Electrical Safety
电气安全

Electrical Safety in the Lab Is No Trivial Matter
实验室电气安全无小事

- **Accident 1**
  事故 1

At 0:42 AM on February 27, 2019, a fire broke out in a laboratory inside a university teaching building in Jiangsu Province. The flames spread rapidly, filling the entire building with thick smoke. After the university reported the incident, 9 fire trucks and 43 firefighters arrived at the scene, using water cannons to extinguish the fire and cool down the area. The blaze was fully put out by 1:30 AM. The main cause of the accident was prolonged operation of equipment: with no personnel on duty in the building at night, the laboratory failed to turn off the power supply to the heat treatment equipment, resulting in an electrical overload that triggered the fire.

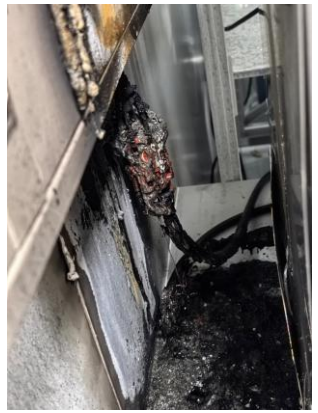
2019年2月27日凌晨0时42分，江苏省某大学教学楼内一实验室发生火灾，火势蔓延迅速，整栋大楼浓烟滚滚，学校报警后9辆消防车、43名消防员到达现场，用水枪喷射明火并且降温，1时30分火灾被扑灭。事故主要原因为设备长时间运行：夜间楼内无人员值守，实验室未关闭热处理设备电源，导致电气线路过载引发火灾。

- 视频链接 https://haokan.baidu.com/v?pd=wisenatural&vid=4179231105132637974

Electrical Safety in the Lab Is No Trivial Matter
实验室电气安全无小事

- **Accident 2**
  事故 2
  - At a laboratory, a muffle furnace was being used overnight to heat samples (ceramic tiles) when the aviation connector, cable, and distribution box connected to it caught fire. The incident resulted in damage to the muffle furnace, destruction of the distribution box, and partial damage to the ceiling, walls, and floor. No personnel injuries or environmental damage occurred.
    某实验室，在夜间使用马弗炉进行样品（陶瓷片）加热时，与马弗炉连接的航空插座、电缆和配电箱起火，事故造成马弗炉受损、配电箱被烧毁、部分天花墙面地面受损，无人员受伤或环境破坏。
  - The exposed copper cores of the two phases came into contact, causing an arc. The arc ignited the insulation, and the resulting open flame then spread to the distribution box and aviation socket, leading to the fire.
    两相间铜芯暴露，引起电弧，引燃绝缘皮，随后明火引燃配电箱和航空插座，导致火灾发生。

before fire



after fire

Objective
目标

◆ **Basic awareness and understanding on:**
对以下内容形成基本认知和理解：

- The possible hazards caused by electricity.
电可能引发的危害

- Safety measures and practices to avoid those hazards.
避免这些危害的安全措施和操作规范

- Statutory requirements on safety standards regarding electrical works, equipment and installations.
有关电气作业、设备及安装的安全标准法定要求。

Contents
目录

Hazards of Electricity
电的危险性

◆ **Classification of Voltages**

电压分类

- Extra low voltage: n.e. 50 volts a.c. / 120 volts d.c. (between conductors or to earth)

  特低电压：交流不超过 50 伏 / 直流不超过 120 伏（导体间或对地）

- Low voltage: Exceed ELV but n.e. 1000/ 600 volts a.c. (between conductors/ to earth); or n.e. 1500/900 volts d.c.

  低电压：超过特低电压，但交流导体间 / 对地不超过 1000/600 伏；或直流不超过 1500/900 伏

- High voltage: Any voltage normally exceeding LV.

  高压：正常情况下超过低电压的所有电压

Hazards of Electricity
电的危险性

◆ **High Voltage**

高电压

- Specific Hazards:

  专项危害:

  - Generate much larger current

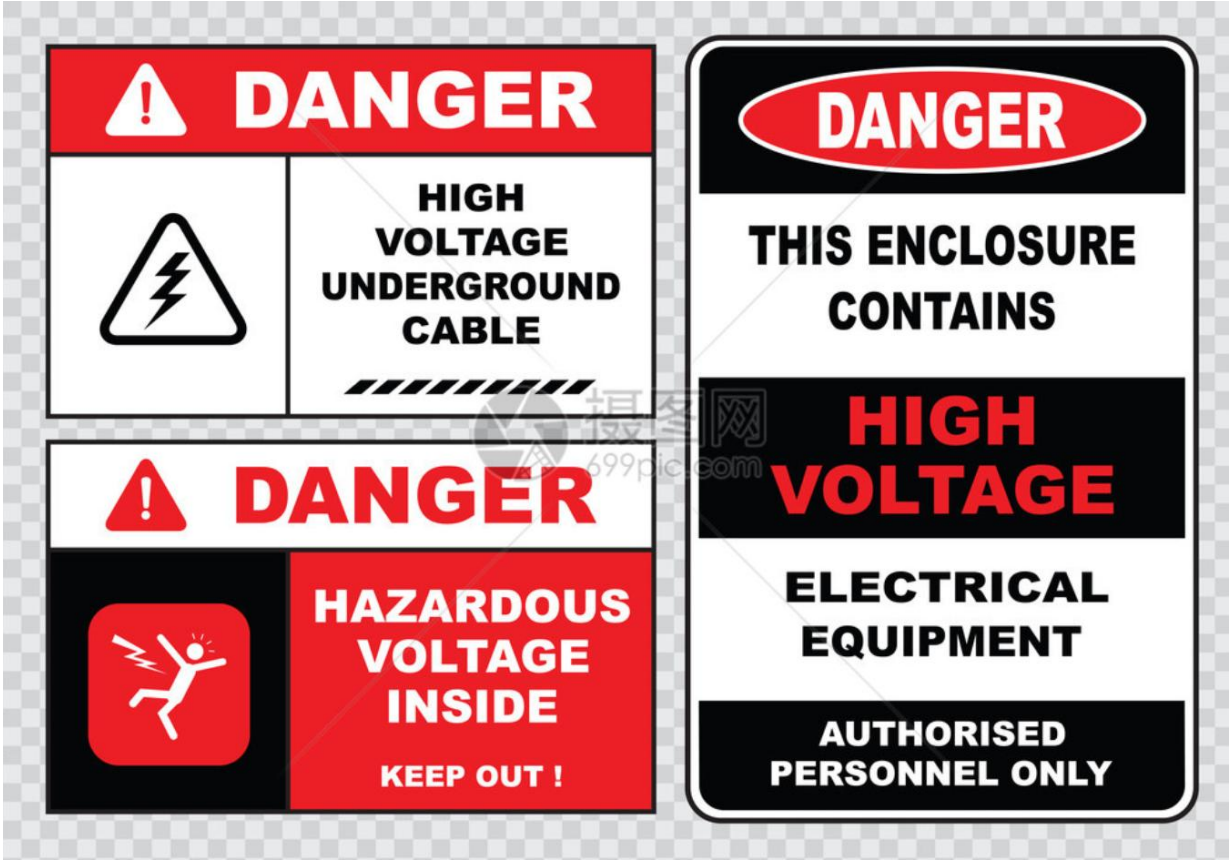
    产生更大电流

  - Current can jump through air – arcing

    电流可通过空气放电 —— 电弧放电

  - Must maintain a safe distance according to the voltage

    需根据电压保持安全距离



Hazards of Electricity
电的危险性

◆ **Stored Energy**

储存能量的危害

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

  储存的电能存在特殊危害，因为即使系统断开电源，储存的能量依然存在。

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

  根据能量大小，储存的能量可能对未察觉其存在的人员造成严重伤害。

- Stored energies commonly came across include those stored in:

