vary from 12 mm (1/2") to 76 mm (3"). Washers of various types and diameters are available for different applications.

Pins should be selected for appropriate length, head size, and application. As a general rule, pins need not be driven into concrete more than 25 mm (1"). Using a longer pin is generally unnecessary and also requires a stronger cartridge.

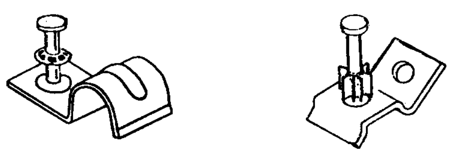
Follow the manufacturer's directions on length, penetration, and appropriate material. For example, one cut-nail fastener is available for fastening drywall to relatively soft base materials, but is recommended for virtually no other application. Testing may be necessary on some masonry materials that vary widely in hardness and durability.



Studs are fasteners consisting of a shank which is driven into the base material and an exposed portion to which a fitting or other object can be attached. The exposed portion may be threaded for attachments made with a nut. Studs are also available in an eye-pin configuration for running wire through the eye.



Clip Assemblies - Fastening to the base material is done by a pin, but the pin is attached to a clip assembly configured to secure a uniquely shaped item. Clip assemblies are available, for instance, to hold conduit. One ceiling configuration comes with pre-tied 12 gauge wire.



Cartridges

Manufacturers recommend certain cartridges for certain applications. Because recommendations cannot cover every possibility, testing may be required with unfamiliar base materials.

Cartridges come in .22, .25, and .27 calibre sizes. Larger calibres hold more powder which drives the fastener further – or into harder base materials. In addition, all three calibres are available with different levels of powder charge. For some tools there may be as many as six different powder charges available. Some manufacturers produce tools that use a long-case version of the .22-calibre cartridge. It is critical that operators understand cartridge selection and cartridge identification systems.

COLOUR	NUMBER	CARTRIDGE POWER
Grey	1	Lowest
Brown	2	
Green	3	
Yellow	4	
Red	5	
Purple	6	Highest

Shots may be packaged/loaded as single cartridges, strips of ten in a plastic holder, or a round disk holding ten cartridges. The tool model will determine the calibre and how the tool is to be loaded.

Number identifications are printed on the outside of cartridge packages. Cartridge tips are colour-dipped for identification. Some strip cartridges are held in a plastic strip the same colour as the cartridge tips.

The general rule is to start with the weakest cartridge and increase one cartridge colour/load number at a time to reach the penetration required. Too strong a charge may cause shattering, ricochets, or blow-through. Too weak a cartridge will keep the fastener from seating itself properly.

Tool Power Controls

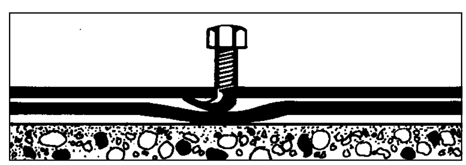
Many tools feature a “power control” device. This allows an operator to make a tool adjustment so that either all or only part of the available cartridge power is used. Power controls may ultimately let manufacturers market only one cartridge in each calibre. The goal would be to handle every application which the calibre is capable of performing with one cartridge, power-controlled to the appropriate driving force needed.

Fastening Steel

Low-velocity powder-actuated tools should not be used on hardened steels, tool steels, or spring steels. Where the grade of steel is unknown, test by trying to hammer the fastener in. If the pin is blunted, bent, or fails to enter at least 2 mm (1/16"), do not use a low-velocity powder-actuated tool – it's not up to the job.

Don't try to fire a fastener any closer than 13 mm (1/2") to the free edge of steel. Keep in mind that this applies only to steel. When fastening steel to concrete, you must consider the allowable margin for concrete as well: 63 mm (2½").

When fastening two pieces of thin sheet steel to a base material, hold the sheets together. Gaps caused by bending may lead to ricochets.



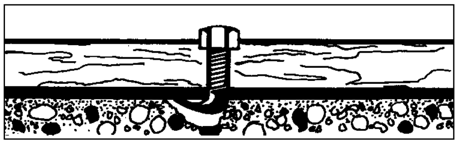
Ricochet

Special spall stops or protective shields are required for applications such as fastening sheet metal to masonry or sheet metal to structural steel. Consult the operating manual or the manufacturer to ensure that the right components are being used for the job.

Fastening Concrete and Masonry

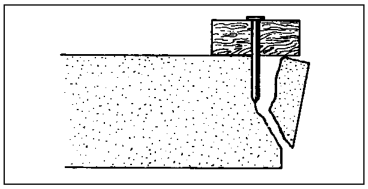
Concrete and masonry materials are not always uniform in consistency or hardness. As a result, they may spall, chip, or cause a ricochet when the fastener strikes a spot or layer harder than the rest. Use the spall guard recommended by the manufacturer.

Once material is spalled or left with a ricochet hole, do not fire a second pin any closer than 50 mm (2") to the damaged area. The area may be weakened and spall further or cause a ricochet off its sloped edge.



Ricochet off a sloped edge.

Pins tend to cause breaks near the edges of concrete and masonry. Don't drive pins closer than 63 mm (2½") to a free edge.



Misfires

With misfired cartridges, follow the procedures stated in the operating manual for the tool you are using. Because of the wide variety of tools available, procedures for misfires may differ. When such information is not available, take the following steps.

- Continue to hold the tool against the base material for at least 30 seconds. This protects against a delayed discharge of the cartridge.
- Remove the cartridge from the tool. During removal keep the tool pointed safely toward soft material such as wood. Never use any kind of prying device to extract the cartridge from the chamber. If the cartridge is wedged or stuck, tag the tool "DEFECTIVE and LOADED" and lock it in its storage container. Never try to dismantle a tool with a cartridge stuck or wedged in it. Again, tag it "DEFECTIVE and LOADED," lock it away, and call the manufacturer's representative for help.
- Regulations require that a misfired cartridge be placed in a container of water.
- Keep the misfired cartridge separate from unused cartridges and return it to the manufacturer for disposal. Never throw misfired cartridges in the garbage.
- Be cautious. The problem may be a misfired cartridge, but the tool may also be defective. Check the tool for obvious damage, perform function tests, and use the tool only if it operates properly.

General Safeguards

- Workers who pick up a powder-actuated tool must immediately prove to themselves that the tool is not loaded. This action must become instinctive and be carried out before anything else is done with the tool. Even after watching someone else handle the tool before passing it on, make sure that it's not loaded.
- Powder-actuated tools should be used, handled, and stored properly.
- Never put your hand or fingers over the end of the muzzle for any reason, even when the tools are not loaded with fasteners.
- Tools must be inspected and function-tested before work starts. Proper training and the operator's manual will describe how to carry out both of these requirements.
- Operators must be trained on the powder-actuated tools they are using and must wear all the required personal protective equipment.
- Fasteners should not be fired through pre-drilled holes for two reasons:
  1) Unless the fastener hits the hole accurately, it will probably shatter the edge.
  2) The fastener derives its holding power from compressing the material around it. A pre-drilled hole reduces this pressure and therefore the fastener's holding power. (This is why studs and pins driven into steel should penetrate completely through the metal. Otherwise the compressed steel trying to regain its original position can loosen the fastener by pushing against the point. With the tip completely through the metal the same pressure only works to squeeze the pin tighter.)
- Firing explosive-actuated tools from ladders is not recommended. From a ladder it can be difficult to press the tool muzzle against the base material with enough pressure to fire. For tasks overhead or at heights, work from a scaffold or another approved work platform to ensure solid, balanced footing. As an alternative use a manufacturer's pole accessory if the reach is normal ceiling height (8-10 feet). The pole secures the tool and permits firing by the operator standing below.
- Do not leave the tool unattended unless it's locked in a box.
- Load the tool immediately before firing. Don't walk around with the tool loaded.
- Do not use powder-actuated tools in areas where there may be exposure to explosive vapours or gases.

Maintenance

Tools in regular use should be cleaned daily. Tools used intermittently should be cleaned after firing.

All parts of the tool exposed to detonation gases from the cartridge should be cleaned and lightly oiled according to the manfuacturer's instructions. The cartridge magazine port, cartridge chamber, and piston sleeve should be wiped clean but **never** be oiled.

The tool brush supplied is adequate for most fouling. Stubborn carbon should be loosened with a manufacturer's spray detergent oil. Tools being checked for immediate use should be wiped dry of oil.

Failure to clean the tool as recommended can lead to corrosion, pitting, fouling, and failure to work properly. Ideally, the tool should be cleaned before being returned to storage.

Tools with a power control adjustment will accumulate additional powder residue from firing–especially when the control is set to restrict the amount of cartridge strength being used. Semi-automatic tools may also accumulate powder residue. These tools need to be cleaned more often.

Sluggish performance may indicate that a tool needs cleaning. Tool action will slow to the point where a competent operator can detect the difference. Most manufacturers recommend major maintenance, inspection, and cleaning every six months. This involves stripping, inspecting, and cleaning parts not covered in daily maintenance.

Storage

Regulations require that both the tool and the cartridges be stored in a locked container with explosive loads of different strengths in separate containers. Cartridges should only be removed from the locked container when they are going to be used immediately.

Regulations

- Any worker using an explosive-actuated tool must be instructed in its safe and proper use.
- Before using the tool, the operator must check to ensure that it is in good working order. This means inspection and function testing.
- Tools firing fasteners at a velocity of more than 90 metres/second must have a protective guard at least 75 mm in diameter, mounted at right angles to the barrel of the tool and centered on the muzzle end of the tool, if practical.
- The tool must require two separate actions before it will fire:
  1) pressure against the surface of the material
  2) action of the trigger.
- Explosive-actuated tools must be stored in a locked container when not in use or when left unattended.
- The tool must not be loaded until ready for immediate use.
- Whether loaded or unloaded, the tool must never be pointed at anyone.
- Cartridges must be marked or labelled for easy identification. Cartridges of different strengths must be stored in separate containers.
- Misfired cartridges must be placed in a container of water and be removed from the project.

6 WELDING AND CUTTING

Welding is a process which uses heat and/or pressure to join metals.

Arc welding is by far the most commonly used in construction. Molten metal from the workpiece and a filler metal from an electrode form a common puddle which cools to form a weld.

Flame cutting is an allied process that requires the use of a torch, fuel gas, and oxygen to cut metals – primarily steel.

For some of the information in this chapter, the Construction Safety Association of Ontario gratefully acknowledges its use of the Canadian Standards Association standard CAN/CSA-W117.2 *Safety in Welding, Cutting and Allied Processes*, copyright CSA.

Welding Methods

Shielded Metal Arc Welding (SMAW) is the most common arc welding process in construction (Figure 20.1).

SMAW uses a short length of consumable electrode which melts as it maintains the arc. Melted metal from the electrode is carried across the arc to become the filler metal of the weld.

The electrode is coated with a complex mix of chemicals that releases a shielding gas such as carbon dioxide to keep air out of the arc zone and protect the weld from oxidation. The composition of the coating varies with the metal being welded.

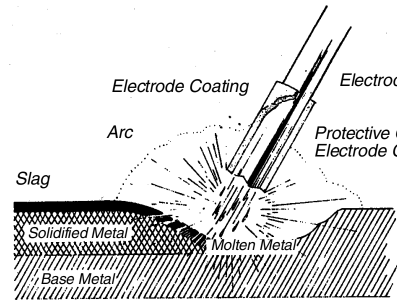


Figure 20.1

Gas Metal Arc (GMAW) or Metal Inert Gas Welding (MIG) uses an uncoated consumable wire that is fed continuously down the middle of the welding torch. A ring-like tube around the wire transports an inert gas such as argon, helium, or carbon dioxide from an outside source to the arc zone to prevent oxidation of the weld (Figure 20.2).

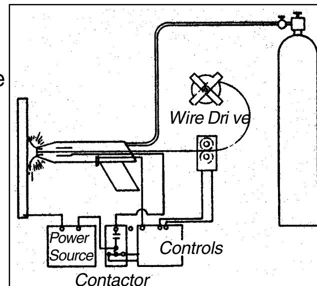


Figure 20.2

Flux Cored Arc Welding (FCAW) is a variation of MIG welding. It uses a hollow consumable wire whose core contains various chemicals that generate shielding gases to strengthen the weld (Figure 20.3).

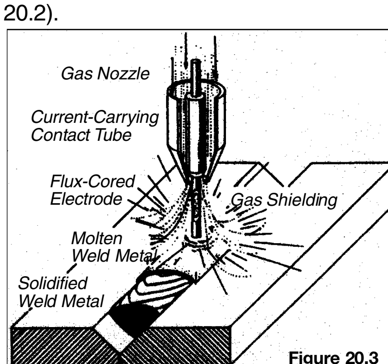


Figure 20.3

Gas Tungsten Arc Welding (GTAW) or **Tungsten Inert Gas Welding (TIG)** uses a non-consumable tungsten electrode that maintains the arc and provides enough heat to join metals (Figure 20.4). Filler metal is added in the form of a rod held close to the arc. The rod melts and deposits filler metal at the weld. Shielding gases may or may not be used, depending on the metal being welded.

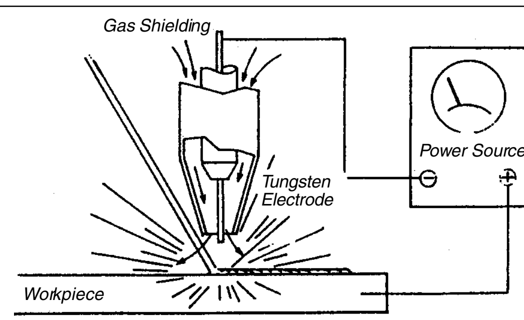


Figure 20.4

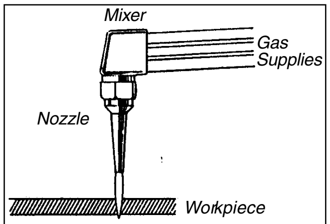


Figure 20.5

Oxyacetylene Welding and Cutting burns a mixture of gases – oxygen and acetylene – to generate heat for welding metals (Figure 20.5). It's the most common fuel gas cutting and welding used in construction. The process may also employ the use of a filler metal.

Acetylene

Acetylene is a mixture of carbon and hydrogen. Its stored energy is released as heat when it burns. When burned with oxygen, acetylene can produce a higher flame temperature (3,300°C) than any other gas used commercially. The wide flammable range of acetylene (2.5% to 81% in air) is greater than that of other commonly used gases, with consequently greater hazard.

