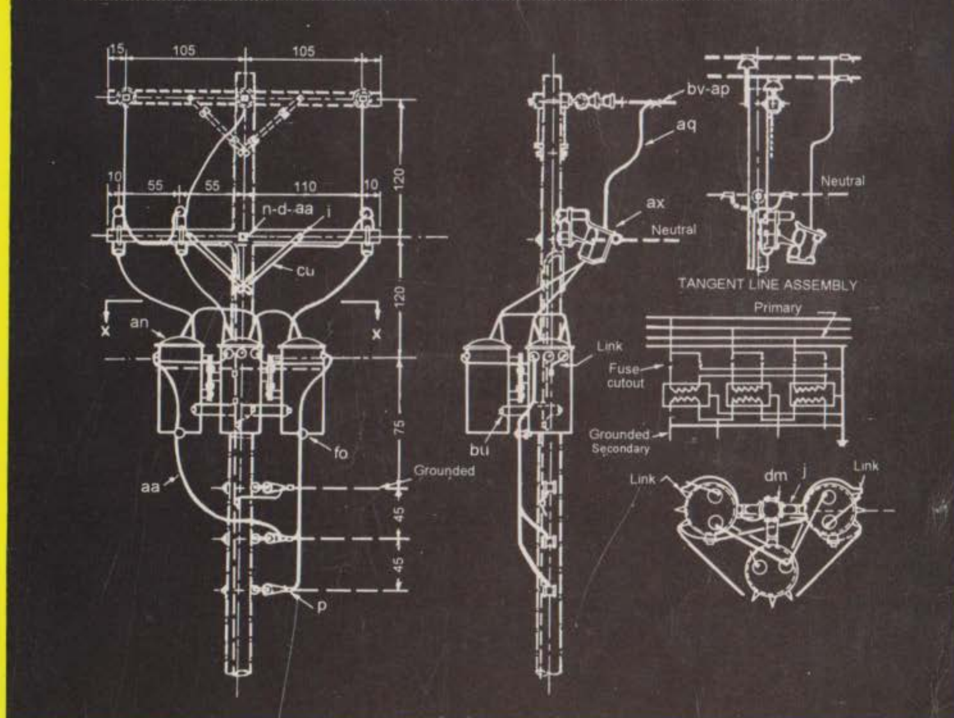
ELECTRICAL layout and estimate

Second Edition



Max B. FAJARDO, Jr.
and Leo R. FAJARDO

ELECTRICAL
LAYOUT AND ESTIMATE

Second Edition

by

Max B. FAJARDO Jr.
Leo R. FAJARDO

Max B. Fajardo Jr. - BS Arch. NU, Member UAP, MPA, PM-III, Regional Director DPWH, Vice Pres. Camarines Sur III Electric Co-operative Inc. Dean College of Architecture and Engineering University of North Eastern Philippines. Author of: Simplified Construction Estimate; Simplified Methods on Building Construction; Plumbing Design and Estimate; Planning and Designers Handbook; Elements of Roads and Highways; Project Construction Management; Specifications and Contract; Electrical Layout and Estimate and Simplified Mathematics of Investment.

Leo R. Fajardo - BSEE; NU Manila; Member IIEE, System Loss Analyst, Camarines Sur III Electric Cooperative Inc. Contractor; Manager ELECOL Engineering Equipment Supply and Service.

FOREWORD

Electricity is a necessity in human's daily activity. From the simplest household to the more elaborate dwellings, complex offices and even to the most sophisticated buildings, electricity is a basic need for human comfort.

The Electrical Layout and Estimate is the fourth volume of the author about construction. It was prepared for engineering students, master electricians, linemen and those interested in the art of electrical circuitry and construction of the distribution lines. The book contains information of various wiring materials, receptacles and accessories with tables of technical data for ready reference. Indeed, not only the basic underlying principles governing electrical layout were stressed but also the generalized concept of good practice in circuitry was incorporated.

Basically, the electric circuitry in a house or building comprises the branch circuit, the feeder, and the main. The National Electrical Code provides that the branch circuit that supplies current to lighting and convenience outlets shall be of ample size and rating to carry the expected load. It shall at all times be protected with an over current protection called fuse or circuit breaker. Thus, the basic approach to protect the circuitry is to know the load, the size of the wire and the rating of the fuse or circuit breaker. That is where this book will come in to assist the reader.

Presented here are problems of circuitry from the small to multiple dwellings and commercial load using electric motors. The fundamental process of finding the size of the branch circuit, the feeder and the main including the size of raceway was thoroughly presented in detail. The rating of the over current protective device was given special emphasis in the presentation. Likewise, the basic fundamental of Illumination was also included because the author believed that lighting is no less important than the circuitry itself. For what use is the circuitry when lighting was not given importance. It could be well appreciated only through the performance and effectiveness of illumination.

Another important feature of the book is the construction of the distribution line used by the 120 Electric Cooperatives lighting the entire country from the heart of the city, to the remotest household in the barangay. Presented are the various parts of the distribution line construction showing the different accessories used to serve as visual aid for familiarization of the materials specified, and itemized in a standard alphabetical coding.

The second edition is the outcome of numerous suggestions prompting improvement of the first edition. Generally, no effort was spared to come out with a better edition. For this second edition, the author wishes to express his grateful acknowledgment for the valuable help of Mr. Gil Mananzala who drafted most of the figures presented and to those persons who have contributed materially and morally in making possible the publication of this book.

MBF

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CONSTRUCTION OF THE DISTRIBUTION LINE

CHAPTER 1

INTRODUCTION TO ELECTRICITY

1-1 Electricity

Electricity is a form of energy generated by friction, induction or chemical change, having magnetic, chemical and radiant effect. In short, electricity is ***Electrons in motion.***

Electricity is one of the most useful discovery of man which paved the way to the numerous inventions from the simple tools to the most sophisticated gadgets making what originally seemed to be impossible become a reality.

Contrary to some belief, electricity is not new. It has been here with us ever since and, its existence is as old as the universe which was discovered accidentally, by the ancient Greeks sometime in 600 B.C. However, the title of ***"Father of Electricity"*** was accredited to William Gilbert, an English Physicist after publishing his studies on the ***"Electric Attraction" and "The Electric Force."***

Electricity is a property of the basic particles of matter which like an atom, consists of:

a) Electron
b) Proton
c) Neutron

The **Electron** is the negatively charged particle of an Atom sometimes referred to as the ***negative charge of electricity***. On the other hand, the **Proton** is the positively charged particle of an Atom which is sometimes referred to as the positive charge of electricity that weighs about 1850 times as much as the Electron.

The **Neutron** is that particle of an Atom which is not electrically charged and weighs slightly more than the proton.

Theory:

1. That, all matters are made up of molecules.
2. That, molecules are made up of atoms.
3. That, atom contains neutrons, electrons and protons.
4. That, neutron is neutral. It is neither positive or negatively charged.
5. That, the electron of an atom of any substance could be transformed into another atom.

1-2 Definition of Terms

Ion is the term applied to an atom or molecule which is not electrically balanced. It is an atom or molecule that is electrically charged. It simply mean there is a loss or gain of one or more electrons.

Ions occur when the electrons in the atom is loosened through friction by another atom. Therefore, the presence of electrons in any organic or inorganic substance is a fact, that electricity is always present.

Volt or Voltage is the *electrical pressure* that causes the electrons to move through a conductor (wire). In other words, *voltage* is the *electromotive force.*

Comparatively, to have 12 volts is like having 12 pounds of water pressure inside the pipe of a water system. Thus, the higher the voltage, the more electricity will be forced to flow.

Volt was named after Alessandro Volta, an Italian scientist who discovered that electrons flow when two different metals are connected by a wire and then dipped into a liquid that conduct or carry electrons.

Ampere - is the standard unit used in ***measuring the strength of an electric current***, named after Andre M. Ampere.

It is the amount of current flow, sent by one volt through the resistance of one Ohm. When there is too much flow of electricity in a small conductor or wire, heat is produced which eventually may blow-off the protective devise called fuse, or burn the wire insulator and create fire.

Watt - is the ***rate or measure of power used or consumed***. It represents the equivalent heat volts and ampere consumed by lights, appliances or motors. A term commonly labeled on light bulbs or appliances, giving us an idea of what kind of circuit would be installed. The term is named after **James Watt** a Scottish inventor.

Circuit refers to the ***wire installations*** that supply current to light and convenient outlets.

Resistance - is the friction or opposition to the flow of current by the wires and transformers, analogous to plumbing installation, where the flow of water is subjected to resistance caused by friction between the water and the inside wall of the pipe, and the various form of turns and fittings. For direct current (DC electricity), the term ***Resistance*** is used for friction, and ***Impedance*** for alternating current (AC electricity).

Factors that Influences Conductor Resistance.

1. **Composition of the Conductor**. This refers to a conductor having free electrons that has low resistance.
2. **Length of Wire**. The longer the wire, the higher is the resistance.
3. **Cross Sectional Area of Wire**. The bigger the cross sectional area of wire, the lower its resistance.
4. **Temperature**. Metal offers high resistance to high temperature (heat).

1-3 Electric Current

By definition, ***Electric Current is the flow or rate of flow of electric force in a conductor***. A current will only flow if a circuit is formed comprising a complete loop and contains all the following required components.

1. Source of voltage
2. A closed loop of wiring
3. An electric load
4. A means of opening and closing the circuit

Electric Current is Classified as:

1. Direct Current (DC)
2. Alternating Current (AC)

Direct Current. The DC electricity, flows in one direction. The flow is said to be from negative to positive. The normal source of a DC electricity, is the dry cell or storage battery.

Alternating Current. The AC electricity constantly reverses its direction of flow. It is generated by machine called generator. This type of current is universally accepted because of its unlimited number of applications with the following advantages.

1. It is easily produced.
2. It is cheaper to maintain.
3. It could be transformed into higher voltage.
4. It could be distribution to far distance with low voltage drop.
5. It is more efficient compared with the direct current

Once a big controversy ensued between the proponents of the DC electricity led by Thomas Edison and the advocates of the AC electricity led by George Westinghouse. According to Thomas Edison, *"The AC electricity is dangerous, because it involves high voltage transmission line."*

The AC advocates on the other hand, countered that:

"The AC alternation is just like a handsaw which cuts on the upstroke and the down stroke. The high voltage in the transmission line could be reduced to the desired voltage as it passes the distribution line."

