ELECTRICAL SAFETY

Objective

Basic awareness and understanding on:

- The possible hazards caused by electricity
- Safety measures and practices to avoid those hazards.
- Statutory requirements on safety standards regarding electrical works, equipment and installations.

Characteristics of Hazard

The Invisible Danger

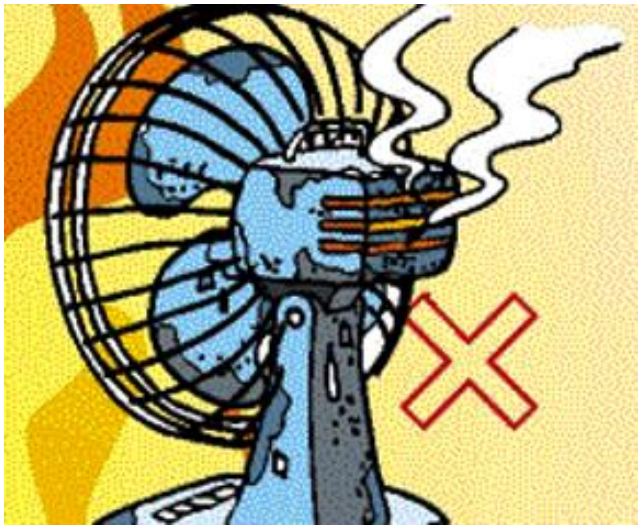
- The Electric Current
- The Voltage

Electricity is everywhere around us. When used properly, electricity can help in every facet of our lives. However, we must not take it for granted. When handled improperly , electricity can be very dangerous. The fact that we cannot actually see it makes electricity even more dangerous.

The degree of the hazards is mainly determined by the magnitude of the electric current and the voltage.

Hazards of Electricity

This part explains the different kinds of possible hazards created by electricity…



Primary Hazards

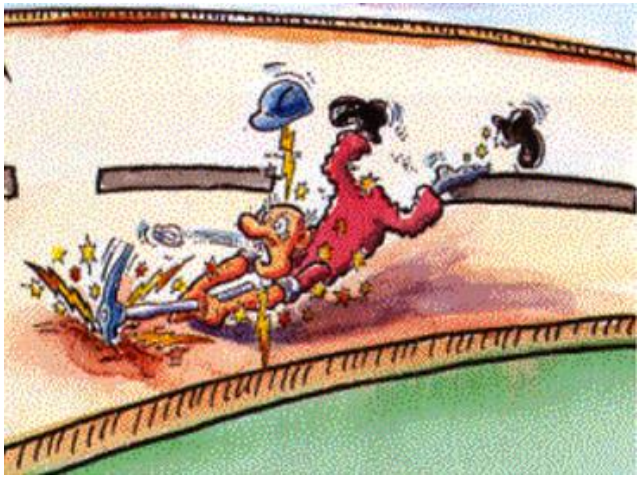
- **Electrocution**

  (Electric shock)

  - Occurs when electric current passes through the human body.

- **Fire & Explosion**

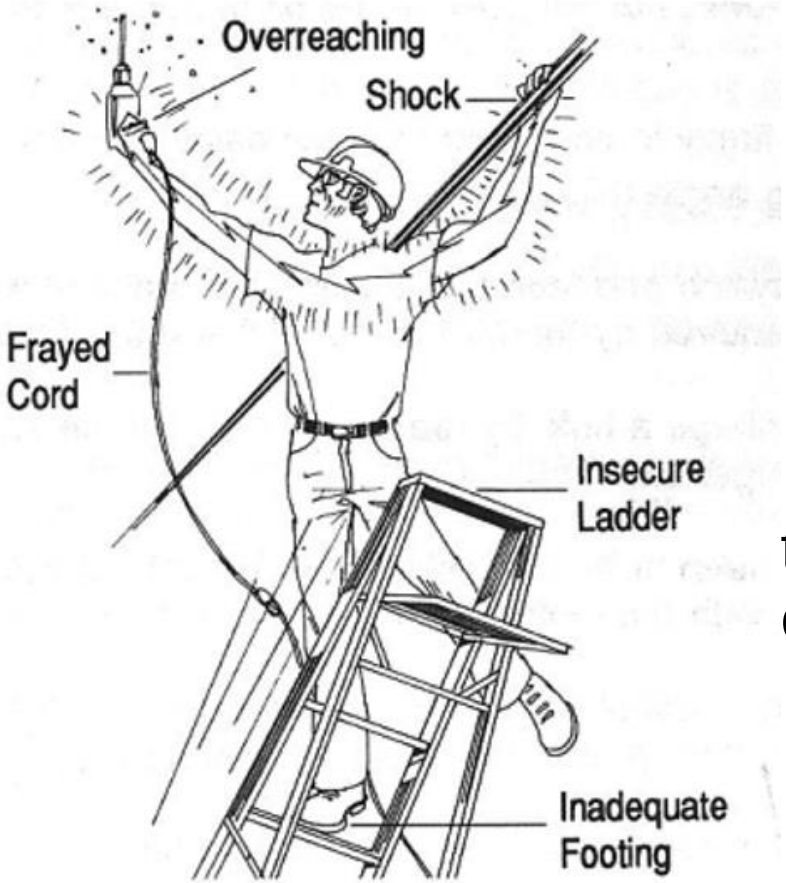
  - About 15% of all fire incidents are caused directly or indirectly by electricity.



Secondary Hazards

- **Burns**

  - Caused by heat energy released by electricity under certain conditions, e.g., short-circuits, electric arcing etc.



Secondary Hazards

- **Falls and other injuries (e.g. bone fracture etc.)**

  - Caused by the jerk reactions of the person suffering from a minor electricity shock.

Harmful Effects of Electric Current to Human Body

Electrocution

Harmful Effect to Body:

Sufficient current flowing through the body will create serious harm:

- Ventricular Fibrillation---- when the heart is affected
- Suffocation---- when the respiratory system is affected
- Cell damage---- by the energy of the electricity current
- Burns ---- by the heat released from the current

Electrocution

Degree of harmful effect to human body depends on:

- Magnitude of current
  - Voltage
  - Body resistance
- The current pathway through the body
- The duration of contact

Lethal Path

Expected Current through body

Current passing through the body depends on:

- Voltage applied
- Resistance of body
  - Moisture of skin
  - Other factors (e.g. size, weight etc.)

According to *Ohm's Law*:

- Current=Voltage/ Resistance
- Domestic power supply in China is 220 volts
- We need to know the typical body resistance to electricity…

Typical Body Resistance

- **The total body resistance to electricity is made up by the Skin Contact Resistance and Internal Body Resistance**

Skin Contact Resistance:

- From 1000 kilo-ohms(dry skin) down to 100 ohms (wet skin)

Internal Body resistance:

- From 100 to 500 ohms

Current through body

We can now calculate the magnitude of electric current flowing through the body in an electric shock incident:

Worst condition (when the body is wet):

- 220 V/ 600 ohms = 367 mA

How much current can a normal person withstand?

We don’t need much electric current to hurt or kill a person (please see next page)

Effects of Current on an Average Human

Current values	Effects on Human Body
≤1 mA	Causes no sensation and is not felt - it is at the threshold of perception.
1-8 mA	Sensation of shock. Not painful. Individual can let go at will as muscular control is not lost.
8-15 mA	Painful shock. Muscular control is not lost.
15-20 mA	Painful shock. Muscular control lost. Cannot let go.
100-200 mA	Ventricular fibrillation. Loss of consciousness. Hold victim to circuit as long as AC flows.
≥200 mA	Severe burns. Severe muscular contractions, so severe that chest muscles clamp the heart and stop it during the shock.

Warning: The above figures are for rough indication only. Do not take it too precisely

Common Sources of Electrical Hazards

Conditions in which electrocution accidents are likely to occur...

Common Sources of Electrical Hazards

Electrical equipment/ appliances

- Portable electrical tools incl. hand tools
- Plug/ Sockets/ Extension boards
- Electric cables
- Exposed electrical conductors
- Metal surfaces/ parts become energized
- Special experimental setups

Electrical Systems & Equipments

- **Fixed system**
  - Wirings
  - Switches, sockets etc.
  - Light fittings
- **Portable equipments**
- **Handheld portable tools**
  - Hand drill/ grinders
  - Hair driers etc.

Notes:

We can identify electrical systems and equipment as fixed systems or portable equipments.

Comparatively speaking, more stringent rules and COP are imposed to fixed electrical systems, and these systems are normally protected by more sophisticated safety devices.