Other Fuel Gases

Fuel gases for welding are used alone or with oxygen. Examples include propane, propylene, and natural gas.

Types of Base Metals Welded

Mild Steel (an alloy of iron, carbon, silicon, and occasionally molybdenum or manganese).

Stainless and High Alloy Steels (containing iron, nickel, chromium, and occasionally cobalt, vanadium, manganese, and molybdenum).

Aluminum (either pure or as an alloy containing magnesium, silicon, and occasionally chromium).

Galvanized steel (steel that has been coated with a layer of zinc to prevent corrosion).

Welding Hazards

Welders in construction are exposed to a wide range of hazards such as inhalation of toxic fumes and gases, serious burns from hot metal, and electric shocks from welding cable.

Eye protection is a must for welders and others who may be exposed to the welding process.

Once a chemical from welding has entered the body it may have a toxic effect. Effects can range from mild irritation to death and are influenced by a number of factors. Different organs may also be affected, such as the lungs, kidneys, and brain.

The two major types of effects are acute and chronic, as described in the chapter on basic occupational health.

Welding Hazards

Physical	- ionizing radiation (x-rays, gamma rays)
	- non-ionizing radiation (ultraviolet, infrared)
	- visible light
	- temperature extremes
	- noise
	- electrical energy
Chemical	- flammable/combustible products
	- welding fumes
	- toxic gases
	- dust
Biological	- bacteria
	- fungi
	- viruses

Physical Hazards

Radiation

Both ionizing and non-ionizing radiation may be encountered by welders and their helpers. Ionizing is more hazardous because it can contribute directly to cancer.

Ionizing - A common source is the emission of x-rays and gamma rays from equipment used to gauge the density and thickness of pipes and to check welds.

Non-ionizing - A major source is ultraviolet, infrared, and visible light radiation from sunlight or welding.

Radiation produced by the welding process is mainly non-ionizing, which includes electromagnetic fields, infrared radiation, visible light, and ultraviolet radiation.

Exposure to ultraviolet (UV) radiation can result directly from the arc or from a reflection off bright objects such as shiny metal or white clothing. It can cause “arc eye” when sight is not adequately protected. Eyes become watery and painful anywhere from 2 to 24 hours after exposure. The condition may last 1-5 days but is usually reversible with no lasting effects. However, repeated exposure may result in scar tissue that can impair vision.

UV exposure may also cause a temporary loss of visual sharpness called “fluorescence.”

Skin reddening, commonly known as sunburn, is another hazard of UV exposure. Blistering may occur in extreme cases. Although excessive exposure to UV radiation from the sun has been linked to skin cancer, there are no reports of increased skin cancer rates from welding exposure.

The intensity of UV radiation varies with the type of welding. Generally, the higher the temperature of the welding process the higher the UV radiation.

Infrared radiation is hazardous for its thermal or heating effects. Excessive exposure to the eye may cause damage.

Visible light is released at high intensity by welding. Short-term exposure can produce “flash blindness” in which vision is affected by after-images and temporary blind spots. Repeated exposure to high-intensity visible light can produce chronic conjunctivitis, characterized by red, tearful eyes.

X-rays and gamma rays are invisible forms of *ionizing* radiation used to inspect welds and can be extremely damaging to unprotected parts of the body. Keep well away from any area where this type of testing is under way. X-rays are also produced during electron beam welding. The welding chamber must be completely shielded to confine the x-rays and protect the operator.

Extreme Temperatures

Very high temperatures are caused by the welding process. Gas flames may reach 3,300°C. Metals melt in a range from 260°C to 2,760°C. Welded materials, the work environment, and weather may all be sources of excessive heat which can cause muscle cramps, dehydration, sudden collapse, and unconsciousness.

Welders may suffer frostbite and hypothermia when working in extreme cold climates or with welding gases stored at temperatures as low as -268°C. Exposure to freezing temperatures can lead to fatigue, irregular breathing, lowered blood pressure, confusion, and loss of consciousness. Heat stress and cold stress are both life-threatening and, if not treated in time, can be fatal.

Noise

Sound waves over 85 dBA emitted at high intensity by welding equipment can lead to hearing loss. Noise has also been linked to headaches, stress, increased blood pressure, nervousness, and excitability. See the chapter on personal protective equipment for information on maximum exposures for workers not equipped with hearing protection.

Welding noise is produced by the power source, the welding process, and by secondary activities such as grinding and hammering. Gasoline power sources may lead to sound exposures over 95 dBA. Arc gouging may produce sound levels over 110 dBA. Grinding, machining, polishing, hammering, and slag removal all contribute to high levels of noise. Substantial hearing loss has been observed in welders.

Electrical Energy

Electrical shock is the effect produced by current on the nervous system as it passes through the body. Electrical shock may cause violent muscular contractions, leading to falls and injuries. It may also have fatal effects on the heart and lungs.

Electrical shock may occur as a result of improper grounding and/or contact with current through damp clothing, wet floors, and other humid conditions. Even if the shock itself is not fatal, the jolt may still cause welders to fall from their work positions.

Electrical burns are an additional hazard. The burns often occur below the skin surface and can damage muscle and nerve tissue. In severe cases, the results can be fatal.

The extent of injury due to electrical shock depends on voltage and the body's resistance to the current passing through it (see Hazards: Electricity). Even low voltages used in arc welding can be dangerous under damp or humid conditions. Welders should keep clothing, gloves, and boots dry and stay well insulated from work surfaces, the electrode, the electrode holder, and grounded surfaces.

Stray Current

Stray welding current may cause extensive damage to equipment, buildings, and electrical circuits under certain conditions.

Chemical Hazards

Chlorinated solvents for degreasing, zinc chromate-based paint for anti-corrosion coatings, cadmium or chromium dusts from grinding, and welding fumes are all classified as chemical hazards.

Arc welders are at particular risk since the high temperatures generated by the arc can release heavy concentrations of airborne contaminants.

Chemical hazards may injure welders through inhalation, skin absorption, ingestion, or injection into the body. Damage to respiratory, digestive, nervous, and reproductive systems may result. Symptoms of overexposure to chemicals may include nosebleeds, headaches, nausea, fainting, and dizziness.

Read the manufacturer's material safety data sheet (MSDS) for information on protective measures for any chemical you encounter in the workplace.

The most common chemical hazards from welding are airborne contaminants that can be subdivided into the following groups:

- fumes
- gases/vapours
- dusts.

The amount and type of air contamination from these sources depends on the welding process, the base metal, and the shielding gas. Toxicity depends on the concentration of the contaminants and the physiological response of individual workers.

FUMES

Some of the metal melted at high temperates during welding vaporizes. The metal vapour then oxidizes to form a metal oxide. When this vapour cools, suspended solid particles called fume particles are produced. Welding fumes consist primarily of suspended metal particles invisible to the naked eye.

Metal fumes are the most common and the most serious health hazard to welders. Fume particles may reach deep into the lungs and cause damage to lung tissue or enter the bloodstream and travel to other parts of the body. The following are some common welding fumes.

Beryllium is a hardening agent found in copper, magnesium, and aluminum alloys. Overexposure may cause *metal fume fever*. Lasting for 18-24 hours, the symptoms include fever, chills, coughing, dryness of mouth and throat, muscular pains, weakness, fatigue, nausea, vomiting, and headaches. Metal fume fever usually occurs several hours after the exposure and the signs and symptoms usually abate 12-24 hours after the exposure with complete recovery. Immunity is quickly acquired if exposure occurs daily, but is quickly lost during weekends and holidays. For this reason, metal fume fever is sometimes called “Monday morning sickness.”

Long term (chronic) exposure to beryllium fumes can result in respiratory disease. Symptoms may include coughing and shortness of breath. Beryllium is a suspected carcinogen — that is, it may cause cancer in human tissue. It is highly toxic. Prolonged exposure can be fatal.

Cadmium-plated or cadmium-containing parts resemble, and are often mistaken for, galvanized metal. Cadmium coatings can produce a high concentration of cadmium oxide fumes during welding. Cadmium is also found in solders (especially silver solder) and brazes.

Overexposure to cadmium can cause metal fume fever.

Symptoms include respiratory irritation, a sore, dry throat, and a metallic taste followed by cough, chest pain, and difficulty in breathing. Overexposure may also make fluid accumulate in the lungs (pulmonary edema) and may cause death. The liver, kidneys, and bone marrow can also be injured by the presence of this metal.

Chromium is found in many steel alloys. Known to be a skin sensitizer, it may cause skin rashes and skin ulcers with repeated exposure. Chromium also irritates mucous membranes in areas such as eyes and nose and may cause perforation of the nasal septa. Inhaled chromium may cause edema and bronchitis.

Lead can be found in lead-based paints and some metal alloys. Lead poisoning results from inhalation of lead fumes from these lead-based materials. The welding and cutting of lead or lead-coated materials is the primary source of lead poisoning for welders. Symptoms include loss of appetite, anemia, abdominal pains, and kidney and nerve damage. Under Ontario law, lead is a **designated substance** requiring special precautions for use and handling.

Nickel is found in many steel alloys including stainless steel and monel. It is a sensitizing agent and in certain forms is toxic and carcinogenic. Nickel fumes can also produce cyanosis, delirium, and death 4 to 11 days after exposure.

Zinc is found in aluminum and magnesium alloys, brass, corrosion-resistant coatings such as galvanized metal, and brazing alloys. Inhaling zinc fumes during the cutting or welding of these metals may cause metal fume fever.

VAPOURS/GASES

A gas is a low-density chemical compound that normally fills the space in which it is released. It has no physical shape or form. Vapour is a gas produced by evaporation.

Several hazardous vapours and gases may be produced by welding. Ultraviolet radiation, surface coatings, shielding gases, and rod coatings are primary sources of vapours and gases. Overexposure may produce one or more of the following respiratory effects:

- inflammation of the lungs
- pulmonary edema (fluid accumulation in the lungs)
- emphysema (loss of elasticity in lung tissue)
- chronic bronchitis
- asphyxiation.

Hydrogen fluoride (HF) gas can be released by the decomposition of rod coatings during welding and irritates the eyes and respiratory system. Overexposure can injure lungs, kidney, liver, and bones. Continued low-level exposures can result in chronic irritation of nose, throat, and bronchial tubes.

Nitrogen oxide (NOx) gas is released through a reaction of nitrogen and oxygen promoted by high heat and/or UV radiation. It is severely irritating to the mucous membranes and the eyes. High concentrations may produce coughing and chest pain. Accumulation of fluid in the lungs can occur several hours after exposure and may be fatal.

Ozone gas is formed by the reaction of oxygen in air with the ultraviolet radiation from the welding arc. It may be a problem during gas-shielded metal arc welding in confined areas with poor ventilation. Overexposure can result in an accumulation of fluid in the lungs (pulmonary edema) which may be fatal.

Phosgene gas is formed by the heating of chlorinated hydrocarbon degreasing agents. It is a severe lung irritant and overexposure may cause excess fluid in the lungs. Death may result from cardiac or respiratory arrest. The onset of symptoms may be delayed for up to 72 hours.

Phosphine or hydrogen phosphide is produced when steel with a phosphate rustproofing coating is welded. High concentrations irritate eyes, nose, and skin.

Asphyxiants are chemicals which interfere with the transfer of oxygen to the tissues. The exposed individual suffocates because the bloodstream cannot supply enough oxygen for life. There are two main classes of asphyxiants – simple and chemical.

Simple asphyxiants displace oxygen in air, thereby leaving little or none for breathing. In welding, simple asphyxiants include commonly used fuel and shielding gases such as acetylene, hydrogen, propane, argon, helium, and carbon dioxide. When the normal oxygen level of 21% drops to 16%, breathing as well as other problems begin, such as lightheadedness, buzzing in the ears, and rapid heartbeat.

Chemical asphyxiants interfere with the body's ability to transport or use oxygen. Chemical asphyxiants can be produced by the flame-cutting of metal surfaces coated, for instance, with rust inhibitors. Hydrogen cyanide, hydrogen sulphide, and carbon monoxide are examples of chemical asphyxiants – all highly toxic.

DUSTS

Dusts are fine particles of a solid which can remain suspended in air and are less than 10 micrometres in size. This means they can reach the lungs. Dusts may be produced by fluxes and rod coatings which release phosphates, silicates, and silica. The most hazardous of these is silica which can produce silicosis – a disease of the lung which causes shortness of breath.

Biological Hazards

Biological hazards are a relatively minor concern for construction welders. However, exposure to bacteria may occur in sewer work, while air handling systems contaminated by bacteria and fungi can cause legionnaires' disease and other conditions. A fungus that grows on bird or bat droppings is responsible for a disease called histoplasmosis, producing flu-like symptoms. Contact may occur where buildings contaminated with droppings are being renovated or demolished.

Fires/Explosions

There is always a threat of fire with welding. Fires may result from chemicals reacting with one another to form explosive or flammable mixtures. Many chemicals by themselves have low ignition points and are subject to burning or exploding if exposed to the heat, sparks, slag, or flame common in welding. Even sparks from cutting and grinding may be hot enough to cause a fire.

In welding, oxygen and acetylene present the most common hazards of fire and explosion.

Pure oxygen will not burn or explode but supports the combustion of other materials, causing them to burn much more rapidly than they would in air.

Never use oxygen to blow dust off your clothing. Oxygen will form an explosive mixture with acetylene, hydrogen, and other combustible gases.

Acetylene cylinders are filled with a porous material impregnated with acetone, the solvent for acetylene. Because acetylene is highly soluble in acetone at cylinder pressure, large quantities can be stored in comparatively small cylinders at relatively low pressures.

Preventive Measures

Welding hazards must be recognized, evaluated, and controlled to prevent injury to personnel and damage to property.

Chapter 2 of this manual explains the information on hazardous materials that can be provided by WHMIS symbols, labels, and material safety data sheets.

Once a welding hazard has been identified, controls can be implemented at its source, along its path, or at the worker.

EXPOSURE FACTORS

Types and effects of airborne contaminants produced by welding depend on the working environment, the kind of welding being done, the material being welded, and the welder's posture and welding technique.

The **environment** for welding is a very important factor in the degree of exposure to fumes, vapours, and gases. Welding is best done outside or in open areas with moderate air movement. Air movement is necessary to dissipate fumes before they reach the welder. Enclosed areas with little ventilation can lead to very high exposure levels because the contaminant is not dispersed. In confined spaces, fume, vapour, and gas levels that are dangerous to life and health may result. Welding may also use up the oxygen in a confined space, causing the welder to lose unconsciousness or even die.

