Low-voltage systems

Low-voltage electrical systems (750 V and below) serve most homes and commercial buildings. Every day, hundreds of B.C. workers work safely on and around low-voltage electricity. Small or large, the job is usually handled without incident. Occasionally, however, something goes horribly wrong—an unexpected hazard has been overlooked and a worker becomes the victim of a sudden explosion or a serious shock.

Part 1 explains why energized low-voltage systems are dangerous and outlines the basic steps to de-energize and lock out equipment. This part also describes the hazards that are often overlooked when someone is working on or around low-voltage systems. It tells you what to look for and how to avoid accidents.

Qualified workers

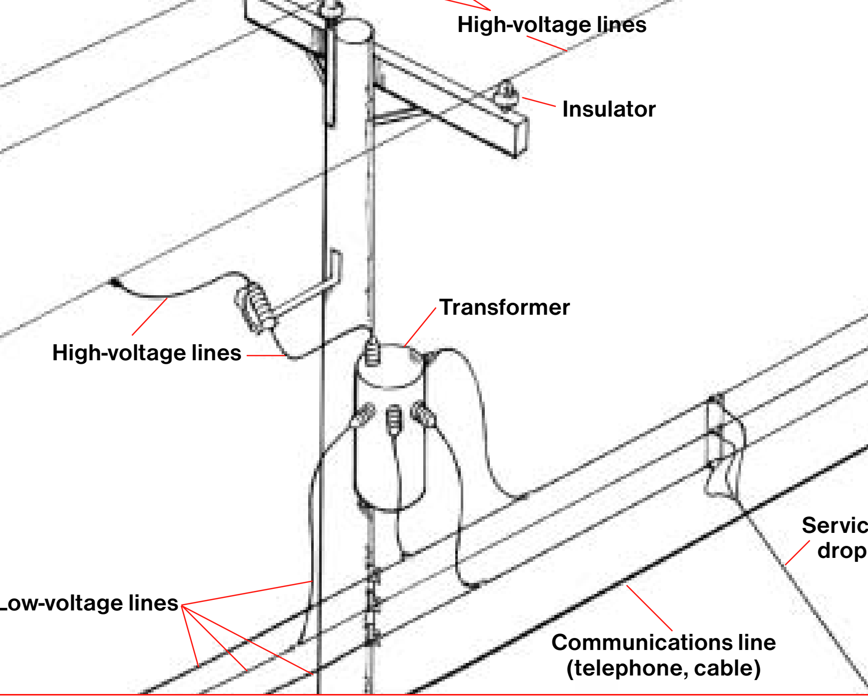
The Electrical Safety Regulation made under the *Electrical Safety Act* defines a qualified person as "an individual who has knowledge of the electrical system and equipment being installed or altered and who is aware of the hazards involved." For more information on who is qualified to do or supervise electrical work and testing, see B.C. Regulation 487/95 or contact the Electrical Safety Branch of the Ministry of Municipal Affairs.

Identifying low-voltage overhead conductors

Utility poles generally carry both low-voltage and high-voltage conductors (power lines) as well as communications lines (such as cable television and telephone). High-voltage conductors are always installed at or near the top of the utility pole. Low-voltage conductors are usually installed as single conductors mounted one above the other (see illustration on page 4).

If there is a transformer on the pole, lines from the high-voltage conductors feed the transformer, which reduces the voltage for distribution through low-voltage lines to homes (120/240 V) and commercial and light industrial buildings (typically 347/600 V). Electricity travels through the low-voltage distribution lines to the service drop (located on the building), taking power to individual customers.

It is the employer's responsibility to accurately determine the voltage of all power lines in the work area.



*rhead electrical conductors can often be identified by their placement
he pole.*

Abbreviations

The following abbreviations are used in this booklet:

A	ampere
mA	milliampere
V	volt
kV	kilovolt (1 kV = 1,000 volts)
kVA	kilovolt ampere

Why energized low-voltage systems are dangerous

People often think that low-voltage contact is much less dangerous than high-voltage contact. They may believe that a mistake made in working on a low-voltage system means only a quick flash and the tripping of a circuit breaker. This is a common misunderstanding.

There are more injuries from low-voltage systems (especially 347 V systems) than there are from high-voltage systems. An electrical current through the heart can cause an irregular heartbeat or a heart attack. Electric shock can also cause the muscles to contract and may prevent the worker from releasing his or her grip, thus extending exposure to the current. In some instances, low-voltage contact can cause serious shock and burn injuries and even death. (See “Types of Electrical Injuries,” pages 49–53.)

