actsafe
Safety Association

Live Performance Electrical Certificate

Candidate Study Guide

Revised: July 2012

What is Actsafe?

Actsafe is dedicated to the promotion of health and safety in British Columbia's motion picture and performing arts industries. Our role is to provide arts workers and employers with the necessary support to ensure everyone goes home safely at the end of the day.

Actsafe is governed by the industries it represents. We operate through two standing committees that represent the motion picture and performing arts communities. Membership on these committees includes both employer and worker representatives.

Our mandate includes providing subsidized training and free industry-related communication, education, services and advice.

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Please note that this study guide has been prepared to cover only academic knowledge of the Live Performance Electrical certification. The LPEC examination includes questions that test the applicant's understanding of both practical and academic knowledge. Therefore, applicants must have two years' experience in the field and should be prepared to answer questions not covered by the study guide.

Note: The material in this publication is intended as educational information only. This publication does not replace the Occupational Health & Safety Regulation administered by WorkSafeBC or authorities having jurisdiction over electrical safety. Employers and workers should always refer to the Regulation for specific requirements that apply to their activities.

www.actsafe.ca

Many thanks to our technical team, who contributed to the development of the examination, supporting materials and review.

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Live Performance Electrical Certificate (LPEC): Exam study guide

OVERVIEW

What is the LPEC?

The Live Performance Electrical Certificate (LPEC) was designed for workers who perform temporary assembly and interconnection of plug-in wiring systems used in the live performing arts, trade shows, conventions, touring shows, and festivals.

Why was this certificate created?

Under the BC Safety Standards Act: Electrical Safety Regulations, individuals are not permitted to perform many of the tasks commonly associated with the set-up and operation of stage lighting and other audio visual systems, unless they hold a valid electrical ticket. There are a significant number of persons employed in the live entertainment industry who are not aware of this regulation, and who have been performing this work without a recognized credential.

Aren't there already electrical certifications that apply to the entertainment industry?

There are currently two certificates — The Full Entertainment (FE) and the Limited Entertainment (LE) tickets — that apply to electrical work in the entertainment industry.

Both of these tickets require a significant level of work experience and a 2-3 hour exam. Please see the Technical Safety BC website for current requirements: www.technicalsafetybc.ca.

How is the LPEC different from the FE or LE certificates?

The LPEC covers the work performed by lighting, audio-visual and sound grips and stagehands, during the setup, run, and strike, of theatrical and other live events. It applies to the tasks that lighting crews commonly perform as they hang, focus, cable, and maintain a lighting rig, as well as the set up of audio systems and audio visual installations used in live entertainment.

The FE and LE tickets cover a much wider scope of work and are more applicable to workers at the department head level who perform power tie-ins and more complex electrical work as well as film and television workers, who deal with high power lighting fixtures and generators. The holder of an FE or LE may also act as a Field Safety Representative and sign for electrical permits, whereas the holder of an LPEC may not.

Who should obtain an LPEC certificate?

This certificate is designed for workers in the live event industry, who set up lighting, sound and AV systems in venues with an existing, fault protected, electrical system as would be found in most theatres and concert halls. The LPEC applies to the tasks that grips and stagehands are normally assigned as part of a lighting/audio/AV crew – namely, the interconnection of plug and cap assemblies and branch circuits. The LPEC certificate DOES NOT apply to the motion picture or television industry. Those workers require an LE or FE or must be supervised by a worker who holds one.

How do I obtain an LPEC certificate?

To obtain an LPEC credential, you must have at least 800 hours of on the job training and you must write the LPEC exam and receive a score of at least 70% correct.

How do I apply to take the LPEC exam, and where can I write it?

Complete the application form and submit it, along with post-secondary transcripts, and letters from employer(s) or your union.

Electrical Safety Authorities

- Technical Safety BC
- Municipal: Electrical Inspector.
- Provincial Electrical Inspector: special equipment approvals (in lieu of CSA approval).
- WorkSafe BC http://www.worksafebc.com/.
- Canadian Standards Authority http://ohs.csa.ca/standards/electrical/index.asp

Examination Subjects and Study Guide

SCOPE OF WORK ALLOWED UNDER THE LPEC CERTIFICATE

A person holding an LPEC is permitted to perform the following work:

- Set up temporary, plug in electrical systems used in performing arts, trade shows, conventions, touring shows and festivals.
- Utilize existing fault protected electrical systems
- Interconnect plug and cap assemblies (extension cords) and branch circuits.
- Set up and interconnect XLR, 3, 4, and 5 pin cables, telex cable, coaxial, cat-5 and A/V cable.
- Service equipment under manufacturer's documented recommendations and instructions.
- Supervise a maximum of 2 uncertified workers on work within the LPEC scope.

Limitations

- All equipment used under this certification must be CSA approved or recognized by the Technical Safety BC.
- Work is limited to a maximum of 240 volt 100 Amp 3 phase permanent utility supplied
- Connection of live parts is not authorized.
- Understanding the relevant sections of the Canadian Electrical Code.
- Understanding of the relevant sections of the Safety Standards Act and applicable regulations as well as basic electrical safety is required.
- An LPEC holder is not authorized to act as a Field Safety Representative (FSR) or sign for permits to do electrical work.
- Regulated work for permanent installations or in hazardous locations is not authorized.

Check your learning

1. An LPEC holder can supervise ______ (zero, one, two) unqualified workers.
2. An LPEC worker is permitted to do electrical work on________(utility, generator) supplied systems up to ______ (240, 600) volts,______(100, 200) amps, _____ (single, three) phase.
3. True or False: Trade show work is specifically prohibited for LPEC qualified workers
4. Under what circumstances is an LPEC holder permitted to plug (or connect) non-CSA approved equipment?
5. True or False: an LPEC holder is permitted to connect bare tails into an electrical panel, so long as the tools have insulated handles and are CSA approved.

Answers: 1. two; 2. utility, 240V, 100A, three phase; 3. False; 4. A recognized alternate certification under the Technical Safety BC; 5. False.

Electrical Theory

WHAT IS ELECTRICITY?

- ***ELECTRICITY*** is the flow or movement of electrons through a conductor.

- ***POTENTIAL*** is the difference in electrical charge between two bodies and is measured in ***VOLTS***.
- ***VOLTAGE*** is also known as ***EMF*** or electromotive force.
- An Electron is a negatively charged fundamental electrical particle.
- Electrons repel each other but are attracted to positively charged objects.
- If two bodies with opposite charges are connected via a conductor, free electrons will flow from the negatively charged body to the positively charged body. The flow will continue as long as there is a difference in charge.
- ***RESISTANCE*** limits the flow of current.
- ***CURRENT***, which is measured in ***AMPS***, is the rate of flow (how much) – it is of most concern regarding personal electrical safety.
- ***POWER***, which is measured in ***WATTS***, is the rate at which work is done through the use of electricity.

Resistance

- Opposes the flow of charges.
- Insulators have very high resistance.
- Conductors have very low resistance.

EXAMPLES

- Conductive materials: Copper, silver, gold, aluminum.
- Insulating materials: plastic, rubber, glass.

Conductors vs. Insulators

- A conductor is an easy path for the flow of electrons. Copper is the favoured conductor used in commercial wires and cables.
- Resistance is a property of materials that impedes the flow of electrons. Conductors have low resistance. Resistors have a high resistance value.
- Insulators have extremely high electrical resistance. Insulators and insulation prevent the flow of electric current through unintended pathways.
- While a resistor (as an electronic component) is thought of as having a relatively constant resistance value, many practical resistive elements have varying resistances:
  → Light bulbs
  → Fluorescent tubes
  → Humans

Basic Electrical Units

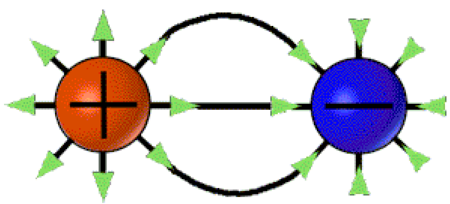
ELECTRICAL QUANTITY	QUANTITY SYMBOL	ELECTRICAL UNIT	UNIT ABBREVIATION
Power	P	Watt	W
Resistance	R	Ohm	Ω
EMF	E	Volt	V
Current	I	Ampere	A

Check your learning

1. The unit of resistance is the ______
2. Insulators have very high___________.
3. Conductors have very low____________.
4. Name two insulators:__________, ________
5. Name two commercially used conductors: _____________,_____________.
6. A passive load with a high__________tends to limit current.
7. The electrical quantity measured in watts is ________.

Answers: 1. Ohm; 2. Resistance;
3. Resistance,;4 . Plastic, glass, rubber;
5. Copper, Aluminum; 6. Resistance; 7 Power.

Electrical Fields



An electric field is a force field that tends to cause a flow of electrons. A flow of electrons is called an electric current.

The field is usually called an electro-motive force (EMF), or potential difference (voltage).
A "tick tester" (AC Sensor) is an electric-field detector.

In situations where you may not know if a wire is live, it would be nice to have a warning before you make a dangerous contact. The AC Sensor is a hand-held device for determining the presence or absence of 50-600 volts AC in insulated wires, wall receptacles, fuses, junction boxes, switches and other voltage-carrying electrical systems. It is not necessary to disconnect the system in question because no direct contact is required for operation and current flow is not necessary to locate voltage. You must test the device on a known working (electronically hot) circuit first, to ensure the device is working. A false negative could kill you.

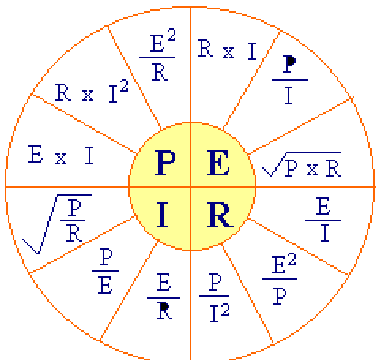
Simply touch the plastic tip to a connection point or move it along a wire. If AC voltage is present, the tip will light up and you will hear an audible tone. The audio alert reacts only to an AC voltage field, and will not beep when it comes in contact with a static field.

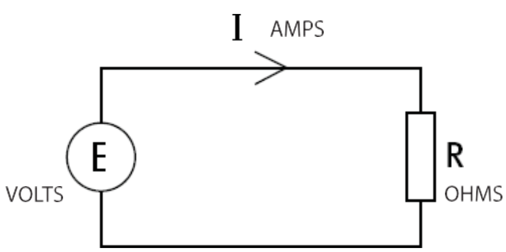
A tick tester is NOT a life-safety tool. A multimeter is a more accurate tool to determine if a circuit is energized, or carrying voltage. Other testing devices include a test lamp or an AC checker that plugs into the U-Ground plug.