Although portable equipment should also comply with appropriate safety standards, they can more easily be abused. This is especially true for handheld portable tools.

People at Risk

Some people can be at a higher risk to electrical hazards

- **Electrical installation, maintenance and repair personnel**
  - Special safety procedures such as Lockout/Tagout procedures need to be established.

- **Research personnel working on experimental setups.**

- **Users of electrical equipments**
  - Portable electrical equipments
  - Plant and equipments

Causes for Failure of Protection

- **Unsafe Installation**

- **Unsafe Equipment**
  - Unsafe design
  - Substandard equipment

- **Unsafe wok practices**
  - Improper Use of equipment
  - Improper Work procedure/ practice
  - Improper or Lack of Maintenance process

Occurrence of Electrocution

Electrocution occurs when a person gets into contact with electric current. Such contacts can occur by way of:

- **Direct Contact**
  - Direct contact with current carrying parts

- **Indirect Contact**
  - Contact with current through conductive parts not normally carrying current
  - Leakage of electric current

Typical Hazardous Conditions

Beware of the following hazardous conditions:

- **Exposed current carrying parts**
  - Open installation- no enclosure
  - Maintenance process- need to open up enclosure
  - Defective/ damaged enclosure

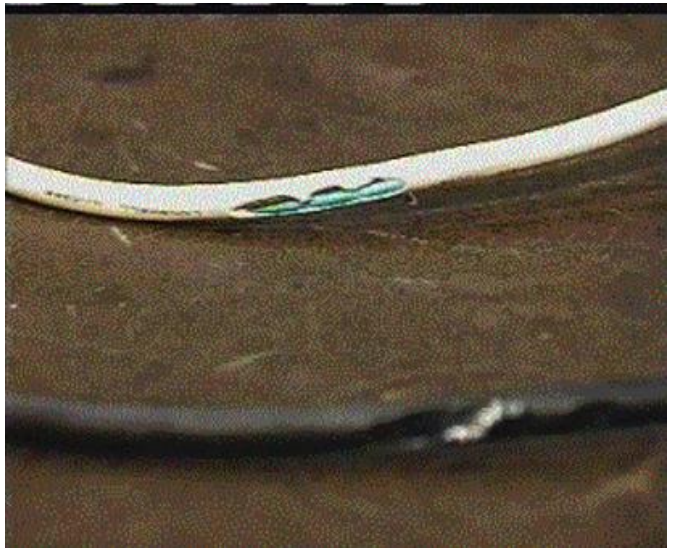
- **Faulty insulation in equipment**
  - Leakage of electricity

- **No/ Improper grounding**
  - Potentially hazardous

- **Inadequate working clearance**
  - Increase risk of contact

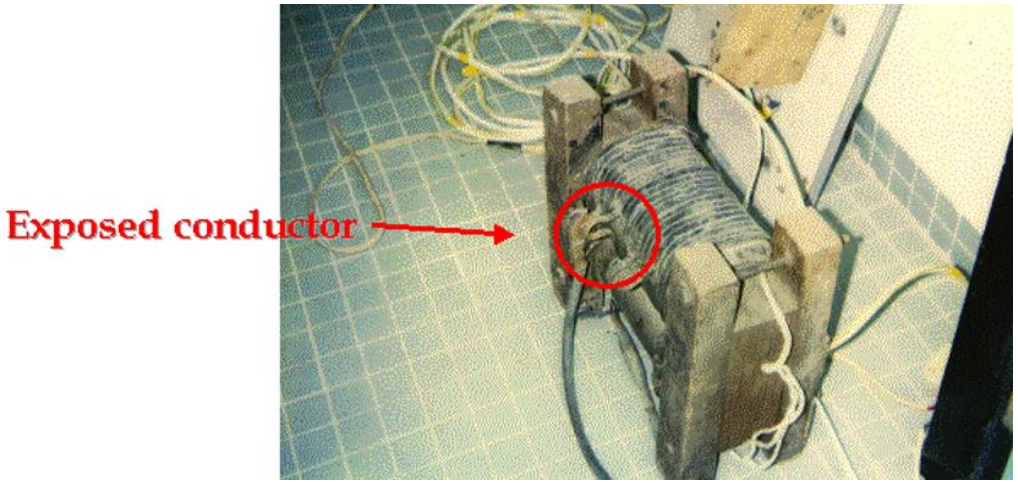
Examples

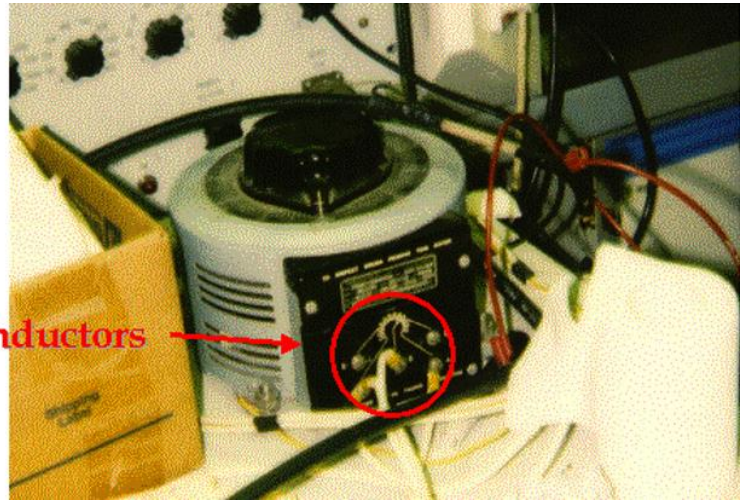
- **Contact with current carrying parts inadvertently**
  - Damaged casing/ cable/ plugs etc. where live conductors are exposed.



Examples

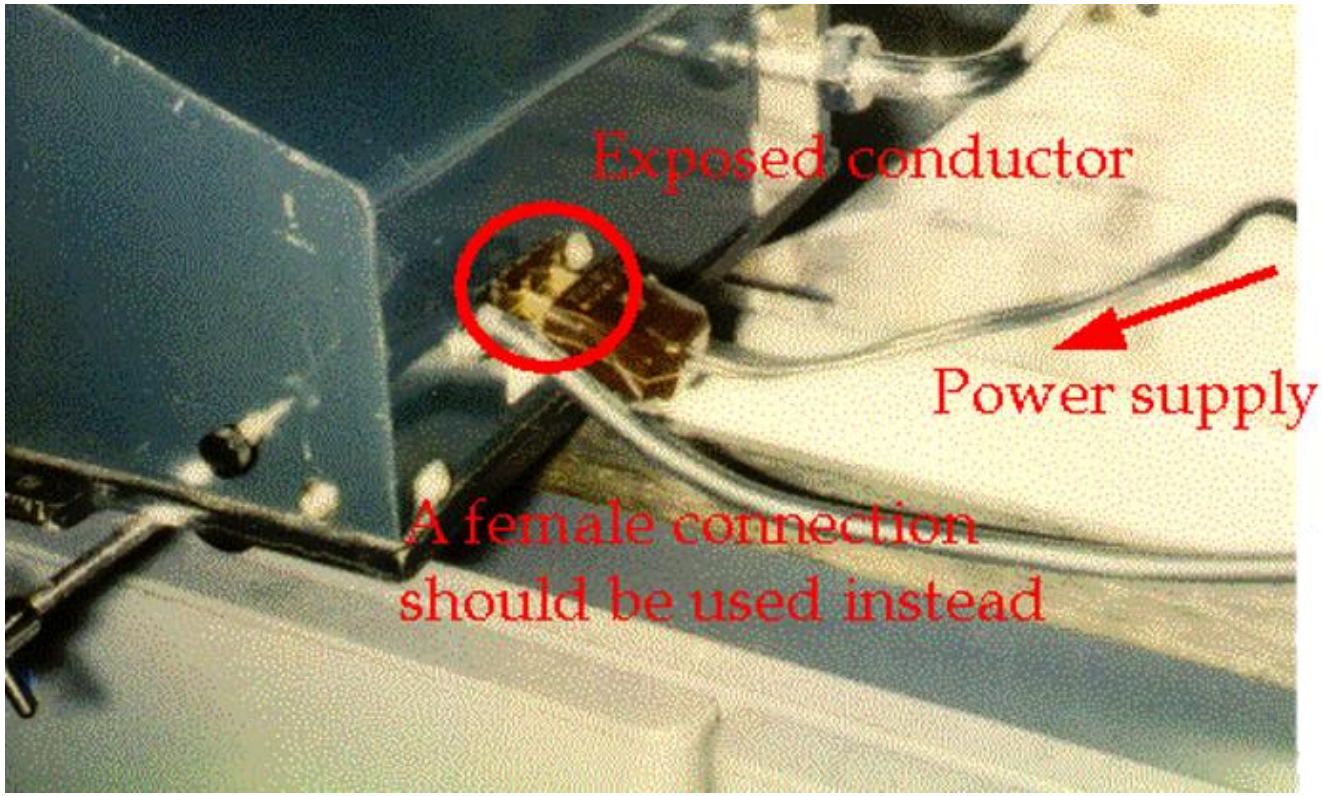
- **Contact with current carrying parts inadvertently**
  - Inadequate insulation





Examples

- **Contact with current carrying parts inadvertently**
  - Unsafe design



Measures for Preventing Electrocution Hazards

Explains the means for preventing people from contact with electric current directly and indirectly.