Two factors can make energized low-voltage equipment extremely hazardous. The first is that the small working clearances between low-voltage components leave little room for error when using tools.

Second, low-voltage equipment in some industrial services may be supplied by an electrical system that can feed incredible amounts of energy into a fault (caused by a short-circuit, for example). In such cases, a fault can cause an intense, persistent, and rapidly expanding arc of electrical energy to build in a split second. This energy is released suddenly in a restricted space. The flames can result in terrible burns on anyone within the arc’s range, which may reach up to 3 metres (10 ft.). Arcs of this kind often leave the electrical structure a charred and melted wreck—stark evidence of the intense heat generated (several thousands of degrees).

Almost all voltages are potentially dangerous because of the shock hazard. With low voltages fed by high-capacity transformers, the danger of arc flash burns is an additional hazard that can result in serious injuries.

As well as causing fire, the heat from the arc can melt solids, vaporize liquids, and expand gases. This results in a huge build-up of pressure causing an arc blast. The blast can throw workers across a room, destroy equipment, and hurl objects and pieces of metal onto nearby workers. In some tests, the noise from an arc blast reached 140 decibels.

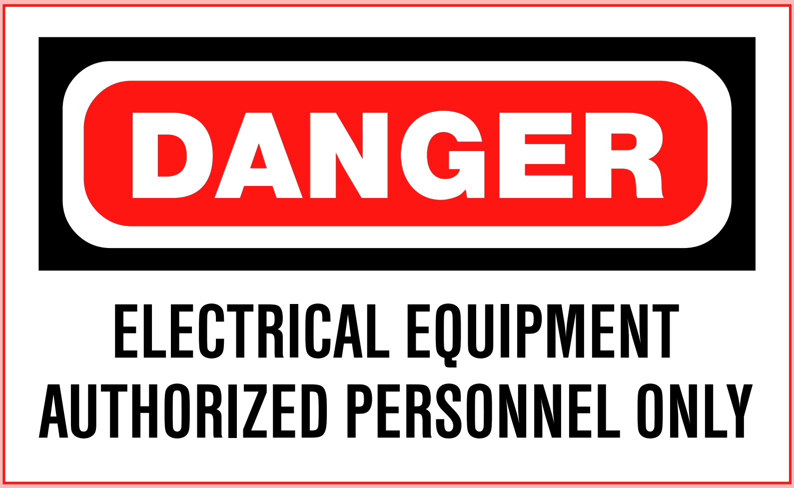
Working close to energized equipment

Uninsulated, energized parts of low-voltage electrical equipment and conductors must be guarded by approved cabinets or enclosures unless the energized parts are in a suitable room or enclosed area that is accessible only to qualified and authorized persons.

Each entrance to a room or other guarded location containing uninsulated and exposed energized parts must be marked with warning signs limiting entry.

If uninsulated, energized parts are not guarded with approved cabinets **or** enclosures:

- Suitable barriers or covers must be provided if a worker unfamiliar with the hazards is working within 1 metre (3.3 ft.) of those parts, **or**
- The worker must be informed of the potential hazards and must follow written safe work procedures