AC and DC Circuits

- The AC (alternating current) for stage lighting and power loads is generally sourced from BC Hydro, although sometimes a generator is used.
- The usual 2-wire load voltage is 120 volts.
- The usual 3 phase voltage we work with is 120/208v.
- DC (direct current) for stage or electronic equipment use is most often derived from devices that convert AC to DC. They are called power supplies and have standard output voltages such as 12V or 24V.
- When dealing with loads that are mainly resistive in character, such as lights and heaters, calculations for current and power in AC and DC circuits is identical so long as the AC voltage is used. The source for voltage information is the nameplate of the equipment under consideration.

OHMS LAW: E = IR (the voltage across a resistor is proportional to the current through the resistor).





EXAMPLE 1
What voltage is applied to a 10.4 ohm resistor that is drawing 20 amps?
(Answer: 208 Volts)

EXAMPLE 2
What voltage is applied to a circuit if it has a 6 Amp load whose resistance is 25 ohms?
(Answer: 150 Volts)

ANOTHER FORM OF OHMS LAW: I = E/R

EXAMPLE 1
How much current does a light bulb draw on 120 volts if the hot resistance of its filament is 144 ohms?
(Answer: 0.83 amps)

EXAMPLE 2
How much current does a bank of 12 lights draw on 120 volts if the combined hot resistance of their filaments is 12 ohms? (Answer: 10 amps)

EXAMPLE 3
A twelvefold increase in the resistance of a tungsten lamp filament would cause the lamp to draw_____times_______(more, less) current.
(Answer: 12 times less)

A LESS OFTEN USED FORM OF OHMS LAW: R = E/I

You can calculate the resistance of a load by applying a known value of voltage and measuring the current drawn.

EXAMPLE Calculate the resistance of an electric heater that draws 11 amps when connected to a 240 volt supply.
(Answer: R = E/I = 240/11 = 21.8 ohms)

WHAT FACTORS AFFECT THE RESISTANCE OF AN ELECTRICAL PATHWAY?

1. Material Used
Lower resistance if copper, higher resistance if tungsten.

2. Length of Resistance Material
Longer pathway has higher resistance. Example: A long run of cable feeding a load cause a higher voltage drop.

3. Cross-sectional Area of the Material
Larger cross-section provides an easier path for current. Example: big wires to feed big (=high current) loads.

4. Loose Connections
Loose connections can create excessive heat and higher resistance.

5. Temperature of the material
Hotter is generally more resistive. Example: lamp filament *Exception*: gaseous media (such as fluorescent tube).

Check your learning

1. True or False: To carry higher currents, larger conductors are used.
2. True or False: High resistance can result from loose connections.
3. Incandescent lamps have a considerable in-rush current when energized directly from a source at their rated voltage because, like most resistive materials, tungsten has ________ (lower, higher) resistance at higher temperatures.
4. If excessive voltage drop occurs over the length of a cable, it can often be remedied by replacing the cable with one of ________ (smaller, larger) size.

Answers:1. True; 2. True; 3. Higher; 4. Larger.

WHAT IS A SHORT CIRCUIT?

- A short circuit is generally an unintended pathway for current, since the current that results is higher than the components are rated for.

- Circuit conductors may be damaged by the high current of a short circuit unless appropriate protective devices, such as fuses or circuit breakers, are present.

What if the electrical pathway were very short?

- The resistance would therefore be very low.
- The current that would result when a voltage source was connected to the load would therefore be very high.

- The result is a short circuit

•

HOW MUCH CURRENT IS IN A SHORT?

- Recall that source voltage and load resistance affect the current according to the formula, I = E / R.

- We know that R will be low because the electrical pathway length is very short.

- Therefore, the current can be described in words as being very large or Fault-level.

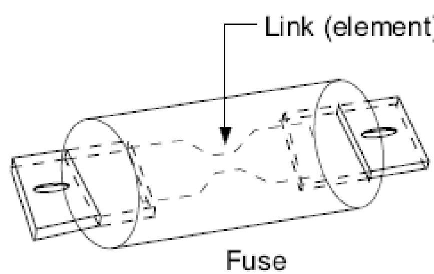
EXAMPLE

Find the current if E = 120 volts and R = 0.01 ohms.

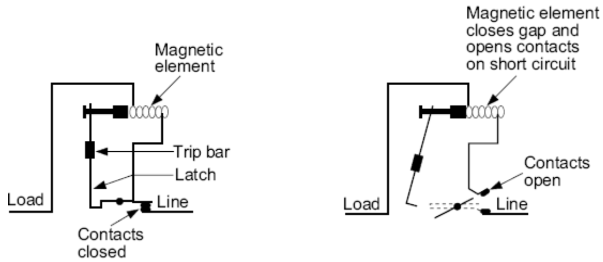
(Answer: By I = E/R, I = 120/0.01/ I=12,000 amps!)

Circuit Protective Devices

- A fuse link melts if it becomes overheated due to current it's carrying.

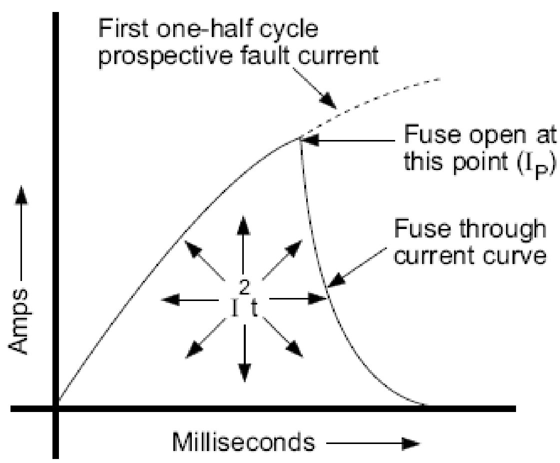


- A circuit breaker trips by two possible mechanisms:
    - Thermal (delayed action)
    - Magnetic (shown below)

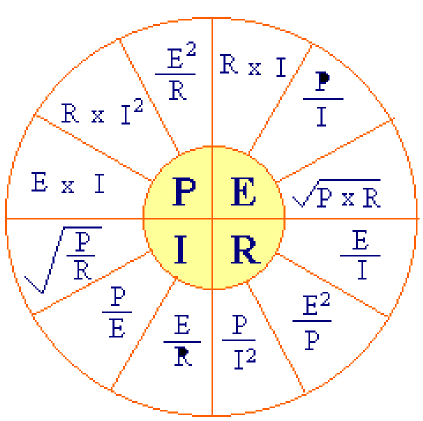


How fast do fuses and breakers react?

- Ideally, a fuse or fast-acting breaker would interrupt the over current before it reached its possible maximum value.
- In reality it takes several cycles to actually operate.



Fuse let-through current wave



POWER CALCULATIONS: 2 – WIRE LOADS

- Power in a load can be calculated by P=EI

EXAMPLE: The source voltage in the circuit is 120V and the load current is 20A. Find the power taken by the load.

- (Answer P=EI, P=120 x 20 = **2400W or 2.4kW**)

Watt's Law Variations on P=E I

- Transposing P=E I can yield I = P/E

EXAMPLE 1: How much current will a 1000 watt rated light fixture draw when energized at its rated 120 volts?
(Answer: By I = P/E, I = 1000/120 = **8.3 amps**)

EXAMPLE 2: How much current will two 1000 watt rated light fixtures draw when energized at their rated 120 volts?

- (Answer: By I = P/E, I = (2x1000)/120 = **16. 7 amps)**

Total Power on a Circuit

- As seen in the last example, the total power is simply the arithmetic sum of the individual loads.

EXAMPLE 1: A 15 Amp, 120 volt household circuit has a 1000W hair dryer, a 14W radio, a 250 W electric heating pad, and two 100W lamps all on at once.

Calculate:

- Total circuit power
- Current draw

EXAMPLE 2: Would it be okay to connect three two-fers to feed one 500W head and three 575W heads on a 20A, 120V circuit?

Answers: 1: Power = 1464 W/ Current =12.2 A; 2.: 18.5A/Yes, so long as not intended for 24/7 operation.

Watt's Law: Power from Voltage and Resistance

Since I = E/R, the fraction can be substituted into P=EI, yielding P = E x E/R or E^2/R

Example: Find the power taken by a 2.4 Ω resistor when connected to 120 volts.

(Answer: P = 120 x120/2.4 = **6000 W or 6 kW**.)

EFFECT OF VOLTAGE VARIATION ON POWER

- Power is proportional to voltage squared. The net result of this is that a seemingly small difference in voltage can have a significant effect on the power of a load.

EXAMPLE: A 240-volt rated, 1000 Watt rated electric hot water heater is energized from a 208-volt source. Compare the rated power versus the actual power output.

VOLTAGE	RESISTANCE	POWER
240V	240^2/1000=57.6 OHM	1000 W
208V	57.6 OHM	=208^2/57.6=751 W

POWER AVAILABLE ON A "2.4kW" CIRCUIT

If two 120-volt circuits are available and each circuit breaker is rated at 20 amps, how many watts of load can each circuit take?

- **Watts = Volts x Amps**

How many 1000 watt luminaires can be fed from this module?

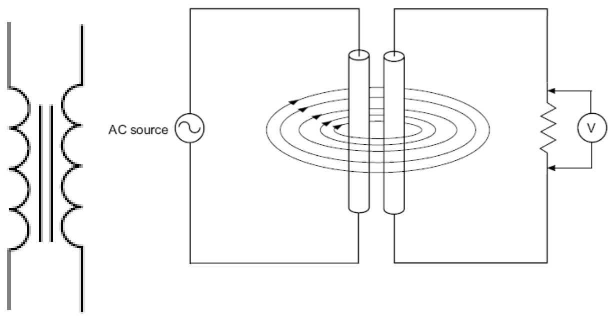
- **Amps = Watts / Volts**

Answer: 1: 2400w or 2.4kW.
Answer 2: 4 luminaires

Check your learning: Calculations of Dimmer Capacity

1. Calculate the current taken by a fully-loaded 120 V, 6 kW circuit.
2. A 2.4kW dimmer module rated at 120V would be capable of supplying _______ amperes of current.

Answers: 1) 50 amps, 2) 20 amps.



A TRANSFORMER:

- Raises or lowers the voltage of an alternating current source (step-up or step down).
- Provides electrical isolation between systems.