  常见的储存能量来源包括:

  - Batteries

    电池

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

    12 伏汽车电池短路时，产生的能量可熔化金属棒

Hazards of Electricity
电的危险性

- **Stored Energy**
  储存能量的危害
  - Stored energies commonly came across include those stored in:
    常见的储存能量来源包括:
    - Capacitors
      电容
      - Store up electrical energy
        储存能量
      - Energy dissipates very slowly
        能量释放速度极慢
      - Memory effect - can regain certain portion of the energy even after discharged
        存在记忆效应 —— 即使放电后，仍可能恢复部分能量
      - Have to be discharged and grounded continuously.
        必须持续放电并接地

Hazards of Electricity
电的危险性

- **Hazards of Electricity**

  电的危害

  - Primary Hazards

    主要危害

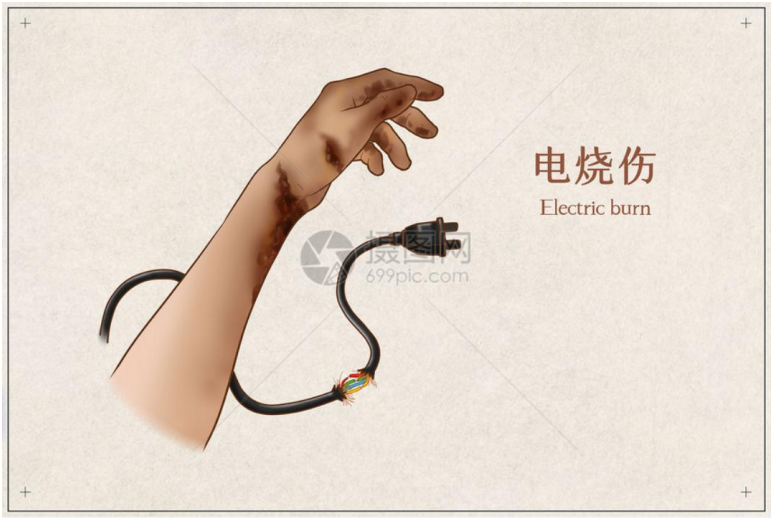
    Electric shock:Occurs when electric current passes through the human body.

    触电/电击：当电流通过人体时发生

    Fire & Explosion:About 15% of all fire incidents are caused directly or indirectly by electricity.

    火灾与爆炸：约 15% 的火灾事故直接或间接由电引起

Hazards of Electricity
电的危险性



- **Hazards of Electricity**

  电的危害

  - Secondary Hazards

    次要危害

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

    烧伤：在特定条件下，如短路、电弧放电等，由电释放的热能导致。

  - Falls and other injuries (e.g. bone fracture etc.): Caused by the jerk reactions of the person suffering from a minor electricity shock.

    人员遭受轻微电击时，身体的猛然反应可能引发此类伤害。

Hazards of Electricity
电的危险性

◆ **Harmful Effects of Electric Current to Human Body**

电流对人体的有害影响

- Electric shock

  触电/电击

- Sufficient current flowing through the body will create serious harm:

  足够强度的电流通过人体会造成严重伤害:

  Ventricular Fibrillation---- when the heart is affected

  心室颤动——影响心脏功能时

  Suffocation---- when the respiratory system is affected

  窒息——影响呼吸系统时

  Cell damage---- by the energy of the electricity current

  细胞损伤——由电流能量导致

  Burns ---- by the heat released from the current

  烧伤——由电流释放的热量导致

Hazards of Electricity
电的危险性

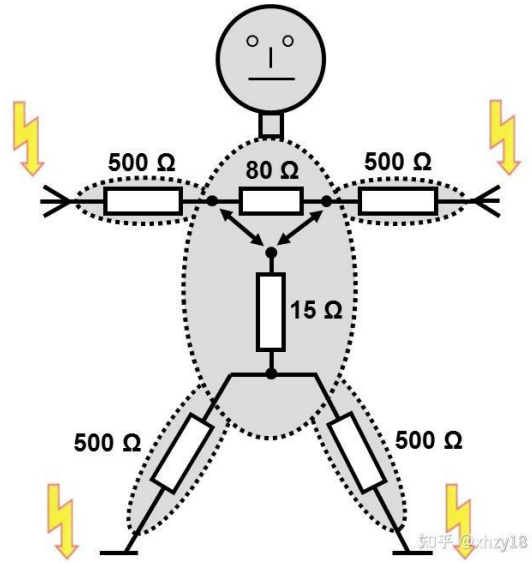
Lethal Path
致命路径

- **Harmful Effects of Electric Current to Human Body**
  电流对人体的有害影响
  - Electric shock
    触电/电击
    - Degree of harmful effect to human body depends on:
      触电对人体的伤害程度取决于:
      Magnitude of current
      电流大小
      Voltage
      电压高低
      Body resistance
      人体电阻
      The current pathway through the body
      电流通过人体的路径
      The duration of contact
      接触时间

Hazards of Electricity
电的危险性

◆ **Harmful Effects of Electric Current to Human Body**
电流对人体的有害影响

- Typical Body Resistance
  典型人体电阻
  - The total body resistance to electricity is made up of the Skin Contact Resistance and Internal Body Resistance.
    人体总电阻由皮肤接触电阻和体内电阻构成
    Skin Contact Resistance:From 1000 kilo-ohms(dry skin) down to 100 ohms (wet skin)
    皮肤接触电阻：干燥皮肤时为 1000 千欧，潮湿皮肤时可降至 100 欧
    Internal Body resistance:From 100 to 500 ohms
    体内电阻：100 至 500 欧
- Current through body
  通过人体电流
  We can now calculate the magnitude of electric current flowing through the body in an electric shock incident:
  可计算电击事故中流经人体的电流大小:
  Worst condition (when the body is wet):
  最恶劣情况（人体潮湿时）：
  220 V/ 600 ohms = 367 mA
  220 伏 / 600 欧 = 367 毫安