Alternating Current or Voltage is a current or voltage that changes in strength according to a sine curve. An alternating current AC reverses its polarity on each alternation and reverses its direction of flow for each alternation. The AC current goes through ***one positive loop*** and ***one negative loop*** to form ***one complete cycle that is continuously repeated.***

The number of times this cycle of plus and minus loop occur per second is called the ***Frequency of alternating current*** AC expressed in cycles per second normally referred to as **Hertz** (hz) named after H.R. Hertz. The frequency of the Direct Current DC is obviously zero Hertz. The voltage is constant and never changes in polarity.

A circuit operating at increased voltage, has a lower power loss, power voltage drop, and economically constructed for using smaller copper wires. On transmission and distribution line, power loss is the most important problem to resolved. This is the main reason why Alternating Current AC gained more favor and acceptance during the middle part of the 19th century. In the USA, an ordinary house current is described as 120 volts 60 hertz.

Resistance

In a hydraulic system, the flow of fluid is **impeded** or **resisted** by friction between the wall of the pipe, fittings and other turns and offsets. In the same manner, the flow of current in a circuit (electrical wiring installation) is also impeded or resisted by the wire, transformer and other devices. This is called **Impedance,** the electrical term for **Friction** in AC electricity. In a direct current DC circuit, this Impedance is called **Resistance.** However, both are expressed in the unit of measure called **Ohms.**

Just as in a hydraulic system, the amount of water flowing, is proportional with the pressure and inversely proportional with the friction. Similarly, in electric circuit, the current is proportional with the voltage and inversely proportional with the circuit resistance or load. Thus:

1. **The Higher the Voltage, the Larger the Current.**
2. **The Higher the Resistance, the Lower the Current.**

Their relationship may be expressed by the following equation known as the **Ohms Law.**

$$I = \frac{V}{R}$$

Where :

I = current
V = voltage
R = resistance for DC electricity

For AC electricity, the **Ohms Law** is expressed as:

$$I = \frac{V}{Z}$$

Where:

I = current
V = voltage
Z = impedance

The unit of current is the ampere (amp. or a.)

1-4 Comparison of AC and DC Electricity

Under the principles of DC electricity. *Power is the product of voltage and Current.*

Watts = Volts x Amperes

Under the principle of **AC electricity**, the product of volts and amperes is equal to the quantity called volt-ampere (v.a.) which is not the same as watts. Thus;

Volt Amperes = Volts x Amperes

And to convert volt-ampere to watts or power, a **power factor (pf)** is introduced. And to get power in an AC circuit, we have the following formula:

Watts = Volts x Amperes x power factor

W = V x I x pf

ILLUSTRATION 1-1

A 12 amperes electric fan and blower with a power factor of 0.85 was connected to a 240 volts convenient outlet (c.o). Calculate the current and power in the circuit.

SOLUTION

Power (watts) = Volts x Amperes x power factor

W = 240 v. x 12 amp. x 0.85

W = 2,448 watts

ILLUSTRATION 1-2

An electric motor has a trade mark label of 2 horse power, 240 volts, 15 amperes. Calculate the motor power factor.

SOLUTION

1. Assume motor efficiency say 85%

2. 1- horse power is 746 watts, convert HP to watts.

$$746 \times 2 = 1{,}492 \text{ watts}$$

3. Efficiency = $\frac{\text{Output}}{\text{Input}}$

$$\text{Input} = \frac{1{,}492}{0.85}$$

$$= 1{,}755 \text{ watts}$$

4. For AC current

Power = Volts x Amperes x power factor

$$\textbf{power factor} = \frac{\textbf{Power}}{\textbf{Volts x Amperes}}$$

$$\textbf{pf} = \frac{1{,}755}{240 \text{ v.} \times 15 \text{ amp.}}$$

$$\textbf{pf} = 0.4875$$

Volt-Amperes = 240 v. x 25

Volt-Amperes = 3,600 v.a.

Take note the difference between volt-amperes and watts.

1-5 The Ohms Law

In 1926, George Simon Ohm, a German scientist, discovered the relationship between the **Current, Voltage** and **Resistance** now referred to as the **Ohms Law** which states that:

"The higher the voltage, the larger the current, and the higher the resistance, the lower the current."

The relationship between the *current, voltage* and *resistance* is presented in the following equations known as the **Ohms Law.**

$$I = \frac{V}{R}$$

Where:

I = Current flow (amperes)
V = Electromotive force (volts)
R = Resistance (Ohms)

To Find the:

* Voltage electrical pressure (volts). .V = **IR**

* Current (Ampere). . . . . $I = \frac{V}{R}$

* Resistance (ohms). . . . . $R = \frac{V}{I}$

ILLUSTRATION 1-3

Determine the current flow in a circuit having a resistance of 5 Ohms on a 120 volts and 240 volts current supply. (*Circuit refers to the electrical wiring installation*)

SOLUTION

1. For 120 volts:

$$I = \frac{V}{R} = \frac{120}{5}$$

I = 24 amperes

2. For 240 volts

$$I = \frac{V}{R} = \frac{240}{5}$$

$$I = 48 \text{ amperes}$$

Examining the Ohms Law, it will be noted that ***the current is inversely proportional to the resistance.*** Thus, ***as resistance decreases, current increases.*** It can be concluded from the foregoing illustrations that a 240 volts circuit, is better choice than using a 120 volt circuit as computed with 48 and 24 amperes respectively.

ILLUSTRATION 1-4

A circuit has a resistance of 20 Ohms and the current flows at 12 amperes. Determine the voltage.

SOLUTION

$$V = I \times R$$
$$= 12 \times 20$$
$$V = 240 \text{ volts}$$

Generally, the basic wire installation is good for 300 volts rating which is the same amount of power that can be carried with less than one half the cost of copper wire. Considering the price of copper wire that is becoming more prohibitive, the use of 240 volts was accepted worldwide except in the U.S.A. where the basic supply of current is rated at 120 volts. And to change their whole systems including all the appliances and equipment to adopt a 240 volts circuit would mean a gigantic cost which would affect the national economy. However, it might be given serious thought, considering the advantages of the 240 volts over the 120 volts circuit.

The Advantages of using 240 volts over the 120 volts current supply are:

1. Economy through the use of smaller wires.
2. Lower power loss.
3. Smaller percentage of power drop.

Comparatively, a system with higher voltage circuit is more economical than the lower voltage circuit. The inherent advantages of a higher voltage for transmission and distribution line paved the way in search for easy methods of transforming one voltage to another. This is one advantage of the AC current that could not be done with the DC current that resulted to the worldwide acceptance of alternating current (AC) and the almost total abandonment of the direct current (DC) for general utilization.

Summary of the Ohms Law Formula

$$\text{Voltage} = \text{Current} \times \text{Resistance}$$

$$V = I \times R$$

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$I = \frac{V}{R}$$

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

$$R = \frac{V}{I}$$

$$\text{Power} = \text{Voltage} \times \text{Current}$$

$$P = V \times I$$

By Further Algebraic Manipulation of the Formula

$$P = I^2 \times R \qquad I = \frac{P}{V} \qquad V = \frac{P}{I} \qquad R = \frac{P}{I^2}$$

$$P = \frac{V^2}{R} \quad I = \sqrt{\frac{P}{R}} \quad V = \sqrt{P \times R} \quad R = \frac{V^2}{P}$$

Other Ohms Law formula use the letter **E** for volts but **V** is used here for clarity.

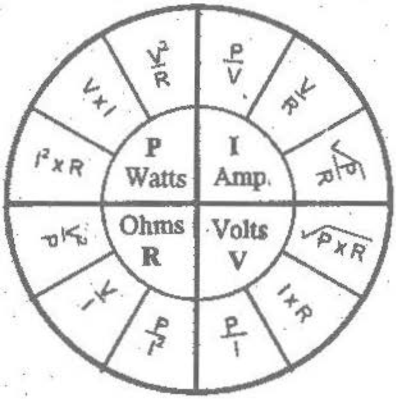


FIGURE 1-1

1-6 Series and Parallel Circuit

A circuit components can be arranged in several ways but with two fundamental types of connections, namely:

1. Series circuit
2. Parallel circuit

In a **Series Connection**, a single path exist for current flow, that is, the elements are arranged in a series one after the other with no branches. Being a single path in a series arrangement, voltage and resistance simply adds, thus:

Voltage total $V_t = V_1 + V_2 + V_3 \ldots.$

Resistance $R_t = R_1 + R_2 + R_3 \ldots.$

Example:

Two automobile headlights are connected in series to a 12 volts battery each having a resistance of 1.0 Ohm. What is the current flowing in the circuit?

Solution

$$V = 12 \text{ volts}$$

Total Resistance: $R = R_1 + R_2$

$$I = \frac{V}{R}$$

$$I = \frac{12\text{ v}}{2.0}\ ; \quad I = 6 \text{ amperes}$$

Under the series arrangement where only one path of current is supplying the light, failure of any one of the bulbs will cause a break in the circuit, cutting off the entire circuitry. Another example of a series connection is the string of Christmas lights having a single wire supplying the current. When a single bulb breaks off, the flow of current is also cut off, putting the entire series of light into total darkness. The next problem is the location of the fault that is very difficult to locate. This problem of series connections however, was addressed by the introduction of Parallel Circuit.

The Parallel Circuit

The parallel circuit is sometimes referred to as ***multiple connections*** where the loads are placed across the same voltage constituting a separate circuit. In hydraulic analogy, the connections are similar to branching pipe arrangement. **Parallel Circuit** is the standard arrangement for house wiring connections wherein the **lights** constitute ***one parallel grouping*** and the ***convenience wall outlets*** constitute ***the second parallel grouping.***

The fundamental principle under this type of circuitry is that; ***"loads in parallel are additive for current, and that each has the same voltage imposed."***

Examining further the **Ohms Law** as previously discussed, current is inversely proportional to the resistance. ***As resistance increases, current decreases.*** When current rises instantly to a very high level, the condition will constitute a ***short circuit.*** Hence, it is mandatory for all circuit to be protected by fuse or circuit breaker that automatically open and disable the line in case of a fault or short circuit.

