



KINGDOM OF CAMBODIA

NATION RELIGION KING



Ministry of Labour and Vocational Training

Competency-based Learning Materials, Level 5

Core COMPETENCY

High Diploma

Module 2

Installing and Testing Electrical in Commercial and Industrial Building



2022

CORE COMPETENCY

Module 2

Installing and Testing Electrical in Commercial and Industrial Building



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PREFACE

Reference to Cambodian Qualifications Framework (CQF), it has identified two sets of competencies: basic competencies and core competencies for Technical and Vocational Education and Training (TVET). Currently, the National Training Board (NTB) has approved and promulgated 44 standard training packages with 188 qualifications from CQF Level 1 to Level 4. In the implementation of the Technical and Vocational Education and Training Development Project (TVETSDP) has encountered a number of problems, including the basic competencies (soft skills) defined in the national competency standard as part of the problem of implementing the competency-based training program as a reforming program in technical and vocational education and training, it is also required the project to develop the learning materials for basic competencies.

The practical integration of basic competencies (soft skills) into technical and vocational education and training has proved difficult recently. While industry employers often satisfy the technical skills of trainees who have completed technical skills or hard skills training, the industry has found that the performance of the trainees for basic competencies (soft skills) do not yet meet job requirements.

Seeing this, the General Directorate of Technical and Vocational Education and Training, the Ministry of Labor and Vocational Training, which get the mission from the Royal Government of Cambodia, received funding from the Technical and Vocational Education and Training Development Project (TVETSDP) through ADB Loan 3167-CAM and AFD Loan 8305-CAM has initiated the idea of developing the basic competency modules or soft skills modules for technical and vocational training institutions to integrate into technical and vocational education and training. Therefore, This is done to meet the needs of the use of qualified skilled labourers, defined jointly between industries and the public sectors in setting of competency profiles for the development of competency standards (CS), which CS become a national competency standard (NCS). NCS is the results of close collaboration of employers and technical practitioners, training providers and TVET partners. Subsequent discussions with key stakeholders, including the Sector Skills Councils in construction, Electrical work, Manufacturing, and Auto-mechanics; Centers of Excellence (COEs), and training providers jointly developed these basic competencies (soft skills) modules for CQF Level 5 training programs, as "**High Diploma**".

These Basic Competencies (Soft Skills) Modules are designed to implement for all CQF level 5 functional occupations of Technical and Vocational Education and Training. These modules are flexible and can be updated by a series of technicians, scholars and stakeholders in response to local needs.

These 7 core competencies (hard skills) modules as follows:

1. **Installing and Testing Electrical in Residential Building**
2. **Installing and Testing Electrical in Commercial and Industrial Buildings**
3. **Maintaining Electrical Machines and Applications**
4. **Maintaining Power System and Switchboards**
5. **Maintaining Electrical Auxiliary Systems**
6. **Programming Intelligent Building Control System**
7. **Maintaining Solar Photovoltaic Systems**

TVETSDP Coordinating Team, comprises of project technical team, soft skills team and COEs have reviewed and approved on the contents of the modules, which developed by Young Development Research & Consultants Co., Ltd. Now the above-mentioned modules were integrated into CQF Level 5 training programme.

The project hopes and believes that the implementation of these basic competencies modules will improve the quality of technical and vocational education and training programs to meet the needs of skilled Labour Market of Cambodia.

Phnom Penh,2021

**Minister attached to Prime Minister,
Permanent Secretary of State and Project director**

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HOW TO USE THIS COMPETENCY-BASED LEARNING MATERIALS

Welcome!

This module contains training materials and activities for you to fulfill the “**Apply of problem-solving techniques in the workplace**” comprises of knowledge, skills and attitudes required for basic competencies of qualification level 5 of the Cambodian National Qualification Framework.

You need to perform a series of learning activities to achieve each learning outcome of the module. In each learning outcome, there is an information sheet and / or operation sheet or job sheet or performance criteria checklist (additional reading references to help you better understand the required activities). Perform these activities yourself and answer the self-check at the end of each learning outcome. You can take out the answer sheet at the end of each module (or take from your facilitator / trainer a piece of white paper) to write your answer for self-check. If you have any questions, do not hesitate to ask your facilitator or trainer/instructor for help.

Remember to:

- Talk to your trainer and agree on how you will organize this training. Read the module carefully. It is divided into sections that cover all the skills and knowledge you need to complete this module successfully.
- Work through all the information and complete the activities in each section.
- Read information sheets and complete the self-check. Suggested references are included to supplement the materials provided in this module.
- Most probably, your trainer will also be your supervisor or manager. He is there to support you and show you the correct way to do things.
- You will be given plenty of opportunities to ask questions and practice on the job. Make sure you practice your new skills during regular work shifts. This way, you will improve your speed/pace, memory, and your confidence.
- Talk to a more experienced coworker or classmate and ask for advice.
- Use the Self-Checks at the end of each section to test your own progress. Use the Performance Criteria Checklist found after the information sheet to check your own performance.
- When you complete, please ask your trainer to see your demonstration this module.
- When you work through activities, ask for written feedback on your progress. Your trainer will continue to provide feedback / pre-assessment. When you have successfully completed each item, ask your trainer to take note of the report you are preparing for the assessment.
- When you feel confident that you have had sufficient practice, ask your Trainer to evaluate you. The results of your assessment will be recorded in your **Progress Chart and Achievement Chart**.
- You need to be competent in this module before you can perform the next module.

Recognition of Prior Learning (RPL)

You may have some or most of the knowledge and skills covered in this learner’s guide because you have:

- Been working for some time.
- Already completed training in this area.

If you can demonstrate to your trainer that you are competent in a particular skill, you don’t have to do the same training again.

If you have qualification or Certificate(s) of Competency from previous training present it to your trainer. If the skills you acquired are still relevant to the module, they maybe become the

part of the evidence you can present for RPL. If you are not sure about the validity of your skill(s), please talk to your trainer.

At the end of this module is a *Trainer's Record Book*. Use this to record important dates, jobs undertaken and other workplace events that will assist you in providing further detail to your trainer or assessors. A Record of achievements is also provided for your trainer to fill-up once you completed the module.

Detailed module content

Course : Installation and Maintenance Power and Control System in Building

Unit of Competency : Install and Test Electrical in Commercial and Industrial Building

Module Title : Installing and Testing Electrical in Commercial and Industrial Building

Module Descriptor : This module covers the outcomes required to design, install, test, and maintain three phase electrical installation and wiring systems in industrial and commercial premises in compliance with relevant local standards, regulations, and codes of practice.

Learning Outcome (L.O):

Upon completion of this module, students or participants will have the following competencies:

- LO1.** Maintain electrical installations
- LO2.** Prepare electrical drawings of electrical installation / equipment
- LO3.** Install and maintain industrial electrical final circuits and wiring systems
- LO4.** Install and maintain emergency lighting systems
- LO5.** Install and maintain 3-phase AC incoming supply system
- LO6.** Inspect and test electrical installations

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មាតិកា៖

- គំនូរនិងដ្យាក្រាមបច្ចេកទេស
- ស្តង់ដារអគ្គិសនីសម្រាប់ប្រព័ន្ធបីផាស
- តំហែរទាំផ្នែកអគ្គិសនីក្នុងអគារ

Information Sheet No. 5.2.1-1: SAFETY IN THE WORKPLACE

Before we get started on our venture into the wiring of a typical commercial building, let us talk about safety.

Electricity can be dangerous! The Occupational Safety and Health Act (OSHA) regulations and National Fire Protection Association (NFPA) 70E, Standard for Electrical Safety in the Workplace, consider working on energized equipment over 50 volts to represent a shock hazard. Working on electrical equipment with the power turned on can result in death or serious injury, either as a direct result of electricity flowing through a person or from an indirect secondary reaction such as falling off a ladder or falling into the moving parts of equipment. Dropping a metal tool onto live parts or allowing metal shavings from a drilling operation to fall onto live parts of electrical equipment generally results in an arc flash and arc blast, which can cause deadly burns and other physical trauma. The heat of an electrical arc flash has been determined to be as much as 35,000°F (19,427°C), or about four times hotter than the sun. Pressures developed during an arc blast can blow a person across the room and inflict serious injuries. Dirt, debris, and moisture can also set the stage for catastrophic equipment failures and personal injury. Neatness and cleanliness as well as wearing appropriate personal protective equipment and following all safety procedures in the workplace are a must.

The OSHA Code of Federal Regulations (CFR) Number 29, Subpart S, in paragraph 1910.332, discusses the training needed for those who face the risk of electrical injury. Proper training means “trained in and familiar with the safety-related work practices required by paragraphs 1910.331 through 1910.335.” Numerous texts are available that cover the OSHA requirements in great detail.

NFPA 70E, the Standard for Electrical Safety in the Workplace, should be used in conjunction with the OSHA regulations to develop and implement an effective electrical safety program for the workplace. The OSHA rules state what is required. NFPA 70E provides information on how to comply with the OSHA rules and achieve a safe workplace. The NEC defines a qualified person as One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved. * Merely telling someone or being told to be careful does not meet the definition of proper training and does not make the person qualified. This definition emphasizes not only recognizing hazards but also avoiding them. Avoiding an electrical accident is usually worth much more than “an ounce of prevention” and certainly much more than “a pound of cure.” Shock and burn injuries usually happen so fast that it is difficult to react quickly enough to get out of harm’s way. Yet these injuries can almost instantly change your life in a very negative manner. Most often, victims are never the same as before the incident.

Important requirements for training are found in NFPA 70E Article 110. The training required is specifically related to the tasks to be performed. The rule includes a statement: A person can be considered qualified with respect to certain equipment and methods but still be unqualified for others. ** If you have not been trained to do a specific task, you are considered unqualified in that area. The training given and received is required to be documented. If you are ever in an electrical accident that is reportable to OSHA, one of the first things they will ask for is a copy of your personnel record to prove you were trained for the task you were performing. Employers are required to provide appropriate training and safety procedures. Employees are required to comply with the safety training they have received.

Only qualified persons are permitted to work on or near exposed energized equipment. To become qualified, a person must

- have the skill and training necessary to distinguish exposed live parts from other parts of electrical equipment;
- be able to determine the voltage of exposed live parts; and
- be trained in the use of special precautionary techniques, such as personal protective equipment, insulations, shielding material, and insulated tools.

An unqualified person is defined in Article 100 of NFPA 70E as A person who is not a qualified person.* Although this seems simplistic, a person can be considered qualified for performing some tasks and yet be unqualified for other tasks. Training and experience make the difference.

Subpart S, paragraph 1910.333, of the OSHA regulations, requires that safety-related work practices be employed to prevent electrical shock or other injuries resulting from either direct or indirect electrical contact. Live parts to which an employee may be exposed are required to be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazard.

Working on “live” equipment is acceptable only if there would be a greater hazard if the system were de-energized. Examples of this would be life-support systems, some alarm systems, certain ventilation systems in hazardous locations, and the power for critical illumination circuits. Working on energized equipment requires properly insulated tools, proper flame-resistant clothing, rubber gloves, protective shields and goggles, and in some cases insulating blankets. As previously stated, OSHA regulations allow only qualified personnel to work on or near electrical circuits or equipment that has not been de-energized. The OSHA regulations provide rules regarding lockout and tagout (LOTO) to make sure that the electrical equipment being worked on will not inadvertently be turned on while someone is working on the supposedly dead equipment. As the OSHA regulations state, “A lock and a tag shall be placed on each disconnecting means used to de-energize circuits and equipment.”

Some electricians’ contractual agreements require that, as a safety measure, two or more qualified electricians must work together when working on energized circuits. They do not allow untrained apprentices to work on live equipment but do allow apprentices to stand back and observe.

According to NFPA 70E, Standard for Electrical Safety in the Workplace, circuits and conductors are not considered to be in an electrically safe work condition until all sources of energy are removed; the disconnecting means is under lockout/ tagout; and the absence of voltage is verified by an approved voltage tester. Proper personal protective equipment (PPE) is required to be worn while testing equipment for absence of voltage during the lockout/tagout procedure. Equipment is considered to be energized until proven otherwise.

Safety cannot be compromised. Accidents do not always happen to the other person.

Follow this rule: Turn off and lock off the power, and then properly tag the disconnect with a description as to exactly what that particular disconnect serves.

Source D:/

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(page2-page3)

Self-Check No. 5.2.1-1

Answer Key No. 5.2.1-1

Information Sheet No. 5.2.1-2: Wiring Color Codes

Wiring for AC and DC power distribution branch circuits are color coded for identification of individual wires. In some jurisdictions all wire colors are specified in legal documents. In other jurisdictions, only a few conductor colors are so codified. In that case, local custom dictates the “optional” wire colors. **IEC, AC:** Most of Europe abides by IEC (International Electrotechnical Commission) wiring color codes for AC branch circuits. These are listed in Table below.

The older color codes in the table reflect the previous style which did not account for proper phase rotation. The protective ground wire (listed as green-yellow) is green with yellow stripe.

IEC (most of Europe) AC power circuit wiring color codes

Function	label	Color, IEC	Color, old IEC
Protective earth	PE	green-yellow	green-yellow
Neutral	N	blue	blue
Line, single phase	L	brown	brown or black
Line, 3-phase	L1	brown	brown or black
Line, 3-phase	L2	black	brown or black
Line, 3-phase	L3	grey	brown or black

UK, AC: The United Kingdom now follows the IEC AC wiring color codes. Table below lists these along with the obsolete domestic color codes. For adding new colored wiring to existing old colored wiring see Cook.

UK AC power circuit wiring color codes

Function	label	Color, IEC	Old UK color
Protective earth	PE	green-yellow	green-yellow
Neutral	N	blue	black
Line, single phase	L	brown	red
Line, 3-phase	L1	brown	red
Line, 3-phase	L2	black	yellow
Line, 3-phase	L3	grey	blue

US, AC:The US National Electrical Code only mandates white (or grey) for the neutral power conductor and bare copper, green, or green with yellow stripe for the protective ground. In principle any other colors except these may be used for the power conductors. The colors adopted as local practice are shown in Table below.

Black, red, and blue are used for 208 VAC three-phase; brown, orange and yellow are used for 480 VAC. Conductors larger than #6 AWG are only available in black and are color taped at the ends.

US AC power circuit wiring color codes

Function	label	Color, common	Color, alternative
Protective ground	PG	bare, green, or green-yellow	green
Neutral	N	white	grey
Line, single phase	L	black or red (2nd hot)	
Line, 3-phase	L1	black	brown
Line, 3-phase	L2	red	orange
Line, 3-phase	L3	blue	yellow

Canada: Canadian wiring is governed by the CEC (Canadian Electric Code). See Table below. The protective ground is green or green with yellow stripe. The neutral is white, the hot (live or active) single phase wires are black , and red in the case of a second active. Three-phase lines are red, black, and blue.

Canada AC power circuit wiring color codes

Function	label	Color, common
Protective ground	PG	green or green-yellow
Neutral	N	white
Line, single phase	L	black or red (2nd hot)
Line, 3-phase	L1	red
Line, 3-phase	L2	black
Line, 3-phase	L3	blue

IEC, DC: DC power installations, for example, solar power and computer data centers, use color coding which follows the AC standards. The IEC color standard for DC power cables is listed in Table below, adapted from Table 2, Cook.

IEC DC power circuit wiring color codes

Function	label	Color
Protective earth	PE	green-yellow
2-wire unearthed DC Power System		
Positive	L+	brown
Negative	L-	grey
2-wire earthed DC Power System		
Positive (of a negative earthed) circuit	L+	brown
Negative (of a negative earthed) circuit	M	blue
Positive (of a positive earthed) circuit	M	blue
Negative (of a positive earthed) circuit	L-	grey
3-wire earthed DC Power System		
Positive	L+	brown
Mid-wire	M	blue
Negative	L-	grey

US DC power: The US National Electrical Code (for both AC and DC) mandates that the grounded neutral conductor of a power system be white or grey. The protective ground must be bare, green or green-yellow striped. Hot (active) wires may be any other colors except these. However, common practice (per local electrical inspectors) is for the first hot (live or active) wire to be black and the second hot to be red. The recommendations in Table below are by Wiles. He makes no recommendation for ungrounded power system colors. Usage of the ungrounded system is discouraged for safety. However, red (+) and black (-) follows the coloring of the grounded systems in the table.

US recommended DC power circuit wiring color codes

Function	label	Color
Protective ground	PG	bare, green, or green-yellow
2-wire ungrounded DC Power System		
Positive	L+	no recommendation (red)
Negative	L-	no recommendation (black)
2-wire grounded DC Power System		
Positive (of a negative grounded) circuit	L+	red
Negative (of a negative grounded) circuit	N	white
Positive (of a positive grounded) circuit	N	white
Negative (of a positive grounded) circuit	L-	black
3-wire grounded DC Power System		
Positive	L+	red
Mid-wire (center tap)	N	white
Negative	L-	black

Source : <https://www.allaboutcircuits.com/textbook/reference/chpt-2/wiring-color-codes/#:~:text=US%20AC%20power%20circuit%20wiring%20color%20codes&text=The%20protective%20ground%20is%20green,red%2C%20black%2C%20and%20blue.>

Self-Check No. 5.2.1-2

1.IEC (most of Europe) AC power circuit wiring color codes

Function	label	Color, IEC	Color, old IEC
Protective earth			
Neutral			
Line, single phase			
Line, 3-phase			
Line, 3-phase			
Line, 3-phase			

2.Canada AC power circuit wiring color codes

Function	label	Color, common
Protective ground		
Neutral		
Line, single phase		
Line, 3-phase		
Line, 3-phase		
Line, 3-phase		

Answer Key No. 5.2.1-2

1. IEC (most of Europe) AC power circuit wiring color codes

Function	label	Color, IEC	Color, old IEC
Protective earth	PE	green-yellow	green-yellow
Neutral	N	blue	blue
Line, single phase	L	brown	brown or black
Line, 3-phase	L1	brown	brown or black
Line, 3-phase	L2	black	brown or black
Line, 3-phase	L3	grey	brown or black

2. Canada AC power circuit wiring color codes

Function	label	Color, common
Protective ground	PG	green or green-yellow
Neutral	N	white
Line, single phase	L	black or red (2nd hot)
Line, 3-phase	L1	red
Line, 3-phase	L2	black
Line, 3-phase	L3	blue

Information Sheet No. 5.2.1-3: Working Drawings

The construction plans for a building are often called blueprints. This term is a carryover from the days when the plans were blue with white lines. Today, a majority of the plans used have black lines on white paper because this combination is considered easier to read and more economical to produce. The terms plans and working drawings will be commonly used in this text.

A set of 10 plan sheets is included at the back of the text, showing the general and electrical portions of the work specified:

- Sheet A1—Architectural Floor Plan; Basement
- Sheet A2—Architectural Floor Plan; First Floor
- Sheet A3—Architectural Floor Plan; Second Floor: The architectural floor plans give the wall and partition details for the building. These sheets are drawn to scale (dimensioned); the electrician can find exact locations by referring to these sheets. The electrician should also check the plans for the materials used in the general construction, as these will affect when and how the system will be installed.
- Sheet A4—Site Plan, East and West Elevations: The plot plan shows the location of the commercial building and gives needed elevations. The east elevation is the street view of the building, and the west elevation is the back of the building. The index lists the content of all the plan sheets.
- Sheet A5—Elevations; North and South: The electrician must study the elevation dimensions, which are given in feet and hundredths of a foot above sea level. For example, the finished second floor, which is shown at 218.33 ft, is 218 ft 4 in. above sea level.
- Sheet A6—Building Cross-Sections
- Sheet E1—Basement Electrical Plan
- Sheet E2—First Floor Electrical Plan
- Sheet E3—Second Floor Electrical Plan
- Sheet E4—Panelboard & Service Schedules, One-Line Diagram of Service and Feeders

These sheets show the detailed electrical work on an outline of the building. Because dimensions usually are not shown on the electrical plans, the electrician must consult the other sheets for this information. It is recommended that the electrician refer frequently to the other plan sheets to ensure that the electrical installation does not conflict with the work of the other construction trades.

To assist the electrician in recognizing components used by other construction trades, the following illustrations are included: Figure 1-6A and Figure 1-6B, Architectural drafting symbols; Figure 1-7, Standard symbols for plumbing, piping, and valves; and Figure 1-8, Sheet metal ductwork symbols. A comprehensive list of electrical symbols typically used for commercial building wiring is included in Chapter 2 of this text. Electrical symbols that are important for reference are included in Appendix H of this text. However, the electrician should be aware that variations of these symbols may be used, and the specification and/or plans for a specific project must always be consulted.

Building Information Modeling (BIM)

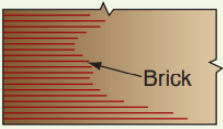
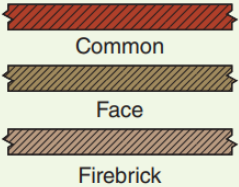
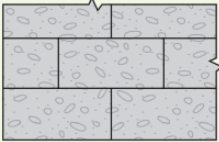
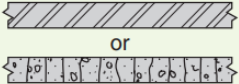
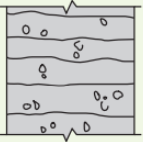
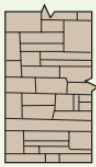
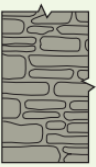











Preparing working drawings has evolved over the years, from draftsmen laboring over a drafting table using T-squares, triangles, compasses, architectural scales, and pen and ink, to computer aided design and drafting software (CADD) programs. The architectural firm prepared the master drawings and furnished these to other disciplines such as mechanical, electrical,


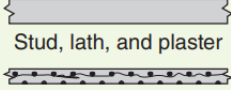






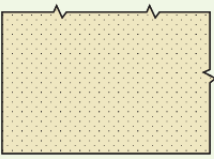
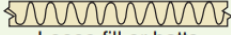



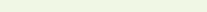


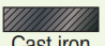
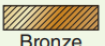

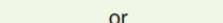
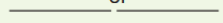


plumbing, and structural engineers, who added design features of their disciplines to the master drawings. A tremendous amount of coordination was necessary to prevent conflicts from developing where piping, equipment, and ductwork, for example, were competing for the same space. Often, these conflicts were not discovered until the building or structure was in some stage of construction. Correcting these conflicts, which almost always required one or more designs to be changed, was time-consuming and expensive. It seemed the larger the project, the more change orders were issued to compensate for conflicts in design.

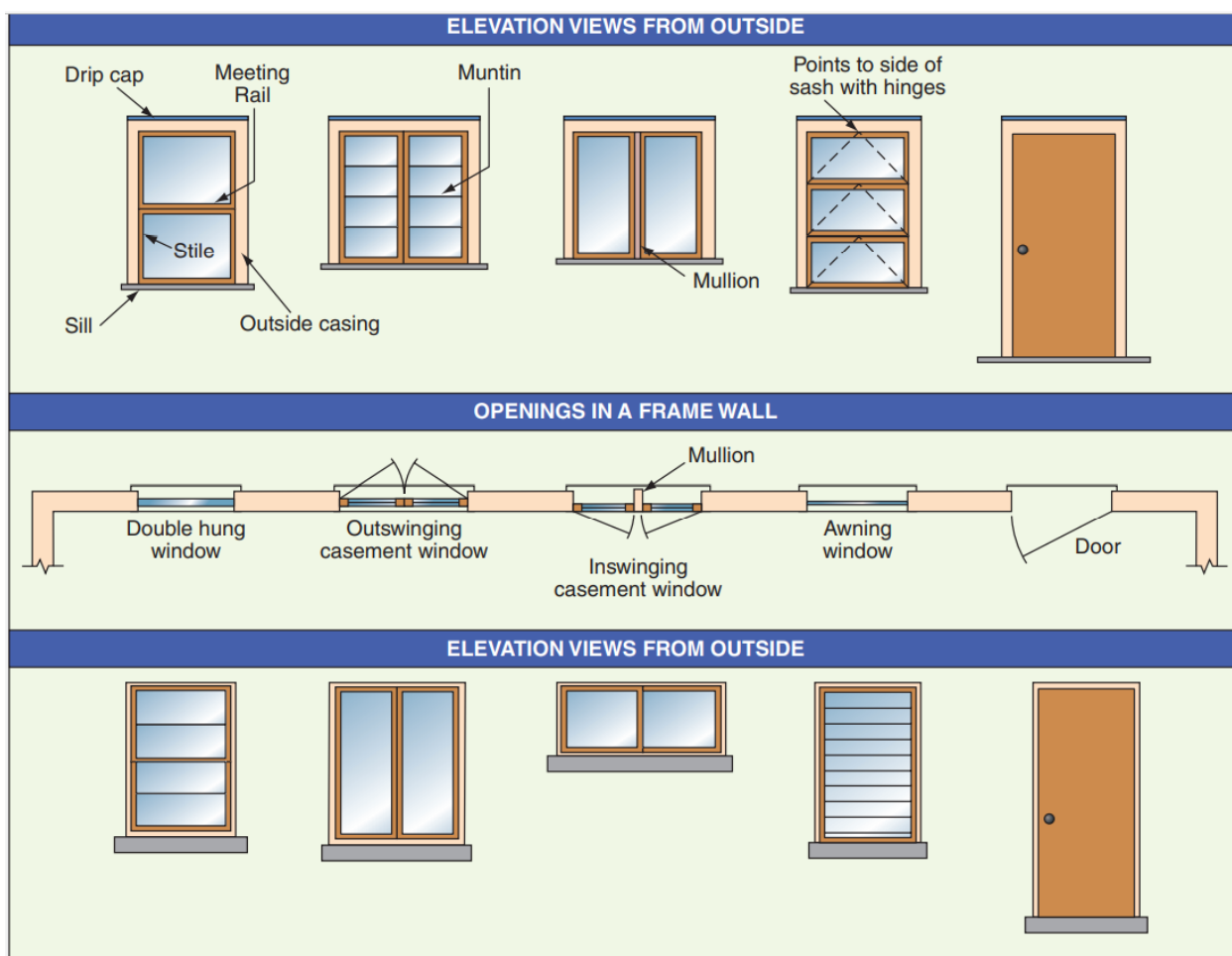
Traditionally, working drawings were and are two-dimensional. This relates to length and width or height of floor plans or cross-sectional drawings. All these drawings were (are) drawn to scale.

Building Information Modeling (BIM) is a significant enhancement to CADD programs. It adds the third dimension of height to the drafting software. This allows a more real-world visualization to take place. Actual dimensions of equipment to be installed, such as panelboards, switchboards, cable tray, conduit and hanger systems are loaded into the software so it can be used effectively in the design process as well as to avoid conflict in design. The dimensions of equipment products or components for all trades or crafts, including mechanical, electrical, plumbing, and structural system components, are entered in a similar way.

The BIM software analyzes design or construction features based on all of the information that has been entered and then produces conflict reports. Typically, a meeting is held weekly, early in the design.

	ELEVATION ↓	PLAN ↓	SECTION ↓
Brick	 With note telling kind of brick (Common, face, etc.)	 Common Face Firebrick	Same as plan views
Concrete block		 or	
Stone	 Cut stone  Rubble	 Cut stone  Rubble  Cast stone (Concrete)	 Cut stone  Cast stone (Concrete)  Rubble or cut stone
Glass	 or 		 Small scale  Large scale

Plaster		 Stud, lath, and plaster  Solid plaster wall	
Wood	 Siding  Panel	Floor areas are left blank; note indicates kind of wood used.	 Ends of boards except trim  Trim
Insulation		 Loose fill or batts  Board and quilt  Solid and cork	Same as plan views
Sheet metal flashing		Occasionally indicated by note	
Metals other than flashing	Indicated by note or drawn to scale	Same as elevation	<div>  Steel  Aluminum  Cast iron  Bronze or brass </div> <div> Small scale Large scale </div>
Structural steel	Indicated by note or drawn to scale	 or  or 	<div> • or — or  </div> Reinforcing bars  L-angles, I-beams, etc. Small scale Large scale



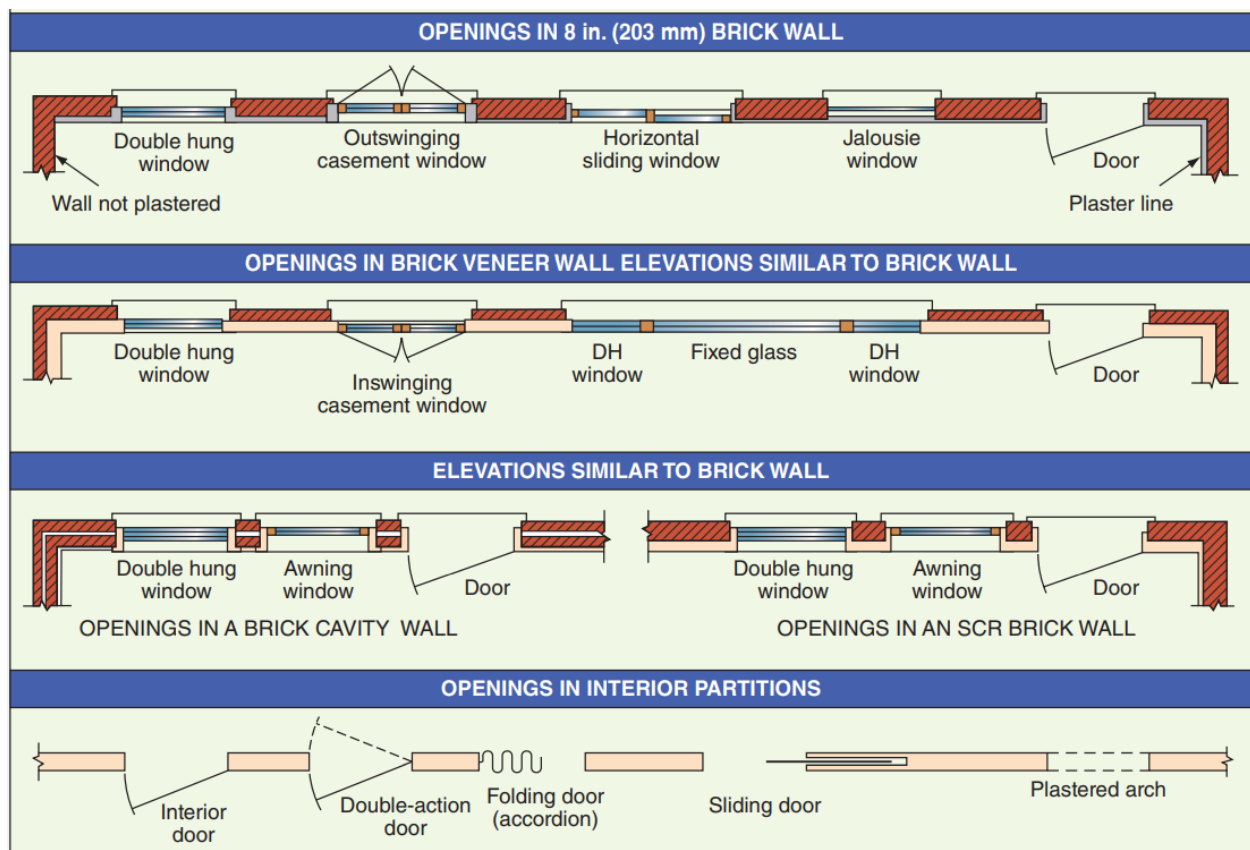


Figure 1-1 Architectural drafting symbols















































































































Plumbing		Plumbing (continued)		Pipe Fittings (continued)		
				Fitting	Screwed	Soldered
Corner Bathtub.....		Drinking Fountain (Projecting-Type).....		Elbow—Long Radius.....		
Recessed Bathtub.....		Hot Water Tank.....		Side Outlet Elbow— Outlet Down.....		
Sitz Bath.....		Water Heater.....		Side Outlet Elbow— Outlet Up.....		
Bidet.....		Meter.....		Base Elbow.....		
Shower Stall.....		Hose Rack.....		Double Branch Elbow.....		
Shower Head.....		Hose Bibb.....		Single Sweep Tee.....		
Overhead Gang Shower.....		Gas Outlet.....		Double Sweep Tee.....		
Pedestal Lavatory.....		Vacuum Outlet.....		Reducing Elbow.....		
Wall Lavatory.....		Drain.....		Tee.....		
Corner Lavatory.....		Grease Separator.....		Tee—Outlet Up.....		
Handicapped Lavatory.....		Oil Separator.....		Tee—Outlet Down.....		
Dental Lavatory.....		Cleanout.....		Side Outlet Tee— Outlet Up.....		
Standard Kitchen Sink.....		Garage Drain.....		Side Outlet Tee— Outlet Down.....		
Kitchen Sink, R & L Drain Board.....		Floor Drain with Backwater Valve.....		Cross.....		
Kitchen Sink, L H Drain Board.....		Roof Sump.....		Concentric Reducer.....		
Combination Sink & Dishwasher.....		Piping		Eccentric Reducer.....		
Combination Sink & Laundry Tray.....		Soil and Waste, Above Grade.....		Lateral.....		
Service Sink.....		Soil and Waste, Below Grade.....		Expansion Joint.....		
Wash Sink (Wall-Type).....		Vent.....		Valves		
Wash Sink.....		Cold Water.....		Valve	Screwed	Soldered
Laundry Tray (Single).....		Hot Water.....		Gate Valve.....		
Laundry Tray (Double).....		Hot Water Return.....		Globe Valve.....		
Water Closet (Tank-Type).....		Fire Line.....		Angle Globe Valve.....		
Water Closet (Integral Tank).....		Gas Line.....		Angle Gate Valve.....		
Water Closet (Flush Valve, Floor Outlet).....		Acid Waste.....		Check Valve.....		
Water Closet (Flush Valve, Wall-Hung) ..		Drinking Water Supply.....		Angle Check Valve.....		
Urinal (Wall-Hung).....		Drinking Water Return.....		Stop Cock.....		
Urinal (Stall).....		Vacuum Cleaning.....		Safety Valve.....		
Urinal (Trough-Type).....		Compressed Air.....		Quick-Opening Valve.....		
Drinking Fountain (Recessed).....		Pipe Fittings		Float Valve.....		
Drinking Fountain (Semi-Recessed).....		Joint.....		Motor-Operated Gate Valve.....		
		Elbow—90°.....				
		Elbow—45°.....				
		Elbow—Turned Up.....				
		Elbow—Turned Down.....				

Figure 1-2 Standard symbols for plumbing, piping, and valves.

Blank Off, adjustable 	Damper automatic 	Damper deflecting 	Damper deflecting up
Damper deflecting down 	Damper volume PLAN ELEVATION 	Duct flow direction 	Duct inclined drop
Duct inclined rise 	Duct section exhaust, return riser to 2nd floor riser to 1st floor 	Duct section supply riser to 2nd floor riser to 1st floor 	Duct section notation type exhaust K E place kitchen
Duct connection below joist 	Fan flexible connection 	Vanes 	Louver & screen air intake
Ventilator, cowl PLAN ELEVATION 	Ventilator, gooseneck PLAN ELEVATION 	Ventilator, rainproof PLAN ELEVATION 	Ventilator, standard PLAN ELEVATION
SINGLE LINE REPRESENTATION			
Supply S 	Return R 	Damper & retractor 	Anchor PA.
Hanger H 	Expansion joint 	Louver opening L 	Register or grille

Figure 1-3 Sheet metal ductwork symbols.



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GENERAL OUTLETS		CONVENIENCE RECEPTACLES			
SYMBOL	NAME	SYMBOL	NAME	SYMBOL	NAME
	General Outlet mounted in the wall		Single Receptacle		Split-Wired Triplex Receptacle
	General Outlet - Wall Mounted		Duplex Receptacle		Single Floor Receptacle
	General Outlet - Ceiling Mounted		Duplex Receptacle in Floor		Single Floor Receptacle
	Recessed Fixture		Ungrounded Duplex Receptacle		Duplex Floor Receptacle
	Junction Box		End of Run (Last Receptacle)		Quadruplex Floor Receptacle
	Blanked Outlet		Duplex Receptacle - GFCI		Single Special-Purpose Receptacle
	Recessed Fixture		Switch and Receptacle		Duplex Special-Purpose Receptacle
	Fan Outlet		Weatherproof Receptacle		Special-Purpose Dishwasher
	Pull Switch Outlet		Range Receptacle		Special-Purpose Heat Pump
	Clock Outlet		Triplex Receptacle		Special-Purpose Clothes Dryer
	Drop Cord Outlet		Triplex Receptacle		Special-Purpose Air Conditioner
	Special-Purpose Outlet		Quadruplex Receptacle		Special-Purpose Range Hood
	Special-Purpose Floor Outlet		Split-Wired Duplex Receptacle		Special-Purpose Garbage Disposal

LIGHTING OUTLETS					
SYMBOL	NAME	SYMBOL	NAME	SYMBOL	NAME
	Incandescent Lighting Fixture		Lighting Fixture - Wall Mounted with Mounting Height		Luminaire Strip Type
	Incandescent Lighting Fixture - Wall Mounted		Lamp Holder Outlet		Fluorescent Strip Lighting
	Incandescent Lighting Fixture - Ceiling Mounted		Lamp Holder - Pull Switch Outlet		Bare Lamp Fluorescent Outlet
	Light Fixture with Pull Chain		Drop Cord Outlet		Fluorescent Fixture Outlet
	Bollard Type Site Lighting		Blanked Outlet		Fluorescent Fixture Recessed Outlet
	In-ground/Floor Mounted Lighting Fixture		Vapor Discharge Lamp Outlet		Continuous-Row Fluorescent Outlet
	Suspended (pendant, chain, etc.) Lighting Fixture		Recessed Light Fixture		Incandescent Track Lighting
	Pole-Mounted on Top Lighting Fixture		Junction Box		Multiple Floodlight Assembly
	Pole-Mounted with Arm Lighting Fixture		Bath Fan/Light Combo		Night light
	Single-Head Spotlight Lighting Fixture		Outdoor Pole - Mounted Fixture		Exit Light and Outlet (Shaded Areas Denote faces)
	Double-Head Spotlight Lighting Fixture		Exit Light Outlet		Emergency Battery Unit with Lighting Heads
			Emergency Battery Remote Lighting Heads		Recessed, Emergency Lighting Fixture
			Luminaire Providing Emergency Illumination (Filled In)		

	Single Receptacle Outlet		Branch Circuit (Number indicates number of circuits and arrow indicates home run to panel)
	Duplex Receptacle Outlet		Three wires in cable or raceway
	Double Duplex Receptacle Outlet (Quad)		Four wires in cable or raceway, etc.
WP 	Waterproof Receptacle Outlet		Wiring concealed in wall or ceiling
GFCI 	Ground-Fault Circuit Interrupter Receptacle Outlet		Wiring concealed in floor
	Triplex Receptacle Outlet		Exposed wiring
D 	Clothes Dryer Outlet		Wiring turned up
R 	Range Outlet		Wiring turned down
DW 	Special-Purpose Outlet (Letter indicates use; DW=dishwasher)		Switch leg, connects outlets with control points
	Floor Outlet		Thermostat
	Clock Outlet		Television Outlet
	Fan Outlet		Telephone Jack
	Floor Duplex Receptacle Outlet		Electrical Panel
			Battery

Self-Check No. 5.2.1-3

1. Draw a symbol :
 - Single receptacle outlet?
 - Television outlet?
 - Floor duplex receptacle outlet?
 - Telephone jack?

Answer Key No. 5.2.1-3

1. Draw a symbol :



Single Receptacle Outlet



Television Outlet



Floor Duplex Receptacle Outlet










Telephone Jack

Information Sheet No. 5.2.1-4: ឧបករណ៍ សម្ភារ បរិក្ខារ និងគ្រឿងប្រដាប់ការពារសុវត្ថិភាពផ្ទាល់ខ្លួន

1. ឧបករណ៍ និងបរិក្ខារ

ល.រ	រូបភាព	បរិយាយ
1		កេសដាស់សម្ភារ និង ឧបករណ៍(Hand Tools, Toolbox) + ជាប្រអប់សម្រាប់ របស់របបសម្រាប់ធ្វើការតម្លើង ជួសជុល និង សម្រាប់លាងជាដើម ឧទាហរណ៍ ដាក់ដង្កាប់ តួណីវិស ម៉ែត្រ...
2		វិស័រពត់បំពង់ PVC ប្រើសម្រាប់ពត់បំពង់ PVC តាមមុំផ្សេងៗស្រប ទៅតាមតម្រូវការប្លង់
3		កន្ត្រែកកាត់ប្រអប់ជ័រ PVC ប្រើសម្រាប់កាត់ប្រអប់ជ័រ PVC តាមមុំ ផ្សេងៗស្របទៅតាមតម្រូវការប្លង់
4		កន្ត្រែកកាត់បំពង់ PVC ប្រើសម្រាប់កាត់បំពង់ PVC ស្របទៅតាម តម្រូវការ
5		រណារកាត់ប្រអប់ជ័រ PVC ប្រើសម្រាប់កាត់តំរឹមប្រអប់ជ័រ PVC និងកាត់ប្រអប់ជ័រ PVC មុំផ្សេងៗស្របទៅតាមតម្រូវការប្លង់
6		ដង្កាប់អូតូម៉ាតិចមាត់ស្មើ(ដង្កាប់ច្របាច់បំពង់ Pinch of Plier) + គេប្រើសម្រាប់ភ្ជាប់ ឬច្របាច់ដើម្បីឱ្យមានលំនឹង

7		<p>ខ្សែនាំ ជាប្រភេទខ្សែជ័រតាន់ដែលអាចបទបែនទីតាំងចង្អៀតហើយមាននៅខាងចុងមានប្រដាប់ថ្នកខ្សែភ្លើង។</p> <p>ការប្រើប្រាស់ យកចុងខ្សែនាំទៅភ្ជាប់និងចុងខ្សែភ្លើងហើយរុំស្មុតអោយជាប់តួចរុញចូលទៅក្នុងបំពង់រត់ខ្សែភ្លើង។</p>
8		<p>ផ្លែបោះពិដាន ប្រើសម្រាប់បោះពិដានដើម្បីបង្កប់អំពូលមូលទៅតាមតម្រូវការប្លង់</p>
9		<p>ម៉ែត្រទាញប្រើសម្រាប់វាស់ខ្នាតក្នុងការងារដំឡើងអគ្គិសនីតាមតម្រូវការប្លង់</p>
10		<p>ម៉ែត្រវាស់កម្រិតល្បឿន ប្រើសម្រាប់វាស់កម្រិតល្បឿនក្នុងការដំឡើង</p>
11		<p>សោគ្រាប់ ប្រើសម្រាប់មូលបន្ទុកប៊ូឡុង ឬមូលរឹត</p>
12		<p>ម៉ាឡេត (Spanner) ប្រើសម្រាប់មូលបន្ទុក ឬ រឹត ដោយយើងអាចលៃតម្រូវបានទៅតាមប្រភេទនៃទំហំខ្នាតអេត្រូ ឬ ក្បាលប៊ូឡុង</p>
13		<p>សោជ្រុង សោតាន់ ឬ សោឈ្មោល (Hexagonal Wrench) ប្រើសម្រាប់មូលបន្ទុក ឬ រឹតខ្នាតដែលមានប្រហោងរាង៦ជ្រុង</p>

14		ផ្លែបោះដែក ប្រើសម្រាប់បោះដែក ទៅតាមតម្រូវការប្លង់
15		ផ្លែបោះ ប្រើសម្រាប់បោះជើងកុងតាក់ ប្រអប់ជ័រPVC និងប្រភេទជ័រផ្សេងៗ ទៅតាមតម្រូវការប្លង់
16		ដង និងផ្លែណាអាវដែក(Hack Saw) ប្រើសម្រាប់អារ ឬ កាត់បំពង់ទុយោទង់ដែង និង ទុយោទឹក
17		ដែកឆាប ប្រើសម្រាប់ឆាបសម្អាតមុខបំពង់ ឬ ទុយោ
18		ញញួរ(Hammer) ប្រើសម្រាប់ដកដែកគោល ឬ ការជំផ្សេងៗ
19		តួណឺវីស ប្រើសម្រាប់មូលបន្ទុរ ឬមូលវីតវីសដែលមានរាងសញ្ញាបូក(+)និងសញ្ញា(-)
20		ដង្កាប់មាត់ខ្លី(ដង្កាប់មាត់ក្រពើ) ប្រើសម្រាប់មូលខ្សែភ្លើង និងជួយសម្រួលការងារផ្សេង

21		ដង្កាប់កាត់ ប្រើសម្រាប់កាត់ខ្សែភ្លើងទៅតាមតម្រូវការផ្សេងៗ
22		ដង្កាប់មាត់វែង ប្រើសម្រាប់មូលខ្សែភ្លើង ធ្វើដំណាខ្សែភ្លើង និងជួយសម្រួលការងារផ្សេងៗ
23		បន្ទាត់កែង (Square ruler) ប្រើសម្រាប់គូសវាស់ ទីតាំងមុំ 90 ជឺក្រេ 45 ជឺក្រេ និងប្រើទៅតាមតម្រូវការផ្សេងៗ
24		ខ្សែតៅ (chalk line) ប្រើសម្រាប់គូសបន្ទាត់ឈរ ឬបន្ទាត់ដេកស្របតាមតម្រូវការការងារ
25		កូនប្រយោល (plum bob) ប្រើសម្រាប់ប្រយោលរកបន្ទាត់ឈរ
26		ក្បាលហ្គាសប្រើសម្រាប់រោលប្លែនកៅស៊ូស្រោមក្បាលកូស

27		ជណ្តើររបញ្ជូ ប្រើសម្រាប់ធ្វើការងារខ្ពស់
28		ជណ្តើរផ្អែក ប្រើសម្រាប់ធ្វើការងារខ្ពស់
29		កន្ត្រៃកាត់ខ្សែភ្លើង ប្រើសម្រាប់កាត់តំរឹមតំណខ្សែ និងកាត់ខ្សែភ្លើង ឬជំនួយក្នុងតម្រូវការការងារផ្សេង
30		ព្រីភ្លើង ប្រើសម្រាប់បន្តចរន្តទៅឧបករណ៍អគ្គិសនីផ្សេងៗ
31		ប៊ិចតេស្តភ្លើង ប្រើសម្រាប់តេស្តតង់ស្យុង
32		ដង្កាប់បកអ៊ីសូឡង់ខ្សែ ប្រើសម្រាប់សកអ៊ីសូឡង់ខ្សែភ្លើងដែល មានទំហំ 0.5mm²-2.5mm²
33		ឧបករណ៍គៀបកូស ប្រើសម្រាប់គៀបកូសដែលមានទំហំ 0.5mm -6mm
34		ឧបករណ៍គៀបកូស ប្រើសម្រាប់គៀបកូសដែលមានទំហំ 10mm-240mm

35		ដង្កាប់បកអ៊ីសូឡង់ខ្សែ ប្រើសម្រាប់បកអ៊ីសូឡង់ខ្សែភ្លើងដែលមានទំហំ 0.5mm²-6mm²
36		កាំបិតចិតអ៊ីសូឡង់ខ្សែ ប្រើសម្រាប់ចិតអ៊ីសូឡង់ខ្សែភ្លើង
37		ឧបករណ៍ពត់បំពង់លោហៈ ប្រើសម្រាប់ពត់បំពង់លោហៈតាមមុំផ្សេងៗស្របទៅតាមតម្រូវការប្លង់
38		ប្រដាប់ដាក់ឧបករណ៍ជាប់ខ្សែក្រវ៉ាត់ ប្រើសម្រាប់ដាក់ឧបករណ៍នៅជាប់និងចង្កេះ
39		ខ្មៅដៃ ប្រើសម្រាប់គូសដៅទីតាំងផ្សេងៗតាមតម្រូវការការងារ
40		តុជាមួយអង្គ ប្រើសម្រាប់ទប់សម្ភារផ្សេងដែលជាតម្រូវការក្នុងការងារអគ្គិសនី
41		ឧបករណ៍ផ្អែកដៅ ប្រើសម្រាប់ផ្អែកម្តៅទៅលើបំពង់ PVC ដើម្បីពត់និងប្រើតាមតម្រូវការផ្សេងៗ

42		ម៉ូលទីម៉ែត្រអាណាឡូក (ពហុម៉ែត្រ) ប្រើសម្រាប់តេស្តសៀគ្វីអគ្គិសនី
43		ម៉ូលទីម៉ែត្រឌីជីថល (ពហុម៉ែត្រ) ប្រើសម្រាប់តេស្តសៀគ្វីអគ្គិសនី
44		ឧបករណ៍តេស្តអ៊ីសូឡង់ ប្រើសម្រាប់តេស្តអ៊ីសូឡង់របស់ខ្សែភ្លើង
45		ម៉ូទ័រកាត់ ប្រើសម្រាប់ការងារកាត់ផ្សេងៗដែលជាតម្រូវការ
46		ម៉ូទ័រស្វានប្រើថ្ម ប្រើសម្រាប់ការងារស្វានតូចៗ ឬការងារមូលបន្ទុក និងមូលរឹតផ្សេងៗដែលជាតម្រូវការ
47		ម៉ូទ័រស្វានបុកប្រើចរន្តអគ្គិសនី ប្រើសម្រាប់ការងារស្វានបុកតិចតួចដែលជាតម្រូវការការងារ

48		ម៉ូទ័រស្វ័យប្រវត្តិ ប្រើសម្រាប់ការងារស្វ័យប្រវត្តិ ដែលជាតម្រូវការការងារ
49		ឧបករណ៍វាស់លំដាប់ផាស ប្រើសម្រាប់វាស់លំដាប់ផាស (L1 L2 L3)
50		ឧបករណ៍តេស្តតង់ស្យុង ប្រើសម្រាប់វាស់ស្ទង់ថាមានតង់ស្យុង ឬគ្មាន
51		ម៉ីហ្គ័រ (Megger) ប្រើសម្រាប់វាស់ស៊ីស្តង់អ៊ីសូឡង់ វាស់តង់ស្យុង និងជំនួយនៅក្នុងការតេស្តនៃការដំឡើង
52		ឧបករណ៍តេស្តចរន្តលេចជ្រាប (RCD tester) ប្រើសម្រាប់តេស្ត រកកម្រិតចរន្តលេចជ្រាប
53		ឧបករណ៍តេស្តម៉ាស់ដីដីចល ប្រើសម្រាប់វាស់កម្រិតស៊ីស្តង់ដី ក្នុងការដំឡើងប្រព័ន្ធខ្សែដី
54		Polarity tester <ul style="list-style-type: none"> • SANS164-2 (Type N) plug socket compatible • Ready-board compatible • LED wiring integrity indication • Faulty Earth Detector (LCD)/Live on earth • ELCB Tester (10-35mA) • Includes SANS 164-1: 16A – 3 PIN adapter plug








2.គ្រឿងប្រដាប់ការពារសុវត្ថិភាពផ្ទាល់ខ្លួន PPE		
ល.រ	រូបភាព	បរិយាយ
1		មួកសុវត្ថិភាព
2		ស្បែកជើងសុវត្ថិភាព
3		ឯកសណ្ឋានសុវត្ថិភាព
4		ស្រោមដៃសុវត្ថិភាព
5		ម៉ាស់ការពារធូលី
6		ខ្សែក្រវ៉ាត់សុវត្ថិភាព

7	 <small>shutterstock.com - 5593964171</small>	វ៉ែនតាសុវត្ថិភាព
8		កាសសុវត្ថិភាព
9		របាំងការពារ

Self-Check No. 5.2.1-4

1.ចូរពន្យល់ពីតួនាទីឧបករណ៍ និងបរិក្ខារ

ល.រ	រូបភាព	បរិយាយ
1		
2		
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13		

2.តើគ្រឿងប្រដាប់ការពារសុវត្ថិភាពផ្ទាល់ខ្លួនមានអ្វីខ្លះ?

