# Electrical Safety Guide For Non-Electrical Workers

2017

Safety Resources

University of Saskatchewan

# Contents


1 Purpose ... 1
2 Scope ... 1
3 Responsibilities ... 1
3.1 Workplace Responsibility System ... 1
3.2 Supervisors ... 2
3.3 Employees ... 2
3.4 Students ... 2
3.5 Facilities ~~Management Division~~Operations and Maintenance ... 3
3.6 Safety Resources ... 3
4 Training and Awareness ... 3
4.1 Faculty and Staff ... 3
4.2 Students ... 3
5 Electrical Hazards ... 4
5.1 DC and AC Electricity ... 4
5.2 Static Electricity ... 7
5.3 Other Hazards ... 8
5.4 Signs of Electrical Hazards ... 8
6 Hazard Assessment ... 9
7 Hazardous Energy Lockout ... 11
8 Academic Programs ... 11
9 General Safety Rules ... 12
10 Utilities Electrical Safety ... 15
10.1 Underground Utilities ... 15
10.2 Overhead Power Lines ... 15
11 Static Electricity Safety ... 16
12 Laboratory Instruments ... 17
13 Protective Devices ... 17
13.1 Introduction ... 17
13.2 Fuses and Circuit Breakers ... 18
13.3 Ground Fault Circuit Interrupters ... 19
13.4 Shielding and Equipment Guarding ... 21
13.5 Cable Clamping ... 21
14 Extension Cords, Power Strips and Power Cords ... 22
15 Grounding ... 24
16 Power Tools ... 24
17 Portable Power Generators ... 25
18 Batteries ... 26
19 Power Supplies ... 27
20 Capacitors ... 29
21 Inductors and Magnets ... 31
22 Semiconductor Components ... 33
23 Multimeters ... 33
24 Soldering Safety ... 35

25 High Voltage Equipment .... 36
26 Fire Safety .... 36
27 Electrical Emergencies .... 37
27.1 Electric Shock .... 37
27.2 Electrical Fire .... 38
27.3 Contact with a Power Line .... 38
28 References .... 39

Appendix A Definitions .... 40
Appendix B Electrical Safety Regulations and Standards .... 48

## 1 Purpose

The *Electrical Safety Guide for Non-Electrical Workers* is intended to provide general electrical safety principles and best practices for faculty, staff and students in the course ~~of work~~of work, research and academic activities where electrical hazards exist.

## 2 Scope

We live in an electrified society. Most of our modern devices, instruments, and appliances at work, at home, and for leisure are electricity powered either through electrical utilities, and/or through the use of batteries. The University of Saskatchewan employs literally thousands of electrically powered devices, instruments, equipment and tools. We are also engaged in many activities that can generate electrical currents such as electrical sparks.

Most of us appreciate the potential dangers of electricity even if we do not fully understand how electricity works. We learn early on in life not to stick things (other than power cords) in electrical outlets or we will get a nasty shock. We learn that it is dangerous to place electrified appliances, such as a hair blow dryer, near or in water. For most of us though, the hazards associated with electricity are not always obvious, and in many cases electrical hazards are hidden inside electrical boxes, behind panel doors, or contained inside equipment and instruments used in the course of our work.

It is a sobering fact that hundreds of preventable electrical accidents occur ~~each year~~each ~~in~~year in Canada, many resulting in serious injury, and even death. Countless electrical incidents (e.g. minor electrical shocks) and unsafe acts involving electrically powered devices or electrical infrastructure go unreported each year.

Electrical safety is not just important for electricians and electrical workers, it is also ~~important for~~important for faculty, staff and students who work with electrically powered devices or who are engaged in activities that may result in electrical hazards. In support of electrical safety at the University of Saskatchewan, the *Electrical Safety Guide for Non-Electrical Workers* has been developed. The guide provides simple tips and best practices that will help minimize the ~~hazards~~ risks associated with the use of electricity on our campus.

The *Electrical Safety Guide for Non-Electrical Workers* document does not replace any relevant regulations or codes for which the university must comply with, nor does it authorize university faculty, staff and students to perform electrical work for which they are not trained or qualified to perform.

## 3 Responsibilities

### 3.1 Workplace Responsibility System

The University of Saskatchewan is dedicated to providing a place of employment and learning that is as free as possible from recognized hazards. This commitment is rooted in ~~the *Workplace*~~the Workplace *Responsibilities System* which formulates employee obligations in health, safety and environmental protection, regardless of affiliation or position, with the aim to create a culture that secures involvement and participation at all levels within the university community.

Under the *Workplace Responsibilities System*, it is fundamentally the responsibility of line management to ensure that activities undertaken in their charge are managed in accordance with university requirements and all applicable legislative requirements.

The *Workplace Responsibilities System* document is available on the Safety Resources website at http://safetyresources.usask.ca/.

### 3.2 Supervisors

Supervisors include anyone who directs the work or activities of others, including students. Managers, faculty, instructors and principal investigators, if directing the work ~~activities of~~activities of others, are considered supervisors under occupational health and safety legislation.

Under the WRS, supervisors are responsible for:

- Providing leadership in promoting health and safety;
- Ensuring that staff and students are provided with a safe environment and receive adequate instruction, and health and safety training for their related areas of work and/or learning;
- Ensuring staff and students understand and follow required procedures and health and safety rules;
- Taking immediate actions to correct unsafe conditions when they become aware of them; and
- Complying with university policies, and applicable health and safety legislation.

### 3.3 Employees

Under the WRS, every university worker (including graduate students paid through the university) is responsible for:

- Complying with university policies, health and safety rules and procedures~~;~~
- Taking an active role in protecting and promoting his/her health and safety~~;~~
- Refraining from activities that may jeopardize the health and safety of others~~;~~
- Reporting immediately to his/her supervisor, when involved in an incident or becomes aware of hazards in the workplace~~; and~~
- Complying with applicable health and safety legislation~~.~~

### 3.4 Students

Every university student (undergraduate and graduate) must act with regard to health and safety and follow all instructions and safety precautions conferred upon them by their supervisor or instructor.

## ~~3.5~~ Facilities Operations and Maintenance ~~Management Division~~

## 3.5

Installations, repairs and maintenance to laboratory or building electrical services shall only be performed by the Facilities ~~Management Division~~Operations and Maintenance ~~(FMD)~~ and by qualified electrical workers.

Maintenance or modifications to commercial appliances, instruments, and equipment must be performed by the manufacturer or ~~FMD~~ by a qualified electrical worker and not by laboratory personnel. For equipment that is directly connected to building or laboratory electrical services (hard-wired), and is not equipped with a disconnect at the equipment, Facilities Operations and Maintenance ~~MD~~ must be contacted. Laboratory research, academic personnel and students may only perform maintenance or modifications to experimental electrical equipment or apparatus used or developed in research or for academic purposes, and only if properly trained and under appropriate supervision.

## 3.6 Safety Resources

Safety Resources is the institutional entity charged with supporting health and safety at the university. In this capacity, Safety Resources is responsible to:

- Promote health and safety and support a culture focused on injury prevention~~;~~
- Be a resource to the campus community in occupational health, safety and environmental protection~~;~~
- Provide training and awareness~~;~~
- Develop programs and services in health, safety and environmental protection~~;~~
- Assist in the identification and resolution of issues and problems in health, safety and environmental protection~~; and~~
- Support regulatory compliance and best practices in health, safety and environmental protection~~.~~

# 4 Training and Awareness

## 4.1 Faculty and Staff

Faculty and staff working with electrical equipment must receive appropriate training on the equipment, understand the hazards associated with the operation of the equipment, and be trained on how to protect themselves from recognized hazards.

Individuals who, through the course of their work activities, may perform adjustments, maintenance or repair of electrical equipment must be appropriately trained and qualified to carry out the work.

Records of training should be maintained by the department or unit.

## 4.2 Students

All students engaged in academic or research activities requiring the use of electrical equipment



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- Their responsibilities in support of health and safety~~;~~
- The proper use of the electrical equipmen~~t~~;
- Work procedures and rules~~;~~
- The known electrical and other hazards~~; and~~
- The health and safety measures in place to protect them from injury~~.~~

Students should be encouraged to ask questions and to raise health and safety concerns, ~~and to~~and to report incidents.
Where possible, health and safety information should be incorporated into the written course material and reviewed with students.

## 5 Electrical Hazards

### 5.1 DC and AC Electricity

A common phrase heard in reference to electrical safety is, "it is not the voltage that kills, it is the current". This is in effect true as it is electric current that burns tissue, freezes muscles, and fibrillates hearts. A current as low as a few milli-amperes (mA) can cause a painful shock, muscle clamping or even ventricular fibrillation. A hair dryer can generate a current of 8,000 mA (8 A), a 100 W light bulb 1,000 mA and a coffee maker 7,000 mA. Under the right conditions, currents of only a few milli-amperes could lead to death.

However, electric current does not occur without sufficient voltage available to ~~motivate electrons~~motivate electrons to flow (current). Electrical equipment operating at voltages as low as 30 V (volts) is capable of delivering dangerous shock currents. High voltage, low resistance electrical circuits can create high currents. Whether direct current (DC) or alternating current (AC) is involved, electric currents high enough to cause involuntary muscle action are dangerous and are to be avoided.

How AC electricity affects the body depends largely on frequency. Low frequency (50 to 60 Hz) AC is used in North America (60 Hz) and European (50 Hz) households. It can be more dangerous than high frequency AC and is more dangerous than DC electricity of the same voltage and amperage. Low frequency AC electricity produces extended muscle contraction (tetany), which may freeze the hand to the current's source, prolonging exposure. DC electricity is most likely to cause a single convulsive contraction, which often forces the victim away from the current's source.

The alternating nature of AC electricity has a greater tendency to throw the heart's pacemaker neurons into a condition of fibrillation, whereas DC electricity tends to just make the heart stand still. Once the shock current is halted, a frozen heart has a better chance of regaining a normal beat pattern than a fibrillating heart. This is why defibrillating equipment (Automated External Defibrillator) works. The jolt of current supplied by the AED unit is DC electricity, which halts fibrillation and gives the heart a chance to recover.

There are three general categories of electrical hazards that can cause injury:

- Electric shock;
- Arc flash; and
- Arc blast.

**Electric shock**

Electrical shock occurs when the body becomes part of the electric circuit, either when an individual comes in contact with both wires of an electrical circuit, one wire of an energized circuit and the ground, or a metallic part that has become energized by contact with an electrical conductor.

Figure 1: Electrical shock warning sign. Image courtesy of 5volt, Flickr.

The severity and effects of an electrical shock depend on a number of factors, such as the pathway through the body, the amount of current, the length of time of the exposure, and whether the skin is wet or dry. Water is a great conductor of electricity, allowing current to flow more easily in wet conditions and through wet skin.

The most damaging route of electricity is through the chest cavity or brain. Fatal ventricular fibrillation of the heart (stopping of rhythmic pumping action) can be initiated by a current flow of as little as several milli-amperes (mA). Nearly instantaneous fatalities can result from either direct paralysis of the respiratory system, failure of the rhythmic pumping action of the heart, or immediate heart stoppage.

The minimum current a human can feel is thought to be about 1 mA. The current may cause tissue damage or fibrillation if it is sufficiently high. Death caused by an electric shock is referred to as electrocution. Generally, currents approaching 100 mA are lethal if they pass through sensitive portions of the body.

The current required to light a 7.5 W, 120 V lamp (63 mA), if passed across the chest, is enough to cause death. The most damaging paths through the body are those through the chest (lungs and heart), and the brain.

When electricity passes through a resistant material such as the human body, energy is given off in the form of heat. This is the cause of electrical burns. The extent of the burn depends ondepends on the size of the current, the pathway (e.g. head to toe, hand to hand), and the duration of exposure. Electrical burns are among the most serious burns and require immediate medical attention.

Damage to internal tissues may not be apparent immediately after contact with an electrical current. Delayed internal tissue swelling and irritation are possible. Prompt medical ~~attention can~~attention can help minimize these effects and avoid long-term injury or death.

**Arc Flash**

When an electric current passes through air between ungrounded conductors or between ungrounded conductors and grounded conductors, temperatures can reach 20,000°C. Exposure to these extreme temperatures burns the skin directly and ignites clothing, which adds to the burn injury. The majority of hospital admissions due to electrical accidents are from arc flash burns, not from shocks. Each year more than 2,000 people in the United States are admitted to burn centres with severe arc flash burns. Arc flashes can kill at a distance of 3 m. Arc flash incidents have occurred at the University of Saskatchewan.