1-7 Volt Transformation

Transformer is a simple static device consisting of a magnetic core wherein the primary and secondary windings are made. ***The voltage is directly proportional to the number of windings or turns.*** Thus, if a 120 AC will be connected to the left side containing 100 turns, 240 volts would be on the right side containing 200 turns.

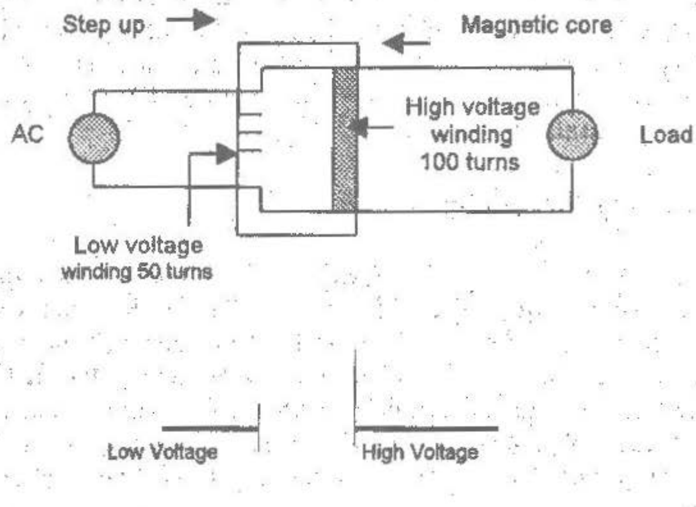


FIGURE 1-2

The **Input side** is classified as the **Primary** while the **Output side** is classified as the **Secondary**. Under this condition, the transformer is said to be 120 /240 volts step up transformer with 120 primary and 240 volt secondary.

The same transformer could be used as step down transformer by reversing the supply and the load. The 240 volts will be the primary and the 120 volt the secondary. In short, **transformers are reversible.**

1-8 Power and Energy

Power and **Energy** is too frequently interchangeably used. **Power** is the technical term for the common word work, and **Work**, is the **product of Power** and **Time** expressed in the following equation:

Energy or **Work = Power x Time**

What is Power? – Power is the rate at which energy is used or alternatively, the rate at which work is done. Since energy and power is synonymous, ***power implies continuity***. That is, ***the use of energy at particular rate over a given span of time.*** The concept of power involves time at the rate at which work is done. Thus, ***multiplying power by time gives energy.***

What is Energy? In electrical terms, energy is synonymous with **Fuel**. It is associated with work. Energy can be expressed in gallons, liters. barrels or tons of oil, coal, kilowatt hour or consumed electricity and cost of operations. In technical terms, **Energy** is expressed in units of BTU (calories), foot pound (joules) or kilowatt hour.

Under the English Unit System, the unit of power is expressed in ***horse power, BTU per hour, watt and kilowatt***. Under the Metric System or SI, it is correspondingly expressed as ***joules per second, calories per second, watts and kilowatts***. In physical terms, power is also the rate at which fuel or energy is used and expressed as liters of fuel per hour, cubic meter of gas per minute or tons of coal per day, etc.

Power in Electric Circuit

The measuring unit of electric power is the **Watt.** When multiplied by 1000, the product is called Kilowatt. Thus, **1,000 watts is One Kilowatt.** Power has several forms: an electric motor produces mechanical power that is measured in terms of horsepower. An electric heater produces heat or thermal power, and light bulb produces both heat and light that is measured in terms of candle power. Watt is the power term. It is a measure of the power consumed. The power input (in watt) to any electrical device having a resistance **R** with the current **I** is expressed in the following equations:

$$\text{Watt} = I^2 \times R$$

By Ohms law:

$$V = IR$$

Since $$W = I^2 R$$

$$W = VI$$

Where :

W is in Watts
R is in Ohms
I in Amperes
V in Volts

ILLUSTRATION 1-5

A mercury lamp having a hot resistance of 50 Ohms, is connected to a socket with 240 v. current supply.

a. How much current, flows through the lamp?
b. Calculate the power drawn.

SOLUTION

$$I = \frac{V}{R}; \quad I = \frac{240}{50}; \quad I = 4.8 \text{ Amperes}$$

Where power factor (pf) in a purely ***resistive circuit***, such as those with only electric heating elements, **impedance** or **resistance** power factor (pf) is equal to 1.0. Thus:

$$W = V I \times pf$$

$$W = 240 \times 4.8 \times 1.0$$

$$W = 1{,}152 \text{ watts}$$

$$W = I^2 R$$

$$W = (4.8)^2 \times 50$$

$$W = 1{,}152 \text{ watts}$$

ILLUSTRATION 1-6

A water heater draws 10 amperes at 240 volts current supply. Determine its heat resistance.

SOLUTION

$$R = \frac{V}{I}$$

$$R = \frac{240}{10}$$

$$R = 24 \text{ Ohms}$$

Energy Calculations

Determine the monthly energy consumption of the following appliances:

Appliances	Load	Daily Used
Electric Iron	1,200 watts	2 hours
Water Heater	1,000 watts	3 hours
Toaster	2,300 watts	30 minutes

SOLUTION

Electric iron	1,200 w = 1.2 kw. x 2 hrs.	=	2.4 kwh.
Water Heater	1,000 w = 1.0 kw. x 3 hrs.	=	3.0 kwh
Toaster	1,300 w = 1.3 kw. x 0.5 hrs.	=	.65 kwh.
	Total..........		6.05 kwh.

If the average cost of energy (not power) is P5.00 per kwh., for 30 days consumption, multiply:

30 x 6.05 = 181.50 kwh. per month
x 5.00
Total cost.....P 907.50

1-9 Voltage and Voltage Drop

Comparatively, in a ***Series Circuit*** - **Current** is the same throughout but **voltage** differs.

In a ***Parallel Circuit***, the **Voltage** is the same, but the **current** differs.

Take note that ***in a parallel arrangement, all current loads cumulatively add.*** For instance, appliances and light loads connected to a parallel circuit has the same voltage imposed, but each load draws a different current according to its wattage rating.

Another one important principle that is worthy to note is; **"The sum of the voltage drop around a circuit is equal to the supply voltage."** This principle is important in a series circuit. On a parallel circuit, each item has the same voltage across it, which constitute a circuit by itself. The voltage drop on wire carrying current is:

Voltage drop in wire = Carried current x Resistance of wire

The power loss in the wire conductor can be calculated as the product of the voltage and the current. It is equal to the ***components resistance times the current squared.***

$$P = I \times (I \times R); \quad P = I^2 R$$

The power loss in the conductor wire is transformed into heat. Comparatively, a 1200 watts appliance rating has 10 amperes current flow on a 120 volts current supply compared to 5 amperes only on a 240 volts current supply. Therefore, it is certain to say that bigger wire is required on a 120 volts than on a 240 volts current supply.

Example:

1.) For a **120 volt** current supply:

$$\text{Current drawn} = \frac{1200 \text{ watts}}{120 \text{ volt supply}} = 10 \text{ amperes}$$

2.) For a **240 volt** current supply we have:

$$\text{Current drawn} = \frac{1200 \text{ watts}}{240 \text{ volts supply}} = 5 \text{ amperes}$$

From the foregoing example, it appears, that ***a smaller diameter wire on a 240 volts current can safely carry more current in proportion with its weight than a larger diameter wire on a 120 volts supply current.*** In effect, less copper is required to carry the same amount of power on a higher voltage current supply.

If the basic wire insulation is rated at 300 volts, the same amount of power can be carried with less than one half the cost of copper. This is the main reason for the almost worldwide use of 240 volts current replacing the 120 volts line for practical and economical reasons.

All other factors considered, ***the higher the circuit voltage, the more economical the system will be.*** The advantages of using high voltage for transmission and distribution line facilitate the conversion from one voltage to another that could not be done with the direct current (DC) but much easier with the alternating current (AC).

Example:

The owner of a 5 kw. electric motor irrigation pump, requested line connection from the electric cooperative. The owner was given an option to avail of either 120 or 240 volts service. What is the good choice if the circuit line has a resistance of .42 Ohms?

Solution in a Comparative Analysis

5 kw. is = 5,000 watts

	120 volts	240 volts
Current drawn	5,000 w / 120 v = 41.66 ampere	5,000 w / 240 v = 20.83 ampere
Minimum wire size required to carry the current without overheating	No. 8 AWG	No. 12 AWG (see Table 1-1)
Relative cost of the No. 8 and No. 12 wire in comparative ratio	2.2	1.0
Voltage drop	41.66 x .42 = 17.50 v. = 14.60%	20.83 x 42 = 8.75 v. = 3.60 %

Advantages of the 240 volts over the 120 volt current supply

1. Smaller wire is required which means, lower in cost.

2. Less power loss.
3. Smaller percentage of voltage drop.

Comments:

1. Comparatively, the current drawn by the 5 kw. motor on a 120 volts current supply is double that of the current drawn from 240 volts supply when the load in watts was divided by the current voltage.
2. The size of the conductor wire is relatively proportional with the amount of load. The use of No.8 AWG wire for the 120 volts line against the No.12 AWG wire for the 240 volts line has a big difference in cost.
3. The 14.6% voltage drop on the 120 volts is too high. Change the No. 8 wire with a bigger No.2 wire to reduce the voltage drop and power loss.
4. And to change the No.8 with No. 2 conductor will increase the cost to a ratio of 10 to 1 instead of 2.2 to 1 ratio as computed
5. Technically, power loss cannot be avoided even to the most sophisticated electric system because this is an inherent effect of resistance between the materials and the current flow although it can be controlled and reduced to the least percentage of voltage drop. Therefore, the 240 volts current supply is more advantageous than the 120 volts line.

TABLE 1-1 WIRE SIZE AND AMPERE CAPACITY

Wire Size No. AWG	Amperes
14	15
12	20
10	30
8	40
6	55
4	70
2	95
0	125
00	145
000	165

It is interesting to note that the capacity of the circuitry increases as the wire number decreases. The ratings of the wires apply only to copper wire be it solid or stranded types. Aluminum wires is not recommended for circuitry or house wiring.

TABLE 1-2 LOAD LIMIT IN WATTS

Circuit Capacity in Amperes	Load Limit in watts
15	18000
20	2400
30	3600

CHAPTER 2

CONDUCTORS AND WIRING ACCESSORIES

2-1 Conductors and Insulators

Electric Conductors are substances or materials used to convey or allow the flow of electric current. **Insulators** on the other hand, are substances or materials that resist the flow of electric current.