Whichever transformer winding that the source is connected to is called the primary winding. The transformer secondary winding is connected to the ***LOAD***.

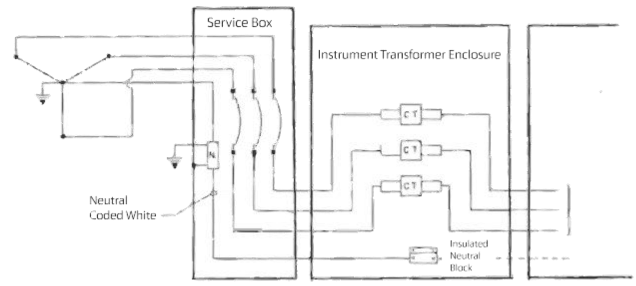
ELECTRICAL DISTRIBUTION IN A THEATRE

Electrical service: BC Hydro service switch and metering.

- In small to medium size venues the service switch (or circuit breaker) is fed from a low voltage (transformer secondary) circuit.
- Anything less than 750V is considered low voltage.
- If you have to operate this switch, use your ***LEFT*** hand and face away from the switch.
- Generally, the service switch will feed a circuit breaker panel which in turn feeds various panels in the building, including one or more dimming panels.
- From the dimming panel, individual dimmer circuits are fed within the theatre.

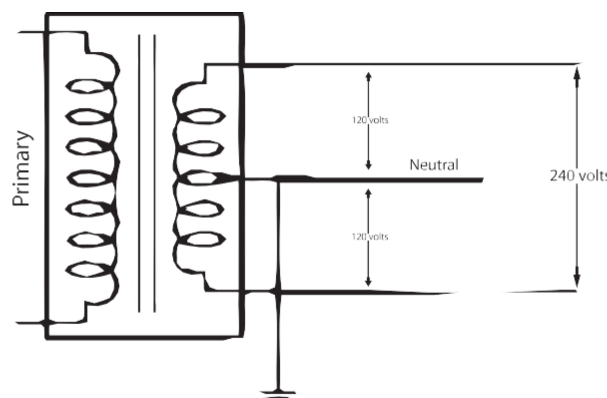
Three-phase, Four-wire Service Wiring: Secondary Metered Service Enclosures – One Possible Arrangement:

- The Main Service Disconnect may be a switch or circuit breaker.
- Downstream of the Instrument Panel Enclosure there may be a breaker panel.



"Grounded circuit conductor" vs "Neutral"

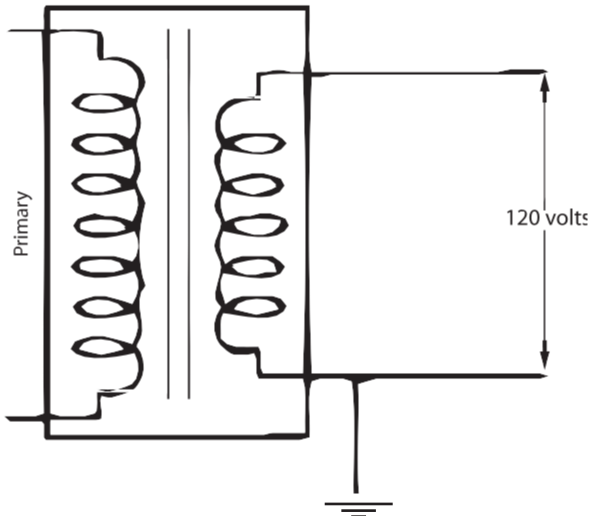
- The grounded line in this circuit is technically called the grounded circuit conductor, or identified conductor.
- It is identified by being coloured white or natural gray.

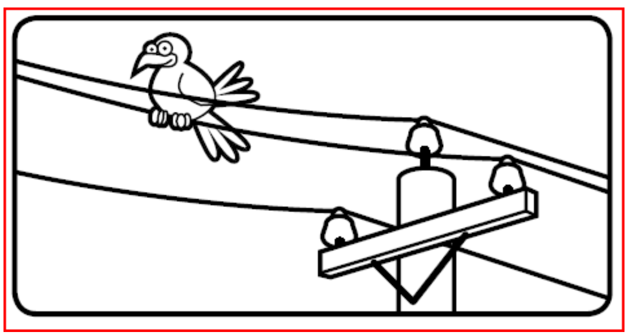


- The identified, or grounded circuit conductor, in this circuit is called a Neutral because of its equipotential status, relative to the Line 1 and Line 2 circuit conductors.

GROUNDING PURPOSES

Have you ever looked up at the power lines and seen birds standing on the wires? Why don't they get electrocuted?





Answer: because they are bridging across only a short portion of supply conductor. The potential difference between their little claws would be less than 1 volt.

GROUNDING CONDUCTORS

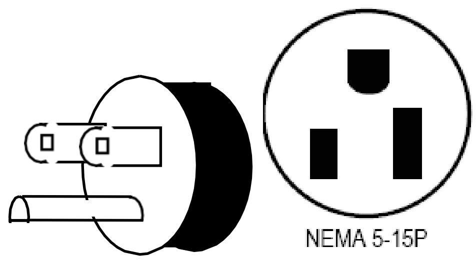
GROUNDING CONDUCTOR: The physical conductor connecting the chassis of an electrical or electronic device to the electrical system's grounding means.

- Sometimes referred to as the ***SAFETY GROUND***, this conductor may be a green insulated conductor, a bare copper wire, or metallic conduit.

- The purpose of the grounding conductor is to provide a low impedance pathway for fault current in the event of a hot wire becoming grounded so that a load circuit may be automatically de-energized by a fuse blowing or circuit breaker tripping.

- A better term to use is ***BONDING CONDUCTOR***. The bond wire in flexible cords is ***GREEN***. In permanently installed wiring system cables it is usually bare. In metallically enclosed conduit and tubing systems, the metal conduit or tubing is generally acceptable as a means of ensuring that all metallic enclosures and chassis are at ground potential.

15 AMP U-GROUND CONNECTORS



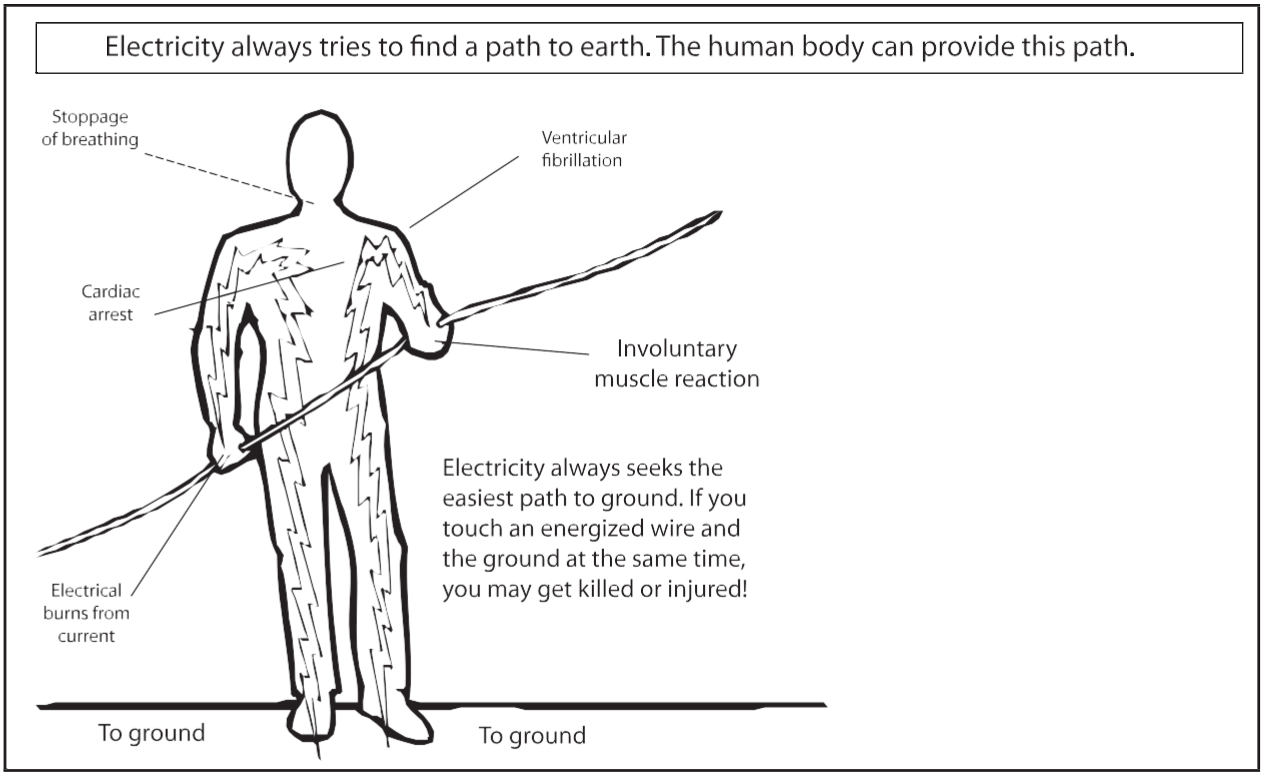
The ground pin on the male end (cap), is longer than the hot and neutral pins in order to ensure that the chassis of metal equipment is grounded before power is applied. Since the longer slot is most likely to be inadvertently contacted, the shorter slot is the hot one.

Two-prong, ungrounded plugs (below) should be used only on devices not requiring a ground connection, such as lamps and "double-insulated" small appliances.

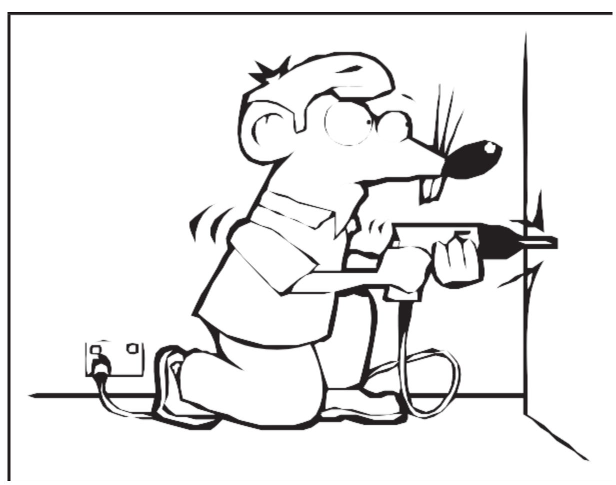
Ground Paths:

On the pictures below, show where you think the pathway from the power source to earth would be.