The **base metal** to be welded is an important factor in the production of fumes, vapours, and gases. The base metal will vaporize and contribute to the fume.

Coatings such as rust inhibitors have been known to cause increased fume levels which may contain toxic metals. All paints and coatings should be removed from areas to be welded as they can contribute to the amount and toxicity of the welding fume.

Welding rod is responsible for up to 95% of the fume. Rods with the fewest toxic substances can't always be used because the chemistry of the rod must closely match that of the base metal.

Shielding gas used during SMAW can effect the contaminants produced. Using a mixture of argon and carbon dioxide instead of straight carbon dioxide has been found to reduce fume generation by up to 25%. Nitric oxide in the shielding gas for aluminum during GMAW has been found to reduce ozone levels.

Welding process variables can have a big effect on the fume levels produced. Generally, fume concentrations increase with higher current, larger rods, and longer arc length. Arc length should be kept as short as possible while still producing good welds. Polarity is also a factor. Welding with reversed polarity (work piece negative) will result in higher fumes than welding with straight polarity (work piece positive).

The welder's **posture and technique** are crucial factors in influencing exposure. Studies have shown that different welders performing the exact same task can have radically different exposures. Welders who bend over close to the welding location, those who position themselves in the smoke plume, and those who use a longer arc than required will have a much greater exposure. The welder should try to take advantage of existing ventilation (cross drafts, natural, or mechanical) to direct the plume away from the breathing zone.

VENTILATION

Ventilation is required for all cutting, welding, and brazing. Adequate ventilation is defined as the use of air movement to

- reduce concentrations of airborne contaminants below the acceptable limits in the worker's breathing zone and the work area
- prevent the accumulation of combustible gases and vapours, and
- prevent oxygen-deficient or oxygen-enriched atmospheres.

You need to take special steps to provide ventilation

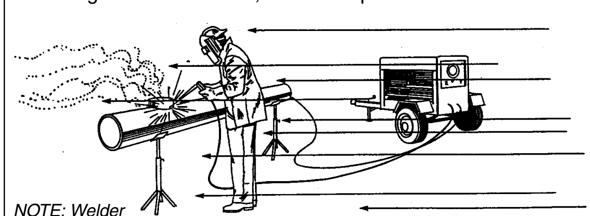
- in a space of less than 283 cubic metres per welder
- in a room with a ceiling of less than 4.9 metres
- in confined spaces or where the area contains partitions or other structures which significantly obstruct cross-ventilation.

Natural dilution ventilation — welding outside in a light breeze or inside with doors and windows open provides large volumes of fresh air which should disperse airborne contaminants sufficiently in most cases. However, it is important for the welder to stay to one side of the plume.

Natural dilution ventilation alone should not be used for welding, cutting, and allied processes in confined spaces or spaces containing structural barriers that restrict natural air movement.

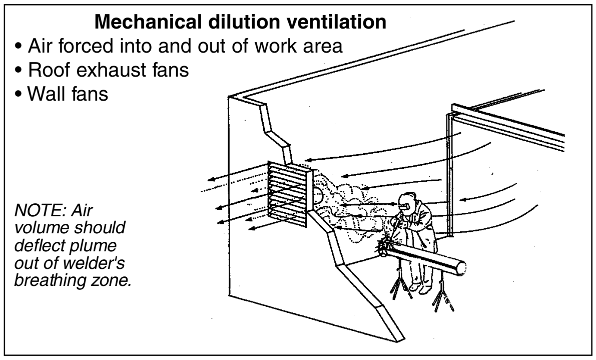
Natural dilution ventilation

- Welding outside in light breeze
- Welding inside with doors, windows open



NOTE: Welder must stay to one side of plume.

Mechanical dilution ventilation is common in most welding shops. Fans such as roof exhaust fans and wall fans force outside air into and out of the building. General mechanical ventilation in most cases will deflect the plume out of the welder's breathing zone. Welders need different amounts of fresh-air ventilation depending on the specific task and the size of rod they're using. For air volume recommendations, see the American Conference of Governmental Industrial Hygienists' *Industrial Ventilation: A manual of recommended practice.*



Local exhaust ventilation consists of an exhaust fan, air cleaner, and ducted system dedicated to removing airborne contaminants at the source and exhausting them outdoors. Local exhaust ventilation is preferred over dilution ventilation because it is better able to prevent airborne contaminants from entering the welder's breathing zone.

Local exhaust ventilation is recommended for welding where toxic airborne contaminants are produced and/or where a high rate of fume is produced – for instance, during GMAW in confined areas with little ventilation where the shielding gases can build up to toxic levels.

There are three types of local exhaust ventilation systems for welding:

1) portable fume extractor with flexible ducting (Figure 20.6)
2) fume extraction gun (Figure 20.7)
3) welding bench with portable or fixed hood (Figure 20.8).

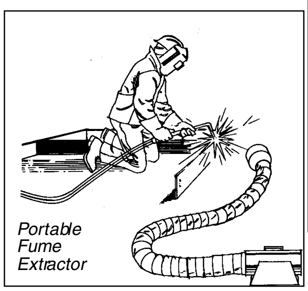


Figure 20.6

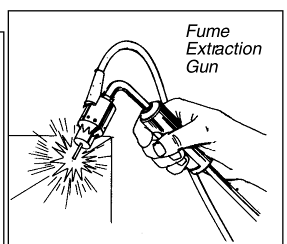


Figure 20.7

Local Exhaust Systems

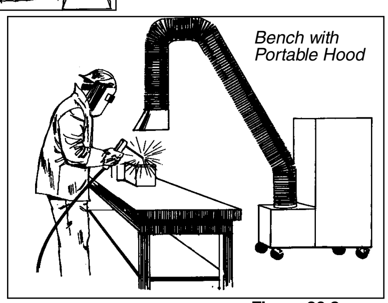


Figure 20.8

The effectiveness of local exhaust ventilation depends on the distance of the hood from the source, air velocity, and hood placement. Hoods should be located close to the source of airborne contaminants. The hood is placed above and to the side of the arc to capture airborne contaminants.

> ***Warning***: In all processes that use shielding gas, air velocities in excess of 30 metres/minute may strip away shielding gas.

Ventilation Requirements

There are two methods for determining ventilation requirements.

One uses air sampling to measure the welder's exposure to airborne contaminants and to determine the effectiveness of the ventilation provided. Monitoring is not well suited to construction because site conditions are constantly changing.

The other method uses tables to select the type of ventilation according to the process, materials, production level, and degree of confinement used in the welding operation.

Ventilation guidelines for different welding processes are spelled out in Canadian Standards Association standard CAN/CSA-W117.2 *Safety in Welding, Cutting and Allied Processes*, copyright CSA.

Other Controls

An isolation chamber is a metal box with built-in sleeves and gloves. The work is welded inside the box and viewed through a window. This method is used to weld metals that produce extremely toxic fumes. The fumes are extracted from the isolation chamber and ducted outdoors.

Respiratory protection will not be required for most welding operations if proper ventilation is provided. However, when ventilation or other measures are not adequate, or when the welding process creates toxic fumes (as with stainless steel and beryllium), respiratory protection must be worn.

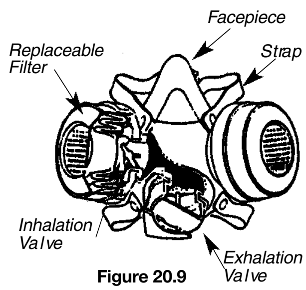


Figure 20.9

Select respiratory protection based on estimated exposure and the toxicity of the materials. Disposable fume respirators are adequate for low fume levels and relatively non-toxic fumes. For higher exposures or for work involving toxic fumes, a half-mask respirator with cartridges suitable for welding fume should be used (Figure 20.9).

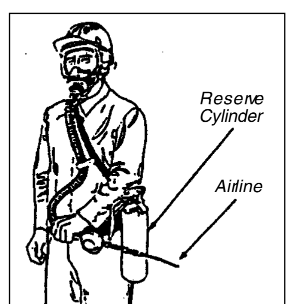


Figure 20.10

In areas where fume or gas concentrations may be immediately dangerous to life and health, a self-contained breathing apparatus (SCBA) or a supplied-air respirator with a reserve cylinder should be used (Figure 20.10). Use only supplied air or self-contained respirators in areas where gases may build up or where there can be a reduction in oxygen.

A welder required to wear a respirator must be instructed in its proper fitting, use, and maintenance. For more information, refer to the personal protective equipment chapter of this manual.

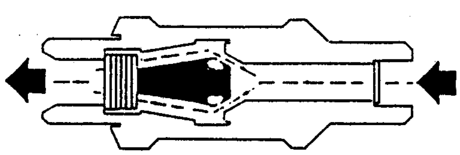
Fire Prevention

Sparks and slag from cutting, grinding, and welding can travel great distances and disappear through cracks in walls and floors or into ducts. They may contact flammable materials or electrical equipment. Fires have started in smoldering materials that went undetected for several hours after work was done.

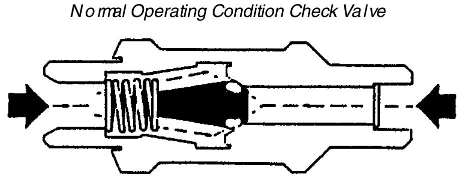
Take the following steps to prevent fires and explosions.

- Obtain a hot work permit through the safety officer if required.
- Keep welding area free of flammable and explosive material.
- Use a flammable gas and oxygen detector to determine whether a hazardous atmosphere exists.
- Provide fire barriers such as metal sheets or fire blankets and fill cracks or crevices in floors to prevent sparks and slag from passing through.
- Provide fire extinguishers suitable for potential types of fire. Know where the extinguishers are and how to use them.
- Provide a firewatch where necessary – a worker to watch for fires as the welder works and for at least thirty minutes afterward. The person must be fully trained in the location of fire alarms and the use of fire-fighting equipment. Some situations may require more than one firewatch, such as on both sides of a wall or on more than one floor.

Cutting torches should be equipped with reverse flow check valves and flame arrestors to prevent flashback and explosion (Figure 20.11). These valves must be installed according to the manufacturer's instructions.



Normal Operating Condition Check Valve



Reverse Flow Condition Check Valve

Figure 20.11

Drums, tanks, and closed containers that have held flammable or combustible materials should be thoroughly cleaned before welding or cutting. As an added precaution, purge with an inert gas such as nitrogen or carbon dioxide and fill with water to within an inch or two of the place to be welded or cut and vent to atmosphere (Figure 20.12).

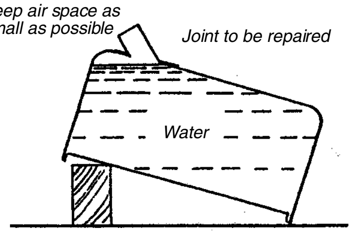


Figure 20.12

Many containers that have held flammable or combustible materials present special problems. Consult the manufacturer or the product MSDS for detailed information.

Arc Welding and Cutting

Equipment

Only use manual electrode holders that are specifically designed for arc welding and cutting and can safely handle the maximum rated current capacity required by the electrodes.

Any current-carrying parts passing through the portion of the holder in the welder or cutter's hand, and the outer surfaces of the jaws of the holder, should be fully insulated against the maximum voltage encountered to ground.

Arc welding and cutting cables should be completely insulated, flexible, and capable of handling the maximum current requirements of the work as well as the duty cycle under which the welder or cutter is working.

Avoid repairing or splicing cable within 10 feet of the cable end to which the electrode holder is connected. If necessary, use standard insulated connectors or splices which have the same insulating qualities as the cable being used. Connections made with cable lugs must be securely fastened together to give good electrical contact. The exposed parts of the lugs must be completely insulated. Do not use cables with cracked or damaged insulation, or exposed conductors or end connectors.

A welding cable should have a safe current carrying capacity equal to or exceeding the maximum capacity of the welding or cutting machine.

> ***Warning:*** Never use the following as part of the current path:
> - cranes
> - hoists
> - chains
> - wire ropes
> - elevator structures
> - pipelines containing gases or flammable liquids
> - conduits containing electrical circuits.

The work lead, often incorrectly referred to as the ground lead, should be connected as close as possible to the location being welded to ensure that the current returns directly to the source through the work lead.

A structure employed as a work lead must have suitable electrical contact at all joints. Inspect the structure periodically to ensure that it is still safe. Never use any structure as a circuit when it generates arc, sparks, or heat at any point.

The frames on all arc welding and cutting machines must be grounded according to the CSA standard or the regulatory authority. Inspect all ground connections to ensure that they are mechanically sound and electrically adequate for the required current.

Procedures

- When electrode holders are to be left unattended, remove electrode and place holder so it will not make contact with other workers or conducting objects.
- Never change electrodes with bare hands or with wet gloves.
- Do not dip hot electrode holders in water to cool them off.
- Keep cables dry and free of grease to prevent premature breakdown of insulation.
- Cables that must be laid on the floor or ground should be protected from damage and entanglement.
- Keep welding cables away from power supply cables and high tension wires.
- Never coil or loop welding cables around any part of your body.
- Do not weld with cables that are coiled up or on spools. Unwind and lay cables out when in use.
- Before moving an arc welding or cutting machine, or when leaving machine unattended, turn the power supply OFF.
- Report any faulty or defective equipment to your supervisor.
- Read and follow the equipment manufacturer's instructions carefully.
- Prevent shock by using well-insulated electrode holders and cables, dry clothing and gloves, rubber-soled safety boots, and insulating material (such as a board) if working on metal.
- All arc welding and cutting operations should be shielded by non-combustible or flame-proof screens to protect other workers from direct rays of the arc.
- Keep chlorinated solvents shielded from the exposed arc or at least 200 feet away. Surfaces prepared with chlorinated solvents must be thoroughly dry before being welded. This is especially important when using gas-shielded metal-arc welding, since it produces high levels of ultraviolet radiation.
- Check for the flammability and toxicity of any preservative coating before welding, cutting, or heating. Highly flammable coatings should be stripped from the area to be welded. In enclosed spaces, toxic preservative coatings should be stripped several inches back from the area of heat application or the welder should be protected by an airline respirator. In the open air, a suitable cartridge respirator should be used. Generally, with any preservative coating, check the manufacturer's MSDS for specific details regarding toxicity and personal protection required.
- Shut off the power supply before connecting the welding machine to the building's electrical power.