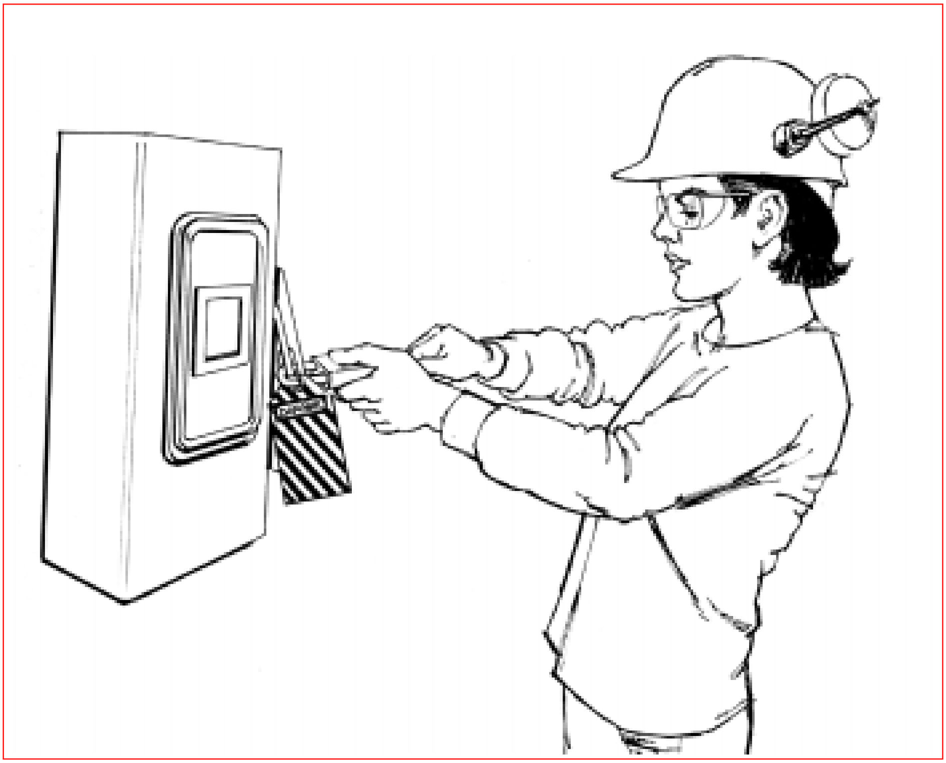
De-energization and lockout

Because of the hazards of working on energized low-voltage equipment, the first choice is to disconnect ("de-energize") and lock out the equipment before maintenance work is done on it. The purpose of de-energization and lockout is to prevent the release of energy that could cause injury or death. A lock or locks are used to make sure that equipment is not accidentally or inadvertently turned on while workers are performing maintenance on it.

Maintenance is any work performed to keep machinery or equipment in a safe operating condition. This includes installing, repairing, cleaning, and lubricating the equipment, as well as clearing obstructions to the normal flow of material.

Workers must follow their employer's safe work procedures to de-energize and lock out equipment. At a minimum, any procedure should include the following five steps:

1. Identify the machinery or equipment that needs to be locked out.
2. Shut off the machinery or equipment. Make sure that *all* moving parts have come to a complete stop. Also ensure that the act of shutting off equipment does not cause a hazard to other workers.
3. Identify and de-activate the main energy-isolating device (such as a switch or valve) for each energy source. There may be more than one source of power, such as backfeed from the load side or control voltage from a separate source.
4. Apply a personal lock to the energy-isolating device for each energy source, and ensure that all parts and attachments are secured against inadvertent movement. (Each worker must apply a personal lock unless group lockout procedures are followed.)
5. Test the lockout to make sure it's effective and to verify that all live components have been de-energized. First ensure that all workers are in the clear and that no hazard will be created if the lockout is not effective. Lockout can be tested after each energy-isolating device is locked out or after a group of nearby devices is locked out.



Apply a lock to the electrical disconnect switches before working on the equipment.

Safe work procedures for work on electrical equipment should include:

- Steps to ensure that all work has been completed on a circuit before the circuit is connected to the power source
- Who is qualified to test electrical circuits
- What types of testing devices are acceptable

Lockout requirements

For more information on lockout, see the following:

- Occupational Health and Safety Regulation, Part 10: De-energization and Lockout
- *Lockout*, a booklet available from the WCB Publications and Videos Section (see page ii)

Working on energized equipment

For most work, the electrical equipment must be de-energized because there is a high risk of injury to workers if they work on energized equipment. It may be possible to schedule such work outside of normal work hours to limit the inconvenience.

Sometimes it is not practicable to completely disconnect low-voltage equipment before working on it. For example, it may be necessary to have equipment running in order to test it or fine-tune it. In such cases, the work must be performed by workers who are qualified and authorized to do the work. They must follow written safe work procedures.

You should observe the following general precautions when working on energized equipment, but note that these are not a substitute for proper training and written safe work procedures:

- **Think ahead.** Assess all of the risks associated with the task. Plan the whole job in advance so that you can take every precaution, including arranging for help in case of paralyzing shock. Consider the use of a pre-job safety meeting to discuss the job with all workers before starting the work.
- **Know the system.** Accurate, up-to-date information should be available to those who work on the system.
- **Limit the exposure.** Have live parts exposed for as little time as necessary. *This does not mean that you should work hastily.* Be organized so that the job can be done efficiently.
- **Cover exposed live metal.** Use insulating barriers or shields to cover live parts.
- **Cover grounded metalwork.** Grounded metal parts should be covered with insulating material as much as possible.
- **Limit the energy to reduce the risk.** All practical steps should be taken to ensure that the fault current at the point of work is kept as low as possible while the work is in progress. For example, when measuring voltage, do it on the load side of the circuit-protective devices with the smallest current rating. Current-limiting devices can be used to reduce the risk of an arc flash.
- **Remove metal rings, bracelets, and wristwatch bands.** These could cause a short-circuit where small clearances are involved. (If it is necessary to wear medic-alert bracelets, secure them with transparent surgical or adhesive tape or rubber bands.)