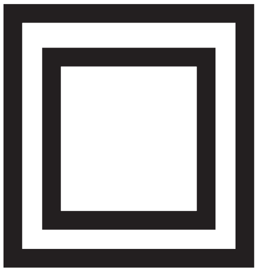
EFFECTS OF ELECTRICAL SHOCK



PHYSIOLOGICAL RESPONSE TO CURRENT LEVELS



What if the drill were double insulated?



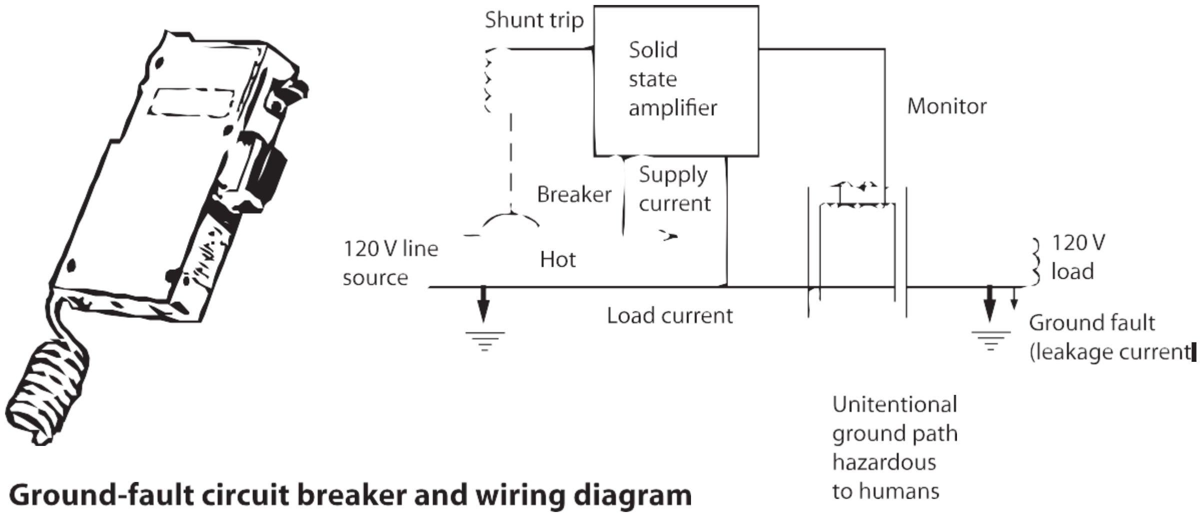
DOUBLE INSULATED SYMBOL

Current Level	Effect on Human Body
1 mA	- Not perceptible, probable tingling sensation
3-5 mA	- "Let go" current for an average child
6-8 mA	- "Let go" current for an average woman
7-9 mA	- "Let go" current for an average man
16 mA	- Maximum current a person can grasp and "let go"
16-20 mA	- Seizure of skeletal muscles
20-50 mA	- Paralysis of respiratory muscles (respiratory arrest)
50-300 mA	- Ventricular fibrillation
Greater than 2 A	- A systole (= flat line)

Hazards of Poor Grounding
http://www.dvorak.org/blog/?p=3195

THE GFCI

The ***GROUND-FAULT CIRCUIT BREAKER***



Ground-fault circuit breaker and wiring diagram

(GCFI) is a thermal-magnetic breaker which incorporates a solid state, ground-fault sensing circuit to detect ground currents of 5 mA or greater.

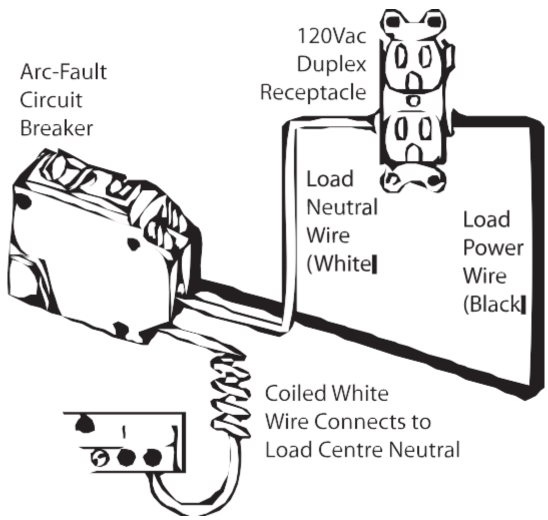
A GFCI should be used in any outdoor, wet or damp location.

If as little as 0.005 amps are sensed, the GFCI will trip.

THE AFCI

- An ***ARC FAULT CIRCUIT INTERRUPTER (AFCI)*** is a circuit breaker designed to prevent fires by detecting non-working electrical arcs and disconnect power before the arc starts a fire.
- AFCIs resemble a GFCI (Ground-Fault Circuit Interrupt Device) in that they both have a test button, though it is important to distinguish between the two.
- GFCIs are designed to protect against electrical shock, while AFCIs are primarily designed to protect against fire.

Check your learning: Shock Hazards



1. Even if it is certain that the supply to a recently de-energized bare terminal has been shut off, it is prudent to first touch the terminal lightly with__________before grasping it firmly.
2. A_____will open the hot wire if a small leakage current to ground is detected.
3. True or False: If amplifier hum is a problem, the chassis ground may be disconnected.

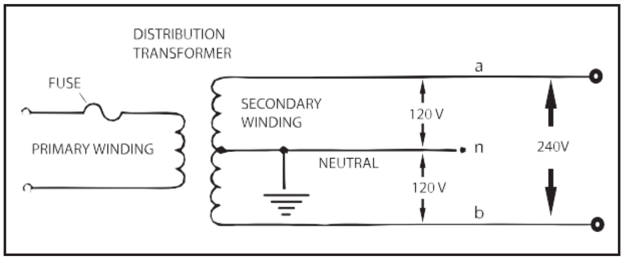
Answers: 1.The back of the fingers (muscle seizure – inability to let-go) or use multi-meter; 2. GFCI; 3. False.

CIRCUIT CHARACTERISTICS

Single-Phase Circuits

Single-phase alternating current is available in two and three-wire services. In general, the three-wire service is used for most single-phase applications such as residential. A single-phase service is supplied by a distribution transformer as in the diagram shown below:

The electric utility supplies a high voltage to the primary winding of the distribution transformer.



The voltage is then reduced or "stepped-down" in the transformer and supplied to the customer from the secondary winding. Electric power is supplied to the customer at 120 / 240 Volts, using 3 wires (a, b, and n) which connect to the transformer secondary winding.

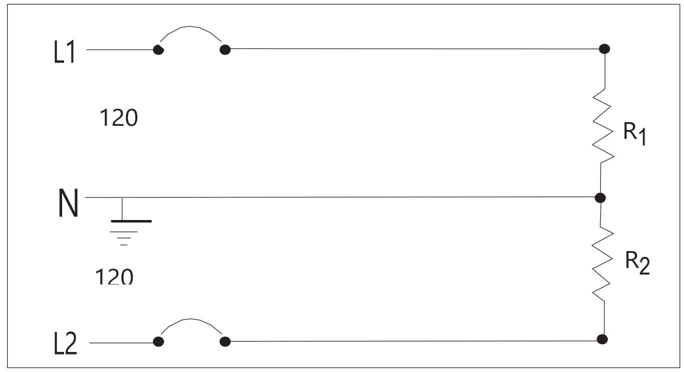
Note that 120 Volt service is often closer to 115 Volts and may be as low as 110Volts. Stage lighting equipment will operate well on any of these voltages.

In three-wire service, 120V is provided between either of the outside lines and the center line (or identified conductor), and 240V is provided between the two outside lines. The 120V connections are used for lighting and small appliances while the 240V connection is used for heavier loads such as electric heaters, dryers, or ovens.

Common single phase voltages are 115/230V and 120/240V, three-wire, with a solid neutral. The term "solid neutral" means that the neutral wire is not interrupted by a switch or fuse or other device. The two voltage values separated by the slanted line indicate that two voltages are available from one three-wire service.

Current and Power Calculations: 3-wire Single-phase Balanced Load

1. Given R1 = 15 Ω, find the current (amps) in



   Line 1
2. Given R2 = 15 Ω, find the current (amps) in Line 2.
3. The current in the centre (neutral) conductor would be____________amps.
4. Calculate the total circuit power.______W + _____ =______W

Answers: 1. 8 Amps; 2.8 Amps; 3. 0 Amps (loads are balanced – no current flows in the neutral), 4. 960 W + 960W = 1920W.

Circuit Voltages

Refer to the previous diagram (above).

1. The voltage from Line 1 to Line 2 is _________ volts.
2. The voltage from Line 1 to Ground is _________ volts.
3. The voltage from Line 2 to Ground is _________ volts.
4. The voltage from Line 1 to Neutral is _________ volts.
5. The voltage from Line 2 to Neutral is _________ volts.
6. The voltage from Neutral to Ground is _________ volts.

Answers: 1. 240V; 2.120V; 3.120V; 4.120V; 5.120V; 6. 0V.

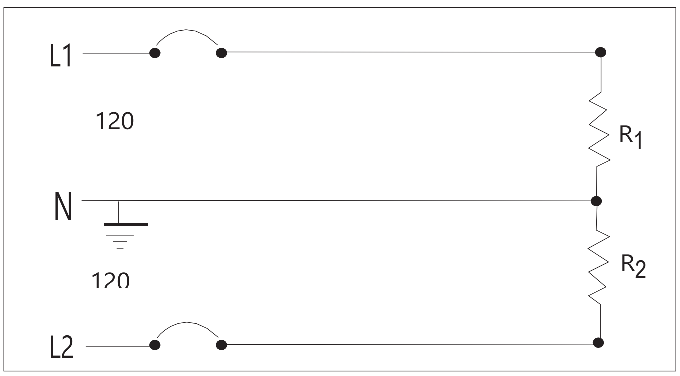
Current and Power Calculations: 3-wire Single-phase Unbalanced Load

In a multi-wire branch circuit, the neutral does not carry the full load of each 120 volt leg. The neutral conductor only carries the unbalanced current between the 2 ungrounded (hot) conductors.

For instance, if phase 1 has a load of 10 amps and phase 2 has 8 amps, the neutral conductor only has a current load of 2 amps.

In a properly functioning electrical system, the neutral conductor carries the imbalance current of the system. For a single-phase system, the imbalance is the difference between the currents in the two "hot" legs of the transformer.