Answer Key No. 5.2.1-4

1.

ល.រ	រូបភាព	បរិយាយ
1		កេសដាស់សម្ភារ និង ឧបករណ៍(Hand Tools, Toolbox) + ជាប្រអប់សម្រាប់ របស់របបសម្រាប់ធ្វើការតម្លើង ជួសជុល និង សម្រាប់លាងជាដើម ឧទាហរណ៍ ដាក់ដង្កាប់ តួណីវិស ម៉ែត្រ...
2		វិសរតតំបំពង់ PVC ប្រើសម្រាប់ពតតំបំពង់ PVC តាមមុំផ្សេងៗស្រប ទៅតាមតម្រូវការប្លង់
3		កន្ត្រៃកាត់ប្រអប់ជ័រ PVC ប្រើសម្រាប់កាត់ប្រអប់ជ័រ PVC តាមមុំ ផ្សេងៗស្របទៅតាមតម្រូវការប្លង់
4		កន្ត្រៃកាត់បំពង់ PVC ប្រើសម្រាប់កាត់បំពង់ PVC ស្របទៅតាម តម្រូវការ
5		រណារកាត់ប្រអប់ជ័រ PVC ប្រើសម្រាប់កាត់តំរឹមប្រអប់ជ័រ PVC និងកាត់ប្រអប់ជ័រ PVC មុំផ្សេងៗស្របទៅតាមតម្រូវការប្លង់
6		ដង្កាប់អូតូម៉ាតិចមាត់ស្មើ(ដង្កាប់ច្របាច់បំពង់ Pinch of Plier) + គេប្រើសម្រាប់តៀប ឬច្របាច់ដើម្បីឱ្យមានលំនឹង

7		ឧបករណ៍គៀបកូស ប្រើសម្រាប់គៀបកូសដែលមានទំហំ 10mm-240mm
8		ដង្កាប់បកអ៊ីសូឡង់ខ្សែ ប្រើសម្រាប់សកអ៊ីសូឡង់ខ្សែភ្លើងដែល មានទំហំ0.5mm ² -6mm ²
9		កាំបិតចិតអ៊ីសូឡង់ខ្សែ ប្រើសម្រាប់ចិតអ៊ីសូឡង់ខ្សែភ្លើង
10		ឧបករណ៍ពត់បំពង់លោហៈ ប្រើសម្រាប់ពត់បំពង់លោហៈតាមមុំ ផ្សេងៗស្របទៅតាមតម្រូវការប្លង់
11		ប្រដាប់ដាក់ឧបករណ៍ជាប់ខ្សែក្រវ៉ាត់ ប្រើសម្រាប់ដាក់ឧបករណ៍ នៅជាប់និងចង្កេះ
12		ខ្មៅដៃ ប្រើសម្រាប់គូសដៅទីតាំងផ្សេងៗតាមតម្រូវការការងារ
13		តុជាមួយអង្កុំ ប្រើសម្រាប់ទប់សម្ភារផ្សេងដែលជាតម្រូវការក្នុង ការងារអគ្គិសនី

2. គ្រឿងប្រដាប់ការពារសុវត្ថិភាពផ្ទាល់ខ្លួនមាន

- មួកសុវត្ថិភាព
- ស្បែកជើងសុវត្ថិភាព
- ឯកសណ្ឋានសុវត្ថិភាព
- ស្រោមដៃសុវត្ថិភាព
- ម៉ាស់ការពារធ្មេញ
- ខ្សែក្រវ៉ាត់សុវត្ថិភាព
- វ៉ែនតាសុវត្ថិភាព
- កាសសុវត្ថិភាព
- របាំងការពារ

ល.ស២៖ រៀបចំគំនូរអគ្គិសនីនៃការដំឡើង / បរិក្ខារអគ្គិសនី

លក្ខណវិនិច្ឆ័យនៃការវាយតម្លៃ៖

១. បកស្រាយគំនូរ និងដ្យាក្រាមសម្រាប់ការដំឡើងបណ្តាញអគ្គិសនី និងបរិក្ខារឱ្យបានត្រឹមត្រូវ
២. ប្រើប្រាស់និមិត្តសញ្ញាអគ្គិសនីឱ្យបានត្រឹមត្រូវតាមតម្រូវការ
៣. គណនាចរន្តរបស់បន្ទុកផ្នែកលើតម្រូវការ
៤. គណនាទំហំឧបករណ៍ការពារបណ្តាញមេ និងចែកចាយដោយអនុលោមតាមតម្រូវការ
៥. ជ្រើសរើសទំហំមុខកាត់ខ្សែមេ និងខ្សែចែកចាយឱ្យបានសមរម្យ
៦. ជ្រើសរើសក្នុងត្រីកោណសម្រាប់ការដំឡើងបណ្តាញអគ្គិសនីផ្អែកតាមតម្រូវការ
៧. បែងចែកបន្ទុកទៅជាសន្លឹកមួយៗនៃប្រភពផ្គត់ផ្គង់ដោយអនុលោមតាមបទប្បញ្ញត្តិ
៨. គូសគំនូរ និងដ្យាក្រាមអគ្គិសនីដោយអនុលោមតាមលក្ខណៈបច្ចេកទេស ស្តង់ដារពាក់ព័ន្ធ និងក្រមប្រតិបត្តិ

មាតិកា៖

- និមិត្តសញ្ញាអគ្គិសនី
- ការគណនាក្នុងត្រីកោណ
- ការគណនានិងបែងចែកបន្ទុកប្រើប្រាស់
- ជ្រើសរើសមុខកាត់ខ្សែ
- ជ្រើសរើសឧបករណ៍ការពារ
- ការប្រើប្រាស់កម្មវិធី AUTOCAD

Information Sheet No. 5.2.2-1: Electrical Symbols

The electrical symbols you are most likely to find on electrical construction drawings are found in Figures 2-2 through 2-11 in this chapter. Knowing the special characteristics of these symbols will improve your ability to remember them and to interpret other symbols that are not used in these drawings. Other symbols you may find on working drawings are included in Appendix H-1 through H-13 of this textbook.

Symbols used in this book are widely understood in the electrical design and construction fields. Other symbols may also be used, provided that a suitable explanation of their meaning is included on the drawings where the symbol is used or that a symbol legend sheet is provided. Most drawings today are produced with computer-aided design and drafting software (a CADD program). A symbols library is included with the CADD software. These symbols may vary slightly from one software package to another, but the experienced electrician can usually readily understand them. Electrical plans are generally drawn to scale. However, graphic symbols indicate only the approximate locations of electrical equipment, such as switches and receptacles, and are not drawn to scale. Details are provided in the specifications or on the plans, which will give mounting heights, dimensions above countertops, distances from doors, height above the floor, and so forth, for accurate locations of receptacles, luminaires, and other equipment. If more than one symbol is located immediately adjacent to another, it usually means that a multigang box for multiple wiring devices and a single cover are to be installed. For example, if three switches are to be located in a common box and under a 3-gang cover plate, three “S” symbols will be drawn at the location. Obviously, the electrician will need to be certain a box with adequate size is selected to enclose the number of wires and devices required. The owner or architect will indicate in the specifications the maximum number of wiring devices permitted in a common box. Typically, this is three or four. Cover plates to accommodate more than four switches are often a special order item. Several figures follow, with blueprint symbols grouped by type. Some symbols have an indicator such as the dimensions of pull boxes, size and number of conductors in a raceway or cable, whether the luminaire is supplied by a normal or emergency circuit, and any special circuitry or switching arrangement. Raceway symbols are shown in Figure 2-2. Additional indicators are shown in Figure 2-3. For installations, an indication of conduit or cable routing on the drawing is diagrammatic—that is, conduit or cable is shown being routed from one location to another. However, actual routing of raceways or cables is left up to the electrician on the job. The electrician may want to install some conduit or cable under the floor and, in other cases, drill holes through joists or other framing




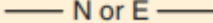


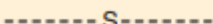

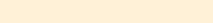
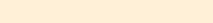
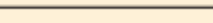
RACEWAY SYMBOLS	
PREFERRED SYMBOL	DESCRIPTION
	Conduit concealed in finished areas, exposed in unfinished areas.
	Conduit concealed in or under floor slab.
	Nonrigid raceway system.
	N = Normal E = Emergency circuit.
	Underfloor telecommunications raceway.
	Underfloor raceway for power and telecommunications.
	Underfloor signal raceway.
	Underfloor raceway for power, telephone, and data.
	Undercarpet flat conductor cable (FCC) wiring system, power.
	Undercarpet flat conductor cable (FCC) wiring system, telephone.
	Undercarpet flat conductor cable (FCC) wiring system, data.

Figure 2-2 Raceway symbols.

members or even run the wiring method above ceiling joists. Note that Type MC cable can most often be substituted for raceways such as electrical metallic tubing (EMT) for branch circuit and feeder wiring unless restricted by the local authority. The labor units for installing Type MC cable are often lower than for EMT, so there may be an economic advantage to using the cable for branch-circuit wiring in commercial buildings. Some smaller commercial buildings are permitted to be wired with nonmetallic sheathed cable. Specific occupancies may require specific wiring methods. For example, patient care areas of doctors' and dentists' offices are required to be wired in a metallic wiring method such as EMT or appropriate Type AC or Type MC cables, in compliance with Article 517.

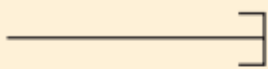


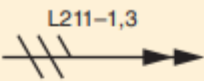


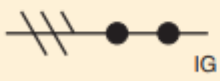
RACEWAY INDICATOR SYMBOLS	
PREFERRED SYMBOL	DESCRIPTION
	Conduit stub. Terminate with bushing or cap if underground.
	Conduit turning up.
	Conduit turning down.
SZ 2C, 4#1&1#6GND. OR SZ 53cm, 4#1&1#6GND.	Indicates trade size 2" or 53 mm conduit with (4) 1 AWG and (1) 6 AWG ground.
(2)SZ 2C, 4#1&1#6GND. OR (2)SZ 53cm, 4#1&1#6GND.	Indicates (2) trade size 2" or 53 mm conduits with (4) 1 AWG and (1) 6 AWG ground conductors in each conduit.
	Homerun to panelboard. Number of arrows indicates number of circuits. (Example: Homerun to panel L211 CKTS. #1 and #3.)
	Flexible connection to equipment.
	Direct connection to equipment.
	Branch circuit, full hashes indicate ungrounded—"hot" (or switch-leg)—circuit conductors. Half hashes indicate grounded neutral circuit conductors. (No hashes indicates 1 hot and 1 neutral.) Dots indicate grounding conductors. Equipment bond size U.N.O. "IG" indicates an isolated grounding conductor.

Figure 2-3 Raceway indicator symbols

Figure 2-3 shows raceway indicator symbols. These symbols supplement or modify the symbols shown in Figure 2-2. When concealed raceways are drawn on plans, they usually are shown as curved lines. Hash marks drawn across raceway or cable lines indicate the number and use of the installed conductors. There are different acceptable ways of using hash marks. One way is to use full slashes to indicate “hot” (or switch-leg) conductor(s), and half slashes to indicate grounded neutral conductor(s). No slashes indicate one “hot” and one grounded conductor. A dot(s) indicates an equipment grounding conductor(s). The letters “IG” are added near the dot to indicate an isolated-insulated grounding conductor(s). Another way is to use long hash marks to indicate a neutral (white) conductor and short hash marks to indicate “hot” ungrounded conductors. Check the plans and/or specifications for a Symbol Schedule to be sure you fully understand the meaning of the hash marks indicated on the plans you are working with. An arrowhead at the end of a branch-circuit symbol indicates that the raceway goes from this point to the panelboard but will no longer be drawn on the plans. This symbol is used to avoid the graphic congestion created if all the lines were to come into a single point on the plans. The small numbers indicate which branch circuits are to be installed in the raceway. As the overcurrent devices in a panelboard are usually numbered with odd numbers on the left and even on the right, it is common to see groups of odd or even numbers. When raceways are installed vertically in the building, from one floor to another, the vertical direction may be represented by the arrow symbol inside a circle. A dot represents the head of the arrow and indicates that the raceway is headed upward. A cross represents the tail of the arrow and that the raceway is headed downward. When both are shown, it means the raceway passes through. This symbol should be shown in the exact same location on the next, or previous, floor plan but should indicate the opposite direction. If the raceway is for telephone system use, the line will be broken and an uppercase “T” will be inserted. Architects and engineers do not often indicate the size or dimensions of pull or junction boxes that are required but leave it up to the electrician to follow the Code rules for proper sizing of these boxes. The location of specific raceways, such as underfloor raceway systems, are often shown on the scaled drawings, so the electrician must carefully follow the layout. The location of power, telephone, and data outlets will also be shown on the scaled floor drawings. It is obviously critical to get these locations correctly positioned before the concrete floor is poured. Symbols for pull and junction boxes and busways are located in Figure H-1 of Appendix H. The location of luminaires (often referred to in trade jargon as “fixtures”) is often specifically identified on the construction drawings. See Figure 2-4 for typical symbols used on construction drawings. The specific type of luminaire to be installed as well as the manufacturer and model is often identified in the specifications or in a luminaire schedule.


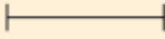

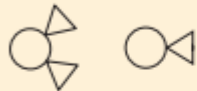




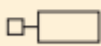
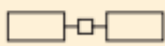


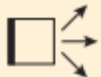
LUMINAIRE (LIGHTING FIXTURE) SYMBOLS	
PREFERRED SYMBOL	DESCRIPTION
	Luminaire: (drawn to approximate shape and to scale or large enough for clarity).
	Luminaire strip type (length drawn to scale).
	Fluorescent strip luminaire.
	Fixture—double- or single-head spotlight or floodlight.
	Exit luminaire fixture. Arrows and exit face as indicated on drawings (mounting heights to be determined by job specifications).
	Light track. Length as indicated on the drawings, with number of fixtures as indicated on drawings, and indicated in the fixture schedule.
	Emergency battery remote luminaire heads.
	Emergency battery unit with luminaire heads.
	Single-luminaire pole-mounted site luminaire fixture.
	Twin-luminaire pole-mounted site luminaire fixture.
	Roadway luminaire—cobra head.
	Bollard-type site luminaire.
	Outdoor wallpack.

Figure 2-4 Luminaire (lighting fixture) symbols.

Luminaires must be designed and installed to be appropriate with all environmental conditions where the luminaire is installed. For example, luminaires installed at a wet location must be identified for those conditions. The luminaire manufacture often includes instructions

for installing the luminaire to prevent the entrance of water, such as gasketing or caulking. These instructions must be followed. Carefully follow any mounting height specified for the luminaire.

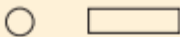

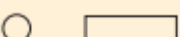





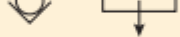


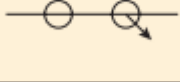
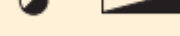
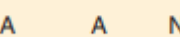
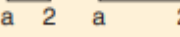
LUMINAIRE (LIGHTING FIXTURE) BASIC AND EXTENDED MODIFIERS	
PREFERRED SYMBOL	DESCRIPTION
	Surface-mounted fixture.
	Recessed fixture.
	Wall-mounted fixture.
	Suspended, pendant, chain, stem, or cable-hung fixture.
	Pole mounted with arm.
	Pole mounted on top.
	In-ground or floor mounted. (Box around symbol.)
	Accent/directional arrow, with or without tail. (Drawn from photometric center in direction of optics or photometric orientation.)
	Directional aiming line. (Drawn from photometric center and may be extended to actual aiming point if required.)
	Track mounted; length, luminaire types and quantities as shown. (Track length drawn to scale.)
	Luminaire providing emergency illumination. (Filled in.)
	Standard designations for all luminaire fixtures. "A" = Fixture type, refer to fixture schedule "NL" = Unswitched night light "2" = Circuit number "a" = Switch control
	Mounting height.
	Louvers.
	Recessed, emergency fixture.
NOTE: Modifiers are shown with specific base symbols for clarity. Each modifier can be used with any of the base symbols.	

Figure 2-5 Luminaire (lighting fixture) basic and extended modifiers.

An indication of luminaire mounting or orientation is provided, as shown in Figure 2-5. As can be seen, these modifiers are important as they indicate the type of luminaire as well as orientation.











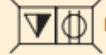




OUTLET AND RECEPTACLE SYMBOLS AND NOTATIONS			
PREFERRED SYMBOL	DESCRIPTION	PREFERRED SYMBOL	DESCRIPTION
	Floor duplex receptacle. F = flush MTD. S = surface MTD.		Multioutlet assembly with outlets on centers as indicated on the drawings and in the specifications, mounted 6" above counter or at height as directed. A—indicates type.
	Duplex convenience receptacle. 20A 125V.		Multioutlet assembly, devices as indicated.
EP-2 CKT.1 	Duplex convenience receptacle on emergency/standby circuit. Specify panelboard and circuit.	 OR 	Special receptacle—typical notation: 1—indicates example "1" = _A_/_V_/_Pole_/_Wire_/_NEMA_ "2" = _A_/_V_/_Pole_/_Wire_/_NEMA_ "3" = _A_/_V_/_Pole_/_Wire_/_NEMA_
	Single convenience receptacle.		Clock hanger outlet recessed mounted 8'-0" AFF or 8" below ceiling as appropriate and as directed.
EP-2 CKT.3 	Single convenience receptacle on emergency/standby circuit. Specify panelboard and circuit.		Flush-mounted floor box, adjustable, with both power and voice/data receptacles.
	Double duplex convenience receptacle.		Duplex receptacle ceiling mounted 15 or 20A 125V.
EP-2 CKT.5 	Double duplex convenience receptacle on emergency/standby circuit. Specify panelboard and circuit.		Double duplex receptacle—ceiling mounted.

Figure 2-6 Outlet and receptacle symbols and notations.

Receptacles And Outlets Typical Outlet Notations:

- “a” = Switched outlet,
- “a”—indicates switch control.
- “C” = Mounted 6" above counter or 42" AFF. Coordinate exact mounting height with architectural drawings.
- “CLG” = Ceiling mounted.
- “D” = Dedicated device on individual branch circuit.
- “E” = Emergency.
- “EXIST.” = Existing device/equipment.
- “F” = Flush floor box with fire/smoke rated penetration.
- “GFCI” = Ground fault circuit interrupter, personnel protection.
- “GFPE” = Ground fault protection of equipment.
- “H” = Horizontally mounted.
- “IG” = Isolated ground receptacle with separate green ground conductor to isolated ground bus in panel.
- “M” = Modular furniture service—provide flexible connection; coordinate exact location with furniture plans.
- “PT” = Poke thru with 2-hour fire/smoke-rated penetration.
- “S” = Surface-mounted floor box.
- “SP” = Surge protection receptacle.
- “T” = Tamper-resistant safety receptacle.
- “TL” = Twist-lock.
- “W” = Wall-mounted device at 48" AFF unless otherwise indicated.

“WP” = Weatherproof receptacle with listed coverplate for wet location with plug installed.
MTD. 48" AFF unless otherwise indicated.
+XX = Dimensioned height.

Figure 2-6 shows typical symbols for outlets and receptacles. Note that the term outlet can refer to a variety of receptacles or connection points for utilization equipment. Outlets include receptacle outlets and outlets for motors, ceiling paddle fans, and luminaires. The location of outlets and receptacles is shown on the drawings. Sometimes, these locations are approximate, and the outlet or receptacle can be moved slightly to accommodate framing members such as studs or joists. At other times, the location identified on the drawings is expected to be precise. The mounting height of these outlets is often included in the specifications or is shown as notations on the drawings. Carefully follow these instructions, including those for the specific height above counters or for special equipment. Having a problem positioning the box for the receptacle or other outlet? Bring this to the attention of the responsible supervisor or agent of the owner for resolution. Note that typical outlet notations provide specific information on type of outlet, mounting instructions, or switching indication.

Typical symbols for switches and sensors are shown in Figure 2-7. Carefully review the specifications or notations on the construction drawings for the height above finished floor or for location in proximity to doors. Switches are not usually permitted on the hinged side of the door but are required to be located on the strike side. In some cases, the switch is required to be located on the outside of the door to the room or area. Special switches such as keyed type and occupancy sensors are indicated by symbols on the drawings. See Figure 2-7. The lighting in some buildings will be controlled by computers or lighting relays. Occupancy sensors and low-voltage switching can be used to facilitate these controls. Other switching designs call for 3-way or 4-way controls. Threeway switches allow one or more luminaires to be controlled from two locations. Four-way switching involves inserting one or more 4-way switches between a 3-way switch that is located at each end of the switch legs. Additional information on wiring 3-way and 4-way switches is included in Chapter 5 of this text. Figure 2-8 shows symbols used to identify the location of disconnecting means and other components of circuits for motorized and HVAC equipment. These symbols often include the ampere or other rating of the equipment used. For example, the symbol for a fusible-type disconnect switch indicates the frame (switch) ampere rating as well as the fuse rating. Special control schemes are often provided on the drawings. Carefully follow the requirements in Article 430 for motors and in Article 440 for airconditioning equipment.


SWITCHES AND SENSOR SYMBOLS	
PREFERRED SYMBOL	DESCRIPTION
\$ or S	Single-pole switch.
\$ ₂ or S ₂	Double-pole switch.
\$ ₃ or S ₃	Three-way switch
\$ ₄ or S ₄	Four-way switch.
\$ _a or S _a	Switch control of luminaire or outlet (lowercase letter).
\$ _{CB} or S _{CB}	Circuit-breaker switch.
\$ _{DT} or S _{DT}	Single-pole/double-throw switch.
\$ _G or S _G	Glow switch toggle, glows in off position.
\$ _H or S _H	Horizontally mounted—with on position to the left.
\$ _K or S _K	Key-operated switch.
\$ _{KP} or S _{KP}	Key-operated switch with pilot light on when switch is on.
\$ _{LV} or S _{LV}	Low-voltage switch.
\$ _{LM} or S _{LM}	Low-voltage master switch.
\$ _{MC} or S _{MC}	Momentary contact switch.
\$ _P or S _P	Switch with pilot light on when switch is on.
\$ _T or S _T	Timer switch.
\$ _{WP} or S _{WP}	Weatherproof single-pole switch.
\$ _D or S _D	Dimmer switch rated 1000W, unless otherwise indicated. "LV" = low voltage "FL" = fluorescent
	Occupancy sensor, wall mounted with off-auto override switch.
	Occupancy sensor—ceiling mounted. "P"—indicates multiple switches wired in parallel.
\$ _{PROJ} or S _{PROJ}	Motorized projection screen raise/lower switch.

Figure 2-7 Switches and sensor symbols.


























MOTORIZED AND HVAC EQUIPMENT—CONTROLS, SYMBOLS	
PREFERRED SYMBOL	DESCRIPTION
xxA 	Disconnect switch, unfused type, size as indicated on drawings. "xxA" indicates amperage.
$\frac{xxAF}{yyAT}$ 	Disconnect switch, fused type, size as indicated on drawings. "xxAF" indicates frame size. "yyAT" indicates fuse rating.
$\frac{xxAF}{yyAT}$ 	Enclosed circuit breaker, size as indicated. "xxAF" indicates frame size. "yyAT" indicates trip size.
	Magnetic contactor; size as indicated on drawings.
RV  NEMA x	Magnetic motor starter. "RV" indicates reduced voltage. Starter size as indicated.
F  $\frac{\text{NEMA } x}{xxA-xP}$	Combination magnetic starter and disconnect switch. Starter size and fuse rating as indicated.
	Automatic temperature control panel.
	Equipment control panel.
	Relay.
	Aquastat.
	Firestat.
	Humidistat.
	Line voltage thermostat.
	Low-voltage thermostat.
	Thermostat.
	Solenoid valve.
	Time switch.
	Airflow switch.
	Electric/pneumatic switch.
	Flow switch.
	Irrigation control.
	Limit switch.
	Pneumatic/electric switch.
	Photo cell or photo control.
	Pressure switch.

Figure 2-8 Motorized and HVAC equipment controls and symbols.



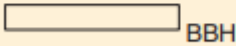

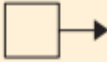


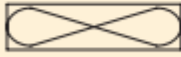

MOTORIZED AND HVAC EQUIPMENT SYMBOLS	
PREFERRED SYMBOL	DESCRIPTION
	Motor "3" —indicates horsepower.
	Motorized damper.
	Baseboard heater.
	Baseboard heater with receptacle (on different circuit).
	Unit-type heater.
	Ceiling exhaust fan.
	Paddle fan.
	Wall fan.
	Water heater.

figure 2-9 Motorized and HVAC equipment symbols.

Included in Figure 2-9 are the symbols for equipment such as motors, baseboard heaters, ceiling (paddle) fans, and water heaters.

Figure 2-10 includes symbols for distribution equipment such as panelboards, motor control centers, transformers, and transfer switches. It is particularly important to review the spacing required for distribution equipment so that the working space requirements of NEC® 110.26 are complied with. The power distribution symbols shown in this figure are supplemented by a one-line riser diagram that indicates the source and destination of feeders as well as the size of conduits, conductors to be installed, and the required overcurrent protection.

Panelboard schedules are typically provided to detail the circuits and overcurrent protection required for distribution equipment. Panelboards are distribution points for electrical circuits. They contain circuit protective devices. See NEC Article 100 for the official definition. The previous two basic classes of panelboards,






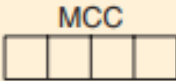
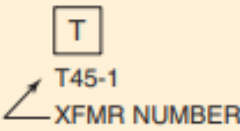

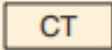
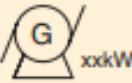


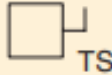
POWER DISTRIBUTION EQUIPMENT SYMBOLS	
PREFERRED SYMBOL	DESCRIPTION
	Lighting or power panel, recessed.
	Lighting or power panel, surface.
	Distribution panel.
	Lighting or power panel on normal/generator feeder.
	Distribution panel on normal/generator feeder.
	Motor control center.
	Dry-type transformer, refer to transformer schedule, "T45"—indicates transformer type floor mounted. Unless otherwise indicated, "W"—indicates wall, and "S"—indicates suspended. "R"—indicates K rating.
	Transformer—pad mount.
	Current transformer cabinet.
	Generator. Size as noted.
	Meter—single.
	Meter and socket.
	Transfer switch. "TS" = manual transfer switch. "ATS" = automatic transfer switch.

Figure 2-10 Power distribution equipment symbols.

power and lighting and appliance, have been deleted. Panelboards are available to accommodate from 2 to 84 branch circuits and from 30 to several hundred amperes rating. The requirements for construction and application of panelboards are set forth in NEC Article 408. In the building used as an example in this text, a panelboard is located in each occupancy, so the tenant will have ready access to the overcurrent devices. The symbols are not drawn to scale, and the installer must consult the shop drawings for specific dimensions. Important note: As required by NEC 240.24(B), all tenants are required to have ready access to the overcurrent devices protecting the wiring in their particular occupancy. The panelboards in the Commercial Building are located to meet this requirement. Security System Components. Symbols used for security system components are shown in Appendix H as Figure H-2. Additional information is usually provided in the specifications for the project or on the drawings. It is fairly common for the security system to report to a monitoring service either on or off the premises through communications circuits. Fire-Alarm Communications and Panels. Symbols used for Fire-Alarm Communications and Panels security system components are shown in Appendix H as Figure H-3. Additional information is usually provided in the specifications for the project or on the drawings. It is fairly common for the security system to report to a monitoring service either on or off the premises. Fire Alarm Indicator Symbols. Fire-Alarm Indicator Symbols are shown in Appendix H as Figure H-4. Additional information is usually provided in the specifications for the project or on the drawings. Fire Alarm Sensor Symbols. Fire-Alarm Sensor Symbols are shown in Appendix H as Figure H-5. Communications—Teledata Symbols. Symbols for communications, data, and telephone equipment are located in Appendix H as Figure H-6. In addition, the plans or specifications may specify installing an empty raceway from the vicinity of the outlet to the location above a suspended ceiling. This facilitates the installation of communications cables later in the project. Communications—Audio/Visual Symbols. Symbols for communications-audio/visual are located in Appendix H as Figure H-7. Communications—Equipment. Symbols for communications equipment are located in Appendix H as Figure H-8. Site Work Symbols. Symbols for site work are shown in Figure 2-11. You might find an additional

SITE WORK	
PREFERRED SYMBOL	DESCRIPTION
----- UF -----	Underground feeder.
----- UT -----	Underground telephone.
----- UFA -----	Underground fire alarm.
----- UTV -----	Underground television (CATV).
— MH —	Manhole.
— HH —	Handhole.
— E — T —	Combination prefabricated manholes for power and tel/data systems. "E" = denotes power, "T" = denotes tel/data.

Figure 2-11 Site work.

variation in the form of underground service lateral. Some plans will require conduit from the building to the utility transformer. Others will permit conduit to be stubbed into the ground and direct burial cable to be run to the transformer. In yet other variations, conduit is required to be installed on power poles to protect the service lateral as it rises to the pole-mounted transformers. Schematic and One-Line Diagram Symbols. Note that these symbols that are commonly used in schematic and on one-line drawings are located in Appendix H in Figure H-9(A), (B), and (C). Schematic symbols for switches are included in Appendix H as Figure H-10. Miscellaneous Symbols. Miscellaneous symbols are included in Appendix H as Figure H-11. These include symbols used on drawings to indicate mechanical equipment, feeders that appear on feeder schedules and sections or details. Abbreviations. Abbreviations commonly used on electrical construction drawings are included in Appendix H as Figure H-12. Nurse Call Systems. Nurse call systems are located in Appendix H as Figure H-13.

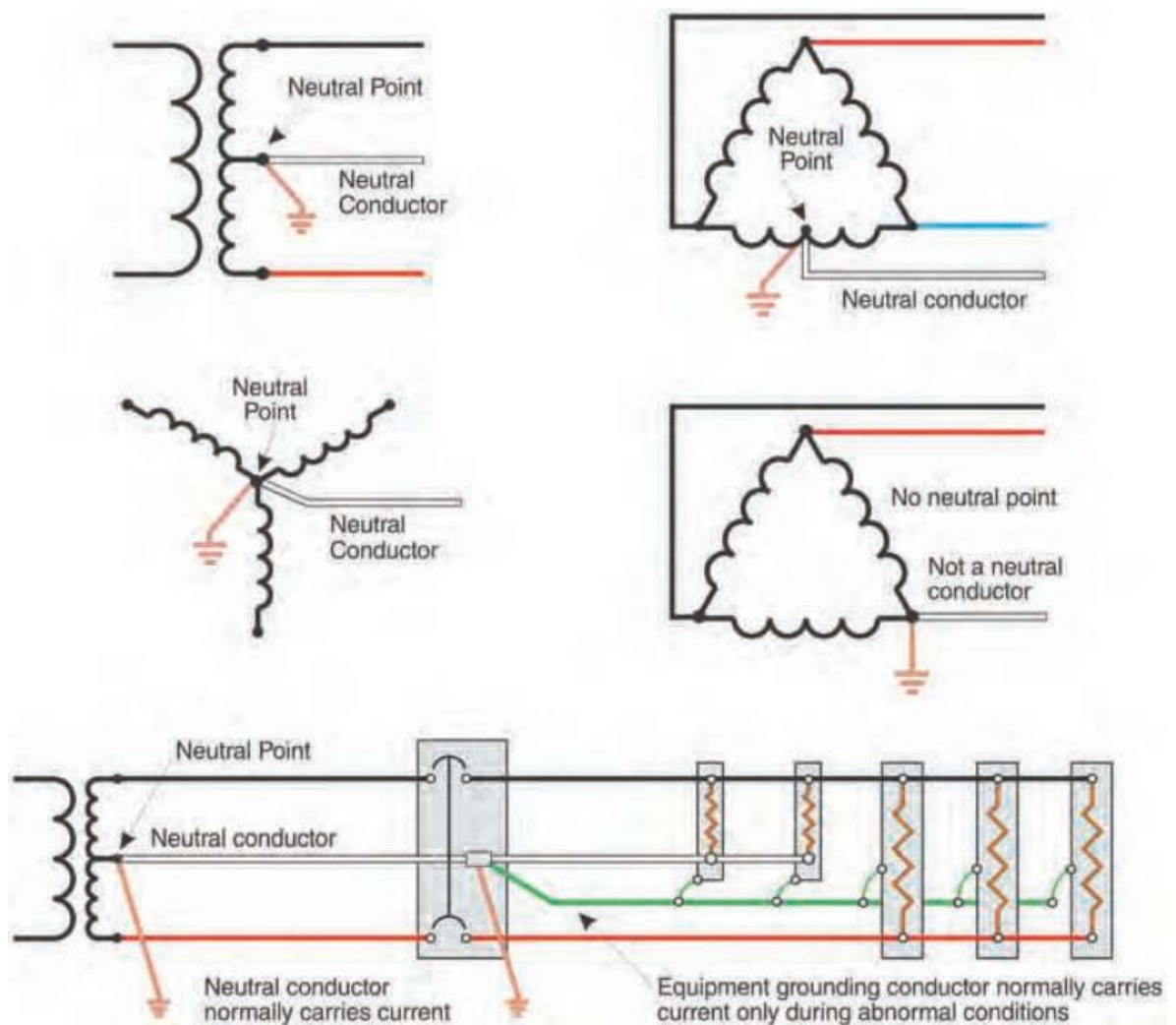


Figure 2-12 Neutral point and neutral conductor.

Conductor Designations

The terms neutral and hot are often used in trade jargon. The terms neutral and grounded conductor are defined terms but hot, or hot wire, is not. The term ungrounded is defined in the NEC. These terms are found many times in the NEC and in this text. These terms are often misunderstood. The NEC contains the following definitions:

- **Neutral Conductor.** The conductor connected to the neutral point of a system that is intended to carry current under normal conditions.* See Figure 2-12. It is important to note that in this definition, the neutral conductor is expected to carry current under normal conditions, whereas the equipment-grounding conductor is expected to carry current only under abnormal conditions. Both connect to the neutral terminal bar at the service or source of a separately derived system.

- **Neutral Point.** The common point on a wye-connection in a polyphase system or midpoint on a single-phase, 3-wire system; or midpoint of a single-phase portion of a 3-phase delta system; or midpoint of a 3-wire, direct-current system.* See Figure 2-12.

- **Ungrounded.** Not connected to ground or a conductive body that extends the ground connection. * Electricians might use the term neutral or they might use the term neutral conductor when referring to the grounded circuit conductor. The lower two drawings on the right in Figure 2-12 show the location of a grounded conductor that is not a neutral.

The Drugstore

A special feature of the Drugstore wiring is the lowvoltage remote-control system. See Chapter 20, “Low-Voltage Remote Control,” for a complete discussion. This system offers control flexibility that is not available in the traditional control system. The switches used in this system operate on 24 volts, and the power wiring, at 120 volts, goes directly to the electrical load. This reduces branch-circuit length and voltage drop. A switching schedule gives details on the system operation, and a wiring diagram provides valuable information to the installer.

One of the reasons for the low popularity of this system is the scarcity of electricians who are prepared to install a low-voltage control system. The system specified for the Drugstore has been around a long time and is still being used. It is the most basic type of low-voltage control available today and is discussed in Chapter 20.

The student is encouraged to request manufacturer’s literature from any electrical distributor. Check out the manufacturer’s websites by browsing the Web. Several companies manufacture lowvoltage control systems.

Different types of illumination systems have been selected for many of the spaces in the building. The student should observe the differences in the wiring requirements.

In the merchandise area, several luminaires are installed in a continuous row. It is necessary to install electrical power to only one point of a continuous row of luminaires. From this point, the conductors are installed to supply other luminaires in the wiring channel of each luminaire. In the pharmacy area, a luminous ceiling is shown. This illumination system consists of rows of strip fluorescents and a ceiling that will transmit light. The installation of the ceiling, in many jurisdictions, is the work of the electrician. For this system to be efficient, the surfaces above the luminous ceiling must be highly reflective (white)


The Bakery

For the production area of the Bakery, a special luminaire is selected to prevent contamination of the food products. These units are totally enclosed and require a separate electrical connection to each luminaire. The luminaires may be supplied by installing a conduit in the upper-level slab or on the ceiling surface. In the sales area, more attractive luminaires have been selected. A conventional control system is to be installed for the lighting in the Bakery. The goal of the system is to provide control at every entry point so that a person is never required to walk through an unlighted space. Often this requires long switching circuits, such as the three-point control of the main lighting in the work area. The

electrician may be responsible for making changes in conductor size to compensate for excessive voltage drop. This requires the electrician to be alert for high loads on long circuits, such as the control circuit on the bakery work area lighting. The panelboard worksheets and feeder load calculations for the Drugstore, Bakery, Insurance Office, Real Estate Office, Beauty Salon, and the owner's loads are found in Appendix A of this text. The panelboard schedules are found on electrical drawing E-4. The drawings are located in the envelope inside the back cover of the book. Table B-1 in Appendix B is a table of useful electrical formulas. The Watts Wheel is included in Appendix B as Table B-2. You will want to refer to these tables and formulas often as you study Electrical Wiring— Commercial.


Self-Check No. 5.2.2-1

Refer to the National Electrical Code or the working drawings when necessary. Where applicable, responses should be written in complete sentences. Answer problems 1–7 by identifying the symbol and the type of installation (wall, floor, or ceiling) for the boxes.


1.  _____

2.  _____

3. \$_{KP} or S_{KP} _____

4.  _____

5. \$ or S _____

6.  _____

7.  _____

Answer Key No. 5.2.2-1

1. Duplex convenience receptacle. 20A 125V
2. Duplex convenience receptacle on emergency/standby circuit. Specify panelboard and circuit.
3. Key-operated switch with pilot light on when switch is on.
4. Paddle fan.
5. Single-pole switch.
6. Disconnect switch, unfused type, size as indicated on drawings. “xxA” indicates amperage.
7. Bollard-type site luminaire.

Information Sheet No. 5.2.2-2: Lighting design and calculations

1. THE LUMEN METHOD

This method is also called: Photometrical Computation and mostly used for interior lighting calculation. To determine the total number of luminaires required to produce a given illuminance by the lumen method we apply the following formula: Total number of luminaires (N) required to provide a chosen level of illumination (E) at a given surface is .

$$N = \frac{E \text{ (lx – required)} \times \text{Area (m}^2\text{)}}{\text{lumen from each luminaire} \times \text{UF} \times \text{MF}}$$

where:

♣ **E** = the illuminance level is chosen after consideration of the IES code, the area is the working area to be illuminated, the lumen output of each luminaire is that given in the manufacturer's specification and may be found by reference tables.

♣ **MF** is maintenance or (the light loss LLF) factor. This factor depends on the maintenance staff of the building, but in general it is taken as 0.8 -0.9.

♣ **Utilization factor (UF)**

The light flux reaching the working plane is always less than the lumen output of the lamp since some of the light is absorbed by the various surface textures. The method of calculating the utilization factor (UF) is detailed in lighting design books, although lighting manufacturers' catalogues give factors for standard conditions. The UF is expressed as a number which is always less than unity; a typical value might be 0.9 for a modern office building.

Example 1

It is proposed to illuminate an electronic workshop of dimensions **9 x 8 x3 m** to an illuminance of **550 lx** at the bench level. The specification calls for luminaires having one **1500 mm 65 W fluorescent natural tube** with an initial output of **3700 lumens**. Determine the number of luminaires required for this installation when the **UF** and **MF** are **0.9** and **0.8**, respectively. The number of luminaires required (N)

$$N = \frac{E \text{ (lx)} \times \text{Area (m}^2\text{)}}{\text{lumen from each luminaire} \times \text{UF} \times \text{MF}}$$

$$N = \frac{550 \times 9 \times 8}{3700 \times 0.9 \times 0.8} = 14.86$$

Therefore 15 luminaires will be required to illuminate this workshop to a level of 550 lx.

----- \rightarrow Other factors that may be taken into consideration when using the lumen method are:

1. Room Index: this includes

❖ Room dimensions:

- (i) Length (a)
- (ii) Width (b)
- (iii) Height (h)

❖ Useful Height - H_k.

This can be calculated as:

- $h_k = h - h_d$ or $h_k = h - h_d - h_v$ (1)

where:

h_k = useful height

h = room height

h_d = height of working area, usually taken as: 0.85 m

h_v = height of illumination unit hanging from the ceiling, measured in (m).

$$\text{Room Index}(k) = \frac{a.b}{h_k(a+b)}$$

2. Utilisation factor

Table -1 gives the utilization factor UF for a fluorescent luminaire with single 40W lamp and prismatic diffuser 0011 mm length for different values of the room reflection coefficients: C – ceiling reflection, W- wall reflection, F- floor reflection. If these values are: (0.5, 0.5, 0.2) and the room index is calculated to be 1.50, then the UF = 0.52.

Table -1

Utilisation factor for fluorescent luminaire with single 40W lamp and prismatic diffuser 1300 mm length.

Room Reflection			Room Index								
C	W	F	.75	1.00	1.25	1.50	2.00	2.50	3.00	4.00	5.00
.70	.50	.20	.44	.50	.56	.60	.65	.69	.72	.75	.77
	.30		.38	.44	.50	.54	.60	.64	.68	.72	.74
	.10		.33	.40	.46	.50	.56	.61	.64	.69	.72
.50	.50	.20	.39	.44	.49	.52	.57	.60	.62	.65	.67
	.30		.34	.40	.44	.48	.53	.56	.59	.62	.64
	.10		.30	.36	.41	.44	.50	.53	.56	.60	.62
.30	.50	.20	.34	.39	.42	.45	.49	.51	.53	.55	.57
	.30		.30	.35	.39	.42	.46	.49	.51	.53	.55
	.10		.27	.32	.36	.39	.44	.47	.49	.52	.54
.00	.00	.00	.22	.26	.29	.31	.34	.36	.38	.40	.41
							UF				

Table -2 gives the maintenance factors for different types of rooms.

Table -2 Maintenance factor

Room classification	Lamp maintenance factor	Maintenance factor for dirty lamp	Total maintenance factor
very clean	0.09	0.85	0.85-0.9
clean	0.9	0.9	0.8
average	0.9	0.8	0.7
dirty	0.9	0.7	0.6

Source: <https://www.scribd.com/document/376254976/EI-Lecture-No-11>

INDUSTRIAL PREMISES

The electrical requirements of industrial premises differ to that of residential units. **Most of the industrial premises require 3-phase supply, which feeds to machineries and other electrical system in the unit.** But the smaller industrial premise could receive 1-phase supply if there is no heavy machineries. Hence, the designer must consider balancing the demand of each phase (L1, L2, and L3 phases), to ensure the design would not any nuisance tripping during the operation.