- **Use one hand with your face and body turned to the side when operating a safety switch.** Limit possible injuries by not placing body parts directly in front of energized equipment when there is danger of an arc flash.
- **Avoid electrical contact when working in awkward positions.** If you must work in an awkward or unbalanced position and reach with your tools, use insulating cover-up material on the tools to avoid contact with live conductors.
- **Use the correct equipment and clothing.** (See "Personal Protective Equipment and Clothing" below.)

Regulation requirements

If you must work on energized low-voltage equipment, see the requirements in the Occupational Health and Safety Regulation:

• Part 8, sections 8.14–8.17	Safety eyewear
• Part 8, section 8.22	Safety footwear
• Part 8, section 8.31	Flame-resistant clothing
• Part 19, section 19.10(2)	Working on energized low-voltage equipment
• Part 19, section 19.10(3)	Working on energized lighting circuits

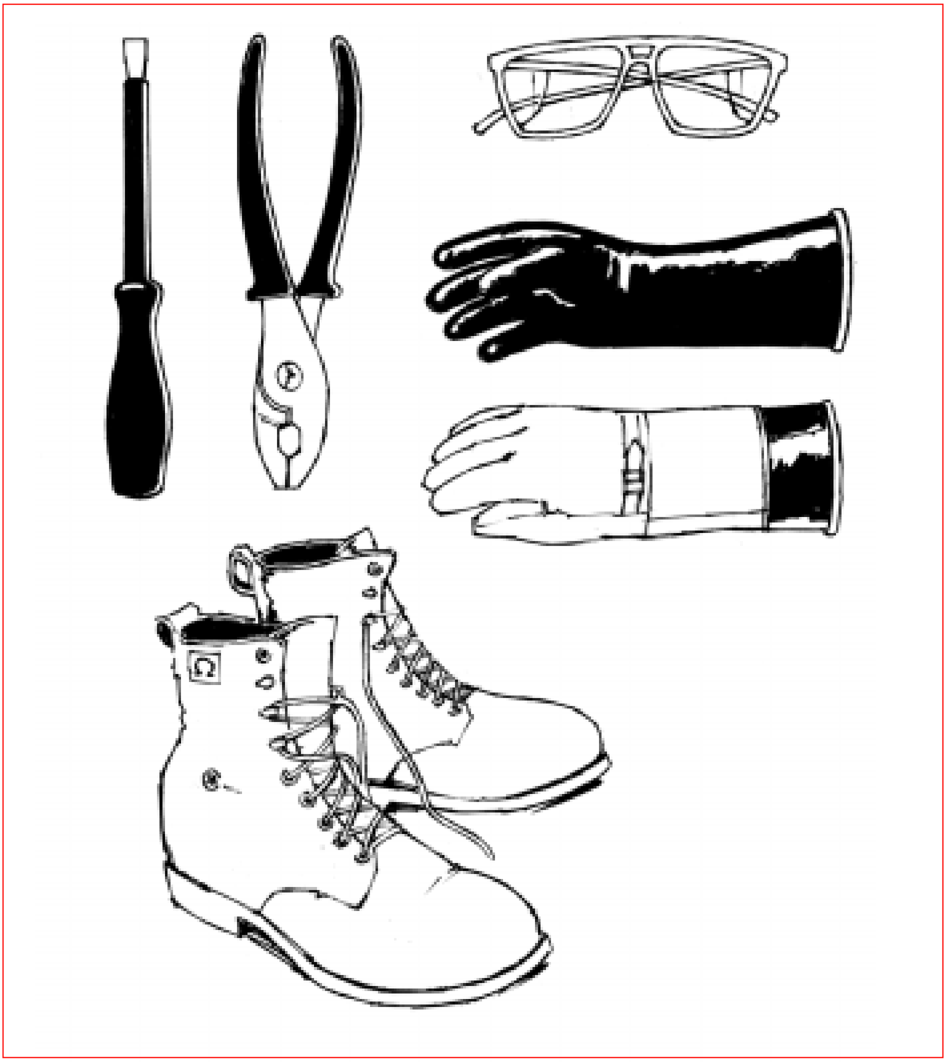
Personal protective equipment and clothing

It is the employer's responsibility to provide the specialized personal protective equipment and clothing needed for work on energized equipment. The supervisor must ensure that workers use the clothing and equipment. Workers are responsible for inspecting the equipment before use and for using it properly.