1. Given R1 = 8 Ω, find the current in Line 1.
2. Given R2 = 10 Ω, find the current in Line 2.



3. The current in the centre (common) conductor would be ___________ amps.
4. Calculate the total circuit power. _____ W + _____W =_____W

Answers:

1. 15A, 2. 12A, 3. 3A (unbalanced loads cause back-flow of current in the neutral), 4. 1800W + 1440W = 3240W

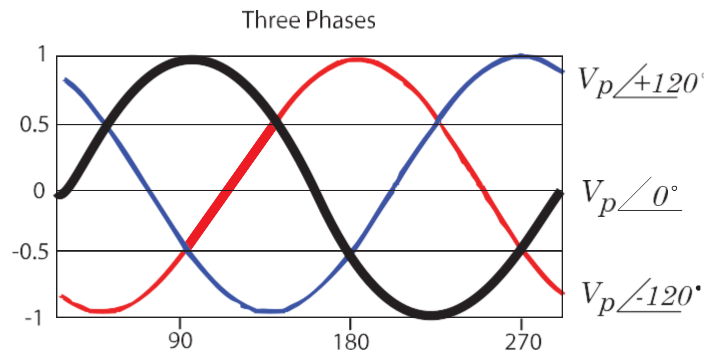
Three-phase Systems

A three-phase system is produced by three sources with the same amplitude and frequency but separated in phase by 120°.

In a three-phase system, the neutral current is the imbalance between all three hot phases. The current imbalance needs to return via the neutral conductor back to the transformer - but, if that neutral is open, the imbalance current will seek other paths to get back to the neutral leg of the transformer. For this reason, ***THE FUSE OR CIRCUIT BREAKER ALWAYS GOES ON THE HOT WIRE – NEVER THE NEUTRAL.***

Balanced three-phase Voltages

Three-Phase service is found in industrial applications and is commonly found in theatres.



Many motors are built to run on 3 phase power. Three-Phase services and circuits can be subdivided into delta (Δ) and wye (Y) connected circuits. The symbols Δ and Y describe the configuration of three-phase connections. In the Δ configuration, the three phases are connected end to end in a closed loop. In a Y configuration, the three phases are connected together at a common point.

Delta-connected Circuits

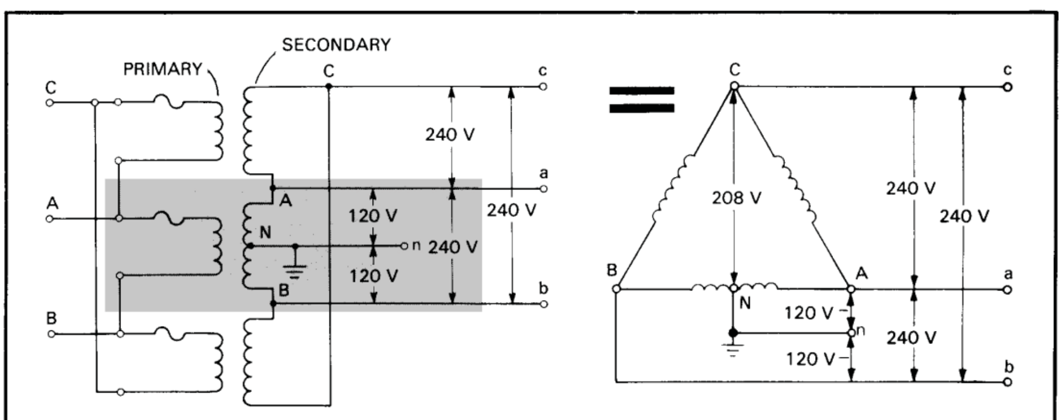
The typical Δ connected service is shown below. The service shown is a four-wire three-phase 120/240V service. It is obtained by connecting the three transformer secondaries in delta – or in series with each other – to form a closed loop:

The junction points A, B, and C, connect to lines a, b, and c. The transformer winding between junction points A and B is center tapped at N. Thus, the line n connected to point N is both the neutral and the fourth wire of the three-phase service. The available voltages are 240V, between **a** and **b, b** and **c**, and **a** and **c**: 120v between **a** and **n**, and **b** and **n**; and 208V between **c** and **n**. The voltage between **c** and **n** is far too high for 120V loads and too low for 240-V loads. Therefore, no load is connected between these two lines (**c** and **n**).

The Δ service is very flexible. It can provide service for 3-wire, three-phase loads and it can also provide service for two-wire, single phase loads if the loads are evenly distributed. It can also provide power for two-wire, single-phase 120V loads. One disadvantage of this type of connection is that any loads connected to the neutral will unbalance the loads. Another disadvantage is that loads cannot be connected between c and n. An advantage of the Δ connection is that if one transformer should fail, the two remaining transformers can still provide three-phase power.

The symbol 3 ∅ is used for "three phase"; the Greek letter phi (∅) stands for the word "phase".

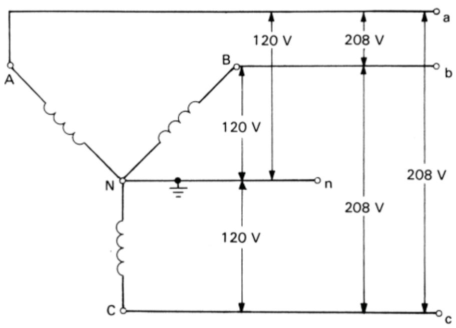
Wye-connected circuits



FOUR-WIRE THREE-PHASE Δ-CONNECTED SERVICE   EQUIVALENT Δ CONNECTION

Three-phase service connected in Y (or "star") is a four-wire, three-phase service.

FOUR-WIRE THREE-PHASE Y-CONNECTED SERVICE



EQUIVALENT Y CONNECTION

The ultimate source of the 3-phase 4-wire, 120/208V power will be the secondary of a transformer.

In a Y connected service, one end of each transformer secondary is connected to the common point **N**. The other ends of the transformer secondaries are connected to service wires, or lines **a**, **b**, and **c** (these lines are called phases). The line connected to the common point **N** is the neutral line **n**, which is grounded.

The voltage between each of the lines **a**, **b**, and **c** and the neutral line n is 120V. Because of the interconnection of phases, the line-to-line voltage is 1.732 times the line-to-neutral voltage. Therefore, the line-to-line voltage is 1.732 X 120 = 208V. The line-to-line voltages are **a** to **b**, **b** to **c**, and **a** to **c**. When single phase loads are used, it is important that the loads be balanced – that is, equally distributed.

The Y-connected service is more flexible than the Δ connected service. The loads which the Y-connected service can supply are:

- Three-phase, three wire 208V loads connected to lines **a**, **b**, and **c**.
- Three phase, four-wire 120/208V loads connected to **a**, **b**, and **c** and **n**.
- Single-phase 208V loads connected to lines **a** and **b**, **b** and **c**, or **a** and **c**.
- Single phase 120/208V loads connected to lines **a**, **b**, and **n**; **b**, **c**, and **n**; or **a**, **c**, and **n**.
- Single-phase 120V loads connected to lines **a** and **n** and **b** and **n** or **c** and **n**.

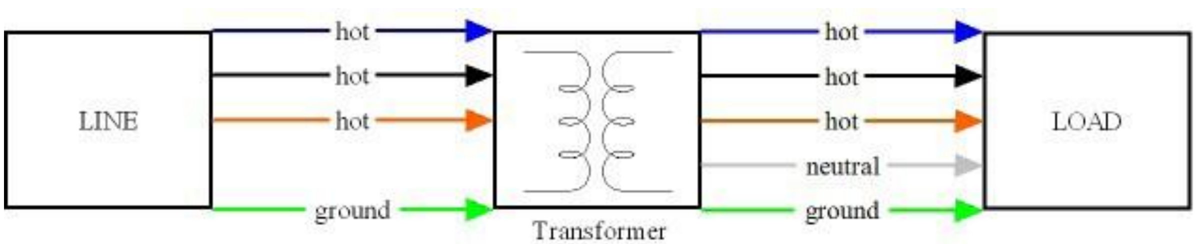
The single phase 120V loads can be either lighting or convenience outlet loads.

Why three-phase?

- Nearly all power generated in Canada is 3-phase, 60 Hz. When single phase is needed, it can simply be taken from one of the three phases.
- The instantaneous power in 3-phase system can be constant (not pulsating). Results in less vibration in 3-phase machines.
- Three phase systems are more economical than single. Amount of wire needed is less than single phase.

Check your learning: Three-phase

1. The direction of rotation of a three-phase motor can be reversed by____________any two line leads.
2. A three-phase system is essentially a connection of three single-phase sources that have the same________and________, but differing in_________by 120º.



FOUR-WIRE THREE PHASE IN

FIVE WIRE THREE PHASE OUT

3. Balancing the loads on three-phase fed circuits will______(reduce, increase) the neutral current and ensure that_______one leg of the source will become overloaded.
4. True or False: a trade show booth with its own 120/240V panel will probably be okay if it is fed from a 120/208V.

Answers: 1.Interchanging; 2. Amplitude; frequency, phase; 3. Reduce, No, 4; T (as long as the color conventions are adhered to) – could be a problem if there are 240V loads which need all of the power.

CAM-LOCKS

- A single wire connector for large wire, 2/0 or 4/0.
- Locked in place by rotating 1/2 turn after insertion.
- Comes in colours to indicate which leg is which.
- Rated up to 400 amps, large venue use.
- Mini-cam size for #1 cable, rated up to 100 amps.
- "J" series cams have longer male and female boots. (entertainment standard).
- "E" series cams have stubby females and short male boots (common on movie sets).

"J" series Cam-Lok

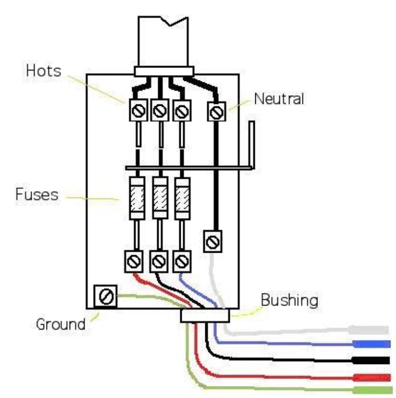
"E" series Cam-Lok

Female Cam-loks: have the power!

- Quite often the supply side will have all female cams
- Occasionally, the ground and neutral will be "turned around". In this case the supply side will have a male ground, a male neutral and three female hots. In theory, this makes it more difficult to inadvertently plug a hot line into the ground or neutral.
- Some touring companies will only turn around the ground. The supply side will be fed with a male ground with female neutral and hots.