Materials Considered as Good Electric Conductors are:

1. Silver	6. Zinc
2. Copper	7. Platinum
3. Aluminum	8. Iron
4. Nickel	9. lead
5. Brass	10. Tin

Various Kind of Insulators:

1. Rubber	7. Latex
2. Porcelain	8. Asbestos
3. Varnish	9. Paper
4. Slate	10. Oil
5. Glass	11. Wax
6. Mica	12. Thermoplastic

Resistance as already discussed, is due to the friction between the flow of current, and the conductor as well as the insulator. There is no such thing as perfect conductor, or perfect insulator, because conductors, insulators, and resistors, are resistive materials. Good conductors are those substances with extremely low resistance to current flow.

On the other hand, good insulators are those with extremely high resistance to current flow and moderate resistance to load resistor.

Conductor Insulators

Electrical conductors are made in numerous types designated by letters according to the kind of insulation used. The conductor insulator serves as physical shield of the wire against heat, water and other elements of nature. Insulation is rated by voltage from 300 to 15,000 volts. If the insulation used is above its specified rating, the risk of breakdown is high which might cause short circuit and arcing that may result to fire. Ordinary conductor wires for buildings is normally rated at 300 or 600 volts.

Wires and Cables

Wires are those electrical conductors 8 mm^2 (AWG No. 8) and smaller in sizes. **Cables** on the other hand, are those which are larger than the wires. Wires and Cables are either:

a.) Stranded wire
b.) Solid wire

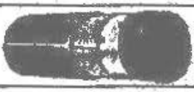
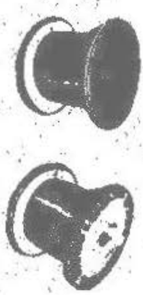
Stranded Wire – consists of a group of wires twisted to form a metallic string. The circular **mil area** of a stranded wire is found by ***multiplying the circular mil area of each strand by the total number of strand.***

Cord – is the term given to an ***insulated stranded wire.***

Mil - Prior to the adoption of the Metric System (SI), all electrical wires and cables sizes were expressed in terms of AWG (American Wire Gauge). The word **mil** that is equal to 1/1000 of an inch was used to describe or measure a round wire diameter. If a wire has a diameter of one mil, it has a cross sectional area of **one circular mil**.

TABLE 2-1 DIFFERENT TYPES OF ELECTRIC WIRES AND CABLES

Product	Description	Operating Temperature	Size Range	Usage
	TW oil resistant thermoplastic	60° C	1.60 mm - 500 mm^2 solid & stranded	Ordinary building wire
	THW -oil, heat & moisture resistant thermoplastic	75° C	1.6 mm - 500 mm^2 solid and stranded	Building wire wet and dry location
	TF thermoplastic fixture wire	60° C	0.60 mm -0.30 mm^2 solid and stranded	FIXTURE WIRE single conductor 2-conductor twisted or parallel 3-conductor twisted
	Copper line wire		# 12- 1000 MCM solid and stranded	Polyethylene insulated weather resistant wire
	Aluminum line wire	75°C	12 - 400 AAC	Polyethylene insulated weather resistant wire
	Bare Copper wire (solid) and stranded		Copper 1.60 mm - 500 mm^2	Bare overhead transmission line and for ground wire
	High-Temperature wire	105° C	# 18 - # 8	Appliance machine tool, motor lead and switchboard wires
	Armored (BX) cable	60° C	1.50 mm - .30 mm^2 solid and stranded 2-3 & 4 conductors	General purpose
	TV antenna wire		No. 24 - No. 20	300 Ohms TV wire
	Automotive wire	105°C	# 18 - # 2	Primary wire spark plug and battery cable
	Power cable	60°C	# 14 - # 10 # 8 - # 1000 MCM	Power cable for aerial and duct 600 volts Power cable for aerial duct and direct burial 600 volts
	Non-Metallic sheathed cable type NM	60°C	1.60 mm - 2.60 mm^2 2, 3 & 4 conductors round or flat	For exposed or concealed works in air voids in masonry blocks or tile walls not exposed to excessive moisture or dampness. 600 volts

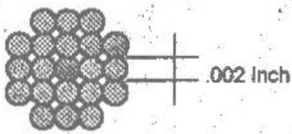
	Appliance or elect. stove heater cord	No 22 - No. 12	Heating equipment dry location
	Jacketed wire	22/3 conductors	Extension cord telephone equipment
	Telephone drop wire flat or twisted 75°C or ESW	No. 17/2 19/2	Service drop from pole
	Self supporting telephone cable	6 pairs thru 300 pairs	Aerial installation and sound system
	Intercom cable shielded or unshielded	1 pair thru 100 pairs	Interior communi-nications & sound system
	ADT telephone cable (REA) specs.	6 pairs thru 909 pairs	For aerial and duct installation
	DBT telephone cable (REA specs.)	6 pairs thru 909 pairs	For aerial and duct installation
	GTO - 15	# 14	Gas tube- oil burner ignition cable
	Welding cable 60°C	# 6 - # 4/0	Arc welding machine
	Control cables 60°C (IPCEA specs)	# 22 - # 8 multi-conductors	For control circuits, aerial ducts and direct burial
	Royal cord 60°C	No. 22 - No. 4 2, 3 & 4 conductors	Portable cords
	Submersible 60°C pump cable	# 14 - # 1 2 & 3 conductors round connection	For submersible pumps of deep water wells
	MAGNETIC WIRE MW 200 200°C	# 14 -# 30 single and heavy	For sealed hermetic motors class 14 insulation
	MW 130°C 130°C	# 7 - # 13 & # 31 - # 44 single & heavy	Class A Insulation
	MWC 105 105°C	# 7 - # 13	Cotton covered Class A & Class H insulation
	MWC 200 200°C	# 14 - # 30	Cotton covered Class A & H insulation

SOURCE : MARTON Wires and Cables

TABLE 2-2 CHARACTERISTICS OF SELECTED INSULATED CONDUCTORS FOR GENERAL WIRING

Trade Name	Type Letter	Operating temp.	Application provision
Moisture and heat Resistant rubber	KHW	75° C	Dry and wet location
Thermoplastic	T	60° C	Dry location
Moisture resistant thermoplastic	TW	60° C	Dry and wet location
Thermoplastic heat resistant	THHN	90° C	Dry location
Moisture and heat resistant thermoplastic	THW	75o C	Dry and wet location
Moisture and heat resistant thermoplastic	THWN	75° C	Dry and wet location
Moisture and heat resistant cross linked thermosetting	XHHW	90° C	Dry location
Polyethylene		75° C	Wet location
Silicon asbestos	SA	90° C	Dry location
Asbestos & varnish cambric	AVA	110° C	Dry location

SOURCE: The National Electrical Code



21 STRANDED CONDUCTOR

Diameter of each strand = 2 mils
Circular mil area = Dx2 = 4 Circular mils
Total circular mil area of conductor is:
4 x 21 = 84 circular mils.

FIGURE 2-1 CROSS SECTION OF A CORD

The universal acceptance of the Metric System (SI), has led to the conversion of English System to Metric measures that brought some inconveniences to most technical men, laymen, and manufacturers who were using the traditional English Measures. Wires and cables were expressed in square millimeter written as mm^2 for short.

The following formula and conversion factor is presented for reference in computing the area of wires and cable sizes.

Circular mil = d^2 ;   Square mil = 3.1416 r^2

Conversion Factor

Square mil	=	Square inch x .000001
Square inch	=	Square mil x 1,000,000
Square mil	=	Circular mil x 0.7854
Circular mil	=	Square mil x 1.273
Millimeter	=	Inches x 25.4
Square millimeter	=	Circular mil x 0.0005067

TABLE 2-3 TABLE OF CIRCULAR MIL - AREA EQUIVALENT

Size AWG or MCM	Area Circular mil	Size AWG or MCM	Area Circular mil
18	1.620	1	83,690
16	2,580	0	105,600
14	4,110	00	133,100
12	6,530	000	167,800
10	10,380	0000	211,600
8	16,510	250	250,000
6	26,240	300	300,000
4	41,700	350	350,000
3	42,620	400	400,000
2	66,360	500	500,000

ILLUSTRATION 2-1

What is the equivalent size in square millimeter of a cable 250 MCM?

SOLUTION

1. MCM stands for thousand circular mils.

$$250\ MCM = 250{,}000\ \text{circular mils}$$

2. Square millimeter = Circular mil x .0005067

$$= 250{,}000 \times 0.0005067$$

$$= 126.67\ mm^2$$

TABLE 2-4 PHYSICAL PROPERTIES OF BARE CONDUCTORS

Size AWG or MCM	Area Circular mils	Diameter		DC resistance Omhs/1000 ft. at 25° C
		Solid	Stranded	
16	2,580	0.0508	-	4.10
14	4,109	0.0641	-	2.57
12	6,530	0.0808	-	1.62
10	10,380	0.1019	-	1.02
8	16,510	0.1285	-	0.64
6	26,240	0.1620	0.184	0.41
4	41,740	0.2040	0.232	0.26
2	66,360	0.2580	0.292	0.16
1	83,690	0.2890	0.332	0.13
0 (1/0)	105,600	0.3250	0.373	0.10
00 (2/0)	133.100	0.3650	0.418	0.081
000 (3/0)	167,800	0.4100	0.470	0.064
0000 (4/0)	211,600	0.4600	0.528	0.051
250 MCM	250,000	0.5000	0.575	0.043
300 MCM	300,000	0.5480	0.630	0.036
400 MCM	400,000	0.6320	0.728	0.027
500 MCM	500,000	0.7070	0.813	0.022

SOURCE: Extracted from the National Electrical Code

ILLUSTRATION 2-2

What is the equivalent area of No.8 conductor wire in square inches?