When working on energized equipment, qualified and authorized workers need the following protective equipment and clothing:

- Insulated tools to avoid shocks and to prevent accidental short-circuits
- Rubber gloves (leather gloves can be used when testing equipment)
- Cover-up blankets to avoid accidental contact with live equipment
- Shock-resistant safety boots or shoes (with appropriate CSA symbol)
- Safety glasses, goggles, or a face shield to protect the worker from molten metal or ultraviolet light
- Flame-resistant clothing if there is a risk of an electric arc that could cause a fire

Safety glasses normally used on construction projects to protect eyes from debris are not designed to prevent injuries from the ultraviolet light of an electric arc. If the risk is high, de-energizing must be the first choice. If work must be done on live equipment, polycarbonate safety glasses are required; however, the use of a complete polycarbonate face shield should be considered. Polycarbonate glasses will filter out most of the ultraviolet light, and yellow tinted glasses will filter out more blue spectrum light without making it too dark to work. However, even the best safety glasses cannot protect against an electric arc or a fireball.



When working on energized low-voltage equipment, workers need protective equipment, including insulated tools, safety eyewear, rubber gloves, and shock-resistant footwear.

Flame-resistant clothing

If there is a fire hazard, workers must wear flame-resistant clothing. Consider wearing clothing made of flame-resistant cotton or wool blends. The fabric should have a smooth, tightly woven finish.

Avoid clothing made of nylon, polyester acetate, or acrylic fibres. These fabrics are moderately flammable and will melt while burning, causing deep and extensive burns to the skin. Workers should also avoid laminated fabric containing polyurethane sponge, as this ignites and burns quickly. Many synthetic materials do not char or ash when they reach ignition temperatures. Rather, they melt and form a hot, tacky residue that sticks to the skin and burns the flesh.

HAZARD ALERT

A journeyman electrician was burned when there was an explosion caused by an electric arc. He was installing a 600 V temporary service to a construction site. The high-visibility vest he was wearing caught fire, and the plastic on the vest melted, increasing the severity of his burns.

Although flame-resistant vests are available, most high-visibility vests are not flame-resistant. If there is any danger of a fire or explosion when working with energized equipment, the worker should remove a vest that is not flame-resistant or should wear a flame-resistant vest.

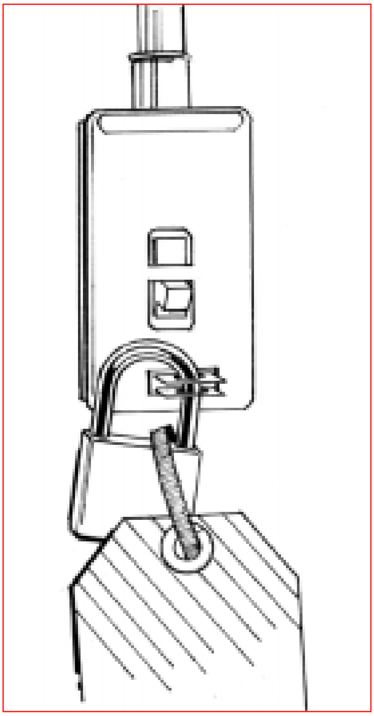
Common problem areas

This section highlights common problem areas and gives examples of actual incidents in which workers have suffered injury while working on electrical equipment. It also offers suggestions to help you work safely.

Lighting circuits (347 volts)

With the increasing use of 347/600 V systems in commercial and industrial buildings, lighting at 347 V is common. De-energize and lock out the power supply before working on electrical components. Then test all conductors to ensure de-energization.

Work must not be done on energized parts of electrical equipment that is connected with lighting circuits operating at more than 250 volts-to-ground without the prior written permission of the WCB.



If only the ballast is being changed, a lock on the wall switch will protect the worker. However, this is not acceptable for three-way, four-way, or low-voltage lighting controls.