Lighting Layout

Lighting point

Unlike the residential units, the lighting points for industrial units are classified into two category:

- General lighting, and
- Task/Specific lighting

The **general lighting** illuminates the area generally. Usually, the number if lighting points are calculated based on the floor area. It will be more accurate if the reflection factors are considered (which includes the type of wall and finishes, the mounting height of lighting points, the average height of the working table/machineries, the type of lighting fittings used etc). Often, fluorescent lighting fittings are used.

Hence an estimate number for lighting point is calculated by using the following formula:

$$\text{No of lighting points} = \frac{\text{Total Floor Area (m}^2\text{)}}{\text{Floor area for 1 lighting point}}$$

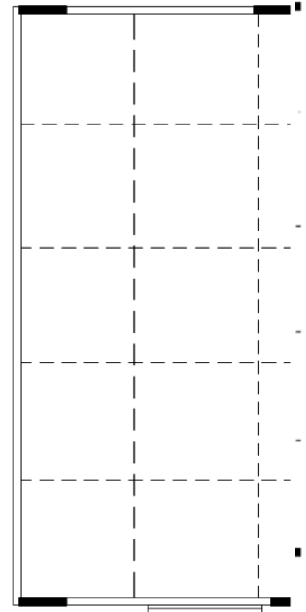


Figure 11-1 Floor area is divided to sections

The lighting points are now positioned to ensure even lighting distribution. At times, one or two lighting points are added to the above calculation. To position the lighting points, the area is divided to boxes according to the number of lighting points to be installed. **Lighting points are placed centrally in each box.**

The **task/specific lighting** is meant to give better luminance to a worker while operating a machine. Fluorescent lighting causes stroboscopic effect, which makes a rotating machine to appear stationary. Hence for task light, incandescent lamps are used even though it could cause some discomfort to the machine operator (i.e. heat dissipation).

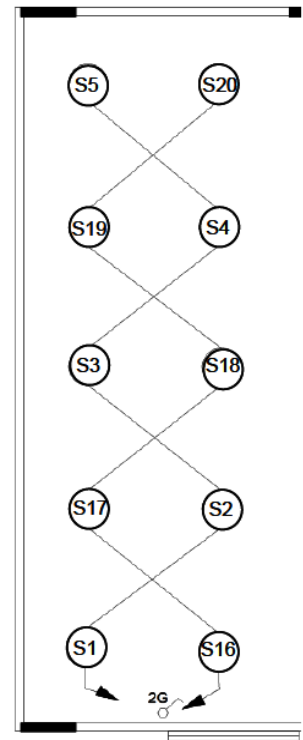


Figure 11-2- Lighting points are placed in each section.

Lighting Switch

The number of lighting points for an industrial unit is significant if the floor area is large. **Hence to cut down the number of switches, a few lighting points are normally connected in parallel and controlled by a switch.** The grouping of points controlled by a switch is done with cost factor, i.e. to minimize the electrical consumption when only a section of the total area needs to be lighted up. Multi-gang switches and multi-positions switches (2-way and intermediate switches) could be considered too.

Since the supply to the premise is a 3-phase supply, the designer must exercise care in the selection and position of switches. While planning for the switches position, consider:

- the convenience for the user, and
- the supply to the switch, that it is fed from the same phase.

Unless a special switch is used (with partitioned box and plate), **a switch will NOT be receiving supply from different phases**, as an accidental contact can cause serious fatality.

Ventilation System

Generally, fans are provided in the working area. Fans are either mounted on the wall or suspended from the ceiling. In additions, exhaust ventilation fans are installed to clear the stale are from the working area. Meanwhile, air-conditioners are provided in the office and meeting rooms. As usual, fans' speed is controlled with regulator (the diagram shows 'R' as regulator panel).

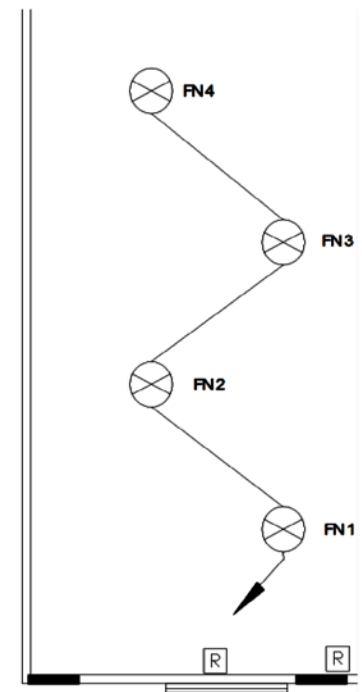


Figure 11-3 Fan points

Power Layout

Switch Socket Outlet

The 13 Amp switch socket outlets (SSO) are provided for light-duty appliances, general maintenance and cleaning work. Hence, they are located along walls and columns for convenience use at 1500 mm above floor level, as they could be subjected to damage if installed at low level. **If the number of SSO is significant, twin 13 Amp SSO are used and run in ring circuits to cut cost.**

15 Amp SSO are used for specific appliances/equipment in the area.

1-Phase and 3-Phase Machineries/Equipment

Depending on the type of industry, machineries installed may require additional electrical devices for their operation, i.e. isolators and motor starters. Three-phase induction motors drive most of today industrial machinery.

Induction motors may be connected directly across the line without damage to the motor. The isolator will provide local isolation for operation and maintenance. CP5 requires all electric motors with a rating above **0.37 kW must be supplied from a suitable motor starter** incorporating overload protection and no-volt protection.

However, **because of the voltage disturbance created in the supply by their high starting currents, motors larger than 2.2 kW are often started at a reduced voltage.**

The types of starters to be used are:

- $P_{out} \leq 2.2 \text{ kW}$, use Direct-On-Line (DOL) starter,
- $P_{out} > 2.2 \text{ kW}$, use reduced voltage starters, such as Star-Delta and Auto-Transformer starters.

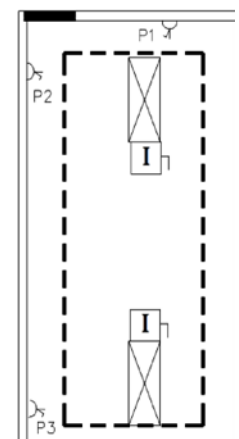


Figure 11-4 Isolator for Machineries
in Cutting Area

The air-conditioner is provided for the office area and meeting rooms only. It is usually fed through 15 Amp SSO or isolators.

Consumer Unit

The consumer unit for an industrial application is specially fabricated to suit the individual design requirement. It contains the MCB for 1-phase (lighting, 13 Amp and 15 Amp SSO, and light-duty machineries) and 3-phase (heavy-duty machineries) supplies for the final circuits and the incoming accessories as required by the supply authority.

As in the residential unit, the consumer unit is placed at a location, which is easily accessible. It is preferred to place it in an electrical room allocated for the consumer unit and meter board.

Meter Board

The Meter Board (MB) consists of:

- a service MCB (a four-pole MCB), which controls the availability of supply to the unit, and
- a 3-phase kWh meter to monitor the electrical consumption.

As stated above, the meter board and consumer unit are placed in an electrical room.

Telecommunication Point

Besides telephone point, more telecommunication points are needed in the office area, such as:

- point for fax machine, and

- point for computer internet access.

The telecommunication points are placed near the equipment in order to maintain a neat wiring system.

Load Calculations

The assumed loading for industrial unit is higher than that of residential unit. Based on the assumption given by the Licensed Electrical Worker (LEW), all loadings for lighting and power points are calculated to determine:

- the incoming cable sizes ; and
- the sizes of incoming protective or control gear .

The assumed loading are as follows:

- lighting point – minimum of 50 W per point,
- fan point – minimum of 100 W per point,
- 13 A SSO – minimum of 500 W per point,
- air-conditioner – as per given details, and
- machines – as per output/rated power given.

Nevertheless, the details of each type of load, is given for every assignment. An allowance, which varies from **15 % to 20 % of the total connected load**, is normally added to the total connected load, to cater for future extension.

For the single-phase load, i.e. lighting, fan and 13 A SSO points, the load (wattages) are to be calculated as follows:

Total Power For Single-Phase Load = Power for lighting, fan points and 13 A SSO.

since $P = \sqrt{3} VI \cos \theta$,

hence **Total Current for Single-Phase Load**, $I = \frac{P}{\sqrt{3} V \cos \theta}$

where V is the voltage at 400 V, and θ is the overall p.f.

For the three-phase load, a sample calculation for machineries loading is listed below.

Given information: 1 no 8 kW motor with 88 % efficiency and power factor (p.f.) of 0.85.

Hence $P_{out} / P_{rated} = 8 \text{ kW}$ $\eta = 88 \%$ $p.f = 0.85$

The final circuit cables require the value of input power/current to the motor, regardless of the loss incurred.

Since $\eta = \frac{P_{out}}{P_{in}}$ therefore, $P_{in} = \frac{P_{out}}{\eta}$

and generally $P_{in} = \sqrt{3} V_{in} I_{in} \cos \theta$,

where V_{in} is 400 V for 3-phase supply, and $\cos \theta$ is the p.f. of the machine.

Therefore, $I_{in} = \frac{P_{in}}{\sqrt{3} V_{in} \cos \theta}$

For the Total Load Current, the calculation is as follows:

Total Connected Load Current = Total Current For Single-Phase Load and Three-Phase

Total Estimated Load Current (I_T) = Total Connected Load Current + Spare

After the total load current (I_T) is determined:

- select the type of incoming accessories set-up:
 - ❖ **Figure 11-5** – for the incoming current less than 100 A, i.e. **$I_T < 100 \text{ A}$**
 - ❖ **Figure 11-6** – for the incoming current more than 100 Amp, but less than 300 A, i.e. **$100 \text{ A} < I_T < 300 \text{ A}$** , and
 - ❖ **Figure 11-7** - for the incoming current more than 300 Amp, i.e. **$I_T > 300 \text{ A}$** .
- select the suitable incoming cable size with the aid of CP : 5 Table 4D1A ;

- ❖ select the correct column, based on the **method of cable installation and the type of supply** (1-ph or 3-ph), where the cables for industrial units are contained in trunking or conduits, and
- ❖ select the cable that has higher current carrying capacity than the accessories' ratings.

Cable Rating > Accessories Rating

For incoming set-up as per Figure 11-5;

- select the suitable rating of protective devices ; I_T
 - ❖ RCCB rating > I_T

There are **standard ratings of RCCB** available in the industry, i.e **40 A, 63 A and 100A, 125 A etc.** For an industrial unit, select the RCCB of **100 mA or higher sensitivity**, for safety reason while preventing regular tripping during normal operation.
 - ❖ Isolation MCB rating > I_T

Normally, the rating of **MCB is similar as the RCCB**, to ensure compatibility. However, the isolation MCB is of **three-pole (3P) and of Type B**, as it would provide discrimination.
 - ❖ Isolator > I_T

The isolator switch acts as a mean for the user to cut-off the electricity supply for maintenance purposes. And again, the rating of **Isolator, MCB and RCCB are similar**, to ensure compatibility.
 - ❖ Service MCB > I_T

The kWh meter and service MCB are provided by the supply authority. **The rating of the service MCB is similar as the other accessories, but of Type C**, for discrimination reason.

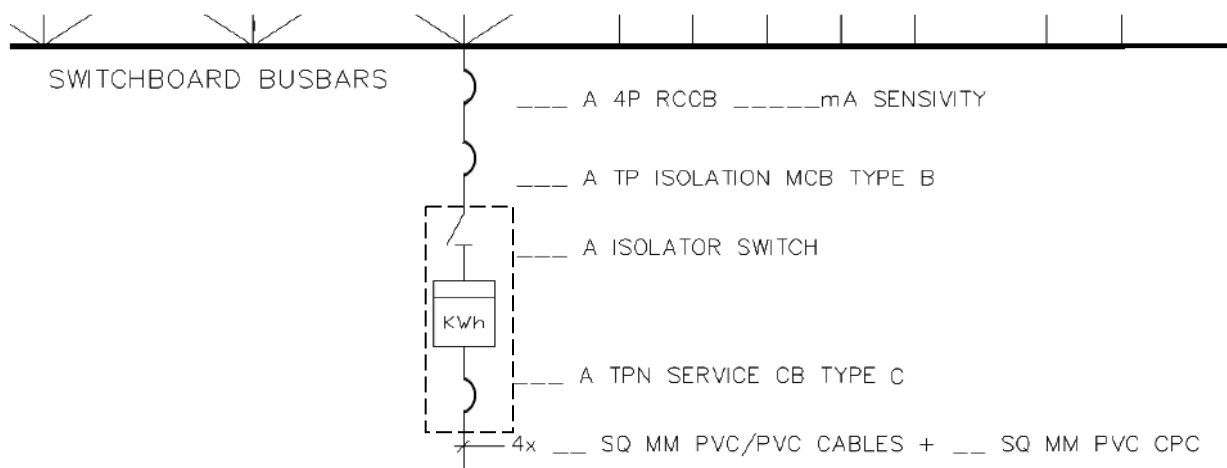


Figure 11-5 Incoming accessories when $I_T < 100A$

For incoming set-up as per Figure 11-6;

- Incoming and outgoing indicator lamps are provided, to signal the supply availability. The fuses are positioned at the origin of the path, to protect the lamps against t damaged due to overloads.
- Voltmeter and ammeter and their selector switches are provided for monitoring the variation of incoming supply.
- The 3-phase kWh meter is fed via two path. The current path is fed through a current transformer, CT. The transformer steps down from the actual current flowing in the incoming cable, and the current that flow to the kWh meter is an indicative for the actual amount for current flow. The voltage coil to the kWh meter is fed via the MCBs. The detailed wiring diagram for the connection will be covered in the later topic.
- There is only one circuit breaker for the set-up. The MCCB is used as the rating is large. It serves a few functions, i.e. for isolation, overcurrent and leakage protections. The signal current to the tripping mechanism is directly fed via the zero phase CT. For overcurrent fault, the difference in the amount of current in the phase and neutral CTs cause the MCCB to trip. For earth-leakage fault, the MCCB trips when the earth-fault relay is activated.

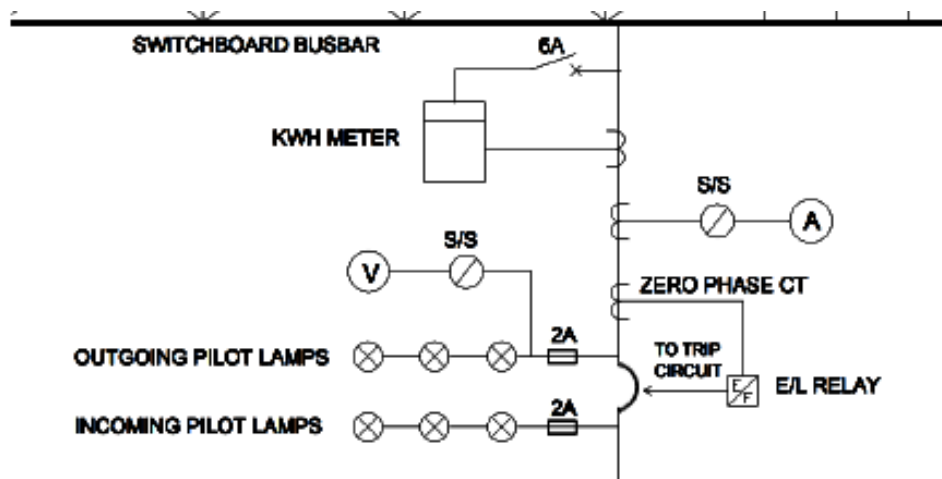


Figure 11-6 – Incoming accessories when $100\text{ A} < I_T < 300\text{ A}$

For incoming set-up as per Figure 10-7;

- There is one difference in the set-up, i.e. the use of overcurrent and earth-leakage relays to trip the MCCB when fault occurs.

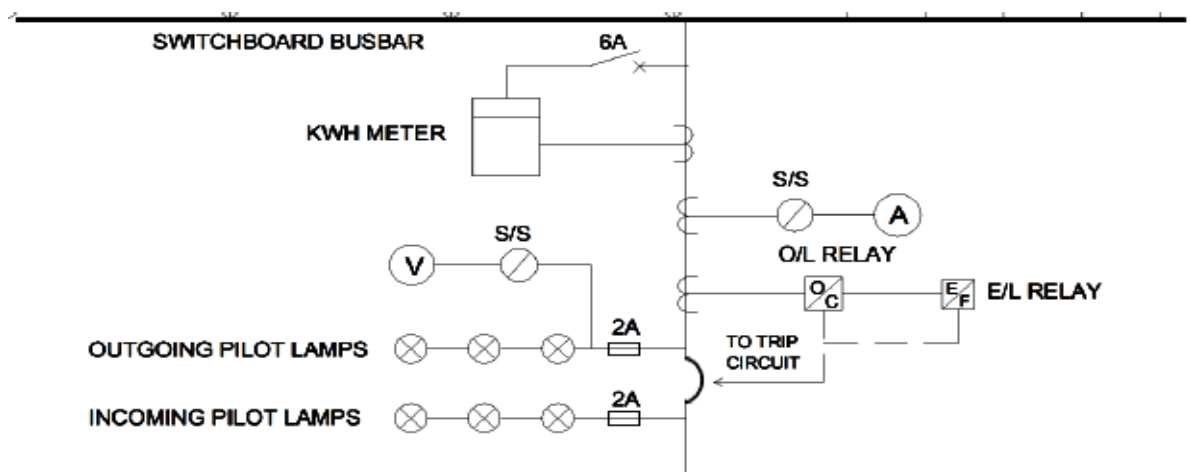


Figure 11-7 – Incoming accessories when $I_T > 300\text{ A}$

RCCB Sensitivity Application

30mA Tripping current designed for additional protection against direct contact, or where specially required by the CP5 wiring regulations, the 30 mA RCCB protects against leakage currents and indirect contact with earth loop

impedance up to 1667 Ohms; for use as additional protection against direct contact, residual tripping current must not exceed 30 mA.

100mA Tripping current is suitable for protection against indirect contact and leakage currents for larger installations; the 100 mA RCCB's operate within 30 ms, but do not provide the same level of personal protection as the 30 mA units; the 100 mA RCCB protects against leakage currents and indirect contact with earth loop impedance up to 500 ohms.

300mA A less sensitive protection suitable for large installations having high levels of leakage current; 300 mA RCCB's protect against leakage current and indirect contact up to 167 ohms earth loop impedance.

Single-Line Diagram

Upon completion of the electrical layout and calculation, a single-line diagram of the electrical installation is planned and drawn. The diagram indicates the final circuits for:

- lighting points,
- 13 A SSO points,
- 15 A SSO points,
- machines, and
- future extensions (spare MCB).

Final Circuit MCB Ratings and Cable Sizes

For domestic installations, the sizes of the protective gears and cables are standardized as recommended in CP: 5, are listed in the Table 11-1 below:

Final circuit	Fuse / MCB rating	PVC cable size
Lighting final circuit	5A / 6A	1.5 mm ²
13A SSO radial circuit	20A (floor area ≤ 50 m ²)	2.5 mm ²
13A SSO ring circuit	30A / 32A	2.5 mm ²
Air-conditioner	min 10A TPN (via 15 A SSO or isolator)	min 2.5 mm ² Cable rating > MCB rating
Machines	2 x I _{in} min 10 A TPN	min 2.5 mm ² Cable rating > MCB rating

Table 11-1 – Final Circuit MCB Ratings and Cable Sizes

Singapore Power requires the minimum cable size for the Circuit Protective Conductor (CPC) as listed below:

Cross-sectional area of phase conductor – S (mm ²)	Minimum cross-sectional area of corresponding CPC – S _p (mm ²)
$S \leq 16$	S
$16 < S \leq 35$	16
$S > 35$	$\frac{S}{2}$

Table 11-2 – CPC Cable Sizes

However exceptions are considered for the following final circuits:

- lighting circuits – 1.5 mm² CPC size,
- power circuits (13 A, 15 A and appliances) - 2.5 mm² CPC size, which phase conductor is also 2.5 mm².

Grouping

When grouping is planned for a final circuit, the designer ought to have prior knowledge on the electrical wiring system. The factors to be considered are for:

- **Lighting/Fan circuits** – both lighting and fan points could be grouped in the same final circuit, with the maximum number to **10 points to one MCB**. With 3-phase supply, the zone for different phases is marked out clearly to ensure that the switches of different phases are located 2 m apart.
- **13 A SSO circuits** – the SSO could be wired in **radial mode (maximum of 4 SSO point to one MCB)** while **ring connection (maximum of 10 SSO points to one MCB)** is advisable. The nearby SSO points are looped together to form one final circuit.
- **15 A SSO point** – one MCB is dedicated to one 15 A SSO, it cannot be shared with other 13 A or 15 A SSO.
- **Air-conditioner** – it is connected to the consumer unit via isolator, and the MCB is dedicated to one air-conditioner compressor.
- **Machines** – one TPN MCB serves one 3-phase machine, and they are connected to the consumer unit via isolator and suitable motor starters.

Example

A garment factory is installed with the following loadings in the respective areas:

Production area

- twenty-nine lighting points,
- nine ceiling-mounted fan points,
- ten 13 A SSO for general maintenance (wall-mounted),
- two 1.5 kW, 90 % efficiency, 0.85 power factor cutting machine (in the cutting area),
- six 13 A SSO for hemming machines (near the machines).,
- three 4.5 kW, 85 % efficiency, 0.85 power factor packing machine, and
- eighteen 13 A SSO for sewing machines (near the machines).

Display/tailoring area

- three lighting points,
- one ceiling-mounted fan point,

- six 13A switched socket outlets,
- one consumer unit.

Office area

- four lighting points,
- eight 13A switched socket outlets,
- one 1.6 kW, 75 % efficiency. 0.85 power factor air-conditioner compressor,
- four telecommunication points.

Washroom

- four lighting points,
- one 13A switched socket outlet for hand dryer (installed in ceiling space).

Outside the Front Gate

- one Meterboard.

The following assumption were made by the LEW in-charge of the installation:

- * one lighting point is to take 50 W,
- * one fan point is to take 100 W,
- * one 13A switched socket outlet is to take 500W,
- * no diversity is allowed for the air-conditioner,
- * each lighting final supplies 10 points,
- * each radial final circuit (20A) supplies 4 points,
- * each ring final circuit (32A) supplies 10 points,
- * one spare is required for lighting and power (13 A SSO) final circuit,
- * 10% allowance is included in the load calculation for the incoming cable,
- * select appropriate lighting switches to suit the users' requirement.

Draw an electrical layout, calculate the total loading and a single-line diagram for the factory. The floor plan is as shown.

Refer to Table 4D1A of CP 5 for the selection of the size of single-core PVC insulated cable.

The single-line diagram should include:

- ** the size of the final circuits and incoming cables used ; and
- ** the rating of the isolator, and
- ** the suitable incoming accessories for the installation.

Take 0.85 as the overall power factor of the installation.

Available circuit breaker sizes are:

6A 10A 16A 20A 32A 40A 63A 80A 100A 125A 150A 175A 200A 250A 300A
400A 500A

Available residual current circuit breaker sizes (if required) are:

4-P 25A 300mA (sensitivity)
4-P 40A 100mA (sensitivity)
4-P 40A 300mA (sensitivity)
4-P 63A 100mA (sensitivity)
4-P 63A 300mA (sensitivity)
4-P 80A 300mA (sensitivity)
4-P 100A 300mA (sensitivity)

Solution:

Electrical Layout

Electrical Layout

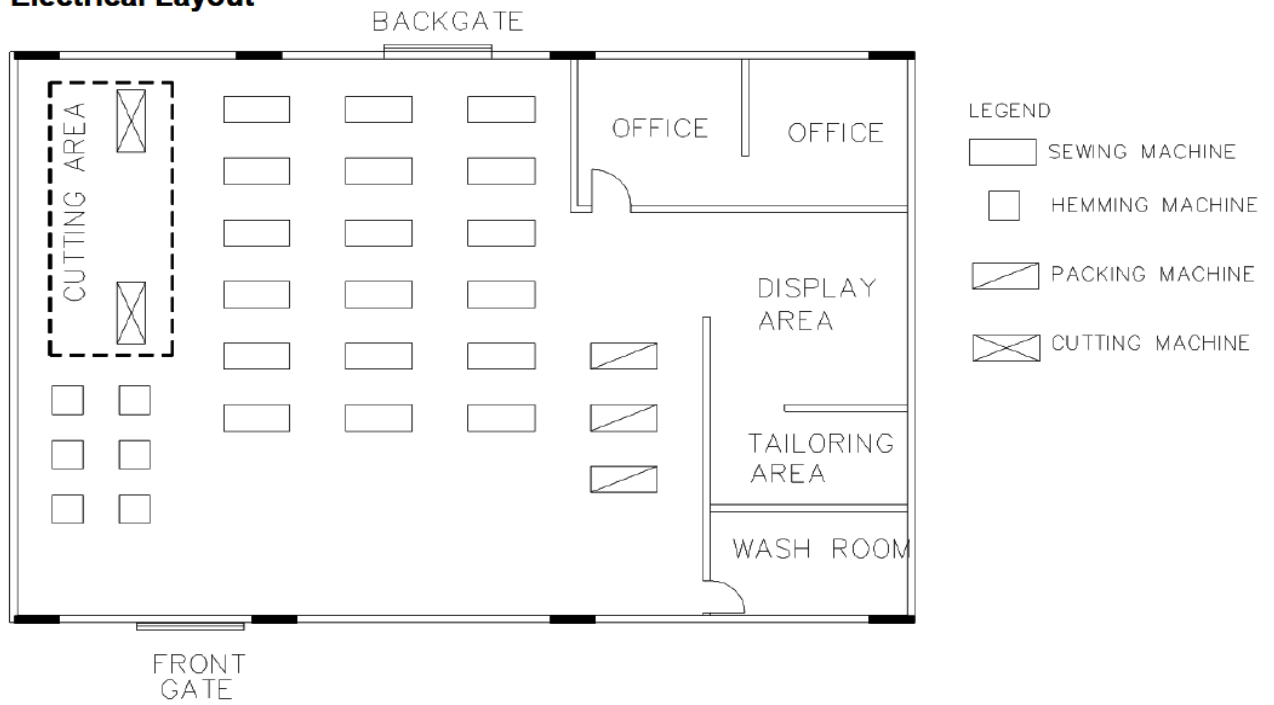


Figure 11-8 - Floor Plan of Garment Factory

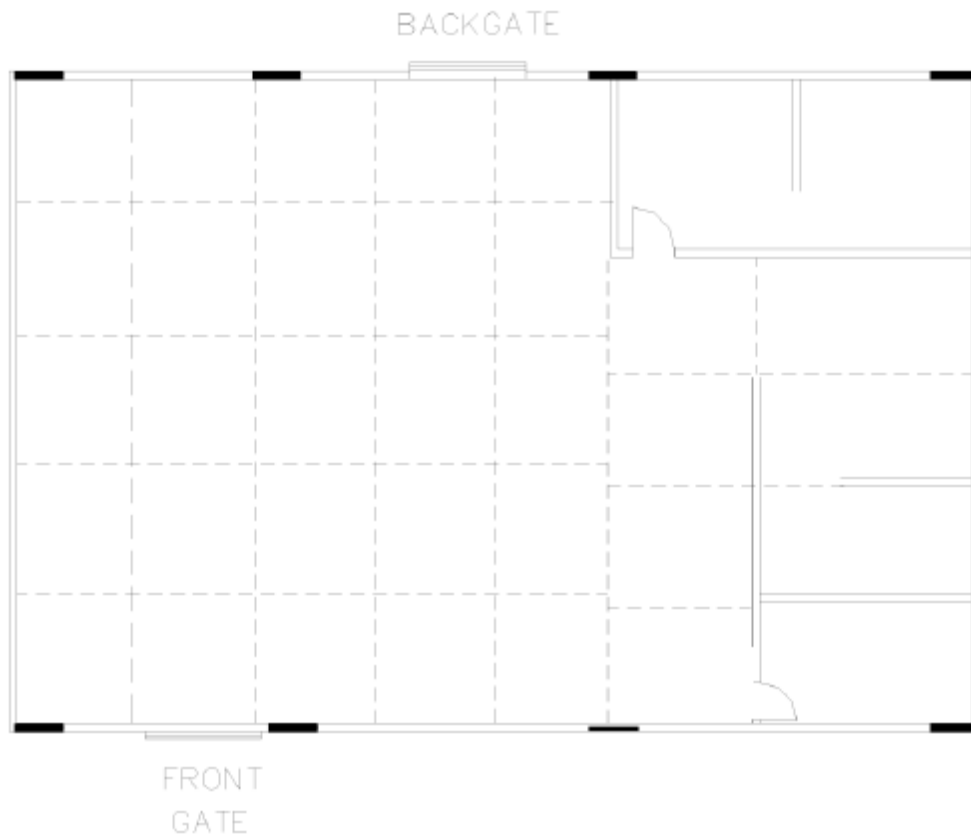


Figure 11-9 - Divided Floor Area for Lighting Points

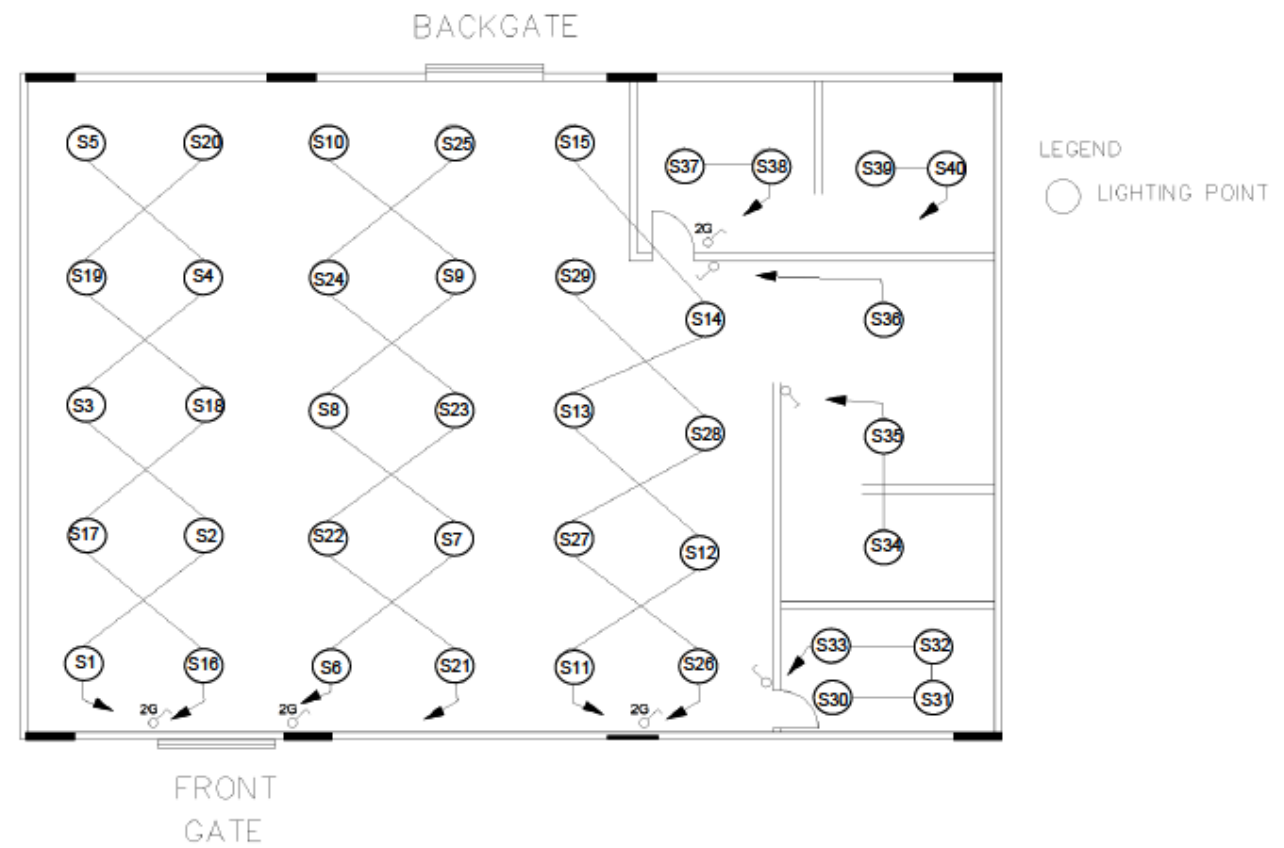
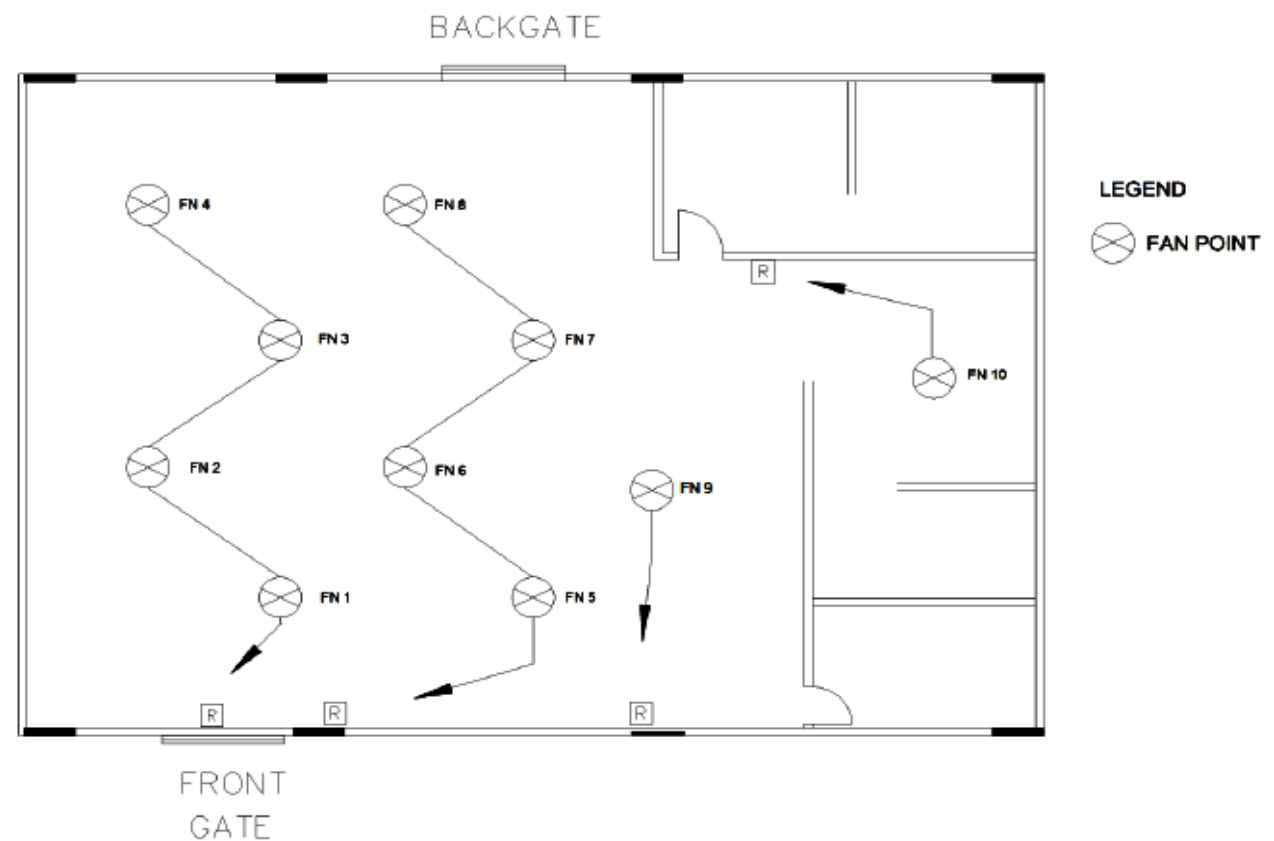


Figure 11-10 - Lighting Layout for Garment Factory



Solution :

Location	Lighting	Fan	13 A SSO	Machines				
				Type	Input Power	Input Curren t	Qty	Sub- total
Production Area	29 x 50W = 1450 W	9 x 100W = 900 W	34 x 500W = 17 000 W	Cutting m/c	1667 W	2.83 A	2	5.66 A
				Packing m/c	5294 W	8.99 A	3	26.97 A
Display / tailoring area	3 x 50W = 150 W	1 x 100W = 100 W	6 x 500W = 3000 W	Air-con	2133 W	3.62 A	1	3.62 A
Office area	4 x 50W	-	8 x 500W	-	-	-	-	-

	= 200 W		= 4000 W					
Washroom	4 x 50W = 200 W	-	1 x 500W = 500 W	-	-	-	-	-
Sub-total	2000 W	1000 W	24 500 W	-	-	-	-	36.25 A
Total power for single-phase load		= 2000 + 1000 + 24 500 = 27 500 W		-				
Total current for single-phase load		$= \frac{27\,500}{\sqrt{3} \times 400 \times 0.85}$ = 46.69 A		Total current for three-phase load		= 36.25 A		
Total Connected Load Current = 46.69 + 36.25 = 82.94 A Total Estimated Load Current (including 10% allowance) = 82.94 x (1 + 0.1) = 91.23 A								

Based on the **TOTAL LOAD CURRENT**:

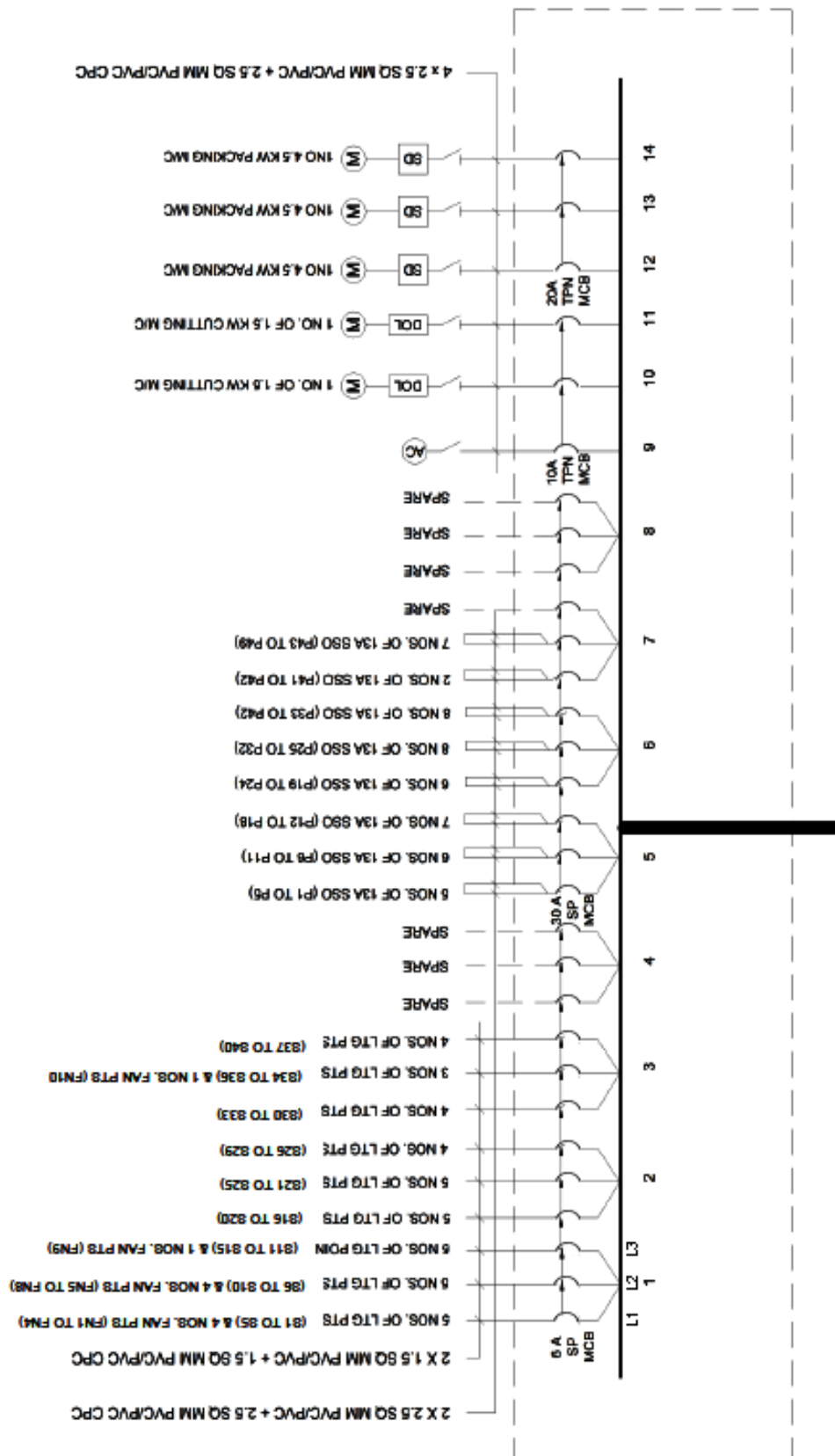
- 4P RCCB rating is _____ A, sensitivity of _____ mA,
- TP Isolation MCB rating is _____ A, Type _____,
- TP Isolator Switch rating is _____ A,
- TPN Service CB is _____ A, Type _____.

From **Table 4D1A of CP 5**,

- The incoming cable size is 4 x _____ mm² PVC/PVC insulated cables.
- The CPC cable for the incoming is _____ mm² PVC/PVC insulated cables.

Solution:

Partial Single-Line Diagram



Assignment 3

1. For the floor plan of a machine shop provided and the information given below:

- draw an electrical layout,
- calculate the electrical loading, and
- draw the single-line diagram of the consumer unit complete with the necessary protective devices and the intake equipment,

The loadings are as follows:

- lighting - 1 point for every 9 square metre,
- fan – 1 point for every 18 square metre,
- 13A switched socket outlet - 20 nos (including office),
- telecommunication point – 4 nos (in the office),
- lathe - 6 nos 4.5 kW 80% efficiency and 0.85 power factor,
- press - 1 no 7.75 kW 77% efficiency and 0.85 power factor,
- milling machine - 2 nos 3.8 kW 90% efficiency 0.8 power factor, and
- split-unit air-conditioner for office area - 1 no 1.6 kW, 75% efficiency and 0.8 power factor.

The following assumption were made by the LEW in-charge of the installation:

- one lighting point is to take 50 W,
- one fan point is to take 100 W,
- one 13A switched socket outlet is to take 500 W,
- no diversity is allowed for the air-conditioner,
- each lighting final circuit supplies 10 points,
- each radial final circuit (20A) supplies 4 points,
- each ring final circuit (32A) supplies 10 points,
- one spare each for lighting and power (13 A SSO),
- 15% allowance is included in the load calculation for the incoming cable, and
- select appropriate lighting switches to suit the users' requirement.

The single-line diagram should include :

- ** the size of the final circuits and incoming cables used ;
- ** the rating of the isolator, and
- ** the suitable incoming accessories for the installation.

Refer to CP 5 for the selection of the single-core PVC insulated cable. (Table 4D1A)

Available circuit breaker sizes are:

6A 10A 16A 20A 32A 40A 63A 80A 100A 125A 150A 175A 200A 250A

Take 0.85 as the overall power factor of the installation.