Prevention of Electrocution

Principles/ Means:

- **Safe System (Protective Devices – Engineering Controls)**
  - Required by local code and regulations
  - Required for fixed installation and portable equipment

- **Safe Equipment**
  - Use of Safe Equipment (with adequate protection)

- **Safe Work Practices**
  - Safe use of equipment (Proper Use)

- **Safety Planning - esp. for non-standard setups**

- **Proper Maintenance**

Protective Devices/Engineering Control (Safe System)

These should be in place for a Safe System

- **Insulation of live conductors (with insulation materials)**
- **Enclosure/ Guarding/ Barrier (of dangerous parts)**
- **Interlocks (cut off electric power automatically when the barrier is removed)**
- **Earth Leakage (Fault) Protection**
  - Means for protecting against indirect contact
    - » Grounding
    - » RCD (Residual Current Device)

Earth Leakage (Fault) Protection

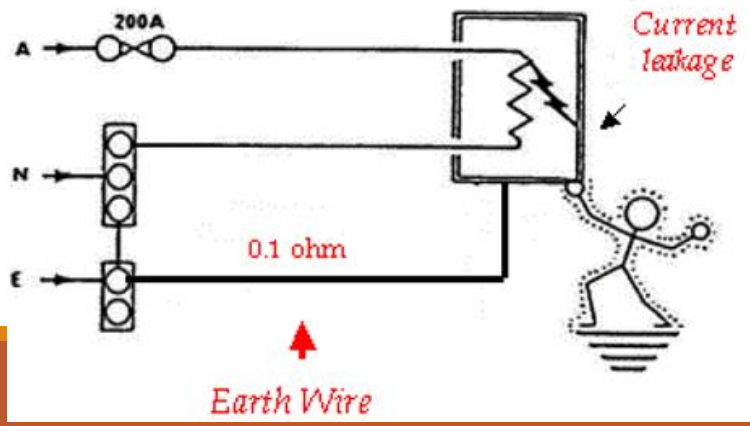
- **Grounding/Earthing/Bonding**

  - The purpose is to eliminate the build up of potential difference between the equipment and the ground

  - This is normally done by installing a conductor (earth wire) for such purpose

  - Without any protection, the potential different across the human body will be the voltage of the system, i.e 220volts in domestic supply when there is a current leakage.

  - The Protection is to use an earth wire to limit the "Touch Voltage" under fault conditions, hence limiting the current flowing through the human body



V=IR
=200x0.1
=20Volts

V=Touch Voltage
Fault Current=200A

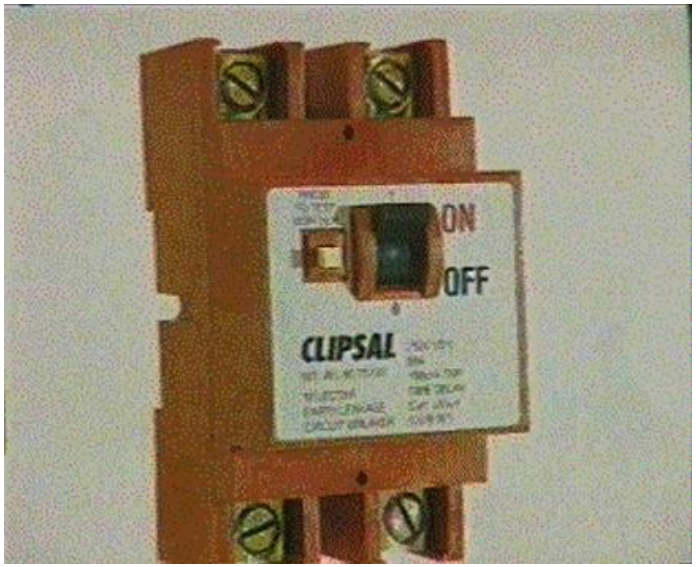
Bonding Conductive Surfaces

- **Sometimes you may see bonding wires connecting metallic surfaces/objects to the earth. The purpose is:**

- **To maintain an "equi-potential" between metallic objects.**
  - Equipotential bonding

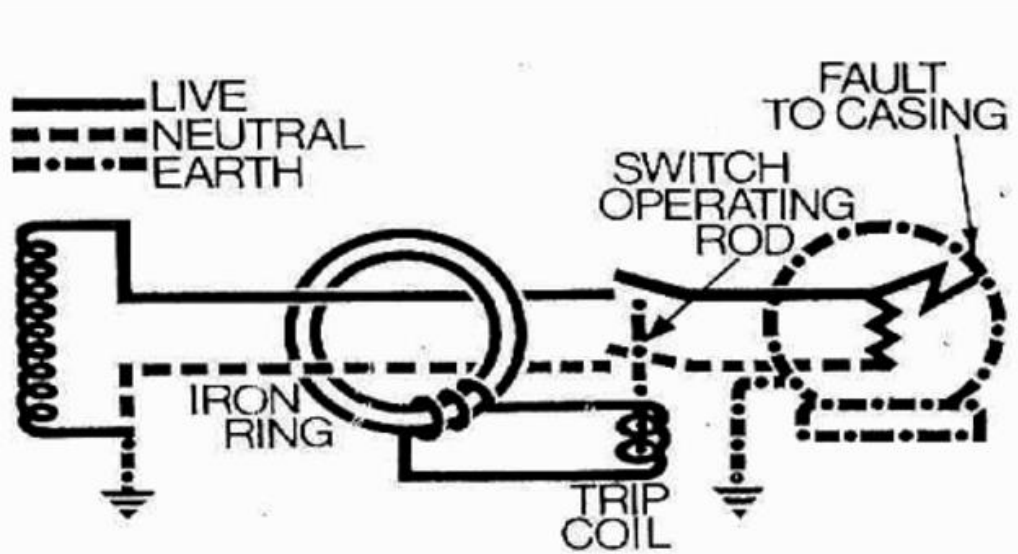
Earth Leakage (Fault) Protection

- **Automatic Disconnection of Power**
  - By installing specially designed device such as:
    - » Residual Current Device (RCD)



Earth Leakage (Fault) Protection

- Simple schematic diagram showing the principle of a Residual Current Device (RCD)



Earth fault on an appliance protected by a current-operated earth-leakage circuit-breaker.

The amount of current flowing out should be the same as those returning to the source, except in condition where there is a leakage of current. RCD protects by tripping open the circuit when it detects any current difference. RCD can detect a very small current difference and can trip open the circuit in a small fraction of a second.

Portable Electrical Equipment

As we need to be in "close contact" with these equipment, we need to pay particular attention to their safety standards and proper use.

Classes of Electrical Equipment

As far as protection against electric shock is concerned, electrical equipment can be classified as:

- **<u>Class I apparatus:</u>**
  - protection against electric shock achieved by providing proper earthing for the apparatus

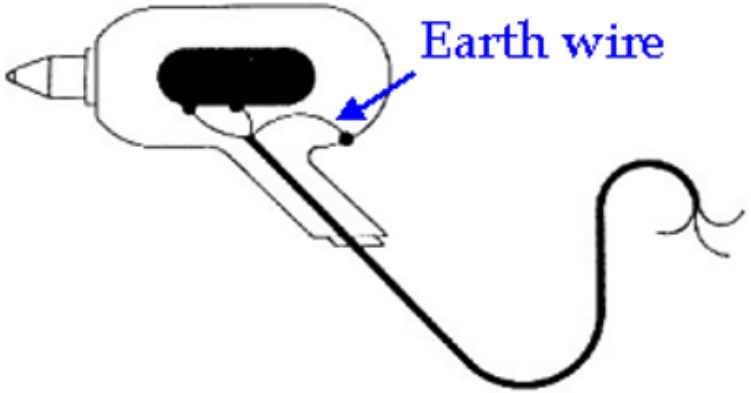
- **<u>Class II apparatus (double insulated):</u>**
  - protection against electric shock achieved by double insulation or reinforced insulation. There is no provision for protective earthing.