Figure 2: Example of an arc flash. Image courtesy of Plant Engineering.

**Arc Blast**

The tremendous temperatures of the arc cause the explosive expansion of both the surrounding air and the metal in the arc path. For example, copper expands by a factor of 67,000 when it turns from a solid to a vapour. The danger associated with this expansion is one of high pressures, sound, and shrapnel. The high pressures can easily collapse lungs and rupture eardrums as the sounds associated with these pressures can exceed 160 dB. Finally, material and molten metal is expelled away from the arc at speeds exceeding 1,100 km/h, fast enough for shrapnel to completely penetrate the human body.

### 5.2 Static Electricity

Static electricity refers to the buildup of electric charge on the surface of objects. Static electricity is usually created when materials are pulled apart or rubbed together, causing positive (+) charges to collect on one material and negative (−) charges on the other surface. If these charges do not have a path to the ground, they are unable to move and become "static".
Static electricity can cause sparks, shocks or materials to cling together.

Figure 3: Example of static electricity. Pieces of paper are shown clinging to a balloon as a result of a buildup of static charge. Image courtesy of njorthr, Flickr.

If static electricity is not rapidly eliminated, the charge will build up. It will eventually develop enough energy to jump as a spark to some nearby grounded or less highly charged object in an attempt to balance the charge. A good example of this in everyday life is lightening. ~~Lightening is~~Lightening is produced by a discharge of electricity from one cloud across an air gap to another cloud or between a cloud and the earth.

The main hazard of static electricity is the creation of sparks in an explosive or flammable atmosphere. These sparks can set off an explosion or fire. The danger is greatest when flammable liquids are being poured or transferred.

Solvents and fuels produced from petroleum (e.g., benzene, toluene, mineral spirits, gasoline, jet fuel) can build up a charge when they are poured or flow through hoses. They tend to hold a charge because they cannot conduct electricity well enough to discharge when in contact with a conducting material, like a metal pipe or container that is grounded. When enough of a charge is built up, a spark may result. If the vapour concentration of the liquid in air is in the "flammable range" and the spark has enough energy, a fire or explosion can result.

Solvents that are soluble in water (or can dissolve some water themselves) do not build ~~up static~~up static electricity. Examples of such liquids include alcohols and ketones like acetone. However, when liquids are transferred into non-conductive containers (e.g., plastic, glass), even conductive solvents may build up a charge because the plastic or glass containers decrease the rate at which the charge in the solvent dissipates.

The flash point and vapour pressure of the liquid and the temperature are other factors to consider. The vapour levels will be higher in the air around the container if you are working outside on a hot summer day than in the winter.

For static electricity to be a hazard, four conditions must be met:

- There must be a means for a static charge to develop~~;~~
- Enough energy must build up to cause ignition~~;~~
- There must be a discharge of this energy (a spark)~~; and~~
- The spark must occur in an ignitable vapour or dust mixture~~.~~

### 5.3 Other Hazards

Voltage sources that do not have dangerous current capabilities may not pose serious shock or burn hazards in and of themselves, and therefore are often treated in a casual manner. However, voltage sources are frequently near lethal circuits, and even a minor shock could cause a worker to rebound into a lethal circuit, fall off a ladder, or be exposed to another hazard. Such an involuntary reaction can result in bruises, cuts, bone fractures, and even death from collisions or falls.

### 5.4 Signs of Electrical Hazards

Following are a number of clues of the presence of electrical hazards associated with the use of electrical equipment.

- Tripped overcurrent protective devices (circuit breakers, fuses and ground fault circuit interrupter)~~;~~
- Hot to the touch on tools, wires, cords, connections, or junction boxes~~;~~
- Dim and flickering lights~~;~~
- Sizzles and buzzes or unusual sounds from electrical equipment, apparatus or circuits~~;~~
- Odour of hot insulation~~;~~
- Mild tingle from contact with case or equipment~~;~~
- Worn or frayed insulation around wire or connection~~; and~~
- Burn marks or discoloration on receptacle plates or plug prongs~~.~~

For university staff and students, PPE requirements, if any, will depend on the type of the activities being undertaken, the electrical hazards present and whether work is being performed on energized circuits.

Figure 4: Frayed wires and power cables pose a signficantsignificant electrical hazard. Image courtesy of marblegravy, Flickr.

## 6 Hazard Assessment

Prior to commencing work on electrical equipment, instruments or tools, a job safety analysis should be performed to determine the hazards present and the protective measures that should be instituted.

In a job safety analysis, each activity is broken down into its key steps. At each step, hazards are identified and appropriate control measures developed to minimize the risk of injury.

Hazard controls should be considered in order of their efficacy. Listed below is the accepted hierarchy of hazard control:

- Eliminate the hazard if possible such as de-energizing the equipment and locking it out prior to performing any work;
- Implement engineering controls (e.g. overcurrent protective device, enclosure, or using insulated tools);
- Develop safe work practices (e.g. training and work procedures); and
- Utilize personal protective equipment (e.g. eye protection, gloves, laboratory coats).

A sample job safety analysis for a student electrical laboratory experiment is presented in Table 1.

Table 1: Sample job safety analysis for a student laboratory experiment involving an electrical voltage divider.

| Basic Job Steps | Possible Hazards | Preventative Measures |
|---|---|---|
| Gather instruments, tools and components for experiment (battery, resistors, cables, multimeter) | • Instruments and parts not working or appropriate for the experiment (e.g. leaking battery) | • Instructor should ensure that instruments, tools and components are appropriate for the experiment and are in good working order |
| | • Students gather the wrong instruments, tools or components | • Ensure that only those instruments, tools and components for the experiments are available to students<br>• Have experimental instruments, tools and components placed at student workbenches prior to experiment |
| | • Electrical shock while carrying battery | • Ensure battery terminals are covered or protected<br>• Instruct students on the proper handling of battery<br>• Place batteries at student workbenches in advance of experiment |
| Assemble circuit with three resistors in series connected to the battery; assemble the circuit using connector cables provided | • Electrical shock assembling circuit | • Establish procedures for assembling circuits<br>• Remove jewelry<br>• Do not connect the circuit to the battery until fully assembled<br>• Use insulated connectors<br>• The instructor should confirm the circuit before connecting to the battery<br>• Connect cables to the battery one at a time (positive first and then negative)<br>• Do not touch the circuit with bare hands or with metal objects<br>• Do not make changes to the circuit while connected to the battery<br>• Remove cables from battery one at a time (negative first and then positive) |
| Measure circuit parameters (voltage, current, resistance) | • Electrical shock measuring circuit parameters | • Provide training on multimeters and their proper use<br>• Do not touch the circuit with bare hands or with metal objects<br>• Ensure that the multimeter cables are in good condition (not frayed, cable probes clean and in good condition)<br>• Test multimeter prior to using<br>• Ensure the multimeter measurement setting is correct prior to taking a measurement<br>• Disconnect the circuit from the battery prior to connecting the multimeter to measure current |
| Disassemble circuit | • Electric shock disassembling circuit | • Do not touch the circuit with bare hands or with metal objects<br>• Remove cables from battery one at a time (negative first and then positive) |

## 7 Hazardous Energy Lockout

In university workplaces, the various forms of energy associated with equipment and machinery have the potential for causing severe injuries, including electrocution, burns, chemical exposures, cuts, bruises, crushing, amputation or death. To protect faculty, staff, students, and visitors from the hazards associated with the inadvertent or accidental start-up of such equipment or machinery during servicing, maintenance or other activities, specific lockout and ~~tagout~~tag out procedures must be implemented to control potentially harmful energy sources.

The University of Saskatchewan *Hazardous Energy Lockout Standard* outlines the responsibilities and minimum requirements and performance objectives for procedures, techniques, and methods to protect individuals from injury from the inadvertent release of hazardous energy including from electrical sources when working with equipment ~~and machines~~and machines.

This standard applies to all instances where the isolation and lockout of hazardous energy sources is required to safely perform work or maintenance on equipment, machines, or processes. Sources of hazardous energy include any electrical, mechanical, hydraulic, pneumatic, chemical, thermal, including gravity or any other source of energy of potential harm to an individual.

A hazardous energy lockout program is not required for normal operations or production ~~work on~~work on equipment, machines, or processes where there is no risk of exposure to hazardous energy sources or if appropriate and effective safeguards are in place to protect workers.

A lockout program is not required for electrical equipment that can be de-energized by physically disconnecting a power cable from an electrical outlet providing the equipment ~~is under~~is under the direct and immediate control of the person performing the work.

The *Hazardous Energy Lockout Standard*, in no way, authorizes university faculty, staff, students or visitors to perform maintenance, repair or adjustments to infrastructure systems of university owned and managed buildings and facilities. This includes electrical supply and distribution systems to buildings and heating, ventilation and air conditioning systems, and emergency systems. Maintenance, repair and adjustments to these systems are the responsibility of the University of Saskatchewan Facilities Operations and Maintenance~~Management Division~~ and shall be performed by appropriately qualified, trained and authorized personnel from the division.

For further information or assistance with this standard or hazardous energy lockout, please contact Safety Resources at 966-4675.

## 8 Academic Programs

Many university academic programs in the sciences and engineering involve the study and use of many types of electrical equipment, instruments, apparatus and circuits. To ensure the safety of students, it is important that faculty and instructors incorporate health and safety into the curriculum.

Following, are general health and safety principles that should be considered in the development of academic programming involving the use of electrical equipment.

- Clearly identify the objective and scope of the academic program element (e.g. laboratory experiment);
- Determine the appropriate equipment and tools that will be used;
- Perform a job safety analysis to identify the electrical safety hazards and other health and safety hazards related to the course element:
    - Determine the key steps involved with a process or procedure;
    - Identify the hazards at each key step;
    - Determine the appropriate control measures to protect against identified electricalidentified electrical hazards. Control measures could include rules and procedures, tools, protective devices, and the use of personal protective equipment;
- Develop procedures to be followed. Where possible, follow a standard document format for all experiments such as:
    - Experiment purpose/objective;
    - Student responsibilities;
    - Safety hazardss;
    - Safety measures (procedural, tools, protective devices, personal protective equipment, emergency);
    - Equipment and materials required;
    - Experimental procedure (re-enforce safety measures throughout the procedure);
- Regularly review the laboratory experiment and supporting documentation.

When providing instruction on electrical equipment, in shops, or laboratories where electrical hazards are present, instructors should:

- Ensure they thoroughly understand the operations or experimental procedures, the equipment and tools to be used and the health and safety hazards and measures to protect staff and students;
- Inspect all electrical systems, equipment, tools, components, cables, connectors and meters prior to instruction. Only properly functioning equipment should be used during instruction;
- Provide specific electrical safety instruction to students at the beginning of the lecture, and prior to allowing students to begin their work. This should include how to use experimental equipment, tools, the proper use of measuring devices and what to do in the event of an emergency situation; and
- Provide appropriate supervision of students and immediately stop unsafe practices.

## 9 General Safety Rules

Faculty, staff and students can significantly reduce electrical hazards and risk of injury by adhering to safe work practices when working with electrical equipment. Following, is a list of general safety that should be considered.

It is noted that installation, repair and maintenance of commercial electrical equipment ~~must only~~must only be performed by properly qualified and authorized persons and under adequate supervision.

*General Safety Rules When Working With Electrical Equipment*

- *Only authorized and qualified electrical workers should install, repair or perform maintenance on commercial electrical equipment. Only authorized and qualified electrical workers from Facilities Operations and Maintenance~~MD~~ are permitted to install, repair or perform maintenance on laboratory and building electrical systems~~;~~*
- *All staff and students should receive health and safety training appropriate to the work and activities they are engaged in~~;~~*
- *Follow the instructions provided by your supervisor or instructor~~;~~*
- *Treat all electrical devices as if they are live or energized~~;~~*
- *Review procedures and safety rules prior to beginning work. Ensure that you understand the procedures, electrical hazards and what measures are in place to protect you. Follow all safety rules including those for the use of required personal protective equipment~~;~~*
- *Review emergency procedures~~;~~*
- *Know the location of electrical panels and shut-off switches so that they can be quickly disconnected in the event of an emergency~~;~~*
- *Know the locations of safety devices such as first aid kits, fire extinguishers, emergency eye washes and showers, automated external defibrillators, etc.~~;~~*
- *Ensure equipment, tools and personal protective equipment is in good operating condition. Never use equipment, tools or personal protective equipment that are in disrepair or not properly maintained~~;~~*
- *When at all possible, electrical equipment should be de-energized prior to working on it. Lockout procedures should be instituted for de-energizing equipment including appropriate testing protocols to confirm that equipment is in a safe state before being worked on~~;~~*
- *Keep flammable materials away from electrical equipment~~;~~*
- *Limit the use of extension cords. Use only for temporary activities. In all other cases, request installation of a new electrical outlet~~;~~*
- *Practice good housekeeping. Poor housekeeping is a major factor in many accidents. A cluttered area is likely to be both unsafe and inefficient~~;~~*
- *Access to electrical panels should not be blocked or covered by materials. There should be a one metre clearance between electrical panels and any object~~;~~*
- *Do not engage in horseplay~~; and~~*
- *Immediately report unsafe acts or conditions to your supervisor or instructor.*

The following additional safety rules apply specifically to staff and students who are engaged in the design, assembly, modification, and testing of electrical equipment or apparatus developed in research, or for the purposes of teaching.