Oxyacetyelene Welding and Cutting

Handling Cylinders

- Do not accept or use any compressed gas cylinder which does not have proper identification of its contents.
- Transport cylinders securely on a hand truck whenever possible. Never drag them.
- Protect cylinders and any related piping and fittings against damage.

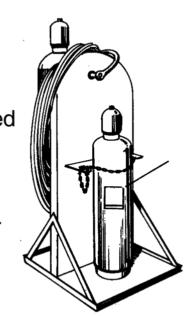


Figure 20.13

- Do not use slings or magnets for hoisting cylinders. Use a suitable cradle or platform (Figure 20.13)
- Never drop cylinders or let them strike each other violently.
- Chalk EMPTY or MT on cylinders that are empty. Close valves and replace protective caps.
- Secure transported cylinders to prevent movement or upset.
- Always regard cylinders as full and handle accordingly.
- For answers about handling procedures, consult the manufacturer, supplier, or the MSDS.

Storing Cylinders

- Store cylinders upright in a safe, dry, well-ventilated location maintained specifically for this purpose.
- Never store flammable and combustible materials such as oil and gasoline in the same area.
- Do not store cylinders near elevators, walkways, stairwells, exits, or in places where they may be damaged or knocked over.
- Do not store oxygen cylinders within 20 feet of cylinders containing flammable gases unless they are separated by a partition at least 5 feet high and having a fire-resistance rating of at least 30 minutes (Figure 20.14).
- Store empty and full cylinders separately.
- Prohibit smoking in the storage area.

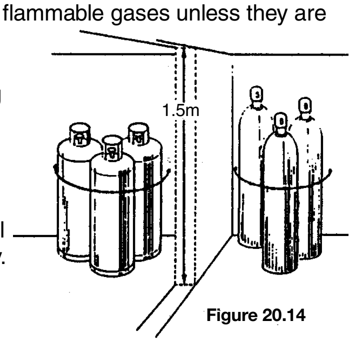


Figure 20.14

Using Cylinders

- Use oxygen and acetylene cylinders in a proper buggy equipped with a fire extinguisher (Figure 20.15). Secure cylinders upright.
- Keep the cylinder valve cap in place when the cylinder is not in use.
- Do not force connections on cylinder threads that do not fit.

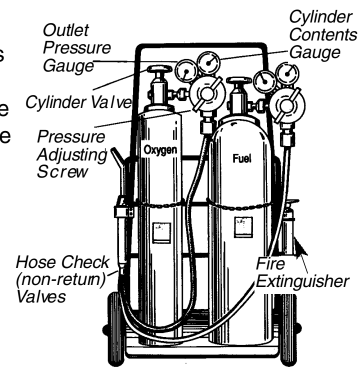


Figure 20.15

- Open cylinder valves slowly. Only use the handwheel, spindle key, or special wrench provided by the supplier.
- Always use a pressure-reducing regulator with compressed gases. For more information see the box below.
- Before connecting a regulator to a cylinder, crack the cylinder valve slightly to remove any debris or dust that may be lodged in the opening. Stand to one side of the opening and make sure the opening is not pointed toward anyone else, other welding operations, or sparks or open flame.
- Open the fuel gas cylinder valve not more than $1\frac{1}{2}$ turns unless marked back-seated.
- Do not use acetylene pressure greater than 15 psig.
- Never allow sparks, molten metal, electric current, or excessive heat to come in contact with cylinders.

- Never use oil or grease as a lubricant on the valves or attachments of oxygen cylinders. Do not handle with oily hands, gloves, or clothing. The combination of oxygen and oil or grease can be highly combustible.
- Never bring cylinders into unventilated rooms or enclosed areas.
- Do not use oxygen in place of compressed air for pneumatic tools.
- Release pressure from the regulator before removing it from the cylinder valve.
- When gas runs out, extinguish the flame and connect the hose to the new cylinder. Purge the line before re-igniting the torch.
- When work is finished, purge regulators, then turn them off. Use a proper handle or wrench to turn off cylinders.

Pressure Regulators

Pressure regulators must be used on both oxygen and fuel gas cylinders to maintain a uniform and controlled supply of gas to the torch.

The oxygen regulator should be designed with a safety relief valve so that, should the diaphragm rupture, pressure from the cylinder will be released safely and the regulator will not explode.

Each regulator (both oxygen and fuel gas) should be equipped with a high-pressure contents gauge and working pressure gauge. Always stand to one side of regulator gauge faces when opening the cylinder valves.

To prevent regulators from being installed on the wrong cylinders, oxygen cylinders and regulators have *right-hand* threads while most fuel gas cylinders and regulators have *left-hand* threads.

Internal and external threads and different diameters also help to prevent wrong connections.

Hoses and hose connections for oxygen and acetylene should be different colours. Red is generally used to identify the fuel gas and green the oxygen. The acetylene union nut has a groove cut around the centre to indicate left-hand thread.

- Protect hoses from traffic, flying sparks, slag, and other damage. Avoid kinks and tangles.
- Repair leaks properly and immediately. Test for leaks by immersing hose in water.
- Use backflow check valves and flame arrestors according to the manufacturer's instructions (Figure 20.11).
- Do not use a hose which has been subject to flashback or which shows evidence of wear or damage without proper and thorough testing.

Backfires occur when the flame burns back into the torch tip, usually accompanied by a loud popping sound. Backfires usually are caused by touching the tip against the work or by using pressures that are too low.

Flashback is much more serious. The flame burns back inside the torch itself with a squealing or hissing sound. If this happens, follow the torch manufacturer's instructions to extinguish the torch in proper sequence.

Many different makes, models, and designs of torches are available. There is no single procedure or sequence to follow in igniting, adjusting, and extinguishing the torch flame. Always follow the manufacturer's instructions.

Oxyacetylene Summary

Startup

- Keep cylinders away from sources of heat or damage and secure them upright.
- Stand to one side and slightly crack cylinder valves to blow out dust.
- Attach regulators to respective cylinders. Tighten nuts with a proper wrench.
- Release pressure adjusting screws on regulators.
- Connect green hose to oxygen regulator and red hose to fuel gas regulator.
- Connect hoses to the torch – green to oxygen inlet and red to fuel gas inlet.
- Connect mixer and welding tip assembly to torch handle.
- Open oxygen cylinder valve slowly and fully.
- Open fuel gas cylinder 3/4 to 1 1/2 turns.
- Open oxygen torch valve. Turn oxygen regulator pressure adjusting screw to desired pressure. Continue oxygen purge for about 10 seconds for each 100 feet of hose. Close oxygen torch valve.
- Open fuel gas torch valve. Turn fuel gas regulator pressure adjusting screw to desired pressure and purge for about 10 seconds for each 100 feet of hose. Close fuel gas torch valve.
- To light torch, follow the manufacturer's instructions. DO NOT USE MATCHES.
- Adjust to desired flame.

Closedown

- Close torch valves according to the manufacturer's instructions.
- Close fuel gas cylinder valve.
- Close oxygen cylinder valve.
- Drain fuel gas cylinder line by opening torch fuel gas valve briefly. Close valve. Drain oxygen line in the same way.
- Re-open both torch valves.
- Release pressure adjusting screws on both regulators.

Regulators and torches can now be disconnected.

Silver Solder Brazing

Silver solder brazing is used for joining metals and steel and disimilar metal combinations where it is necessary to perform the joining of these metals at low temperatures. Applications include medical and laboratory systems, refrigeration, aerospace, and electronic equipment. In brazing, the major hazards are heat, chemicals, and fumes.

Fumes generated during brazing can be a serious hazard. Brazing fluxes generate fluoride fumes when heated. Cadmium in silver brazing alloys vaporizes when overheated and produces cadmium oxide, a highly toxic substance. Cadmium oxide fumes inhaled into the respiratory tract can cause pulmonary distress, shortness or breath, and in cases of severe exposure may cause death.

The most serious cause of cadmium oxide fumes is overheating the silver brazing filler metal. Care must be taken to control the temperature of the silver brazing operation. The torch flame should never be applied directly to the silver brazing filler rod. The heat of the base metal should be used to melt and flow the brazing filler metal.

Cadmium-plated parts can be an even more hazardous source of cadmium fumes, since in brazing these parts the torch flame is applied directly to the base metal. Cadmium plating should be removed before heating or brazing. When in doubt about a base metal, check with the supplier of the part.

Safe Silver Solder Brazing

- Do not heat or braze on cadmium-plated parts.
- Read warning labels on filler metals and fluxes and follow instructions carefully.
- Work in a well-ventilated area or use a supplied-air respirator.
- Apply heat directly to the base metal–not to the brazing filler metal.
- Do not overheat either the base metal or the brazing filler metal.
- Wash hands thoroughly after handling brazing fluxes and filler metals.

Confined Spaces

Welding in enclosed or confined areas creates additional hazards for the welder. The employer must have a written rescue procedure for confined spaces.

In addition to the procedures outlined in the chapter on confined spaces in this manual, take the following precautions.

- Inspect all electrical cables and connections that will be taken into the confined space.
- Perform leak tests on gas hoses and connections to eliminate the risk of introducing gases into the confined space.
- Check for live electrical systems and exposed conductors.
- Use inspection ports, dipsticks, and the knowledge of plant personnel to evaluate hazards from any liquids, solids, sludge, or scale left in the space.
- Isolate the space from any hydraulic, pneumatic, electrical, and steam systems which may introduce hazards into the confined area. Use isolation methods such as blanks, blinds, bleeding, chains, locks, and blocking of stored energy. Tag isolated equipment.
- A competent person must test and evaluate the atmosphere before workers enter a confined space, and at all times during work there. A hazardous atmosphere may already exist or gases and vapours may accumulate from cutting or welding. Oxygen content may become enriched or depleted.
- Ventilate space with clean air before entry and maintain ventilation as long as necessary to prevent the accumulation of hazardous gases, fumes, and vapours.
- Different gases have different weights and may accumulate at floor, ceiling, or in between. Air monitoring should be done throughout the confined space.
- Keep compressed gas cylinders and welding power sources outside the confined space.
- Where practical, ignite and adjust flame for oxy-fuel applications outside the space, then pass the torch inside. Similarly, pass the torch outside the space, then extinguish it.
- When leaving a confined space, remove the torch and hoses and shut off gas supply.
- If adequate ventilation cannot be maintained, use a suitable supplied-air respirator.

It is the responsibility of the employer to have a written **emergency rescue plan** and communicate the plan to all involved. Each person should know what do to and how to do it quickly. Rescue requirements are shown on page 166.

Personal Protective Equipment

In addition to the protective equipment required for all construction workers, welders should wear flame-proof gauntlet gloves, aprons, leggings, shoulder and arm covers, skull caps, and ear protection.

Clothing should be made of non-synthetic materials such as wool. Woollen clothing is preferable to cotton because it is less likely to ignite. Keep sleeves rolled down and collars buttoned up. Wear shirts with flaps over pockets and pants with no cuffs. Remove rings, watches, and other jewelry. Never carry matches or lighters in pockets. Clothing should be free from oil and grease.

Wear high-cut CSA grade 1 footwear laced to the top to keep out sparks and slag.

Protective screens or barriers should be erected to protect people from arc flash, radiation, or spatter. Barriers should be non-reflective and allow air circulation at floor and ceiling levels. Where barriers are not feasible or effective, workers near the welding area should wear proper eye protection and any other equipment required.

Signs should be posted to warn others of welding hazards.

Eye and Face Protection

Welding helmets provide radiation, thermal, electrical, and impact protection for face, neck, forehead, ears, and eyes. Two types are available – the stationary plate helmet and the lift-front or flip-up plate helmet.

The lift-front type should have a fixed impact-resistant safety lens or plate on the inside of the frame next to the eyes to protect the welder against flying particles when the front is lifted. All combination lenses should have a clear impact-resistant safety lens or plate next to the eyes.

There are also special models incorporating earmuff sound arrestors and air purification systems. Special prescription lens plates manufactured to fixed powers are available for workers requiring corrective lenses.

The typical lens assembly for arc welding is shown in Figure 20.16.

The filtered or shaded plate is the radiation barrier. It is necessary to use a filter plate of the proper lens shade to act as a barrier to the harmful light rays and to reduce them to a safe intensity. Guidelines for selection are shown in Figure 20.17.

In addition to common green filters, many special filters are available. Some improve visibility by reducing yellow or red flare. Others make the colour judgment of temperature easier. Some have a special gold coating on the filter lens to provide additional protection by reflecting radiation.

The arc welding lens assembly consists of 3 parts. The outside lens is clear plastic or tempered glass. It protects the shade lens from damage. The centre lens is a shade lens that filters out the harmful light. The inner lens is clear and must be plastic.

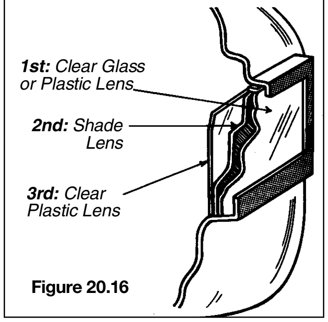


Figure 20.16

Welding hand shields are designed to provide radiation and impact protection for the eyes and face. They are similar to welding helmets except that there are no lift-front models.

Spectacles with full side shields designed to protect against UV radiation and flying objects and suitable filter lenses should always be worn in conjunction with full welding helmets or welding hand shields.

Where only moderate reduction of visible light is required (for instance, gas welding) use eyecup or cover goggles with filter lenses for radiation protection. Goggles should have vents to minimize fogging and baffles to prevent leakage of radiation into the eye cup.

> Welders should not wear contact lenses because airborne dust and dirt may cause excessive irritation of the eyes under the lenses.

Hearing Protection

For hearing protection see the chapter on personal protective equipment. Welders may find that ear muffs are cumbersome and interfere with the welding helmet. Ear plugs may be a better choice but must be properly inserted to ensure protection.

Welders should have their hearing checked every year or so. A simple test can be arranged through your doctor. Once hearing is damaged, the loss is likely permanent. Checkups can detect any early losses and help you to save your remaining hearing.

Lens Shade Selection Guide for Welding

Shade numbers are given as a guide only and may be varied to suit individual needs.