Hazards of Electricity
电的危险性

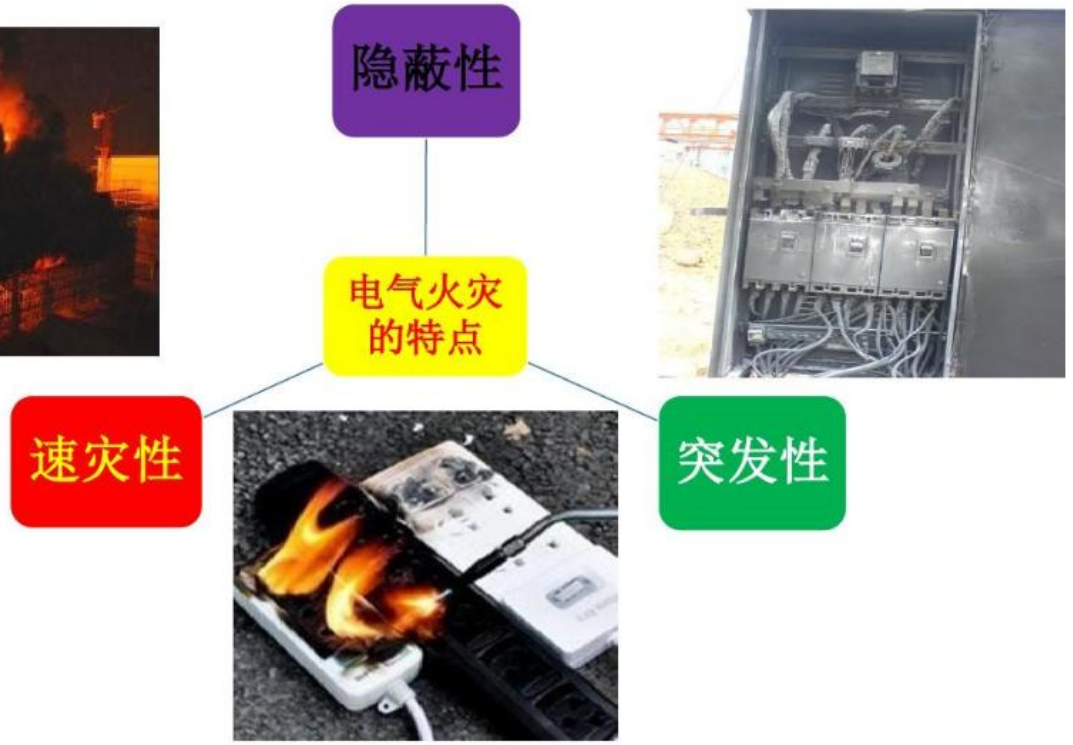
- **Harmful Effects of Electric Current to Human Body**
  电流对人体的有害影响
  - Effects of Current on an Average Human
    电流对普通人体的影响

Warning: Figures are for rough indication only. Do not take them too precisely
警告：数据仅为粗略参考，请勿过于绝对化解读。

Current values电流值	Effects on Human Body 对人体的影响
≤1 mA	Causes no sensation and is not felt - it is at the threshold of perception. 无任何感觉，处于感知阈值以下
1-8 mA	Sensation of shock. Not painful. Individual can let go at will as muscular control is not lost.有电击感，无疼痛感，肌肉控制能力未丧失，可自主脱离电源
8-15 mA	Painful shock. Muscular control is not lost. 电击疼痛明显，肌肉控制能力未丧失
15-20 mA	Painful shock. Muscular control lost. Cannot let go. 电击疼痛剧烈，肌肉控制能力丧失，无法自主脱离电源
100-200 mA	Ventricular fibrillation. Loss of consciousness. Hold victim to circuit as long as AC flows. 心室颤动，失去意识，交流电持续通过时，受害者会被吸附在电路上
≥200 mA	Severe burns. Severe muscular contractions, so severe that chest muscles clamp the heart and stop it during the shock. 严重烧伤，肌肉剧烈收缩，胸部肌肉强烈夹紧心脏，导致电击期间心脏骤停

Hazards of Electricity
电的危险性

- **Characteristics of Electrical Fires**
  电气火灾特点
  - Rapid Burning and High Temperature
    燃烧速度快，温度高。
  - Strong Concealment
    隐蔽性强
  - High Suddenness
    突发性强
  - Difficult to Extinguish
    扑救困难
  - Highly Hazardous
    危害性大
  - Seasonal and Temporal Patterns
    季节性与时间性特征
  - Generation of Toxic Smoke
    产生有毒烟气
  - Complex and Technical Causes
    成因复杂，技术性强



Hazards of Electricity
电的危险性

- **Electrical Systems & Equipment**
  电气系统及设备
  - Fixed system
    固定系统
    - Wirings
      布线
    - Switches, sockets etc.
      开关插座等
    - Light fittings
      照明装置
  - Portable equipment
    便携式设备
  - Handheld portable tools
    手持式便携式工具
    - Hand drill/ grinders
      手电钻/砂轮机
    - Hair driers etc.
      吹风机等

Notes:注：

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

电气系统及设备可分为固定系统和便携式设备两类。

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

相对而言，固定电气系统有更严格的规则和操作规范，且通常配备更复杂的安全保护装置。

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

便携式设备虽也需符合相应安全标准，但更易被滥用，手持式便携式工具尤其如此。

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Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

◆ **People at Risk**

风险人群

- Electrical installation, maintenance and repair personnel

  电气安装、维护及维修人员

  - Special safety procedures such as Lockout/Tagout procedures need to be established.

    需制定专门安全程序，如挂牌上锁程序

- Research personnel working on experimental setups.

  从事实验装置相关工作的研究人员

- Users of electrical equipments

  电气设备使用者

  - Portable electrical equipments

    便携式电气设备使用者

  - Plant and equipments

    工厂设备使用者

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

- **Common Sources of Electrical Hazards**
  电气危害的常见来源
  - Electrical equipment/ appliances
    电气设备 / 器具:
    - Portable electrical tools incl. hand tools
      便携式电动工具（含手动工具）
    - Plug/ Sockets/ Extension boards
      插头 / 插座 / 延长线板
    - Electric cables
      电缆
    - Exposed electrical conductors
      裸露的导电体
    - Metal surfaces/ parts become energized
      带电的金属表面 / 部件
    - Special experimental setups
      特殊实验装置

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

◆ **Common Electrical Hazard Sources in Laboratories**

实验室常见电气风险源

- **Equipment-related Risks**: Damaged cables/plugs, improper grounding, non-compliant equipment.
  设备类风险：破损的线缆/插头、接地不良、不合格设备。
- **Environmental & Operational Risks**: Use of electricity in damp environments, power overload, messy cabling, unauthorized repairs.
  环境与操作类风险：潮湿环境用电、电源过载、线路杂乱、私自维修。
- **Special Equipment Risks**: Capacitors, high-power equipment, high-frequency/high-voltage equipment.
  特殊设备风险：电容、大功率设备、高频/高压设备。

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

- **Occurrence of Electric shock**
  触电的发生形式
  - Electric shock occurs when a person gets into contact with electric current. Such contacts can occur by way of:
    当人体接触电流时会发生触电，接触形式主要有:
    - Direct Contact
      直接接触
      - Direct contact with current carrying parts
        直接接触带电部件
      - Plan the shut down of the system.
        规划系统停机流程
    - Indirect Contact
      间接接触
      - Contact with current through conductive parts not normally carrying current
        通过正常不带电的导电部件接触电流
      - Leakage of electric current
        电流泄漏导致接触