- *When designing circuits and systems include circuit protection devices as needed;*
- *Do not wear loose clothing or ties near equipment. Remove metal jewelry (watches, rings, etc.) before working on electrical circuits;*
- *Turn off power and unplug power and extension cords from the wall before assembling or working on an electronic circuit or apparatus, except when absolutely necessary;*
- *Ensure electrical components (switches, resistors, capacitors, inductors, transistors, etc.) are appropriate for the circuit or apparatus;*
- *Place exposed electrical conductors (especially those with greater than 50 volts) in protective chassis boxes or behind Plexiglas shields;*
- *Complete all wiring and check it carefully before applying power to the circuit power. Use the shortest wires possible and ensure that all connections are secure. Students should have circuits inspected by instructors prior to applying power;*
- *When a circuit or apparatus is to be reconfigured or rewired, turn the power supply off. It is also a good practice to disconnect power and extensions cords from the power supply. Ensure to test the circuit using an appropriate multimeter to confirm that the circuit or apparatus is fully de-energized;*
- *Safely discharge capacitors and inductors in equipment before working on the circuits. Large capacitors found in many laser flash lamps and other systems are capable of storing lethal amounts of electrical energy and pose a serious danger even if the power source has been disconnected;*
- *Avoid contact with energized electrical circuits. Never touch live circuit components with bare hands;*
- *Make sure equipment chassis or cabinets are grounded. Never cut off or defeat the ground connection on a plug;*
- *When performing measurements on a live/active circuit, be sure to shift meter probes and connectors using only one hand. It is best to keep the other hand off other surfaces and behind your back;*
- *Do not work on electrical equipment in a wet area or when touching an object that may provide a hazardous earth ground path;*
- *Never overload circuits;*
- *Never leave unprotected systems unattended;*
- *Never place containers of liquid on electrical systems;*
- *Ensure to turn off the power supply first before disassembling the circuit;*
- *Use only tools and equipment with non-conducting handles when working on electrical devices;*
- *Never use metallic pencils or rulers, or wear rings or metal watchbands when working with electrical equipment;*
- *When it is necessary to handle equipment that is plugged in, be sure hands are dry and, when possible, wear nonconductive gloves and shoes with insulated soles;*
- *If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipmentnt;*

- *Equipment producing a "tingle" should be disconnected and reported promptly for repair. "Shorts" (ground faults) are extremely hazardous especially where in contact with metal framework of an exhaust hood or damp floor;*
- *Do not rely on grounding to mask a defective circuit nor attempt to correct a fault by insertion of another fuse or breaker, particularly one of larger capacity; and*
- *Never touch another person's equipment or electrical control devices unless instructed toinstructed to do so.*

## 10 Utilities Electrical Safety

### 10.1 Underground Utilities

Accidental contact with underground utilities (e.g. electrical, natural gas) can result in severe injury or even death. It is very important that underground utilities be located prior to any excavations or penetrations of the ground.

In accordance with the University of Saskatchewan *Underground Utility Assessment Policy and Permit Requirements*, it is the responsibility of all individuals (employees, students, contractors) who intend to perform excavating, trenching, boring or otherwise penetrating the grade (to any depth) with any product including, but not limited to a temporary or permanent fence post, tent support, peg or other penetrating object to apply for an *Underground Locate and Verification Permit*.

Contact FMD Work Control CentreFacilities Operations and Maintenance Customer Service Center at 966-4496 for information on obtaining an *Underground Locate and Verification Permit*.

*Safety Tips*

- *Never dig without knowing where underground utilities are located;*
- *Call Safety Resources and FMDFacilities Operations and Maintenance to have utilities identified and marked;*
- *Ensure an all Uunderground lLocate and Verification Permit haves been completedacquired before proceeding with any excavation; and*
- *If a utility line is cut, immediately move away from the excavation, and notify Facilities Operations and Maintenance Customer Service FMD Work Control Centre atCenter at 966-4496.*

### 10.2 Overhead Power Lines

Contact with an overhead power line can cause property damage, serious injury or even loss of life. Always use extreme caution when working around electrical power lines.

*Safety Tips*

- *Check for overhead power lines before moving high equipment;*
- *Always lower equipment before moving it under overhead power lines;*
- *Keep at least three metres away from overhead power lines. For high voltage*

*transmission lines, keep at least six metres away;*

- *Never raise/handle ladders, long pipes or other long conducting materials without checking for safety distances from power lines~~;~~*
- *Never try to lift a power line~~;~~*
- *Trimming trees near wires is to be performed only by qualified individuals~~;~~*
- *Do not clear storm-damaged trees, limbs or other debris that are touching power lines~~;~~*
- *Do not approach a vehicle or equipment that is contact with a power line (call 911)~~;~~*
- *Never touch anyone in contact with overhead power lines (call 911)~~;~~ and*
- *Stay a minimum of 10 metres away from fallen power lines~~.~~*

## 11 Static Electricity Safety

Common sources of static electricity include:

- Liquid flowing through pipes~~;~~
- Spraying or coating~~;~~
- Blending or mixing~~;~~
- Filling tanks, drums, cans or pails~~;~~
- Dry powdered material passes through chutes or pneumatic conveyors~~; and~~
- Non-conductive conveyor belts or drive belts and moving appliances are plugged into electrical outlets~~.~~

People can also accumulate static charges generated by clothing or footwear. This is most likely to happen in dry atmospheres, such as heated buildings in winter, or when walking across carpets.

Most static electricity control measures provide ways for the static charges to dissipate harmlessly before sparks occur.

*Safety Tips*

- *Practice bonding and grounding to equalize the potential charges between objects. When dispensing flammable liquids, both bonding and grounding are required~~;~~*
- *Employ a static collector such as needle pointed copper combs, spring copper brushes or metallic tinsel bars to remove build-up of static electricity~~;~~*
- *A relative humidity of 60% to 70% at 21°C may reduce static electricity. A high relative humidity, however, is no guarantee against the accumulation of static electricity. Therefore, do not rely solely on humidification as a control measure in areas where there are flammable liquids, gases, or dusts~~;~~*
- *Use anti-static additives (such as in fuels) which increase the conductivity or lowers the resistance of the liquid. Additives also reduce the time it takes for the static charge to leak through the wall of the container and to the ground~~;~~*
- *Install conductive flooring in work areas~~;~~*
- *Wear conductive clothing and footwear (cotton or linen clothing instead of wool, silk or synthetic materials)~~; and~~*
- *Use non-conductive or sparking tools~~.~~*

## 12 Laboratory Instruments

In research there are literally hundreds of different types of electrical instruments and devices. Examples include hand held tools, microscopes, baths, centrifuges, shakers, incubators, ovens, spectrometers, autoclaves, refrigerators, fume hoods, and biosafety cabinets. The list ~~is long~~is long and varied and beyond the scope of this guide to address electrical safety issues that may be specific to each instrument or device. However, following are some general electrical safety tips that should be followed when using electrically powered laboratory instruments.

*Safety Tips*

- *Follow the manufacturer's instructions for the installation of the instrument. If the instrument has specific power requirements or must be directly connected to laboratory/building electrical systems, contact Facilities Operations and Maintenance~~FMD;~~*
- *Review the manufacturer's operations manual and safety requirements before using the instrument~~;~~*
- *Ensure that staff and students using the instrument receive appropriate training. As necessary, develop a standard operating procedure for the use of the instrument~~;~~*
- *As directed, use appropriate personal protective equipment when using the instrument;*
- *Each time before using the instrument, inspect the instrument and power cord. Never use an instrument that is damaged, in disrepair, or is malfunctioning~~;~~*
- *Ensure that the instrument is properly maintained and tested/calibrated at a frequency as recommended by the manufacturer and/or governing regulator (e.g. fume hoods and biosafety cabinets must be tested at least annually)~~;~~*
- *Only use the instrument for its intended purpose~~;~~*
- *Do not modify the instrument~~; and~~*
- *Utilize only qualified electrical workers to perform maintenance, or make repairs. Depending on the instrument and its configuration, the manufacturer or FMD should be contacted~~.~~*

## 13 Protective Devices

### 13.1 Introduction

Circuit protection devices are designed to automatically shut off the flow of electricity in the event of an overload, short circuit or ground fault in the wiring system. Fuses, circuit breakers and ground fault circuit interrupters are three common examples of such devices.

Overcurrent protective devices should be selected carefully to make sure they will open the circuit safely under any abnormal overcurrent condition. Interrupting ratings and opening times, especially under short circuit and ground fault conditions, must also be carefully observed. Failure to select the properly rated overcurrent protective device can result in fires, explosions, injuries, and death. Consult with the manufacturer or Facilities Operations and Maintenance~~MD~~ when purchasing protective devices.

### 13.2 Fuses and Circuit Breakers

Fuses and circuit breakers are designed to sense abnormal overloads and short circuits and open the circuit before catastrophic events occur. Each device, however, has different time characteristics and must be used and applied according to the appropriate standards and manufacturer's recommendations for the individual application. Fuses and circuit breakers must be able to discern the difference between normal current variations that pose no threat to equipment, and dangerous overloads or short circuits that can cause extensive damage to equipment and compromise safety. Not all devices are designed to protect against both overloads and short circuits. For example, most motor starters provide only overload protection, while some circuit breakers provide only short-circuit protection.

Figure 5: Example of a typical circuit breaker. Image courtesy of vaprotan, Flickr.

*Safety Tips*

- *All commercial electrical equipment, appliances and instruments should be certified by a recognized certification body (e.g. CSA, ULC, etc.). Refer to Appendix B for a list of recognized certification bodies and symbols;*
- *Proper selection of overcurrent protective devices is critical to protecting equipment and people;*
- *Ensure that fuses are properly sized for the circuit. Never install a fuse with a higher amperage rating than that specifically listed for the circuit;*
- *Never defeat the purpose of a fuse or circuit breaker;*

- *Circuit breakers should be tested on a regular frequency (at least once per month) and in accordance with the manufacturer's instructions;*
- *Electrical equipment should be properly maintained. Poorly maintained or improperly functioning equipment can result in increased safety risks and can result in frequent blown fuses and nuisance trips of circuit breakers; and*
- *If a circuit breaker continually trips or fuse continually blows, there could be a problem with the electrical system or with the electrical equipment, apparatus or circuit connected to power. Contact the FMD Customer Service Centre at 966-4496.*

### 13.3 Ground Fault Circuit Interrupters

A ground fault occurs when a current-carrying conductor comes in contact with ground. A faulty appliance or the presence of water in contact with a conductor, are possible ways a ground fault can occur.

A ground fault circuit interrupter (GFCI) is essentially a fast-acting circuit breaker. It ~~senses small~~senses small imbalances in the circuit a ground fault creates. The GFCI continually matches the amount of current going to an electrical device against the amount of current returning from the device along the electrical path. Whenever the amount "going" differs from the amount "returning" by approximately 5 milli-amperes, the GFCI interrupts the electric power within as little as 1/40 of a second.

Although the GFCI is an effective safety device, it is not a guarantee against shock in every situation. The GFCI does not protect against a line-to-neutral or a line-to-line shock. Also, if GFCI protected equipment contains transformers, a ground fault (shock) on the secondary side of the transformer may not trip the GFCI.

There are three types of GFCIs that can be used in the workplace and laboratory (see Figure 6):

- A GFCI receptacle can be used in place of a standard receptacle;
- A portable GFCI device that plugs into a regular house outlet and provides protection to whatever is plugged into it; and
- A GFCI circuit breaker.