Available residual current circuit breaker sizes (if required) are:

4-P 63A 100mA (sensitivity)

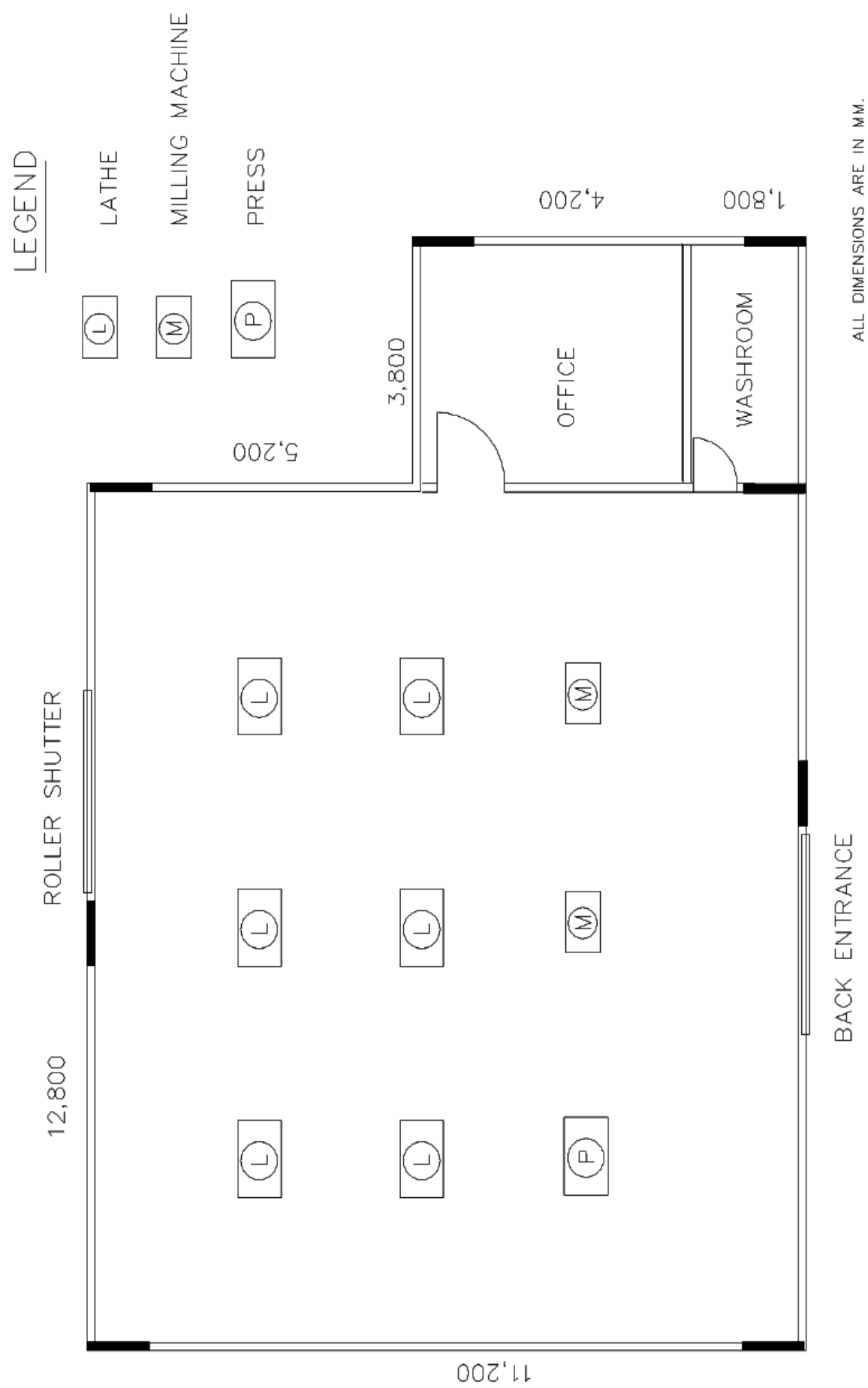
4-P 100A 100mA (sensitivity)

4-P 100A 300mA (sensitivity)

2. Use the following layer and colour scheme for the various accessories.

Application	Layer Name	Colour	Text Size/Style
Lighting points and switches	LTG	Cyan	3 mm /Arial
Fan points and regulators	FAN	Red	3 mm /Arial
13 A switched socket outlets	13 A SSO	Brown (24)	3 mm /Arial
Telephone point	TVTP	Green	3 mm /Arial
Isolator	ISOL	Magenta	3 mm /Arial
Meterboard and Consumer Unit	ACC	Black	3 mm /Arial
Single-line diagram	SLD	Black	3 mm /Arial

3. Save electrical layout and single-line diagram as **FactoryLayout.dwg** and **FactorySLD.dwg** respectively.



FLOOR PLAN OF MACHINE SHOP

Self-Check No. 5.2.2-2

1. It is proposed to illuminate a class room of dimensions 6 x 8 x 2.85 m to an illuminance (E) of 400 lx at the bench level. The specification calls for luminaires having one 1050 mm 40 W fluorescent natural tube with an initial output of 3200 lumens with white metal base and prismatic plastic diffuser (its UF is given in Table -2) . Determine the number of luminaires required for this installation when the MF is 0.7, respectively. The reflection coefficients are: (C= 0.70, W= 0.3, F=0.2)

Answer Key No. 5.2.2-2

Solution

From the room dimension we can calculate the room index (k)
assuming the working table height is 0.85 m. Hence,
 $h_k = 2.85 - 0.85 = 2\text{m}$

$$\text{Room Index}(k) = \frac{a.b}{h_k(a+b)}$$

$$k = \frac{6 \times 8}{2 \times (6 + 8)} = 1.71$$

From Table -1, UF = 0.57

$$N = \text{No. of luminaires} = \frac{\text{lumen required} \times \text{Area}(m^2)}{\text{lamp lumen} \times U.F \times M.F}$$

$$N = \frac{400 \times 48}{3200 \times 0.7 \times 0.57} = 14.58 \approx 15$$

Since 15 luminaire are large number that can be installed in the ceiling, so we suggest to use luminaire with 2x40 W fluorescent lamps with prismatic diffuser. Hence, the number of luminaires required will be,

$$15 \div 2 = 7.5 \Rightarrow 8 \text{ luminaires}$$

Luminaires distribution:

Distance between two adjacent luminaires is

$$= \frac{\text{Room length}}{\text{No. of luminaire in a single row}} = \frac{8}{4} = 2\text{m}$$

Distance between the luminaire and its adjacent wall = ($\frac{1}{2}$ to $\frac{1}{3}$) x (room height):

$$\text{or } \frac{2.85}{2} = 1.425 \approx 1.50 \text{ m}$$

Note: Usually we take the factor $\frac{1}{2}$ when the dimensions of the room are such that the ratio of the length to the width is less than 1.6, otherwise we take the factor of $\frac{1}{3}$. The distribution of the luminaires are shown in Fig.A

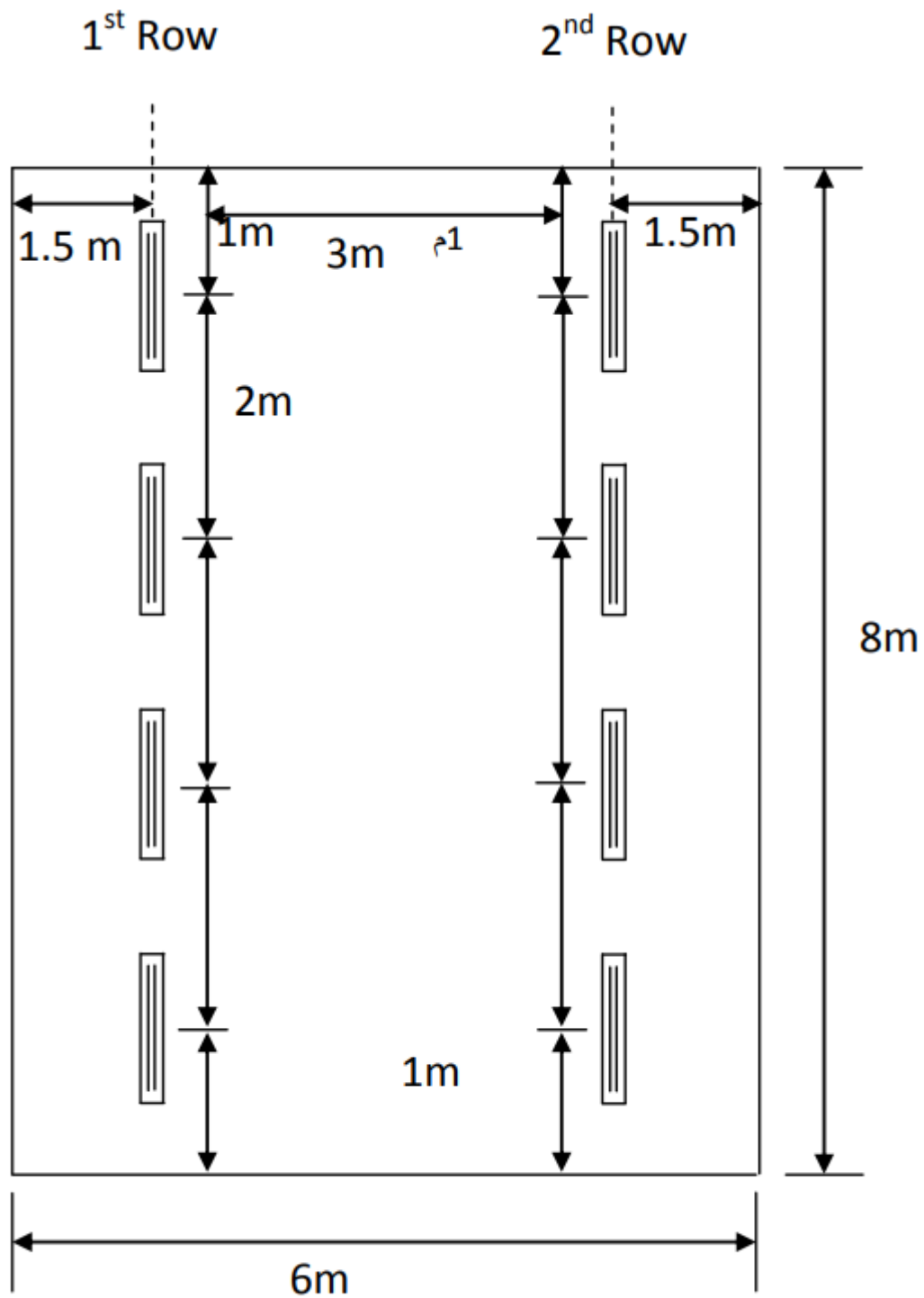


Fig.A Luminaires distribution on room ceiling

1.Introduction

Feeders are the part of the electrical system that connect the branch-circuit panelboards to the electrical service equipment. See Figure 8-1. Conductors from on-site generators and transformers are also feeders, not service conductors. Service conductors extend from the utility source to the service disconnecting means. In the Commercial Building, a feeder is installed to each of the five occupancies, and one to the panelboard for the owner's circuits.

The feeder layout is shown in a riser diagram on working drawing E4. Specific requirements for feeders are given in NEC® Article 215 concerning installation requirements and in NEC Article 220, Part II, concerning calculated loads and demand factors.

Some of the information presented in this unit has been introduced previously in Chapter 3 of this book. This redundancy is intentional because of its application to both feeders and branch circuits.

What about Future Growth?

As you study Electrical Wiring Commercial, you will learn how to make load calculations in conformance to the NEC. You will also note that the authors have added additional load values in certain instances. This provides for future growth. The NEC talks about future growth in 90.8. As you read through this section, you'll find that the text gives a recommendation, not a requirement. Providing spare capacity in the design of the electrical system, such as leaving unused space in conduits and other raceways, along with unused spaces in panelboards, accommodates future growth in the electrical system and should be practiced. This is above and beyond the minimum NEC requirements but is considered good practice by electricians, contractors, and consulting engineers.

oltages and Rounding Values: Electrical calculations always involve certain values that come about from rounding up, rounding down, or following certain Code requirements.

For example, we might solve for amperes using the following formula:

$$I = \frac{S}{\sqrt{3} \times U} \text{ or } I = \frac{kVA \times 100}{E \times 1.732}$$

The value of 1.732 is the square root of 3 ... !3. Using a calculator to find !3, we find 1.732050808. To be practical, the electrical industry uses 1.732, although some may shorten this to 1.73.

In the above formula, when E or U equals 380 volts, the result of $E \times 1.732 = 658.179$. Again, to be practical, we use 660 in many calculations.

The value of 380 is the product of 220×1.732 . This comes from 380Y/220 volt, 3-phase systems. These systems are created by connecting three, 220- volt transformers in a Y configuration with one end of each transformer connected in the center. The voltage between outer points of the three-phase transformer connections is about 380 volts. This is another example of rounding off. Actually, $220 \times 1.732 = 381.04$. Multiply 220 by 1.732050808 and we get 381.04.

Because electrical systems may operate at slightly varying voltages, NEC 220.5(A) contains the following rule to simplify calculations by telling us,

Voltage. Unless other voltages are specified, for purposing of calculating branch-circuit and feeder loads, nominal system voltages of 220, 380Y/220.

The word nominal means "in name only, not in reality."

A branch-circuit nominal voltage might be 220 volts, but the actual operating voltage be 220, 225, 230, or just about anything. As an example, the Code decided that for consistency, calculations will use the value of 220 volts.

NEC 220.5(B) goes on to state, Fractions of an Ampere. Except where the calculations result in a major fraction of an ampere (0.5 or larger), such fractions are permitted to be dropped.

Take a look at Informative Annex D in your NEC which contains examples of load calculations. You will find the Code Panel has rounded the results up or down and do not show

any value other than full amperes. So, as you work your way through this text, don't get "hung up" and waste time trying to pin down precise calculation results.

The Electrical Load

To plan any electrical wiring project, the first step is to determine the load the electrical system is to serve. Only with this information can components for the branch circuits, the feeders, and the service be properly selected. The NEC provides considerable guidance in determining the minimum loading that is appropriate, for a given occupancy, for feeders and the service. Often the electrician or electrical contractor is asked to generate this information. It is quite common for electrical inspection departments to require load calculation information to be submitted before the permit will be issued for the project. See NEC 215.5. This unit of this text provides a foundation for performing load calculations so proper selection of electrical circuit components can be accomplished.

NEC Article 220 establishes the procedure that is to be used to calculate electrical loads for services, feeders, and branch circuits. Section 220.40 states the overall concept for load calculations, The calculated load of a feeder or service shall not be less than the sum of the loads on the branch circuits supplied, as determined by Part II of this article, after any applicable demand factors permitted by Part III or IV or required by Part V have been applied.

Load calculations for many types of equipment such as for air-conditioning equipment, cranes and hoists, fire pumps, and electric welders are provided in other articles in the NEC. See NEC Table 220.3 for this information.

As we will see, lighting loads in commercial occupancies are generally considered to be continuous, that is, in operation for 3 hours or more. To prevent overheating conductors and terminals for equipment such as circuit breakers and connections for fusible switches, additional capacity not less than 125% of the continuous load is required to be added to any noncontinuous load. See the following table for application of this rule.

Component	NEC Section	Continuous	Noncontinuous
		Load	Load
Branch-circuit conductor	210.19 (A)(1)(a)	125%	100%
Branch-circuit overcurrent device	210.20(A)	125%	100%
Feeder conductor	215.2 (A)(1)(a)	125%	100%
Feeder overcurrent device	215.3	125%	100%
Service conductors	230.42(A)(1)	125%	100%

These factors must be applied where appropriate so that the conductors and overcurrent protection as well as the equipment that contains the overcurrent protection will be sized properly. An exception is permitted to be applied to these rules for equipment that is rated at 100%, or continuous duty, as well as for grounded (often referred to as “neutral”) conductors that do not connect to the overcurrent device.

Most overcurrent protective devices in the up to 600-volt class of equipment are not rated for continuous, or 100%, duty and must be increased in ampacity to compensate for continuous load.

Calculated or Connected Load?

Lighting loads can either be a calculated load based on the area in square feet (square meters), using a unit load as determined from NEC Table 220.12, or may be the actual connected load, obtained by referring to the nameplate on the equipment. Always use the larger load determined by the methods.

Using the Drugstore in this text as an example case, the application of these procedures will be illustrated.

- The phrase calculated load will be used to designate when the value is in compliance with the requirements of NEC Article 220. This calculated load is often determined by selecting an appropriate unit load and multiplying this by the number of units.
- The phrase connected load will be used to designate the value of the load as it actually exists and is to be connected to the electrical system.

NEC TABLE 220.12		
Table 220.12 General Lighting Loads by Occupancy.		
Type of Occupancy	Unit Load	
	Volt-Amperes/ m²	Volt-Amperes/ ft²
Armories and auditoriums	11	1
Banks	39 ^b	3½ ^b
Barber shops and beauty parlors	33	3
Churches	11	1
Clubs	22	2
Court rooms	22	2
Dwelling units ^a	33	3
Garages — commercial (storage)	6	½
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants ^a	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	1½
Office buildings	39 ^b	3½ ^b
Restaurants	22	2
Schools	33	3
Stores	33	3
Warehouses (storage)	3	¼
In any of the preceding occupancies except one-family dwellings and individual dwelling units of two-family and multifamily dwellings:		
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways	6	½
Storage spaces	3	¼

^aSee 220.14(J).

^bSee 220.14(K).

Receptacle Outlets

- A single piece of equipment consisting of a multiple receptacle comprised of four or more receptacles is required to be calculated at not less than 90 volt-amperes per receptacle. As shown in Figure 8-2, the first outlet has one receptacle on a strap or yoke, for a calculated load of 180 VA. The second outlet has two receptacles on a strap or yoke, for a calculated load of 180 VA. The third outlet shows two straps or yokes, for a total of four receptacles, resulting in a calculated load of 360 VA. The fourth outlet shows a single piece of equipment or wiring device with four receptacles. This represents a calculated load of 360 VA. See NEC 220.14(I).
- The actual rating is used for specific loads such as receptacles for a copy machine and cash registers, NEC 220.14(A).

The allowance for the receptacle outlets for non-specific loads is 15 on the first floor and 6 in the basement storage area for a total of 21 outlets @ 180 VA = 3780 VA

Receptacle for Servicing AC Equipment

The receptacle outlet is required to be located at the same level as the HVAC equipment and within 25 ft (7.56 m) of the equipment, by NEC 210.63.

NEC 210.8(B)(3) requires that the receptacle be GFCI protected. No load allowance is stipulated other than the 180 VA from NEC 220.14(I). The arbitrary allowance by the author is 1 receptacle outlet for servicing the HVAC @ 1500 VA per outlet = 1500 VA

Sign Outlet

Article 600 in the NEC covers the installation of signs and outline lighting. Here, we discuss the required load for a sign outlet and the very important safety requirement—the disconnecting means.

A sign outlet

- Is a requirement of NEC 600.5(A).
- Is assigned a minimum allowance of 1200 voltamperes in NEC 220.14(F) for each branch circuit required in NEC 600.5(A).
- Branch circuit(s) is required to be rated at least 20 amperes and shall not supply other loads.
- A 125% factor is applied in the calculation, as the sign is considered to be a continuous load.

1 sign outlet @ 1200 VA per outlet = 1200 VA.

In accordance with NEC 600.6, each sign and outline lighting system is required to have a disconnecting means (switch or circuit breaker) that

- is externally operable.
- opens all ungrounded (“hot”) conductors.
- is within sight of the sign or is capable of being locked in the off position.
- does not rely on portable means of locking the disconnect off. Exception: Indoor signs that are cord-and-plug connected do not require another disconnect. The cord-and-plug connection serves as the required disconnecting means.

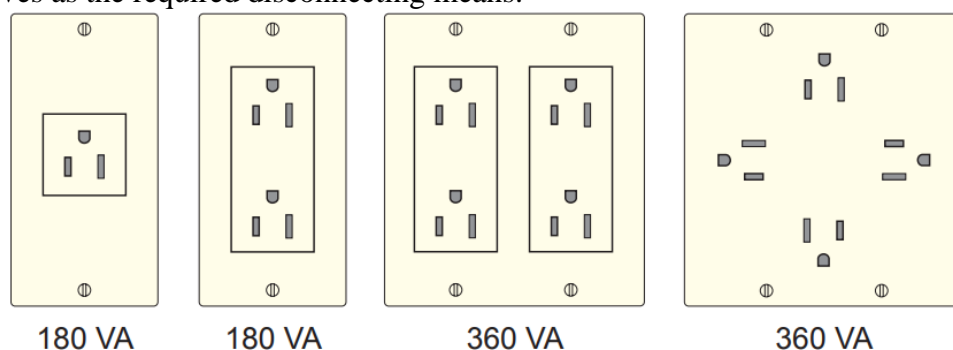


FIGURE 8-2 Minimum receptacle outlet allowance.

Source: [Electrical Wiring Commercial \(PDFDrive \).pdf](#)(page193-198)

Receptacle Loads

Receptacle loads are not generally considered continuous unless the receptacle is for dedicated loads that are continuous in nature. A calculated load of 180 VA is used for most convenience receptacles for cord-and-plug-connected loads.

Other Loads

A specific allowance is provided for

- cash registers,
- electric door operators,
- copy machine,
- exhaust fans,
- water heater,
- unit heater for storage space, and
- receptacles for servicing HVAC equipment

HVAC Equipment

The connected motor loads are used. The load for the compressor would normally be shown in the Continuous Load column to satisfy the requirement in NEC 430.24 that 125% of the largest motor load be used in the load calculation. However, in this feeder the heating load is used rather than the air-conditioning equipment, because only one of the loads will operate at any one time. The NEC considers this as noncoincident loads; see NEC 220.60. The branch circuit for fixed electric space heating equipment is required to be considered a continuous load by NEC 424.3(B). However, the load on the feeder is shown as a noncontinuous load based on NEC 220.51.

Feeder Requirements

Feeder Ampacity

General requirements for the sizing of feeder conductors are contained in NEC 215.2(A)(1). This section reads,

- (1) General. Feeder conductors shall have an ampacity not less than required to supply the load as calculated in Parts III, IV, and V of Article 220. Conductors shall be sized to carry not less than the larger of (a) or (b).
 - (a) Where a feeder supplies continuous loads or any combination of continuous and noncontinuous loads, the minimum feeder conductor size shall have an allowable ampacity not less than the noncontinuous load plus 125 percent of the continuous load.
 - (b) The minimum feeder conductor size shall have an allowable ampacity not less than the maximum load to be served after the application of any adjustment or correction factors.*

In actuality, the calculated load for branch circuits from Part II of Article 220 is included in the feeder calculations of Part III by virtue of the statement in NEC 220.40. Several demand factors are included in Part III of Article 220, including for lighting, receptacles, electric ranges, and dryers. The demand factors for lighting often do not apply to commercial buildings, such as office buildings, because the lighting loads are usually on for more than 3 hours. These loads are then considered continuous loads, and a 125% load factor must be applied. See NEC 210.19(A)(1) for branch circuit loads and 215.2(A)(1)(a) for feeder loads.

The following is a summary of the requirements for sizing feeder conductors:

- A feeder must have an ampacity no smaller than the sum of the volt-amperes of the coincident loads of the branch circuits supplied by the feeder as reduced by demand factors; see NEC Article 220, Part II.
- Demand factors are allowed in selected cases if it is unlikely that all the loads would be energized at the same time; see NEC 220.42 for demand factors for lighting loads, and 220.44 for demand factors for receptacle loads.
- Only the larger of any noncoincident loads (loads unlikely to be operated simultaneously such as the air-conditioning and the heating) need be included; see NEC 220.60.

- Referring to NEC 220.61, a feeder neutral conductor may be reduced in size in certain situations. It may not be reduced in feeders consisting of 2-phase wires and a neutral conductor of a 3-phase, 4-wire, wye-connected system because it carries approximately the same current as the ungrounded conductors.

The neutral conductor of a 3-phase, 4-wire, wye-connected system may be reduced in size provided it remains of a size sufficient to

- carry the maximum unbalanced load.
- carry the nonlinear load.

Self checks No. 5.2.2-3

1. Amperes using the following formula(3phase)?
2. Amperes using the following formula(1phase)?

Answer Key No. 5.2.2-3

1. $I = \frac{S}{\sqrt{3} \times U}$

2. $I = \frac{S}{U}$

Information Sheet No. 5.2.2-4: Wiring Calculation

1. Type of insulate

1.1 RHW and RHW-2

R = Rubber Insulation



A rubber outer layer that is very important when it comes to copper cables, especially when those cables are utilized in possible hazardous environments. Like XHHW and XHHW-2, RHW-2 wires are insulated by cross-linked polyethylene (XLPE). Even though the “R” stands for rubber, it also incorporates other neoprene insulations that XLPE falls under.

H = Heat Resistance of 75° C

Cables must be able to withstand the elements. The insulation’s length and width determine its heat resistance. The thinner the XPLE insulation, the less resistant it is to heat.

W = Water Resistance

Possibly the most important factor when considering the environment of your wire. The “W” means the cables can be submerged in water if needed. Even though the wire has a rubber outer layer and is acceptable for use in damp environments, the “W” designation is required for use in the presence of water and other liquids.

RHW and RHW-2 – The Difference:

RHW – RHW cable is a wire insulated by rubber or XLPE as mentioned above. RHW cable can withstand heat up to **75° C**, and is water resistant. It is acceptable to use RHW cables underground and in wet locations.

RHW-2 – Having the same inherent qualities as RHW, the NEC lists RHW-2 as having the ability to withstand heats of up to **90° C**. RHW-2 cable is suitable for direct burial in both wet or dry conditions.

USE-2

U = Underground

S = Service

E = Entrance

USE-2 cable stands for Underground Service Entrance cable. USE-2 cable can be used underground since it is able withstand pressure and is resistant to other elements such as sunlight (black only), oil and gas. USE-2 is a good choice for industrial applications where better insulation toughness and resistance to moisture and heat are desired. USE-2 can be used as RHW-2 or RHH cable at temperatures up to 90°C in wet or dry locations.

What does the “-2” stand for? It is a designation used for the 90° C temperature rating. In the past, there was a plain USE, but it is now generally considered obsolete and replaced by USE-2.

RHH

Very similar to RHW/RHW-2 cable. As mentioned above, the **R** stands for Rubber – but in this case the extra “H”, or **HH** in RHH, stands for High Heat resistance of 90° C. The trade-off is that RHH cable does not possess the water resistance characteristic of RHW / RHW-2 cable.

Similarities: Both RHH and RHW / RHW-2 cable hold a 600 V rating. Both cables can be found in lighting, power systems and general wiring applications – depending on the location and environmental conditions.

Source: <https://www.multicominc.com/training/technical-resources/rhh-rhw-2-use-2-and-rhh-building-wire-explained/>

1.2.THHN / THWN / THWN-2

THHN	THWN	THWN-2
T = Thermoplastic HH = High Heat Resistance N = Nylon Coated Temp Rating: 90° C in dry locations	T = Thermoplastic H = Heat and W = Water Resistance N = Nylon Coated Temp Rating: 90° C in dry locations and 75° C in wet locations	T = Thermoplastic H = Heat and W = Water Resistance N = Nylon Coated Temp Rating: 90° C in both dry and wet locations

The most popular type of building wire used in construction is Thermoplastic High Heat-resistant Nylon coated (THHN) wire. THHN wire is also commonly used in machine tools, control circuits and some appliances.

THHN wire comes in a variety of characteristics:

- Conductors: Depending on the size can be either stranded or solid
- Wire material: Copper or aluminum
- Jacket: Polyvinylchloride (PVC) insulation with a nylon jacket

Aside from the mechanical protection, a nylon jacket protects the wire from abrasion as it's pulled through conduit. In addition, the jacket protects the wire from hydrocarbons such as oil, gasoline and grease. The tough nylon jacket also protects the wire from being puncture or accidentally cut as it protects the insulation.

THHN wire is approved for up to 600V and is listed by Underwriters Laboratory (UL), as rated for 90° C (194° F) in dry and 75° C (167° F) in wet environments. THHN wire comes with a dual rating: THHN / THWN, which means it's appropriate for both dry and wet applications.

1.3. XHHW and XHHW-2

XHHW	XHHW-2
X = Cross-Linked Polyethylene (XLPE) HH = High Heat-Resistance W = Water Resistance Temp Rating: 90° C in dry locations and 75° C in wet locations	X = Cross-Linked Polyethylene (XLPE) HH = High Heat-Resistance W = Water Resistance Temp Rating: 90° C in both dry and wet locations

XHHW-2 wire is the next generation XHHW wire. While its main use is for residential, commercial and industrial buildings, it is also used in raceways, feeder and circuit wiring.

- Conductors: Copper or aluminum
- Wire: Solid or stranded cable – stranded wire is used to maintain flexibility

XHHW-2 is approved for use up to 600V and is UL Listed for 90° C (194° F), in both dry and wet locations. The previous generation of XHHW had a lower temperature rating, approved up to 75° C in wet environments, making the next generation XHHW-2 wire a more useful and an 'all environment'-type product.

Source: <https://www.multicominc.com/training/technical-resources/thhn-vs-xhhw-difference/>

1.4. Polyvinyl Chloride (PVC)

Sometimes called simply “vinyl,” Polyvinyl Chloride (PVC) provides cables with the ability to resist oils, acids alkalis, sunlight, heat weathering and abrasion. This range of properties makes PVC a great outer covering for such wire types as underground feeders (UF), control, street lighting, direct burial wires and aerial.


It’s often used as an impervious jacket in installations that require cables to be highly protected. Most PVC compounds do not have extremely high- and low-temperatures in the same formulation, and usually range from -20°C to 60°C. Different varieties also have different pliability and electrical properties.

PVC can be found on such copper wire products as Machine Tool Wire (MTW), Appliance Wiring Material (AWM) and TW/THW, among others.

Source: <https://www.kristechwire.com/insulation-polyvinyl-chloride-pvc/>



2.Size cable



Cable Cross Sectional Area (mm ²)	Typical Current Rating (amps)	Recommended Circuit Breaker Rating (amps)
1.5 mm ²	7.9 - 15.9A	8A
2.5 mm ²	15.9 - 22A	15A
4 mm ²	22 - 30A	20A
6 mm ²	30 - 39A	30A
10 mm ²	39 - 54A	40A
16 mm ²	54 - 72A	60A
25 mm ²	71 - 93A	80A
50 mm ²	117 - 147A	125A
70 mm ²	147 - 180A	150A
95 mm ²	180 - 216A	200A
120 mm ²	216 - 250A	225A
150 mm ²	250 - 287A	275A
185 mm ²	287 - 334A	300A
240 mm ²	334 - 400A	350A

3.Electrical wiring Color code

ELECTRICAL WIRING COLOR CODES (NEC & IEC) - 1 & 3 PHASE (AC)								
www.electricaltechnology.org								
PHASE SUPPLY	WIRE & CABLE	NEC - US / CANADA (120, 208 & 240V)	NEC - US / CANADA (277 & 480 V)	IEC- UK & EU	CHINA & RUSSIA (Old)	AUS & NZ	JAPAN	INDIA, PAK & SA
3-PHASE	LINE 1 "L1"							
	LINE 2 "L2"							
	LINE 3 "L3"							
COMMON	NEUTRAL "N"							
GROUND / EARTH "PG" or "PE"								
1-PHASE	LINE "L"							
	NEUTRAL "N"							

4 .ការជ្រើសរើសមុខកាត់ខ្សែចម្លង

ការជ្រើសរើសមុខកាត់ខ្សែចម្លងនេះ គឺតាមចរន្តអនុញ្ញាតរបស់ខ្សែចម្លងដែលត្រូវធ្វើការជ្រើសរើសពីបន្ទាប់មកធ្វើការគណនាការទន្លាក់តង់ស្យុងតាមរូបមន្តខាងក្រោម តារាងមុខកាត់ខ្សែ៖

$$\text{តាមរូបមន្ត: } V_d = \frac{M_v \times I_b \times L}{1000}$$

ដែល M_v ជាទន្លាក់តង់ស្យុងលើមុខកាត់ខ្សែពីតារាងមុខកាត់ខ្សែ) $mV / A / m$)

L ជាប្រវែងនៃខ្សែចម្លង

I_b ជាចរន្តបន្ទុកប្រើប្រាស់គិតជា) A)

សម្រាប់មុខកាត់ខ្សែដែលមានទំហំតូចជាង យោងតាមសៀវភៅ) $25mm^2$ GUIDELINES FOR ELECTRICAL WIRING IN RESIDENTIAL BUILDINGS) និងតាមរូបមន្តក្នុងតារាងខាងក្រោម គឺ សម្រាប់គណនាទន្លាក់តង់ស្យុងលើមុខកាត់ខ្សែដែលមានទំហំ $25mm^2$ ឬធំជាងនេះ។ (យោងតាមសៀវភៅ Electrical installations in buildings - Part 5-52) IEC standard governing cable sizing។

Circuit	Voltage drop (V_d)	In %
	In volts	
សម្រាប់ប្រព័ន្ធន័យ – ហ្វា	$V_{d.3\phi} = \frac{\sqrt{3}I_b(R\cos\varphi + X\sin\varphi)L}{1000}$	$\frac{100V_{3\phi}}{V_L}$
សម្រាប់ប្រព័ន្ធទាត់ – ហ្វា	$V_{d.1\phi} = \frac{2I_b(R\cos\varphi + X\sin\varphi)L}{1000}$	$\frac{100V_{1\phi}}{V_n}$

ដែល $V_{d.1\phi}$ ទន្លាក់តង់ស្យុងក្នុងប្រព័ន្ធទាត់ – ហ្វា (V)

$V_{d.3\phi}$ ទន្លាក់តង់ស្យុងក្នុងប្រព័ន្ធន័យ – ហ្វា (V)

R តម្លៃរេស៊ីស្តង់របស់ខ្សែចម្លង Ω / km

X តម្លៃរេអាក់តង់របស់ខ្សែចម្លង Ω / km

$\cos\varphi$ កត្តាអានុភាពបន្ទុក

L ប្រវែងរបស់ខ្សែចម្លង (m)

V_L តង់ស្យុងរវាងហ្វា–ហ្វា (V)

V_n តង់ស្យុងរវាងហ្វា–ណឺត (V)

5. ការជ្រើសរើសឌីស្យុងទ័រ

ដើម្បីការពារបណ្តាញអគ្គិសនីយើងគួរជ្រើសរើស ឲ្យមានសុវត្ថិភាពដល់អ្នកប្រើប្រាស់ ឬបរិក្ខារអគ្គិសនី ឌីស្យុងទ័រ ឧបករណ៍ការពារដូចជា ឬកុយស៊ីបយកមកប្រើប្រាស់។ ការជ្រើសរើសយើងអាចកំណត់បានតាមរូបមន្តដូចខាងក្រោម៖

$$\text{រូបមន្ត } I_{CB} = I_b \times 1.25$$

ដែល I_b ជាចរន្តរបស់បន្ទុកប្រើប្រាស់គិតជា [A]

I_{CB} ជាចរន្តណូមីណាល់របស់ឌីស្យុងទ័រគិតជា [A]

ក្នុងការជ្រើសរើសមុខកាត់ខ្សែចម្លងតាមស្តង់ដារអនុវត្តន៍ជាក់ស្តែង យើងធ្វើជ្រើសរើសគឺ៖

- មុខកាត់ខ្សែ និងឌីស្យុងទ័រសម្រាប់ប្រព័ន្ធបំភ្លឺគឺ $1C \times 3 \times 1.5mm^2 / Cu / PVC / MCB(1P - 10A)$
- មុខកាត់ខ្សែ និងឌីស្យុងទ័រសម្រាប់ប្រព័ន្ធបំភ្លឺគឺ $1C \times 3 \times 2.5mm^2 / Cu / PVC / RCB(1P - 20A)$

- មុខកាត់ខ្សែ $1C \times 3 \times 4mm^2 / Cu / PVC / MCB (1P - 20A)$ និងឌីស្យុងទំរសម្រាប់ឧបករណ៍កំដៅទឹកក្ដៅ
- មុខកាត់ខ្សែ និងឌីស្យុងទំរសម្រាប់ម៉ាស៊ីនត្រជាក់គឺ $1C \times 3 \times 2.5mm^2 / Cu / PVC / MCB(1P - 20A)$
- មុខកាត់ខ្សែ និងឌីស្យុងទំរសម្រាប់អ្នកប្រើប្រាស់នីមួយៗ $1C \times 3 \times 6mm^2 / Cu / PVC / MCB(2P - 32A)$

✚ ការជ្រើសរើសមុខកាត់ខ្សែតាមជាន់

ការជ្រើសរើសមុខកាត់ខ្សែតាមទន្លាក់តង់ស្យុងសម្រាប់ជាន់ទី២ ដែលមានអានុភាពប្រើប្រាស់សរុប 122.28 kVA យើងធ្វើការជ្រើសរើសមុខកាត់ខ្សែលេខ $70mm^2$ Multi-Core Cables Having Xlpe Insulation, Non-Armoured (Copper Conductor) ពីតារាងមុខកាត់ខ្សែលេខ

$$\text{តាមរូបមន្ត: } V_{3\phi} = \frac{\sqrt{3}I_b(R\cos\varphi + X\sin\varphi)L}{1000}$$

ដែល $L = 10m$, $R = 0.59 mV / A / m$ និង $X = 0.13 mV / A / m$ ជាទន្លាក់តង់ស្យុងលើមុខកាត់ខ្សែពីតារាងមុខកាត់ខ្សែតាមតារាង៥៥.

$$\text{ជាចរន្តបន្ទុកប្រើប្រាស់ } I_b = \frac{S_{total}}{V} = \frac{129.77 \times 10^3}{\sqrt{3} \times 400} = 188A$$

$$\text{ទន្លាក់តង់ស្យុង) V) } V_{3\phi} = \frac{\sqrt{3} \times 188 \times (0.59 \times 0.98 + 0.13 \times 0.20) \times 10}{1000} = 1.96V$$

$$\text{ទន្លាក់តង់ស្យុង) V\%) } V_d \% = \frac{V_d}{V} \times 100 = \frac{1.96}{400} \times 100 = 0.49\%$$

ទន្លាក់តង់ស្យុងតូចជាង 3 % ដូចនេះយើងអាចជ្រើសរើសខ្សែដែលមានមុខកាត់ $4C \times 70mm^2 / Cu / XLPE / PVC$ មកប្រើប្រាស់បាន។

Self checks No. 5.2.2-4

1. ចូរសរសេររូបមន្តទន្លាក់តង់ស្យុងសម្រាប់មុខកាត់ខ្សែដែលមានទំហំធំជាង **16mm** ក្នុងប្រព័ន្ធទាញ និង ៣ ហ្វា?

Answer Key No. 5.2.2-4

Circuit	Voltage drop (V_d)	
	In volts	In %
សម្រាប់ប្រព័ន្ធន័៣ – ហ្វា	$V_{d.3\phi} = \frac{\sqrt{3}I_b(R\cos\varphi + X\sin\varphi)L}{1000}$	$\frac{100V_{3\phi}}{V_L}$
សម្រាប់ប្រព័ន្ធទ១ – ហ្វា	$V_{d.1\phi} = \frac{2I_b(R\cos\varphi + X\sin\varphi)L}{1000}$	$\frac{100V_{1\phi}}{V_n}$

**ល.ស៣៖ ដំឡើង និងថែទាំប្រព័ន្ធបណ្តាញអគ្គិសនីក្នុងអគារពាណិជ្ជកម្ម និងអគារឧស្សាហកម្ម
លក្ខណវិនិច្ឆ័យនៃការវាយតម្លៃ៖**

១. ទទួល និងបកស្រាយព័ត៌មានពាក់ព័ន្ធ និងតម្រូវការសម្រាប់ការដំឡើង
២. ដំឡើងគ្រឿងបន្ថែមស្របតាមតម្រូវការនៃការរចនា
៣. ដំឡើងប្រព័ន្ធអគ្គិសនី សម្រាប់ការដំឡើងស្របតាមតម្រូវការនៃការរចនា
៤. ដំឡើងខ្សែដែលមានទំហំមុខកាត់ និងពណ៌ត្រឹមត្រូវ
៥. ដំឡើងប្រព័ន្ធខ្សែស្របតាមតម្រូវការ
៦. ត្រួតពិនិត្យ និងធ្វើតេស្តការដំឡើងសម្រាប់ដំណើរការត្រឹមត្រូវ
៧. អនុវត្តតាមបច្ចេកទេសសមស្រប ដើម្បីកែតម្រូវកំហុចក្នុងការដំឡើង

មាតិកា៖

- ការប្រើប្រាស់ឧបករណ៍និងបរិក្ខារក្នុងការដំឡើងបណ្តាញអគ្គិសនី
- ការប្រើប្រាស់បរិធានដ្ឋានក្នុងការដំឡើងបណ្តាញអគ្គិសនី
- ការជ្រើសរើសឧបករណ៍និងបរិក្ខារក្នុងការដំឡើងបណ្តាញអគ្គិសនី
- ការដំឡើងបណ្តាញអគ្គិសនីក្នុងអគារ
- ការគណនានិងដំឡើងប្រព័ន្ធខ្សែ
- ការជួសជុលនិងថែទាំបណ្តាញអគ្គិសនី

Non-Metal Conduits

For use above ground, this conduit must be flame retardant, tough, and resistant to heat, sunlight, and low-temperature effects.

1. Non-metallic conduit (NMC)



Non-metallic conduit is common both in rigid and flexible conduits. They are usually made of PVC.

Available in various colors such as Blue, Yellow, Red in the market.

Advantages:

- Easy to install.
- Lightweight, hand bendable.
- Resistant to corrosion and good protection from moisture ingress.

Applications:

- Available in long lengths, convenient for laying cables such as Ethernet, Fiber optic.

2. Rigid Polyvinyl Chloride (Rigid PVC)



This is the most popular type of non-metallic conduit has several advantages.

PVC conduits are used for electrical wires that may be required to run under the ground or in an open environment that is exposed to air, dust, and water.

Advantages:

- Lightweight.
- Typically less expensive than other options,
- Versatile and easy to install available in a variety of wall thicknesses.

Disadvantages:

PVC conduit is not recommended for use in areas of direct sun exposure. Sunlight can break down the material over time.

Applications:

- It may be used in wet locations and has good resistance to many highly corrosive chemicals.
- It is absolutely waterproof, thus ideal for wet areas in industrial and commercial structures.

Source: Electrical Estimating Methods by Wayne J DelPico.

How to Install Electric pvc conduit pipe Wiring System

1.5 How to do Cleaning and Protection of Electric PVC Conduit

While working at site, Civil Engineer mainly face difficulty in the Electric pvc conduit pipe Installation procedure and they also don't know how to know the quality of Electric pvc conduit pipe. To help them to know the complete information about the Electric pvc conduit pipe Installation procedure, we will guide everything from the scratch.

What is Electric pvc conduit pipe?

These shall be grey coloured rigid PVC conduit of perfectly circular tubing having minimum wall thickness of medium gauge 1.8 mm approved by F.I.A. & I.S.I. and shall conform to IS 9537 Part III. No PVC conduit of less than 25 mm dia shall be used for electrical wiring.

- i) Up to 38 mm diameter – min. 1.8 mm wall thickness
- ii) Above 40 mm diameter – min. 2.2 mm wall thickness

Electric PVC Conduit fittings

Connections between PVC conduits should be with rigid PVC conduit accessories only. PVC conduit accessories / fittings such as couplers, unions, bends, tees, junction boxes, reducers,

chase nipples, split couplings, plugs etc. should be designed and manufactured for their particular purpose.

All conduit accessories should be PVC grip type and shall conform to IS: 2667-1964 and IS: 3857-1966. As far as possible, the conduit system should be so laid out that it will alleviate the use of tees, and sharp bends.

No elbows shall be used and only PVC regular bends, slip in type shall be used for bonding/turning.

In long distance straight runs of conduits, inspection boxes at reasonable intervals shall be provided. The conduit pipes including all bends, unions, couplers, tees, junction boxes etc. forming part of the conduit system shall be adequately supported.

Large radius while laying bending of conduit at site is to minimize use of readymade bends shall be adopted as far as possible. For diversion purpose pipes shall be bent.

Electric PVC Conduit Cross Section / Size-

Electric PVC Conduit should be of enough section area to make as per the drawing of PVC wires/cables.

Total cross section of wires/cables measured overall, should not be more than half the inside area of the Electric PVC Conduit.

Electric pvc conduit pipe Installation procedure

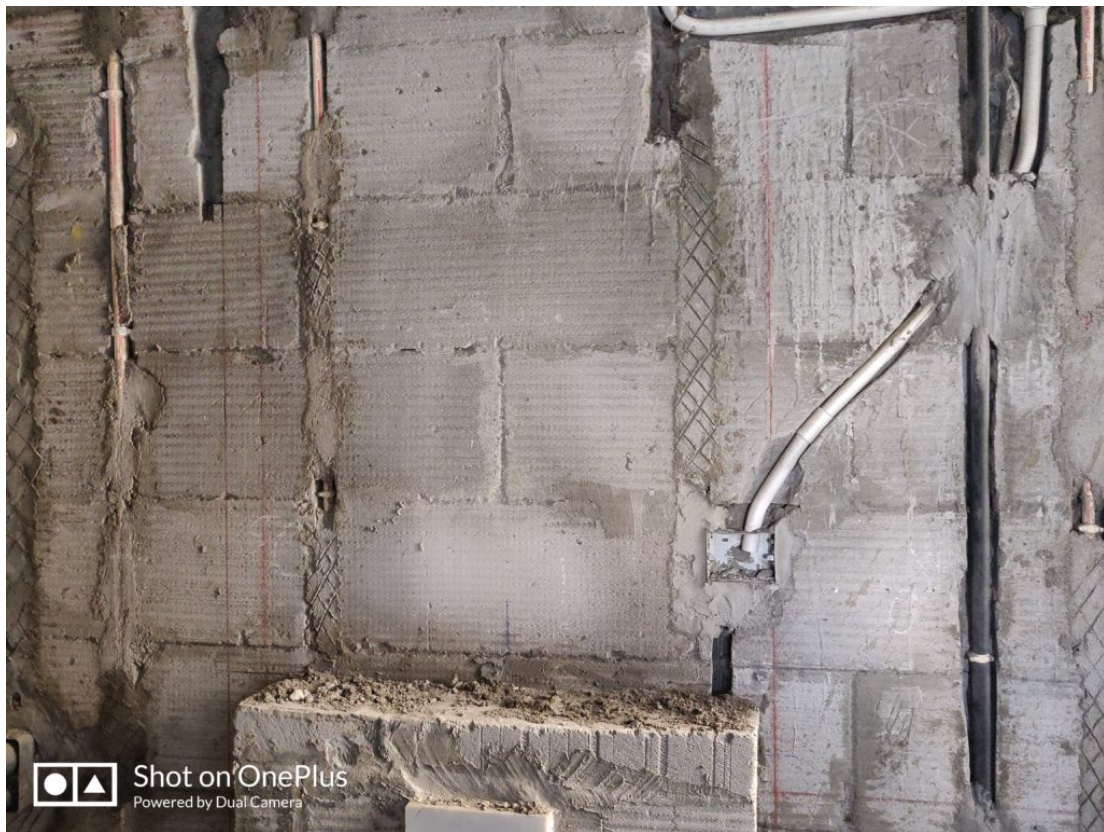


Electric PVC Conduit should be laid before Concrete casting in the upper portion of a slab or in PCC if below flooring or otherwise, so as to cover the entire length of conduits and ceiling boxes with a concrete cover of minimum 12 mm.

Conduits shall be so laid that they are interconnected. This will help the electrician while pulling of wires from different routes in case of any of the portion of conduit or junction box or outlet box is blocked during concrete slab casting.

Construction of bituminous road-Process in Bituminous Road Construction

During the Vertical cutting of walls should be cut in masonry work by the mason to provide sufficient depth to give full thickness of plaster over conduits. The width of the chases will be made to accommodate the required number of conduits.



The Vertical cutting of walls chases will be filled with cement, coarse sand mortar (1:4) and properly cured by watering by the Labour for 7 days and making cross line over that so when the plaster is done it can make hold with the plaster .

This filling of chases should be done by electrical mason before the finishing plaster work on walls started.

When the conduit is to be embedded in a concrete member it should be tied by steel wires to the reinforcement to prevent displacement during casting or due to vibration of concrete.

Conduit in chases or laid in the slab should be supported at maximum of 1 m centre. Cutting of chases in any R.C.C. member/finished floor/ already finished wall surface is not allowed.

If a chase is cut in an already finished surface, mason should fill the chases and finish it to match the existing finish

Worker should not cut any steel reinforcement bars or steel structure to fix the conduits. Puncturing of wooden/ steel shuttering for R.C.C. slab/beams/column etc. for conduit work is also not allowed.

Electric PVC conduit pipe laying through expansion joints in R.C.C. structure should be avoided as much as possible and if impossible, then the flexible conduit pipe should be used with ceiling outlet box on both sides of expansion joint.

How to Install Electric PVC Wall Conduiting pipe Wiring System

Electric PVC Conduit on surface of walls/R.C.C. members shall be avoided as far as possible and if unavoidable clamps, screws and a minimum 5 M conduit laid on surface shall be taken, to achieve best possible workmanship.

During the Electric PVC Conduit work the distance between 2 consecutive clamps for fixing conduit on surface should not be more than 600 mm.

Electric PVC Conduit and Electric boxes fixed on surface should be painted with finishing paint with proper finish.

How to Install Electric PVC Conduiting pipe Wiring System below floor

During the ground floor Electric conduiting below the flooring should be avoided. Wherever it is unavoidable GI `A` class pipe or heavy gauge PVC pipe/Raceways shall be used with prior approval of Site Engineer.

Steel draw wires in Electric PVC Conduit

Electric PVC Conduit should be provided with steel draw wires or we called as fish wires of at least 16 SWG.

How to do Cleaning and Protection of Electric PVC Conduit

The entire Electric PVC Conduit system including outlet boxes, junction boxes and switchboxes should be properly cleaned after completion of work and It should be tested for non-blockage by air/sound or steel wire with minimum 16 gauge prior to finishing of building and before drawing in of cables and wires.