Double Insulation (Class II apparatus)

Double insulated tools are designed so that the inner electrical parts are isolated physically and electrically from the outer housing. Shock protection depends upon the ability of the internal protective insulation and the non-conductive external housing to shield the user from the electrical parts.

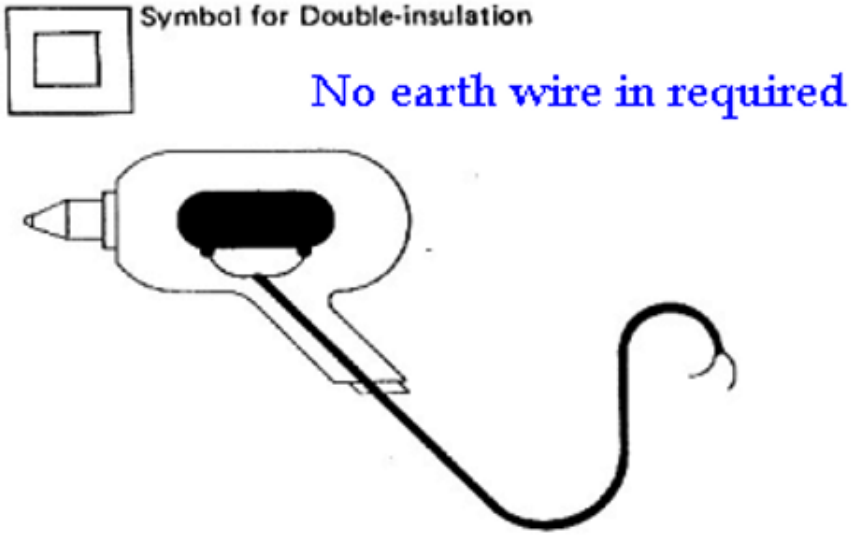
No earth wire is required for double insulated equipment.

Schematic diagrams showing the differences in design between Class I and II apparatus



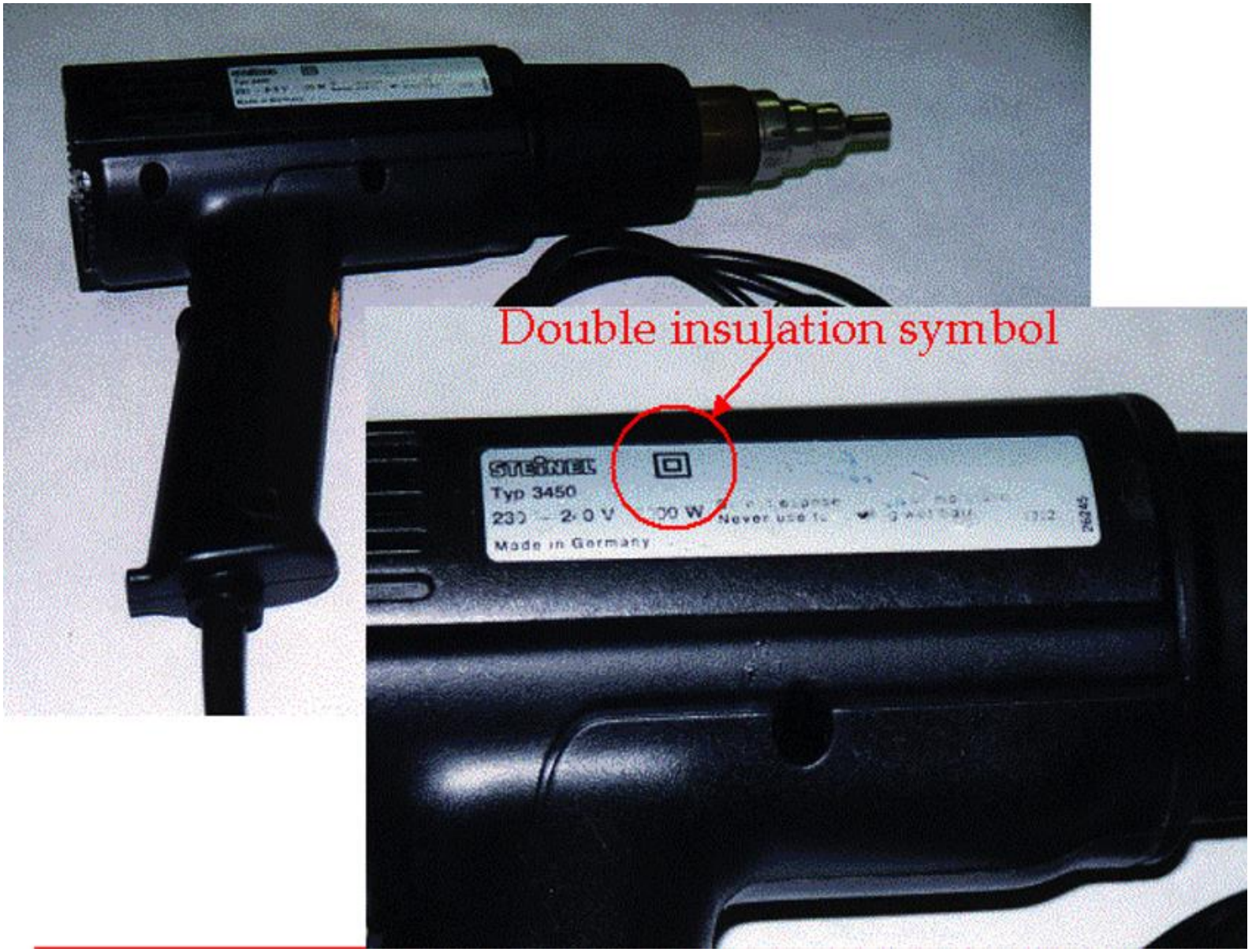
Connexions for Metalclad Portable Drill

Class I apparatus



Connexions for Double-insulated or All-insulated Portable Drill

Class II apparatus


Double insulation symbol
STEINEL
Typ 3450
Made in Germany

Some warning for using double insulated apparatus

- If immersed in water, a leakage path for electricity can still occur.
- Handling the apparatus with wet hands, I high humidity or outdoors after a rainstorm can be dangerous.
- Double insulation does not protect against defects in the cord, plug or receptacle.

Safety Standards

for Electrical Equipments

Summary of essential safety standards for Electrical Equipments

Highlights of the essential safety requirements for electrical equipments

General Safety Requirements

- The apparatus shall be so designed and constructed as to present no danger, either in normal use or under fault conditions, providing particularly:

  - personal protection against electric shock.
  - personal protection against the effects of excessive temperature.
  - personal protection against the effects of radiation.
  - personal protection against the effects of implosion and explosion.
  - personal protection against the effects of mechanical instability and of moving parts.
  - protection against fire.

Safety Standards for Equipment (1)

- **Prevention of Electric Shock**

  Requirements on:

  - Enclosure/ covers/ vent holes for limiting accessibility of live parts
  - Provision of protective earthing
  - Insulation of live parts -- adequacy of insulating materials
  - Adequate creepage distance and clearance between conductive parts
  - Rigidity of wiring connection (at terminals)
  - Protections against faults causing accessible conductive parts to become live
  - Ability to withstand humid conditions

Safety Standards for Equipment (2)

- **Terminal devices**

  Requirements for:

  - Proper plugs and sockets
  - Terminals for external flexible cables:
    - » properly shielded and located (loose strand clear of conductive parts)
    - » screw terminal will not work loose
    - » do not damage conductors
  - Earth terminals
    - » properly connected to ensure effectiveness of earth (to connector socket/ to earth lead from mains)
    - » ensure low resistance (<0.1 ohms)
    - » no excessive corrosion

Safety Standards for Equipment (3)