SOLUTION

1. Refer to Table 2-3. The area of No. 8 conductor wire in circular mil is 16,510 mils. Using the conversion factor.

Square Inch = Square mil x .000001
Square mil = Circular mil x 0.7854

2. By Substitution:

Square Inch = 16,510 x 0.7854 x .000001

= .013 square inch

2-2 Different Types of Cables

Armored Cable (AC) is a fabricated assembly of insulated conductors enclosed in flexible metal sheath. Armored cable is used both on exposed and concealed work

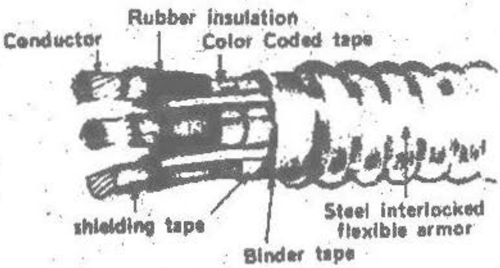


FIGURE 2-2 TYPE OF AC FLEXIBLE ARMORED CABLE (BX)

Metal Clad Cable (MC) is a factory assembled cable of one or more conductors each individually insulated and enclosed in a metallic sheath of interlocking tape of a smooth or corrugated tube. This type of cable is especially used for service feeders, branch circuit, and for indoor or outdoor work.

Mineral Insulated Cable (MI) is a factory assembly of one or more conductors insulated with a highly compressed refractory mineral insulation enclosed in a liquid and gas tight continuous copper sheath. This type of cable is used in dry, wet or continuously moist location as service feeders or branch circuit.

FIGURE 2-3 MINERAL INSULATED CABLE

Non-Metallic Sheathed Cable (NM) is also a factory assembly of two or more insulated conductors having a moisture resistant, flame retardant, and non-metallic material outer sheath. This type is used specifically for one or two family dwellings not exceeding 3 storey buildings.

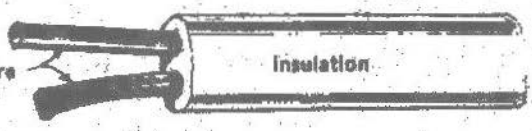


FIGURE 2-4 TYPICAL NEC NON METALLIC TYPE CABLE

Shielded Non-Metallic Sheathed Cable (SNM). This type of cable is a factory assembly of two or more insulated conductors in an extruded core of moisture resistant and flame retardant material covered within an overlapping spiral metal tape. This type is used in hazardous locations and in cable trays or in raceways.

Underground Feeder and Branch Circuit Cable (UF) is a moisture resistant cable used for underground connections including direct burial in the ground as feeder or branch circuit.

Service Entrance Cable is of the types SE and USE. A single or multi-conductor assembly provided with or without an over all covering primarily used for service wire.

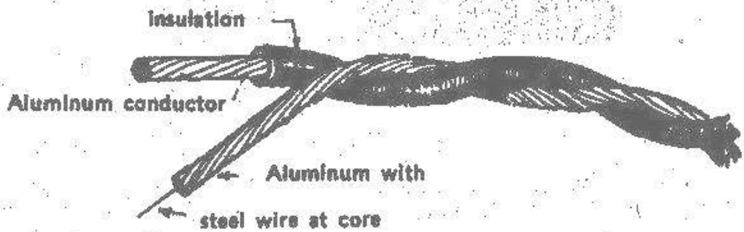


FIGURE 2-5 SERVICE ENTRANCE CABLE

Power and Control Tray Cable (TC). This is a factory assembled two or more insulated conductors with or without associated bare or covered grounding under a metallic sheath. This is used for installation in cable trays, raceways, or where it is supported by messenger wire.

Flat Cable Assemblies (FC). Is an assembly of parallel conductors formed integrally with an insulating material web designed specially for field installation in metal surface or raceways.

Flat Conductor Cable (FCC) consists of three or more flat copper conductor placed edge to edge separated and enclosed within an insulating assembly. This type of cable is used for general purposes such as: appliance branch circuits, and for individual branch circuits, especially in hard smooth continuous floor surfaces and the like.

Medium Voltage Cable (MV Cable) is a single or multi-conductor solid dielectric insulated cable rated at 2,000 volts or higher. This type is used for power system up to 35,000 volts.

The MV cables has different types and characteristics

1. Trade name : Medium Voltage Solid Dielectric.
2. Type letter : MV – 75; MV – 85; MV – 90.
3. Maximum operating temp. – 75° C; 85° C; MV 90° C.
4. Application : Dry or wet locations, rated at 2,000 volts or higher.
5. Insulation : Thermoplastic or thermosetting.
6. Outer covering; Jacket, Sheath or Armor.

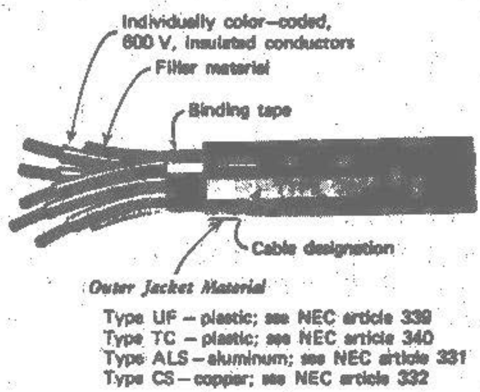


FIGURE 2-6 ALL 600 VOLTS JACKETED CABLES

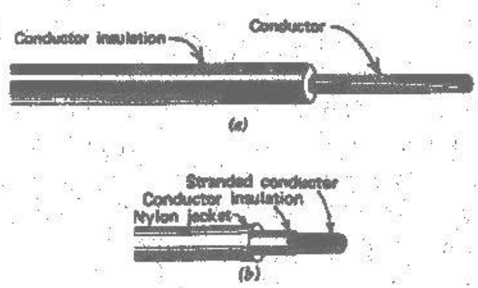


FIGURE 2-7

Typical construction of jacketed building wire such as Type T and Type TW conductors normally solid through No. 8 AWG, and stranded from No. 6 AWG and larger.

2-3 Ampacity of Electrical Conductors

Ampacity is defined as the ability of the wire or conductor to carry current without overheating. Conductor resistance to current flow, generate not only heat but also contribute to the voltage drop expressed in the following equation:

Voltage drop in wire = Circuit current x Resistance of wire

Power loss in wire = Circuit current x Voltage drop

$$P = I \times (I \times R)$$
$$P = I^2 R$$

Power Loss is equal to the ***components resistance times the current squared.*** This power loss being converted into heat, must be dissipated. A small wire diameter can safely ***carry more current in proportion to its weight***. The ***use of copper wire*** is most preferred. **Section 3.1.2.1** of the National Electrical Code provides that:

"Conductor size and rating shall have sufficient ampacity to carry load. They shall have adequate mechanical strength and shall not be less than the rating of the branch circuit and not less than the maximum load to be served."

Conductors Ampacity is determined by the maximum operating temperature that its insulation can withstand continuously without heating. Current flow and conductor's resistance normally generates heat. Thus, the operating temperature depends upon the amount of ***current flow, wire resistance,*** and ***environment.*** Environment refers to either ***enclosed*** or ***open condition*** on which the wire is placed.

The Ampacity or ability of the conductor to carry load, increases as the sizes of conductor increases. If more than 3 conductors are inserted into a conduit, the temperature also increases and it requires derating of the conductors ampacity as prescribed in Tables 2-5, 2-6 and 2-7.

TABLE 2-5 ALLOWABLE AMPACITIES OF INSULATED COPPPER CONDUCTORS NOT MORE THAN 3 WIRES IN RACEWAY

SIZE		Temperature Ratings of Conductor			
		60° C (140° F)	75° C (167° F)	90° C (194° F)	110° C (230° F)
mm²	AWG MCM	Type T TW	Types RHW THW THWN XHHW	Types SA RHH THHN XHHW	Type AVA
2.0	14	15	15	25	30
3.5	12	20	20	30	35
5.5	10	30	30	40	45
8.0	8	40	45	50	60
	6	55	65	70	80
	4	70	85	90	105
	3	80	100	105	120
	2	95	115	120	135
	1	110	130	140	160
	0	125	150	155	190
	00	145	175	185	215
	000	165	200	210	245
	0000	195	230	235	275
	250	215	255	270	315
	300	240	285	300	345
	350	260	310	325	390
	400	280	335	360	420
	500	320	380	405	470
	600	355	420	455	525
	700	385	460	490	560
	750	400	475	500	580
	800	410	490	515	600
	900	435	520	555	

TABLE 2-6 CURRENT CARRYING CAPACITY DERATING FACTORS

Number of Conductors In a Raceway	Derating Factor
4 to 6	0.80
7 to 24	0.70
25 to 42	0.60
43 and above	0.50

TABLE 2-7 TYPICAL AMBIENT TEMPERATURE

Location	Temperature	Minimum rating required Conductor insulation
Well ventilated normally heated building	30° C	See note below
Building with such major heat sources as power stations or industrial processes	40° C	75° C
Poorly ventilated spaces such as attics	45° C	
Furnaces and boiler room	Min. 40° C Max. 60° C	75° C 90° C
Outdoor in shade in air	40° C	75° C
In thermal insulation	45° C	75° C
Direct solar exposure	45° C	75° C
Place above	60° C	110° C

Note: 60° C up to No. 8 AWG copper wire and 75° C for bigger than No. 8
SOURCE: The National Electrical Code

Derating of Conductors Ampacity - means that, the full amount of allowable ampacity, is reduced to a certain percentage due to the environmental condition it is exposed of and the number of wires placed inside the conduit. The current rating of wire in a free air environment is higher than those placed inside the conduit. Concomitant with this, if the ambient temperature is above 30° C, the allowable ampacity will be reduced by the factors given in Table 2-6.

2-4 Raceway

Raceways are channels or wiring accessories so designed for holding wires, cables or busbars that are either made of metal, plastic, or any insulating mediums.