Figure 6: Example of ground fault circuit interrupter. Image courtesy of University of Saskatchewan.

There are two major classes of GFCI: Class A and Class B. Class A GFCIs are the most common type and are designed to trip when there is a ground fault current of 4-6 mA (milli- ampere). The Class B GFCI is designed to trip at a fault current of 20 mA or more. It should be noted that a Class A GFCI is designed for personal protection while a Class B GFCI is designed to protect equipment.

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

- Mount GFCI receptacles and GFCI circuit breakers in dry locations. If this is not possible, use portable GFCIs rated as rain proof;
- Connect only as many pieces of equipment to each GFCI as recommended by the manufacturer (i.e. do not overload the GFCI);
- Keep equipment and tools dry;
- Maintain extension cords and power tools in good condition;
- Use extension cords intended for industrial/heavy duty usage or better;
- Do not use extension cords longer than 45 metres (150 feet); and
- Test and maintain the GFCI as per the manufacturer's instructions/specifications.

Since GFCIs can cause equipment to shutdown unexpectedly, they may not be appropriate for certain electrical equipment or apparatus. Consult with FMD.

*Safety Tips*

- *Only appropriately trained and qualified individuals should select and install GFCI devices. Proper selection of GFCI devices is critical to protecting equipment and people. All commercial electrical equipment, appliances and instruments should be certified by a recognized certification body (e.g. CSA, ULC, etc.). Refer to Appendix B for a list of recognized certification bodies and symbols;*

- *GFCI breakers with adjustable trip currents and delay times should only be set ~~by trained~~by trained and qualified electrical workers. Trip currents and delay times that are set too high (to account for nuisance trips) provide little protection for staff and students;*
- *GFCIs should be tested on a regular frequency (at least once per month) and in accordance with the manufacturer's instructions. Portable ground fault interrupters should be tested prior to each use; and*
- *Electrical equipment should be properly maintained. Poorly maintained or improperly functioning equipment can result in increased safety risks and can result in nuisance trips of overcurrent protective devices. A GFCI that is not working properly should be removed from service immediately and replaced. FMD should be contacted for GFCI receptacles and breakers that require repair or replacement. Call FMD Work Control Centre at 966-4496.*

### 13.4 Shielding and Equipment Guarding

Exposed, un-insulated electric components provide a source of electrical shock and should be appropriately guarded.

*Safety Tips*

- *Equipment operating at 50 volts or more must be guarded against accidental contact;*
- *Plexiglas shields may be used to protect against exposed live electrical circuits and parts; and*
- *Shields may be removed for service only after the equipment has been de-~~energized and~~energized and locked out.*

### 13.5 Cable Clamping

Suitable mechanical-strain-relief devices such as a cord grip, cable clamp, or plug should be used for any wire or cable penetrating an enclosure where external movement or force ~~can exert~~can exert stress on the internal connection. Grommets or similar devices should not be used as strain relief (see Figure 6).

Figure 6: Example of cable clamping and grip devices. Image courtesy of University of Saskatchewan.

## 14 Extension Cords, Power Strips and Power Cords

Extension cords provide a convenient method of bringing AC power to a device that is not located near a power source. They are also used as temporary power sources. As such, extension cords are heavily used. They are also often involved in electrical code and safety violations.

A power strip is a variation of an extension cord, where the cord terminates in a row or grouping of receptacles. Power strips are commonly used in offices to provide multiple receptacles to office equipment. In general, safety principles pertaining to extension cords also apply to power strips.

Improper use of extension cords and power strips can lead to shock hazards. In addition, use of an undersized extension cord results in an overheated cord and insufficient voltage delivered to the device, thus causing device or cord failure, and a fire hazard.

Extension cords are labeled with information as to the use, size and wattage rating of the cord. Cords are offered in many lengths and are marked with a size or "gauge." The gauge is based on the American Wire Gauge (AWG) System, in which the larger the wire, the smaller the AWG number. For example, a 12 gauge wire would be larger, and can power larger wattage equipment than a 14 gauge wire. Before deciding which extension cord to use, first carefully read the manufacturer's instructions for the equipment that is to be used.

Extension cords that can be used outdoors will be clearly marked "Suitable for Use with Outdoor Appliances." Never use an indoor extension cord outdoors as it could result in an electric shock or fire hazard.

To determine the required size, or gauge of the cord, first determine how long the cord needs to be. A cord, based on its gauge, can power an appliance of a certain wattage only at specific distances. As the cord gets longer, the current carrying capacity of the cord gets lower. For example, a 16 gauge extension cord less than 50 feet in length can power a 1,625 watt (W) appliance. A 16 gauge cord that is longer than 50 feet in length can only power an appliance up to 1,250 W. All commercial equipment, instruments and appliances should indicate how much wattage is consumed when operated. The power rating can be found on the equipment itself and often within the operations manual that accompanies the product. If using an extension cord with two or more appliances, add together the wattage rating for all appliances. The total power rating will determine which gauge size cord is needed.

*Safety Tips*

- *Extension cords should be a minimum 16 gauge (AWG)~~;~~*
- *Extension cords are for temporary use only. For permanent applications, request installation of additional electrical outlets from Facilities Operations and Maintenance~~MD~~ (966-4496);*
- *Using only approved (e.g. UL approved) electrical power strips with surge protection~~;~~*
- *Use polarized extension cords with polarized equipment, instruments and appliances~~.~~ Polarized plugs have one blade slightly wider than the other and can only be inserted one way into the outlet. Polarization and grounding ensure that certain parts of appliances that could have a higher risk of electric shock when they become live are instead connected to the neutral, or grounded, side of the circuit. Such electrical products should only be used with polarized or grounding type extension cords~~;~~*
- *Routinely inspect power and extension cords. The plug should be molded to the cord or have a clamping mechanism that fits snugly around the cord without pinching. The cord should not be frayed or have exposed wiring. Even a small nick in the insulation of a power cord or extension cord can be deadly. Electrical tape is not an acceptable repair for a damaged cord, replace the entire cord~~;~~*
- *Power cords must have grounding plugs or be double insulated. Never remove the third (round or U-shaped) ground prong from electrical cords. The ground prong is a safety feature designed to reduce the risk of shock and electrocution~~;~~*
- *Do not connect multiple cords or power strips together~~;~~*
- *Carefully place power and extension cords so they don't come in contact with water or chemicals. Contact with water is a shock hazard. Corrosives and solvents can degrade the cord insulation~~;~~*
- *Do not allow cords to dangle from counters or hoods in such a manner that equipment could be unplugged, fall, or cords could be tripped over or snagged~~;~~*
- *Do not have cords that are strained~~;~~*
- *Do not allow cords to run under movable equipment or chairs~~;~~*
- *Properly secure cords for temporary installations when they cross travel ways~~;~~*

- *Do not use staples or nails to attach extension cords to a baseboard or to another surface. This could damage the cord and present a shock or fire hazard~~;~~*
- *Do not allow cords to contact hot surfaces to prevent melting insulation~~;~~*
- *Do not lift a piece of electrical equipment by the cord or pull the cord to disconnect it from the outlet in order to prevent damage~~;~~*
- *Never use an extension cord while it is coiled or looped, it could overheat~~;~~*
- *Never cover any part of an extension cord with newspapers, clothing, rugs, or any object's while the cord is in use~~;~~*
- *Extension cords may be plugged into cord connected ground fault circuit interrupters if the permanently attached cord on the GFCI device is less than six feet in length~~;~~*
- *Insert plugs fully so that no part of the prongs are exposed when the extension cord is in use~~;~~*
- *Check the plug and the body of the extension cord while the cord is in use. Noticeable warming of these plastic parts is expected when cords are being used at their maximum rating. However, if the cord feels hot or if there is a softening of the plastic, this is a warning that the plug wires or connections are failing and that the extension cord should be discarded and replaced~~; and~~*
- *Check for hot or discolored outlet wall plate that may indicate dangerous heat buildup at the connections~~.~~*

## 15 Grounding

Only equipment with three-prong plugs should be used. The third prong provides a path to ground for internal electrical short circuits, thereby protecting the user from a potential electrical shock.

*Safety Tips*

- *Electrical appliances are grounded through the electrical receptacles~~;~~*
- *Electrical outlet receptacles must have a grounding connection and accept three-prong plugs. Never remove a grounding prong~~; and~~*
- *Grounds to prevent static load and/or discharge should be grounded to a grounding terminal and not to the ground of an electrical receptacle~~.~~*

## 16 Power Tools

Power tools are widely used in industry, in construction, and around the house for driving, drilling, cutting, shaping, sanding, grinding, polishing, painting, and heating. Stationary power tools for metalworking, wood working or other purposes (grinders, drills, saws, lathes, etc.) are usually referred to as machine tools.

The safe use of power tools will be dependent on the tool being used and the work being performed. Following, are a number of general safety tips related to electrical safety when working with power tools.

*Safety Tips*

- *Ensure that individuals are appropriately trained and are familiar with the use of the power tool. Individuals should review the operations manual and manufacture's safety precautions before using electrically powered tools;*
- *Wear appropriate personal protective equipment;*
- *Inspect power tools prior to each use. Inspect tool power cords for damage, frays or exposed wires. Never use power tools that are in disrepair, or are malfunctioning;*
- *Never bypass safety features of power tools;*
- *Never remove the ground prong from a power cord plug;*
- *Never leave a power tool operating unattended;*
- *Do not expose electric power tools to rain or wet conditions. wet tools increase the likelihood of electric shock;*
- *Avoid body contact with grounded surfaces like refrigerators, pipes and radiators when using electric powered tools. This will reduce the likelihood of shock if the operator's body is grounded;*
- *Use only approved extension cords that have the proper wire size (gauge) for the length of cord and power requirements of the electric tool that you are using. This will prevent the cord from overheating. Never connect multiple extension cords together;*
- *Do not plug several power cords into one outlet by using single-to-multiple outlet adapters or converters; and*
- *Stop using an electric power tool if you feel a tingle in your fingers. This is a warning that the tool is faulty and needs repair.*

## 17 Portable Power Generators

Portable electric generators offer great benefits when outages occur or when power is required in locations where no accessible power is available. Following are tips for safely connecting and operating portable generators.

*Safety Tips*

- *Read and adhere to the manufacturer's instructions for safe operation;*
- *To prevent electrical shock, make sure the generator is properly grounded. Consult the manufacturer's manual for correct grounding procedures;*
- *Do not connect a generator directly to facility electrical wiring. Connecting a portable electric generator directly to facility wiring can be deadly. A generator that is directly connected to facility wiring can 'back feed' onto the power lines connected to the facility. Utility transformers can then "step-up" or increase this back feed to thousands of volts, enough to kill a utility lineman making outage repairs a long way from your facility. It could also cause expensive damage to utility equipment and the generator. The only safe way to connect a portable electric generator to existing wiring is to have a qualified electrical worker install a transfer switch. The transfer switch transfers power from the utility power lines to the power coming from the generator;*

- *Never plug a portable electric generator into a regular outlet. Plugging a generator into a regular outlet can energize "dead" power lines and injure neighbors or utility workers. Connect individual appliances that have their outdoor rated power cords directly to the receptacle outlet of the generator, or connect these appliances to the generator with the appropriate outdoor rated power cord having a sufficient wire gauge to handle the electrical load;*
- *Do not overload the generator. Do not operate more appliances and equipment than the output rating of the generator. Overloading the generator can seriously damage appliances and electronics. A portable electric generator should be used only when necessary, and only to power essential equipment;*
- *Never use a generator indoors. Just like an automobile, a portable generator uses an internal combustion engine that emits carbon monoxide. Be sure to place the generator where exhaust fumes will not enter the house. Only operate it outdoors in a well-ventilated, dry area, away from air intakes to the home, and protected from direct exposure to rain and snow, preferably under a canopy, open shed or carport. A carbon monoxide detector is advised when using any combustion engines near a building;*
- *Use the proper power cords. Plug individual appliances into the generator using heavy duty, outdoor rated cords with a wire gauge adequate for the appliance load. Overloaded cords can cause fires or equipment damage. Do not use extension cords with exposed wires or worn shielding. Make sure the cords from the generator do not present a trippinga tripping hazard. Do not run cords under rugs where heat might build up or cord damage may go unnoticed;*
- *Do not store fuel indoors or try to refuel a generator while it's running. Gasoline (and other flammable liquids) should be stored outside of living areas in properly labeled, non- glass safety containers. The vapor from gasoline can travel invisibly along the ground and be ignited by pilot lights or electric arcs caused by turning on the lights. Avoid spillingAvoid spilling fuel on hot components. Put out all flames or cigarettes when handling gasoline. Always have a fully charged, approved fire extinguisher located near the generator. Never attempt to refuel a portable generator while it's running;*
- *Turn off all equipment powered by the generator before shutting down the generator; and*
- *Be careful when touching the generator during operation and immediately after turning off. Many generator parts are hot enough to burn.*

## 18 Batteries

Batteries are comprised of one or more electrochemical cells that convert stored chemical energy into electrical energy. Batteries, which may be single use or rechargeable, are used in a wide range of devices ranging from handheld instruments to large powered mobile equipment. Depending on their size and use, batteries pose numerous hazards including:

- Electrical;
- Fire and explosion;
- Hazardous chemicals; and
- Physical hazards.