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

- **Causes for Failure of Protection**
  保护失效的原因
  - Unsafe Installation
    不安全安装
  - Unsafe Equipment
    不安全设备
    - Unsafe design
      设计缺陷
    - Substandard equipment
      不合格设备
  - Unsafe EquipmentUnsafe wok practices
    不安全作业行为
    - Improper Use of equipment
      设备使用不当
    - Improper Work procedure/ practice
      作业流程 / 操作不规范
    - Improper or Lack of Maintenance process
      维护流程不当或缺失

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

- **Typical Hazardous Conditions**
  典型危险场景
  - Beware of the following hazardous conditions:
    需警惕以下危险场景:
    - Exposed current carrying parts
      带电部件裸露
      - Open installation- no enclosure
        开放式安装（无外壳）
      - Maintenance process- need to open up enclosure
        维护过程中（需打开外壳）
      - Defective/ damaged enclosure
        外壳缺陷 / 损坏
    - Faulty insulation in equipment
      设备绝缘故障
      - Leakage of electricity
        漏电

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

◆ **Typical Hazardous Conditions**

典型危险场景

- Beware of the following hazardous conditions:

  需警惕以下危险场景:

  - No/ Improper grounding

    无接地 / 接地不当

    - Potentially hazardous

      存在潜在危险

  - Inadequate working clearance

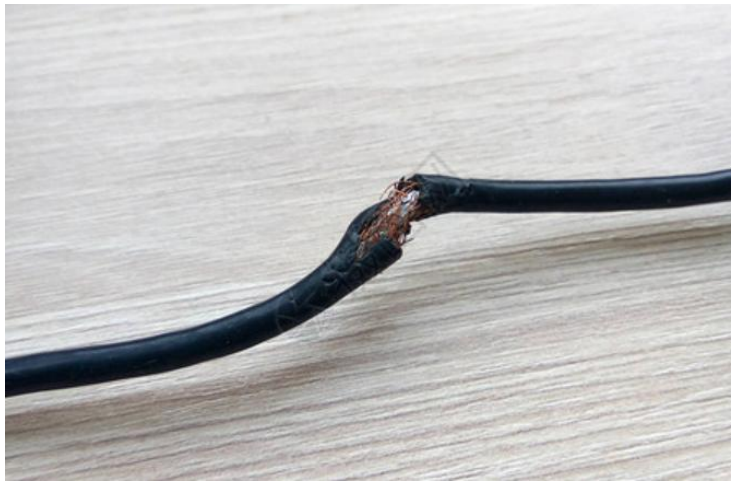
    作业空间不足

    - Increase risk of contact

      增加接触风险

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

- **Typical Hazardous Conditions**
  典型危险场景
  - Examples
    示例
    - Contact with current carrying parts inadvertently
      意外接触带电部件
      - Damaged casing/ cable/ plugs etc. where live conductors are exposed.
        外壳 / 电缆 / 插头等损坏，导致带电导体裸露
      - Inadequate insulation
        绝缘不足



Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

- **Typical Unsafe Practice & Conditions**
  典型不安全作业行为及场景
  - Causing Electrical Shock
    易引发触电
    - Earth wire accidentally pulled out of its plug terminal (not properly wired)
      接地线意外从插头端子拉出（接线不当）
    - Remove plug by tugging the cord instead of holding the plug
      拉扯电缆拔插头，而非握住插头操作
    - Earth wire not connected or even cut away Cable not firmly gripped
      接地线未连接或被剪断，电缆固定不牢固
    - Wrong connections at terminals of plug
      插头端子接线错误
    - Inserting screwdriver into earth pin hole to open up covers for live and neutral pins
      用螺丝刀插入接地插孔，试图撬开火线和零线插孔的盖板
    - Plugs are loosely fitted to socket
      插头与插座接触松动
      - esp. for two pin plugs (fire hazard)
        尤其是两孔插头（存在火灾隐患）

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

- **Typical Unsafe Practice & Conditions**
  典型不安全作业行为及场景
  - Causing Electrical Shock
    易引发触电
    - Badly made joints in flexible cables
      软电缆接头制作不良
      - loss insulation capacity
        绝缘性能下降
      - easily pulled apart
        易脱落
    - Flexible cable damaged
      软电缆损坏
    - Coiling of cable under load condition (fire hazard)
      电缆带载时盘绕（存在火灾隐患）
    - Damaged or missing covers/ enclosure
      外壳 / 盖板损坏或缺失
    - Servicing apparatus without disconnecting power
      未切断电源即对设备进行维修

Common Sources, Unsafe Acts, and Hazardous Conditions
常见来源、不安全行为、危险场景

- **Typical Unsafe Practice & Conditions**
  典型不安全作业行为及场景
  - Overloading– causing fire
    过载——引发火灾
    - Lower rating plugs (and cable) are used
      使用额定值偏低的插头（及电缆）
    - Too many plugs are connected to a single socket outlet via adaptors or extension socket boards
      通过适配器或延长线板在单个插座上连接过多插头
    - Cable with insufficient size
      使用截面积不足的电缆
  - Trailing cables
    拖曳电缆

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Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - General Safety Requirements
    通用安全要求
    - The apparatus shall be so designed and constructed as to present no danger, either in normal use or under fault conditions, providing particularly:
      设备的设计和制造应确保在正常使用和故障状态下均 无危险，尤其需满足:
      - personal protection against electric shock.
        防触电人身保护
      - personal protection against the effects of excessive temperature.
        防过热人身保护
      - personal protection against the effects of radiation.
        防辐射人身保护
      - personal protection against the effects of implosion and explosion.
        防爆裂和防爆炸人身保护
      - personal protection against the effects of mechanical instability and of moving parts.
        防机械不稳定及运动部件伤害人身保护
      - protection against fire.
        防火保护

Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - Safety Standards for Equipment
    设备安全标准
    - Prevention of Electric Shock
      防触电
      - Enclosure/ covers/ vent holes for limiting accessibility of live parts
        外壳 / 盖板 / 通风孔需限制带电部件的可触及性
      - Provision of protective earthing
        配备保护接地装置
      - Insulation of live parts -- adequacy of insulating materials
        带电部件绝缘 —— 绝缘材料需达标
      - Adequate creepage distance and clearance between conductive parts
        导电部件间需有足够的爬电距离和电气间隙
      - Rigidity of wiring connection (at terminals)
        接线端子处的布线连接需牢固
      - Protections against faults causing accessible conductive parts to become live
        防止可触及导电部件因故障带电的保护措施
      - Ability to withstand humid conditions
        耐受潮湿环境的能力

Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - Safety Standards for Equipment
    设备安全标准
    - Devices
      端子装置
      - Earth terminals
        接地端子要求:
        » properly connected to ensure effectiveness of earth (to connector socket/ to earth lead from mains)
        连接可靠，确保接地有效性（与插座连接器 / 电源接地线连接）
        » ensure low resistance (<0.1 ohms)
        保证低电阻（ < 0.1 欧）
        » no excessive corrosion
        无过度腐蚀

Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - Safety Standards for Equipment
    设备安全标准
    - Devices
      端子装置
      - Proper plugs and sockets
        插头和插座需符合标准
      - Terminals for external flexible cables:
        外部软电缆端子要求:
        - properly shielded and located (loose strand clear of conductive parts)
          屏蔽良好且安装位置合理（松散线芯不得接触导电部件）
        - screw terminal will not work loose
          螺纹端子不会松动
        - do not damage the conductors
          不损坏导体

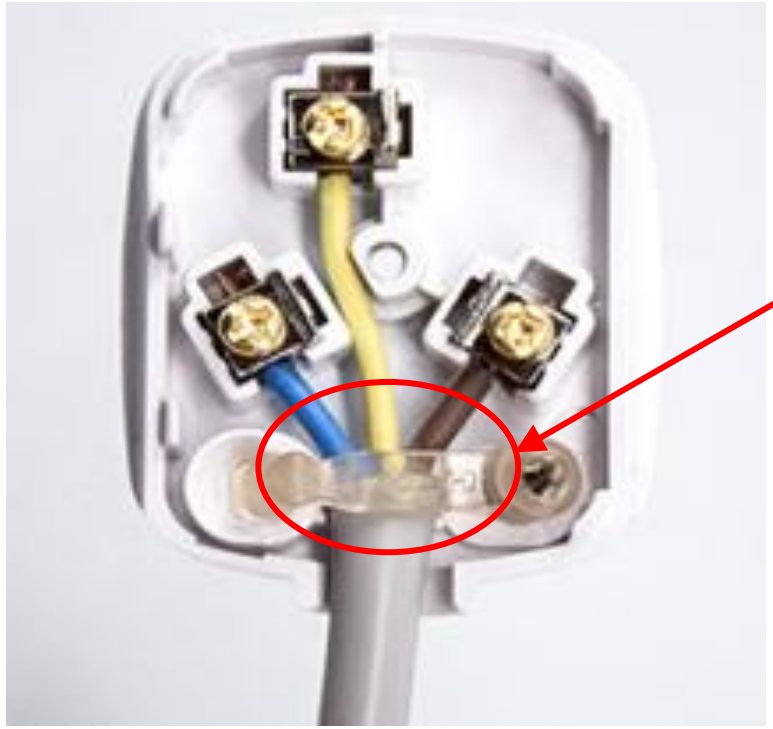
Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - Safety Standards for Equipment
    设备安全标准
    - External Flexible Cable
      外部软电缆
      - Adequate cross sectional areas
        截面积达标
      - Provided with earth wire for Class I equipment
        I 类设备需配备接地线
      - Connecting points of cables relieved from mechanical strain.
        电缆连接点需能承受机械应力
      - Outer shield protected from abrasion and cut, incl. at point of entry.
        外部护套需防磨损和切割（包括入口处）
      - Not be able be pushed back
        电缆不得轻易被推入设备内部

Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - Some examples illustrating the safety standard requirements
    安全标准要求示例

Provision of earth wire for Class I equipment
I 类设备接地线配置

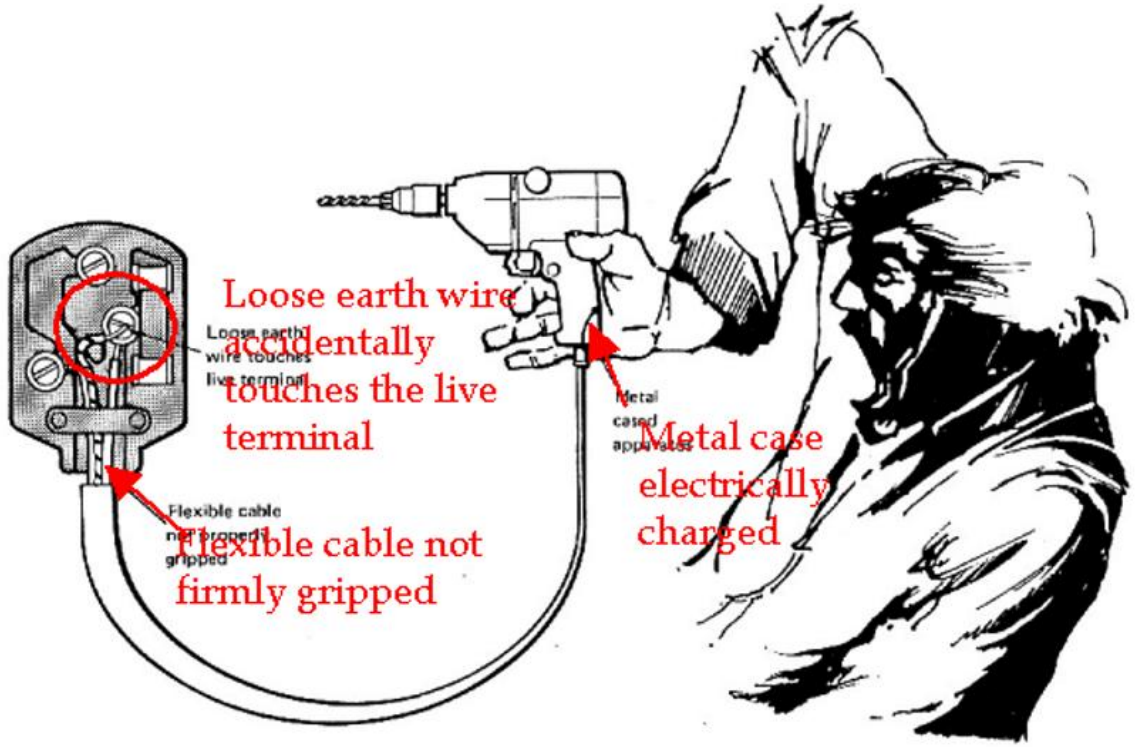


This is to prevent the conductors from getting loose from the terminals which may cause serious injuries.
此举可防止导体从端子松动，避免引发严重伤害。

Connecting points of cables relieved from mechanical strain
电缆连接点的机械应力防护

Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - Some examples illustrating the safety standard requirements
    安全标准要求示例



Fatal Contact
致命接触示例

Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - Electrical accessories should have the following marks:
    电气附件需标注以下内容:
    - Rated current (amperes)
      额定电流（安培）
    - Rated voltage (volts)
      额定电压（伏特）
    - Symbols of power supply properties
      电源性质符号
    - The name or trademark or identifying mark of the manufacturer or seller
      制造商或销售商的名称、商标或识别标志
    - Model number (can be product catalog number)
      型号（可为产品目录编号）

Protection Measures & Standards
防护措施与标准

- **Safety Standards for Electrical Equipments**
  电气设备安全标准
  - Electrical accessories should have the following marks:
    电气附件需标注以下内容:
    - 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
      防触及危险部件和防固体异物侵入的防护等级第一特征数（若宣称高于IP2X）；固定式插座若宣称高于 IP4X，需同时标注第二特征数。
    - 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
      防有害进水的防护等级第二特征数（若宣称高于 IPX0）；固定式插座若宣称高于 IPX2，需同时标注第一特征数
    - The number of the standard, e.g. GB/T 2099.1
      标准编号，如 GB/T 2099.1