The common types of raceways for household wiring installations are:

1. The conduits
2. The connectors and other accessories

TABLE 2-8 CHARACTERISTICS OF RACEWAYS

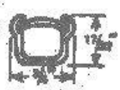
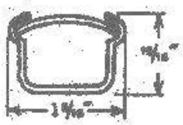
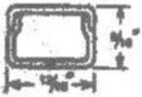
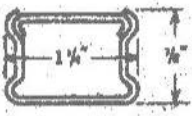
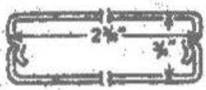
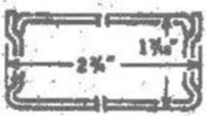
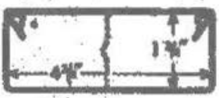
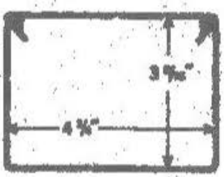
Raceway Type No.	Section through raceway	Wire size	Number of Wires	
			Type RHW	Type T,TW
200		14 12	3 2	3 3
500		14 12 10	5 4 2	6 6 4
700		14 12 10	7 6 3	8 8 6
1000		14 12 10	10 10 6	10 10 8
1500		14 12 10	4 4 4	8 6 4

TABLE 2-8 CHARACTERISTICS OF RACEWAYS

Raceway Type No	Section through Raceway	Wire size	With No Devices		With No. Devices	
1900		14 12	3 3	3 3	3 3	3 3
2000		14 12	3 3	3 3	3 3	3 3
2100		14 12 10	b b -	17 14 10	b b b	17 14 10
2200		14 12 10	- - -	- - -	10 10 10	10 10 10
3000		14 12 10	b b b	44 40 20	b b b	56 42 20
4000		14 12 10 8	17 15 11 7	28 24 20 12	17 15 11 7	68 53 41 22
6000		14 12 10 8 6	61 54 38 27 20	97 82 68 41 25	61 54 38 27 20	234 184 141 27 38

Other Types of Raceways

Aside from the conduits and connectors, there are other type of raceways such as:

1. Conduit coupling, elbows and other fittings
2. Conduit supports, such as clamps, hanger, etc.
3. Cable trays, cable bus, etc.
4. Metal raceways.
5. Nonmetal raceways and other.

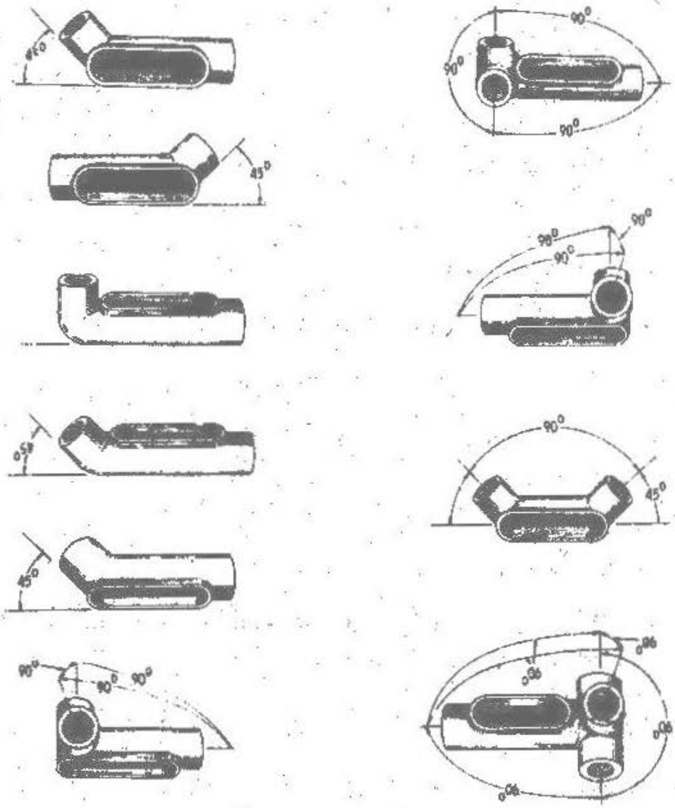


FIGURE 2-8 TYPES OF CONDUIT FITTINGS

2-5 Conduit

Conduit pipe is the most common electrical raceways used in all types of construction. With respect to the type of materials used, conduit may be classified into:

1. Metallic such as steel pipes, aluminum, etc.
2. Non-metallic such as plastic and the like

With Respect to its Make, Conduit may be Classified as:

1. Rigid metal
2. Flexible metal
3. Rigid non-metal
4. Flexible non-metal

The Purpose of Electrical Conduits are:

1. To provide a means for the running wires from one point to another.
2. To physically protect the wires.
3. To provide a grounded enclosure.
4. To protect the surroundings against the effect of fault in the writing.
5. To protect the wiring system from damage by the building and the occupants.
6. To protect the building and the occupants from damage by the electric system.

Connector

Connector is a metal sleeve usually made of copper that is slipped over and secured to the butted ends of conductors in making a joint.

Connector is otherwise called **splicing sleeve**.

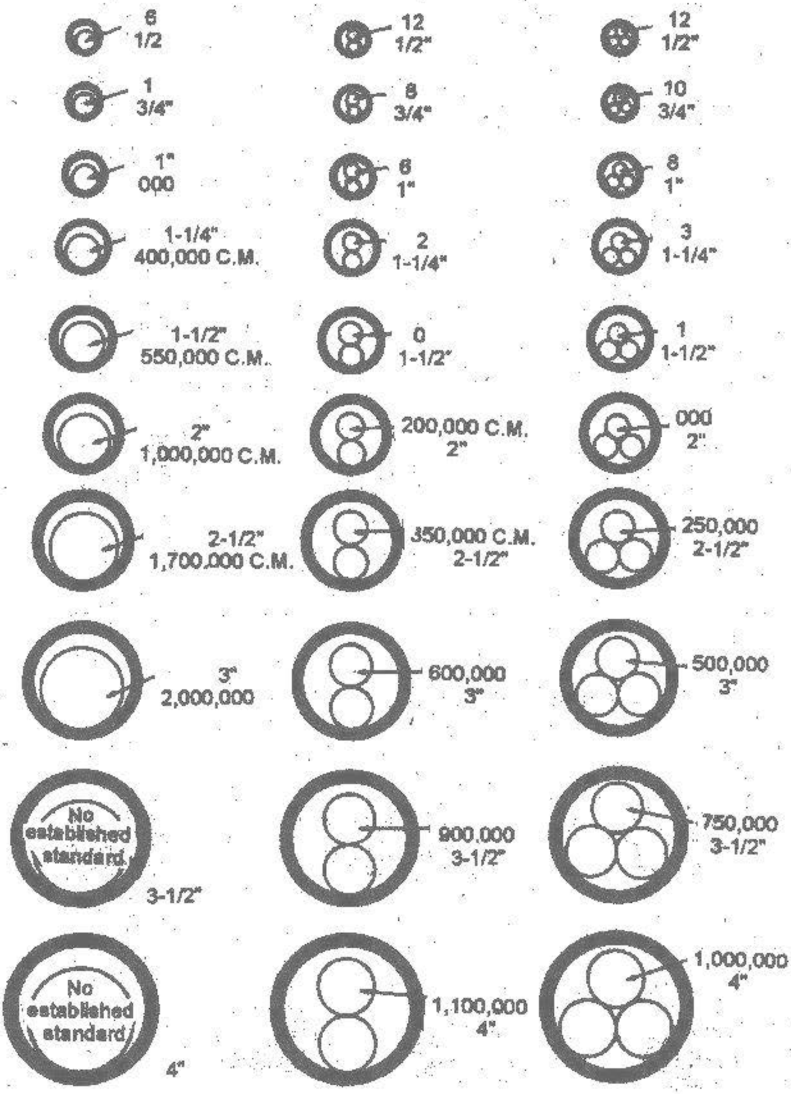


FIGURE 2-9
STANDARD SIZE OF CONDUIT FOR INSTALLATION OF WIRE CABLE

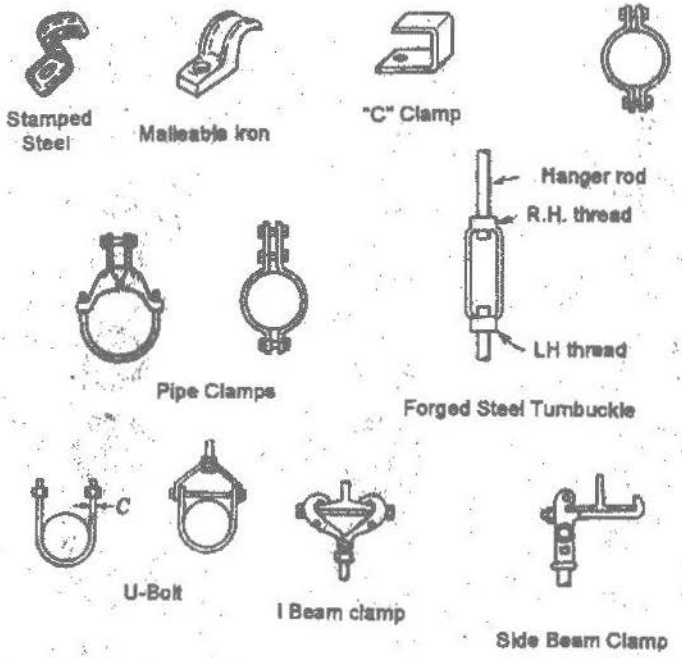


FIGURE 2-10 OTHER TYPES OF RACEWAYS

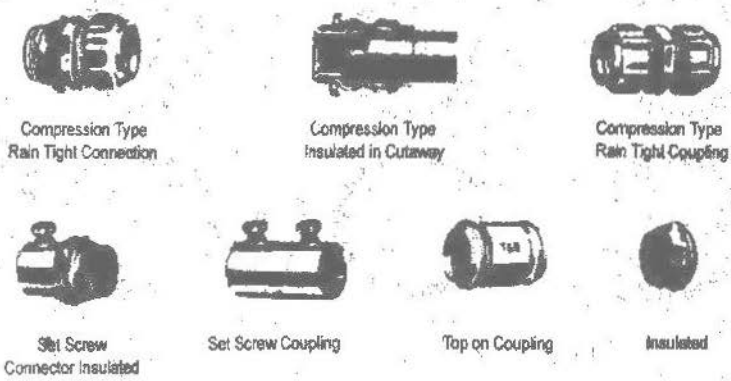


FIGURE 2-11 VARIOUS TYPES OF EMT CONNECTORS

TABLE 2-9 MAXIMUM NUMBER OF WIRES IN A CONDUIT

	Number of Wires in One Conduit (mm)								
Size of Wire	1	2	3	4	5	6	7	8	9
14	13	13	13	20	20	25	26	27	28
12	13	13	20	20	20	25	25	25	32
10	13	20	20	25	25	25	32	32	32
8	13	20	25	25	25	32	32	32	32
6	13	25	32	32	38	38	50	50	50
5	20	32	32	32	38	50	50	50	50
4	20	32	32	38	50	50	50	50	63
3	20	32	32	38	50	50	50	63	63
2	20	32	38	38	50	50	63	63	63
1	20	38	38	50	50	63	63	75	75
0	25	38	50	50	63	63	75	75	75
00	25	50	50	63	63	75	75	75	88
000	25	50	50	63	75	75	75	88	88
0000	32	50	63	63	75	75	88	88	100
20000	32	50	63	63	75	75	88	88	100
22500	32	63	63	75	75	88			
250000	32	63	63	75	75	88			
300000	32	63	75	75	88	88			
350000	32	63	75	88	88	100			
400000	32	75	75	88	100	100			
450000	38	75	75	88	100	113			
500000	38	75	75	88	100	113			
550000	38	75	88	100	113	125			
600000	50	75	88	100	113	125			
650000	50	88	88	100					
700000	50	88	88	113					
750000	50	88	88	113					
800000	50	88	88	113					
850000	50	88	100	113					
900000	50	88	100	113					
950000	50	100	100	125					
1000000	50	100	100	125					

2-6 Outlet and Receptacles

An outlet is a point in the wiring system at which current is taken to supply utilization equipment. In a simple term, an outlet is any point that supplies an electric load. An outlet usually consists of a small metal or non-metal box into which a raceway and or cable ends.