*Safety Tips*

- *Follow manufacturer instructions. Use only batteries recommended by the manufacturer;*
- *Never use faulty, leaking, or visibly damaged batteries~~;~~*
- *Do not dissemble or modify batteries. Only qualified electrical workers should attempt to service a battery (that is serviceable)~~;~~*
- *Do not mix charged and uncharged batteries, new and old batteries, other types of batteries or batteries with different capacities or brands. This may result in leakage, heat generation or rupturing~~;~~*
- *Never smoke in the vicinity of a battery or generator~~;~~*
- *Always wear eye protection, such as safety glasses, when working with batteries~~;~~*
- *Remove all loose jewelry before working with batteries~~;~~*
- *Always use proper lifting techniques when handling large batteries. Use your legs as much as possible, and keep the load close to you. Have someone assist you with the installation of large batteries, such as lead-acid batteries used in vehicles~~;~~*
- *Always verify proper voltage and polarity before connecting batteries~~;~~*
- *Batteries should be installed in a well-vented area to prevent the possible ~~build up~~buildup of explosive gasses~~;~~*
- *Use insulated tools when working with batteries~~;~~*
- *Never lay tools or other metal parts on top of a battery~~;~~*
- *Never touch both battery terminals with your bare hands at the same time~~;~~*
- *Do not short circuit battery cables. Fire or explosion can occur~~;~~*
- *Neutralize static buildup just before working on battery by contacting nearest grounded surface~~;~~*
- *Always connect batteries first then connect the cables to the inverter or controller. This will greatly reduce the chance of spark in the vicinity of the batteries~~;~~*
- *Consider covering battery terminals and connectors if possible with an insulating blanket before overhead inspections or repairs~~;~~*
- *Ensure chargers are turned off before connecting or disconnecting a battery to prevent arcing~~;~~*
- *Ensure proper polarity when connecting battery chargers. Severe equipment damage or explosion is possible if connected incorrectly~~;~~*
- *Have an ABC dry chemical fire extinguisher in charging areas or readily available;*
- *In the event of exposure to battery electrolyte, wash the area with soap and water. If acid enters the eyes, flood them with running cold water for at least 15 minutes and get immediate medical attention~~; and~~*
- *Contact Safety Resources at 966-4675 in the event of a spill involving a battery and for proper disposal information.*

## 19 Power Supplies

A power supply is a device that supplies electrical energy to one or more electric loads. The term is most commonly applied to devices that convert one form of electrical energy to another, though it may also refer to devices that convert another form of energy (e.g., mechanical, chemical, solar) to electrical energy.

A power supply may be implemented as a discrete, stand-alone device or as an integral device that is hardwired to its load. In the latter case, for example, low voltage DC power supplies are commonly integrated with their loads in devices such as computers and household electronics.

The simplest DC power supply circuit consists of a single diode and resistor in series with the AC supply. This circuit is common in rechargeable flashlights.

Because a wide range of power supplies are used, no single set of health and safety considerations can be applied to all cases. The following classification scheme may be helpful in assessing power supply hazards:

Power supplies of 50 volts or less with currents greater than 5 mA

Because they are not "high voltage", these power sources are often treated without proper respect. In addition to direct shock and burn hazards, a risk of injury also exists when trying to get away from the source of a shock. Cuts and bruises, and even serious or fatal falls have resulted from otherwise insignificant shocks.

Power supplies of 50 volts or more (high voltage) with current capability under 5 mA (non-dangerous current capability)

These power supplies are often treated in a casual manner because of their low current capability. However, they are frequently used near lower voltage lethal circuits, and a minor shock from the power supply could cause a recoil into such a circuit. Also, an involuntary reaction to a minor shock could cause a serious fall (for example from a ladder or experimental apparatus).

Power supplies of 50 volts or more (high voltage), with current capability over 5 mA

These power supplies have the same hazards cited above to an even greater degree because of the higher voltage. In addition to the risk of injury from recoil, the higher voltage is considered to be a shock hazard. The high voltage combined with current capability can be lethal. Consequently, all such power supplies must be treated with extreme caution.

Figure 8: Example of a power supply. Image courtesy of markusram, Flickr.

*Safety Tips*

- *Follow manufacturer operating and maintenance instructions~~;~~*
- *Routinely inspect the supply. Do not use a power supply that is not working properly~~;~~*
- *Locate equipment away from water and large metal areas~~;~~*
- *Power supplies should be shielded and grounded~~;~~*
- *Power supplies and electronic equipment used in damp conditions or near water sources should be equipped with ground fault circuit interrupters breakers~~;~~*
- *Use only approved connectors. Never attach an exposed connector such as an uninsulated alligator clip to a power supply~~; and~~*
- *Do not use connectors and jack fittings that allow accidental skin contact with energized parts~~.~~*

## 20 Capacitors

A capacitor (formerly known as condenser) is a device for storing electric charge. The forms of practical capacitors vary widely, but all contain at least two conductors separated by a non-conductor. Capacitors used as parts of electrical systems, for example, consist of metal foils separated by a layer of insulating film.

A capacitor or capacitor bank presents a potentially serious electrical hazard. A capacitor or capacitor bank capable of discharging 25 J (joule) in less than 3 seconds, or 10 J in less than 0.5 seconds can be lethal. Relatively small capacitors can store potentially lethal charges.

Capacitors may store hazardous energy even after the equipment has been de-energized and may build up a dangerous residual charge without an external source. Grounding capacitors in series, for example, may transfer rather than discharge the stored energy.

Another capacitor hazard exists when a capacitor is subjected to high currents that may cause heating and explosion.

Capacitors may be used to store large amounts of energy. An internal failure of one capacitor in a bank frequently results in explosion when all other capacitors in the bank discharge into the fault.

Because high voltage cables have capacitance and thus can store energy, they should be treated as capacitors.

The liquid dielectric in many capacitors, or its combustion products, may be toxic.

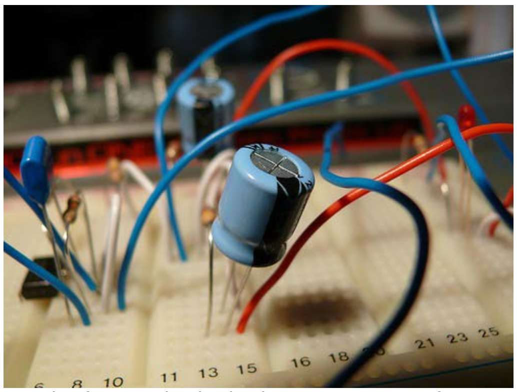


Figure 9: Example of a capacitor in circuit. Image courtesy of SystemF92, Flickr.

*Safety Tips*

- *Only qualified personnel should engage in the installation and repair of power capacitors*~~;~~
- *Discharging a capacitor or capacitor bank by means of a* grounding hook *can cause an electric arc at the point of contact. Safety glasses should be worn during this procedure*~~;~~
- *To prevent inadvertent contact, never energize power capacitors outside an enclosure or without proper barriers*~~;~~
- *Use automatic shorting devices that operate when the equipment is de-energized or when the enclosure is opened*~~;~~
- *Before servicing or removing power capacitors, ensure that they have been safely discharged, shorted, and grounded. Shorts or shunts should remain in place until the work is completed*~~;~~
- *Ensure that shorting and grounding devices for power capacitors are certified, tested, and rated for the intended use*~~;~~
- *Do not rely on automatic shunts only. Use grounding hooks and additional positive grounds*~~;~~
- *Inspect shorting and grounding devices for general condition, cleanliness, connection integrity, and resistor condition (if a resistor is used) before each use*~~;~~
- *Use proper personal protective equipment when applying shorting and grounding devices to capacitors*~~;~~
- *Remove all shunts before re-energizing equipment*~~;~~

- *Small capacitors should have connections shorted together and to the case if the case is metal;*
- *Capacitors with paper or ceramic cases should have terminals shorted together and properly stored; and*
- *Never lift heavy capacitors by shorting wires. Ceramic terminal insulators can break; and*
- *Capacitors that are bulging or leaking should be taken out of service immediately, and disposed of properly.*

## 21 Inductors and Magnets

An inductor is a passive electrical component that can store energy in a magnetic field created by the electric current passing through it. Typically an inductor is a conducting wire shaped as a coil, the loops helping to create a strong magnetic field inside the coil. Inductors are one of the basic electronic components used in electronics where current and voltage change with time, due to the ability of inductors to delay and reshape alternating currents.

Figure 10: Examples of an inductor. Image courtesy of oskay, Flickr.

A magnet is a material or object that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet, a force that pulls on other ferromagnetic materials like iron and attracts or repels other magnets.

An electromagnet is made from a coil of wire which acts as a magnet when an electric current passes through it, but stops being a magnet when the current stops. Often an electromagnet is wrapped around a core of ferromagnetic material like steel, which enhances the magnetic field produced by the coil.

Some magnets may be non-hazardous while others may be very dangerous. Without proper protection or labeling, staff and students could assume that a magnet is non-hazardous and could get seriously hurt if they came in contact with one.

The following are some hazards particular to inductors and magnets:

- Damage to inductors due to overheating caused by overloads, insufficient cooling, or failure or possible rupture of cooling systems;

- Production by electromagnets and superconductive magnets of large external force fields that may affect the proper operation of the protective instrumentation and controls;
- Attraction by magnetic fields of nearby magnetic material, including tools and surgical implants, causing injury or damage by impact;
- Production of large eddy currents in adjacent conductive material whenever a magnet is suddenly de-energized causing excessive heating and hazardous voltages. This state may cause the release or ejection of magnetic objects;
- Uncontrolled release of stored energy due to interruption of current in a magnet. Engineered safety systems may be required to safely dissipate stored energy. Large amounts of stored energy can be released in case of a quench (loss of superconductivity) due to system or component failure in a superconducting magnet;
- Production of high voltage potential upon interruption of current; and
- Uncontrolled release of energy may result if the inductor's current is ~~suddenly interrupted~~suddenly interrupted.

In addition, workers should be cognizant of the potential health hazards. The American Conference of Governmental Industrial Hygienists (ICGIH) recommends that routine occupational exposure to static magnetic fields should not exceed 60 mT (600 G) whole-body exposure. This is a level which is believed that nearly all workers may be repeatedly exposed day after day without any adverse health effects.

Safety hazards may exist from the mechanical forces exerted by the magnetic field upon ferromagnetic tools and medical implants. Cardiac pacemaker and similar medical electronic device wearers should not be exposed to field levels exceeding 0.5 mT (5 G).

*Safety Tips*

- *Use freewheeling diodes, varistors, thyrites, or other automatic shorting devices to provide a current path when excitation is interrupted~~;~~*
- *Pay particular attention to connections in the current path of inductive circuits. Poor connections may cause destructive arcing~~;~~*
- *Protect liquid-cooled inductors and magnets with thermal interlocks on the outlet of each parallel coolant path. Include a flow interlock for each device~~;~~*
- *Units with pulsed or varying fields must have a minimum of eddy-current circuits. If large eddy-current circuits are unavoidable, they should be mechanically secure and able to safely dissipate any heat produced~~;~~*
- *Ground the frames and cores of magnets, transformers, and inductors~~;~~*
- *Beware of the hazards of residual voltages that exist until rotating electrical equipment comes to a full stop~~;~~*
- *Fabricate protective enclosures from materials not adversely affected by external electromagnetic fields. Researchers should consider building a nonferrous barrier designed to prevent accidental attraction of iron objects and prevent damage to the cryostat. This is especially important for superconducting magnet systems~~;~~*
- *Use magnet covers for magnets that are electrical hazards, or terminal boots for magnets that are only startle hazards~~;~~*

- *Provide equipment supports and bracing adequate to withstand the forces generated during fault conditions~~;~~*
- *Restrict personnel exposure to magnetic fields greater than 60 mT~~;~~*
- *Provide means for safely dissipating stored energy when excitation is interrupted or a fault occurs~~; and~~*
- *Verify that any inductor is de-energized before disconnecting the leads or checking continuity or resistance~~.~~*

## 22 Semiconductor Components

Sensitive electronic circuits and electronic components such as diodes, transistors and integrated circuits should be handled with care. Such devices can be damaged by overcurrent, overheating, mixing up the polarity, or by electrostatic discharge.