To prevent Electric PVC Conduit system against filling up with the plaster or cement slurry all the outlet and switch boxes is to be filled with the temporary jute or cotton filling, covers and plugs etc. This should be replaced later on by hylem sheet cover after wiring.

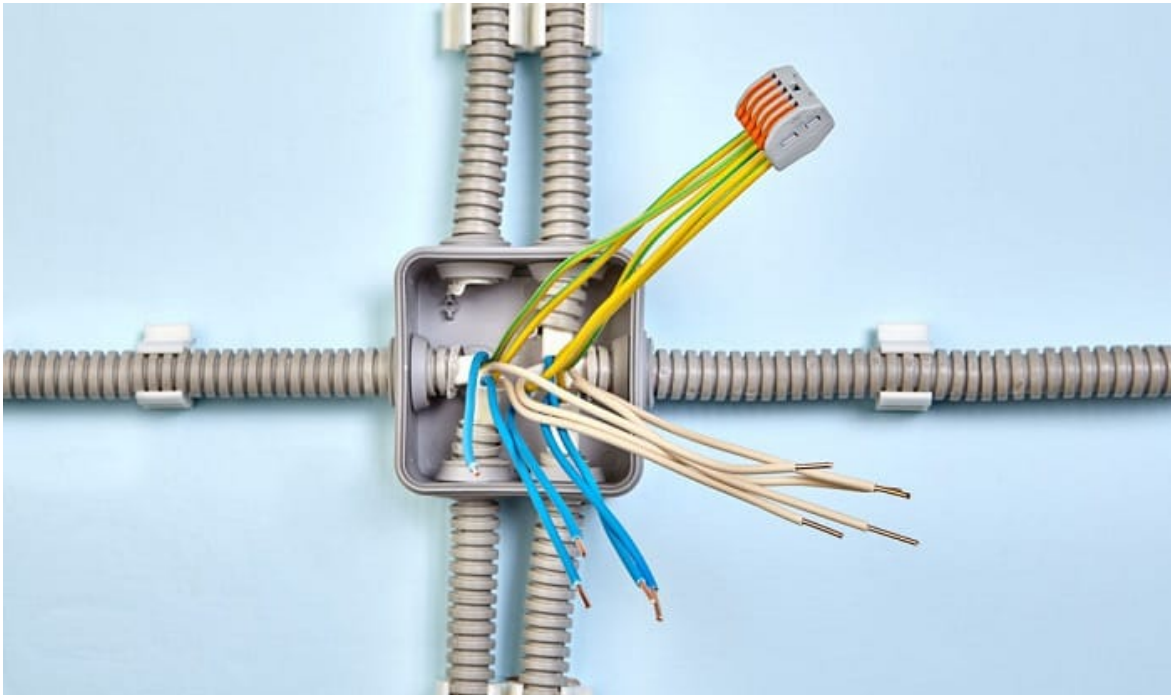
Connecting the Conduit to the Electrical junction Box

Did you install electrical boxes for a new set of circuit series? It's a must to keep wirings around the house safe with a PVC electrical conduit connecting to an electrical box— this type of enclosure is necessary for protecting wiring splices.

Moreover, you as a homeowner must comply with the National Electrical Code (NEC) rules and regulations, so it's best to learn how to connect PVC conduit to an electrical box.

Cut the pipe, apply PVC cement, and insert it into the electrical box, just as easy as that. But always keep in mind to let your electrician inspect your work afterward.

What You Will Need



Before starting this project, you'll need to prepare a few essentials. First and foremost, you'll be working with electricity, so make sure you have the proper PPE, like insulated gloves and boots. Then, proceed to get these materials.

1. Gray/electrical PVC pipes



This type of conduit pipe is the best to handle electricity due to its ability to withstand harsh weather conditions, especially extreme heat. There are different colors of PVC/CPVC conduits for industrial use.

There's white for plumbing and black for handling hot water. However, take note that grey PVC pipes are specific for electrical wirings and the most heat-proof among the three.

There are two types of gray PVC conduits, Schedule 40 and Schedule 80. Schedule 40 PVC has a larger diameter than Schedule 80 for pulling wirings more easily, but its shell is thinner. On the other hand, Schedule 80 PVCs are thicker for more wiring protection, but it has a tighter space inside.

Either of the two works great for electrical usage, although Schedule 80 is better for outdoor junction box installation and areas where people frequent. On the flip side, Schedule 40 is best for secluded areas. So it's better to have them both if you're planning to run a significant length of electrical conduits around the house.

2. Conduit fittings

Like PVC pipes, conduit fittings are necessary to ensure that your wirings are safe from elements like dirt and moisture. You can use them as a connector for conduit-to-conduit or conduit-to-box. There are a variety of sizes and shapes for different pipe situations or personal preferences.

There are nine types of fittings. Each fitting has its own purpose, but metal locknuts and plastic bushings are enough for connecting PVC conduit to electrical boxes with built-in connectors.

3. Threaded Hubs

Suppose your metal electrical boxes don't have factory-threaded connectors available. In that case, you'll need to accompany them with pairs of threaded hubs to affix your PVC conduits into the holes of the box. This tool will serve as a sealant between the two connections.

You can use either metal hubs, plastic hubs, or mixed as long as the plastic won't crack and the locknuts and bushings keep everything in place. Also, double-check the diameter of your PVC to see it sits perfectly into the slot of your connector. Otherwise, the PVC cement would be useless, and dirt/water particles could still get inside.

4. PVC cement



This solution's purpose is to attach the plastic electrical conduit securely into the fittings. It is available as a bottle with a cap and an applicator sponge attached, and just by dabbing a small amount, it immediately provides airtight and watertight security.

You can purchase the typical type—a small can for applying to conduits less than three inches in diameter. If your pipe is bigger, buy a large can with a larger applicator pad. Avoid universal solvent types of cement too; only get the can of glue designed specifically for PVC.

5. Rough-grade sandpaper

Rough-grade sandpaper is the best I can recommend for deburring the edges of a cut PVC conduit. You'll need this to smoothen out the rough patches that can potentially harm your wirings in the long run.

But if sandpaper is not available, you can always use a sharp knife or a cutter to remove the jagged areas.

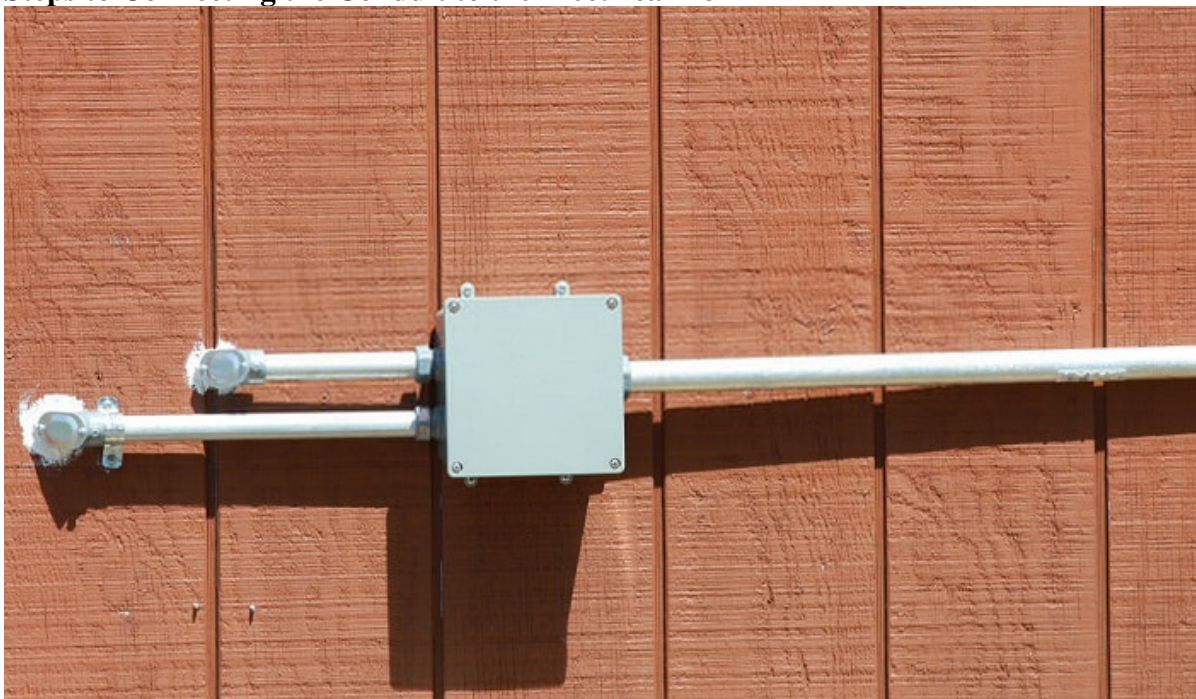
6. Hand saw/ hacksaw



PVC conduits aren't that challenging to cut. You can do this with minimal effort using a hand saw or a small blade, and it will do the job just fine.

However, if you want to work faster and with fewer ridges after cutting, a hack saw or a circular saw can make the surface smooth quickly. Either way, both can do it. It's a matter of personal preference, but the latter choice is preferable if you're on a deadline.

Steps to Connecting the Conduit to the Electrical Box



With all the items you've gathered from the hardware shop, gear yourself up and get to work with this PVC electrical conduit installation guide.

Step 1. Power off



First, the number one safety protocol before working on electrical maintenance is switching off the main breaker. With this step, you can freely move in your workspace without the risk of touching a live wire. Later on, you'll need full force to pull wirings from a tight tube, so going powerless is the most efficient and safe manner to do this.

Step 2. Cut the conduit



While cutting your tubes, make sure they match the corners and path of your wiring system. The edges must fit through the fittings when connecting PVC conduit to metal box.

To do this precisely, you can mark a straight line where you're supposed to cut it, then use a clamp to grip your PVC as you chop it down. However, if you're in a rush, you can try more straightforward methods like using a PVC cutter.

Step 3. Smoothen it out

Now, of course, a fresh-cut PVC will always have rough edges of plastic hanging inside or outside of the pipe. Always deburr the ends of your PVC with the help of rough-grade sandpaper or a knife. These patches of plastic can be sharp to touch at times, and with that, they can potentially damage the wiring insulations if you disregard them.

Step 4. Install the fittings

If your electrical box has an in-built fitting, you can skip this part. Otherwise, before attaching the conduit to the junction box, prepare the threaded hubs, bushings, and locknuts first. Insert the proper size of PVC fitting in the box hole and use the locknut and bushing to keep it watertight. After this, you can now glue them up.

Step 5. Apply the PVC cement



First of all, your electrical PVC doesn't need a primer. Your hardware retailer has glue or cement specific for a conduit-to-fittings connection. When you do this procedure, wear a glove as you dab a small cement portion on the tip of the pipe. Do the same step inside the electrical box's fitting, but don't try to overfill it.

Never try to dry-fit your PVCs and their fitting for measuring purposes. It doesn't work like a Lego or a puzzle that you can slip in and out with no problem. Always smear the PVC cement first.

Step 6. Connect the pipe and the box



Once that's all settled, connect your outdoor electrical conduit inside the fittings of the box. Remember to install one box at a time and never do multiple simultaneously, or you'll struggle trying to run all your conduits. The trick is to connect your PVCs into one box at a time while doing a conduit run.

Step 7. Fish the wirings through

Wait for 15 minutes to dry the glue and a few hours to cure, depending on the temperature, when installing PVC conduit outside the house. Then, fish your wirings through the pipes going into the junction box. You can use fish tape or what they call an electrician's snake to draw the wire through the conduit.

Connect a PVC conduit to an electrical switch box?



First of all, in addition to the PVC electrical conduit and the electrical box, you also need to prepare an adaptor with locknut and PVC glue.

As for the installation method, so easy. The first step is to glue the pipe to the adaptor, remember to use glue, and you can reference our previous Pro Tips content about glue conduit pipes. The second step is to insert the threaded part of the adaptor into the electrical box, and then lock it with the locknut. Of course, you can also add a little glue to the locknut part, which is more firm and reliable, and it is also the simplest way of waterproofing.

Of course, if your electric box is integrated with fittings, then you can directly apply glue to the wire tube and insert it into the electrical box.

In addition, if the flexible pipe needs to be connected to the electrical box, you just follow the above steps, the only difference is you need to pick up another adaptor used for flexible pipe for the locking part is needed to fix the flex pipe end.

I believe you will know how to connect through the pictures.

Formulas for Calculating Conduit & Pipe Bends

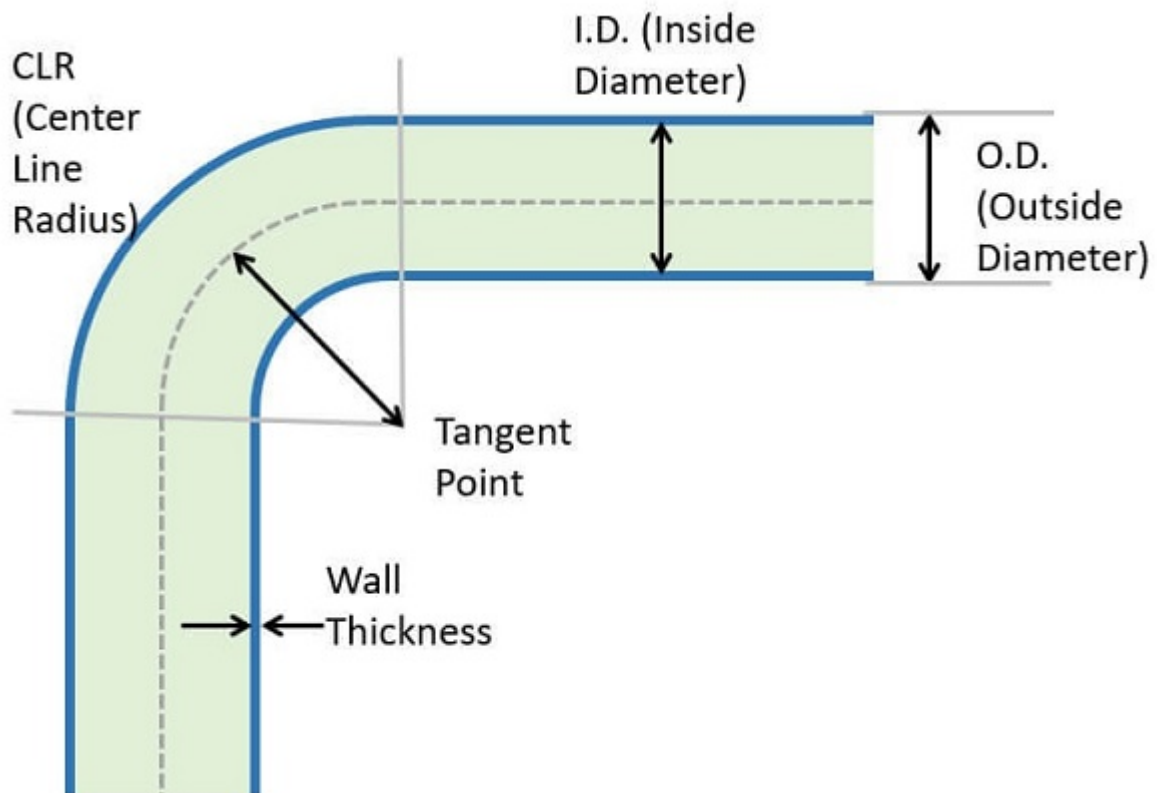
Calculations & Formulas

Using just a few mathematical formulas allows you to properly calculate a bend of nearly any angle. An inexpensive scientific calculator and an angle finder are the only additional tools required.

When calculating bend allowances to determine the cut length of HDPE conduit or PVC pipe, one must calculate from the center line radius (CLR) of the finished, bent pipe. This radius will vary depending on the outside diameter of the tube, the wall thickness, and the angle at which the tube is to be bent.

Elements Of A Bend

It is important to understand the different elements of a bend in order to make accurate calculations.



Calculating Wall Thickness

ISO 161-1 uses the following formula to calculate the wall thickness of pipe:

$$\Sigma s = \text{PN} \cdot (\text{da} - s / 20 \cdot s) = \text{PN} \cdot S$$

Σs = hoop stress (N/mm²) | PN = normal pressure (bar) | da = external pipe diameter (mm)

s = wall thickness (mm) | S = pipe serial (-)

Calculating Standard Dimension Ratio

Using the same variables as above, the standard dimension ratio (SDR) of a pipe can be calculated thusly:

$$SDR = da/s$$

HDPE Pipe SDR	Minimum Long-Term Cold Bending Radius
9 or less	20x pipe OD
11, 13.5	25x pipe OD
15.5, 17, 21	27x pipe OD
26	34x pipe OD
32.5	42x pipe OD
41	52x pipe OD
With fitting or flange present in bend	100x pipe OD

Calculating CLR (Center Line Radius) for Bend Angle

After you've selected the appropriate die for bending your pipe, based on the pipe's outside diameter and wall thickness, you should be able to find the radius of the bend.

A simple way to determine the center line radius of a bend of a specific angle is calculate a full circle, then divide that number by 360 to find the measurement of one degree. Then, use this formula:

$$\pi(2r) \text{ or } \pi D$$

$$\pi (\text{pi}) = 3.1416$$

For example, if your die creates a 2.2" radius, and you need to create a 35° bend, your calculations would look something like this:

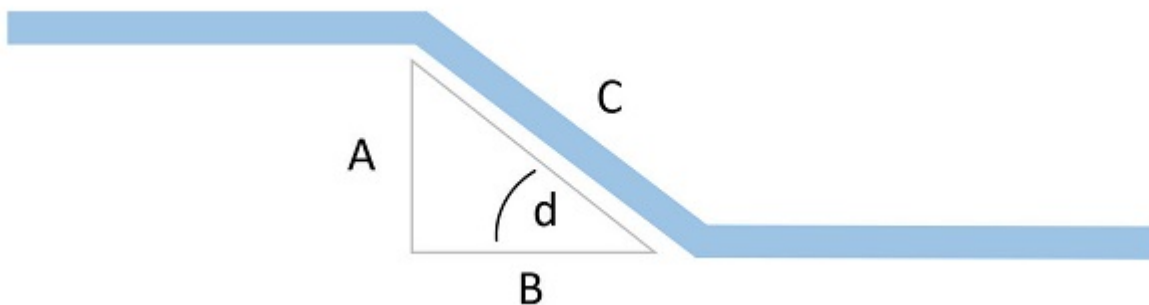
to calculate one degree of bend

$$3.1416(2 \times 2.2) = 13.823 / 360 = 0.0384$$

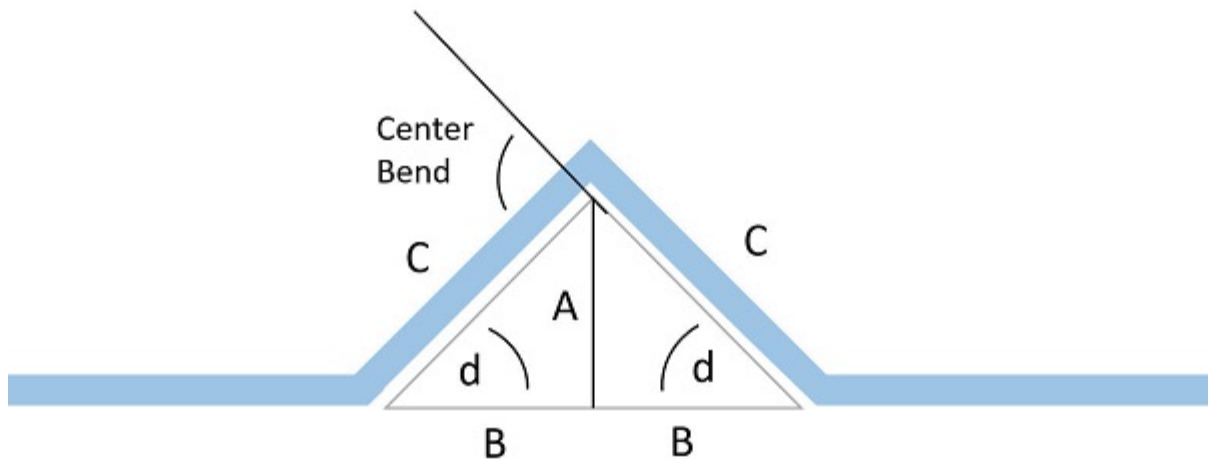
to calculate CLR of 35° bend

$$0.0384 \times 35 = 1.344''$$

Offset Bend Calculation



3-Point Saddle Bend Calculation



4-Point Saddle Bend Calculation



Most bends other than 90° can be calculated using the geometry of a triangle. The black line represents an offset bend in a tube; the red triangle represents the triangular geometry this offset creates.

The lengths/sides of the triangle are labeled “a,” “b,” and “c”. The “d” represents the angle at which the pipe is bent. No matter how the tube is bent in this configuration (or how the triangle is oriented), one of the angles of the triangle will be 90°; the other angle will depend on the first angle (d), and can be calculated as (90 – d).

The relatively simple math formulas of sine, cosine, and tangent can be used to determine the angles of the triangle, and, therefore, the necessary angles of your pipe bend(s). Most scientific calculators (and even the calculators built into smart phones) have these functions.

Sine Calculation

$$\text{Sine}(d) = A/C$$

$$A = \text{sine}(d) \times C$$

$$C = A/\text{sine}(d)$$

Cosine Calculation

$$\text{Cos}(d) = B/C$$

$$B = \text{cos}(d) \times C$$

$$C = B/\text{cos}(d)$$

Tangent Calculation

$$\text{Tan}(d) = A/B$$

$$A = \text{tan}(d) \times B$$

$$B = A/\text{tan}(d)$$

Task sheet No. 5.2.3-1

TASK SHEET 5.1.2-1	
Title:	Bend PVC
Performance Objective/s:	
Supplies/Materials	:PVC 20mm (2 PCS)
Equipment	:PVC bender ,heat gun, hack saw, angle ruler
Steps/Procedure:	<ol style="list-style-type: none"> 1. Use PPE 2. create using AutoCAD, the electrical symbols for lighting point, wall mounted spotlight, switch socket outlet, single-pole switch, 2-way switch, 20A double pole c/w Neon light indicator lamp and marked “water heater” and insert them on apartment layout layer. 3. Show clearly all the control switch/switches for each lighting point. 4. Do not group more than two lights in one circuit. 5. Complete the drawing on a Figure1B with the Electrical Symbols in AutoCAD.
Assessment Method:	Demonstration with oral questioning

Performance Criteria Checklist	YES	NO
Did you....		

Answers Key No. 5.2.3-1

❖ **Electrical Conduit**

What is Electrical Conduit?

An electrical conduit is a piping system used to carry electrical wiring in domestic, commercial, and industrial use. The purpose of conduits is to protect the enclosed wiring from fires, mechanical damages, and corrosion.

Conduits protect electrical wires as well as any individual who come in close proximity to electrical wires.

These are available in different sizes with accessories such as junctions, clamps, bends, T- shapes, C-shapes, L-shapes, etc.



Types

Electrical conduits are basically divided into two types

- Metal
- Non-metal

Electrical Metal conduits

1. Electrical Metal Conduit (EMC)
2. Flexible Metal Conduits (FMC)
3. Rigid Metal Conduit (RMC)
4. Intermediate Metal Conduit (IMC)
5. Liquid-tight Flexible metal conduit (LMC)

There are various types of metal and non-metal conduits are available in the market, we discuss seven types only which are used for residential, commercial, and industrial application purposes.

1. Electrical Metal Conduit (EMC)



EMC is a thin wall conduit that is far the widely used nonflexible conduit.

Except for situations where it will be subject to severe physical damage, it may be and is used in almost all places where rigid conduit may be used.

It may be used in exposed or concealed in or on walls, floors, or ceilings. It can be embedded in the concrete or buried in the ground.

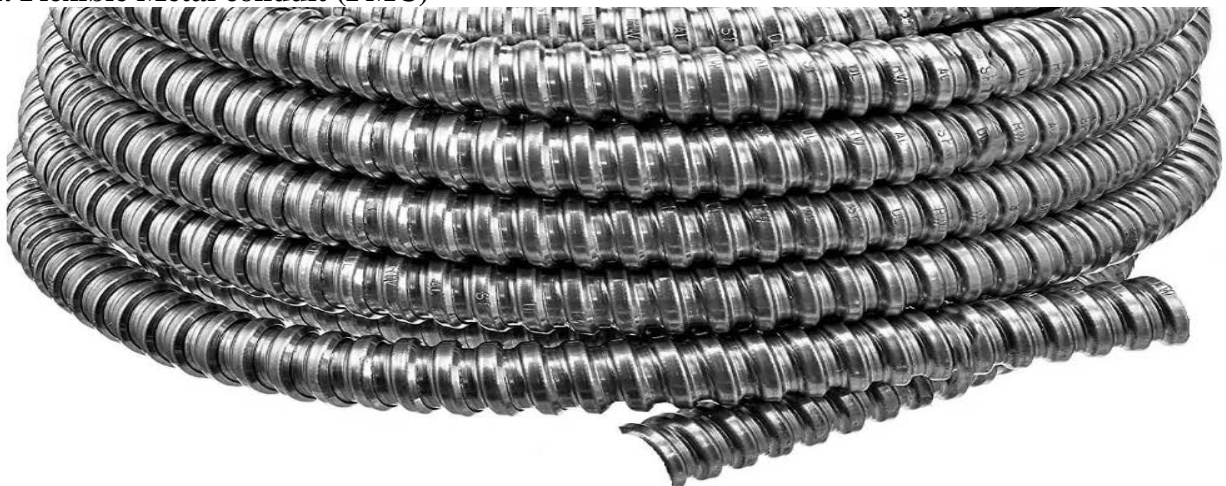
Advantages:

- It is preferable to use rigid conduit as it is much lighter, thus easier to handle.
- It is easier to cut and ream.
- Bending to follow various complicated forms is quite easy with the smaller diameters.
- These are thin wall circular cross-sections, are galvanized outside for corrosion protection, and the inside has a corrosion-resistant organic coating.

Applications:

- Used in residential, commercial, and industrial construction.

2. Flexible Metal conduit (FMC)



Flexible Metal conduit (FMC) is used wherever good flexibility is required due to movement or vibration of equipment, or where bends and offsets would be difficult with rigid conduit.

To meet various physical or chemical requirements, flex is made of galvanized steel, aluminum, brass, or bronze.

Advantages:

The flexible metal conduit cannot be used in wet locations unless conductors are of the lead-covered type or of another type specially approved for the conditions.

Disadvantages:

Flexible metal conduit not intended for general purpose raceway for long-distance.

Applications:

The flexible metal conduit can be used for lighting fixture connections, above suspended ceilings.

3. Rigid Metal Conduit (RMC)

Rigid Metal Conduit (RMC): Both ferrous and non-ferrous metals as a rigid metal conduit, in practice, galvanized pipe is generally used-the same type galvanized pipe commonly found in water supply and gas lines. As always the use of pipe smaller than ½" trade size is not allowed.

They are similar in appearance to water pipes and are threaded at both ends.

Advantages:

- It is much lighter and convenient to handle.
- It can be used in severe corrosive areas.

Disadvantages:

When it is cut, all cut ends must be reamed to remove any rough edges, if any rough edges are left, they are likely to tear the insulation when insulated conductors are pulled through.

Applications:

It is used in outdoor applications and provides structural support for electrical cables.

4. Intermediate Metal Conduit (IMC)

This type of conduit is heavier than Electrical Metal Conduit (EMC) and lighter than Rigid Metal Conduit (RMC). This is a thicker metal conduit making it is a great choice for outdoor applications.

The conduit pipe has to be supported at no longer than 10 feet of interval. This type of conduit has a straight length of 10 feet, with one coupling and both ends threaded. All rough edges must be smoothened when the conduit is cut.

Advantages:

It can be used on the earth or in corrosive locations.

The smooth interior of the pipe makes it easier to pull the cable through the conduit.

Applications:

Used in exposed runs to and from exterior service panels.

It can be used as an equipment grounding conductor with its fittings.

5. Liquid Tight Flexible Metal Conduit (LFMC)



Liquid-tight is another type of spiral flexible metal armor and an outer plastic jacket has been added, that plastic being both liquid-tight and sunlight resistant.

Liquid-tight carries no marking for wire size, insulation, or voltage rating because wires must be pulled as needed.

The difference between flexible metal conduit (FMC) and Liquid-tight flexible metal conduit is that PVC coated on LFMC.

Its use in residences is quite limited. It is generally used in short runs for wiring outdoor air conditioning equipment or for wiring disposals under kitchen sinks.

The sizes of liquid tight metal conduit must be electrical trade sizes ½ inch to 4 inches, inclusive.

Advantages:

Provides good protection from entry of water, Oil, dust, etc.

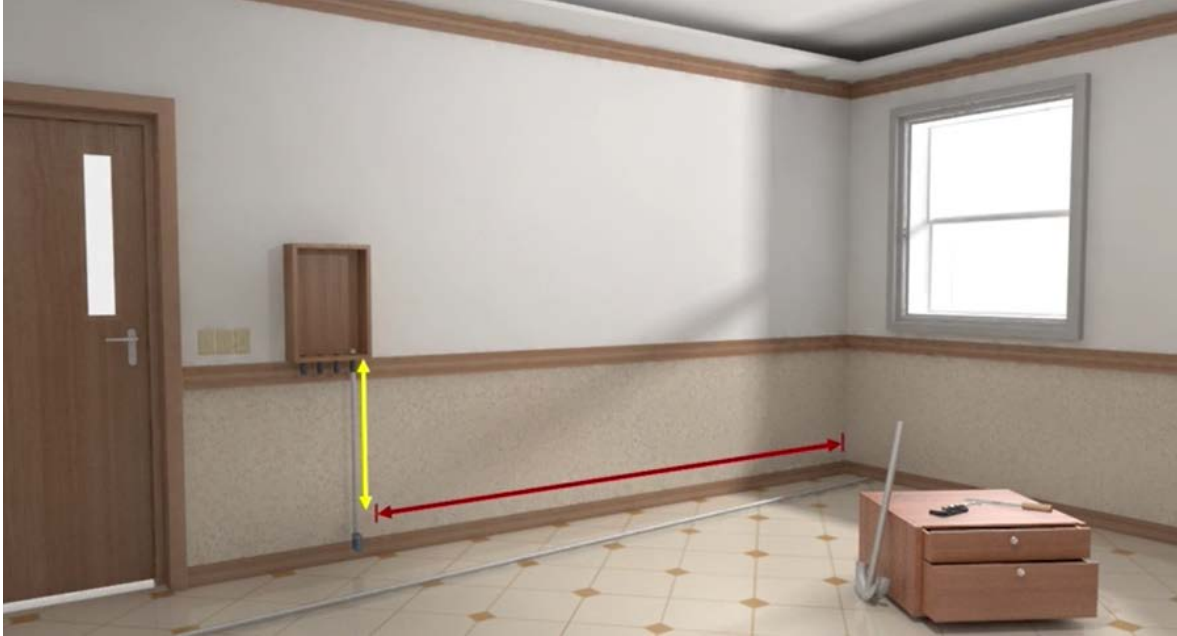
Applications:

It is used in short runs for wiring outdoor air conditioning equipment or for wiring disposals under kitchen sinks. Its use in residence is quite limited.

Bend conduit

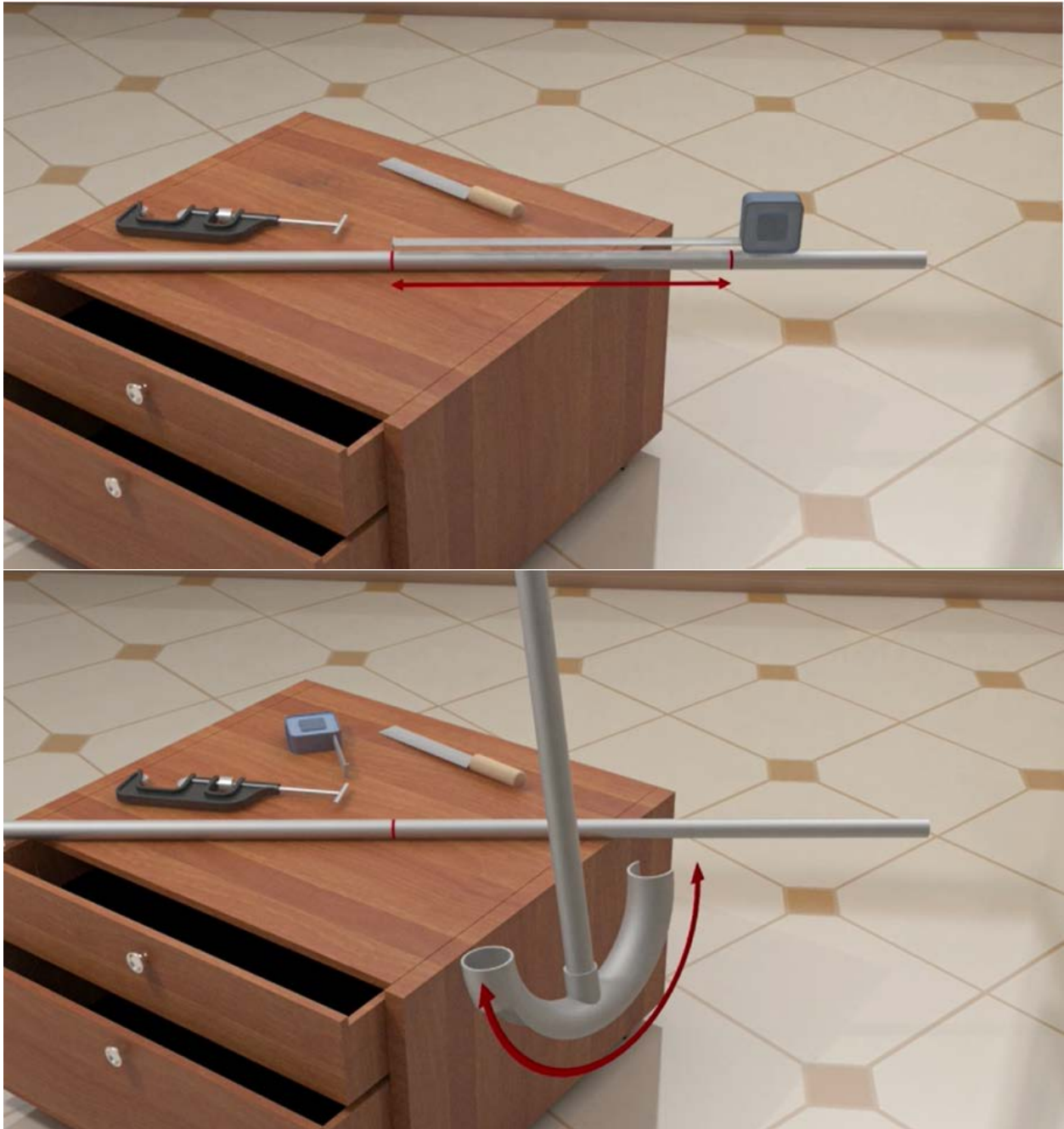
Whether you're wiring a new home, replacing old electrical construction or even creating a furniture masterpiece, you'll need to know how to bend conduit correctly and safely. You can bend conduit to fit many angles and work it around corners, under or over ceilings, and past other permanent structures. The hardest part of bending conduit is getting the proper measurements and applying just the right amount of pressure to make a good bend.

1. Preparing the Conduit for Bending



a. Measure the length of conduit you'll need. Start from a corner or other orienting point, then measure from the corner to where the conduit will end (usually a converter box). Place a pencil mark on the conduit at the measurement where the corner should be.[1]

Make sure that you have some extra conduit on hand if you do not do it often. It's easy to make a mistake regarding the take up of the bend, especially when performing more complex bends.



b. Calculate the amount of extra conduit you will need. When you bend conduit, you lose length as the conduit is bent in the direction of another plane. The amount of conduit you'll need for the corner depends on the diameter of the conduit. A ½-inch (1.27 cm) pipe requires 5 inches (12.7 cm) of extra conduit, ¾-inch (1.905 cm) conduit takes 6 inches (15.24 cm) and a 1-inch (2.54 cm) conduit pipe requires 8 inches (20.32 cm).[2]

c. Cut the conduit to the size you need, removing burrs from the end. Use a conduit reamer or knife to scrape the edges to get rid of any fragments, or burrs. Ensure that all burrs are removed before you install the conduit. Otherwise, this may cause a short or ground fault after the wire has been installed.[3]



2. Making a Basic Bend



a. Work with a bender. A bender is an essential for any conduit bending project. The tool should fit the correct sized conduit tube that you need to use.[4] Before you start the bending process, locate any instructions on the conduit bender that may describe how much conduit should remain past the bend to the end of the bending shoe. If there are no instructions on the bender, follow the standards (as listed above) for the size conduit you are using. As you'll see, the bender should have three or four distinctive features:

- The 90° mark. This is the point at which a bent conduit has reached a right angle. It is one of the most commonly used angle marks.
- Other angle marks. Common angle marks include the 10°, 22.5°, 30°, 45°, and 60°.
- Stub height mark. This mark will usually list a number (like 6 inches (15 cm)) to use for the bender take-up.



b. Slide the conduit into the bender. Be sure to leave the appropriate amount past the arrow on the bending shoe. Set the conduit on a level, firm ground and place your foot firmly on top of the foot of the bender. The top of the pipe should come through the bender, so your foot should be able to steady it as well.



c. Pull the bender handle toward you to create the bend. Use a firm and steady motion to avoid kinks or crimps in the conduit. Make sure your foot and hand remain securely on the bender; any small slip in the conduit can cause an off-centered bend, and you will need to start over with a new piece of conduit.

- Make sure that you apply firm pressure with your foot to avoid creating kinks in the bend.
- Be aware that when you bend, you may need to overbend slightly to compensate for any spring back in the conduit. Do this slowly and carefully.[5]



d. Bend until your bender reaches the 90° mark or other desired corner angle. Most benders include marks for 15°, 30°, and 60° as well. Go slow and take your time.

e. Check to make sure your bend is the right angle. You can do this either holding it up to the wall or using a level held snugly against the front side of the pipe. You can also hold it to a surface you know is level to check it.



3. **Mastering Bending Techniques**

a. Learn how to air bend in a pinch. Most of the time, you'll use your bender and the floor to bend the conduit. But sometimes, especially if you're doing a more complicated bend, like a back to back bend or an offset bend, you won't be able to use the floor as a fulcrum. If you need to use an airbend to twist your conduit, here's how:

- Put the hilt of the bender on the ground. Secure it in place with both feet or another reliable anchor.
- Keep the bender straight and let your body apply the pressure to the conduit. Don't try to use the bender to airbend.
- Make sure the head of the bender stays rigid as the conduit bends into the cradle.



b. Use the correct-sized bender for the type of conduit you're using. While it's tempting to think that your bender is a one-size-fits all tool, it's not. Be prepared to use or buy a bender for each different type of conduit you need to bend. For example, 1/2 inch (1.3 cm) conduit shouldn't be bent using a 1 inch (2.5 cm) bender.



c. Use a level and protractor to double-check the measurements. Don't be afraid to use a water level and protractor to measure your angles with certainty. Of course, sometimes getting the exact

angle on a bend isn't important; but often, whole conduit systems will be thrown out of whack if just a single angle is off 5°.



d. take your time to make sure the bends are aligned. This is particularly important on conduits with multiple bends. Be careful about creating a dog leg when you shape conduit. A dog leg is where multiple bends on a line don't line up in the same plane. Examine the alignment in all directions before bending off.



e. Experiment with different kinds of bends. A typical electrical job will require more than simply a 90° stub-up bend. In fact, there are dozens of different combinations of bends you can use. It's helpful to experiment with bending a couple of them. Remember that practice makes perfect!

- Back to back bends. Two 90° stub up bends on opposite sides of the conduit, with both stubs moving in the same direction.
- Offset bends. Almost a sidewinder pattern, this bend incorporates two 45° angles in order to shift the conduit beside an obstacle but still run in parallel with the old line.
- Three- and four-point saddle bends. A variant of the offset, where the 45° bend returns back 45° after clearing an obstacle. A four-point saddle offers more clearance than a three-point saddle.

f. Be patient and keep practicing. Bending conduit is an art and can take some time to do correctly. Don't get frustrated if it doesn't come out the way you want it to, just be patient and keep practicing. In time, your skills will improve.

Things You'll Need

- Conduit bender (these come in different sizes depending on diameter of conduit)
- Tape Measure
- Marker or pencil
- Pipe cutter or hacksaw

4.Bending conduit

Conduit can be bent with a bending machine. (Fig 15-1) Conduit is bent in the bending machine by placing it between a steel former and a movable steel roller. When the roller is pulled down, it presses the conduits round the former, producing an even bend. A set is produced by bending the conduit at two different points, in opposing directions. The angle of 'set' is usually 45° . Both sides of a set should be parallel.

Examples of good practice for conduit work are:

- a) conduits ends should be cut squarely;
- b) any burrs should be removed either with a round file or a reamer
- c) they should be threaded correctly, using stocks and dies
- d) the radius should be bent not less than 2.5 times the diameter of the conduit
- e) use of solid elbows or tees should be limited
- f) all entries into enclosures should be correctly bushed
- g) correct space factors should be applied to the number of cables installed
- h) unused conduit entries should be blanked off
- i) drainage holes should be provided to avoid collection of condensation
- j) all covers and box lids should be in place and securely tightened
- k) all bushes, couplings and accessories should be securely tightened
- l) all recommendations regarding corrosion should be taken into consideration

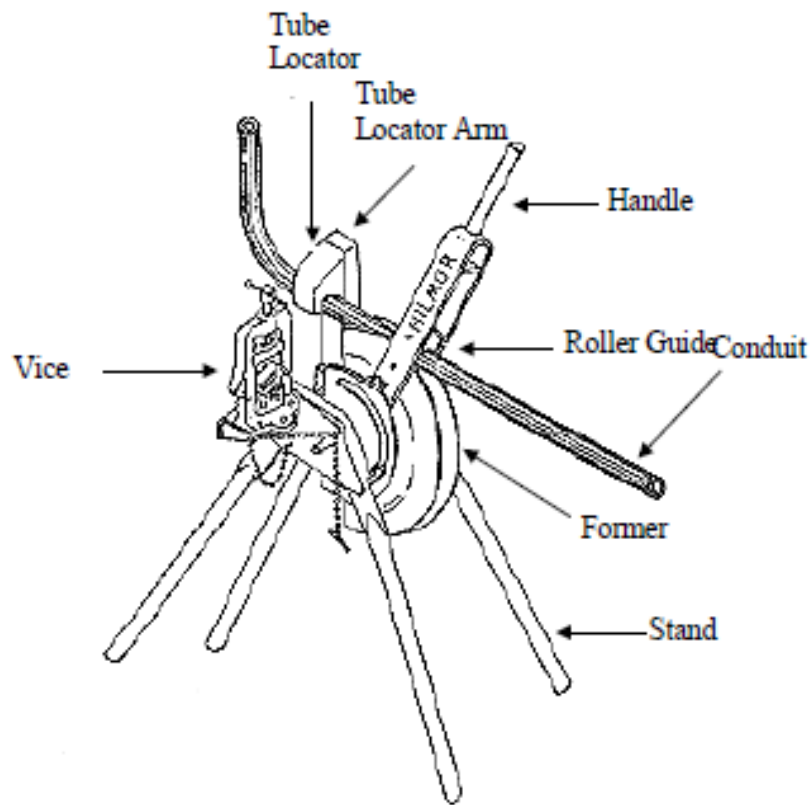


Fig 15-1 Conduit Bending Machine

5. Conduit termination

Conduit ends are terminated by:

- Male bush and coupler or
- Female bush and locknuts

The ends of conduits are reamed to prevent abrasion of cables. Conduits terminating at a box or trunking shall be bushed for the same reason by means of male or female bushes.

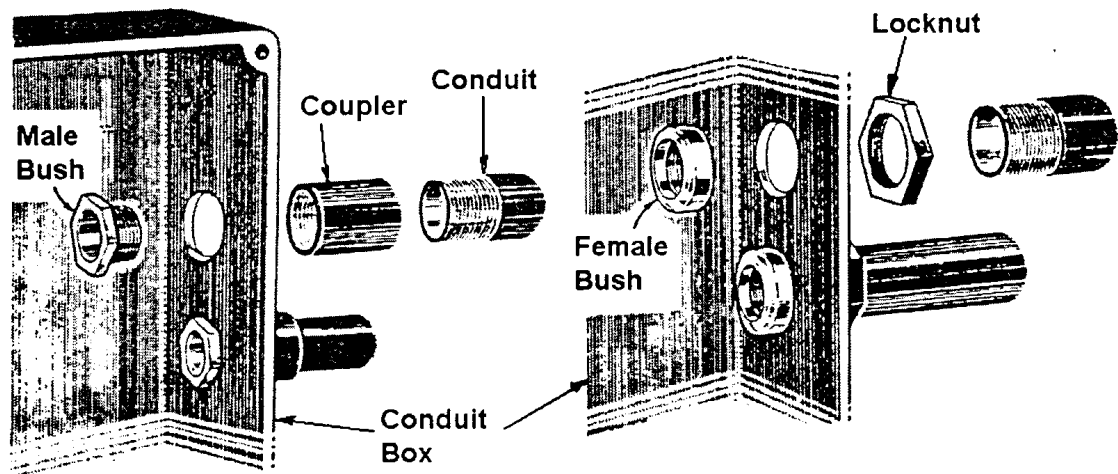


Fig 9-8 Methods of Conduit Termination

6. Conduit fixings

Conduits are securely supported by the following fixings.

- (i) **Conduit clips** - satisfactory in saving an additional fixing screw, if the conduit is not subjected to any strain.
- (ii) **Ordinary saddles** - provide a very secure fixing by means of 2 screws, not nails.
- (iii) **Spacer bar saddles** - are ordinary saddles mounted on a spacing plate of 3 mm thick. This plate is approximately the same thickness as the other conduit fittings and therefore serves to keep the conduit straight. Some types of saddles have slots instead of holes so that the fixing screws need only be loosened to enable the saddle to be removed, slipped over the conduit and replaced.
- (iv) **Distance saddles** - made of malleable cast iron and are designed to space conduits approximately 10 mm from the wall or ceiling for better protection against corrosion. They are also used to eliminate the possibility of dust and dirt collecting behind and near the top of the conduit where it is generally inaccessible.