Operation	Electrode Size mm (32nd in.)	Arc Current (Amperes)	Minimum Protective Shade	Suggested[1] Shade No. (Comfort)
Shielded Metal Arc Welding (SMAW)	less than 2.5 (3)	less than 60	7	–
	2.5-4 (3-5)	60-160	8	10
	4-6.4 (5-8)	>160-250	10	12
	more than 6.4 (8)	>250-550	11	14
Gas Metal Arc Welding and Flux Cored (GMAW)		less than 60	7	–
		60-160	10	11
		>160-250	10	12
		>250-500	10	14
Gas Tungsten Arc Welding (GTAW)		less than 50	8	10
		50-150	8	12
		>150-500	10	14
Air Carbon (light)		less than 500	10	12
Arc Cutting (heavy)		500-1000	11	14
Plasma Arc Welding (PAW)		less than 20	6	6 to 8
		20-100	8	10
		>100-400	10	12
		>400-800	11	14
Plasma Arc Cutting (PAC)				
Light[2]		less than 300	8	9
Medium		300-400	9	12
Heavy		>400-800	10	14
Torch Brazing (TB)		–	–	3 or 4
Torch Soldering (TS)		–	–	2
Carbon Arc Welding (CAW)		–	–	14
		Plate Thickness mm	**in.**	
Gas Welding (GW)				
Light		under 3.2	under 1/8	4 or 5
Medium		3.2 to 13	1/8 to 1/2	5 or 6
Heavy		over 13	over 1/2	6 to 8
Oxygen Cutting (OC)				
Light		under 25	under 1	3 or 4
Medium		25 to 150	1 to 6	4 or 5
Heavy		over 150	over 6	5 or 6

Figure 20.17

1. Shade numbers are given as a general rule. It is recommended to begin with a shade that is too dark to see the weld zone. Then one should go to a lighter shade which gives sufficient view of the weld zone without going below the minimum. In gas welding or oxygen cutting where the torch produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line in the visible light of the operation (spectrum).
2. These values apply where the actual arc is clearly seen. Experience has shown that light filters may be used when the arc is hidden by the workpiece.

Radiographic and X-Ray Testing

Some construction trades will encounter situations in which welds, metals, or special coatings require on-site non-destructive testing.

Methods include

1) radiography using a radioactive source for general materials

2) x-rays for testing thicker sections.

Radiography is federally regulated across Canada by the Atomic Energy Control Board. Users must be licensed and operators must be trained according to a Canadian Government Standards Board (CGSB) program.

X-ray testing is provincially regulated–in Ontario by Regulation 632/86.

While many requirements apply to licensed users in both situations, this section will only cover the basic health and safety guidelines for field use.

RADIOGRAPHIC TESTING

Licensed users of radiographic testing systems are responsible for general safety in the field, transportation, emergency procedures, and record-keeping.

Radiographic testing must be carried out in the presence of persons certified to CGSB Standard 48GP4a. In general these people are employees of a recognized testing agency.

Radiographic materials and equipment must be kept locked up in shielded storage containers accessible only to certified personnel. The containers must be conspicuously marked and kept in an area not normally occupied by the workforce. There may be other special requirements which apply, depending on the strength of the radioactive source and the location.

> Radiographic cameras in the field must be used in conjunction with pocket dosimeters, survey meters, directional shields, barrier ropes, radiographic warning signs, and an emergency source container.

General Safety Precautions

- Radiographic testing should be conducted, whenever possible, on an off-shift with as few workers as possible in the work area. The radiographic source should be no stronger than is required for the job. Determining the strength of the source is not generally the responsibility of construction site personnel.
- Equipment should be checked before use. The regulation includes a list of items to be checked, but doing so is not usually the responsibility of site personnel.
- After taking tests where the camera will be moved, the area should be checked using a survey meter.
- Licensed users are required to keep records regarding the use of sources, including dates, times, locations, and other details. These records must be made available to inspectors from the Atomic Energy Control Board. Users are also responsible for advising the local fire department when radioactive material will be in a municipality for longer than 24 hours.

Specific requirements for radiographic camera users are the responsibility of the certified persons operating the equipment.

- The survey meter must be checked to ensure that it is working and calibrated properly.
- Barrier ropes should be set up around the area where testing will be carried out unless this area is isolated and access can be controlled. Barriers must be set up according to the strength of the source.
- Warning signs must be posted along the barriers.
- A patrol must be provided to ensure that no unauthorized persons enter the testing area.
- Before the camera shutter is opened and testing is conducted, the area must be properly shielded.
- Personnel working within the testing area should carry personal dosimeters. Dosimeters may also be advisable for workers in the immediate vicinity outside the barriers.

X-RAY TESTING

Certain basic health and safety precautions are required for the x-ray testing of welds and metals.

- There must be suitable means to prevent unauthorized persons from activating the equipment.
- There must be some device to indicate when the x-ray tube is energized.
- The housing must adequately shield the equipment operator.
- Employers using X-ray equipment must advise the Ministry of Labour that they have such equipment.
- Employers must designate certain persons to be in charge of x-ray equipment who are trained and competent to do so, and must give the Ministry of Labour the names of these designated persons.

Measures and procedures at the x-ray testing site are similar to those required for radiographic testing. The following are the employer's responsibilities.

- Test during off-shifts.
- Cordon off the test area if it cannot be isolated or if entry cannot be controlled.
- Post warning signs along the barrier or at the entrance to the room where testing is taking place.
- Have a patrol to prevent unauthorized entry.
- Install shielding as required before any equipment is activated.
- Ensure that employees in the controlled area wear personal dosimeters.
- Keep dosimeter records.
- Keep at least one radiation survey meter of a suitable type with each portable x-ray machine and calibrate it at least once each year.

Training

Welders, fitters, and welding supervisors should be trained in both the technical and safety aspects of their work. Health and safety training should include but not be limited to the following:

- hazard identification
- safe welding, brazing, and cutting practices
- fire and safety precautions
- control methods for welding hazards

- use, maintenance, and limitations of personal protective equipment.

The effectiveness of health and safety training should be periodically evaluated through

- a workplace inspection to ensure that safe working procedures, equipment, and conditions are implemented.
- air monitoring of common contaminants to determine the effectiveness of controls and compliance with acceptable limits.
- an assessment of control performance (for instance, testing of the ventilation system)
- review of lost-time-injuries
- discussion of the program with the health and safety committee or representative(s).

Any corrective actions necessary should be taken immediately.

7 FORMWORK

Glossary

The following definitions are used in the forming industry. Some terms may be used by other trades as well, but their meanings may be different from these depending upon the application.

Falsework, in relation to a form or structure, means the structural supports and bracing used to support all or part of the form or structure.

Flying formwork is a designed system which can be hoisted between levels as a unit.

Forms are the moulds into which concrete or another material is poured.

Formwork is a system of forms connected together.

Gangforms are large panels designed to be hoisted as a unit, and to be erected, stripped, and re-used.

Knock-down forms are traditional formwork supported by falsework and shoring, assembled from bulk materials, used once, and then dismantled.

Panels are sections of form intended to be connected together.

Sheathing is the material directly supported by wales, and against which concrete is to be placed.

Specialty formwork is designed specifically for a particular structure or placing technique.

Struts are vertical members of shoring that directly resist pressure from wales.

Wales are horizontal members of shoring that are placed against sheathing to directly resist pressure from the sheathing.

General

In most cases, the formwork required for concrete construction is built by carpenters. Shoring and bracing support the forms that contain the wet concrete. Formwork must also support the temporary weight of material such as bundles of reinforcing steel and live loads of workers and equipment.

There are three stages in formwork operations:
— assembly and erection
— concrete placement
— stripping and dismantling.

To be done safely, each of these jobs requires planning, knowledge, and skill from both supervisors and workers. Design and planning are a supervisory function that may also legally require a professional engineer's involvement. Small construction and renovation jobs, however, sometimes call for design on site by workers.

Where design drawings are provided, it is important to construct the formwork as designed. Any confusion regarding the design should be cleared up with the designer.

If site conditions require changes or the design does not seem to suit the situation, clarification should also be obtained from the designer. Formwork failures frequently involve deviations from the original design that were done without consulting the designer. They may also involve human error. For these reasons, formwork and shoring must always be inspected before concrete is placed.

All large formwork installations in Ontario must be designed by a professional engineer. But there are always smaller jobs of moderate height or depth – basements, footings, stairs – that may include formwork designed and constructed on the site.

Every carpenter should therefore know the type of formwork needed and how to build, install, and dismantle it safely.

Formwork must always be constructed according to good, safe, and sound carpentry practice. There must be

— adequate braces and supports
— reliable bearing surfaces, especially where wood structures are involved
— adequate ties, bolts, or bracing to prevent movement or bulging.

Because wood is relatively soft, it will crush under heavy loads such as concrete when the bearing surface of joists on stringers, or studs on wales, is not adequate.

Crushing can be avoided by increasing the bearing area between members, using spreader washers (Figure 189), or increasing the number of joists or studs.

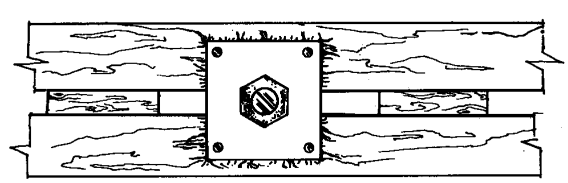


Figure 189
Spreader Washer on Wooden Wale System

Hazards

The following are the main hazard areas in formwork operations.

- **Falls** – They are the major hazard because they are **potentially fatal**. Cramped work areas, inadequate access, failure to install guardrails, failure to use fall-arrest systems, tools or material left underfoot, and surfaces slippery from form oil can all lead to falls. Ladders are also frequently involved in falls.

  Workers must have fall protection whenever they are exposed to the risk of falling more than 3 metres, or falling from any height into dangerous machinery, substances, or objects such as rebar. In some circumstances, you must use fall protection when the height is 2.4 metres (8 ft.) or more. (See chapter on Guardrails.)
- **Materials handling** – **The activity most frequently connected with injury**. Improper or excessive materials handling can result in sprains, strains, and overexertion in shoulders, arms, and back, as well as bruises, abrasions, and crushed fingers.
- **Struck against** – Common because formwork operations are constantly changing and involve the movement of heavy, awkward, and pointed components. Wales, beams, panels, snap-ties, nails, bolts, and rebar can cause punctures, cuts, contusions, and abrasions.
- **Struck by** – Another common cause of injury. Rebar, formwork panels, concrete buckets, and other material hoisted overhead can strike workers. Struck-by injuries can also be caused by hammers, pry bars, stakes, wedges, and material such as joists and panels during stripping.
- **Electrical contact** – Power tools, extension cords, and temporary supply and wiring systems, used under less-than-ideal conditions – mud, ground water, wet excavations, fresh concrete – can lead to ground faults, shortcircuits, and shock hazards. Ground fault circuit interrupters are legally required for portable tools used outdoors or in wet locations.
- **Collapses** – Even with advanced methods of design and installation, there is always the risk that formwork, slabforms, wall forms, and other large components can come loose, slip out of place, or fall over, striking or crushing workers underneath.
- **Health hazards** – The spraying of form oils and curing compounds can irritate the lungs. Contact with these chemicals can irritate the skin, leading to redness, inflammation, or dermatitis. The same conditions can result from the abrasive/corrosive effect of skin contact with concrete or cement, especially when inadvertently left inside boots all day.
- **Environmental conditions** – Ice, snow, and rain create slippery conditions. Wind can be a major hazard. Handling sheets of plywood becomes more difficult, panels may require more bracing, and hoisting gets harder, especially with large panels or tables.
- **Dust and concrete** – Blowing dust and flying concrete particles during the chipping or cleaning of formwork can injure unprotected eyes.
- **Access equipment** – Access equipment such as ladders and scaffolds is involved not only in falls but in slips, trips, and other accidents. Hazards include ladders not tied off, workers carrying materials while climbing, ladders obstructed at top or bottom, scaffolds not completely decked in, and scaffolds erected or dismantled without fall protection.
- **Lighting** – Inadequate lighting can create or aggravate hazards when workers install or strip forms in dark areas or place concrete at night.

Injuries

Formwork hazards can lead to the injuries – and be prevented by the measures – described below.

- **Eye injuries** – These are quite prevalent in formwork operations. Most result from particles of wood or concrete that fall or are blown into the eye during chipping and cleaning. The injuries may not be severe but most can be prevented by wearing eye protection. It is strongly recommended that everyone on site wear eye protection at all times.
- **Cuts, scrapes, punctures** – The manhandling necessary to install and strip formwork can lead to cut hands, arms, and legs, as well as pinched or crushed fingers. Gloves help to prevent injuries from rough or sharp edges on formwork components. But workers must also have the knowledge, skill, and physical ability necessary for safe materials handling. That means knowing your limitations and asking for help when needed. Formwork involves protruding objects such as nails, snap ties, conduit, and bolts that can give you cuts and punctures. Where possible, these objects should not be left sticking out or should be covered over.
- **Back injuries** – These injuries are frequently related to materials handling. The most important preventive measure is back care. Exercise programs, warm-ups before work, and knowing your limitations can help to prevent sprains and strains. Wherever necessary, get help or use dollies, carts, or other mechanical devices.
- **Ankle sprains and fractures** – Working in close quarters, stepping over debris and material, climbing into excavations, turning with awkward loads, jumping down from scaffolds or benches — these can lead to ankle and other foot or leg injuries. Prevention starts with proper housekeeping and materials handling.
- **Bruises and contusions** – Handling formwork under rushed, cramped, or slippery conditions or beyond your limitations can lead to bruises. Bruises and contusions also result from contact with protruding formwork components. More serious are contusions from falling formwork materials. Formwork must be braced to ensure stability, especially under windy conditions. Try to avoid areas where work such as hoisting or stripping is being done overhead.
- **Fall injuries** – All of the injuries above, and many others, can result from falls. Most falls are caused by missing or inadequate guardrails, failure to use fall-arrest equipment, failure to completely plank scaffolds and other work platforms, and standing or climbing on

surfaces not meant to be used as such – the tops of wall forms or 2 x 4 wales, for example. Installing and stripping formwork often requires the use of a fall-arrest system.

Falls also result from holes left unguarded or uncovered in formwork. These should be covered up or fitted with guardrails as quickly as possible. Where this cannot be done, the area should be roped off and posted with warning signs to prevent unauthorized entry.

Planning

Planning is the first and most important step in reducing hazards and preventing injuries.

Because formwork operations must often be carried out in congested areas where other trades are also working, planning is essential in making the most of the time and space available to improve safety and efficiency.