*Safety Tips*

- *Always keep work area clean and clear of unnecessary material, particularly common plastics (sources of static electricity)~~;~~*
- *Return static electricity sensitive items to their protective containers when not actively working with the items~~; and~~*
- *Do not hold static electricity sensitive items like semiconductor device (diodes, transistors, integrated circuits) against clothing~~.~~*

## 23 Multimeters

A multimeter, is an electronic testing instrument that combines several measurement functions into one unit including the ability to measure voltage, current and resistance. A multimeter is typically a hand-held device useful for basic fault finding and field service work or a bench instrument which can measure electrical parameters to a very high degree of accuracy. ~~They are~~They are routinely used to troubleshoot electrical problems in a wide array of electrical devices such as batteries, motor controls, instruments, appliances, power supplies, and wiring systems.

Multimeters should have the following features:

- Fused current inputs (high energy fuses)~~;~~
- Overload protection on the ohms function~~;~~
- Test leads that have shrouded connectors and finger guards~~;~~
- Recessed input jacks~~; and~~
- Meet the latest safety standards (CAT III-600 V or CAT IV 600 V/CAT III 1000 V) and are independently certified~~.~~

Figure 11: Example of a multimeter. Image courtesy of Flickr.

Other testing devices include solenoid voltage meters and proximity testers. Care should be taken on the selection and use of these devices. Solenoid voltage meters have no other built-in functions (such as the ability to measure current and resistance). Solenoid voltmeters are not precise and not appropriate for low voltage circuits (for example, 12 volt circuits). The basic range of the voltmeter starts at around 90 V (AC or DC).

Proximity testers only measure AC. Proximity testers will not indicate a voltage inside grounded enclosures, shielded cables or for internally wet cables. Proximity testers may not indicate a voltage if the cable is partially insulated or if the test point is in contact with ground metal, or the operator is isolated from ground.

Staff and students using multimeters should receive instruction on their function and use. The following safety measures should be followed when using a mulitimeter.

*Safety Tips*

- *The multimeter should be inspected prior to each use. Do not use a meter, cables or connectors that are damaged;*
- *When working on live circuits, practice safe measurement techniques:*
    - *Remove watches or other jewelry;*
    - *Wear appropriate personal protective equipment (safety glasses, insulating gloves, etc.) and use appropriate tools (insulated tools, insulating mats, etc.);*
    - *Always connect the grounded lead first, hot second;*
    - *Disconnect the hot lead first, grounded lead second;*
    - *Hang or rest the meter if possible. Try to avoid holding it in your hands, to minimize personal exposure to the effects of transients;*

- *Use the three-point test method. Test ~~known circuit~~known circuit~~, measure~~, ~~target~~measure target ~~-~~circuit, then re-test known circuit. This verifies that your meter worked properly before and after the measurement~~; and~~*
- *Use the old electricians' trick of keeping one hand in your pocket. This lessens the chance of a closed circuit across your chest and through your heart~~.~~*

## 24 Soldering Safety

Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal into the joint, the filler metal having a relatively low melting point.

Soft soldering is characterized by the melting point ~~of the~~of the filler metal, which is below 400°C. The filler metal used in the process is called solder.

There are a number of hazards associated with soldering including:

- Burns~~;~~
- Electric shocks~~;~~
- Inhalation of hazardous fumes and vapours released during soldering~~; and~~
- Skin contact with lead in solder~~.~~

Most burns from soldering are likely to be minor and treatment is simple. If burned by ~~a soldering~~a soldering iron or solder, immediately cool the affected area under gently running cold water. Keep the burn in the cold water for 15 minutes. Do not apply any creams or ointments. The burn will heal better without them. A dry dressing, such as ~~a~~ clean guaze~~handkerchief~~, may be applied to protect the area from dirt. Following, is general information on the classification of burns. Seek assistance from your health care provider for detailed information and treatment. If the burns appear more serious, seek medical attention immediately.

- **First degree burns** occur when the first layer of skin is burned. For a first degree burn, the skin is red, there may be swelling and pain. First degree burns are generally minor in nature unless a large area is burned~~.~~
- **Second degree burns** occur when the first layer of skin has been burned through and the second layer of the skin (dermis) also is burned. For second degree burns, the skin takes on an intensely reddened, splotchy appearance. Blisters develop and there is severe pain and swelling~~.~~
- **Third degree burns** occur when all layers of the skin are burned. Fat, muscle and even bone may be affected. Areas may be charred black or appear dry and white~~.~~

*Safety Tips*

- *Solder on a fire resistant surface. Keep flammable liquids and materials away from work area~~;~~*
- *Use lead free solder when possible~~;~~*
- *Never solder on a live circuit~~;~~*
- *Never touch the element or tip of the soldering iron. They are very hot (about 400°C)~~;~~*

- *Wear eye protection, either a face shield or safety glasses. Avoid wearing contact lenses, the fumes can get under the lenses and cause severe irritation~~;~~*
- *Legs, arms, torso, and feet should be covered to avoid burns from splashed hot solder~~;~~*
- *Work in a well-ventilated area. The smoke formed from melted solder is mostly from the flux and quite irritating. Exhale as each connection is made to direct any fumes away from you. Use a fume extraction devices as required~~;~~*
- *When cutting off electrical leads make sure they are held such that they cannot fly away;*
- *Use pliers or vice to hold work in order to avoid burns from objects that are heated~~;~~*
- *Always return the soldering iron to its stand when not in use. Never put it down on the workbench~~;~~*
- *Allow joints a minute or so to cool down before touching them~~;~~*
- *Never leave the soldering iron plugged in and unattended~~; and~~*
- *Practice good hygiene. Wash hands thoroughly after soldering. Do not eat or smoke while soldering~~.~~*

## 25 High Voltage Equipment

Repairs of commercial high voltage electrical equipment (> 600 V as defined by FMD) should only be performed by qualified electrical workers either through the manufacturer, or by FMD. Repairs to equipment that are directly connected (hard-wired) to building electrical systems must involve Facilities Operations and Maintenance~~MD~~.

## 26 Fire Safety

Electrical devices, plugs, cords, and other equipment can provide a source of ignition sufficient to ignite combustibles and flammable or explosive vapors.

*Safety Tips*

- *Receive fire safety training. Contact Safety Resources for fire extinguisher training~~;~~*
- *Know the locations of fire extinguishers in your work area~~;~~*
- *Only Class C fire extinguishers should be used for electrical fires. General fire extinguishers used by the university are classified as ABC meaning that they may be used for regular combustibles (wood, paper, trash), flammable liquids (fuel, oil, grease, paint thinner) and electrical equipment. Do not use water on an electrical fire~~;~~*
- *Routinely inspect all electrical equipment, power cables, extension cords and powers strips. Poorly maintained equipment can result in fire hazards~~;~~*
- *Keep flammable materials away from electrical equipment~~;~~*
- *Do not store flammable organic liquids above electrical devices~~;~~*
- *Extension cords, power strips, and power cords located on the floor can provide ~~a source~~a source of ignition in the event of a flammable liquid spill. Position these items carefully~~;~~*
- *Receptacles providing power for equipment used inside a fume hood should be located outside the hood~~;~~*
- *Make sure that equipment used where flammable vapours may be present is specially rated to not produce sparks. Many household appliances such as hot plates, vacuum*

*cleaners, and drills do not meet this requirement so they should be used only under very controlled conditions;*

- *If refrigeration or freezing is needed, flammable materials should only be stored in laboratory safe flammable refrigerators or explosion proof equipment. These do not contain any ignition sources such as lights and switches;*
- *Do not plug heating mantles directly into a 110 volt outlet as they can overheat, leading to fire hazard. They need a variable autotransformer to control the input voltage;*
- *Be aware that if drying ovens are used to dry organic materials that they or their vapours may accumulate inside the oven and ignite or escape into the lab atmosphere. Take care to prevent developing explosive mixtures in air by using the ovens properly, not packing them too full or not drying organic materials that can create these conditions;*
- *Motor driven electrical equipment should be kept away from flammable liquids and vapors. In laboratories where volatile flammable materials are used, motor-driven electrical equipment should be equipped with non-sparking induction motors or air motors (intrinsically safe);*
- *Avoid series-wound motors, such as those generally found in some vacuum pumps, rotary evaporators and stirrers. Series-wound motors are also usually found in household appliances such as blenders, mixers, vacuum cleaners and power drills. These appliances should not be used unless flammable vapours are adequately controlled. Although some newer equipment has spark-free induction motors, the on-off switches and speed controls may be able to produce a spark when they are adjusted because they have exposed contacts. One solution is to remove any switches located on the device and insert a switch on the cord near the plug end; and*
- *Ventilate and control all flammable vapours.*

## 27 Electrical Emergencies

The major hazards associated with electricity are electrical shock and fire. All electrical devices used in a workplace setting present a potential danger of injury due to improper procedures, poorly installed and/or maintained systems or fires due to sparks serving as an ignition source for flammable or combustible materials.

*Safety Tips*

- *Develop emergency procedures for each work area. Ensure that staff and students are familiar with emergency procedures;*
- *Have staff trained in first aid and fire safety;*
- *Know the location of electrical panels and shut-off switches so that they can be quickly disconnected in the event of an emergency; and*
- *Know the locations of safety devices such as first aid kits, fire extinguishers, emergency eye wash and showers, automated external defibrillators, etc..*

### 27.1 Electric Shock

When someone suffers serious electrical shock, he or she may be knocked unconscious. Do not touch a victim that is still in contact with a power source as you could electrocute yourself. If the victim is still in contact with the electrical current, immediately turn off the electrical power source. If you cannot disconnect the power source, try to separate the victim from the power source with a nonconductive object, such as a wood handled broom.

Have someone call for emergency services immediately (from a University land line call 5555 or 9-911). Administer first aid as appropriate.

### 27.2 Electrical Fire

If an electrical fire occurs, try to disconnect the electrical power source, but only if you can do so without endangering yourself.

If safe to do so and trained, attempt to extinguish the fire. Ensure that a proper fire extinguisher is used (type ABC, BC or C). Never use water to extinguish an electrical fire.

If the fire cannot be extinguished or is too large, immediately inform other staff and students and evacuate the area. Activate the fire alarm and call emergency services (from a University land line call 5555 or 9-911~~call 5555 or 911~~).

### 27.3 Contact with a Power Line

If a vehicle or piece of equipment comes into contact with an overhead power line, the following steps should be adhered to:

1. If you are unhurt and can move the vehicle, slowly move it away from the line~~.~~
2. If the vehicle cannot be readily moved, stay in the vehicle~~.~~
3. Call for assistance (5555 or 911)~~.~~

If there is a fire or medical emergency and you must exit the vehicle, the following steps should be adhered to. This is a very dangerous maneuver that should only be used as a last resort.

1. Open the vehicle door all the way while seated. Look up and around to ensure you can exit the vehicle without contacting the fallen lin~~e~~.
2. Stand on the frame of the car with your arms close to your body or crossed over your chest. Slide your feet together~~.~~
3. Jump out of the car as far as possible with your feet together and your arms close ~~to your~~to your body. Never make contact with the car and the ground at the same time.
4. Hop or shuffle quickly away, keeping your feet together~~.~~
5. Move at least 10 metres away from the scene. Slowly slide your feet, one in front of the other, maintaining contact with the ground. If you feel tingling, put your ~~feet back~~feet back together and hop further away until you no longer feel the tingling sensation~~.~~
6. Once you are safe, call for assistance~~.~~

## 28 References

Saskatchewan Occupational Health and Safety Act, 1993
Saskatchewan Occupational Health and Safety Regulations, 1996
Saskatchewan Electrical Licensing Act
Saskatchewan Electrical Inspections Act
Canadian Electrical Code
Canadian Standards Association (CSA) Z462-15, Workplace Electrical
Safety Lessons on Electrical Circuits (Volumes I through VI)
Saskatchewan Construction Safety Association (SCSA)
SaskPower
Canadian Centre for Occupational Health and Safety (CCOHS)
Industrial Accident Prevention Association (IAPA)
American Conference of Governmental Industrial Hygienists (ACGIH)
United States Occupational Safety and Health Administration (OSHA)
Unites States Department of Energy (DOE) Handbook Electrical Safety
Wikipedia

## Appendix A

## Definitions

## Definitions

Following are a number of common definitions used in electrical safety.