Protection Measures & Standards
防护措施与标准

- **Measures for Preventing Electric Shock Hazards**
  触电危害的预防措施
  - Prevention Principles/ Means of Electric shock
    触电预防原则/方式
    - Safe System (Protective Devices – Engineering Controls)
      安全系统（保护装置 —— 工程控制）
      - Required by local code and regulations
        符合当地法规要求
      - Required for fixed installation and portable equipment
        固定安装和便携式设备均需配备
  - Safe Equipment
    安全设备
    - Use of Safe Equipment (with adequate protection)
      使用具备充分保护功能的安全设备
  - Safe Work Practices
    安全作业规范
    - Safe use of equipment (Proper Use)
      设备安全使用方法（正确操作）
  - Safety Planning - esp. for non-standard setups
    安全规划 —— 尤其针对非标准装置
  - Proper Maintenance
    定期维护

Protection Measures & Standards
防护措施与标准

- **Measures for Preventing Electric Shock Hazards**
  触电危害的预防措施
  - Protective Devices/Engineering Control (Safe System)
    保护装置 / 工程控制（安全系统）
    - Insulation of live conductors (using insulation materials)
      带电导体绝缘（使用绝缘材料）
    - Enclosure/ Guarding/ Barrier (for dangerous parts)
      外壳 / 防护装置 / 屏障（遮挡危险部件）
    - Interlocks (cut off electric power automatically when the barrier is removed)
      联锁装置（屏障移除时自动切断电源）
    - Earth Leakage (Fault) Protection
      漏电（故障）保护
    - Means for protecting against indirect contact
      防止间接接触的保护方式
      - Grounding
        接地
      - RCD (Residual Current Device)
        剩余电流装置（RCD）

Protection Measures & Standards
防护措施与标准

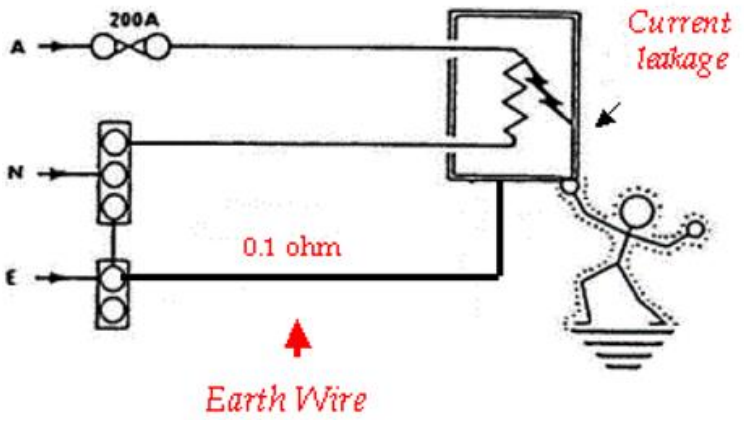
◆ Measures for Preventing Electric Shock Hazards
触电危害的预防措施

- Earth Leakage (Fault) Protection
  漏电（故障）保护
  - Grounding/Earthing/Bonding
    接地 / 等电位联结
    - The purpose is to eliminate the build up of potential difference between the equipment and the ground.
      接地的目的是消除设备与地面之间的电位差。
    - This is normally done by installing a conductor (earth wire) for such purpose
      通常通过安装专用导体（接地线）实现该功能。
    - 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.
      无任何保护时，设备漏电情况下，人体承受的电位差等于系 统电压，即家庭供电的 220 伏。

Protection Measures & Standards
防护措施与标准

◆ **Measures for Preventing Electric Shock Hazards**
触电危害的预防措施

- Earth Leakage (Fault) Protection
  漏电（故障）保护
  - Grounding/Earthing/Bonding
    接地 / 等电位联结
    - 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.
      接地保护通过接地线限制故障状态下的 “接触电压”，进而限制 流经人体的电流。



V=IR
=200x0.1
=20Volts

V=Touch Voltage
Fault Current=200A

Protection Measures & Standards
防护措施与标准

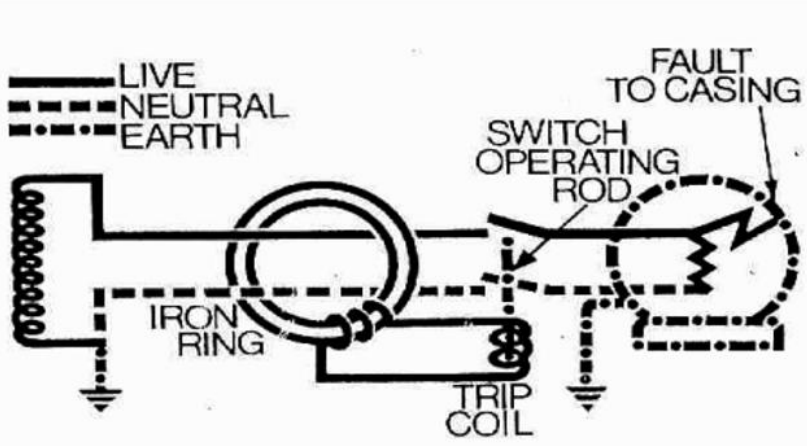
- **Measures for Preventing Electric Shock Hazards**
  触电危害的预防措施
  - Earth Leakage (Fault) Protection
    漏电（故障）保护
    - Automatic Disconnection of Power
      自动断电
      - By installing specially designed device such as:
        通过安装专用装置实现自动断电，如：
        - ✓ Residual Current Device (RCD)
          剩余电流装置（RCD）

小型漏电保护器

Protection Measures & Standards
防护措施与标准

◆ **Measures for Preventing Electric Shock Hazards**
触电危害的预防措施

- Earth Leakage (Fault) Protection
  漏电（故障）保护
  - Simple schematic diagram showing the principle of a Residual Current Device (RCD)
    剩余电流装置（RCD）工作原理示意图



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,
    正常情况下，流出电源的电流与流回电源的电流相等。
    except in condition where there is a leakage of current.
    当发生漏电时，电流会出现差值。
    RCD protects by tripping open the circuit when it detects any current difference.
    剩余电流装置检测到电流差值后，会在极短时间内跳闸切断电路。
  - ➢ RCD can detect a very small current difference and can trip open the circuit in a small fraction of a second.
    该装置能检测到极小的电流差值，并快速响应断电。

Protection Measures & Standards
防护措施与标准

◆ **Measures for Preventing Electric Shock Hazards**
触电危害的预防措施

- Bonding Conductive Surfaces
  导电表面等电位联结
  - Sometimes you may see bonding wires connecting metallic surfaces/objects to the earth. The purpose is:
    有时会看到连接金属表面 / 物体与地面的联结线，其目的是:
  - To maintain an "equi-potential" between metallic objects.
    使金属物体之间保持 “等电位”
    - ➢ Equipotential bonding
      等电位联结