HAZARD ALERT

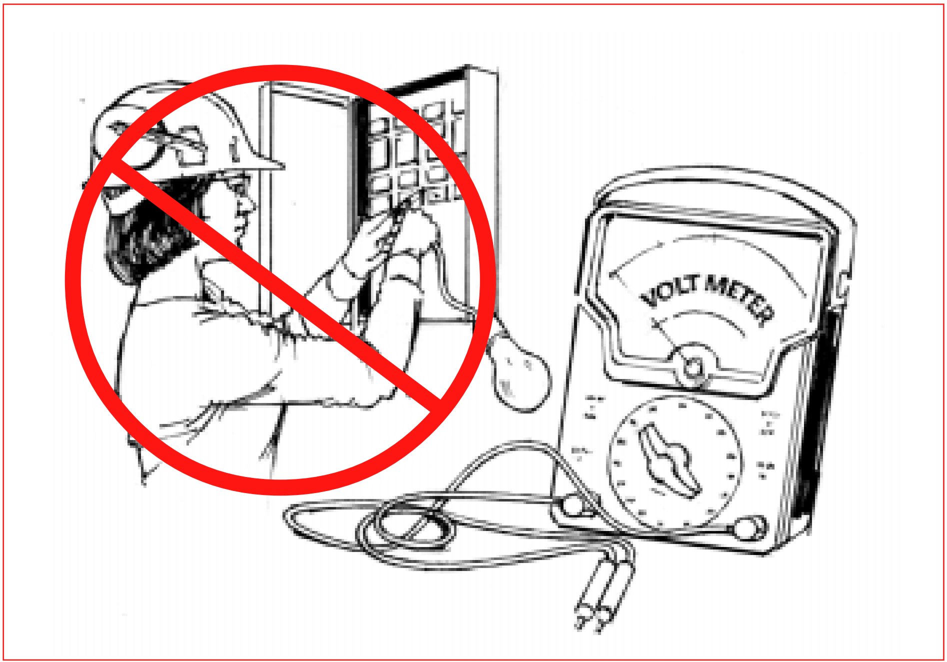
A worker contacted an energized wire while working on an energized 347 V ballast box above the suspended ceiling. Using safe work procedures, a co-worker pulled him away from the paralyzing contact. Subsequently, one finger had to be amputated.

In another, similar incident, a worker suffered electric shock and died.

Checking voltages with a meter

Checking voltages with a meter must be performed by workers who are qualified and know the hazards. Testing can be dangerous, particularly if it is done by unqualified workers who have little or no electrical experience. For example, workers must never use an improvised test lamp, which can cause an electric arc. If a worker incorrectly connects a meter to measure current rather than voltage, the low resistance of the ammeter could allow an abnormally high current to flow when voltage is checked.

Workers often lean close to the equipment to see where the test probes must be put. In the event of an electric arc, the worker's face will bear the brunt of the intense heat. Goggles or safety glasses must be worn; if there is a high risk, a full face shield must be used (see page 11 for more information on safety glasses).



Use approved portable meters and leads, not an improvised test lamp.

An electric arc may be started in one of the following ways:

- An improvised test probe (possibly a screwdriver blade or bare aligator clips) with more than the necessary exposed metal may create a phase-to-phase or phase-to-ground short-circuit on the closely spaced fuse clips or busbars of a 600 V panel.

- A screwdriver that is being used on energized equipment may slip and ground out the live parts.
- A multimeter that is not switched from the ammeter or ohmmeter mode may create a short-circuit across phases when the probes are placed on the conductors to measure voltage. The multimeter may disintegrate because the internal fuse may not be designed to protect against this kind of misuse. This, however, is not the worst that can happen. The arcing caused at the test probes can ionize the air, resulting in a fireball. (This problem should not occur if testing equipment meets the requirements listed below.)

The testing equipment must meet CSA standards or other standard acceptable to the WCB. Alternatively, acceptable testing equipment must have the following characteristics:

- It has high rupturing capacity (HRC) fuses or alternative protective circuitry to protect the worker in case of a fault.
- Measurement ranges are clearly and unambiguously marked.
- The insulation on the instrument leads is in good condition and is rated to the maximum voltage reading of the meter.
- The lead wires are not cracked or broken. They have a current carrying capacity (ampacity) that meets or exceeds the maximum current measurement of the meter.
- There is only a minimum amount of exposed metal at the probe tips to avoid short-circuiting closely spaced live parts.

When checking voltages with a meter, qualified workers must use an approved meter and should follow safe work practices, which include the following:

- Set the meter to the correct mode and voltage range. If possible, check its operation on a 120 V convenience outlet (for example, a system with a low available fault current). Multi-range instruments should always be turned off or set to their maximum AC voltage range when not in use.
- Use a single-function meter (voltmeter) rather than a multimeter if possible.
- Where possible, test on the load side of the fuse or circuit breaker having the smallest rating.
- Make sure meter leads are connected to the appropriate terminals of the meter for the measurement involved.
- Set the meter at the highest range that will allow for the expected reading to be achieved.