**Alternating Current (AC)** – the movement of electric charge periodically reverses direction. In direct current (DC), the flow of electric charge is only in one direction. AC is the form in which electric power is delivered to businesses and residences.

**Ampacity** – the current, in amperes, that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

**Approved** – acceptable to the authority having jurisdiction.

**Approved** (as applied to electrical equipment) – equipment that
(a) has been certified by an accredited organization in accordance with the requirements of Canadian Standards Association (CSA) Standards (or other recognized documents, where such CSA Standards do not exist or are not applicable); or
(b) conforms to the requirements of the regulatory authority having jurisdiction. In Canada, accreditation of certification organizations is provided by the Standards Council of Canada.

**Approved** – means approved as defined in the Electrical Inspection Act, 1993. Approved means approved by the chief inspector pursuant to this Act, The Electrical Inspection Act or The Electrical Inspection and Licensing Act, 1981.

**Arc flash hazard** – a dangerous condition associated with the possible release of energy caused by an electric arc.

**Barrier** – a physical obstruction that is intended to prevent contact with equipment or energized electrical conductors and circuit parts or to prevent unauthorized access to a work area.

**Battery** – an electrochemical system that is capable of storing, under chemical form, the electric energy received, and can give it back by reconversion.

**Bonding (bonded)** – a low-impedance path that is obtained by permanently joining all non-current-carrying metal parts to ensure electrical continuity and has the capacity to ~~conduct safely~~conduct safely any current likely to be imposed on it.

**Bonding conductor** – a conductor that connects the non-current-carrying parts of electrical equipment, raceways, or enclosures to the service equipment or system grounding conductor.

**Capacitor** – is a passive electronic component consisting of a pair of conductors separated by a dielectric (insulator). When a potential difference (voltage) exists across the conductors, an electric field is present in the dielectric. This field stores energy and produces a mechanical force between the conductors.

**Charge** – also known as electric charge, electrical charge, or electrostatic charge and symbolized *q*, is a characteristic of a unit of matter that expresses the extent to which it has more or fewer electrons than protons. In atoms, the electron carries a negative elementary or unit charge; the proton carries a positive charge. The two types of charge are equal and opposite.

**Circuit breaker** – a device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its ratings.

**Combustible** – Able to be ignited or burned.

**Conductor** – a wire, cable, or other form of metal installed for the purpose of conveying electric current from one piece of electrical equipment to another or to ground.

**Current** – a flow of electric charge (a phenomenon) or the rate of flow of electric charge (a quantity). This flowing electric charge is typically carried by moving electrons, in a conductor such as wire; in an electrolyte, it is instead carried by ions, and, in a plasma, by both.

**Direct current** (**DC**) – is the unidirectional flow of electric charge. Direct current may flow in a conductor such as a wire, but can also flow through semiconductors, insulators, or even through a vacuum as in electron or ion beams. The electric charge flows in a constant direction, distinguishing it from alternating current (AC).

**De-energized** – free from an electrical connection to a source of potential difference and from electrical charge, i.e., not having a potential different from that of the earth.

**Electrical equipment** – any apparatus, appliance, device, instrument, fitting, fixture, machinery, material, or thing used in or for, or capable of being used in or for, the generation, transformation, transmission, distribution, supply, or utilization of electric power or energy, including, e.g., any assemblage or combination of materials or things that is used, or is capable of being used or adapted, to serve or perform any particular purpose or function when connected to an electrical installation, even if part or all of such materials or things are mechanical, metallic, or non-electric in origin.

**Electrical hazard** – a dangerous condition such that contact or equipment failure can result in electric shock, arc flash burn, thermal burn, or blast.

**Electric potential** – is the energy required to move a unit electric charge to a particular place in a static electric field.

**Electrically safe work condition** – a state in which an electrical conductor or circuit part has been disconnected from energized parts, locked out in accordance with established standards, tested to ensure the absence of voltage, and grounded (if grounding is determined to be necessary).

**Electrical safety** – recognizing hazards associated with the use of electrical energy and taking precautions so that such hazards do not cause injury or death.

**Electrical Worker** – in the case of work of electrical installation as defined in The Electrical Inspection Act, 1993 that is regulated by that Act, means a person who is authorized pursuant to The Electrical Licensing Act to perform that work. In the case of any work with electrical equipment that is not regulated by The Electrical Inspection Act, 1993, means a person who is qualified to perform that work.

**Electricity** – is a general term encompassing a variety of phenomena resulting from the presence and flow of electric charge. These include many easily recognizable phenomena, such as lightning, static electricity, and the flow of electrical current in an electrical wire.

**Electromagnet** – is made from a coil of wire which acts as a magnet when an electric current passes through it, but stops being a magnet when the current stops. Often an electromagnet is wrapped around a core of ferromagnetic material like steel, which enhances the magnetic field produced by the coil.

**Flammable** – how easily something will burn or ignite.

**Flammable and Combustible Liquids** – Liquids that can burn. They are classified, or grouped, as either flammable or combustible by their flashpoints. Generally speaking, flammable liquids will ignite (catch on fire) and burn easily at normal working temperatures. Combustible liquids have the ability to burn at temperatures that are usually above working temperatures.

**Flashpoint** - The flashpoint of a liquid is the lowest temperature at which the liquid gives off enough vapour to be ignited (start burning) at the surface of the liquid. Sometimes more than one flashpoint is reported for a chemical. Since testing methods and purity of the liquid tested may vary, flashpoints are intended to be used as guides only, not as fine lines between safe and unsafe.

**Fuse** – an overcurrent protective device with a circuit-opening fusible part that is heated and severed by the passage of overcurrent through it.

**Ground** – a connection to earth obtained by a grounding electrode.

**Grounded** – connected effectively with the general mass of the earth through a grounding path of sufficiently low impedance and having an ampacity sufficient at all times, under the most severe conditions liable to arise in practice, to prevent any current in the grounding conductor from causing a harmful voltage to exist between the grounding conductors and neighbouring
(a) exposed conducting surfaces that are in good contact with the earth; or
(b) surfaces of the earth itself.

**Ground fault** – an unintentional electrically conducting connection between an ungrounded conductor of an electrical circuit and normally non-current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth.

**Ground-fault circuit interrupter (GFCI)** – a device whose function is to interrupt, within a predetermined time, the electrical circuit to a load when a current to ground exceeds a predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

**Ground-fault current path** – an electrically conductive path from the point of a ground fault on a wiring system through normally non-current-carrying conductors, equipment, or the earth to the electrical supply source.

**Guarded** – covered, shielded, fenced, enclosed, or otherwise protected by suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger.

**High Voltage** – means any voltage over 750 volts. The Facility Management Division (FMD) defines high voltage as any voltage above 600 volts.

**Incident** – is any undesirable or unplanned event or sequence of events that has had unintended effect on employees, students, facilities, operations, property, contractors or on legal or regulatory compliance.

**Inductor** – is a passive electrical component that can store energy in a magnetic field created by the electric current passing through it. An inductor's ability to store magnetic energy is measured by its inductance, in units of henries. Typically an inductor is a conducting wire shaped as a coil, the loops helping to create a strong magnetic field inside the coil due to Faraday's Law of Induction. Inductors are one of the basic electronic components used in electronics where current and voltage change with time, due to the ability of inductors to delay and reshape alternating currents.

**Insulated** – separated from other conducting surfaces by a dielectric (including air space) offering a high resistance to the passage of current.

**Insulating** (as applied to non-conducting substances) – capable of bringing about the condition defined as insulated.

**Job Safety Analysis (JSA)** – a procedure which helps integrate accepted safety and health principles and practices into a particular task or job operation. In a JSA, each basic step of the job is to identify potential hazards and to recommend the safest way to do the job. Other terms used to describe this procedure are job hazard analysis (JHA) and job hazard breakdown.

**Lockout** – placement of a lock on an energy-isolating device in accordance with an established procedure, thereby indicating that the energy-isolating device is not to be operated until removal of the lock or in accordance with an established procedure.

**Magnet** – is a material or object that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet: a force that pulls on other ferromagnetic materials like iron and attracts or repels other magnets.

**Multimeter** – an electronic testing instrument that combines several measurement functions into one unit including the ability to measure voltage, current and resistance. A multimeter is typically a hand-held device useful for basic fault finding and field service work or a bench instrument which can measure electrical parameters to a very high degree of accuracy. They are routinely used to troubleshoot electrical problems in a wide array of electrical devices such as batteries, motor controls, instruments, appliances, power supplies, and wiring systems.

**Outlet** – a point on a wiring system at which current is taken to supply utilization equipment.

**Overcurrent** – a current in excess of the rated current of equipment or the ampacity of a conductor. It can result from an overload, short circuit, or ground fault.

**Overcurrent device** – a device capable of automatically opening an electric circuit, under both predetermined overload and short-circuit conditions, by fusing, metal, or electromechanical means.

**Overload** – operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, will cause damage or dangerous overheating. A fault, e.g., a short-circuit or ground fault, is not an overload.

**Personal Protective Equipment (PPE)** – means any clothing, device or other article that is intended to be worn or used by a worker to prevent injury or to facilitate rescue.

**Power Supply** – is a supply of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of loads is called a power supply unit. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

**Qualified person (worker)** – one who has skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.

**Receptacle** – one or more female contact devices, on the same yoke, installed at an outlet for the connection of one or more attachment plugs.

**Rectifier** – an electrical device that converts alternating current (AC) to direct current (DC), a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid state diodes, vacuum tube diodes, mercury arc valves, and other components.

**Resistance** – is a measure of its opposition to the passage of a steady electric current. An object of uniform cross section will have a resistance proportional to its length and inversely proportional to its cross-sectional area, and proportional to the resistivity of the material.

**Risk assessment** – a comprehensive evaluation of the probability and degree of possible injury or damage to health in a hazardous situation, undertaken to select appropriate safeguards.

**Safeguarding** – the consistent administrative enforcement of safe work practices. Safeguards include training in safe work practices, cell line design, safety equipment, personal protective equipment, operating procedures, and work checklists.

**Semiconductor** – a material that has an electrical conductivity between that of a conductor and an insulator.

**Shock hazard** – a dangerous condition associated with the possible release of energy caused by contact with or approach to energized electrical conductors or circuit parts.

**Shorting** – a slang term indicating the act of establishing a short circuit. Sometimes the term "shorting bar" is used as applied to a purposefully created short circuit with the purpose of maintaining a de-energized state by preventing re-energization. It is synonymous with crowbar.

**Short-circuit current rating** – the prospective symmetrical fault current at a nominal voltage to which an apparatus or system is able to be connected without sustaining damage exceeding defined acceptance criteria.

**Shunt** – In general, an alternate path around a component or device. Often in electric circuits the shunt implies a low impedance (or low resistance) path, such that the majority of the current passes through the shunt instead of the main circuit. For example, a precision low-voltage resistor placed across the terminals of an ammeter to increase its range; the shunt may be either internal or external to the instrument.

**Supervisor** – any person who is authorized by an employer to oversee or direct the work of workers.

**Switch** – a device for making, breaking, or changing connection in a circuit.

**Transformer** – a device that transfers electrical energy from one circuit to another through inductively coupled conductors; the transformer's coils. A varying current in the first or primary winding creates a varying magnetic flux in the transformer's core, and thus a varying magnetic field through the secondary winding. This varying magnetic field induces a varying electromotive force (EMF) or "voltage" in the secondary winding. This effect is called mutual induction.

**Vapour** – the gaseous form of a substance that is normally solid or liquid.

**Vapour Pressure** – the pressure exerted by a saturated vapour above its own liquid in a closed container.

**Voltage (of a circuit)** – the greatest root-mean-square (rms) (effective) difference of potential between two conductors of a circuit.

**Multi-Plug Power Strip** – an outlet case that houses multiple grounded (3-prong) outlets, circuit breakers, and cord assembly in one unit, and also has a mechanism for power control.