Planning is a must for fall protection, work platforms, material staging areas, housekeeping, and material handling and movement.

Planning should take place at every level from manager through supervisor to worker. Planning labour, materials, equipment, and work schedules to meet design requirements is the responsibility of management and supervision.

Workers must plan the details of their assigned tasks based on the most effective work methods and safety measures to follow in each case.

Design

Safety and economy are the main factors in design. Both have to be considered because adjustments in one affect the other.

For example, reducing the support structure for wall forms in expectation of reduced pouring rates should not be considered if the rate of pour is not going to be controlled on the job.

Fresh concrete exerts a pressure on formwork similar to liquids. However, concrete starts to set when poured so that if the pour rate is slow the maximum pressure can be reduced, since concrete at the bottom will be set before concrete at the top is poured. Similarly, if the forms are filled to the top immediately, they must be able to withstand the pressure of the full liquid head. Liquid concrete exerts a minimum pressure of 150 pounds/foot^2 times the height in feet.

Other factors determine how long concrete will remain liquid, such as temperature, slump, vibration, and admixtures. For example, concrete will set much more quickly in hot summer weather than in cold winter weather. As a result, the same form filled at the same pour rate may be subjected to greater pressure in winter than in summer.

Concrete pumping may cause additional pressure, as well as vibration, on forms and must be considered at the design stage. The action of the pump sends surges of pressure through the piping system which are often transmitted directly to the forms, especially for narrow walls or columns. Vibration may move the forms or loosen bracing, ties, or spreaders.

Pressure acts perpendicular to formwork surfaces (Figure 190). This causes an outward thrust for typical wall or column forms. However, it can also cause uplift for battered or sloping forms. These require hold-down anchors or tie-down braces. The anchors will prevent the forms from lifting up or floating on the concrete.

Consider using bracing systems and spreaders for wall forms. Concrete filling the bottom of the form may cause forces at the top to push the two sides together unless they

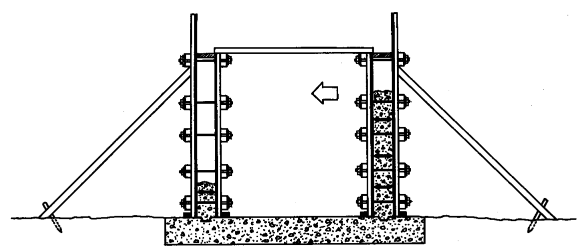


Figure 191
Open-cut tunnel formwork with bracing and spreaders on each side

are properly braced and/or separated with spreaders. Formwork has to be designed to resist such forces. During pouring, ensure that spreaders are not removed until concrete has reached at least two-thirds of the form height.

Where box forms are used – for instance, on one-piece covers for open-cut tunnels – you must use bracing against the side thrusts caused by the uneven pouring rates of the walls. Resisting these forces requires that the system be tied together and securely braced (Figure 191).

Formwork should be designed and constructed with stripping and removing as well as pouring in mind. On wooden forms, crush plates or filler strips should be used at corners such as slab-and-column or slab-and-wall

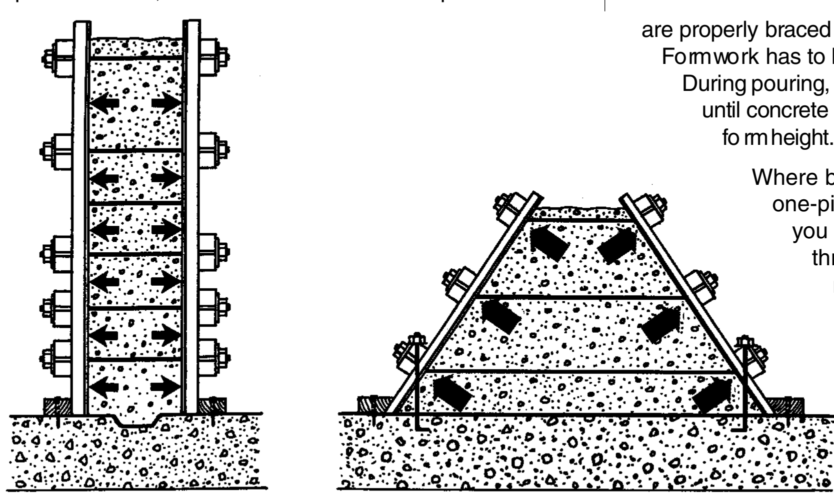


Figure 190 — Pressure of Concrete on Vertical and Battered Formwork
(Note expansion anchors holding down battered form.)

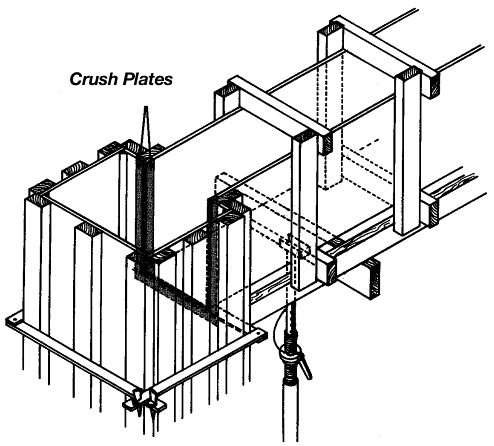
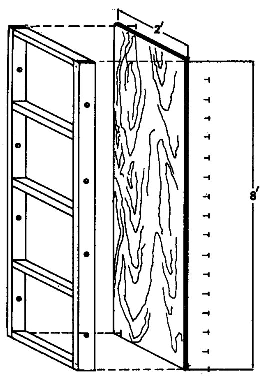


Figure 192 — Crush Plates



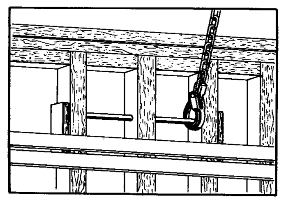


Figure 193 — Formwork Panel

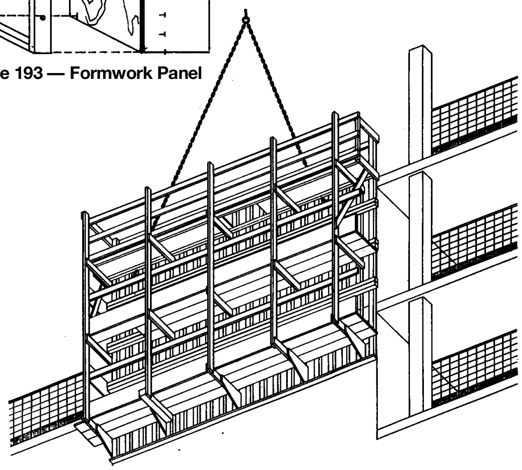


Figure 194 — Formwork Lifted as Single Unit

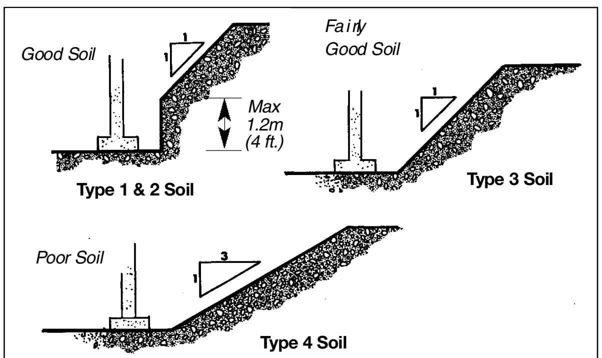


Figure 195 — Excavation Slopes for Good, Fairly Good, and Poor Soil

intersections (Figure 192). The plates or strips are easily removed with a wrecking bar and, once removed, make the stripping of adjacent panels much easier.

The strips should be big enough to leave space at the edges of the panels to accommodate wrecking bars.

When formwork has to be manhandled during assembly or dismantling, the design should ensure that the components are manageable. Formwork panels are not only heavy but awkward (Figure 193). Realistic design demands consideration of the size as well as the weight of panels.

A formwork panel or wall form to be lifted as a single unit must be designed to withstand the loads and forces exerted by hoisting (Figure 194). In most cases, this means designing a more substantial structure. Fastening components may also need more attention at the design stage. For example, simple nailing may not be enough to hold plywood sheets.

Special attention must also be applied to the design, construction, and use of pick points for hoisting. The strongbacks and wales must be securely attached to the formwork. The pick points must be located so that the panel hangs properly during installation, concrete placement, and removal.

Types of Formwork

Below Grade

The first concern with formwork below grade is the stability of the excavation walls. Walls must be either shored or sloped according to soil type as defined by the Construction Regulation (O.Reg. 213/91). Figure 195 shows typical slopes.

In most cases the shoring must be designed by an engineer. Engineers may also specify slopes for excavations. In both instances the design drawings must be kept on the project.

Excavations should be kept essentially dry. Water should be pumped out. Mud should be cleared off and replaced by compacted granular material in work areas and on surfaces where concrete will be placed. Mud presents slipping hazards and can lead to inferior construction if not removed or replaced.

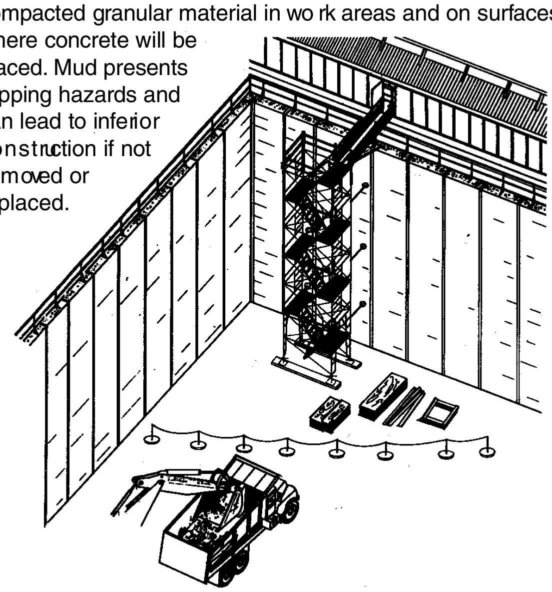


Figure 196
Formwork Roped-Off from Other Operations

Since mud has to be removed before concrete is placed, it might as well be removed before formwork is constructed, thereby reducing slipping hazards at both stages.

Water and mud also contribute to electrical hazards. Grounding and insulation must be effective and intact. Ground fault circuit interrupters (GFCIs) are required by law on all portable tools used outdoors or in wet locations.

Formwork for footings and grade walls frequently begins before excavation in the area is complete. Trucks and excavating equipment put workers on foot at the risk of being struck down or run over.

Wherever possible, formwork operations should be roped off from other work such as excavation or pile-driving (Figure 196). Separate access ramps for vehicles and workers are strongly recommended.
Stairs are an even better alternative for personnel on foot.

Mud sills must be used to support any shoring or bracing that rests on soil in the excavation (Figure 197). The sill must bear on the soil throughout its length. Sills should not be used to bridge holes or irregular surfaces. To ensure uniform bearing, soil should be levelled before sills are set in position.

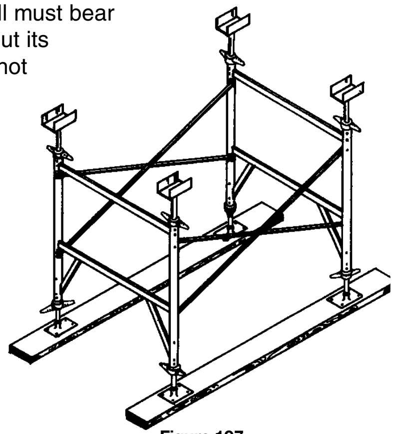


Figure 197
2" x 10" Mud Sills Under Shoring Frames
Good Soil Bearing Capacity – Moderate Load

The soil must have the capacity to bear whatever loads are applied. This information may or may not be on the design drawings.

In Situ Bearing Pressure for Dry Soil Conditions
(Conservative Estimates)

Silt and clay	1200 lbs/ft^2
Sands	4000 lbs/ft^2
Gravelly sands	6000 lbs/ft^2
Gravel	8000 lbs/ft^2

Soil that supports bracing or shoring should be compacted and qualify as good soil at least (cohesive, hard, with no water). Professional advice is recommended and may be required for heavy structures such as elevated equipment supports shored at or below grade.

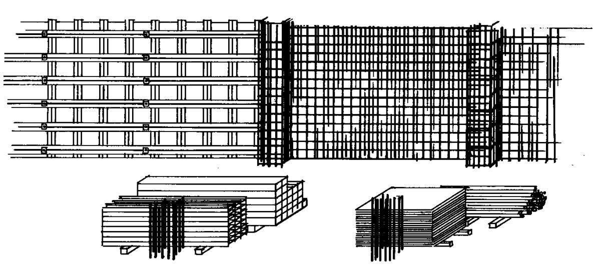


Figure 198
Well-Planned Storage, Access, and Setup

Formwork in these situations is frequently built in place. Planning is required to store material and equipment out of the way, dispose of scrap and debris, and ensure safe, efficient access (Figure 198). Because conditions are often cramped and scrap accumulates quickly, it is important to clean up as work proceeds.

Wall Forms

Wall forms built in place are hazardous to construct. Hazards include

- dowels sticking up from concrete slabs or footings
- unstable work surfaces and access created by poor planning
- manual handling of heavy material such as plywood sheets, panels, wales, and buckets of snap-ties, wedges, and plates
- slippery surfaces at and below grade
- inadequate design
- improper construction.

The best protection against dowels is a wood cover built of lumber at least 1-1/2 inches thick and wired in place (Figure 199).

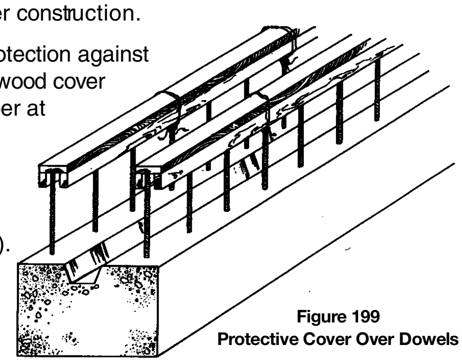


Figure 199
Protective Cover Over Dowels

Starting the Form

Setting up the first form is always hard, heavy, manual work. It calls for enough workers to do the job without overexertion or injury.

Temporary bracing (Figure 200) is needed from the start and at every step to prevent wind loads from toppling the forms – historically the cause of many serious injuries. A wind of 30 km/h will create a dangerous wind load on formwork.