Working alone

Electrical work is often done by someone working alone or in isolation, such as on a rooftop or after regular hours so that de-energization does not inconvenience as many workers.

The employer must develop and implement a written procedure for checking the well-being of someone doing electrical work alone or in isolation. The procedure must include the time interval between checks and the procedure to follow in case the worker cannot be contacted (including provisions for emergency rescue). Someone must be designated to establish contact with the worker at predetermined intervals and at the end of the work shift. The time intervals must be determined in consultation with the worker assigned to work alone or in isolation.

Storage batteries

Some batteries may have a high level of stored energy (for example, batteries in battery-powered vehicles or large banks of storage batteries). Short-circuiting by a ring or wristwatch bracelet can severely burn a worker, even if no shock hazard exists. The voltage of some battery banks, however, may be high enough to be a shock hazard.

Proper protective equipment must be used for testing, connecting, or disconnecting batteries. For protection from the battery acid, a face shield, plastic apron, and plastic gloves are needed. There must be an eye wash station nearby in case of splashes to the eye. Insulated tools (wrenches, screwdrivers, etc.) must be used.

HAZARD ALERT

A technician was installing a storage battery when his wristwatch came in contact with the battery terminal. The wristwatch caused the battery to short-circuit and the worker suffered severe burns to his hands.

Ladders

Metal ladders or wire-reinforced wooden ladders must not be used by workers working on energized electrical equipment or by workers working near energized electrical equipment if there is a possibility of contacting bare energized components.

Low-voltage sections of unit substations

Workers have been injured while they were replacing components on low-voltage sections of unit substations. Unfortunately, this type of low-voltage section of the switch gear is often close to the supply transformer terminals—a place where there is very little impedance to limit the flow of fault current. If there are a number of loads on a busbar, the supply transformer may be quite large. The larger the transformer, the larger the current that will pour into a fault. Working on live installations of this kind can be extremely dangerous. De-energizing must be your first approach in such cases.

Some electrical equipment is designed so that sections of the unit substations are electrically isolated. This equipment can be maintained safely without de-energizing all of the electrical equipment. Consult the manufacturer's instructions and provide workers with written safe work procedures.

HAZARD ALERT

Two workers were attempting to add a new 400 A switch to the energized 600 V section of a 1,500 kVA power centre. A number of important loads were fed from the low-voltage busbars where the workers were going to install a new fused switch. They didn't want to inconvenience other operations by de-energizing the other loads connected to the busbars. Instead of planning a shutdown, they decided that they could install the switch live because it was "only" low voltage. The workers were severely burned during the installation.

Working near low-voltage overhead lines

Individual buildings such as houses often receive low-voltage electricity from overhead distribution lines and service drops. These lines are usually out of reach. However, workers using a ladder may come close to the area of low-voltage lines—for example, when washing windows or painting. These lines are not insulated well enough that a person can safely touch them. They should be considered energized and dangerous.

When a work process (such as window washing or painting) results in a *temporary* encroachment by a worker into the area of low-voltage lines, either:

- Barriers or covers must be provided if a worker unfamiliar with the hazards is working within 1 metre (3.3 ft.) of those parts, **or**
- The worker must be informed of the potential hazards and must follow written safe work procedures

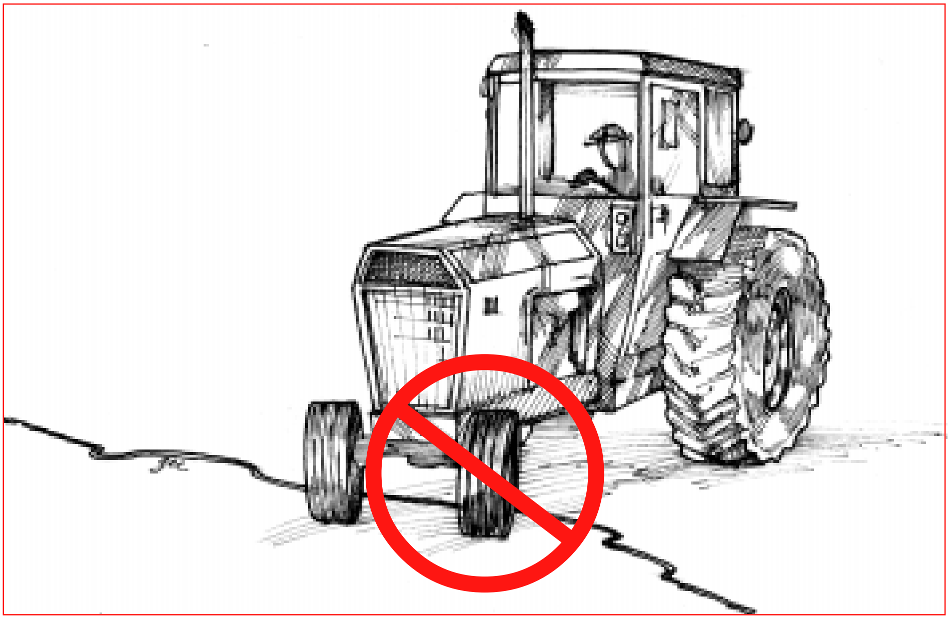
Sometimes there may be a *permanent* change in the building (such as a new stairway or work platform) that allows workers to move close to the low-voltage lines. In this case, qualified and authorized workers must reposition or cover the lines with conduit or other approved cover to protect workers from contact.