**Surge Protection** – a mechanism, often incorporated into multi-plug power ~~strips, that~~strips that preventss over-powering of electrical equipment or appliances in the event of a surge in the power line to that device.

**Working on energized electrical conductors or circuit parts** – coming in contact with energized electrical conductors or circuit parts with the hands, feet, or other body parts, or with tools, probes, or test equipment, regardless of the personal protective equipment a person is wearing. There are two categories of working on:

(a) Diagnostic (testing): taking readings or measurements of electrical equipment with approved test equipment that does not require making a physical change to the equipment.

(b) Repair: physical alteration of electrical equipment, e.g., making or tightening connections or removing or replacing components.

## Appendix B

## Electrical Safety Regulations and Standards

## Legislation and Standards

It is noted that the legislation and standards presented herein is focused on the performance of work by qualified electrical workers in an occupational setting involving the design, installation, repair and maintenance of electrical equipment and electrical systems.

### 1 Occupational Health and Safety

The Saskatchewan *Occupational Health and Safety (OHS) Act and Regulations* set health and safety standards for all places of employment and set rules and requirements for controlling hazards in specific industries, processes and conditions. The Ministry of Labour Relations and Workplace Safety (MLRWS) is the governing body charged with ensuring compliance with the legislation.

Under the *OHS Act and Regulations*, employers are responsible for ensuring, where reasonably practicable:

- A safe work environment~~;~~
- Systems and equipment that are maintained~~;~~
- Established work processes and procedures~~;~~
- Workers are qualified and trained~~; and~~
- That appropriate tools and personal protective equipment are used in the performance of electrical work~~.~~

Following, is a summary of the key sections of the *OHS Act and Regulations* as they relate to electrical safety.

**<u>Part III General Duties</u>**

**Regulations Section 12 (a)** *The duties of an employer at a place of employment include the provision and maintenance of plant, systems of work and work environments that ensure, as far as is reasonably practicable, the health, safety and welfare at work of the employer's workers.*

**Regulations Section 12 (c)** *The provision of any information, instruction, training and supervision that is necessary to protect the health and safety of workers at work.*

**Part VII Personal Protective Equipment**

**Regulations Section 94 (3)** *Where there is a risk of injury to the skin of an electrical worker from arc flash, an employer or contractor shall provide the electrical worker with, and require the electrical worker to use, arc flash protection that meets an approved standard.*

**Part XXX Additional Protection for Electrical Workers**

**Electrical Workers Section 451 (1)** *An employer or contractor shall permit only electrical workers to construct, install, repair or maintain electrical equipment.*

**Electrical Equipment Section 452 (1)** *An employer or contractor shall ensure that only approved electrical equipment is used by workers and that the electrical equipment is:*

*(a) approved for the intended use and location of the electrical equipment~~;~~*

*(b) maintained in proper working condition and capable of safe operation~~; and~~*

*(c) tested in accordance with the manufacturer's recommendations~~.~~*

**Electrical Equipment Section 452 (2)** *Where defects or unsafe conditions have been identified in electrical equipment, an employer or contractor:*

*(a) shall ensure that:*

*(i) steps are taken immediately to protect the health and safety of any worker who may be at risk until the defects are repaired or the unsafe conditions are corrected~~; and~~*

*(ii) the defects are repaired or the unsafe conditions are corrected as soon as is reasonably practicable~~; or~~*

*(b) shall ensure that the electrical equipment is disconnected and removed from use~~.~~*

**Extension and Power Supply Cords Section 456** *An employer or contractor shall ensure that an electrical extension or power supply cord used for supplying energy to any electrical equipment:*

*(a) is approved for the intended use and location of the electrical extension or power supply cord~~;~~*

*(b) is fitted with approved cord end attachment devices that are installed in an approved manner~~;~~*

*(c) is provided with a grounding conductor~~; and~~*

*(d) is maintained and protected from physical or mechanical damage~~.~~*

**Portable Power Cables and Cable Couplers Section 457 (1)** *An employer or contractor shall ensure that every portable power cable and cable coupler is:*

*(a) protected from physical or mechanical damage~~;~~ and*

*(b) inspected by a competent person at intervals that are sufficient to protect the health and safety of workers~~.~~*

**Portable Power Cables and Cable Couplers Section 457 (2)** *An employer or contractor shall ensure that:*

*(a) where any unsafe condition is identified in a portable power cable or cable coupler, the portable power cable or the cable coupler is repaired or taken out of service; and*
*(b) every splice in a portable power cable is sufficiently strong and adequately insulated to retain the mechanical and dielectric strength of the original cable.*

**Portable Power Cables and Cable Couplers Section 457 (3)** *A worker shall take all reasonably practicable steps not to drive equipment over, or otherwise damage, a portable power cable or cable coupler.*

**Exposed Metal Parts Section 459** *An employer or contractor shall ensure that every exposed metal part of portable electrical equipment that is not designed to carry electrical current is connected to ground unless:*

*(a) the electrical equipment is of an approved, double-insulated type and is clearly marked as such;*
*(b) power is supplied to the equipment through an isolating transformer having a non-grounded secondary of not more than 50 volts potential;*
*(c) power is supplied to the equipment through a class A ground fault circuit interrupter; or*
*(d) power is supplied to the equipment from a battery of not over 50 volts potential.*

**Fire extinguishers Section 463** *An employer or contractor shall ensure that a fire extinguisher approved for Class C fires is readily available to workers working on or near energized high voltage electrical equipment.*

**Regulations Section 465 (1.2)** *No qualified electrical worker shall undertake high voltage electrical work unless the worker:*

*a) Has written proof of approved training in high voltage electrical safety.*

**Regulations Section 465 (5)** *Where a qualified electrical worker works closer to an exposed energized conductor than the minimum distance set out in column 2 of Table 22 of the Appendix, an employer or contractor shall ensure that:*

*a) The qualified electrical worker:*
   *i) performs the work in accordance with written instructions for a safety work procedure that have been developed and signed by a competent person who has been appointed by the employer or contractor for that purpose;*
   *ii) uses equipment that is approved for the intended use of the equipment; and*
   *iii) uses personal protective equipment that meets the requirements of Part VII.*
*b) The conductor is operating at 25 kilovolts or less and is fitted with rubber and rubber-like insulating barriers that meet the requirements of an approved standard.*

**Regulations Section 466** *Where work is being carried out in proximity to exposed energized electrical conductors operating at 31 to 750 volts, an employer or contractor shall ensure that the work is carried out so that accidental contact with the energized electrical conductor by any worker is prevented.*

**Regulations Section 467 (1)** *Where an electrical worker may come in contact with an exposed energized electrical conductor and that contact may affect the health or safety of the worker, an employer or contractor shall develop and implement an emergency program that sets out the procedures to be followed in the event of that contact.*

## 2 Electrical Inspection Act

The Saskatchewan *Electrical Inspections Act, 1993*, establishes the requirements for the inspection of electrical equipment, installations and materials.

Under the Act there are certification requirements for electrical equipment:

**Manufacture, Sales, etc. 18 (1)** *No person shall manufacture, sell or offer for sale, display, advertise, rent, use or otherwise provide or offer for use any electrical equipment, or attempt to do any of those things, unless the electrical equipment is:*

*a) approved; or*

*b) certified by a testing laboratory.*

**Manufacture, Sales, etc. 18 (2)** *All electrical equipment must bear evidence, in a manner satisfactory to the chief inspector, of the approval or certification mentioned in subsection (1).*

Electrical equipment certification bodies recognized by Saskatchewan are presented in Table 1. Acceptable field inspection certification labels for Saskatchewan are presented in Table 2.

Table 1: Electrical equipment certification bodies.

| Certification Body | Certification Marks | | Description |
|---|---|---|---|
| CSA International | | | The CSA certification mark alone without any identifier indicates products approved to Canadian National Standards. If another country's identifier is present (i.e. US, NRTL), then the small 'c' Canadian identifier is required to indicate that the product also complies with Canadian National Standards. The 'Blue Flame' certification mark is a Canada only mark indicating compliance to Canadian National Standards. They do not require a small 'c' Canadian identifier. |
| QPS Evaluation Services Inc. | | | The QPS certification mark requires the small 'c' Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small 'c' is required. |
| Intertek Testing Services NA Ltd. (ETL (Entela) | | | The ETL Intertek Entela certification mark requires the small 'c' Canadian identifier at the 8 o'clock position to indicate compliance to Canadian National Standards. Identifiers |

| Certification Body | Certification Marks | | Description |
|---|---|---|---|
| | | | for other countries may be present but in all cases, the small ‘c’ is required. ETL Intertek Semko has two certification marks, the ETL mark and the WH mark. Each mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| FM Approvals | | | The FM certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| Met Laboratories | | | The MET certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| Quality Auditing Institute | | | The QAI certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| TÜV Product Service | | | The TÜV Product Service certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| TÜV Rheinland of North America | | | The TÜV Rheinland certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| Underwriters’ Laboratories | | | The UL certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. The ULC certification mark is a Canada only mark indicating compliance to Canadian National Standards. It does not require a small ‘c’ Canadian identifier. |
| Curtis – Struas LLC | | | The Curtis – Struas LLC certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may |

| Certification Body | Certification Marks | Description |
|---|---|---|
| | | be present but in all cases, the small ‘c’ is required. |
| NSF International | | The NSF International certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| Nemko Canada Inc. | | The Nemko Canada Inc. certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| OMNI Environmental Services Inc. | | The OMNI Environmental Services Inc. certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |
| Lab Test Certification Inc. | | The Lab Test certification mark requires the small ‘c’ Canadian identifier to indicate compliance to Canadian National Standards. Identifiers for other countries may be present but in all cases, the small ‘c’ is required. |

Table 2: Acceptable field inspection certification labels.

| Name of Field Inspection Agency | Special Inspection Label: All labels must read “CSA SPE-1000” | Name of Field Inspection Agency | Special Inspection Label: All labels must read “CSA SPE-1000” |
|---|---|---|---|
| CSA International | | QPS | |
| ETL Intertek Entela | | Intertek Testing Services | |
| ETL Intertek Semko | | Quality Auditing Institute | |

| Name of Field Inspection Agency | Special Inspection Label: All labels must read "CSA SPE-1000" | Name of Field Inspection Agency | Special Inspection Label: All labels must read "CSA SPE-1000" |
|---|---|---|---|
| TÜV America Inc. |  | Underwriters Laboratories of Canada |  |
| Electrical Safety Authority – ESA |  For use on panels only  For use on all electrical equipment covered by the accreditation | Nemko Canada Inc. |  |
| Lab Test Certification Inc. |  | | |

## 3 Canadian Electrical Code

The *Canadian Electrical Code* serves as the basis for wiring regulations across Canada. The code is referenced in the Saskatchewan *Electrical Inspection Act, 1993* as the standard to which governs all work of electrical installation with respect to workmanship and any other matter.

This Code covers all electrical work and electrical equipment operating or intended to operate at all voltages in electrical installations for buildings, structures, and premises, including factory- built relocatable and non-relocatable structures, and self-propelled marine vessels stationary for periods exceeding five months and connected to a shore supply of electricity continuously or from time to time. The Code does not apply to vehicles, systems operated by an electrical or communications utility, railway systems, aircraft or ships; since these installations are already regulated by separate documents.

The Canadian Electrical Code is published in four parts: Part I is the safety standard for electrical installations. Part II is a list of standards for the evaluation of electrical equipment or installations. (Part I requires that electrical products be approved to a Part II standard). Part III is a group of standards relating to power distribution and transmission circuits. Part IV is set of objective-based standards that may be used in certain industrial or institutional installations.

## 4 Canadian Standards Association Z462 Workplace Electrical Safety

The new Canadian Standards Association (CSA) Standard Z462-15, *Workplace Electrical Safety*, issued in 2015~~08~~, is based on the United States National Fire Protection Agency (NFPA) standard 70E, *Standard for Electrical Safety in the Workplace* and has been harmonized with Parts I, II and III of the *Canadian Electrical Code,* CSA Z460, *Control of Hazardous Energy – Lockout and Other Methods*, and CSA-M421, *Use of Electricity in Mines*.

The new standard specifies requirements for and provides guidance on safety management systems, safe work practices, and selection of personal protective equipment and other safety devices for persons exposed to hazards associated with energized electrical equipment. In addition, the standard sets out criteria for the identification and training of qualified electrical workers and for determination of hazardous work to be performed only by those qualified individuals.