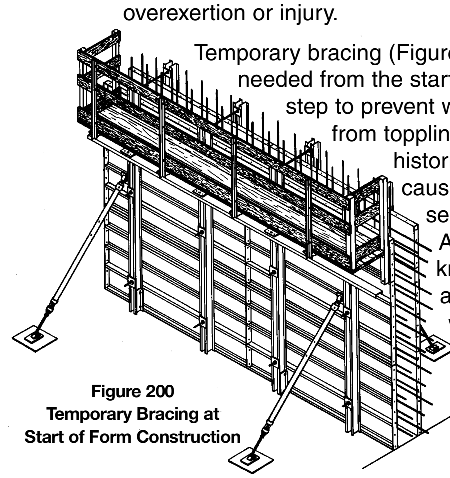


Figure 200
Temporary Bracing at Start of Form Construction

Access to wall forms is not always given enough thought. Forms more than 2 metres high will require access platforms for workers involved in concrete placing. The platforms can also be used to complete the upper portion of the formwork.

An alternative is a frame scaffold, which can also be used to install reinforcing steel (Figure 201).

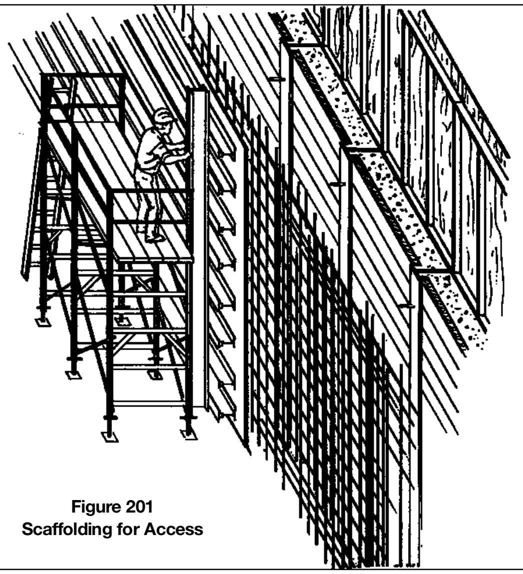


Figure 201
Scaffolding for Access

Fall-arrest systems or scaffolds with guardrails must be used where workers may fall more than 3 metres (10 feet), or onto hazards such as projecting dowels (Figure 202). In some circumstances, you must use fall protection when the height is 2.4 metres (8 ft.) or more. (See chapter on Guardrails.)

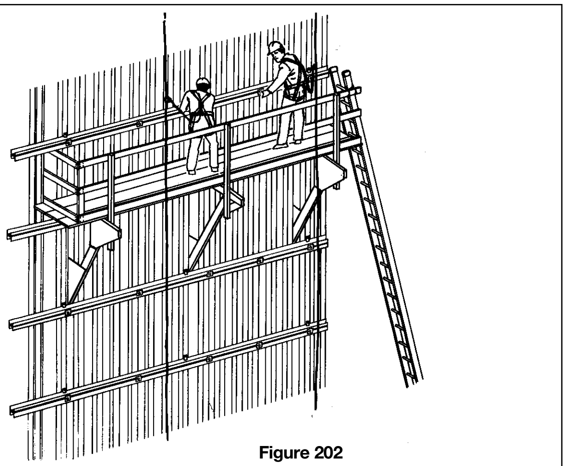


Figure 202
Workers wear fall-arrest while attaching wales to threaded rods.

Materials should be distributed along the work location to minimize further handling. But traffic and work areas must be kept clear for the safe movement and installation of material.

Form Construction

Wall forms must be constructed as designed. The design must indicate clearly what is required.

Some wall forms are designed for specific concrete placement rates expressed in metres of height per hour (m/hr). A wall form in which concrete is placed to a height of one metre in one hour would have a placement rate of 1 m/hr. Slower pouring rates result in lower formwork pressure because the bottom concrete has started to set.

Ensure that ties and braces are installed where indicated on design drawings. Ties should be snugged up. Braces should be securely fastened to forms and wedged or fastened to a support that will not settle or deform under load (Figure 203).

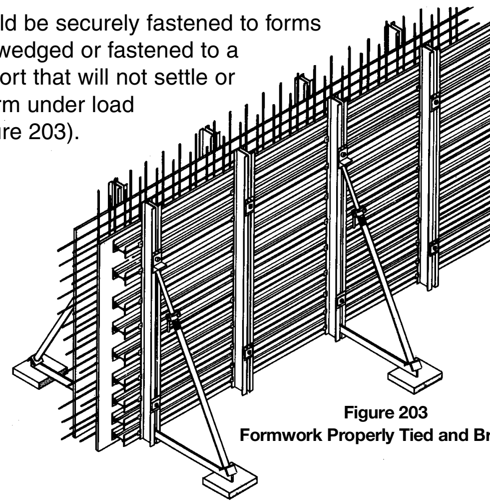


Figure 203
Formwork Properly Tied and Braced

Formwork platforms must be

– capable of bearing at least 50 pounds/foot^2
– adequately supported
– equipped with guardrails
– secured at the level or levels where work such as pouring and stripping will be done.

Recommended design pressures for various pour rates and environmental conditions are set out in CSA Standard S269.3 *Concrete Formwork*. The standard defines a number of other design considerations and should be consulted by field staff.

Slab Forms or Falsework Built in Place

With slab forms built in place the major hazard is falls. Injuries are also connected with the manual handling of heavy materials and components.

Forms built in place usually have to be taken down in place. This should be considered at the construction stage. Stability may also be a consideration where the structure is high, carries heavy loads, and is placed on grade as in bridge and overpass construction.

Fall protection is difficult to provide for workers building slab forms in place. That's why planning is essential in the design and erection procedure.

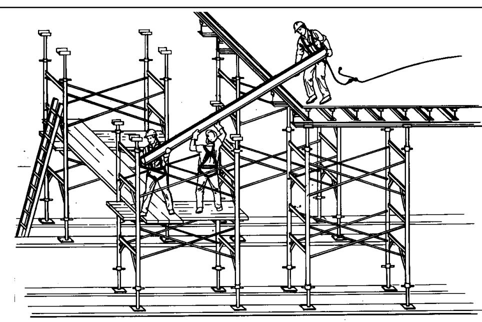


Figure 204
Workers tie off to shoring frames while placing stringers.

Workers should wear a safety harness with the lanyard tied off to the structure of the formwork (Figure 204). This means tying off to the support structure where shoring frame structures are being constructed, tying off to a lifeline when placing plywood panels at a leading edge, constructing a guardrail at the edge of the formwork, or tying off to the support structure when tying it together with tube and clamp. Don't wait for the structure to be completed before tying-off. Make sure you have fall protection at all stages of formwork construction.

Wherever possible, cranes or other equipment should be used to move material, thereby reducing the amount of manual carrying, lifting, and handling.

Shoring towers require special consideration.

- Towers must remain stable during construction and dismantling. Guys may be necessary to maintain stability (Figure 205).

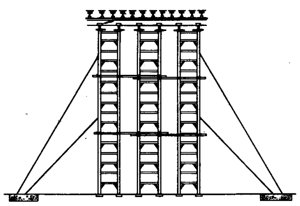


Figure 205
High Guyed Towers

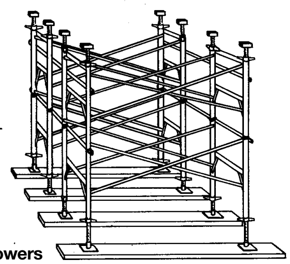


Figure 206
Tube-and-Clamp Tie-Ins for Shoring Towers

- If towers are to be tied together and braced horizontally, this should be done as work progresses (Figure 206).
- Shoring towers and shores should be installed so they are plumb to within 1/8 inch in 3 feet.
- Shoring towers should be snugged up under the stringers with adjustable base plates and U-heads (Figure 207).
- If frames do not ride tightly on top of one another after tightening, one or more are out of square and should be replaced (Figure 208).

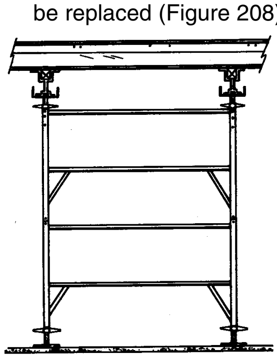


Figure 207
Typical Shoring Tower with Stringers, Adjustable Base Plates, and U-Heads

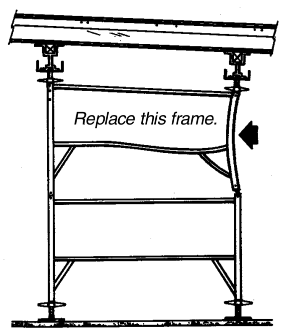


Figure 208
Frame Bent Out of Shape

- With single-post shores, provide adequate lateral bracing (Figure 209). Stairwells and balconies are places where horizontal bracing for single-post shoring systems may be required.

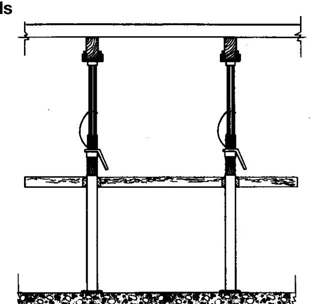


Figure 209
Single-Post Shores with Lateral Bracing

Frequently, supports for built-in-place forms are

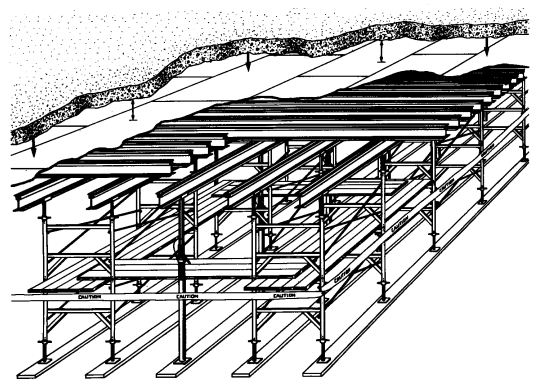


Figure 210
Two Rows of Shoring Frames with Row of Shoring Posts in Centre

deliberately left out to allow other work to be done. One example might be a row of single-post shores left out until work below is complete. Or, an area might be supported temporarily during construction by a few single-post shores that will be replaced later by a shoring tower.

In these and other instances of incomplete formwork, heavy temporary loads such as bundles of rebar or stacks of plywood should not be placed on the structure. Even on completed formwork, make sure that landed material will not overload the structure.

Flying Forms

Flying forms must always be designed by a professional engineer and constructed, hoisted, moved, and set strictly according to the instructions of the designer or manufacturer.

Using forms designed for typical floors in non-typical situations has resulted in serious accidents. Before using any flying form under non-typical conditions, consult the designer or manufacturer. Wall forms should not be extended in height or width, for instance, or slab panels cantilevered without professional consultation. Such situations usually occur with penthouses or mechanical rooms where wall and ceiling heights are greater than for typical floors.

Apart from misuse, hazards with flying forms include

– stability during initial fabrication
– fill-in work between slab panels
– stripping, flying, and re-setting.

In the last category especially, falls are a common hazard. For fall protection, see the next section.

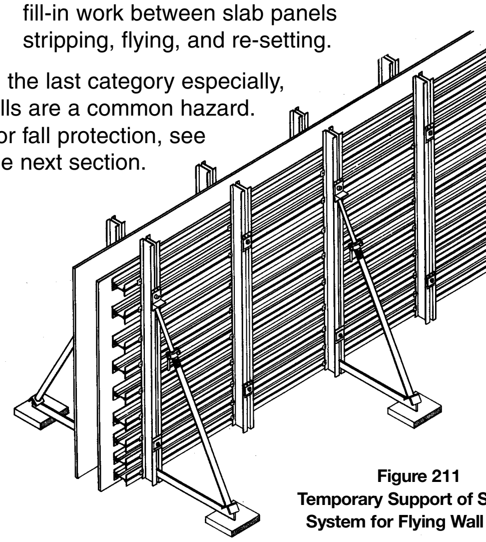


Figure 211
Temporary Support of Shoring System for Flying Wall Form

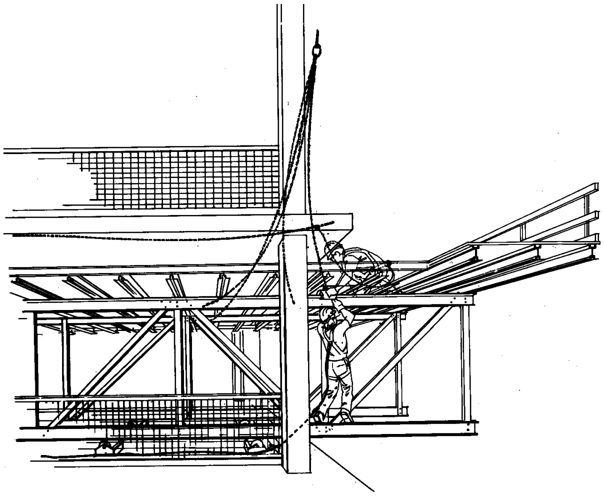


Figure 212 — Helping Worker Above

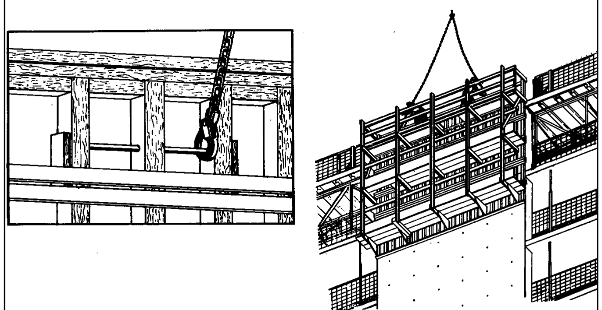


Figure 213
Attaching Chain Sling to Wall Form

Fall Protection — Flying Forms

A fall-arrest system should be used by any worker who is

- installing
- pushing a panel out toward the slab edge
- receiving a panel in from the slab edge
- helping other workers attach rigging hardware such as slings (Figure 212)
- getting on and off
- bolting and unbolting wall forms for exterior walls and elevator shafts (Figure 213)
- stepping onto a panel to attach slings to pick points (Figure 214).

Each worker's fall-arrest system must be attached to an individual anchor independent of the flying form. Contractors can provide for anchorage by casting rebar anchors in columns or other areas to be covered over or filled in later (Figure 215).