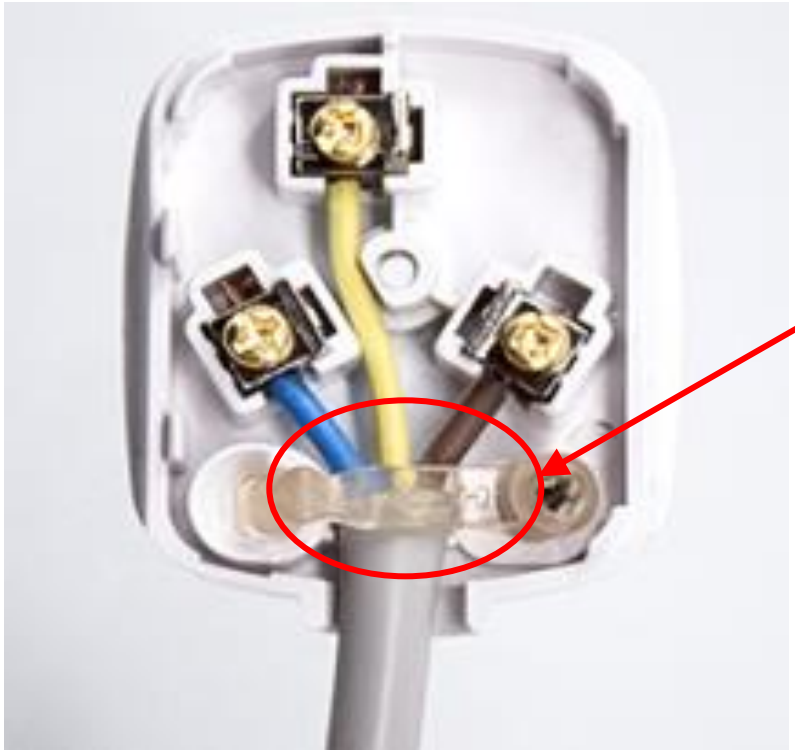
- **External Flexible Cable**

  - Adequate cross sectional areas
  - Provided with earth wire for Class I equipment
  - Connecting points of cables relieved from mechanical strain.
  - Outer shield protected from abrasion and cut, incl. at point of entry.
  - Not be able be pushed back

Some examples illustrating the safety standard requirements

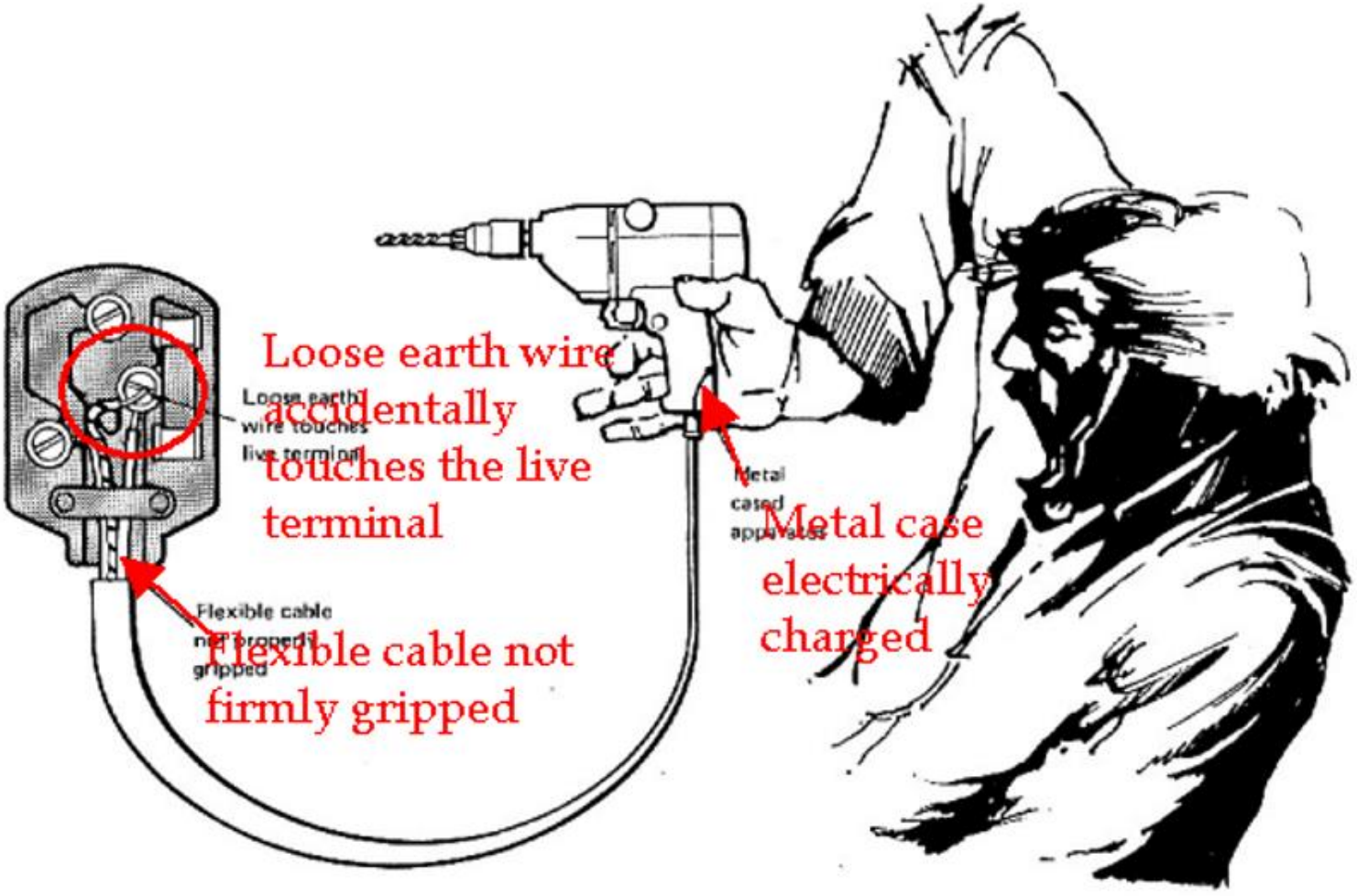
Provision of earth wire for Class I equipment

Connecting points of cables relieved from mechanical strain

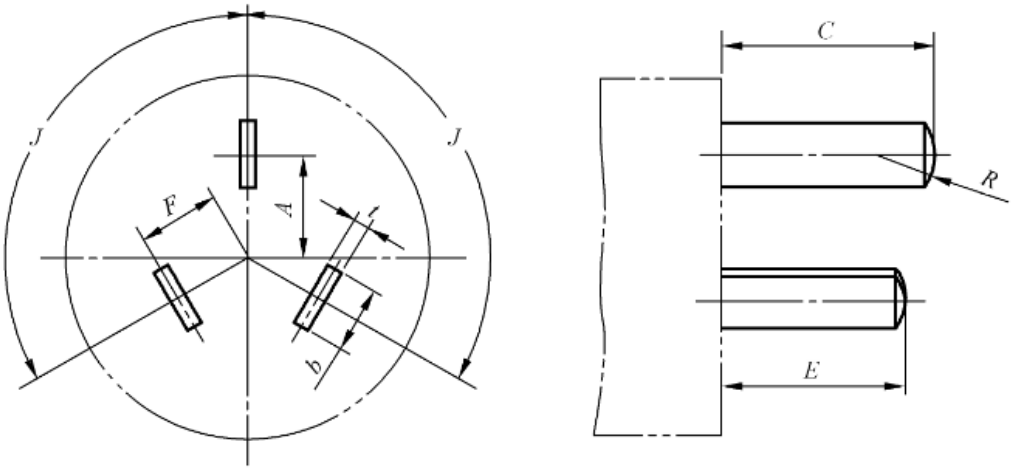


This is to prevent the conductors from getting loose from the terminals which may cause serious injuries.