Protection Measures & Standards
防护措施与标准

◆ **Simple Guidelines For guarding against electrical hazards**
电气危害防护简易指南

- Do not operate electrical equipment when you hands/ body or the environment is wet.
  手部 / 身体潮湿或环境潮湿时，切勿操作电气设备
- Choose equipment that is suitable for its working environment, e.g. flame-proof type for flammable atmosphere.
  根据作业环境选择合适设备，如易燃环境使用防爆型设备
- Inspect electrical tools before use. Never use unsafe tools.
  使用前检查电动工具，切勿使用不安全工具
- Avoid trailing cables across walkways to prevent tripping hazards.
  避免电缆横穿人行道，防止绊倒危险
- Electrical equipments must be properly maintained by qualified personnel.
  电气设备必须由合格人员进行定期维护
- Before maintaining electrical appliances, all switches must be turned off and cables unplugged.
  维护电气设备前，必须关闭所有开关并拔掉电缆插头

Protection Measures & Standards
防护措施与标准

◆ **Simple Guidelines For guarding against electrical hazards**
电气危害防护简易指南

- Faulty equipment must be taken out of use and properly labelled.
  故障设备必须停止使用并正确标识
- Do not overload the circuit by connecting too many appliances to a single socket outlet.
  切勿在单个插座上连接过多设备，避免电路过载
- Properly designed (with fuse protection) extension boards should be used if multiple-connections to power source is unavoidable.
  若确需多个设备连接电源，应使用设计合理（带保险丝保护）的延长线板
- Broken plugs must not be used and must be replaced immediately
  插头损坏后严禁使用，需立即更换
- Frayed or worn out cables must not be used.
  电缆磨损或老化后严禁使用
- Use proper connectors or cable couplers to join lengths of cable. Do not use adhesive tape
  连接电缆需使用专用连接器或电缆耦合器，切勿使用胶带

Protection Measures & Standards
防护措施与标准

- **Portable Electrical Equipment**
  便携式电气设备
  - Classes of Electrical Equipment
    电气设备分类
    - Class I apparatus:
      I 类设备:
      - protection against electric shock achieved by providing proper earthing for the apparatus
        通过可靠接地实现防触电保护
    - Class II apparatus (double insulated):
      II 类设备（双重绝缘）:
      - protection against electric shock achieved by double insulation or reinforced insulation. There is no provision for protective earthing.
        通过双重绝缘或加强绝缘实现防触电保护，无保护接地装置。
      - Double-insulated Tools are designed so that the inner electrical parts are isolated physically and electrically from the outer housing.
        双重绝缘工具的设计特点是内部电气部件与外部外壳在物理和电气上完全隔离。
      - 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.
        防触电保护依赖内部防护绝缘层和不导电外部外壳，隔绝使用者与电气部件的接触。
      - No earth wire is required for double insulated equipment.
        双重绝缘设备无需接地线。

Protection Measures & Standards
防护措施与标准

◆ Portable Electrical Equipment

便携式电气设备

- Classes of Electrical Equipment

  电气设备分类

  - Ⅱ类设备（双重绝缘）：

    - Some warning for using double insulated apparatus

      双重绝缘设备使用注意事项

      If immersed in water, a leakage path for electricity can still occur.

      设备浸入水中后，仍可能形成漏电通道。

      Handling the apparatus with wet hands, I high humidity or outdoors after a rainstorm can be dangerous.

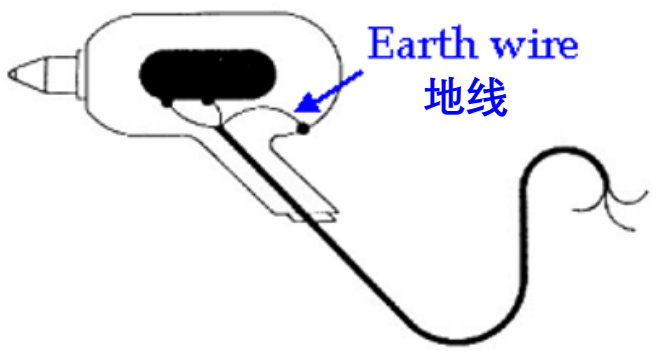
      湿手操作、在高湿度环境或暴雨后户外使用时存在危险。

      Double insulation does not protect against defects in the cord,plug or receptacle.

      双重绝缘无法防护电缆、插头或插座的缺陷。

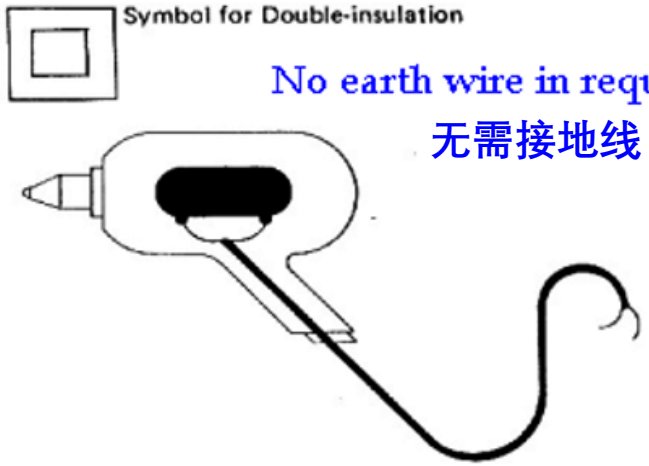
Protection Measures & Standards
防护措施与标准

- **Portable Electrical Equipment**
  便携式电气设备
  - Classes of Electrical Equipment
    电气设备分类
    - Schematic diagrams showing the differences in design between Class I and II apparatus
      I 类与 II 类设备设计差异示意图



Connexions for Metalclad Portable Drill

Class I apparatus



Connexions for Double-insulated or All-insulated Portable Drill

Class II apparatus

Protection Measures & Standards
防护措施与标准

- **Specific Safety Procedures**
  专项安全程序
  - Lockout / Tagout Procedures
    挂牌上锁程序
    - Applicable Scenarios
      适用场景
      - Electrical/Mechanical System Maintenance
        电气 / 机械系统维护
      - Operations with similar risks
        其他类似风险作业

    - Purpose of Lockout/Tag out procedure:
      目的:
      - 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.
        通过有效隔离电源，避免能量（电气和 / 或机械）意外释放，对作业人员造成严重伤害。

Protection Measures & Standards
防护措施与标准

- **Specific Safety Procedures**
  专项安全程序
  - Lockout / Tagout Procedures
    挂牌上锁程序
    - Principles of Lockout/ Tagout Procedure
      挂牌上锁程序原则
      - ➢ Plan the shut down of the system.
        规划系统停机流程
        - » Identify all power supply points of the system
          识别系统所有供电点
          - Develop work schedules and coordination of parties involved
            制定作业进度表并协调相关方
      - ➢ Alert operator and other users of the shut down.
        通知操作员及其他使用者即将停机
      - ➢ Lockout the power supply points to the system at the most appropriate points.
        在最适宜的位置对系统供电点实施挂牌上锁
      - ➢ Have all workers place their personal & individual padlocks on the lockout point.
        所有作业人员在挂牌上锁点放置个人专用挂锁