Different kinds of outlet

1. Convenience outlet or attachment cap.
2. Lighting outlet.
3. Receptacles outlet

A **Convenience outlet or attachment cap** is a device that by insertion into a receptacle establishes connection between the conductor of the flexible cord and the conductors connected permanently to the receptacle.

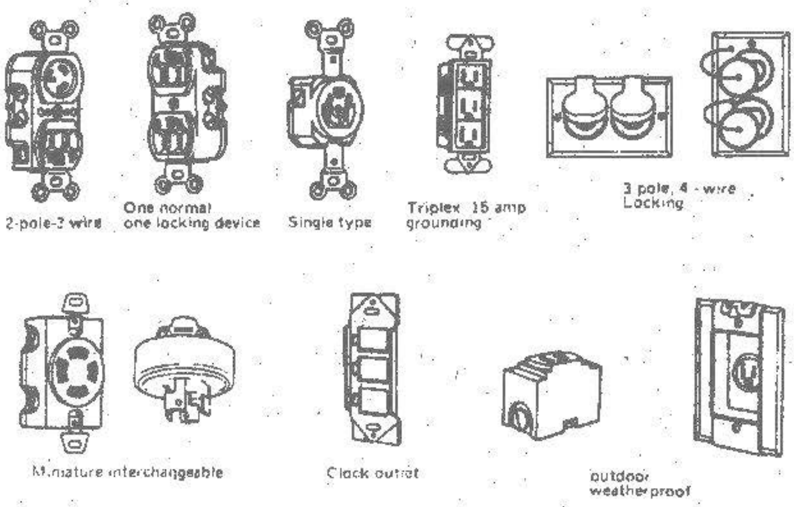


FIGURE 2-12 VARIOUS CONVENIENCE OUTLET

Wall Outlet. The common Wall Outlet is called ***Convenience Outlet***. And to call it ***wall plug is not correct***. A **plug** is another name for the attachment cap on the wire coming from a device such as lamps or appliances.

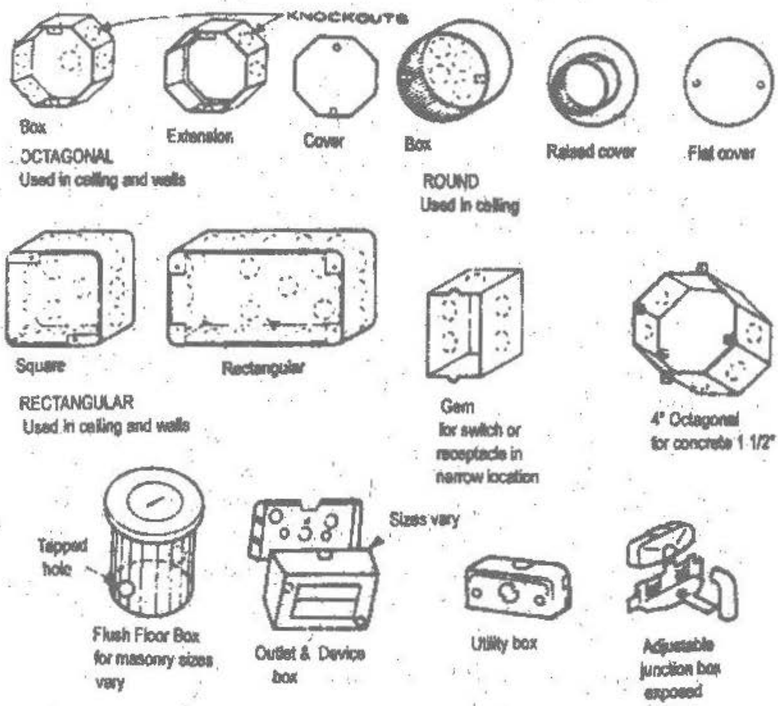


FIGURE 2-13 VARIOUS TYPES OF OUTLET BOXES

Lighting Outlet is an outlet intended for direct connection to a lamp holder, lighting fixture, or a pendant cord, terminating in a lamp holder.

Receptacle Outlet is an outlet where one or more receptacles are installed. Aside from the outlets, there are also other wiring accessories such as:

1. The junction box
2. Receptacles
3. The pull box
4. Switches and the like

Junction Box *is not an outlet*. By definition, it does not supply current to utilization device. ***Do not allow your electrical contractor to count wall switches and junction boxes as outlets.*** This is an important thing to clarify specially when payment is to be made from a contract based on the number of outlets.

An **Outlet** on the other hand, ***refers only to the box itself***. It does not include the items. The ***receptacle device is not an electrical load but rather an extension of the box wiring.*** The outlet is separate from the load device even if it is included as part of the device.

The **Pull Box** is a box with a blank cover that is inserted in one or more runs or raceways to facilitate pulling-in the conductors. It may also serve to distribute the conductors.

Receptacles are contact device installed at the outlet for the connection of a single attachment plug. Receptacles are included in the general classification of wiring devices. It includes all receptacles and their matching cap (plug), wall switches, small dimmers, and outlet box mounted lights.

Receptacle is defined by the National Electrical Code as:

"A contact device installed at the outlet for the connection of a single attachment plug."

Any number of receptacles mounted together in one or more coupled boxes is classified as ***one outlet***. The lower the number of outlets the lower is the cost. A circuit with 6 duplex receptacles individually mounted is normally more than twice the cost of the same 6 receptacles installed in two outlets group of three gang each. Receptacles are described and identified according to the pole of wires.

Mounting the Receptacles

1. A wall convenience receptacle is vertically mounted between 30 to 45 centimeters above the finished floor line.
2. In industrial areas, shops, workroom and the like, the mounting height is from 105 to 110 centimeters. This is above the table height horizontally mounted so that the cords will not hang on top of each other.
3. The GFI or GFCI (ground fault circuit interceptor) receptacle should be installed on locations where sensitivity to electric shock is high such as in wet areas.

Switch

A Switch is a device that open or closed the circuitry in an electric circuit.

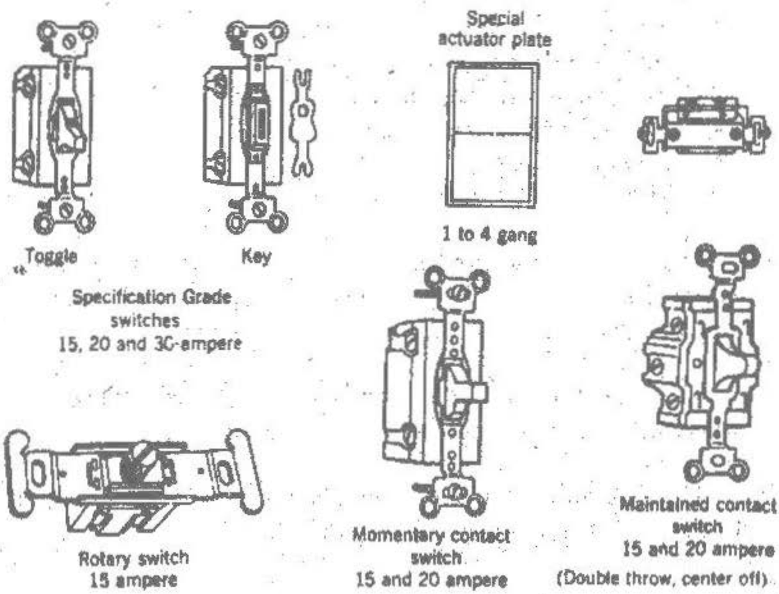


FIGURE 2-14 BRANCH CIRCUIT SWITCHES

TABLE 2-10 PERMISSIBLE CONNECTION IN BOXES

Type of Box	Sides	Depth	No. 14	No. 12	No. 10	No. 8
Octagonal	4	1 ¼	6	5	5	4
	4	1 ½	7	6	6	5
	4	2 ⅛	10	9	8	7
Square	4	1 ¼	9	8	7	6
	4	1 ½	10	9	8	7
	4	2-1/8	15	13	12	10
	4-11/16	1 ¼	12	11	10	8
	4-11/16	1 ½	14	13	11	9
Switch	3 x 2	2 ¼	5	4	4	3
	3 x 2	2 ½	6	5	5	4
	3 x 2	2 ¾	7	6	5	4
	3 x 2	2 ½	9	8	7	6

Switches are Classified into:

1. General use switch
2. General use snap switch
3. AC general use snap switch
4. AC-DC general use switch
5. Isolating switch
6. Motor circuit switch

The **General use switch** is intended for use in the general distribution and branch circuit rated in amperes. It is capable of interrupting the rated current at a rated voltage.

The ***General use snap switch*** is a form of general use switch installed in flush device boxes or an outlet box cover.

The ***Isolating switch*** is a switch intended for isolating an electric circuit from the source of power.