Power Source:

- Prior to your connecting cam-locks, a certified ***ELECTRICIAN*** or LE/FE holder will have connected the tails to the disconnect switch or circuit breaker.
- The phase colours in a 120/208V or 250V system in Canada are ***RED-BLACK-BLUE.***



Connecting Cam-Loks

It is important not to make a Cam-Lok connection under load. Making a connection under load could cause an arc flash!

- **The proper procedure MUST be followed when connecting the cables, or an unsafe situation can occur.**
- **Turn off the disconnect switch.**
- **Important! - Make the Green safety ground cam-lock connection first.**
- **Important! - Next, make the White neutral cam-lock connection.**
- **Next, make the Hot phase connections. These connections are usually marked with Red, Black and Blue.**
- **Make sure all workers are clear of any hazards that may be created when the power is turned on.**
- **Turn on the switch with your left hand while facing away from the switch.**

Connecting Cam-locks – Key Points:

- Connect them with the power turned off but always treat them as though the power is on anyway. Someday it may be!

- ***NEVER* *PLUG THE HOTS IN FIRST!*** The result may be that a 120V load may experience 208V and be destroyed.
- Or worse yet, someone may be electrocuted!

Disconnecting Cam-Loks

It is important not to break a Cam-Lok connection under load. Doing so could create an arc which can jump to the person holding the connector!

- **The proper procedure MUST be followed when disconnecting the cables, or an unsafe situation can occur.**
- **Turn off the disconnect switch or circuit breaker.**
- **Important! - Disconnect the Hot phase connections first.**
- **Important! - Next, disconnect the White neutral cam-lock connection.**
- **Next, the Green safety ground cam-lock may be disconnected.**
- **Before working on downstream equipment as though it is dead, try turning it on if possible, to confirm that you are working on dead equipment.**

Check your learning:
Cam-Lok Connections

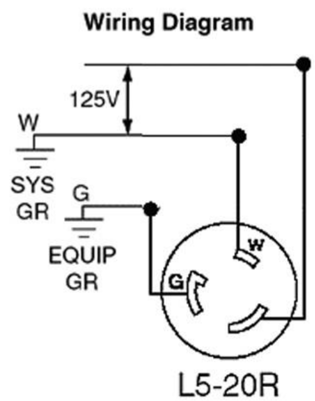
1. True or False: Cam-Lok connectors are made for single-conductor and multi-conductor connections.
2. True or False: Aside from being easier to handle, single-conductors have higher current-carrying capacity than multi-conductor cables with the same size conductors.
3. A tail connected to a panel on one end most likely has________(male, female) Cam-Lok on the other end.
4. Load side Cam-Loks are typically _______ (male, female) ends.
5. True or false: When connecting Cam-Loks, a back-feed hazard may be created if connections are made in the wrong order and loads are connected while the circuit breaker is on.
6. Connecting tails to circuit breakers is NOT permitted to be done by________(LPEC, LE, FE,) qualified workers.
7. Making Cam-Lok connections must be done in the following order when there are five line side and five load side connectors. ________,________,________.

Answers: 1. F, 2.T, 3.Female, 4.Male, 5.T, 6. LPEC, 7. Ground, neutral, hot (s).

120/208 VOLT POWER DISTRIBUTION FOR THEATRE LIGHTING LOADS

- The “2.4 kW” circuitry commonly used for 120V stage lighting circuits is fed from a 20 Amp circuit breaker in a dimming or non-dim module.
- As calculated previously, the theoretical maximum loading for one of these circuits is 2400 W or 2.4 kW.

The connection is usually a 20 Amp, twist-lock type cap, as shown



- Note that in the L5-20R diagram the W denotes the White wire (the identified circuit conductor). The ground marked “W SYS GR” is done ahead of the electrical service box in the building and nowhere else.

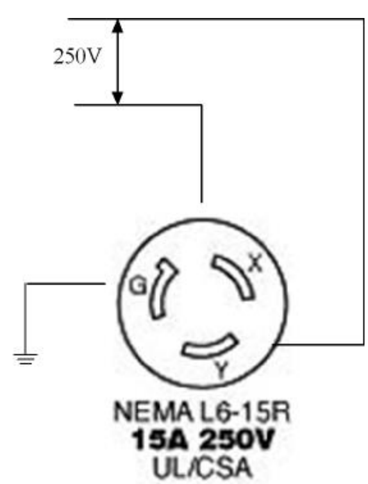
- The bond pin is marked ‘G’ and is described as the “EQUIP GR”. This bond connection is done locally at the receptacle and continues via bare wires or metal conduits back to the main panel.

- A receptacle may be at the end of an extension cord. It is possible to put two 1000 watt heads on one circuit for a total of 2000 watts.

- To allow more than one load to be plugged into a circuit, two such receptacles may be spliced together at the end of an extension cord that has a single male connector at the other end, commonly called a two-fer.

STAGE-PIN Connectors:

- Another connector which is commonly used in North American Theatre is the grounded Stage-pin, GSP or Bates connector. These 3-pin connectors utilize a ground pin, a neutral pin and a hot pin. Newer models have a longer ground pin to ensure greater safety when making connections.



- As is the case with twist-lock connectors, different amperage Stage-pins are different sizes and use different pin configurations. They come in 20A, 30A, 60A and 100A ratings.
- Advantages of Stage-pins are that they are more rugged than many other connectors and like Cam-Lok, the split pins can be spread to compensate for wear, always providing a solid connection. If the pins were to become too compressed, the resulting bad connection would cause arcing, pitting and eventual destruction of the connector.

SOCA Connectors

- SOCAPEX - A multi-pin connector which can carry a series of lighting or sound circuits. Very robust and designed for touring. Available in 19 (6 centered first-mate ground pins) and 37 pin configurations. In 19 pin configurations, pin 19 is not used.

- Soca outputs are found on many dimmer racks, however many adapters are available to "break out" or "break into" U-ground/ Edison or Stage Pin connectors when required.

HOW TO WIRE SOCAPEX 19-PIN

PIN NUMBER	CABLE CORE No.
1	Circuit 1 Live
2	Circuit 1 Neutral
3	Circuit 2 Live
4	Circuit 2 Neutral
5	Circuit 3 Live
6	Circuit 3 Neutral
7	Circuit 4 Live
8	Circuit 4 Neutral
9	Circuit 5 Live
10	Circuit 5 Neutral
11	Circuit 6 Live
12	Circuit 6 Neutral
13	Earth
14	Earth
15	Earth
16	Earth
17	Earth
18	Earth
19	Unused

Pin and Sleeve Connectors

- Pin and Sleeve connectors are high quality, durable connectors used around the world in high abuse situations and are good for sealing power connections from the environment. They are found in many hotels, conference centers, touring productions and are used by many rental houses.

- A locking ring helps to prevent accidental disconnection under load.

- Available in many different voltages and amperages around the world, we commonly encounter them at 120/208V up to 600V in 60A, 100A and 125A ratings.

Power Cable Ratings

Flexible power cable is referred to as cabtire. The *Canadian Electrical Code* refers to it as flexible cord.

- Cabtire has a rubber or neoprene outer covering

Canadian Electrical Code: Part 1 - Table 11

Locations	Use	Kind	CSA Type	Voltage Rating	Temperature Rating
Damp (or Dry)	Hard Usage	Flexible Cord	SJ	300	60 , 75, 90, 105C
Damp (or Dry)	Extra-Hard Usage	Flexible Cord	SO	600	60, 75, 90, 105C
Wet (or Damp or Dry)	Extra-Hard Usage	Outdoor Flex-ible Cord	SOW	600	60, 75, 90, 105C
Wet (or Damp or Dry)	Hard Usage	Stage Lighting (single conductor)	PPC	600	60 , 75, 90, 105C

Wire Sizes & Markings on Power Cables

- 12AWG 3C (or 12/3):
  - "Twelve three, SO"
  - "Twelve" #12 American Wire Gauge size
  - "SO" – O for Oil
  - 10/4 SOW would be four-conductor, 10 gauge for wet locations

AWG Size PPC	Current Rating Single Conductor
0000 (4/0)	400A
000 (3/0)	350A
00 (2/0)	300A
0 (1/0)	260A
1	220A
2	190A

AWG Size Flexible	Current Rating 3 current carrying
6	45A
8	35A
10	25A
12	20A
14	15A
16	10A

CURRENT CARRYING CAPACITY OF COPPER CONDUCTORS

Current carrying capacity is defined as the amperage a conductor can carry before melting either the conductor or the insulation.

Heat, caused by an electrical current flowing through a conductor, will determine the amount of current a wire will handle. Theoretically, the amount of current that can be passed through a single bare copper wire can be increased until the heat generated reaches the melting temperature of the copper.

There are many factors which will limit the amount of current that can be passed through a wire. These major determining factors are:

Conductor Size

The larger the conductor, the greater the current capacity.

Insulation

The amount of heat generated should never exceed the maximum temperature rating of the insulation material.

Ambient Temperature

The higher the ambient temperature, the less heat required to reach the maximum temperature rating of the insulation.

Number of Conductors

Heat dissipation is lessened as the number of individually insulated conductors, bundled together, is increased.

Check your learning: Power Wire and Cable

1. What the Canadian Electrical Code calls a flexible cord is commonly called ___________.
2. Flexible cords used in theatre productions must be rated for_____________usage.
3. True or False. The load capacity of a #12 wire is greater than that of a #8 wire.
4. Type______(SO, SJ, SOW, PPC) flexible cable is least preferred for the severe usage to which stage production cables are subjected.
5. A flexible cable marked 12/3 has _____ conductors of #_____gauge.

Answers: 1. Cabtire; 2. Extra hard; 3. F; 4. SJ' 5. 3/#12

POWER QUALITY TERMINOLOGY

Key Terms

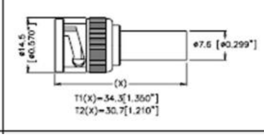
- Blackout - complete loss of electrical power.
- Brownout - a long duration voltage sag (low voltage) .
- Sag - Any short-term (less than 1 minute) decrease in voltage.
- Surge - A sudden dramatic increase in voltage that typically lasts less than half a cycle.
- Spike - an imprecise term used to describe a very short duration voltage transient.
- Noise - An unwanted high-frequency electrical signal that alters the normal sine wave.
- Harmonic - A whole multiple of the basic power frequency. On a 60 Hz system the 2nd harmonic is 120 Hz, the third harmonic is 180 Hz, the fourth is 240 Hz and so on.