Fatal Contact



Safety Features of Plugs



基本参数		单相两极带接地插头的主要尺寸 mm							
额定电压 V	电流 A	开挡距离			插头插销尺寸				
		A	*F*	*J*	*t*	*b*	*C*[a]	*E*[a]	*R*
250	≤10	10.3±0.14	7.9±0.11	120°±30′	$1.5^{+0.15}_{-0.05}$	$6.4^{0}_{-0.22}$	21±0.42	18±0.35	6.0±1
	16	11.1±0.14	9.5±0.11	120°±30′	$1.8^{+0.15}_{-0.05}$	$8.1^{0}_{-0.22}$	21±0.42	18±0.35	6.0±1

注 1：插头的实际额定电流见 GB/T 2099.1—2021 的表 1。

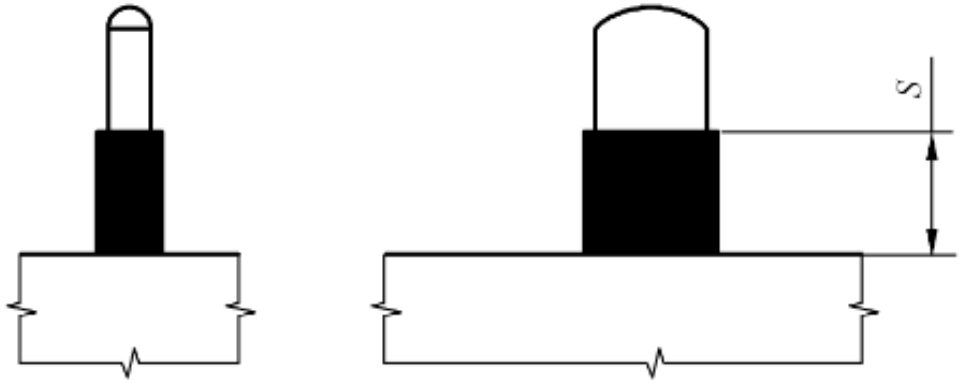
注 2：*t*、*b* 值指外露的导电金属部分的尺寸。

[a] *C*、*E* 端部厚度适当倒角，倒角长度最大宜为 1 mm。

图 3　单相两极带接地插头

《家用和类似用途单项插头插座 型式、基本参数和尺寸》(GB/T 1002-2021)

Plug Pins insulation sleeves



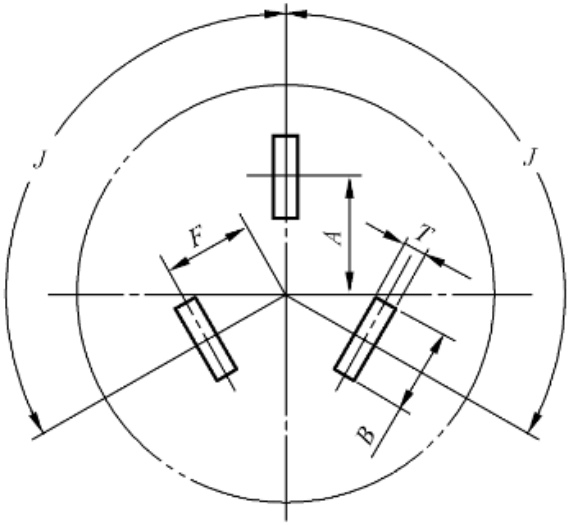
标引序号说明：

S——绝缘护套高度。

绝缘护套的外形尺寸不应超过对应插孔的最小尺寸。

《家用和类似用途单项插头插座 型式、基本参数和尺寸》(GB/T 1002-2021)

Safety Features of Sockets



基本参数		单相两极带接地插座的主要尺寸 mm				
额定电压 V	额定电流 A	开挡距离			插座插孔尺寸	
		A	*F*	*J*	*T*	*B*
250	10	10.3±0.14	7.9±0.11	120°±30′	$2.0^{+0.3}_{0}$	$7.3^{+0.3}_{0}$
	16	11.1±0.14	9.5±0.11	120°±30′	$2.4^{+0.3}_{0}$	$9.0^{+0.3}_{0}$

图 4　单相两极带接地插座

《家用和类似用途单项插头插座 型式、基本参数和尺寸》(GB/T 1002-2021)

Markings

Electrical accessories should have the following marks:

- Rated current (amperes)
- Rated voltage (volt)
- Symbols of power supply properties
- The name or trademark or identifying mark of the manufacturer or seller
- Model number (can be product catalog number)
- The first characteristic number of the protection class against access to hazardous parts and against the entry of solid hazards, if declared to be higher than IP2X, and for stationary sockets if it is higher than IP4X, the second characteristic number shall be indicated simultaneously
- The second characteristic number of the protection level against harmful water effects, if declared to be higher than IPXO, and for stationary sockets if it is higher than IPX2, the first characteristic number shall be indicated simultaneously
- The number of the standard, e.g. GB/T 2099.1

《家用和类似用途插头插座 第1部分：通用要求》(GB/T 2099.1-2021)

Unsafe Practice & Conditions

This section highlights commonly found unsafe practices and conditions associated with the use of electrical equipments

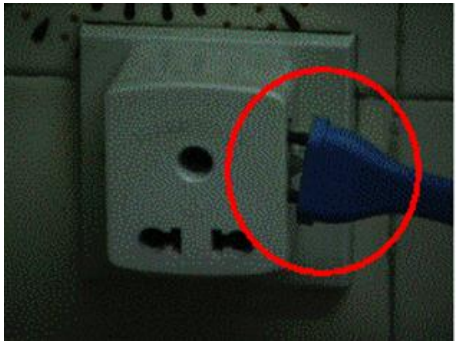
Typical Unsafe Practice & Conditions - 1

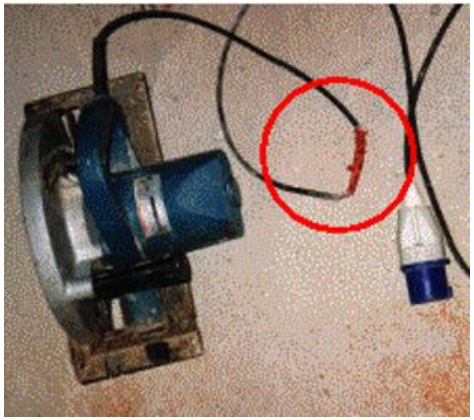
- **Causing Electrical Shock**

  - Earth wire accidentally pulled out of its plug terminal (not properly wired)
  - Remove plug by tugging the cord instead of holding the plug
  - Earth wire not connected or even cut away Cable not firmly gripped
  - Wrong connections at terminals of plug
  - Inserting screwdriver into earth pin hole to open up covers for live and neutral pins

Typical Unsafe Practice & Conditions - 2

- Plugs are loosely fitted to socket
  - esp. for two pin plugs (fire hazard)
- Badly made joints in flexible cables
  - loss insulation capacity
  - easily pulled apart
- Flexible cable damaged
- Coiling of cable under load condition (fire hazard)
- Damaged or missing covers/ enclosure
- Servicing apparatus without disconnecting power