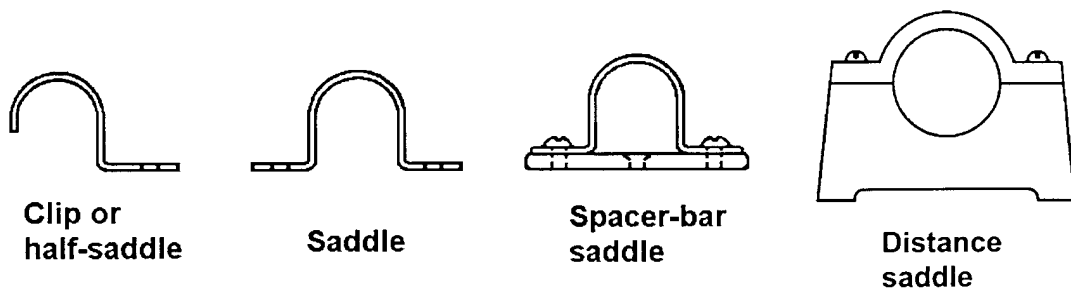
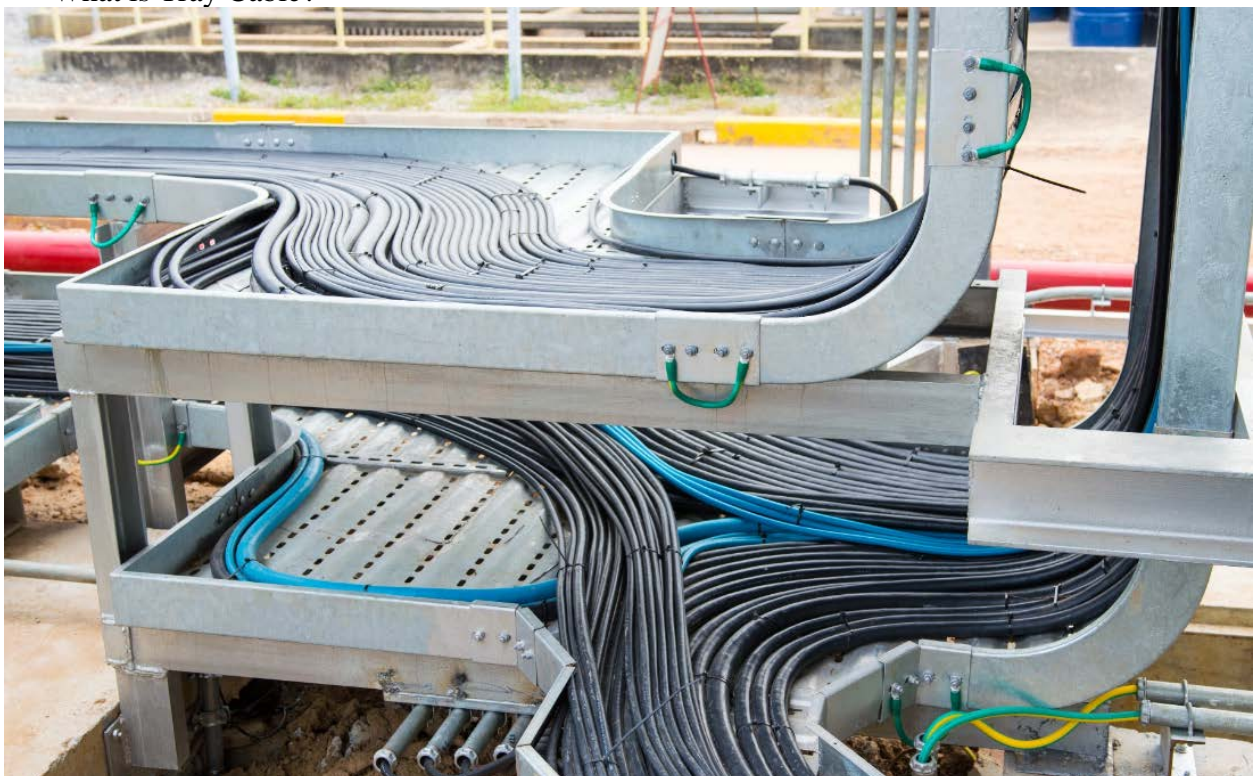


Fig 9-9 Types of Conduit Saddles

❖ Cable tray

What is Tray Cable?



Tray cable is a multipurpose and multiconductor cabling used in industrial power/control, communications systems, traffic control, switching, lighting, and signal transmission. You will find tray cable installed in conduits, ducts, raceways, and cable tray systems. Tray cable jackets are resistant to fire, UV, chemicals, and oil. This ability to withstand unforgiving environments makes them ideal for wiring mission-critical machinery and systems.

What are the types of tray cable?

Two main classifications of tray cable are Power Limited Tray Cable (PLTC) and Vinyl Nylon Tray Cable (VNTC). Let us run through some of their key features.

Power Limited Tray Cable:

- 300 volt rating
- Flame Retardant/UV Resistant PVC jacket
- 105 Degree Celsius operating temperature
- Approved for Class I and II, Division 2 Hazardous environments
- Industrial control, burglar alarms, point of sale systems, intercom

Vinyl Nylon Tray Cable:

- 600 volt rating
- Flame Retardant/UV Resistant/Burial Rated PVC Jacket
- 194 Degrees Celsius (dry) and 167 degrees Celsius (wet)
- Telemetering, power/control, traffic control, lighting, and signal transmission
- Approved for Class I and II, Division 2 Hazardous environments

What overall jacket material is used in tray cable?

Typically tray cable jackets are made up of Polyvinyl Chloride (PVC), Chlorinated Polyethylene (CPE), and Low Smoke Zero Halogen (LSZH). The most common overall jacket is PVC, which is flame retardant sunlight resistant per UL 1277.

What are insulation materials used in tray cable?

For most PLTC the insulation is PVC. In 600V rated VNTC, each insulated conductor jacket meets UL 62 for Thermoplastic Flexible Fixture (TFFN) or UL 83 for Thermoplastic High Heat-Resistant Nylon Water-Resistant (THWN) or Thermoplastic High Heat-Resistant Nylon (THHN) wire.

Can you put tray cable in conduit?

Absolutely. Tray cable is meant for conduit, cable trays, wireways, ducts, and channels. Tray cable is recognized by NEC for use in Class 1, 2 and Division 2 hazardous locations. These are defined as areas where flammable gasses, vapors, or liquids are present either some or all the time.

Is tray cable direct burial?

Yes, all tray cable is rated for direct burial installation.

How many conductors are in tray cable?

Tray cable has at least 2 conductors and, depending on the wire gauge, can hold up to 50 conductors. These can either be individual multiconductor, or in multipair style. The color coding for multiconductor cable follows ICEA Method 1-E2 table.

Why is cable tray used?

According to the **National Electrical Code (NEC®)**, a cable tray is a unit or assembly of units or sections with associated fittings that form a rigid structural system used to securely fasten or support cables and raceways.

Due to their durability and high efficiency, they are used as a smart option to support wires and cables. In fact, cable tray wiring systems are the preferred wiring system when compared against equivalent conduit wiring systems in terms of safety, dependability, space and cost.

Another significant reason for investing in cable tray usage is to add to the efficiency of a business. Cable tray wiring systems are known for dependable service in the industry.

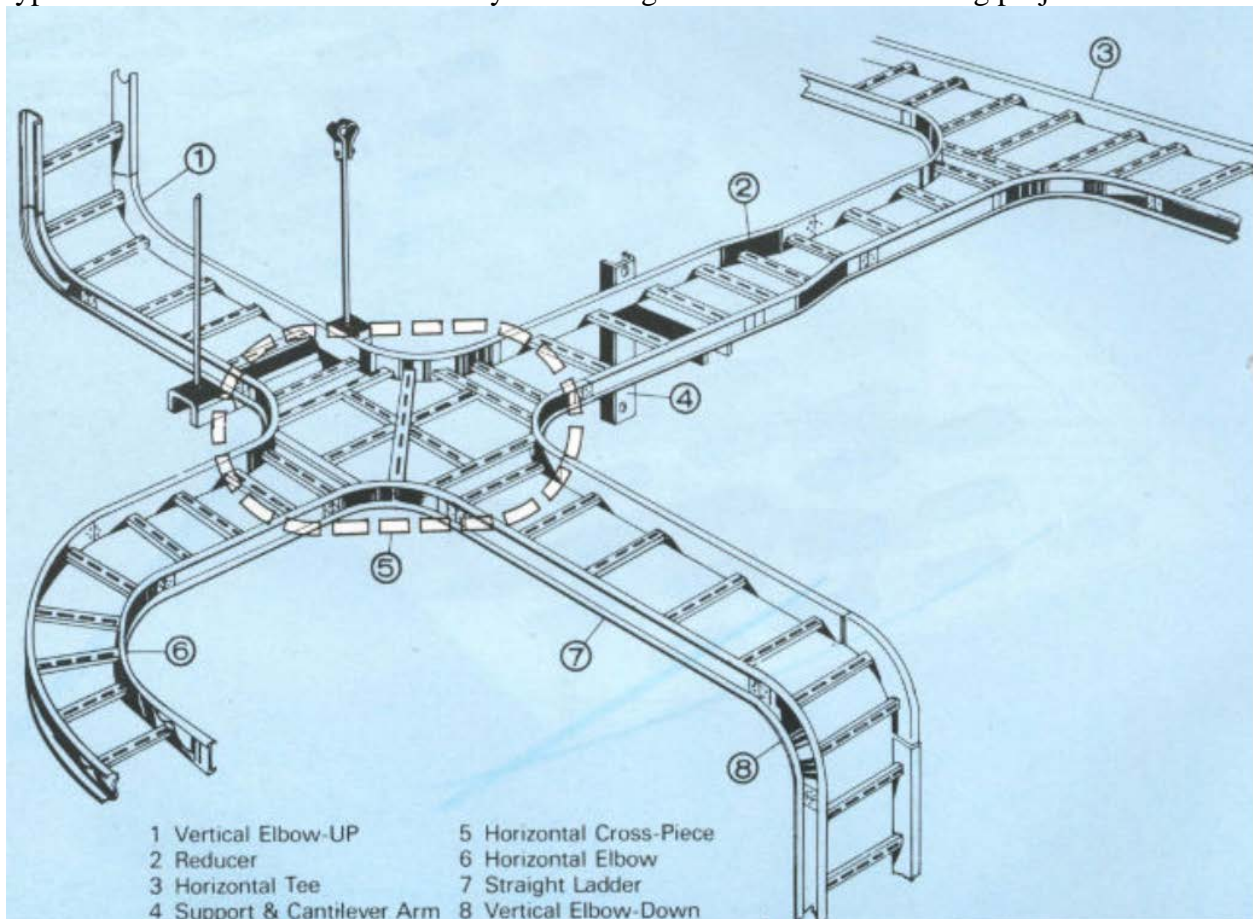
In continuous processing systems, an electrical system failure can procure a hefty outgoing of money and present serious safety issues for a corporation, clientele and its employees. A well-designed and installed cable tray system fitted with suitable cable types will provide a network of wires with increase benefits.

❖ **METHOD STATEMENT FOR INSTALLATION OF CABLE TRAY OR TRUNKING**

Electrical Engineers seldom show interest acquiring knowledge and experience on cable tray installations. Most of them think it's a concern of mechanical fabricators to be taken care of it. A proper and professional way of cable tray installation requires good involvement and coordination of people from both electrical and mechanical disciplines. If cable tray system has been installed appropriately in a project, following advantages can be counted:

- Cable Tray system enhances safety of electrical wiring system.
- Cable tray installation provides dependability in any circumstances.
- Cable Tray system saves space, materials, labor, time and cost.
- Maintenance and extension of cable tray installation are easier than any other wiring system.

Hence, electrical installation of a project must give high priority to adopt properly evaluated cable tray wiring system if aesthetic impact is low. This article explains how to make a typical method statement for cable tray or trunking installation for a building project.



1. INTRODUCTION AND SCOPE OF THIS METHOD STATEMENT

This method statement is written for the purpose of establishing method and procedures for the Installation of Cable Tray and G.I Trunking System for the building MEP services.

2. APPLICABLE PROJECTS SPECIFICATION

- Section: ELECTRICAL CONTAINMENT
- Division: INSTALLATION
- Sub Division: Subdivision

3. LOCATION OF ACTIVITY

Inside and outside the building.

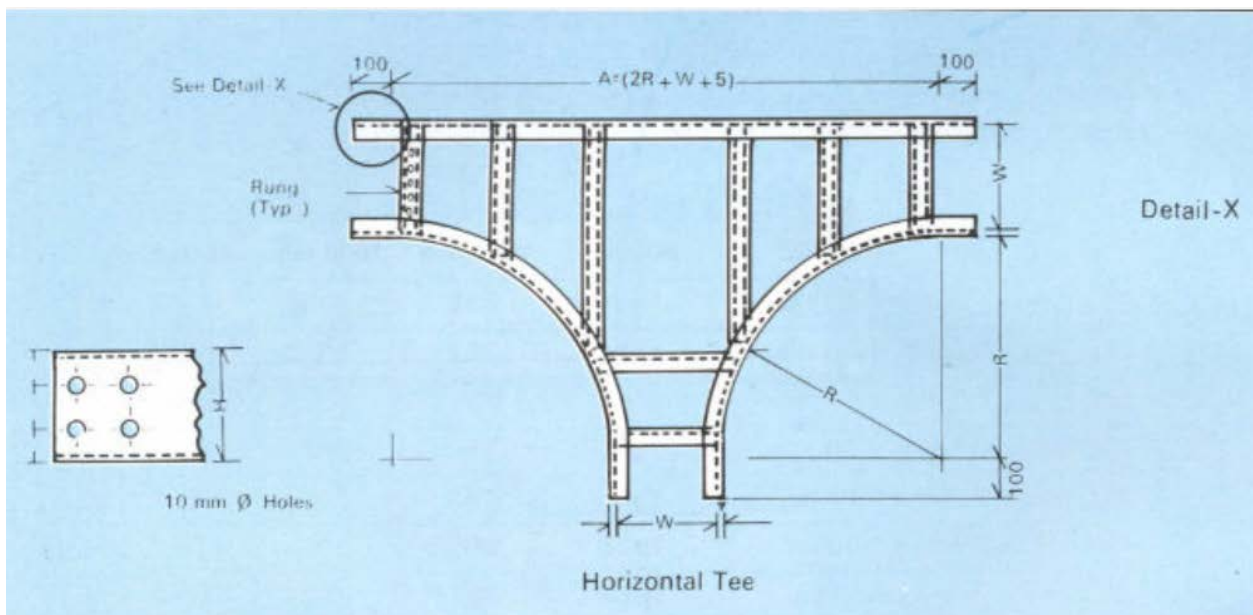
4. HEALTH AND SAFETY HAZARDS

Specific safety measures have to follow as applicable, and all the safety measures are covered separately in the project safety plan.

5. OPERATION

a. Materials: Materials used will be as per the material submittal approved by the engineer and routing as well and sizes will be as per the approved drawings in co-ordination with other services.

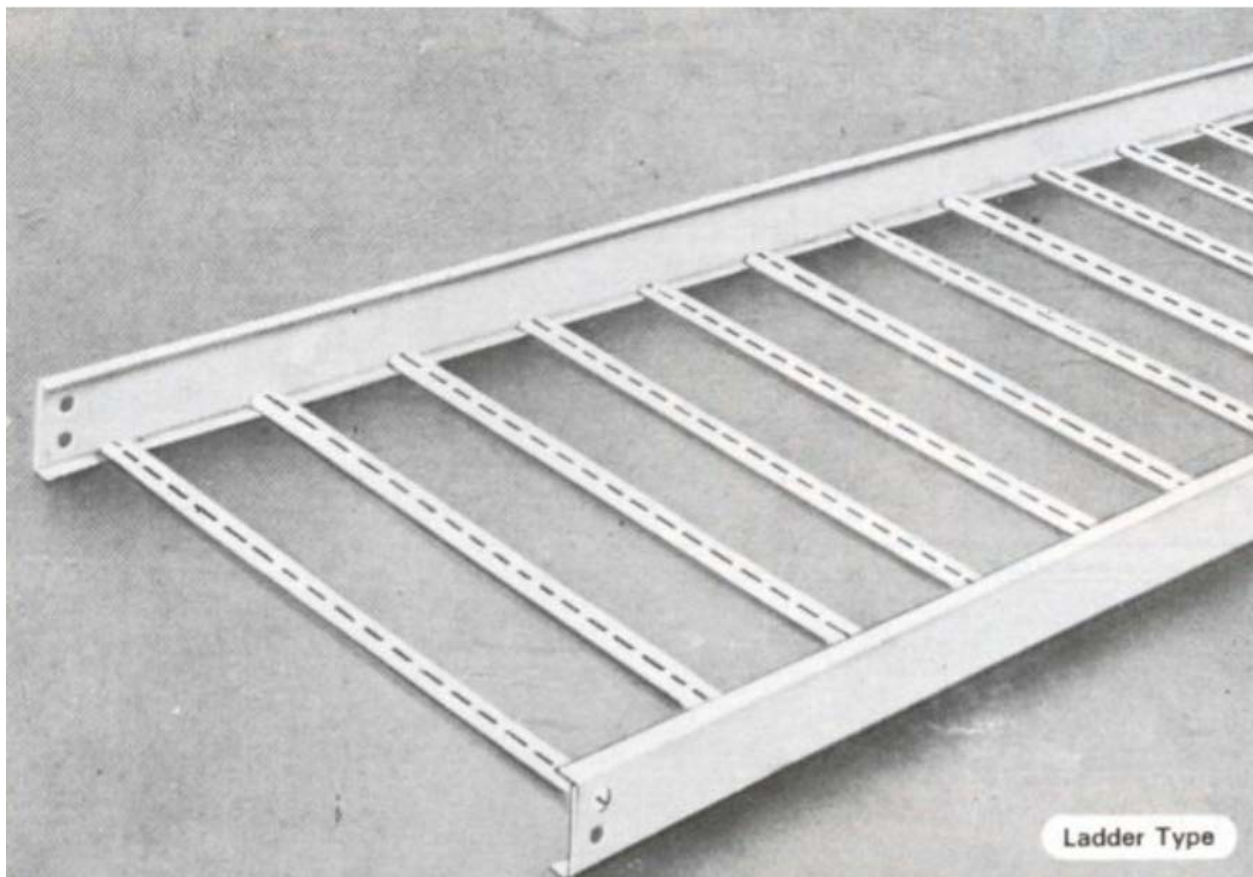
b. Storage / Protection: Cable Trays, Trunking and Accessories shall be unloaded with care to avoid any damages. If they are shipped in packs or pallets, each pack of pallet shall be lifted individually with suitable lifting equipment. Every precaution shall be taken to preserve their cleanliness before installation.



6. INSTALLATION OF CABLE TRAY OR TRUNKING SYSTEM FOR BUILDING ELECTRICAL SERVICES

- To make sure that the entire installation is in conformance and in accordance with the design intent of the project for the Electrical and Low Voltage System in addition to the specification and as per approved shop drawings and comply with Local and International Standards.
- Adhere to the drawings as closely as possible. The right is reserved to vary the runs and sizes of Cable Trays / Trunking and to make offsets but maintain as far as possible the free area of each duct work section, where necessary to accommodate conditions arising at the building.
- Before beginning installation in any area, examine all parts of the adjoining work onto which applicable work is to be placed. Should any condition be found which will prevent the proper execution of the work, installation shall not proceed in that area until such conditions are corrected by the contractor.

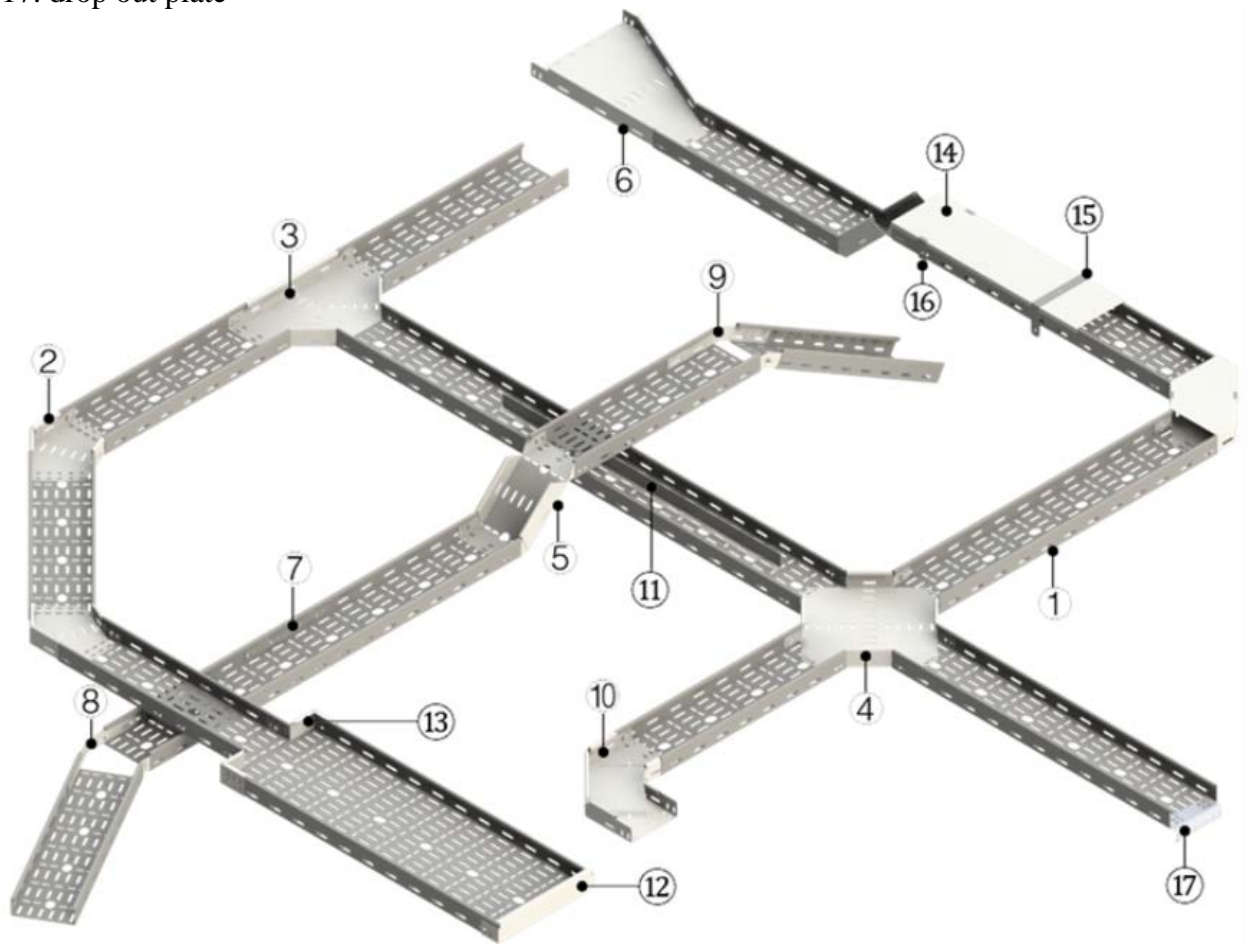
- d. Cable Tray / Trunking shall be stored on site under cover in dry, well ventilated storage facilities.
- e. Where sizes of Cable Trays / Trunking are not detailed on drawing then tray shall be adequately sized to support the cables without bunching and a 25% reserve margin shall be allowed in size and weight be loaded.
- f. All routes are chosen to allow ease of access to all cables when installed. All horizontal cables are to be set around all vertical rising services as necessary. Ensure sufficient clearance from soffit for every installation.
- g. Earth continuity conductors shall be provided across gaps in all Cable Tray / Trunking runs and bolted connections.
- h. Support shall be by means of steel brackets installed at intervals necessary to provide a rigid fixing and to ensure that deflection does not exceed 5mm mid span of support when fully loaded. Treatment of cut edges as per cut edges to be included. Supports for Tray / Trunking (spacing) shall be as per standard practice and manufacturer's recommendations.
- i. Additional support shall be provided where the Cable Tray / Trunking changes direction or cables drop out of the cable tray. Dome headed bolts, nuts and washers of finish suitable to the tray shall be used between trays.
- j. Suspension sets comprise threaded M10 zinc or cadmium plated hanger rods together with nuts and locking washers, supports channel hold down clips all of which shall have a galvanized finish. Any cut ends supports, rods, etc, must be corrosion protected by use of galvanized or equal. No extended rods to be left.
- k. The cable tray shall be installed with a 40mm minimum space between the structure and the tray.
- l. All cable shall be securely fixed to the tray, work and the complete installation must be carried out in a neat and workmanlike manner without crossovers.
- m. Cables on face-up horizontally fixed tray must be secured by use of the tie wraps where not in view. If cables are bunched or single cables greater than 25sq mm are installed, cleats or metal straps shall be used.



Cable tray accessories

1. straight section
2. horizontal elbow
3. horizontal tee
4. horizontal cross
5. flexible riser
6. reducer
7. splice connector
8. horizontal splice connector
9. vertical splice connector
10. flexible horizontal elbow
11. barrier strip
12. blind end
13. reduction splice connector
14. straight flat cover
15. heavy duty cover clamp
16. universal cover clamp

17. drop out plate



Task sheet No. 5.2.3.2

Information Sheet No. 5.2.3-3: Electrical Protective Devices

1. Protection Against Indirect Contact – Local Requirement

All socket outlet and lighting circuits in the household should be protected by one or more residual current device having a rated residual operating current not exceeding 30mA.

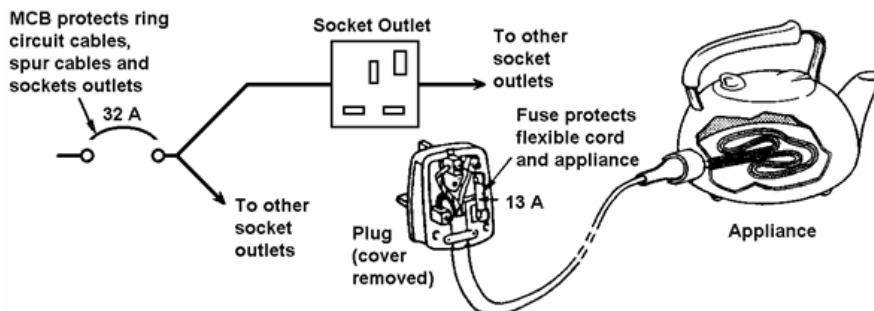
2. Standard Circuit Arrangements

The standard circuit arrangements, as recommended in the Regulation are:

- Final circuits using socket outlets complying with SS 145 or equivalent. (This consists of ring or radial circuits using 13A switched socket outlets)
- Final circuits using socket outlets complying with BS 546.
- Final radial circuits using socket outlets complying with IEC 309-2 or BS 4343.
- Cooker final circuits in household premises.

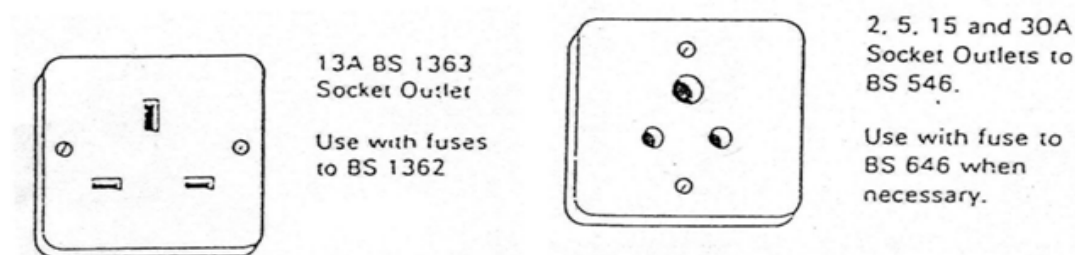
3. Definition of Terms

- Power point - A termination of the fixed wiring intended for the connection of power point.
- Plug - A device, provided with contact pins, which is intended to be with a socket outlet or with a connector.
- Socket outlet - A device, provided with female contacts, which is intended to be installed with the fixed wiring, and intended to receive a plug.



4. Socket Outlet and Plug

- Socket outlets and plugs are designed to enable portable apparatus to be connected to the final circuits.
- The socket outlet is the fixed portion connected to the fixed wiring and comprises two or more terminals.
- The plug is the movable part connected to the apparatus by flexible wire and comprises two or more contact pins to fit into the contact terminals of the socket outlet.
- They are made in many varieties, rating from 2A to 125A.



The following types of plugs and socket outlets, from the Code of Practice, are recognised as being suitable for electrical installations for low voltage circuits.

Plugs and socket outlets for low voltage circuits

Type of plug and socket outlet	Rating (amperes)	Applicable Standard
Fused plugs and shuttered socket outlets, 2-pole and earth, for a.c.	13	SS 145 (fuses to SS 167)
Plugs, fused or non-fused, and socket outlets, 2-pole and earth	2,5,15,30	BS 546 (fuses, if any, to BS 646)
Plugs, fused or non-fused, and socket outlets, protected type, 2-pole with earthing contact	5,15,30	BS 196
Plugs and socket outlets (theatre type)	15	BS 5550, Subsection 7.3.1
Plugs and socket outlets (industrial type)	16,32,63,125	BS 4343

These plugs and socket outlets are designed so that it is not possible to engage any pin of the plug into a live contact of a socket outlet. Whilst any other pin of the plug is exposed (not a requirement for ELV circuits), and the plugs are not capable of being inserted into socket outlets of systems other than its own.

Where a plug containing a fuse is required, they must be non-reversible and arranged so that the fuse cannot be connected in the neutral conductor.

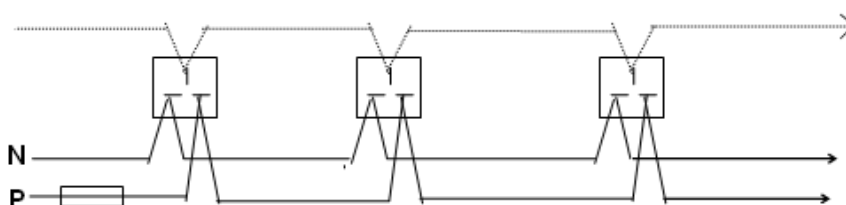
Where socket outlets are mounted vertically they should be fixed to a height above floor level or working surface so that the plug and associated flexible cord is not subjected to mechanical damage during insertion or withdrawal of the plug.

It is recommended that the minimum mounting height of a socket outlet on a wall is 150mm from the floor level or working surface.

Plugs and socket outlets other than those shown in the CP may also be used on single phase AC or 2-wire DC circuits operating at voltages not exceeding 250V for the connection of:

- Electric clocks – use clock connecting unit incorporating a fuse not exceeding 3A.
- Electric shavers - provided that the socket outlets are either incorporated in a shaver supply unit complying with BS 3052 or, in rooms other than that of bathrooms, are a type complying with BS 4573.

5. Requirements for radial final circuit under SS 145 or equivalent



20A fuse or MCB protection with 2.5 mm² PVC or 1.5 mm² MI cables feeding a floor area of not more than 50 m².

32 A fuse or MCB feeding through 4.0 mm² PVC or 2.5 mm² MI cables to supply a floor area no greater than 75 mm².

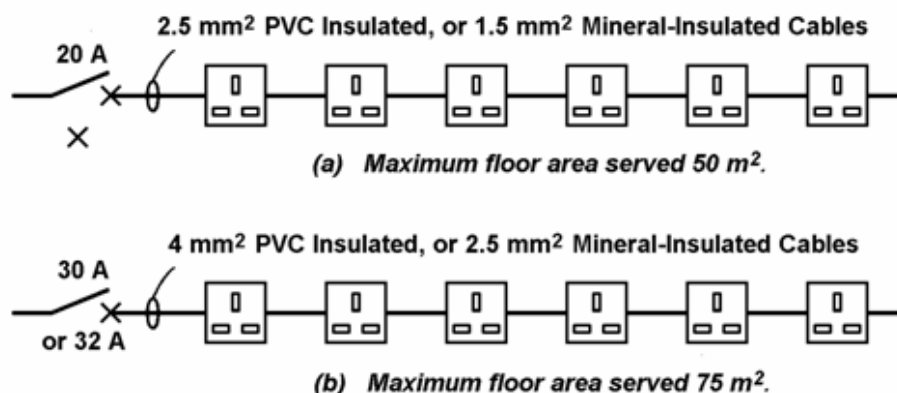
Number of socket-outlets depends on loading of circuit. If the circuit feeds a kitchen or utility room, it must be remembered that high current using equipment such as a washing machine or a

tumbler dryer leaves little capacity for the rest of the sockets. Consideration should be given to the provision of a separate circuit.

The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device, i.e. 20A or 32A.

It may feed permanently connected equipment.

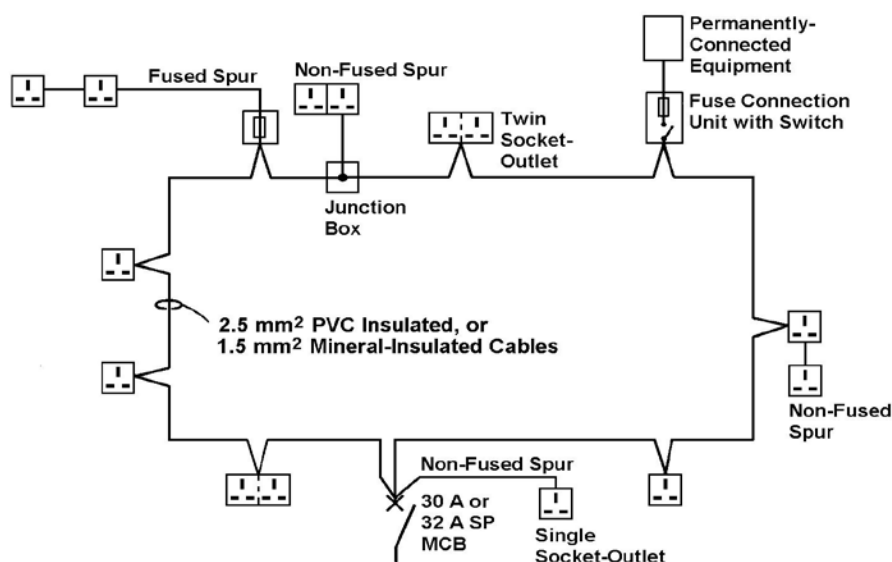
Each socket outlet of a twin or multiple socket outlets is regarded as one socket outlet.



The floor area served by the circuit is determined by the known or estimated load but should not exceed the above values.

6. Requirements for ring final circuit under SS145 or equivalent

- The floor area served by each ring must not exceed 100m² for domestic situations.
- Where ring circuits are used in commercial or industry buildings, the diversity must be assessed to ensure that the maximum demand will not exceed the rating of the protective device.
- Consideration should be given to the provision of a separate ring (or radial) circuit in a kitchen.
- Where there is more than one ring circuit in the same building, the installed sockets should be shared approximately evenly between them.
- Cable sizes for ring circuits are 2.5mm² PVC or 1.5mm² mineral insulated (MI) cables.
- Permanently connected equipment and an unlimited number of socket outlets, inclusive of spurs if any, can be fed.
- The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device.
- Every twin socket outlet counts as single socket outlets.



Maximum floor area served 100 m².

Type of circuit	Rating A	Overcurrent Protective device Type	Minimum conductor size mm²			Max. Floor area served in mm²
			Copper, PVC or Rubber	Copper claded aluminium PVC insulated	MICC	
A1 Ring	30 / 32	Any	2.5	NA	1.5	100
A2 Radial	30/ 32	Cartridge fuse or CB	4	NA	2.5	75
A2 Radial	20	Any	2.5	NA	1.5	50

7. Spur

- It is a branch cable connected to a ring or radial circuit.
- Spurs can be fused or non-fused:

7.1 Fused Spur

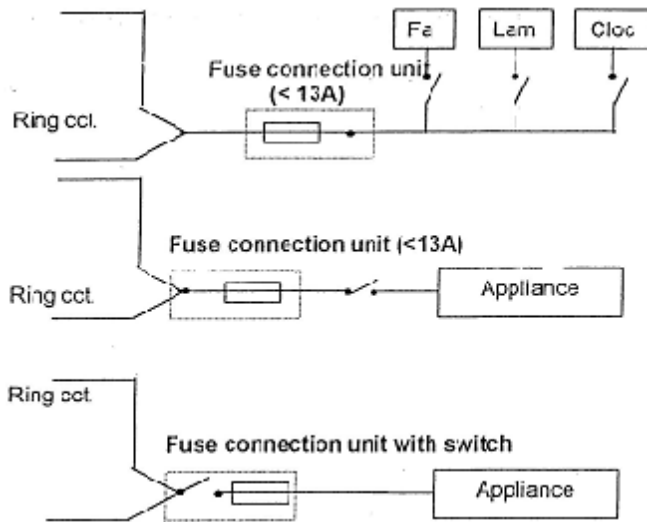
A fused spur is connected to the circuit through a fused connection unit.

The rating of the fuse should not exceed that of the cable forming the spur, should not exceed 13A.

The minimum size of the conductor used for a fused spur is:

- 1.5mm² for rubber or PVC insulated copper cables.
- 1.0mm² for mineral insulated copper cables.

The total number of fused spurs is unlimited.

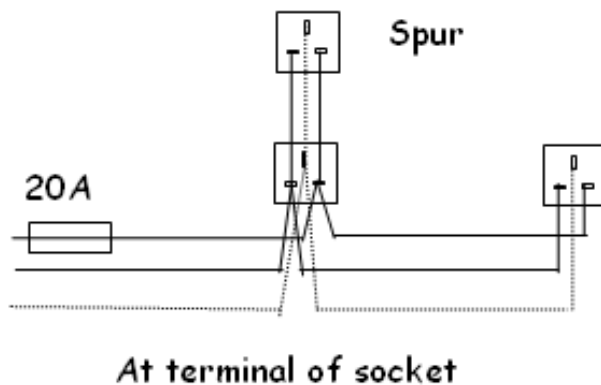


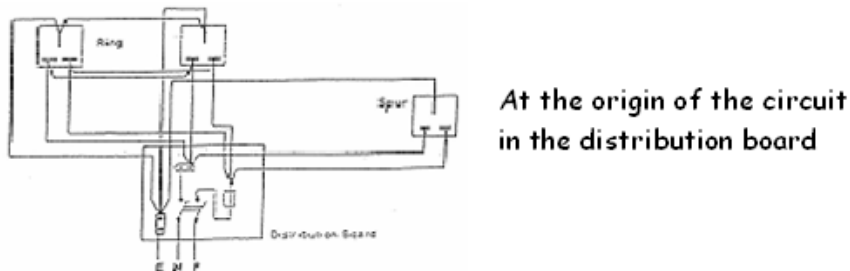
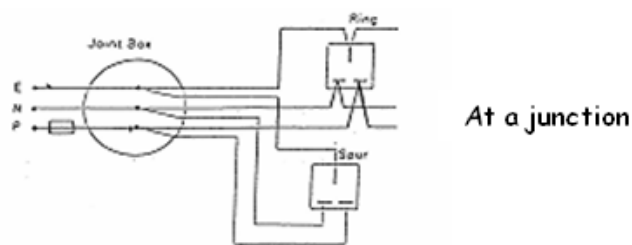
7.2 Non-fused spur

The 3 methods of connecting non-fused spurs to a circuit are:

- (i) At the terminal of socket outlet.
- (ii) At joint boxes.
- (iii) At the origin of the circuit in the distribution board.

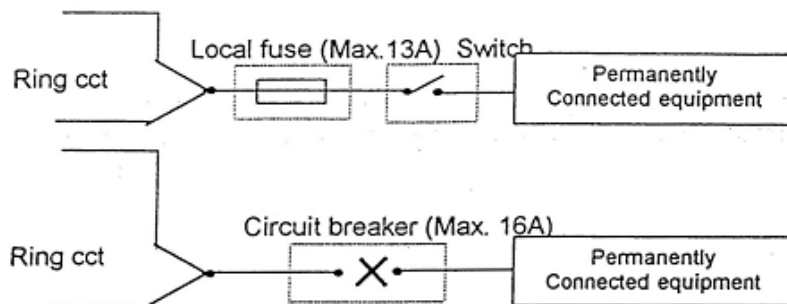
Non-fused spur may supply only one single or one twin socket outlet or one permanently connected equipment.





8. Permanently Connected Equipment

Permanently connected equipment should be locally protected by fuse rating not exceeding 13A and controlled by a switch or protected by a circuit breaker of rating not exceeding 16A



9. Circuit for Immersion Heaters

Where immersion heaters are to be installed to storage vessels in excess of 15 litres capacity, or a comprehensive space heating installation, eg. electric fire are to be installed, separate circuits should be provided for each heater.

10. Industrial Plug and Socket Uses, Applications, Connections



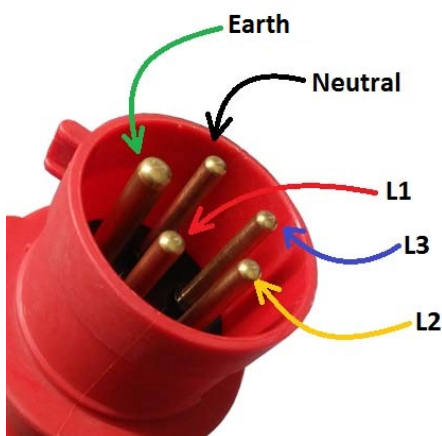
Industrial Plug and Sockets are widely used in indoor and outdoor for electrical power distribution, provide power supply to large machines. They are very reliable and easy to connect. There are various types of industrial plugs and sockets are available.

According to the way of installation, there are three types of industrial plug and socket available which are Mobile type, Exposed installation, Hidden Installation.

According to interlock configuration, there are three types of industrial plug and socket available which are non-interlock type, mechanical interlock type, electrical interlock type.

Industrial Plug Pins Identification

Here, you can see a three-phase industrial plug is shown in the below picture. This plug has a total of five pins - Earth, Neutral, Line 1(R), Line 2(Y), Line 3(B).



If you open that pins from its cover then you can see its pin identification because its backside identification is written.

Industrial Plug and Socket Uses and Applications

There are huge applications of Industrial plug and sockets. Some important uses are given below.

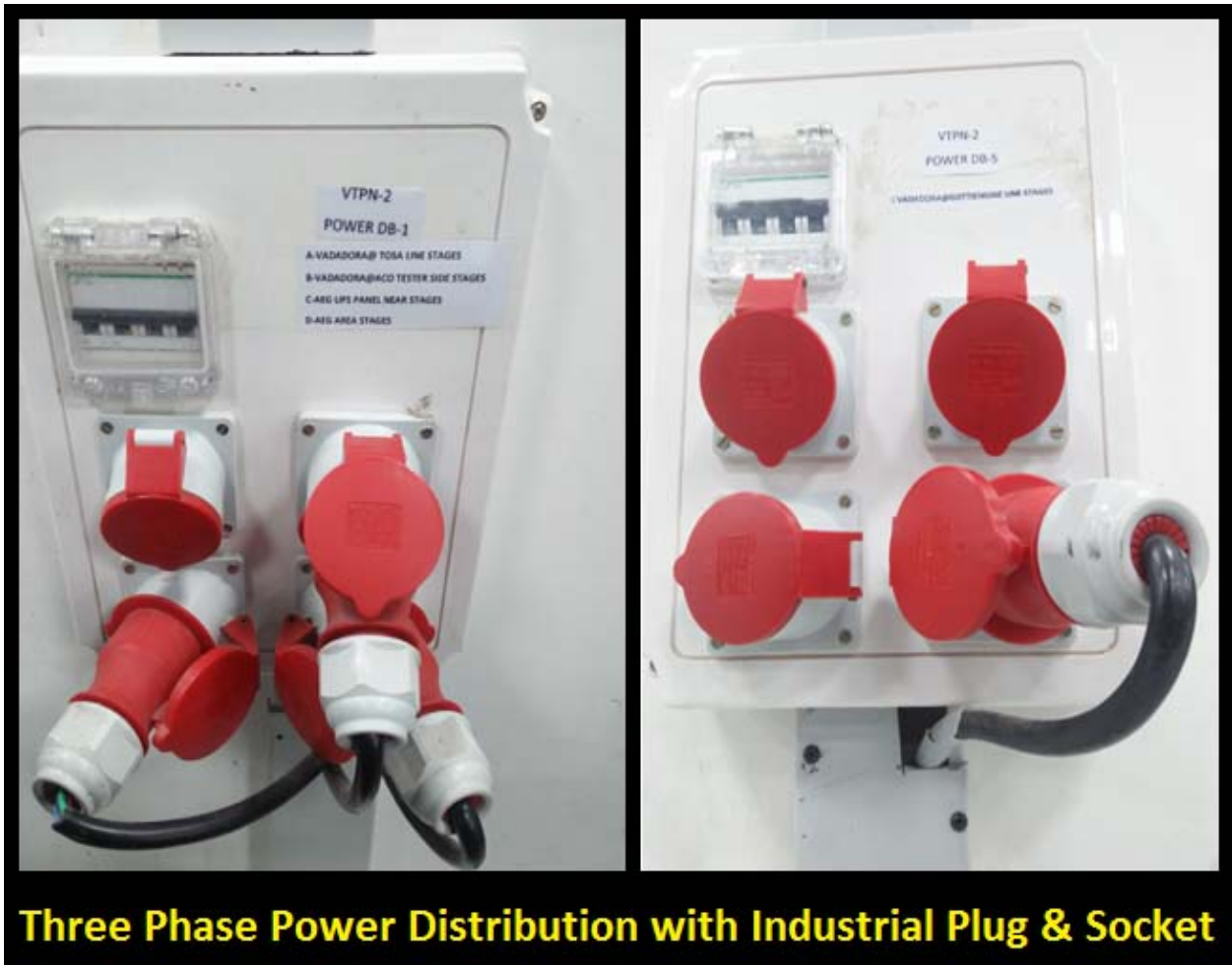
1. Industrial Socket and Plugs are used for high voltage and high current electrical power distribution purposes in industries.



2. Industrial Sockets and Plugs are used to provide high voltage and high current power supply to large machines such as SMT Soldering machines, Testing machines, X-Ray machines, etc.



3. Industrial Plug and Sockets are used in outdoor also. They used to provide temporary power supply to large machines such as cranes, elevators, etc.



Industrial Plug and Socket Advantages

1. They are available in both single-phase and three-phase.
2. High voltage power can be distributed through those sockets and plugs.
3. They are easy to use.



4. They provide electrical safety and insulation.
5. They are weatherproof.
6. They are reliable.



Industrial Plug & Socket Connection - Three Phase

Self-Check No. 5.2.3-3

1. How is the training process of coaches and trainers different?

Answer Key No. 5.2.3-3

1. The differences between the training process between the coach and the trainer are as follows:

- **Coach:**

1. Actively listens to determine the need.
2. Breaks the role down into skills and tasks.
3. Observes what novice already knows.
4. Decides what skills are needed to communicate more effectively.
5. Demonstrates or describes the task by:
 - questioning, giving advice
 - giving an example
 - talking over the procedure
 - Setting a new problem.
6. Observes/reflects.
7. Demonstrates/describes further.

- **Novice/trainers:**

1. Makes initial attempt at task.
2. Demonstrates or describes the task by:
 - Observes/reflects.
 - Listens/reflects.
3. Applies model/description.
4. Change's approach.

Information Sheet No. 5.2.3-4: Earthing

1. Introduction

The general mass of earth is made up almost entirely of materials that are reasonably electrical conductors themselves or are made so by being moist. From this, it follows that a current will flow to earth through a live conductor to earth, provided that some other point of the system at a different potential is also connected to earth.