LOW ENERGY THEATRE SYSTEMS

- Local area network (Ethernet)
- Lighting control communication (DMX)
- Telephone
- Classical Serial cabling
- Audio
- Intercom
- Video feeds

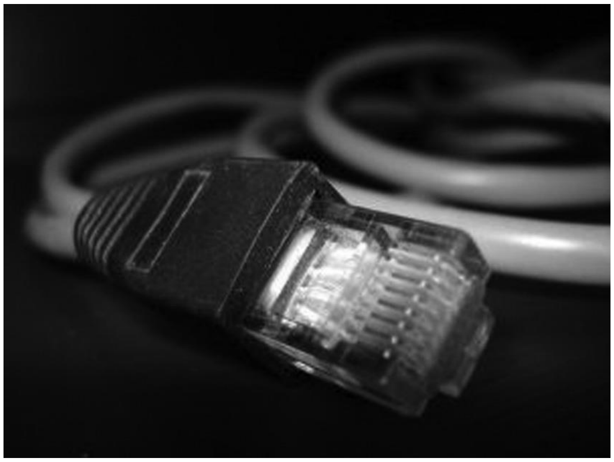
BNC Connectors

- Video lines terminate with BNC connectors.
- Video cables are co-axial.
- They have a centre-conductor and a braided shield.
- Co-axial shielding prevents the ingress of spurious signals.

PRODUCT - FIGURE	DRAWING Dimensions in mm (inches)	DESCRIPTION & CABLE TYPE RG-/U
		**Crimp Plug** RG-6 Type .295" O.D. max. Belden 9248, 1694A (Single Shield)

Remedies for Power Problems

Blackout	- Emergency lighting, flashlight, up-to-date circuit directory
Brownout	- Initially set the voltage a little on the high side (5%). Talk with the neighbours / BC Hydro.
Sag	- Uninterruptible Power Supplies for sensitive, critical equipment. Talk with the neighbours / BC Hydro.
Surge	- Uninterruptible Power Supplies for sensitive, critical equipment
Spike	- Surge suppressors, isolation transformers, lightning arrestors.
Noise	- Isolation transformers
Harmonics	- avoid harmonic-producing loads such as PC's, lamp dimmers, variable speed drives. Do not share neutrals between lines, run a separate return for each hot wire.



- Used for video feeds for CCTV

Local Area Network Cable

- Patch cable needed for Internet high speed connection to cable or phone line modem.
- Wall jacks needed for distributed ethernet – type local area network.
- Modular 8 pin design: 8-position, 8-pin Connector is called an RJ-45
- Available in Cat 5, Cat 5e, and Cat 6 versions.
- Cable type is UTP (Unshielded Twisted Pair) solid for infrastructure wiring, stranded for patch cables.

DMX Network Link Cable

- DMX control protocol used between lighting console and dimmers or other devices.
- Developed by the Engineering Commission of United States Institute for Theatre Technology (USITT), the DMX512 standard was created in 1986 and revised in 1990. For more information, see: http://en.wikipedia.org/wiki/DMX512
- The connectors themselves must be five-pin XLR, although only three pins of the five are always used – the presence of the other two pins makes connection to unintended gear impossible.
  - 1. Data Link Common
  - 2. Data 1- (Primary Data Link)
  - 3. Data 1+ (Primary Data Link)
  - 4. Data 2- (Secondary Data Link): unused
  - 5. Data 2+ (Secondary Data Link): unused

Philosophy of Shielding and Pair Twisting

- To prevent the ingress of unwanted signals into communication cables, three main strategies are used, singly or in combination:

1. Maximizing the physical distance between control signals and potential sources of noise.
2. Shielding the cable conductors with braid or foil.
3. Twisting the wires of each pair in the cable.

- Maintain a foot of distance between cables wherever possible. When crossing other cables is unavoidable, cross at right angles.
- In general, communication cable shields should be grounded at the source end and insulated at the load end by taping or heat-shrink tubing. The objective of this radial grounding network is to prevent ground loops.
- Communication cables of the twisted-pair type are manufactured with tightly twisted pairs. Do not allow the pairs to splay out any more than ¾” at terminations. This reduces

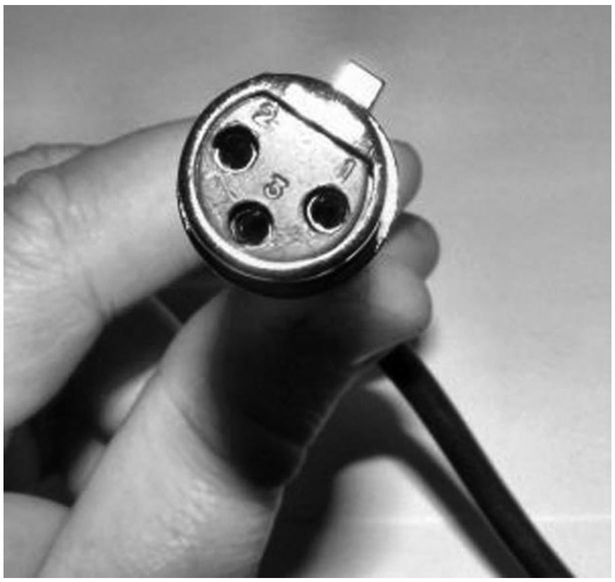
crosstalk.

XLR Connectors

Microphone and Intercom lines usually terminate with XLR-3 connectors as do some control lines (moving lights).

XLR-type connectors are wired in accordance with IEC 268 to suit low-impedance microphones:

- HOT conductor to pin 2
- COLD conductor to pin 3



- SHIELD to pin 1.

Conventions for Audio Polarity and Wire Colours

In general, a red conductor is regarded as HOT and a black conductor as COLD.

- Two-pole connectors (1/4” phone, 3.5mm mini, RCA, phono, etc.):
  → HOT conductor to tip, COLD conductor and SHIELD to sleeve.
- Three-pole connectors (1/4” phone, 3.5mm mini, ‘TT’, etc.):
  → HOT conductor to tip, COLD conductor to ring, SHIELD to sleeve.

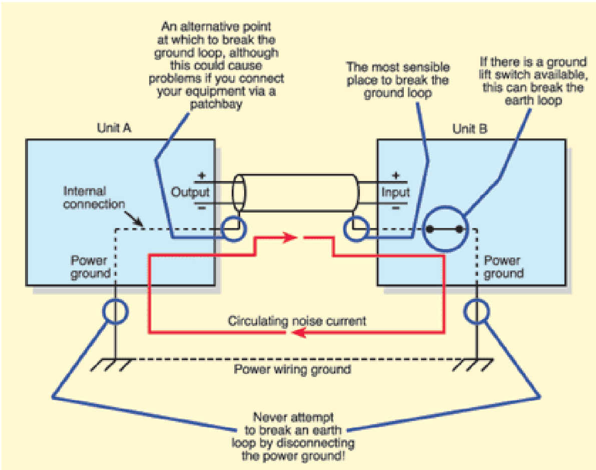
TRS CONNECTOR - TIP, RING, AND SLEEVE

- A **TRS** (tip, ring, sleeve) **connector** (also called an **audio jack, phone plug, jack plug, stereo plug, mini-jack**, or **mini-stereo)**, is a common audio connector. It is cylindrical in shape, typically with three contacts, although sometimes with two (a **TS connector**) or four (a **TRRS connector**).

- It was invented for use in telephone switchboards in the 19th century and is still widely used, both in its original quarter-inch (6.3 mm) size and in miniaturized versions.

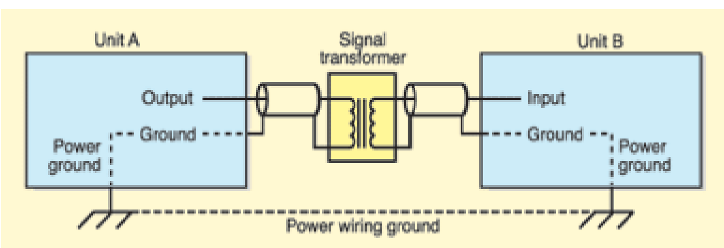
- A female connector is called a jack. The terms *phone plug* and *phone jack* are commonly used to refer to TRS connectors, but are also sometimes used colloquially to refer to RJ11 and older telephone plugs and the corresponding jacks that connect wired telephones to wall outlets. (The similar terms *phono plug* and *phono jack* refers to RCA connectors.) To unambiguously refer to the connectors described here, the diameter or other qualifier is often added, e.g. *1/4-inch phone plug*, *3.5 mm phone jack*, and *balanced phone jack* or *stereo phone plug* for the three-contact version.

Some Signal Current Will NOT Take the Preferred Path



Break the Signal Ground Path **without** Interrupting the Safety Ground.

Use a DI box with a ground lift switch to avoid



ground loop problems.

Lifting the ground on a piece of audio equipment could create a high potential between the system ground and the signal ground or equipment chassis. Anyone who touches the equipment chassis or signal ground and another grounded point could receive a lethal shock!

Check your learning: Communication Cable

1. Video feeds use________cable with _______ connectors.
2. Audio and intercom lines often terminate with________connectors, which are also sometimes used for lighting control.
3. Ground lifting is always done in the ________ (signal, power) path.
4. Interference in audio and communication cables can be minimized by running them ________ (parallel, at right angles) to power cables.

Answers: 1. Co axial/BNC; 2. XLR; 3. Signal; 4. At right angles.

LOCKOUT PROCEDURE

- Lockout / tagout is an important procedure to ensure that equipment is de-energized and unable to be re-energized until the person performing the work decides that it is safe to do so.
- CAN/CSA-Z460-05- Control of Hazardous Energy - Lockout and Other Methods: “This Standard specifies requirements for controlling hazardous energy associated with potentially harmful machines, equipment, or processes. The purpose of this Standard is to specify requirements and performance objectives for procedures, techniques, designs, and methods to protect personnel from injury from the inadvertent release of hazardous energy.”

When lockout is required

- Situations may arise during normal production work when related work needs to be done. Follow these steps in making a decision about whether or not lockout is required:
  - ***DECIDE IF THERE IS A RISK OF INJURY*** to any person from the movement of the machinery or equipment or exposure

to an energy source while the activity is carried out. When assessing the risk of injury, imagine what would happen if the unexpected occurs.

- All sources of hazardous energy must be considered, such as loaded springs and suspended equipment that could roll or fall.
- If there is no risk of injury, then lockout is not required.
- If there is risk of injury, decide if the machinery or equipment is effectively safeguarded to protect persons from the risk. If there are effective safeguards in place, then lockout is not required.
- Safe work procedures must be followed during the activity.