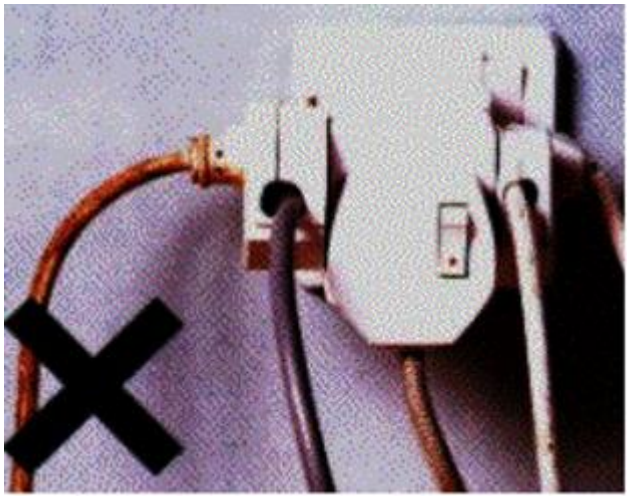




Typical Unsafe Practice & Conditions - 3

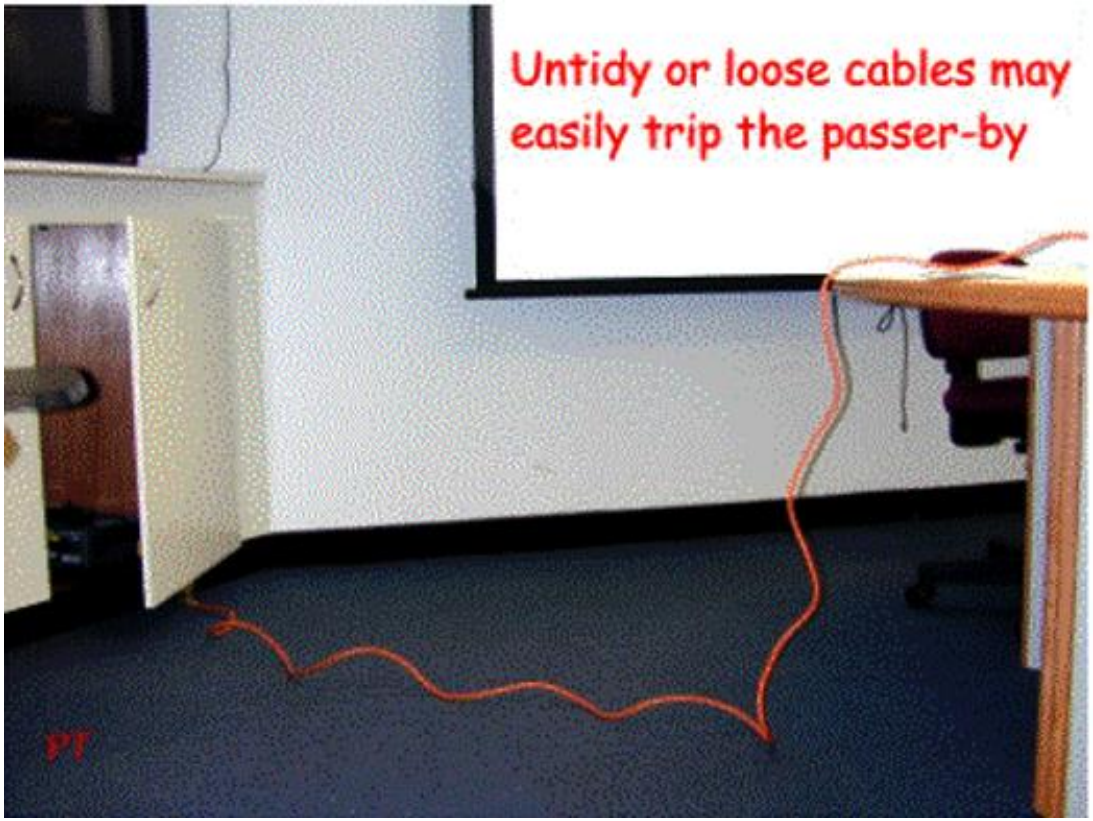
- **Overloading– causing fire**

  - Lower rating plugs (and cable) are used
  - Too many plugs are connected to a single socket outlet via adaptors or extension socket boards
  - Cable with insufficient size



Typical Unsafe Practice & Conditions - 4

- **Trailing cables**



Safety Planning For Non-standard/ Experimental Setups

Safety Planning For Non-standard/ Experimental Setups

- **Identify hazards and anticipate problems**
- **Seek help (from supervisors, HSE etc.) as necessary**
- **Make appropriate arrangements**
  - ensure adequate control devices
  - protective devices
  - warning signs
  - administrative procedures

Specific Safety Procedures

Lockout / Tagout Procedures

for:
Electrical/Mechanical System Maintenance
or
Operations with similar risks

Lockout / Tagout Arrangement

Purpose of Lockout/Tag out procedure:

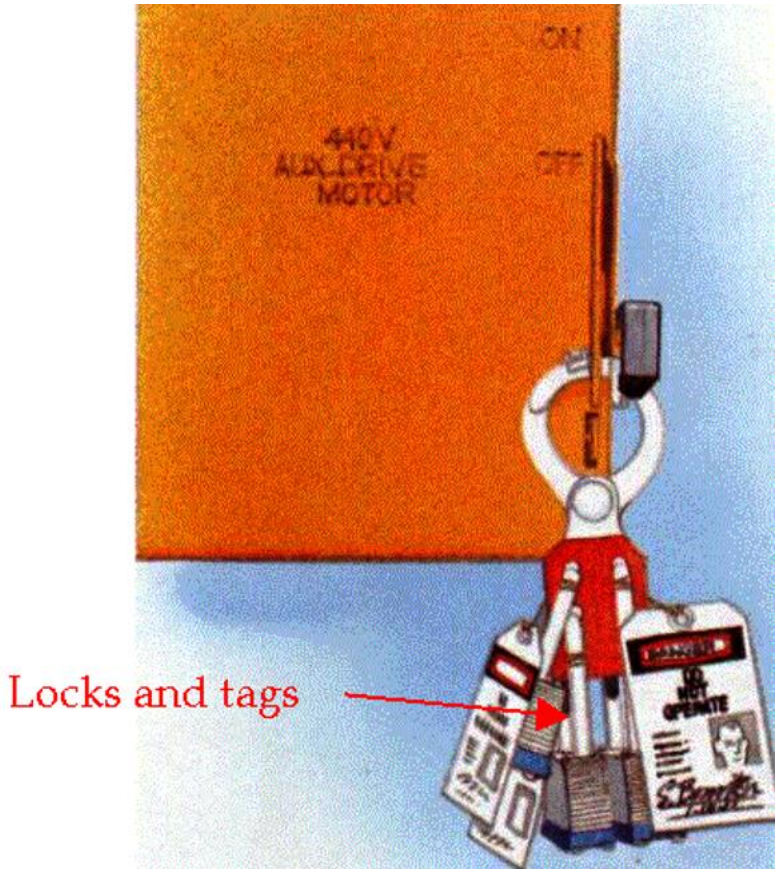
- To avoid inadvertent release of energy (electrical and / or mechanical) causing serious harm to people working on the system by
- Effective isolation of power supply.

Principles of Lockout/ Tagout Procedure -1

- **Plan the shut down of the system.**
  - Identify all power supply points of the system
  - Develop work schedules and coordination of parties involved
- **Alert operator and other users of the shut down.**
- **Lockout the power supply points to the system at the most appropriate points.**
- **Have all workers place their personal & individual padlocks on the lockout point.**

Principles of Lockout/ Tagout Procedure -2

- Put a warning tag at the lockout.
- Release all stored or residual energies (e.g. capacitors, loaded spring etc.)
- Test the circuit to confirm it is dead.
- Each worker should remove only his own padlock upon completion of his part of work.



High Voltage

Specific Hazards:

- Generate much larger current
- Current can jump through air – arcing
  - Must maintain a safe distance according to the voltage

Classification of Voltages

- Extra low voltage: n.e. 50 volts a.c. / 120 volts d.c. (between conductors or to earth)
- Low voltage: Exceed ELV but n.e. 1000/ 600 volts a.c. (between conductors/ to earth); or n.e. 1500/900 volts d.c.
- High voltage: Any voltage normally exceeding LV.

Typical hazardous conditions

Stored Energy

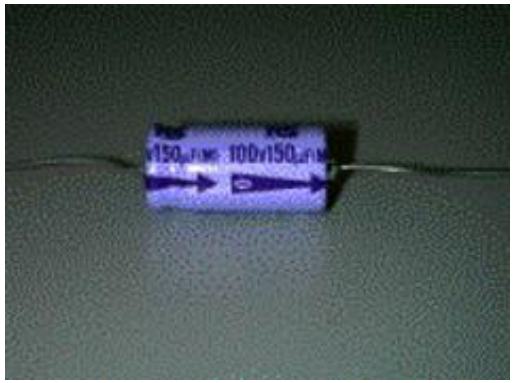
- Stored electrical energies pose specific hazards because the energy will still be there after the system has been removed from the power source.

- Depending on its magnitude, the stored energy can cause serious harm to anyone who is not aware of its existence.

- Stored energies commonly came across include those stored in:
  - Batteries
  - Capacitors

Stored Energy

- **Batteries**
  A 12-volt car battery can melt a metal bar when shorted across its terminals