Safety Below Flying Forms

The previous section covered the safety of workers flying the forms. But precautions must also be taken to protect workers below the hoisting operation and the public at large, since forms are often swung out over sidewalks and streets. The most efficient protection for workers is to rope off the area below to prevent anyone from entering the area. Pedestrian traffic on sidewalks, as well as vehicle traffic if necessary, should be detoured around the area while hoisting is under way.

Communication

Flying forms are heavy, large, and awkward. To hoist and move them safely requires clear reliable communication. While hand signals are often necessary, direct radio

Although a flying form is designed to be stable when complete, it may not be stable during fabrication or erection. Temporary bracing or temporary support by a crane may be necessary to ensure stability during certain phases of the operation (Figure 211).

One example is setting up trusses for a flying slab formwork table. The trusses must be held upright to be connected or disconnected. If not adequately supported, they can fall over on workers. Trusses and wall panels have also been blown over by wind during fabrication and dismantling.

Work with flying forms requires adequate space for stacking materials and components. Working in cramped quarters is not only difficult but hazardous.

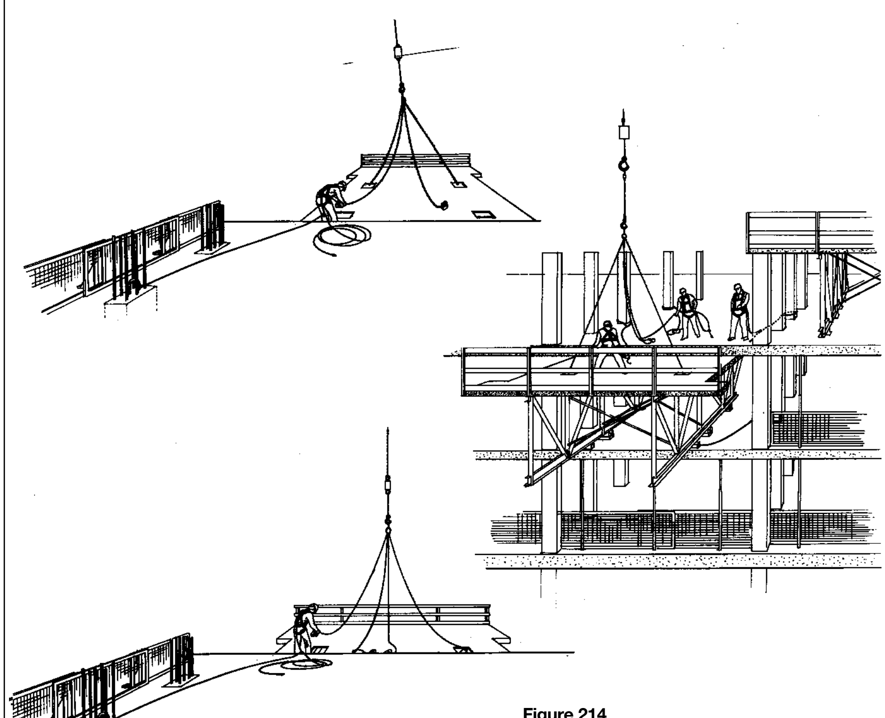


Figure 214
Attaching Slings to Pick Points

communication between work crew and crane operator is more accurate and effective. Relying on hand signals alone is not recommended.

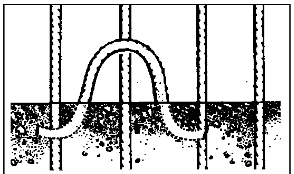


Figure 215
Rebar Anchor Cast in Concrete

Stripping

General

Formwork stripping is probably the most hazardous operation in concrete construction. Hazards include

- falling material
- material and equipment underfoot
- manual handling of heavy or awkward forms, panels, and other components
- prying forms loose from concrete presents risk of overexertion, lost balance, and slips and falls.

Hazards can be reduced by

- planning and providing for stripping when designing and constructing formwork
- supplying facilities and equipment for removing materials as they are stripped
- providing proper tools and adequate access for the stripping crew
- training personnel properly for this and other aspects of formwork.

Forms can be designed with crush plates or filler strips to facilitate removal at difficult intersections of columns, beams, and wall forms. Later, form oils should be used liberally to make stripping easier.

Wherever possible, materials and debris should be removed from the area as work proceeds. This will reduce the need to walk over or work around things left on floor or ground.

Providing carts or cradles can help the crew remove material and reduce the need for lifting and carrying. Material on a cart can be rolled away. Material in cradles can be hoisted off by a crane.

Climbing partially stripped formwork is not only hazardous but unnecessary. Safe access such as rolling scaffolds or powered elevating work platforms should be provided for stripping formwork at elevated locations.

Poor lighting is sometimes a hazard in formwork stripping. Mobile light stands are probably the best solution, since pigtail stringers can easily be knocked down and damaged during stripping.

Wherever possible, stripping crews should be small. This is especially important with knock-down systems. In small crews each person can keep track of what the others are doing. Workers are not as likely to cause problems for each other. Crews of two or three are recommended for knock-down systems. If more workers are required, they can still be divided into small crews working in separate areas.

> Other trades and operations should not be allowed in areas where stripping is under way. Given the many hazards involved, the area should be roped off and warning signs posted.

Knock-Down Slab Systems

Stripping these forms is difficult because much of the work is overhead. The usual arrangement involves shoring frames or a combination of shoring frames and jacks.

Wherever possible, the work should proceed from one side. That means taking out one row of formwork supported by a row of stringers on shoring frames.

The first step is to back off the adjustable base plates and U-heads in one area, which will in turn lower the stringers, joists, and plywood (Figure 216).

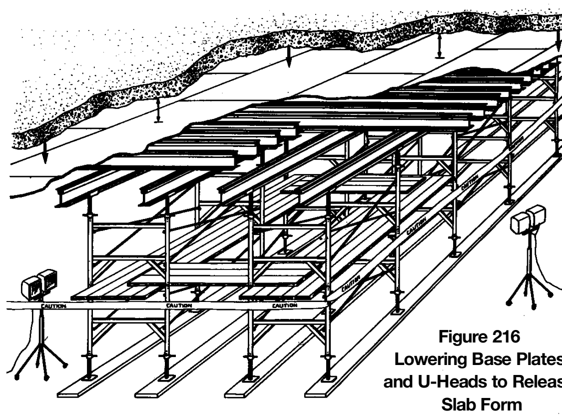


Figure 216
Lowering Base Plates and U-Heads to Release Slab Form

In practice, however, the plywood will stick, especially around beams, column caps, and similar points. Wherever possible, stuck sheets should be loosened and removed before the shoring structure is dismantled.

Stripping should proceed in reverse order to erection. Plywood should be removed first, followed by joists and stringers. The last items to be removed are the shoring frames.

When scaffold or shoring frames are used for access, the platform should be completely decked in with planks (Figure 217). Otherwise planks can shift and slide as workers pry or pull at stuck pieces of formwork, lose their balance, and fall. This has been a frequent cause of injuries.

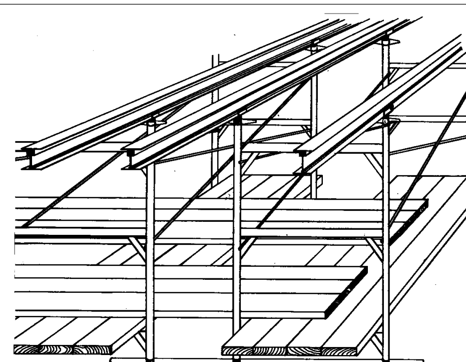


Figure 217
Shoring Frame Fully Planked for Access

The area where stripping starts should allow access for taking away material as it is dismantled.

Sound training, well-designed forms, safe access facilities, and immediate and continuous cleanup can help reduce hazards in stripping knock-down slab forms.

Built-in-Place Wall Forms

These forms are frequently of only moderate height. Taller types usually make use of large panels erected and removed by crane rather than hand.

Built-in-place wall forms are usually a stud-and-wale system using some type of ties.

Where workers cannot reach the top of the wall, scaffolding should be provided for removing wales on the upper level (Figure 218). Safe access is essential for the dismantling and manhandling of wales that are frequently long, heavy, and waterlogged.

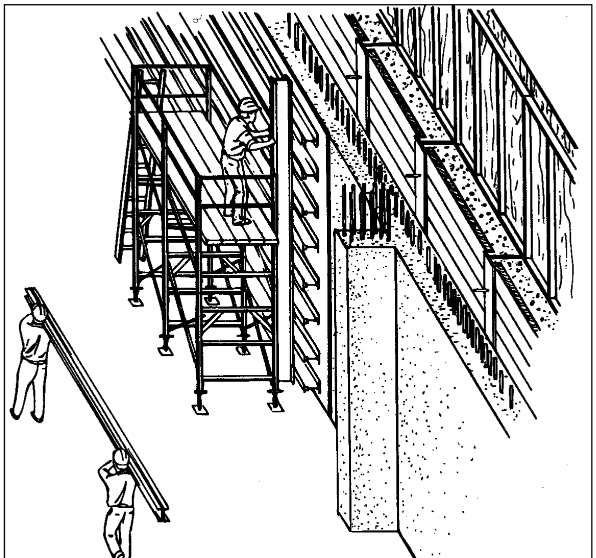


Figure 218
Scaffold for Dismantling Wall Forms

Material should then be removed immediately to a staging area.

Inspection

Before concrete placing begins, formwork must be inspected and signed off by the designer or a competent person to ensure that it has been constructed to provide for worker safety and to meet job specifications.

In Ontario, formwork requiring design by an engineer must be inspected by an engineer or a designated competent worker. The worker does not have to be an engineer.

A report must be filed stating whether the formwork has been constructed according to the design. Any discrepancies should be cleared up with the design engineer before concrete placing proceeds.

Regardless of the specific responsibility, it is in everyone's best interest to ensure that the formwork has been inspected by a competent person for workmanship, stability, and adherence to design drawings and specifications.

Inspection should start when the forms are being constructed and continue until concrete placing is complete.

Checking line and grade is best carried out while the formwork is being constructed. Shoring structures should be within the alignment limits specified on the design drawings. Line and grade should also be checked during the pour to determine whether formwork is shifting or deflecting.

Dimensions of special features like beams, column capitals, and inserts are best checked during construction. If inspection is delayed until formwork is completed, some details may be covered up or become more difficult to check.

Columns

Check that

- the proper size and type of materials are used
- column ties or column clamps are spaced according to design drawings
- the spacing of ties or clamps is based on a sound assessment of concrete pressure (generally columns are designed for a full liquid head of 150 pounds/foot^2 times height in feet)
- columns are adequately braced where they are not tied in to a slab-form structure.

Note: For more information on column formwork pressures, refer to CSA Standard S269.3, *Concrete Formwork* or the American Concrete Institute (ACI) standard *Formwork for Concrete* (SP-4).

Wall Forms

Check that

- materials and any manufactured components are as specified in design drawings (size and spacing of studs, wales, and ties are crucial to safety)
- ties are snugged up before concrete is placed
- wedges in wedged systems are tight
- nuts in threaded systems are tight
- bracing conforms to design drawings
- free-standing formwork is braced to ensure stability and resistance to loads during concrete placing
- specified pour rates are not exceeded (wall forms are often designed for specific pour rates; exceeding these rates can cause failure or collapse).

Slab Forms

From a safety perspective, this is the most critical type of formwork. The collapse of slab forms has caused many injuries and deaths, whether from flawed design, unauthorized modifications in the field, or failure to inspect.

Proper inspection demands knowledge, experience, and the ability to

1) distinguish between similar but different materials and shoring equipment
2) read and interpret design drawings
3) identify and clear up with the designer any apparent or real discrepancies in components such as shoring frames.

Check that

- grade beams or mud sills supporting shoring are properly sized and located
- hazardous soil conditions such as excessive moisture, freezing, and uncompacted soil are reported and discussed with the designer

- shoring frames and jacks are located and aligned within tolerances specified on the drawings
- shoring frames and jacks are out of plumb no more than 1/8 inch in 3 feet
- adjustable base plates for shoring frames and jacks are snugged up
- U-heads are wedged in place
- stringers are the specified size and number, with supports properly spaced
- aluminum stringers have no bent flanges or other damage
- joists are the specified size and properly spaced
- support structures and shoring for beam bottoms and column capitals are constructed according to design
- lateral bracing is provided where required (for instance, on freestanding formwork for bridges and overpasses)
- the bearing surface for lateral bracing is adequate — that is, stable footings or well-compacted soil
- temporary loads such as rebar are not obviously overloading the system.

Concrete Placing

Inspection of forms should continue during concrete placing. Any signs of movement, crushing, or deflection are cause for alarm. Pouring should be suspended until the situation is corrected.

Watch for the following warning signs:

- movement of single-post shoring for slab forms
- movement or deflection of lateral bracing for single-post shores
- movement of stringers on U-heads
- crushing of wooden stringers on U-heads (Figure 219)
- shoring that is not snugged up under stringers
- deflection of stringers between supports (Figure 220)
- deflection of wales or strongbacks on wall forms
- bulging of wall forms
- crushing of wales or strongbacks at washers for ties
- movement of wall forms
- uplifting of battered forms
- pour rates that exceed design specifications.

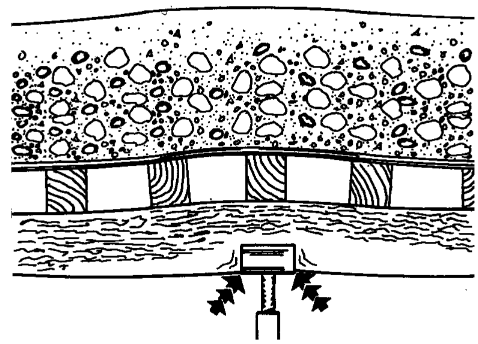


Figure 219 — Crushing of Stringer Over U-Head

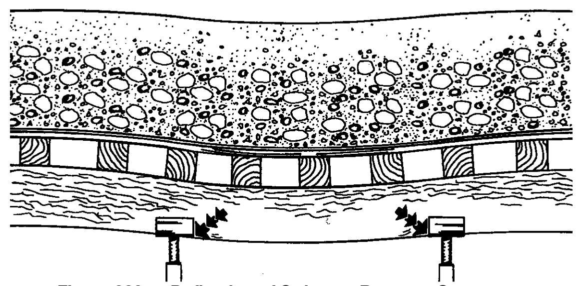


Figure 220 — Deflection of Stringers Between Supports

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