Protection Measures & Standards
防护措施与标准

- **Specific Safety Procedures**
  专项安全程序
  - Lockout / Tagout Procedures
    挂牌上锁程序
    - Principles of Lockout/ Tagout Procedure
      挂牌上锁程序原则

      - Put a warning tag at the lockout.
        在挂牌上锁点张贴警示标签
      - Release all stored or residual energies (e.g. capacitors, loaded spring etc.)
        释放所有储存能量或残余能量（如电容器、加载弹簧等）
      - Test the circuit to confirm it is dead.
        测试电路确认无电
      - Each worker should remove only his own padlock upon completion of his part of work.
        作业完成后，每名作业人员仅移除自己的挂锁

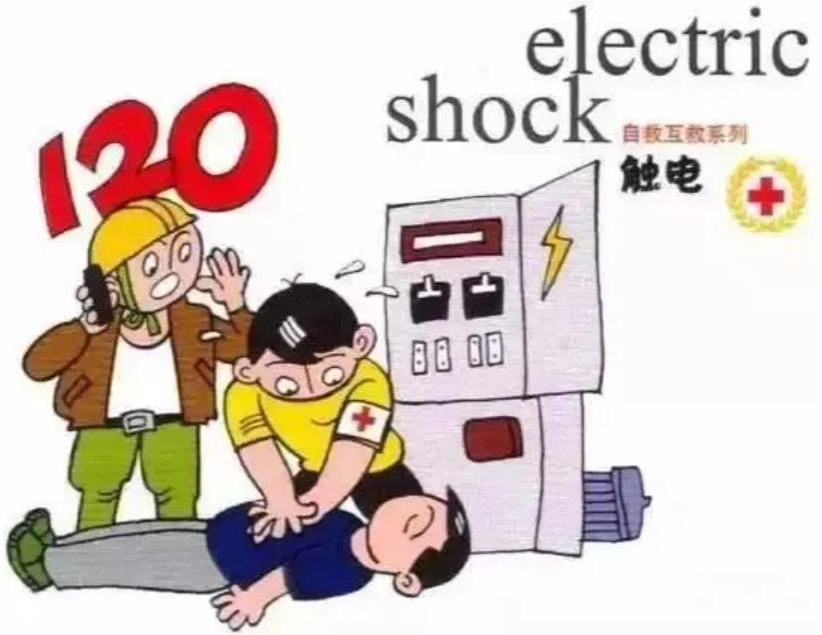
Protection Measures & Standards
防护措施与标准

- **Safety Planning For Non-standard/ Experimental Setups**
  非标准 / 实验装置的安全规划
  - Identify hazards and anticipate problems
    识别危害并预判问题
  - Seek help (from supervisors, LHSD etc.) as necessary
    必要时寻求帮助（如向主管、实验室健康与安全处等）
  - Make appropriate arrangements
    制定相应安排
    - ensure adequate control devices
      确保配备充足的控制装置
    - protective devices
      配备保护装置
    - warning signs
      设置警示标志
    - administrative procedures
      制定管理程序

Contents
目录

Emergency & Operational Guidelines
应急与操作指南

Item 序号	Electrical Shock Emergency Response Process 触电应急处置流程
1	On-site warning to inform other lab personnel 现场警示，告知同实验室人员
2	Insulate/isolate power supply to separate person from live parts 绝缘隔离 / 断电，使人脱离带电体
3	Call for help + report to school fire control center (88330110) + escalate step by step with key info 呼救 + 报消防控制中心（88330110）+ 逐级上报，说明核心信息



Emergency & Operational Guidelines
应急与操作指南

Item 序号	Electrical Shock Emergency Response Process 触电应急处置流程
4	Fire control center dispatches security, verifies surveillance; university departments send rescuers after notification 消防控制中心派保安、核监控，校级相关部门接报后派人救援
5	LHSD: formulate plan, allocate materials; Security Department: evacuate + cordon; Lab Service Department: inspect lines + cut power 实验室健康与安全处：定方案、调物资；安保处：疏散 + 警戒；实验室服务处：查线路 + 断电
6	Report to Emergency Command if serious; activate special plan; LHSD supervisor leads on-site command 情况严重时上报应急指挥部，启动专项预案，LHSD负责人现场指挥
7	Establish on-site command; clarify disposal process; coordinate materials and on-site handling 成立现场指挥部，明确处置流程，协调物资与现场处置

Emergency & Operational Guidelines
应急与操作指南

Item 序号	Electrical Shock Emergency Response Process 触电应急处置流程
8	Low-voltage equipment (≤380V): certified electrician turns off branch switch; High-voltage equipment (>1000V): activate high-voltage power cut process低压设备（≤380V）持证电工断分路开关；高压设备（＞1000V）启动高压断电流程
9	Isolate equipment + post "No Switching On" sign + cordon; allow first aiders near after verifying no residual voltage 设备隔离 + 挂 “禁止合闸” 牌 + 围蔽，验电无残留后允许急救人员靠近
10	Contact school clinic for rescue; perform CPR on the injured/treat electrical burns (prevent infection) 联系校门诊部施救，对伤者心肺复苏 / 处理电灼伤（防感染）

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Item 序号	Electrical Fire Emergency Response Process 电气火灾应急处置流程
1	Call other lab personnel to assist in fire fighting 呼叫同实验室人员协助救火
2	Use nearby fire-fighting equipment to extinguish fire, remove combustibles; evacuate + press manual fire alarm if fire cannot be controlled; cut power first for 用就近器材灭火、搬离可燃物；无法扑灭则撤离 + 按手动报警；电气火灾先断电
3	Call 88330110 to report to school fire control center, escalate step by step to unit leader, and provide key information 拨打 88330110 报消防控制中心，逐级上报至单位负责人，说明核心信息
4	Maintain a safe distance, control lab entrance, assist in emergency response/evacuation, and keep phone accessible 保持安全距离，管控实验室入口，协助应急 / 疏散，保持电话畅通

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Item 序号	Electrical Fire Emergency Response Process 电气火灾应急处置流程
5	Fire control center verifies surveillance, dispatches security and volunteer fire brigade to extinguish fire, and reports to university-related departments simultaneously 消防控制中心核监控、派保安与义务消防队灭火，同步上报校级相关部门
6	Security organizes evacuation + cordon; volunteer fire brigade wears protective equipment, extinguishes fire safely after assessment, and does not enter blindly if fire is large 保安组织疏散 + 警戒；义务消防队穿戴防护装备，评估后安全灭火，火势大不盲目进入
7	LHSD rushes to the scene with 4-in-1 gas detector and other protective/testing equipment 实验室健康与安全处携带四合一气体探测器等防护 / 检测设备赶赴现场
8	University-related departments assess the on-site situation and announce the end of emergency response after meeting standards 校级相关部门评估现场情况，达标后宣布应急响应结束

Reference
参考

- 《国家电气设备安全技术规范》(GB 19517-2023)
- 《测量、控制和实验室用电气设备的安全要求》(GB 4793.1-2022)
- 《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)
- 《用电安全导则》(GB/T 13869-2017)
- 《剩余电流动作保护装置安装和运行》GB/T 13955-2017

THE END
结束