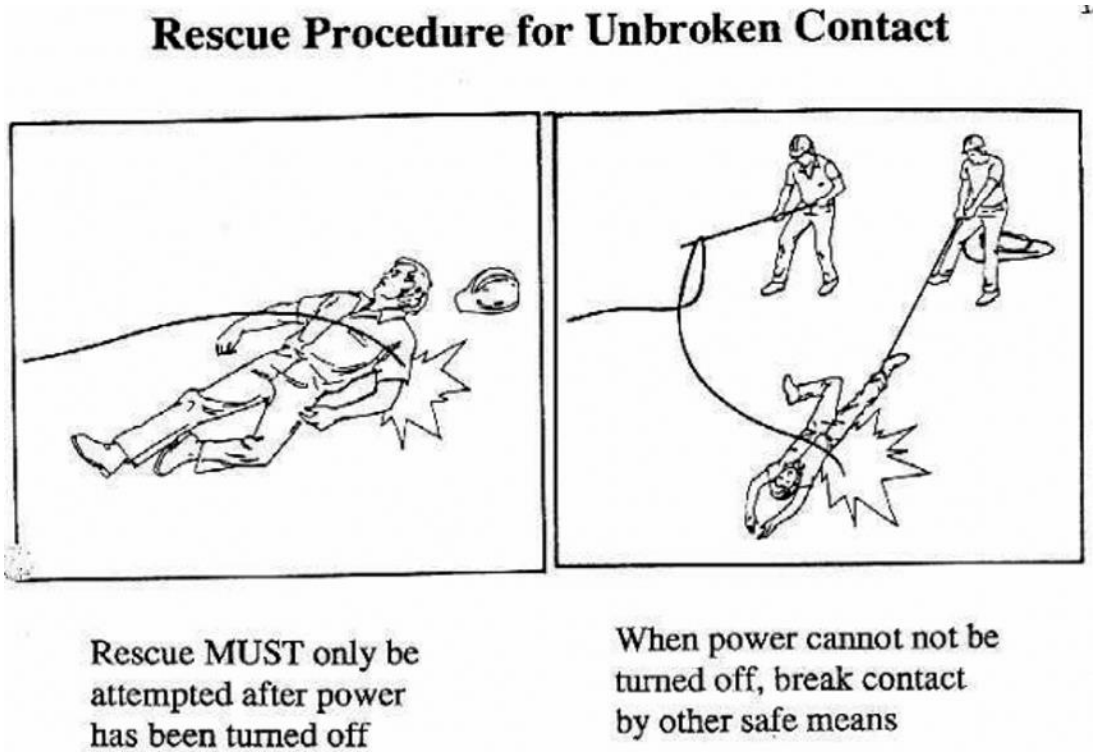
- **Capacitors**
  - Store up electrical energy
  - Energy dissipates very slowly
  - Memory effect - can regain certain portion of the energy even after discharged
  - Have to be discharged and grounded continuously.

Handling Emergencies

First Aid for Electrocuted Victims

When attempting to save a person from electric shock:

- Electric shock victim MUST be removed from contact with electricity by safe means before doing any necessary first aid treatment
- CPR (should be performed by a competent person)



Fire & Explosion Hazards

This section explains particular hazards and respective preventive measures concerning fire and explosion hazards

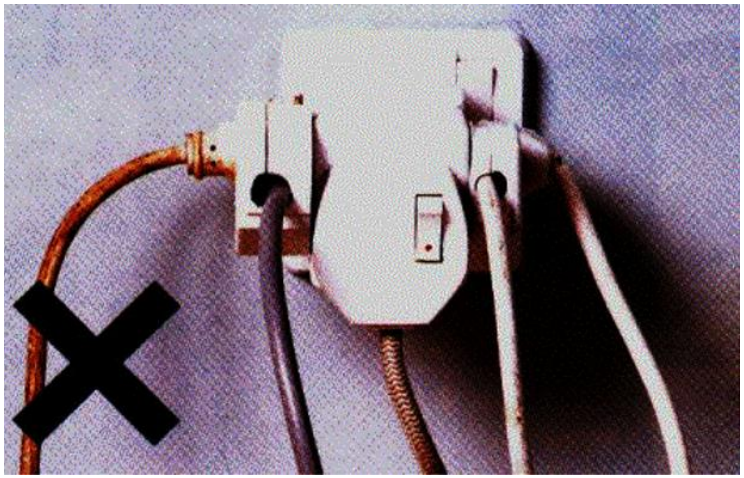
Common Causes for Fire & Explosion

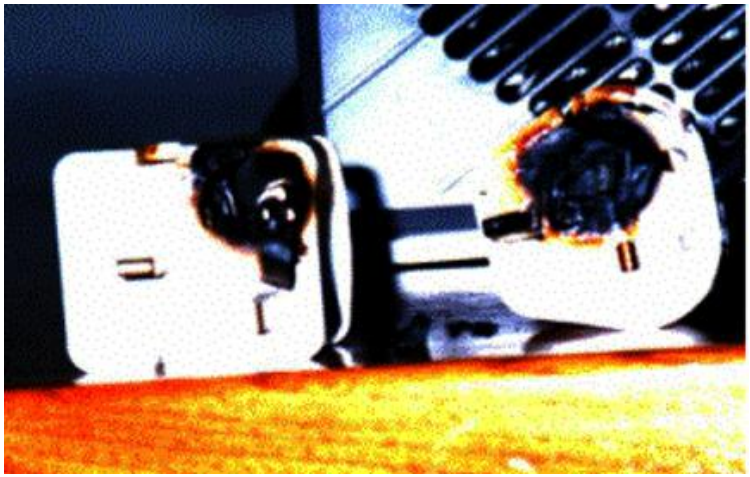
- **Overloading of circuits**
  - Cable with insufficient size

Electric current flowing through a conductor will generate heat. If the size of the conductor is not sufficient for carrying the current, the heat can be high enough to cause a fire.

Common Causes for Fire & Explosion

- **Excessive heat generated (overloading) in conductors**
  - Abused use of adaptors and extension socket boards
  - Substandard plugs/ adaptors





This may be caused by “poor contacts” developed inside the plugs/ adaptors. The high resistance generated tremendous heat which can cause a fire.

Common Causes for Fire & Explosion

- **Heat generated by electric arcs**
  - Poor electrical contacts
    - » Plugs are loosely fitted to socket (poor electric contact)

– esp. for two pin plugs

The "poor contacts" between the plug pins and the socket holes can generate sparks (intermittent electric arcs)

Common Causes for Fire & Explosion

- **Sparks generated by certain electrical tools and equipment, e.g.... motor, plugging and unplugging.**
- **Especially in hazardous atmosphere, i.e. atmosphere containing flammable gases/ vapors, e.g. in**
  - Flammable Dangerous Goods stores
  - Areas where spray painting is being carried out

Avoid Generation of Sparks in Hazardous Atmosphere

- **Use spark proof/ intrinsically safe equipment and installation in hazardous areas where are:**
  - flammable liquids;
  - combustible liquids operating at a temperature above their flash point; or
  - gases or combustible dusts that may be present in flammable, explosive and combustible concentrations.

Simple Guidelines For guarding against electrical hazards

Having understood the hazards and the principles of protection, there are many things we should or should not do to safeguard ourselves against the electrical hazards. The next pages summarize some of those things

Simple Guidelines -1

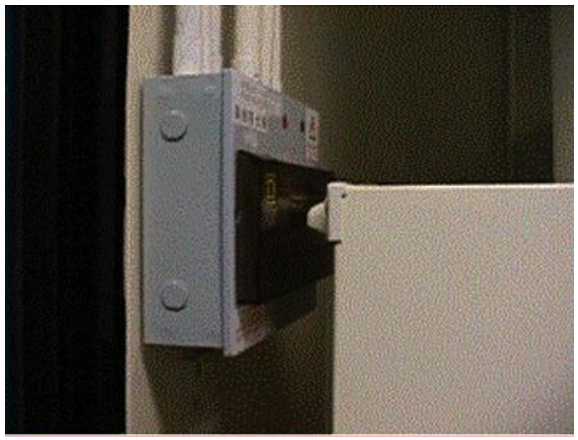
- Do not operate electrical equipment when you hands/ body or the environment is wet.
- Choose equipment that is suitable for its working environment, e.g. flame-proof type for flammable atmosphere.
- Inspect electrical tools before use. Never use unsafe tools.
- Avoid trailing cables across walkways to prevent tripping hazards.
- Electrical equipments must be properly maintained by qualified personnel.
- Before maintaining electrical appliances, all switches must be turned off and cables unplugged.

Simple Guidelines -2

- Faulty equipment must be taken out of use and properly labelled.
- Do not overload the circuit by connecting too many appliances to a single socket outlet.
- Properly designed (with fuse protection) extension boards should be used if multiple-connections to power source is unavoidable.
- Broken plugs must not be used and must be replaced immediately.
- Frayed or worn out cables must not be used.
- Use proper connectors or cable couplers to join lengths of cable. Do not use adhesive tape.

Simple Guidelines -3

- For major electrical or mechanical repairs and maintenance, appropriate Lockout/ tagout procedures should be implemented.
- Always assume electrical equipment energized unless positively proven
- Re-set circuit breaker only after problem rectified
- Maintain clearance around electrical equipment and switch boxes/panels



Reference

- 《国家电气设备安全技术规范》(GB 19517-2009)
- 《测量、控制和实验室用电气设备的安全要求》(GB 4793.1-2007)
- 《电线电缆识别标志方法 第2部分: 标准颜色》(GB/T 6995.2-2008)
- 《家用和类似用途插头插座 第1部分：通用要求》(GB/T 2099.1-2021)
- 《家用和类似用途单项插头插座 型式、基本参数和尺寸》(GB/T 1002-2021)
- 《电气安全管理规程》(1986年版)

THE END