Sequence of Lock-Out Procedure

Once you have determined that lockout is required, follow these five basic steps to lock out machinery and equipment. They apply to all types of machinery and equipment.
Every person must know and follow these steps.

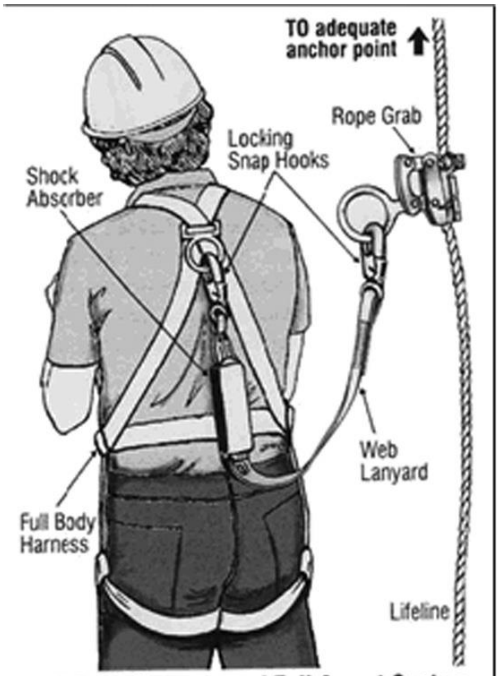
1. Identify the machinery or equipment that needs to be locked out and notify all affected personnel that a lock-out is required and the reason for locking-out.
2. If the equipment is operating, shut it down by the normal stopping procedure (depress the stop button, open the toggle switch, etc.). Make sure that all moving parts have come to complete stop. Also ensure that the act of shutting off equipment does not cause a hazard to other workers.
3. Identify and **deactivate** the switch, valve, or other energy isolating device so that the energy source (s) is disconnected or isolated from the equipment. Stored energy such as that in capacitors, springs, elevated machine members, rotating flywheels, hydraulic systems, and air, gas, steam or water pressure, etc., must also be dissipated or restrained by methods such as grounding, repositioning, blocking, bleeding, etc.
4. Apply a personal lock to the energy-isolating device for each energy source, and ensure that all parts and attachments are secured against movement. Tag the lock identifying the date of application and the individual applying the lock.
5. After ensuring that no personnel are exposed, operate the push button or other normal operating controls to ensure that the equipment will not operate.

Other Hazards Aside from Electrocution

- Falls caused by involuntary muscle recoil
- Arc blast force – over 2100 psi
  → bone fracture
  → concussion
  → Deafness, tinnitus
  → detachment of retina
- Arc flash energy – burns, blindness

Personal Protective Equipment

- Safety glasses must be worn whenever eye hazards are present, ideally with side shields, and should be CSA-approved industrial quality.
- Long-sleeved garments, fire-inhibiting (heavy cotton, wool, leather; no polyester, synthetics or fleece).
- Gloves where shards, burrs, hot objects may be handled.
- Hard hat.
- Safety harness for fall protection.
- Safety boots with the green electrical approval label.



Full Body Harness and Fall Arrest System


Properly laced safety boots with CSA labels

Test for Safe Work Conditions

- Be constantly aware of where you are relative to "the other side of the circuit."
- Use a tester as a final test before coming in contact with recently de-energized parts.
- After locking out or tagging out equipment to be worked on make sure, as a final precaution, that you attempt to start the equipment from its normal location.
- If you have de-energized a certain device, or piece of equipment, initially brush it lightly with the back of your hand prior to working on it.
- Think of all sources of stored energy that may be hazardous:
  - → Electrical charges: batteries, static charges, capacitors;
  - → Pneumatic: compressed gasses, rams, bags,;
  - → Hydraulic: accumulators;
  - → Springs;
  - → Elevated objects.

Check your learning: Work Conditions

1. Energized equipment to be locked out must first be shut down by operating its _____________ (main power disconnect switch or circuit breaker, normal control stop button or switch).
2. Two examples of stored energy hazards are ________ and________.
3. When disconnecting electrical loads, a worker should treat the connections as though they are________.

Answers: 1. Normal control stop button or switch; 2. Electrical charges: batteries, static charges, capacitors; pneumatic: compressed gasses, rams, bags; hydraulic: accumulators, springs, and elevated objects; 3. Live.

CHAIN MOTORS

Many lighting, video and audio rigs, especially larger concert setups, utilize truss-type systems which are lifted and supported overhead by chain motors. Chain motor is a term used in the entertainment industry that describes a (120V/208V-3 phase) electric chain hoist.

Control

Each motor needs a power source and a method of controlling its operation. A separate cable is run to each motor to provide the necessary power usually in the form of twist lock using SO cable or motor soca. Motor soca carries power and control in each cable but when twist lock is used, another smaller twist is often run for control. These two cables are usually "loomed" together and the control is often reversed to avoid confusion.

Motor cables are usually run back to a main distribution /controller or 'distro'. At the distro, each specific motor can be operated individually, in groups, or all at once, allowing individual trusses to be taken out, brought in, or levelled.

MOTOR DISTRO

Depending upon the number of motors that the distro can control, they can require various power sources ranging from 30A three phase twists, up to 400A cam-loks. Motor distros are usually the first thing energized and the last thing de-energized during the event. Individual motors can be controlled or tested on the ground by plugging a handheld controller into the control cable on the motor. Because of their shape, these controllers are often called 'pickles'.

The most important thing to be aware of with motors is that proper phasing is maintained. Phasing in different venues can vary so after the motor distro is energized the phase is checked by running a motor in the down direction. If the motor goes down, phasing is correct. If the motor travels up while in the down position the phasing is incorrect. Usually a motor distro is equipped with a phase reversal switch to correct this. However the preferred method to correct phase problems is to de-energize the service and swap any two of the hot phase conductors.

Swapping any two hot phases will reverse the direction that the motor operates. If two of the hots are reversed in an individual motor cable, that one motor will be out of phase and run in the opposite direction to other motors. Care must be taken when repairing motor cables to observe proper phasing to avoid this, and each motor should be individually 'bumped' to check that it is working and is properly phased before lifting any loads to avoid a potentially dangerous rigging situation.

Limit Switches

Chain motors incorporate internal limit switches as a safety feature to prevent the motor from rising or lowering too much and causing damage to itself or other rigging components. If a motor has gone past this preset limit, the limiting switch will be activated and the motor will stop operating in the direction it was moving. Before assuming that the motor has lost power, an attempt should be

CHAIN MOTOR

made to run it in the opposite direction. If the motor operates and the limit had been tripped this will also reset the switch.

With an intermittently bad connection on any hot leg of a three phase motor service the motors will still operate but the system will exhibit other issues such as a higher current draw on the remaining phases which may cause breakers to trip or fuses to blow. The complete loss of one hot leg on a three phase motor system would create a single phase situation which would prevent motors from starting and cause breakers to trip or fuses to blow.

Noisy or chattering motors can be a sign of low voltage at the motors. This voltage drop can be a result of undersized cable or excessive cable lengths to the motors. The inrush produced by motors starting can create amperage draws several times higher than normal which needs to be taken into consideration when sizing overload protection and cable sizing for motor distribution.

GLOSSARY OF ELECTRICAL TERMS

An electrical glossary limited for this course follows on the next two pages. A very comprehensive electrical glossary is at: http://www.youngco.com/young2.asp?ID=4&Type=3

ELECTRICAL TERMS

AMPMETER: An instrument Calibrated in amperes, used to measure the current in an electrical circuit. An ampere of electrical current is present when one volt of electrical pressure is applied against one ohm of electrical resistance.

BALLAST: A device that provides a high starting voltage yet limits the lamp current of a fluorescent or high intensity discharge lamp.

CAPACITANCE: The property of a capacitor or other device to store energy in an electric field. It is measured in Farads.

CAPACITOR: A device that stores an electrical charge. It usually consists of two conducting objects separated by insulating material.

CIRCUIT: An unbroken path through which an electrical current can flow.

CIRCUIT BREAKER: A switch which protects an electrical circuit by opening the circuit when the current flow exceeds a predetermined level.

CONDUCTOR: Any material through which an electrical current may be transmitted easily.

CONTINUITY: Continuous or complete circuit. Can be checked with an Ohm meter.

FUSE: a protective device in a circuit which protects circuit overload by breaking the circuit when specific amperage is present. The device is constructed around a strip of wire of a lower amperage rating than the circuit it is designed to protect. When a higher amperage than the rated fuse is present in the fuse in the circuit, the strip of wire melts, opening the circuit.

GENERATOR: A device which converts mechanical energy into electrical energy.

INDUCTION: A means of transferring electrical energy in the form of a magnetic field. Principle used in a transformer to increase (step up) or decrease (step down) voltage.

JOULE: The metric unit of work or energy. A Joule of energy is expended when one Newton of force is exerted through a distance of one metre to do one Joule of work.

LUMINAIRE: A lighting fixture consisting of a light source, socket, electrical wiring and connector, enclosure, and optionally, switch, reflectors(s), lens(es), ballast, supporting devices, and additional apparatus for altering the quality, colour, and quantity of light emitted by the apparatus.

MODULE: Electronic control unit, amplifier or a solid state or integrated design which uses small signals to control large currents. Stage lighting dimmers use SCR and IGBT modules.

OHM: The unit used to measure the resistance of a conductor to electrical flow .One ohm is the amount of resistance that limits current flow to one ampere in a circuit of one volt pressure.

OHMMETER: An instrument used in measuring the resistance, in ohms, of an electrical pathway or device.

PRIMARY: The transformer winding that a power source is connected to.

RELAY: A control device that is capable of receiving a signal in one circuit to control current flow in another circuit.

RESISTANCE: The opposition to the flow of current through a circuit or electrical device, and measured in ohms. Resistance is equal to the voltage divided by the amperage.

RESISTOR: A device usually made of wire, which opposes the current in an electrical circuit.

RHEOSTAT: a variable resistor that is connected in series with a load.

SECONDARY: The transformer winding that a load is connected to.

SENSOR: A device designed to measure operating parameters such as pressure, flow, force, speed and temperature. Sometimes called a transducer.

SOLENOID: A coil used to produce a magnetic field, the result of which is used to do useful mechanical work.

THERMOSTAT: A sensor made of two dissimilar types of metal that bend when heated or cooled. They usually act as On/Off switches.

VARIAC: A brand of autotransformer that is adjustable by means of rotating a shaft.

VOLTMETER: An instrument used for measuring electrical force in units called volts.

WATTS: The standard unit of measurement of electrical power. A watt is a rate of energy use equal to 1 joule per second.

Notes