Portable electrical equipment and extension cords

Portable electrical equipment must be checked to ensure it is approved. Portable power tools and extension cords must be maintained in good repair and be suitable for the conditions where they are being used. For example, the outer jacket of an extension cord may appear undamaged but may conceal a broken ground conductor. Portable electrical equipment must be effectively grounded unless it has double insulation or equivalent protection.

Additional precautions are needed if approved portable electrical equipment is used outdoors or in wet or damp locations. This equipment, including temporary lighting, requires a class A–type ground fault circuit interrupter (GFCI) installed at the receptacle or on the circuit panel unless another means of protection is provided that is acceptable to the WCB, such as the Assured Grounding Program.

Workers have been electrocuted or badly burned as a result of contact with damaged extension cords. Electrical cords are often left unprotected, stretched across ground in the path of machinery. Over time, these cords become frayed, cut, and damaged from constant use and the pressure of vehicle traffic running over them. Sometimes wires are left exposed or a cut cord is repaired only with electrical tape. These cords are particularly hazardous when the ground is wet.



Damaged cords can result in serious electrical injuries.

GFCIs and Assured Grounding Program

A GFCI is a device that detects any leakage current in an electrical circuit and trips (turns off) the circuit whenever the leakage current is greater than 5 milliamperes. The Assured Grounding Program is an acceptable alternative to using GFCIs.

Using GFCIs

To prevent nuisance tripping of GFCIs, the following safe work practices are recommended:

- Mount GFCI receptacles and GFCI circuit breakers in dry locations; if this is not possible, use portable GFCIs rated rainproof.
- Connect only one power tool to each GFCI.
- Cover power tools to protect them from the rain when they are not in use.
- Store power tools and extension cords in a dry location.
- Maintain extension cords and power tools in good condition.
- Use extension cords that are rated for hard usage or better.
- Do not use extension cords longer than 45 metres (150 ft.).

Assured Grounding Program

An Assured Grounding Program may be used as an alternative to GFCIs for portable electrical equipment used outdoors or in a wet or damp location. The purpose of this program to ensure that the black wires (hot), white wires (neutral), and, in particular, green wires (ground) of extension cords and power tool cords are properly connected. This is done by testing every extension cord and power tool when it is first put into service, following repairs, and every three months.

An Assured Grounding Program has four parts:

1. Worker training

   All workers using extension cords and power tools under an Assured Grounding Program must be trained on the program.

2. Daily visual inspection

   Extension cords and power tools must be checked for damage daily by the persons who will be using them. Any damage found must be repaired before the cord or tool is used. Damaged extension cords and power cords of tools must not be spliced. The cords can either be replaced or be shortened to remove the damaged portion.

3. Continuity and polarity testing every three months

   A qualified worker must test every extension cord and power tool for circuit continuity and correct polarity before they are used for the first time, following repairs, and during the months of January, April, July, and October. A qualified worker is a person who has been authorized by a supervisor to perform the task and who has received appropriate training.

4. Colour-coding extension cords and power tools

   Extension cords and power tools that have been tested must be tagged with a coloured band about 10 cm (4 inches) from the male plug. Coloured electrical tape is suitable for this purpose. A different colour is required for each quarter of the year. These colours are standard for all worksites using an Assured Grounding Program in British Columbia:

Red	January, February, March
White	April, May, June
Blue	July, August, September
Green	October, November, December

   As an example, a new extension cord tested on February 8 will have a red tag at the male plug. The extension cord must be retested and marked with a white tag during April.