In practice, the neutral at the supply transformer (Fig 6-1) is always connected to the general mass of earth. This is done by connecting a conductor from the neutral at the supply origin to a rod driven into the ground. This is called earthing.

Thus, to prevent the potential of live conductors rising above the safe value, all exposed metal parts of an electrical installation must be connected to earth.

Fig 6-1 Typical Distribution System

GENERAL

The **earth** is considered as a large conductor at **zero potential**. Earthing, therefore, is to connect all exposed-conductive-parts of an installation to the main earthing terminal of that installation.

OBJECTIVE

- To provide an alternative path for the fault current to flow so that the protective devices can sense and operate to isolate the faulty circuit rapidly.
- To ensure that any exposed conductive part does not reach a dangerous potential with respect to earth
- To maintain the voltage at any part of an electrical system at a definite value with respect to earth, so as to prevent any dangerous overvoltage or excessive current on the equipment.

CRITERIA OF GOOD EARTH

Good earth must meet the following criteria:

- Low electrical resistance
- Good corrosion resistance
- Able to carry high fault current repeatedly
- Reliable

TYPES OF SYSTEM EARTHING

TT and **TN-S** systems (Fig 6-2) are adopted in **Singapore**.

FIRST LETTER	SECOND LETTER	SUBSEQUENT LETTERS
--------------	---------------	--------------------

Earthing arrangement at energy source	Relationship of exposed conductive parts and earth	Arrangement of protective conductor and neutral
<i>T</i> One or more point of the supply are connected to earth	<i>T</i> Exposed conductive parts connected directly to earth which is independent of the supply earth	
<i>T</i> Supply system not earthed, or one point earthed through a fault limiting impedance	<i>N</i> Exposed conductive parts connected directly to the earth point of energy source	<i>S</i> Separate neutral and protective conductor

Table 6-1 Types of System Earthing

TT and TN-S Comparison

	TT	TN-S
Earth fault loop impedance	High	Low
RCD preferred?	Yes	Yes
Need earth electrode at site?	Yes	No
PE conductor cost	Low	Highest
Risk of broken neutral	No	High
Safety	Safe	Safest
Electromagnetic interference	Least	Low
Safety risks	High loop impedance (step voltages)	Broken neutral
Advantages	Safe and reliable	Safest

Table 6-2 TT and TN-S comparison

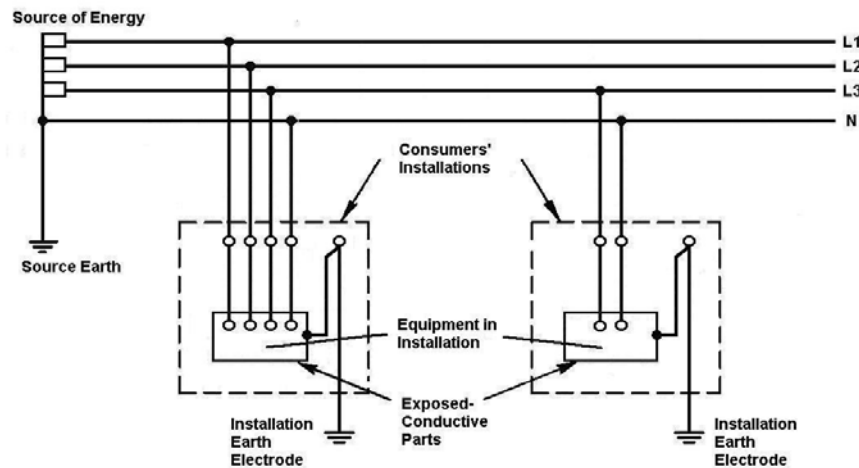


Figure 4. TT System

All exposed-conductive parts of an installation are connected to an earth electrode which is electrically independent of the source earth.

NOTE. ALL OTHER SYSTEMS SHALL NOT BE ALLOWED IN THE REPUBLIC OF SINGAPORE

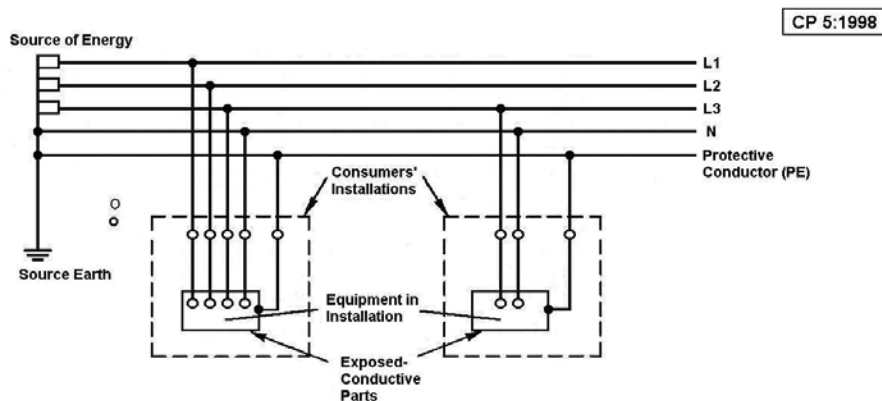


Figure 3. TN-S System

Separate Neutral and Protective Conductors Throughout the System

The protective conductor (PE) is the metallic covering of the cable supplying the installation or a separate conductor.

All exposed-conductive parts of an installation are connected to this protective conductor via the main earthing terminal of the installation.

Fig 6-2 Earthing Systems in Singapore

Earth fault loop impedance

An earth fault current is a fault current which flows to Earth.

Earth fault loop impedance is the impedance of the earth fault current loop starting and ending at the point of earth fault. This impedance is denoted by the symbol Z_s .

The earth fault loop comprises the following, starting at the point of fault:

- The circuit protective conductor, and
- The consumer's earthing terminal and earthing conductor, and
- For TN-S system, the metallic return path, and
- For TT system, the earth return path, and
- The path through the earthed neutral point of the transformer, and

- The transformer winding, and
- The phase conductor from the transformer to the point of fault.

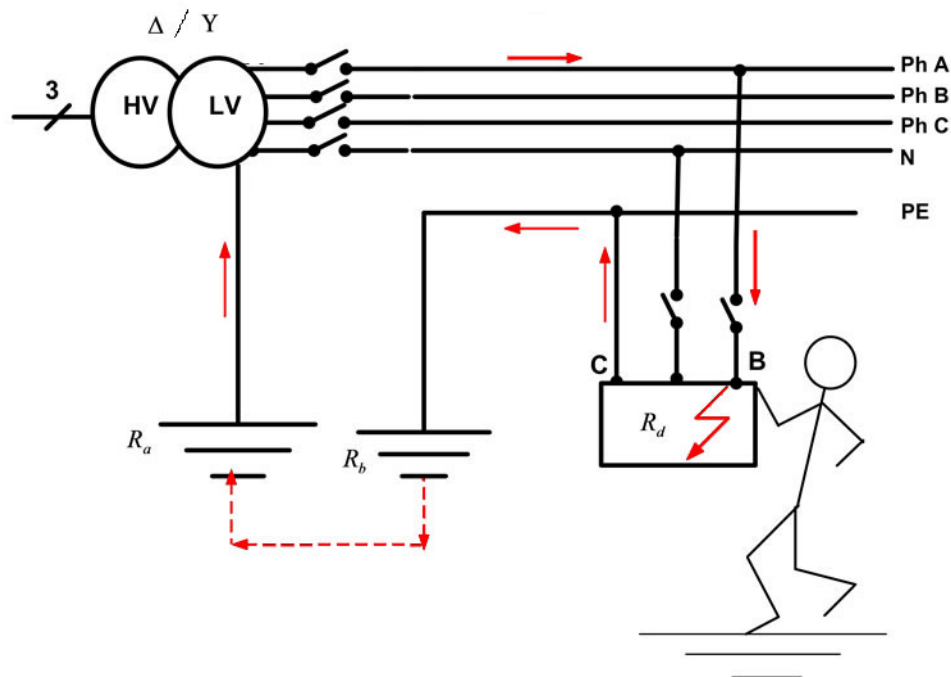


Fig 6-3 Path for earth fault current

TT SYSTEM

Used for consumers taking LV supply from Singapore Power as the energy source from Singapore Power and the consumer installation earth are separate.

In a TT earthing system, the **protective earth connection of the consumer** is provided by a **local connection to earth, independent** of any **earth connection at the generator**.

Earth Path of TT System

It is the path taken by earth fault current.

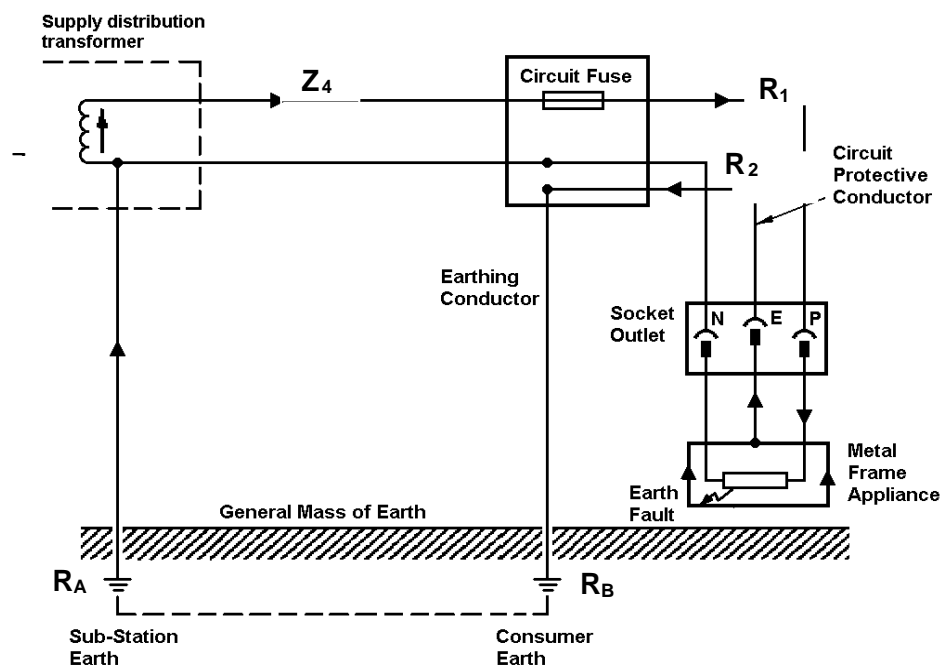


Fig 6-4 Earth Fault Loop of TT System

and the earth loop impedance, Z_s is

$$Z_s = Z_0 + Z_4 + R_1 + R_2 + R_A + R_B$$

- where
- Z_0 = Transformer impedance
 - Z_4 = Phase conductor impedance external to circuit
 - R_1 = Phase conductor circuit resistance
 - R_2 = Protective conductor circuit resistance
 - R_A = Source earth resistance
 - R_B = Installation earth resistance

For **TT** system, the earth loop impedance is generally higher; the protective device is preferably being **residual current type** than overcurrent type.

TN-S SYSTEM

Used for consumers taking **HV** supply (eg 22kV).

In a TN-S system, the protective earth (PE) and neutral (N) conductors are connected **only near the power source** as shown in Fig. 5-5.

Earth Path of TN-S System

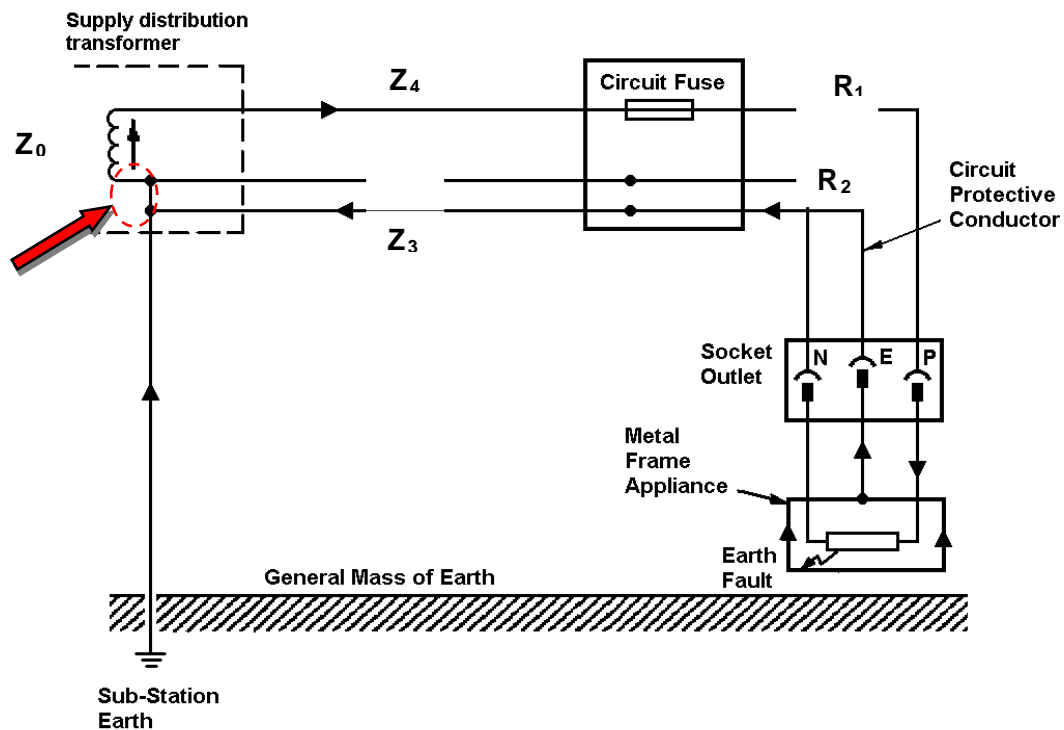


Fig 6-5 Earth Fault Loop of TN-S System

and the earth loop impedance, Z_s is

$$Z_s = Z_4 + R_1 + R_2 + R_3$$

- where
- Z_3 = Resistance of main earthing conductor

This system does not arrange earth fault current to flow through the general mass of earth. Thus the fault current could be very high. The protective device shall be overcurrent type and / or residual current type

EARTHING INSTALLATION

An earthing installation consists of:

- Earth electrodes
- Earthing conductors
- Circuit protective conductors
- Main equipotential bonding conductors
- Supplementary equipotential bonding conductors.

The example of the earthing arrangement is as shown in Fig 6-6.

ILLUSTRATION OF EARTHING AND PROTECTIVE CONDUCTOR TERMS

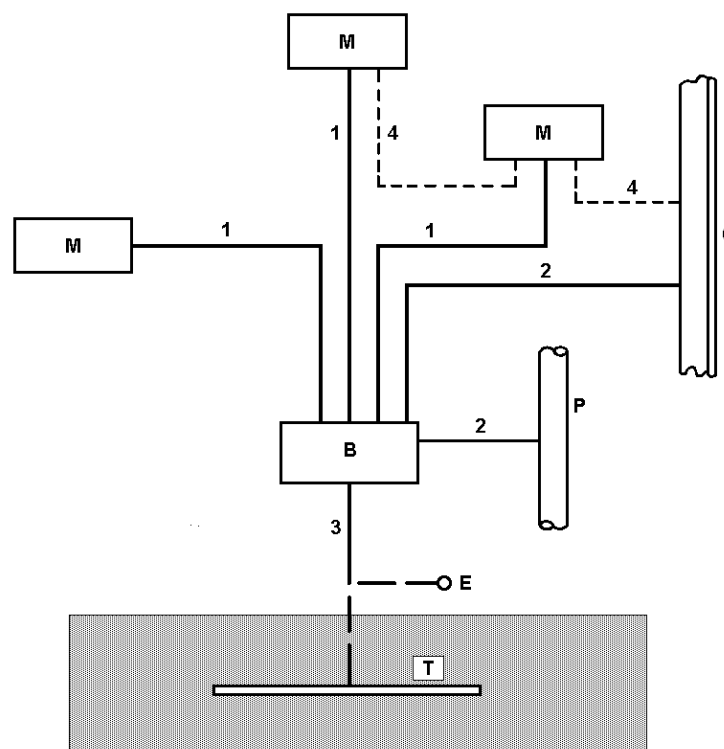


Fig 6-6 Earthing and Protective Conductors

Legend

- 1, 2, 3, 4 = Protective conductors
 - 1 = Circuit protective conductor
 - 2 = Main equipotential bonding conductor
 - 3 = Earthing conductor
 - 4 = Supplementary equipotential bonding conductor (where required)
- B = Main earthing terminal
- M = Exposed-conductive part
- C = Extraneous-conductive part

TYPES OF EARTH ELECTRODE

Earth Electrode

A conductive part, which may be embedded in the soil or in a specific conductive medium, e.g concrete in electrical contact with the earth.

Alternative it can be explain as a conductor or group of conductors is in intimate contact with, and providing an electrical connection to, Earth.

The recognised earth electrodes are:

- Earth rods or pipes
- Earth tapes or wires
- Earth plates
- Underground structural steelworks in foundations
- Welding metal reinforcement of concrete (except pre-stressed concrete) embedded in the ground
- Lead sheaths and other metal coverings of cables, where not precluded by SS 638 clause 542.2.5
- Other suitable underground metalwork

Earth electrode must be installed in such a way that their resistance does not increase due to climatic conditions such as soil drying and corrosion etc.

The metalwork of a gas, water or other service should not be used as a protective earth electrode.

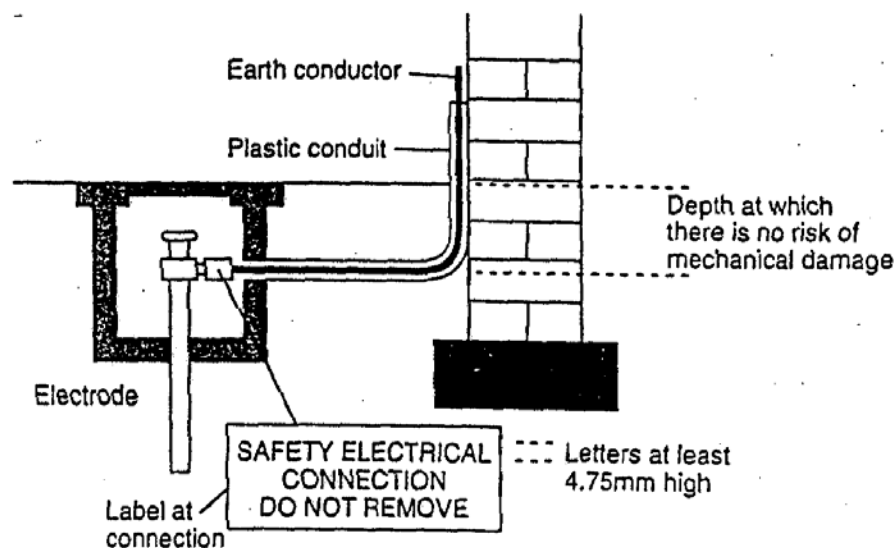


Fig 6-7 Installation of an Earth Electrode

PROTECTIVE CONDUCTORS

The conductors joined from the earth electrode to various parts of metalwork in the earthing installation. It includes:

- Earthing conductor
- Circuit protective conductor
- Main equipotential bonding conductor

- Supplementary equipotential bonding conductor

Earthing Conductor

It is a protective conductor connecting the main earthing terminal of an installation to an earth electrode or to other means of earthing.

A permanent label for earthing connection shall be fixed. This is to ensure that the earthing connection is not removed unintentionally.

Circuit Protective Conductor

It is a protective conductor connecting the exposed-conductive-parts of equipment to the main earthing terminal.

Main Equipotential Bonding Conductor

It is a protective conductor connecting extraneous-conductive-parts to the main earthing terminal to maintain equal potential. Its joint to gas and water services should be made as near as possible to the point of entry.

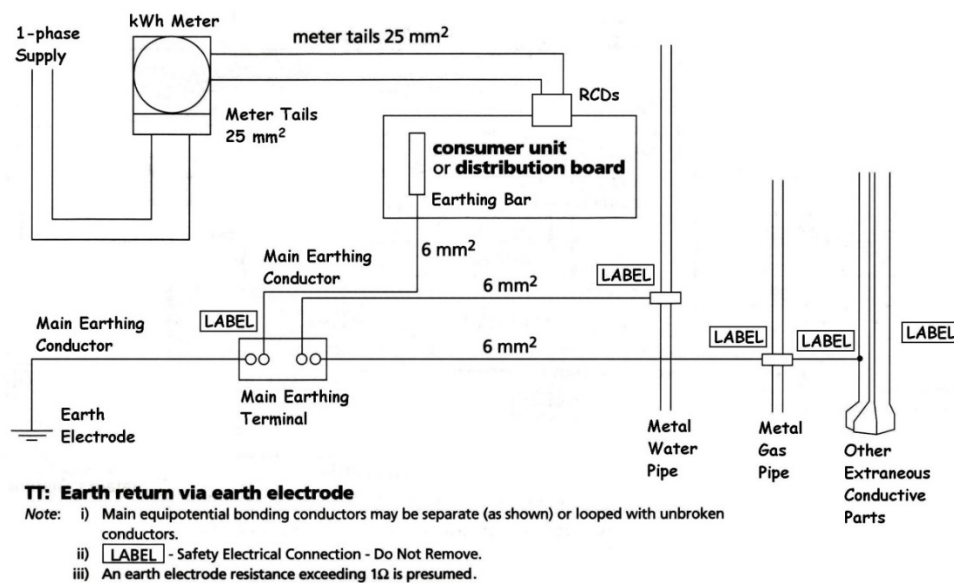


Fig 6-8 Main Equipotential Bonding Conductor

Supplementary Equipotential Bonding Conductor

It is a protective conductor connecting two exposed-conductive-parts, or an exposed-conductive-part to an extraneous-conductive-part or two extraneous-conductive-parts to maintain substantially equal potential.

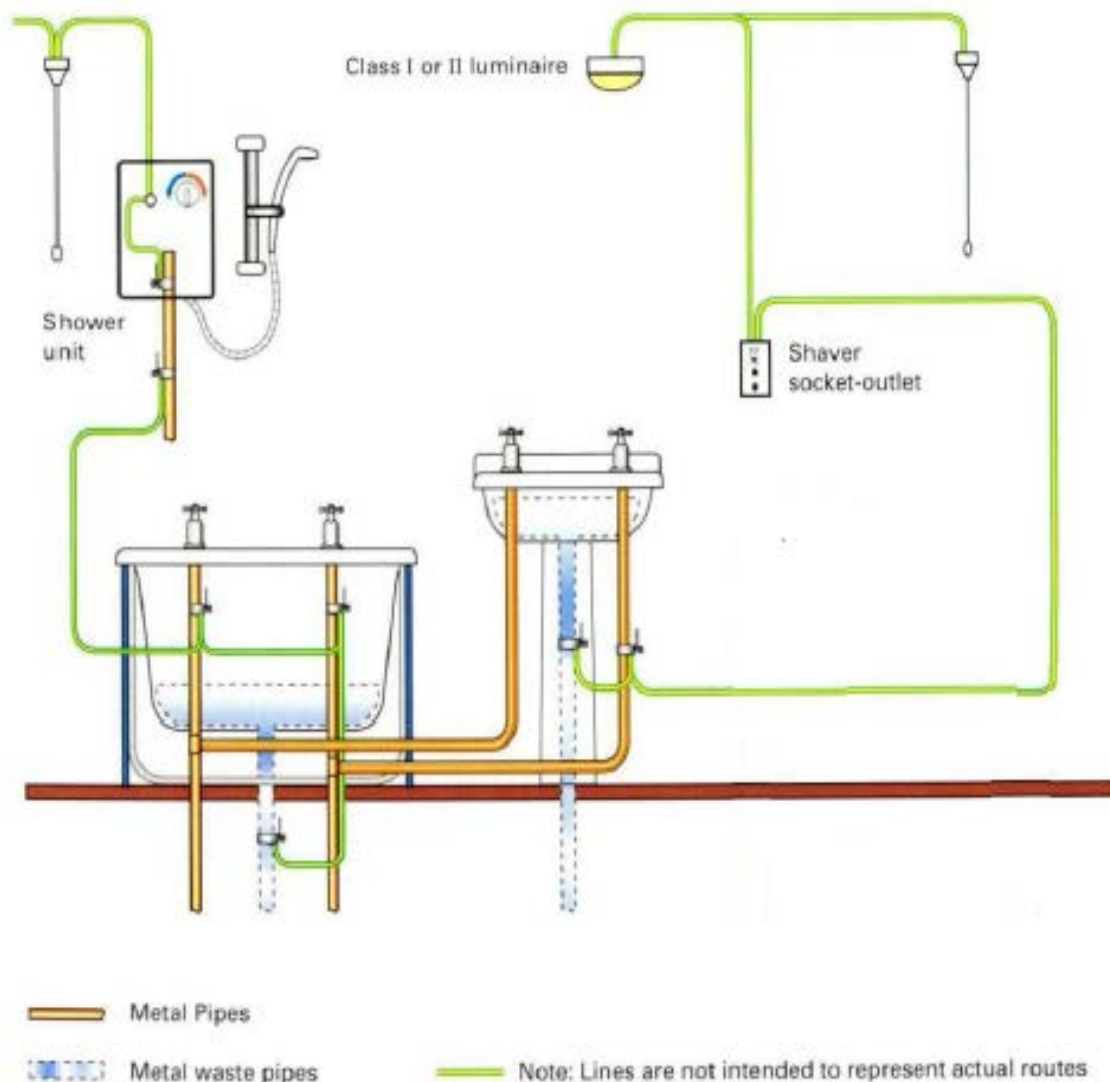


Fig 6-9 (17th Editions of IEE) - Supplementary Equipotential Bonding Conductor

Notes:

1. All simultaneously accessible metal (class 1) equipment (e.g. electric heaters and showers), central heating pipes hot and cold water and waste pipes require supplementary bonding in or close to, the bathroom.
2. Metal baths not connected to a metal building structure do not require supplementary bonding if all metal pipes connected to them has been bonded.
3. Connections to pipes to be made with BS 951 clamps (complete with "Safety Electrical Connection" label).

BONDING

It is a protective conductor connecting the exposed and extraneous-conductive -parts to the main earthing terminal.

Objective

To keep the fault voltage between exposed and extraneous conductive parts to a minimum.

Exposed Conductive Part

An exposed conductive part is a conductive part which **can readily be touched** and which is **not normally alive**, but which **may become alive under fault conditions**. It is also refers to conductive part of electrical

equipment, which can be touched and which is not normally live, but which can become live when basic insulation fails. Typical exposed conductive parts are walls of enclosures, operating handles.

Extraneous Conductive Part

An extraneous-conductive-part is a conductive part liable to **introduce a potential**, generally **earth potential** and **does not form part of the electrical installation**. It can also be said to be metalwork which has nothing to do with an electrical appliance/installation and which **could become live (indirectly)** i.e. a radiator.

Example of extraneous-conductive-parts:

- Main water pipes
- Main gas pipes
- Main service pipes and ducting
- Risers of central heating and air conditioning systems
- Exposed metallic parts of the building structure

SIZE OF PROTECTIVE CONDUCTIVE CONDUCTOR

Protective Conductor	Size	Minimum Size		
		With Mechanical Protection	Without Mechanical Protection	Without Corrosion Protection
1. Earthing conductor	Calculation or Table 54.1	2.5mm ²	4mm ² 16mm ² (buried)	25mm ² (buried)
2. Circuit protective conductor	Calculation or Table 54.7	2.5mm ²	4mm ²	Not applicable
3. Main bonding conductor	(Earthing Conductor) ÷ 2	6mm ²		
4. Supplementary bonding conductor				
i) Exposed conductive part to exposed conductive part	Smaller CPC Connected	2.5mm ²	4mm ²	
ii) Extraneous conductive part to exposed conductive part	4 (i)	2.5mm ²	4mm ²	
iii) Extraneous conductive part to extraneous conductive part (No connection to exposed conductive part)	One of the minimum	2.5mm ²	4mm ²	

Table 6-3 Sizes of Protective Conductors

TYPES OF CABLE USED AS PROTECTIVE CONDUCTORS

- a. A single core cable
- b. A conductor in a cable
- c. An insulated or bare conductor in a common enclosure with insulated live conductors
- d. A fixed bare or insulated conductor
- e. A metal covering, for example, the sheath, screen or armouring of a cable

Note :

A protective conductor of **6 mm² or less** must be **insulated** and of cross-sectional-area of **10 mm² or less** must be of copper.

RESIDUAL CURRENT DEVICES (RCDs)

When automatic disconnection of supply cannot be afforded by overcurrent device if the earth loop impedance cannot satisfy the requirements of Tables 41A, 41B1, 41B2, 41C and 41D. The RCD must be used.

RCD can also be used in conjunction with the overcurrent device for the protection against indirect contact as RCD is more sensitive at low residual / leakage current.

Types:

- Residual current circuit breaker without integral overcurrent protection (RCCB)
- Residual current circuit breaker with integral overcurrent protection (RCBO)
- Earth leakage relay (not to be covered).

RCCB comes with sensitivities of 10mA, 30mA, 100mA, 300mA, 500mA. The **30mA** RCCB is commonly used for **domestic installations**.

POINTS TO NOTE

- a. Main gas and water services must be bonded within **600mm** from the respective supply authority's meter on the consumer's side of the installation.
- b. Never use aluminium conductors to make final terminations to copper earthing rods or plates. Corrosion will set in and contaminate the mechanical bond.
- c. The metalwork of a gas, water or other service shall not be used as a protective earth electrode.
- d. The connection of an earthing conductor to an earth electrode must be electrically & mechanically sound and labeled permanently with the words "**Safety Electrical Connection – Do Not Remove**".
- e. Metallic flexible conduit, gas pipe, oil pipe and exposed-conductive-part of equipment shall not be used to form a protective conductor.
- f. No switching device shall be inserted in a protective conductor.

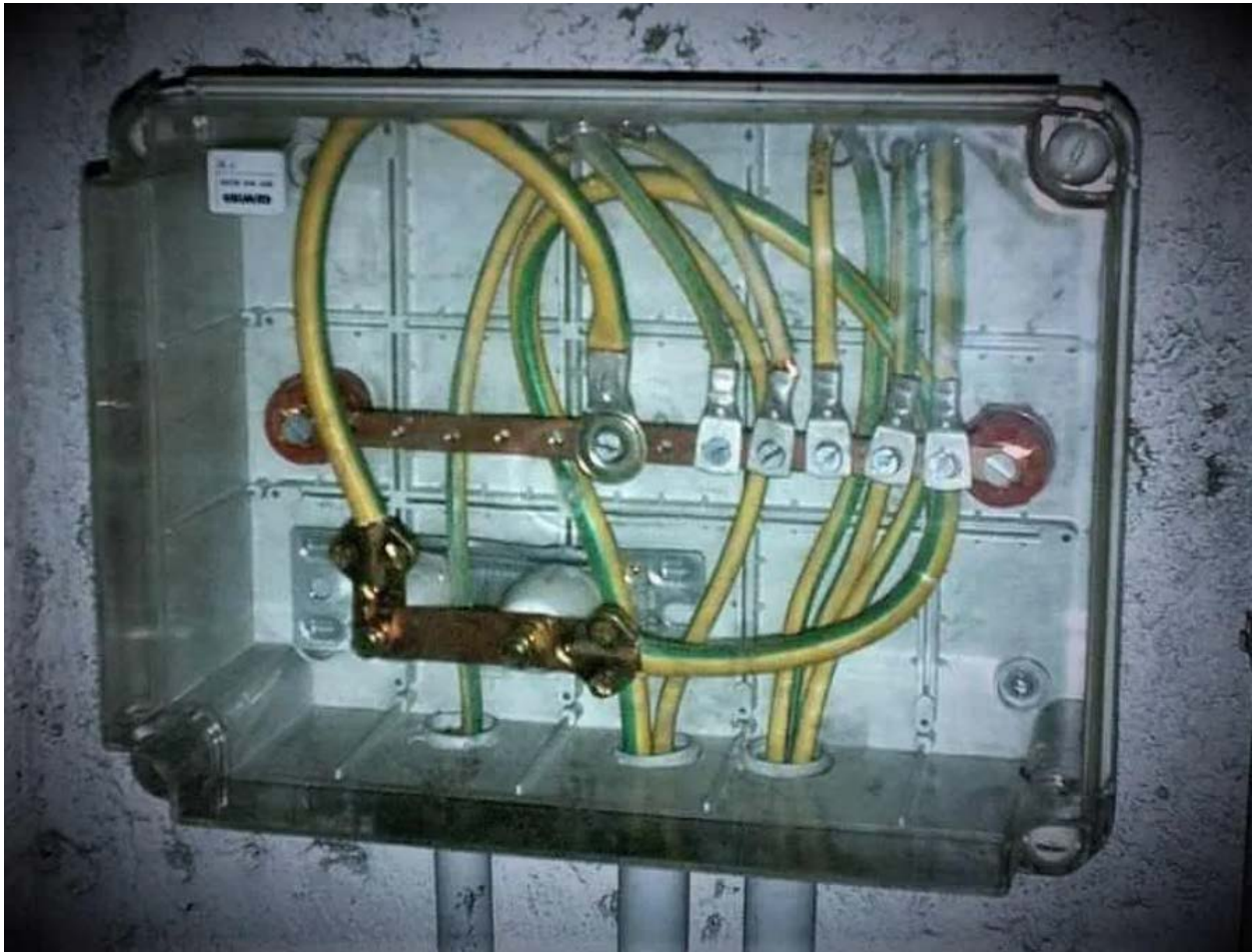
Testing and Inspection of Bonding and Grounding Systems

Bonding and grounding are very effective techniques for minimizing the likelihood of ignition from static electricity.

A **bonding** system connects various pieces of conductive equipment and structures together to keep them at the same potential. Static sparking cannot take place between objects which are at the same potential.

Grounding is a special form of bonding in which the conductive equipment is connected to the facility grounding system in order to prevent sparking between conductive equipment and ground.

Bonding and Grounding



In potentially flammable locations, all conductive objects that are electrically isolated from ground by nonconductors such as nonconductive piping or hoses, flexible hoses, flexible connections, equipment supports or gaskets should be bonded.

An isolated conductive object can become charged sufficiently to cause a static spark. Objects that can become isolated include screens, rims of nonconductive drums, probes, thermometers, spray nozzles and high pressure cleaning equipment.

In order to successfully achieve the objective of the same ground potential for all materials and their containers when there are additional and/or redundant grounding systems, and particularly when there are supplementary grounding electrodes, all such grounding electrodes and systems must be interconnected as required by the NEC and NFPA Lightning Protection Code.

Bonding and grounding conductors must be durable and of a low resistance. Connections of bonding conductors to equipment must be direct and positive for portable equipment. Clamps must make contact with metal surfaces through most paint, rust and surface contaminants. Single point clamps are superior to battery type and “alligator” type clamps for making direct contact.

Caution must be exercised in the installation of static grounding systems so that no part of the electrical current-carrying system is used as a ground. Fires have occurred in plants where static-control grounds were tied into the electrical system neutrals. These neutrals must never be part of the ground system except at the service entrance or other approved common bonding point.

Testing and Inspection of Bonding and Grounding Systems

The proper installation of bonding and grounding devices is important in the protection of personnel and equipment. At the time of installation, a resistance test is needed to confirm electrical continuity to ground. In addition, an effective inspection and periodic maintenance program is needed to ensure that continuity exists throughout the system.

In evaluating maintenance requirements, the bonding and grounding requirements can be divided into three categories:

1. The point type clamps equipped with flexible leads used for temporary bonding of portable containers to the facility grounding system.
2. The fixed grounding conductors and busbars used to connect the flexible leads and fixed equipment to ground.

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A more thorough inspection should be made regularly using an approved ohmmeter to test electrical resistance and continuity. One lead of the ohmmeter is attached to a clean spot on the container, the other lead is connected to the facility grounding system. The measured resistance should be less than 25 ohms and will usually be about 1 ohm. Shake the leads to make sure that the contact point and the leads are sound. Do not rely on contact through dirt or rust.

The fixed leads and the busbar are not usually subject to damage or wear but should be annually checked with an ohmmeter. They are checked between the leads or bus and the facility ground. The measured resistance should be less than 1 ohm.

Conductive hoses should be checked regularly and after any repairs are made. The conductive segments may break or may not be properly repaired. Nonconductive hoses with an internal spiral conductor should be installed so that the spiral conductor makes contact with the adjacent metallic fittings. Shake the hose whenever possible when making the measurements.

Facility Ground System

The final component of the static bonding and grounding system is the facility ground system. The facility ground must conform to the rules of the NEC. Underground piping equipped with cathodic protection should not be used as the grounding system.

What is Ground, and importance of a Grounding System?

Grounding is a very complex subject. The proper installation of grounding systems requires knowledge of soil characteristics, grounding conductor materials and compositions and grounding connections and terminations.

Article 250 of the National Electrical Code (NEC) contains the general requirements for grounding and bonding of electrical installations in residential, commercial and industrial establishments. Many people often confuse or intermix the terms grounding, earthing and bonding.

To understand the simple terms:

Grounding

Grounding is connecting to a common point which is connected back to the electrical source. It may or may not be connected to the earth. An example where it is not connected to earth is the grounding of the electrical system inside an airplane.

Earthing

Earthing is a common term used outside the US and is the connection of the equipment and facilities grounds to Mother Earth. This is a must in a lightning protection system since earth is one of the terminals in a lightning stroke.

Bonding

Bonding is the permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

WHY GROUND?



A good **grounding system** must receive periodic inspection and maintenance, if needed, to retain its effectiveness. Continued or periodic maintenance is aided through adequate design, choice of materials and proper installation techniques to ensure that the grounding system resists deterioration or inadvertent destruction. Therefore, the minimal repair is needed to retain effectiveness throughout the life of the structure.

The grounding system serves three primary functions which are listed below.

Personnel Safety

Proper grounding facilitates the operation of the overcurrent protective device protecting the circuit.

Proper grounding facilitates the operation of the overcurrent protective device protecting the circuit.

Equipment and Building Protection

Equipment and building protection is provided by low impedance grounding and bonding between electrical services, protective devices, equipment, and other conductive objects so that faults or lightning currents do not result in hazardous voltages within the building.

Also, the proper operation of overcurrent protective devices is frequently dependent upon low impedance fault current paths.

Electrical Noise Reduction

Proper grounding aids in electrical noise reduction and ensures:

- The impedance between the signal ground points throughout the building is minimized.
- The voltage potentials between interconnected equipment are minimized.
- That the effects of electrical and magnetic field coupling are minimized.

Another function of the grounding system is to provide a reference for circuit conductors to stabilize their voltage to the ground during normal operation. The earth itself is not essential to provide a reference function. Another suitable conductive body may be used instead.

The function of a grounding electrode system and a ground terminal is to provide a system of conductors that ensures electrical contact with the earth. Two Fine Print Notes (FPN) that appear in Section 250-1 of the NEC provide a good summary of the reasons for grounding systems and circuit conductors and the conductive materials which enclose electrical conductors and equipment.

Ground Detector Principle

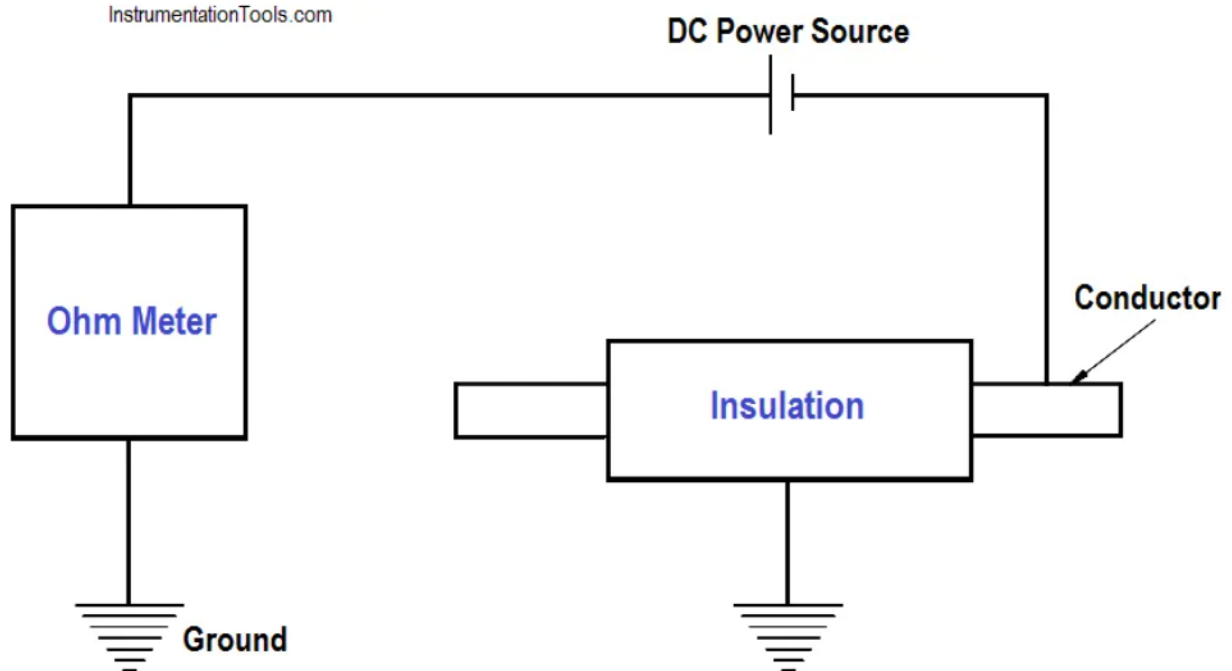
The ground detector is an instrument which is used to detect conductor insulation resistance to ground. An ohm meter, or a series of lights, can be used to detect the insulation strength of an ungrounded distribution system. Most power distribution systems in use today are of the grounded variety; however, some ungrounded systems still exist.

Ohm Meter Ground Detector Method

In the ohm meter method (below Figure), a DC voltage is applied to the conductor. If a leakage path exists between the conductor insulator and ground, a current will flow through the ground to the ohm meter proportional to the insulation resistance of the conductor.

Ohm Meter Ground Detector

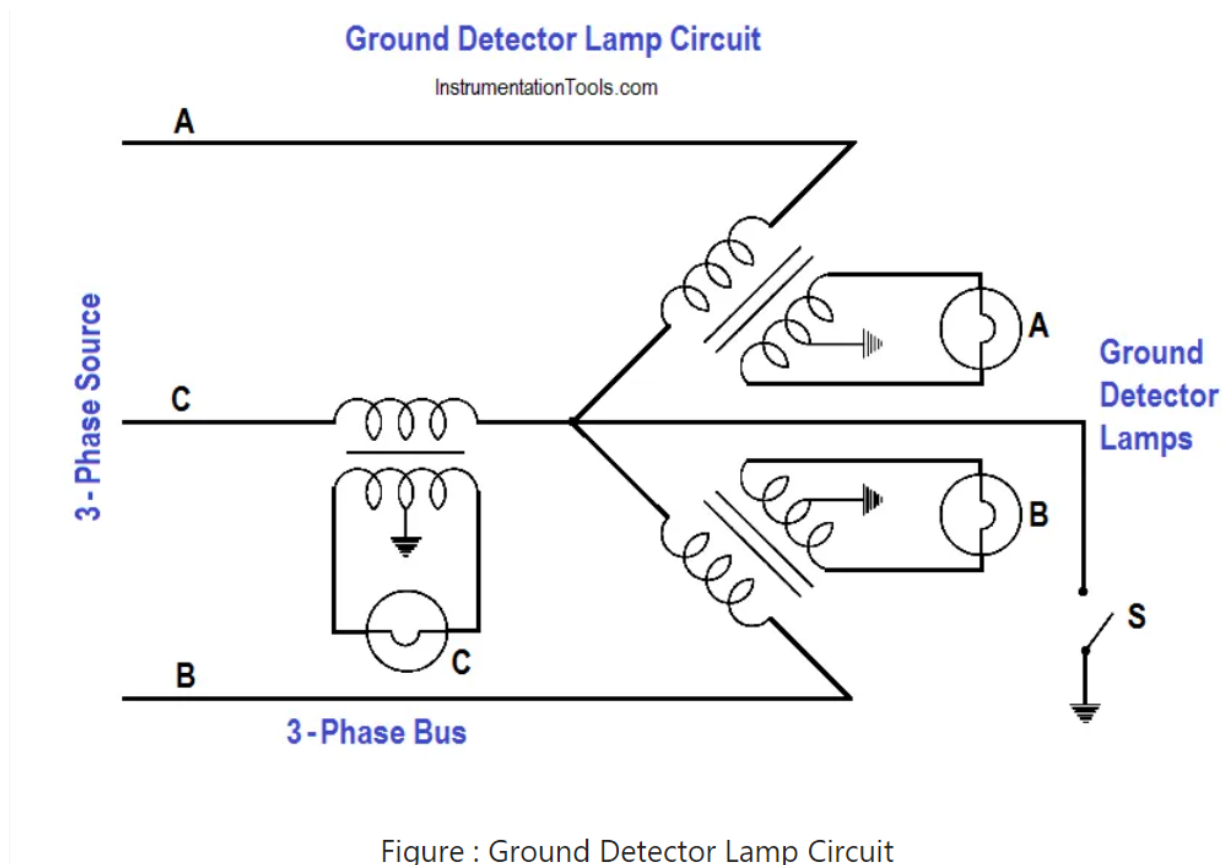
InstrumentationTools.com



Ground Detector Lamp Method

In the ground detector lamp method (below Figure), a set of three lamps connected through transformers to the system is used. To check for grounds, the switch is closed and the brilliance of the lamps is observed.

If the lamps are equally bright, no ground exists and all the lamps receive the same voltage. If any one lamp is dark, and the other two lamps are brighter, the phase in which the darkened lamp is in is grounded. In this case, the primary winding of the transformer is shorted to ground and receives no voltage.



Neutral Grounding Practice in Power System

- Generally on neutral grounding is provided at each voltage. There will be several voltage levels between the generation of the power and distribution of the power in the power system. Only one ground is provided for each voltage level of the power system
- Grounding of the power system is provided at the source and not at the load end
- Each of the major bus section in the system are grounded
- For generator grounding, neutral of the generator is grounding through a resistance which limits the stator fault current. The value of the resistor employed for the grounding the generator decides the percentage of the generator windings left unprotected
- Synchronous motors and synchronous capacitors are provided with reactance type of grounding. This reactance grounding provides additional reactance which provides additional lagging currents which nullifies the capacitive grounding currents
- When several generators are connected to a common neutral bus, the bus is connected to the ground through a single grounding device. Disconnect switches are used to ground the desired generators to the neutral bus
- When several generators are operating in parallel, only one generator neutral is earthed. This is to avoid the interference between the zero sequence currents
- In generating stations there is a provision to ground neutral of at least two generators, though one at a time. The other generator neutral is grounded when the first generator is out of service
- When there are one of the two supply sources, no switching equipment is used in the grounding circuit.
- For the protection purpose, the neutral point of the star side of the power transformer is usually grounded

- The star connected secondary sides of the protective CTs and PTs are grounded at one point. This ensures stable neutral, proper measurement of the voltages and currents, kWh and kVA on the secondary side measuring instruments and controls
- For the circuits between 3 kV and 33 kV resistance or reactance grounding is used. But for low voltages less than 600V and high voltages above 33 kV solid or effective grounding is used. Effective grounding limits the voltages of healthy phases to line-to-neutral values in the events of ground faults and also eliminates the arcing grounds. The effective grounding causes the ground fault currents of very high magnitudes flow through the machine. But modern day protection systems are very sensitive and fast operating so that faults are cleared in very short time

Self-Check No. 5.2.3-4

1. How is the training process of coaches and trainers different?

Answer Key No. 5.2.3-4

1. The differences between the training process between the coach and the trainer are as follows:

- **Coach:**

8. Actively listens to determine the need.
9. Breaks the role down into skills and tasks.
10. Observes what novice already knows.
11. Decides what skills are needed to communicate more effectively.
12. Demonstrates or describes the task by:
 - questioning, giving advice
 - giving an example
 - talking over the procedure
 - Setting a new problem.
13. Observes/reflects.
14. Demonstrates/describes further.

- **Novice/trainers:**

5. Makes initial attempt at task.
6. Demonstrates or describes the task by:
 - Observes/reflects.
 - Listens/reflects.
7. Applies model/description.
8. Change's approach.

Information Sheet No. 5.2.3-5: Lighting Circuits

Household electrical systems consist of a number of separate circuits. Some supply power socket outlets, other supply the fixed lighting, and there are separate circuits for individual high-power appliances such as cookers and air-conditioners. Each circuit, start at the consumer unit, and each has its own MCB or fuse and sized accordingly.

1. Final Circuits

Electrical apparatus is connected by cables to the electricity supply and to the associated protective and controlling devices (usually circuit breakers and switches). This arrangement of cables is known as a circuit. Such circuits connected to current-using equipment to the consumer unit or distribution board, are called final circuits.

Final circuits can be divided into the following types, all of which will need different treatment when planning the size of conductors and the rating of the overcurrent devices:

- Final circuit feeding lighting outlets
- Final circuit feeding fluorescent or other types of discharge lighting
- Final circuit feeding 13 A switched socket outlets to SS 145
- Final circuit feeding fixed equipment
- Final circuit feeding sockets to IEC 609-2
- Final circuit feeding cookers
- Final circuit feeding motors

LIGHTING CIRCUITS

All lighting circuits are primarily meant for on/off control. The current flow out from the consumer unit (CU) along the live (brown) cable, and back along the neutral (blue) cable. In between, it is intercepted by a switch which breaks the flow of current.

Understanding how house lighting circuits work makes it easier to track down faults and is essential if you plan to alter or extend your lighting in the future.

In domestic installations, it is **not a good practice** for a lighting circuit to feed a total load **exceeding 6 A**. This means up to 10 lights, assuming each rated at 100 W, can be connected to one lighting final circuit.

In normal installations, good planning usually limits the number of lights on each circuit to about 10, with more than one lighting circuit to each house. This ensures that the whole of a building is unlikely to be plunged into darkness by the operation of the MCB.

The simplest lighting circuit is one lamp controlled by one switch and is known as one-way circuit (Fig 2-1).

One-Way Switch Circuit

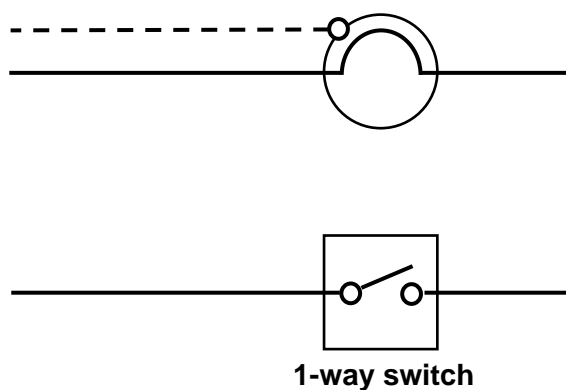


Fig 2-1 One-Way Switch Controls One Lamp

Where additional lighting points are required, the circuit is extended as shown in Fig 2-2. This circuit shows two lamps being controlled by one switch.

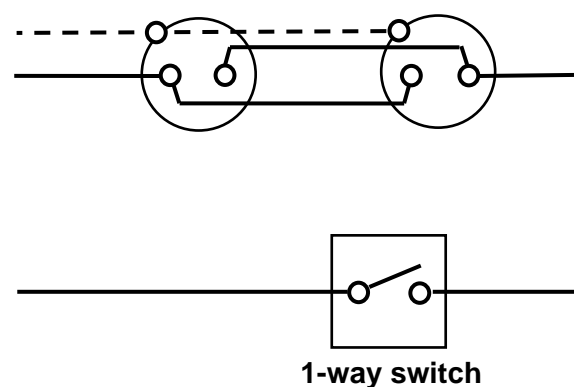


Fig 2-2 One-Way Switch Controls Two Lamps

If the lamps required to be switched on independently from each other, it would be necessary to extend the circuit as shown in Fig 2-3. This is known as the 'loop in' method of wiring.

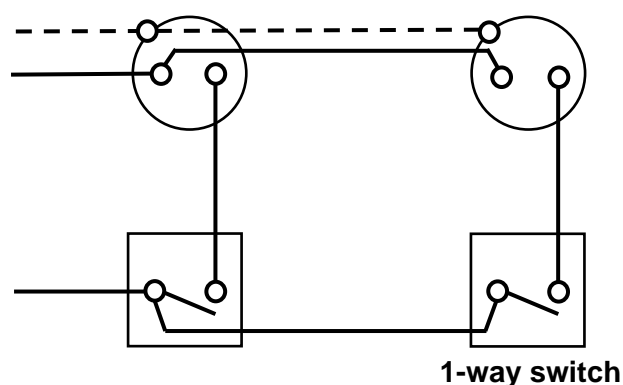
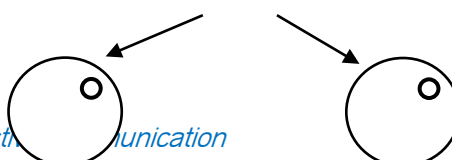


Fig 2-3 Two Lamps Controlled by Two 1-Way Switches

Another method of 'loop in' method of wiring is shown in Fig 2-4. This uses a 3-plate ceiling rose which the phase terminal must be shrouded so that it cannot be touched when the cover is removed for replacement of the flexible cord.



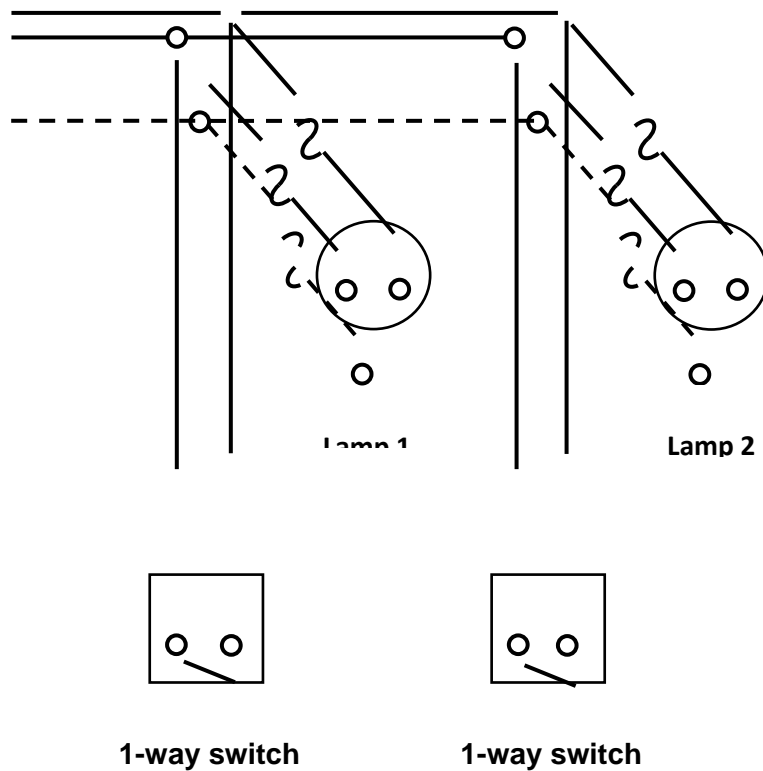


Fig 2-4 Two Lamps Controlled by Two 1-Way Switches
Using the 3-Plate Ceiling Roses

Two-Way Switch Circuit

For independent control from two positions, for example on a staircase, two-way switches are required as shown in Fig 2-5. These switches have 3 terminals, one of which is called the common (C); the other two are called the strappers and are usually marked L1 and L2 respectively.

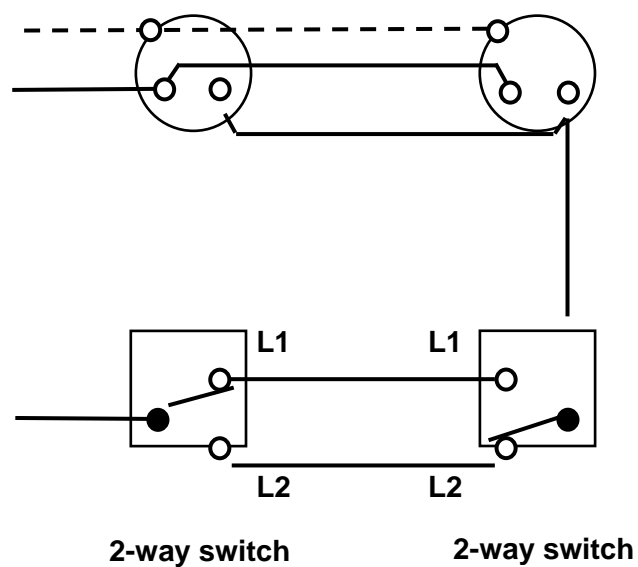
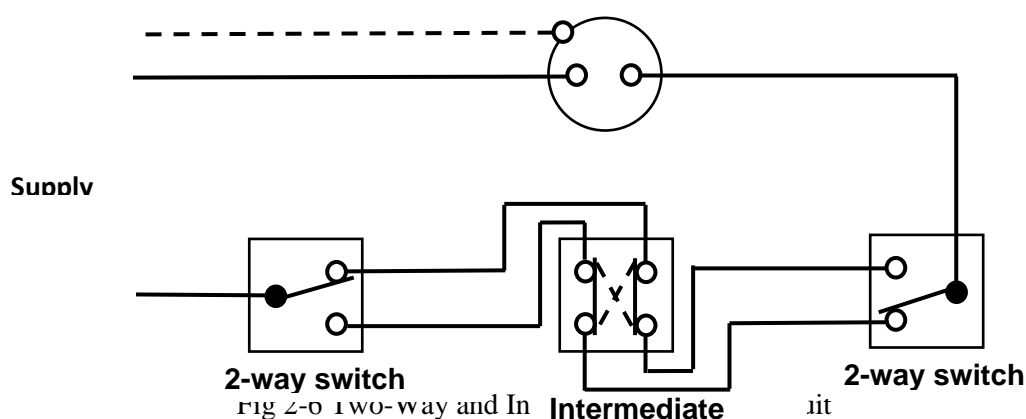


Fig 2-5 Two-Way Switch Circuit

Two-Way and Intermediate Switch Circuit

If it is desired to have control from three or more positions, intermediate type switches are necessary as well as the two 2-way switches. Intermediate switches have 4 terminals and although the switch action of different makes of switch end up with the same results, the connections vary. So it is advisable to check the switch action before connecting up. The circuit is wired as shown in Fig 2-6.



CONVERSION OF 1-WAY CIRCUIT INTO A 2-WAY switch

On occasion, an electrician is called upon to make alteration to existing circuits. One of the popular requests is to make a one-way circuit into a two-way. The conversion can be carried out quite simply by running three cables from the existing switch position into a new position. The connections are made as shown in Fig 2-7.

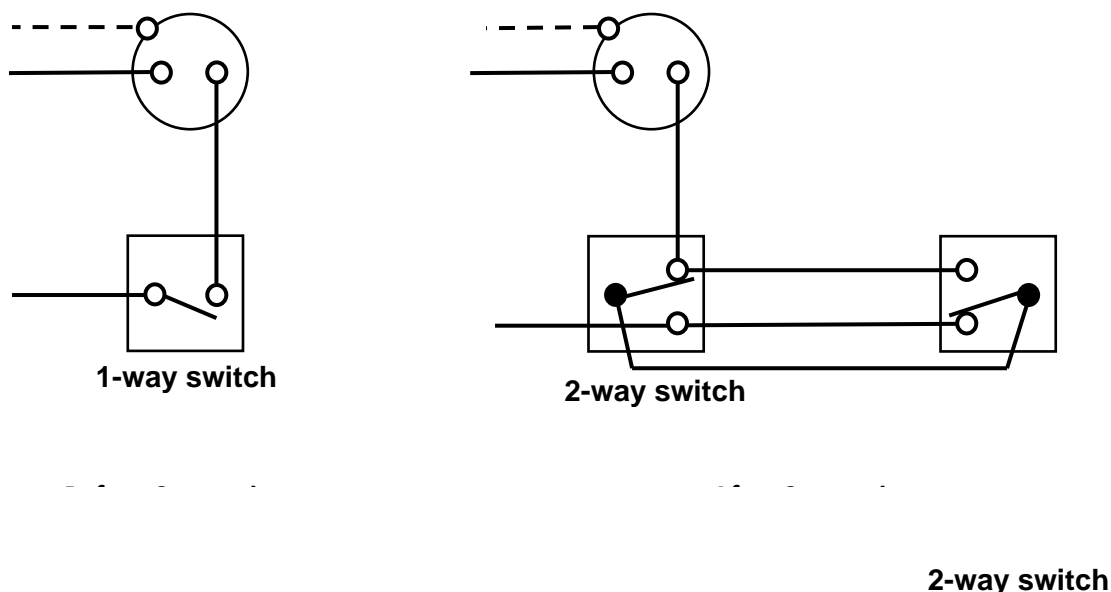


Fig 2-7 Conversion of a 1-Way Switch Circuit into a 2-Way Switch Circuit

Self-Check No. 5.2.3-5

1. How is the training process of coaches and trainers different?

Answer Key No. 5.2.3-5

1. The differences between the training process between the coach and the trainer are as follows:

- **Coach:**

15. Actively listens to determine the need.
16. Breaks the role down into skills and tasks.
17. Observes what novice already knows.
18. Decides what skills are needed to communicate more effectively.
19. Demonstrates or describes the task by:
 - questioning, giving advice
 - giving an example
 - talking over the procedure
 - Setting a new problem.
20. Observes/reflects.
21. Demonstrates/describes further.

- **Novice/trainers:**

9. Makes initial attempt at task.
10. Demonstrates or describes the task by:
 - Observes/reflects.
 - Listens/reflects.
11. Applies model/description.
12. Change's approach.

Information Sheet No. 5.2.3-6: Power Circuits

1. Power Circuit

Power circuits supply current to sockets into which you plug your electrical appliances and lamps. Some appliances in more or less constant use (i.e. washing machines, refrigerators) may not plug in, but instead connect directly to the power circuit. There are also special circuit for individual appliances which use a lot of electricity, such as cookers and water heaters.

Like lighting circuits, the power circuits start at the consumer unit, and each has its own MCB or fuse.

The fuse in the 13 A plug protects the flexible cord and the appliance, so the power circuit MCB or fuse now protects only the circuit cables and the socket outlets.

RECOMMENDED ARRANGEMENTS OF DOMESTIC CIRCUITS USING SOCKET-OUTLETS

The standard circuit arrangements, other than lighting final circuits, are:

- Final circuits using socket outlets complying with SS 145.
- Final circuits using socket outlets complying with BS 546.
- Final radial circuits using socket outlets complying with IEC 309-2 or BS 4343.
- Cooker final circuits in household premises.

Consideration should be given to the provision of a separate circuit in a kitchen.

A. FINAL CIRCUITS USING SOCKET OUTLETS COMPLYING WITH SS 145

Final circuit using socket outlets complying with SS 145 consists of:

- (i) Radial final circuit using 13A switched socket outlets
- (ii) Ring final circuit using 13A switched socket outlets

(i) RADIAL FINAL CIRCUIT

Radial circuit wiring consists of a cable run from consumer unit to a number of socket outlets looped-in (ie. connected in-parallel) on one circuit. (Fig 3-1)

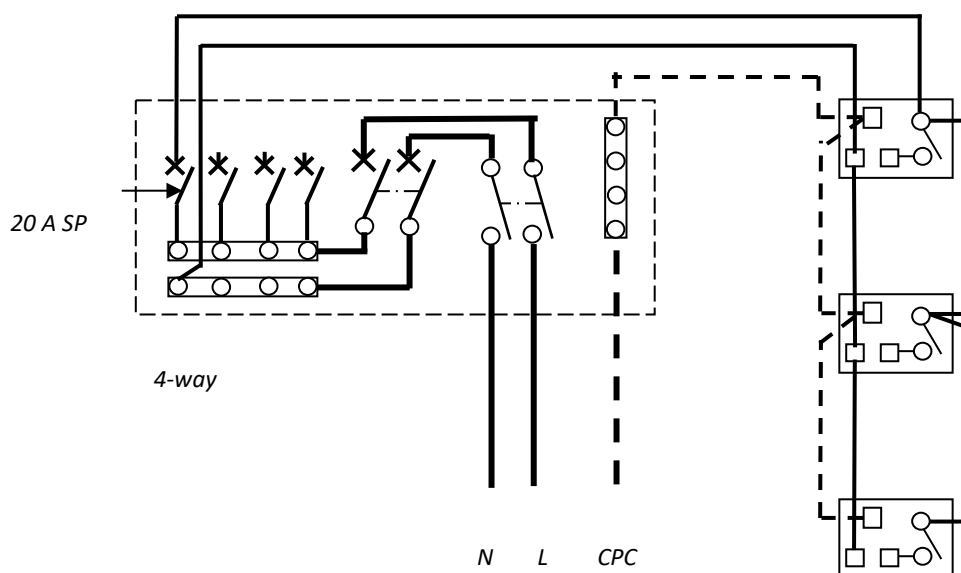


Fig 3-1 Wiring Diagram of a Radial Final Circuit Using 13A SSOs

General Requirements for Radial Final Circuits

- a. 20 A fuse or MCB protection with 2.5 mm² PVC or 1.5 mm² MI cables feeding a floor area of not more than 50 m². If the circuit feeds a kitchen or utility room, it must be

remembered that high current using equipment such as a washing machine or a tumbler dryer leaves little capacity for the rest of the sockets. Consideration should be given to the provision of a separate circuit.

- b. 32 A fuse or MCB feeding through 4 mm² PVC or 2.5 mm² MI cables to supply a floor area no greater than 75 m².
- c. Permanently connected equipment and an unlimited number of socket outlets, inclusive of spurs if any, can be fed.
- d. The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device (OCD).
- e. Guidelines on the rating of protective device; type and minimum size of conductor; and maximum floor area to be served are given in Fig 3-2.

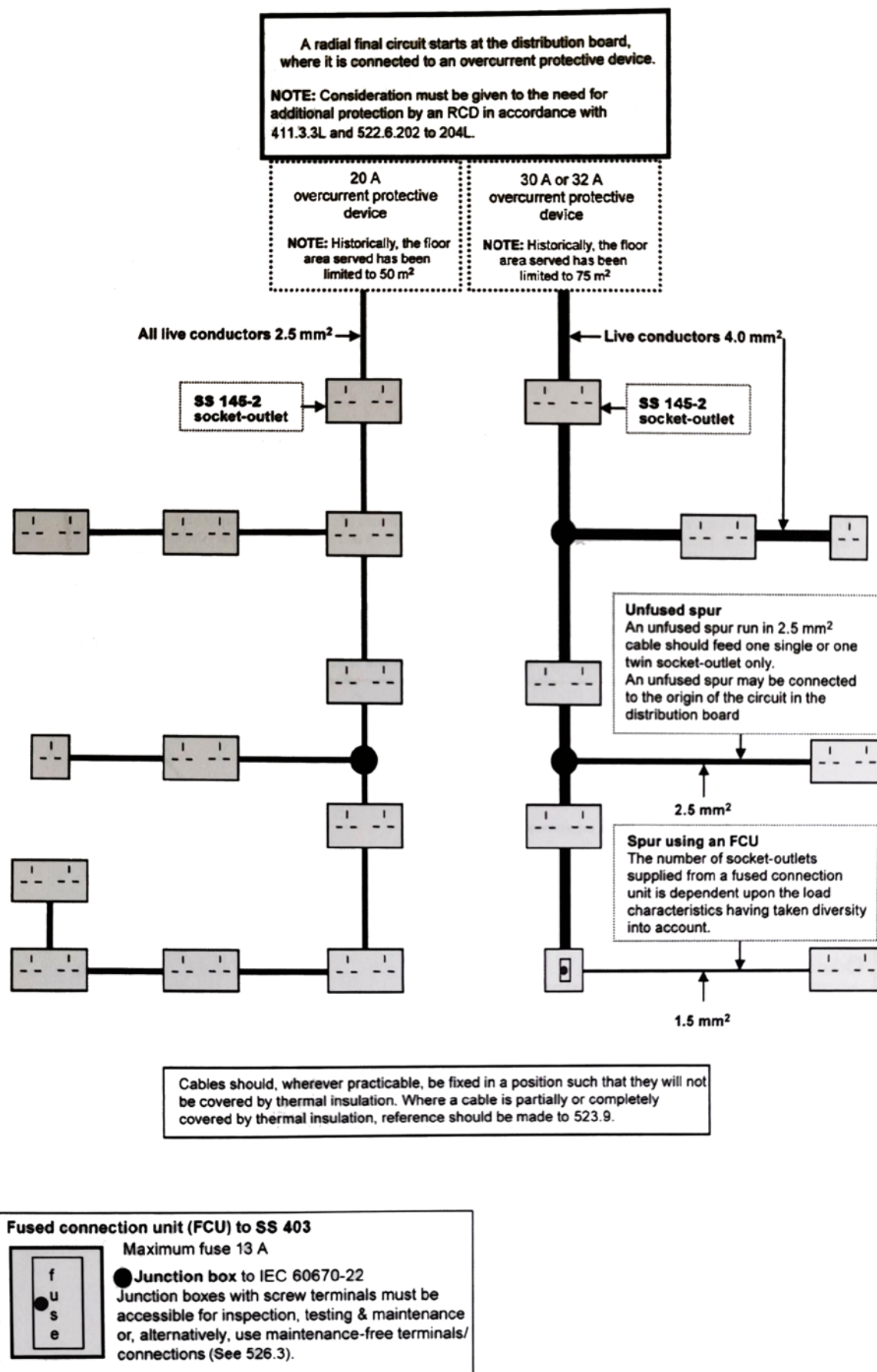


Fig 3-2 Radial Final Circuit arrangements for 13A Switched Socket Outlets

(ii) RING FINAL CIRCUIT

The cable in a ring circuit wiring runs from the consumer unit to each socket on the circuit and then back to the consumer unit again as shown in Fig 3-3.

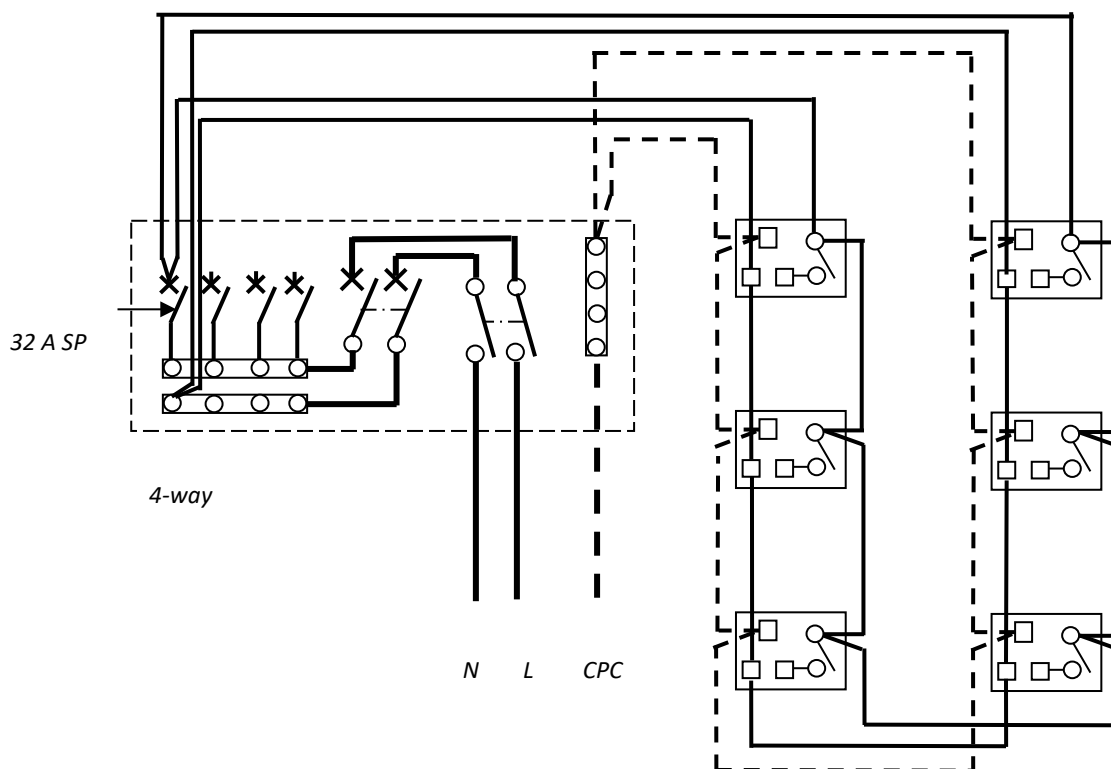


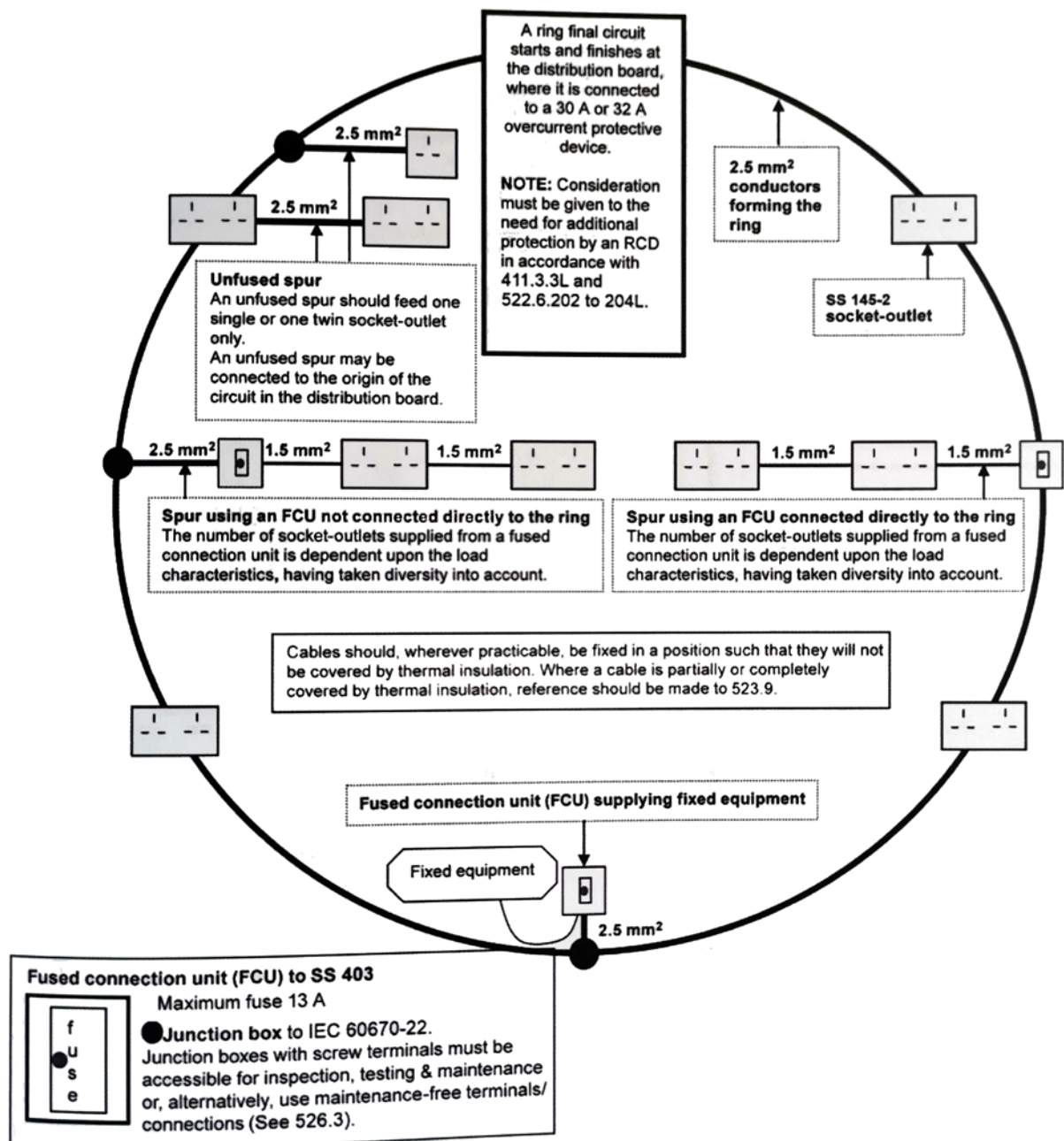
Fig 3-3 Wiring Diagram of a Ring Final Circuit

General Requirements for Ring Final Circuits

- The floor area served by each ring must not exceed 100 m² for domestic situations.
- Where ring circuits are used in commerce or industry, the diversity must be assessed to ensure that the maximum demand will not exceed the rating of the protective device.
- Consideration should be given to the provision of a separate ring (or radial) circuit in a kitchen.
- Where there is more than one ring circuit in the same building, the installed sockets should be shared approximately evenly between them.
- Cable sizes for ring circuits are 2.5mm² PVC or 1.5mm² mineral insulated (MI) cables.
- Permanently connected equipment and an unlimited number of socket outlets, inclusive of spurs if any, can be fed.
- The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device (OCD).
- Guidelines on the rating of OCD; type and minimum conductor size and maximum floor area served are given in Fig 3-4.

Note:

Each socket outlet of a twin or multiple sockets is regarded as one socket outlet.



Maximum floor area served 100 m².

Fig 3-4 Ring Final Circuit arrangements

SPURS

Spur is a branch circuit cable connected to a ring or radial final circuit. This is a result where most homes still do not have enough socket outlets to cope with the demands of modern living.

One answer is to use adaptors or extension leads, but these can be dangerous as well as inconvenient, and they are certainly no good for powering fixed appliances such as refrigerators.

The only satisfactory solution is to install extra sockets or fused connection units, exactly where you need them, so that flexible cords to appliances are kept short and outlets cannot be overload.

NON-FUSED SPURS

A spur is a branch cable connected to a 13 A circuit and **cannot** be used in kitchens.

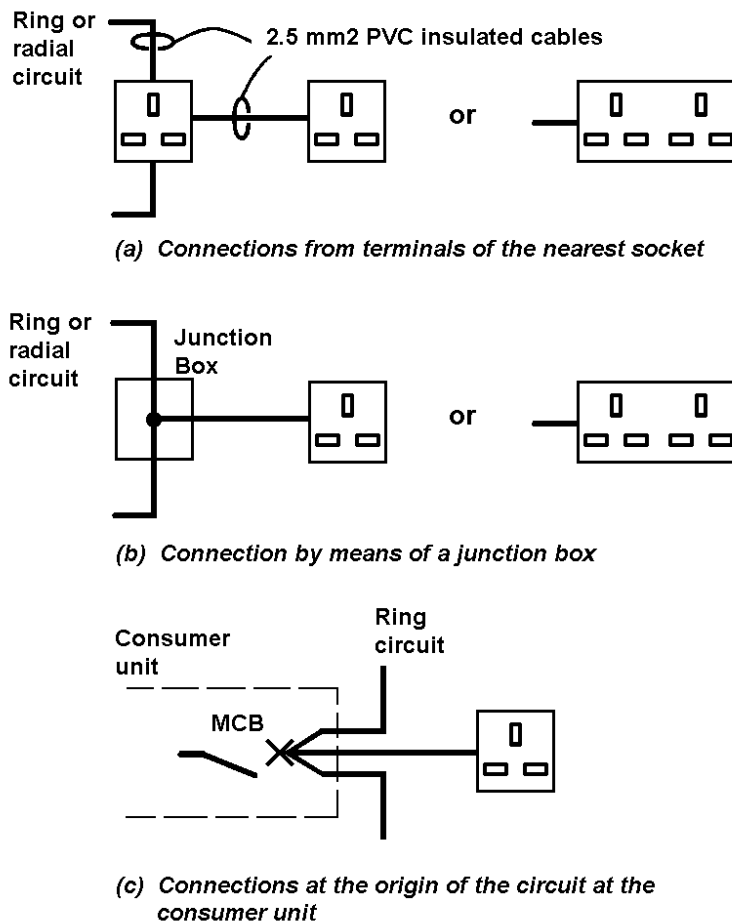


Fig 3-5 Non-Fused Spurs

The total number of non-fused spurs which may be connected to a 13A circuit must not exceed the total number of socket or fixed appliances connected direct in the ring.

Each non-fused spur may feed not more than one single or one twin socket outlet or one fixed appliance.

Non-fused spurs may be looped from the terminals of the nearest socket, or by means of a junction box in the circuit. For ring circuit, they can be connected at the origin of circuit at the consumer unit.

The size of the cable feeding non-fused spurs must be the same size as the circuit cable.

FUSED SPURS

The cable forming a fused spur must be connected to the ring circuit by means of a fused connection unit.

The rating of the fuse in this unit shall not exceed the rating of the cable forming the spur, and must not exceed 13A.

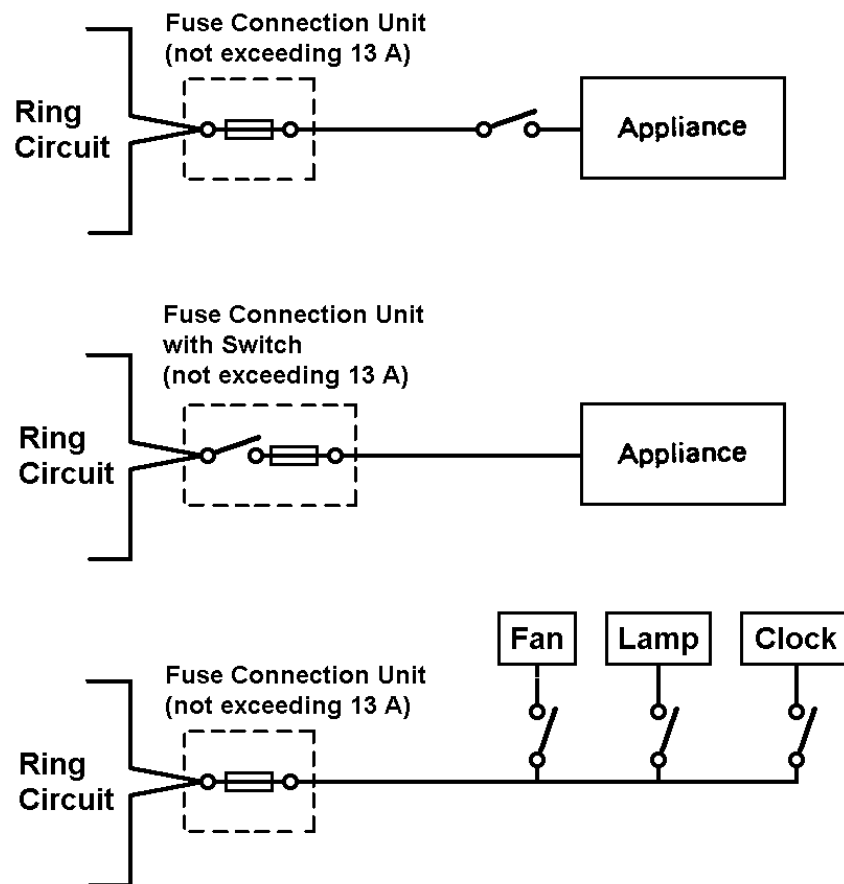


Fig 3-6 Fused Spurs

There is no limit to the number of fused spurs that may be connected to a ring.

The minimum size of cables forming a fused spur shall be 1.5mm² PVC with copper conductors, or 1.0mm² mineral insulated cables with copper conductors.

Fixed appliances permanently connected to 13A circuit (not connected through a plug and socket), must be protected by a fuse not exceeding 13A and a double-pole switch or a fused connection unit which must be separate from the appliances and in an accessible position.

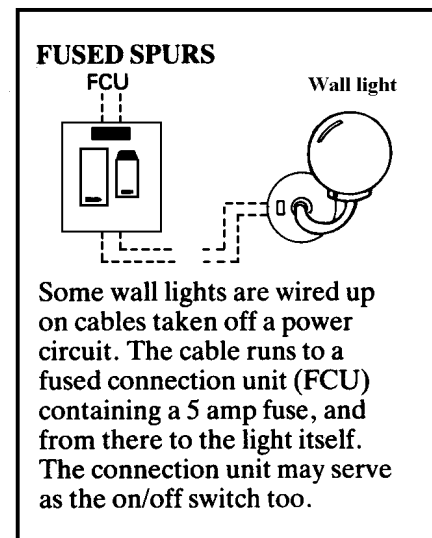


Fig 3-7 Example of a Fused Spur

PERMANENTLY CONNECTED EQUIPMENT

Permanently connected equipment or fixed loads should be locally protected by a fuse not exceeding 13A and be controlled by a switch or be protected by a circuit breaker not exceeding 16A.

Cable size for spur is dependent on the magnitude of the connected load.

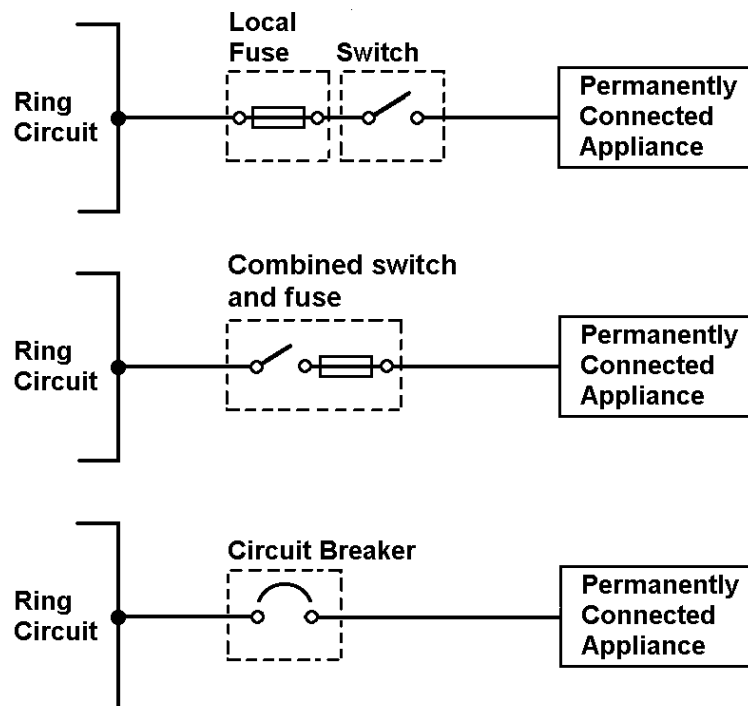


Fig 3-8 Permanently Connected Equipment

B. FINAL RADIAL CIRCUITS USING 16A SOCKET OUTLETS COMPLYING WITH IEC 309-2 OR BS 4343

There is no reason at all to prevent the installation of 13A socket outlets in industrial situations. Indeed, where light industries, such as electronics manufacture, are concerned, these sockets are most suitable.

Plugs and sockets to IEC 309-2 or BS 4343 (Fig 3-9) are available in 16A, 32A, 63A and 125A. They are for use in industrial circuits and construction site installations.

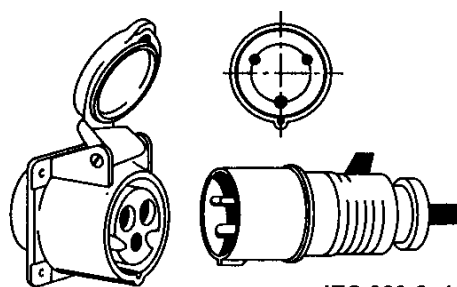
Fig 3-9 Industrial Plug and Socket to IEC 309-2 or BS 4343

Voltage Discrimination for IEC 309-2 Socket Outlets

This is achieved in two ways:

- By colour codes
- By the positioning of the earth contact in relation to a keyway.

The range of sockets, cable couplers are available for single a voltage between at a rated current of up



accessories consists of plugs, and appliance inlets. They and three-phase supplies with phases not exceeding 750V to 125A.

IEC 309-2 16 A / 32 A socket interiors

COLOUR	VOLTAGE
White	50V (12h) through isolating transformer
Yellow	110V – 130V (4h)
Blue	220V – 240V (6h)
Red	380V – 415V (6hr)

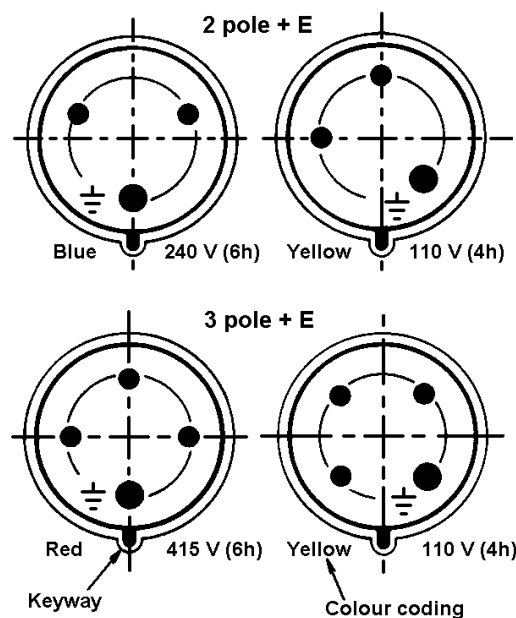


Fig 3-10 Colour Coding and Voltage Discrimination of IEC 309-2 Sockets

COOKER FINAL CIRCUITS IN HOUSEHOLD PREMISES

A cooker is regarded as a piece of fixed equipment unless it is a small table-mounted type fed from a plug by a flexible cord.

A cooking appliance circuit must include a control switch or cooker control unit which may incorporate a socket outlet.

The rating of the circuit should be properly calculated and determined by assessment of the current demand with allowances for diversity from Guidance notes or from the designer of the installation.

A circuit of rating exceeding 15 A but not exceeding 50 A may supply 2 or more cooking appliances where these are installed in one room.

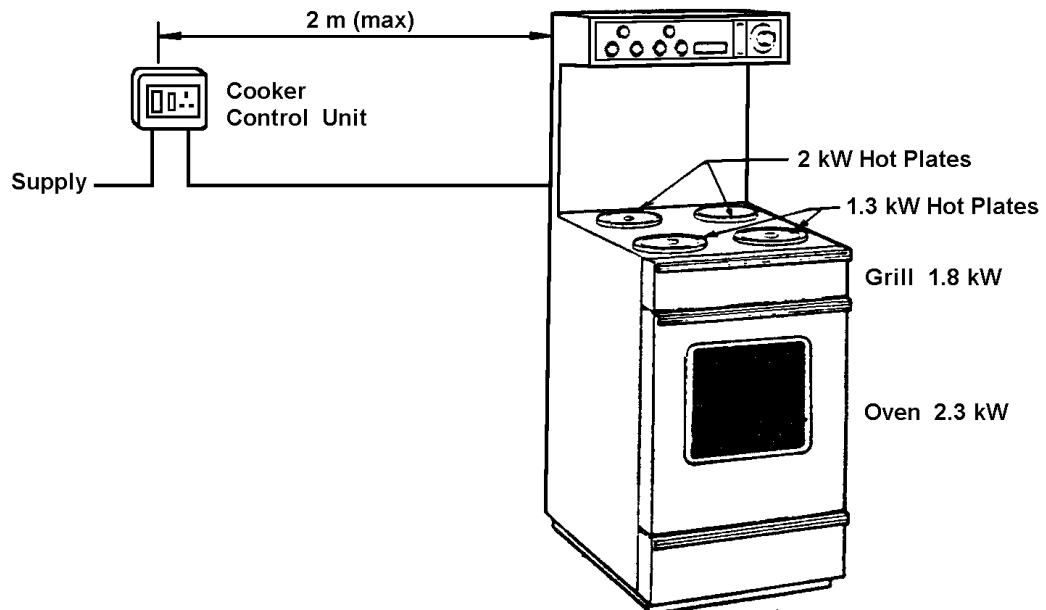


Fig 3-11 Electric Cooker Circuit

Example 1

A 230 V, 50 Hz domestic electric cooker has the following connected loads:

- (a) 2 nos 2.0 kW hot-plates;
- (b) 2 nos 1.3 kW hot-plates;
- (c) 1 no 1.8 kW grill; and
- (d) 1 no 2.3 kW oven

Determine the maximum demand of this cooker circuit if it is connected with a cooker control unit incorporating a 13A switched socket outlet.

Solution:

$$\begin{aligned}\text{Total cooker load control unit} &= (2 \times 2) + (2 \times 1.3) + 1.8 + 2.3 \\ &= 10.7 \text{ kW}\end{aligned}$$

$$\text{Total current} = \quad = \quad = 46.52 \text{ A}$$

The demand is made up of:

$$\begin{aligned}\text{First 10 A} &= 10.0 \text{ A} \\ + 30 \% \text{ of remainder} &= \quad = 10.96 \text{ A} \\ + \text{allowance for socket outlet} &= 5.0 \text{ A} \\ \text{Total} &= 25.96 \text{ A}\end{aligned}$$

A 30 A protective device is selected for use.

Self-Check No. 5.2.3-6

2. How is the training process of coaches and trainers different?

Answer Key No. 5.2.3-6

2. The differences between the training process between the coach and the trainer are as follows:

- **Coach:**

- 22. Actively listens to determine the need.
- 23. Breaks the role down into skills and tasks.
- 24. Observes what novice already knows.
- 25. Decides what skills are needed to communicate more effectively.
- 26. Demonstrates or describes the task by:
 - questioning, giving advice
 - giving an example
 - talking over the procedure
 - Setting a new problem.
- 27. Observes/reflects.
- 28. Demonstrates/describes further.

- **Novice/trainers:**

- 13. Makes initial attempt at task.
- 14. Demonstrates or describes the task by:
 - Observes/reflects.
 - Listens/reflects.
- 15. Applies model/description.
- 16. Change's approach.