CHAPTER 3

THE BRANCH CIRCUIT

3-1 Introduction

Electric Circuit refers to the complete path traversed by an electric current. In short, ***electric circuit is the entire house wiring installation.***

Branch Circuit is defined by the National Electrical Code (NEC) as: ***"the circuit conductors between the final over current protective device and the outlets."*** Meaning, the branch circuit is only the wiring installed between the circuit over current protective device i.e. fuse or circuit breaker, and the outlets.

In practice however, it is a common knowledge that the branch circuit comprises the following:

1. The source of voltage
2. The wiring and
3. The load

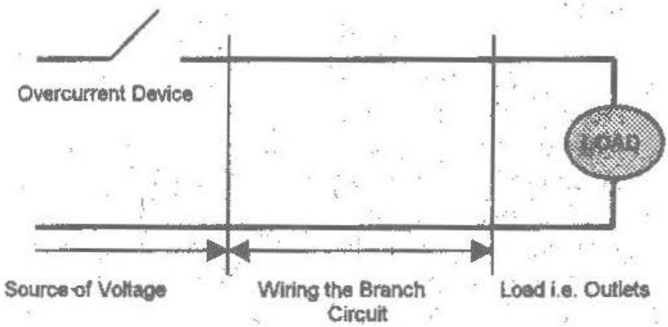


FIGURE 3-1 DIVISION OF ELECTRICAL CIRCUIT INTO ITS COMPONENT

Circuitry design varies according to the number of designers. However, good circuitry design is based on the following considerations:

1. Flexibility of the circuit
2. Reliability and efficiency of service
3. Safety of the circuitry
4. Economy as to cost
5. Energy consideration
6. Space allocation

Flexibility of the Circuit means that the installation can accommodate all probable pattern arrangements and location of the loads for expansion, or future development.

Reliability and Efficiency of Service means to have a continuous service and supply of power that are all dependent on the wiring system.

Reliability of electric power in a facility is determined by two factors:

1. The utility service
2. Building electric system

Safety means that independent service can be used in lieu of emergency equipment as backup for normal services. For reliability of the circuitry, the following principles should be considered.

1. To provide double emergency power equipment at selected weak points in the system.
2. That the electrical service and the building distribution system must act together so that the power can reach the desired point of service.
3. Critical loads within the facility must be pinpointed to determine the best way to serve them by providing a reliable power either from the outside source, or by standby power package for them.

4. The system design must readily detect any equipment failure and to be corrected automatically.

Economy refers to the initial cost as well as the operating costs. These two cost-factors stand in inverse relationship to one another. ***Over design is as bad as under design***. It is wasteful both on initial and operating costs.

The Effect of Acquiring Low Cost Equipment

1. High energy cost
2. Higher maintenance cost
3. Shorter life

Energy Consideration is a complex one considering the following factors:

1. Energy laws and codes
2. Budget
3. Energy conservation technique
4. Energy control

Space Allocation – must consider the following:

1. Easy maintenance
2. Ventilation
3. Expandability
4. Centrality
5. Limitation of access

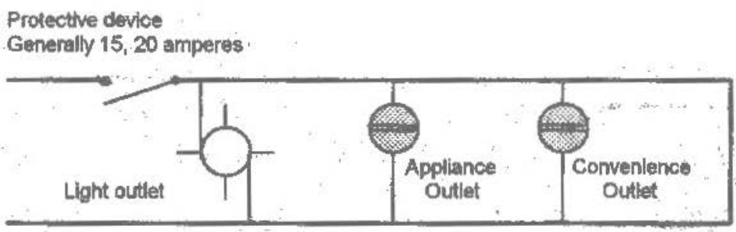


FIGURE 3-2 GENERAL PURPOSE BRANCH CIRCUIT

Branch Circuit – The branch Circuit is classified into:

1. General purpose branch circuit.
2. Appliance branch circuit.
3. Individual branch circuit.

The National Electrical Code defines the different types of branch circuit as follows:

1. **General purpose branch circuit** supplies outlets for lighting and appliances, including convenience receptacles.

2. **Appliance branch circuit** supplies outlets intended for feeding appliances. Fixed lighting however, is not supplied.

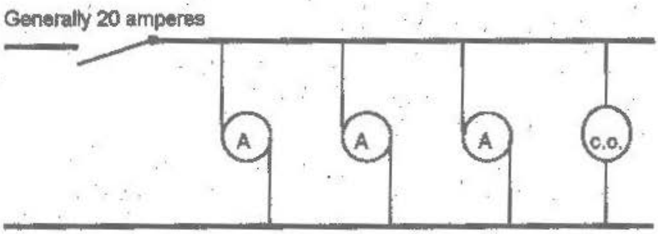


FIGURE 3-3 APPLIANCE BRANCH CIRCUIT

3. **Individual branch circuit** is designed to supply a single specific item.

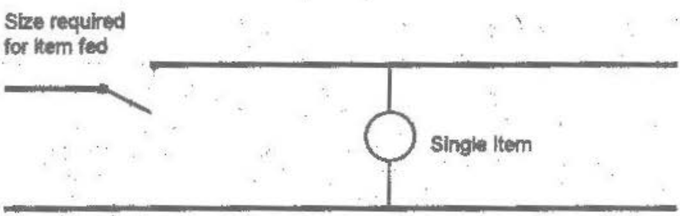


FIGURE 3-4 INDIVIDUAL BRANCH CIRCUIT

3-2 Circuiting Guidelines

There are many ways of doing the circuitry but there is no optimum or perfect way of doing it. However, there are certain rules and guidelines promulgated by the *National Electrical Code (NEC)* for flexibility, economical and convenient way of installing a circuitry.

1. The Code requires sufficient circuitry to supply residential load of 30 watts per square meter in buildings excluding porches, garages and basements.
2. The requirement of 30 watts per square meter is up to 80 sq. m. for a 20 amperes circuit (2,400 watts) or 60 square meters for 15 amperes circuit (1,800 watts).
3. Good practice suggests that the load should not exceed 1,600 watts for a 20 amperes circuit and 1,200 watts for a 15 amperes circuit. Thus:

    a) Observe a minimum load of 1,200 watts on a 15 amperes circuit with a maximum area of 40 square meters.
    b) A maximum load of 1,600 watts on a 20 amperes circuit with a maximum area of 53 square meters.

4. The Code requires a minimum of 20 amperes appliance branch circuit to feed all small appliance outlets in the kitchen, pantry, dining and family room.
5. The general purpose branch circuit, shall be rated at 20 amperes circuit, wired with No. 12 AWG being the minimum size of conductor wire required for all convenience outlet.
6. Circuit load on a 15-ampere circuit shall be limited to the values given in Table 3-1 and Table 3-2.
7. Plug outlets or convenience receptacles shall be counted in computing the load if it is not included in the load for general lighting circuit. To find the number of outlets for 9 and 12 amperes loading on a 15 and 20 amperes circuit respectively, we have:

a) For 15 amp circuit: $\frac{9}{1.5}$ = 6 outlets

b) For 20 amp circuit: $\frac{12}{1.5}$ = 8 outlets

8. Convenience receptacles should be planned properly, so that in case of failure by any one of the circuitry, the entire area will not be deprived of power supply. In terms of reliability of service, each area should be provided alternately with different circuits.

9. All kitchen outlets should be fed from at least two of these circuits.

10. The Code further stipulated that; "***all receptacles are potential appliance outlet and at least two circuits shall be supplied to serve them.***"

11. Certain outlets in the room should be designed as appliance outlet like:

    a) All kitchen receptacles
    b) Dining room receptacles
    c) One in the living room

12. The Code requires that, "***at least one 20 amperes circuit supply the laundry outlets.***"

13. If air conditioner is anticipated, provide a separate circuit for this particular appliance.

TABLE 3-1 BRANCH CIRCUIT CAPACITY - ELECTRIC HEAT

Circuit Breaker Size	Maximum Watts	
	120 volts	240 volts
15 amp.	1440	2880
20 amp.	1920	3840
30 amp.	2880	5760

TABLE 3-2 BRANCH CIRCUIT REQUIREMENTS

	15 amp.	20 amp.	30 amp.	40 amp.	50 amp.
Maximum size of conductor	No.14	12	10	8	6
Minimum size taps	No.14	14	14	12	12
Over current device rating	15 amp	20	30	40	50
Lamp holders permitted	Any type	Any type	H.Duty	H.Duty	H.Duty
Receptacle rating permitted	15 amp	15-20	30	40-50	50
Maximum load	15 amp	20	30	40	50

Other Good Practices in Circuiting

1. Lighting and receptacles should not be combined in a single circuit.
2. Avoid connecting all building lights on a single circuit.
3. Lighting and receptacles should be supplied with current from at least two circuits so that, if a single line is out, the entire area is not deprived of power.
4. Do not allow combination switch and receptacle outlets.
5. Provide at least one receptacle in the bathroom, and one outside the house. Both must be Ground Fault Circuit Interrupter (GFCI) type.
6. Provide switch control for closet lights. Pull chain switch is a nuisance.
7. Convenience outlet though counted as part of the general lighting load shall be limited to 6 convenience outlets on a 15 amperes circuit and 8 convenience outlets on a 20 amperes circuit.
8. The Code requires that, at least one 20 amperes circuit supply shall be installed to the laundry outlets.
9. Convenience outlet shall be laid out in such a manner that no point on a wall is more than 2.00 meters from an outlet. Use a grounding type receptacle only.

3-3 Protection of the Branch Circuit

As a **Rule,** ***branch circuit should be protected from over current.*** Hence, an over all current protective devices shall be installed in all branch circuitries..

The function of the over-current protective devices is to open the circuit (*disconnect the line*) when the current rating capacity of the equipment being protected is exceeded. The circuit protective device represents the source of voltage. ***It is always connected at its hot line end to the voltage source and its load end to the circuit wiring.*** Apparently, it becomes the source of voltage.

The Panel Board wherein the over current protective device is a part, the busbars become the source of voltage as we look upstream from the over current devices. The National Electrical Code also defines the branch circuit as ***"that portion of the circuit beyond the over current device."***

Causes of Over Current

There are two principal causes of over current

1. Overload in the equipment or conductors
2. Short circuit or ground fault

Both were the results of excessive current flow in the circuit. The primary function of the over-current devices is to protect the branch circuit and the load device against excessive current supply. However, regardless whether the excess current is being caused by an equipment problem of overloading, or by a circuit problem such as un-intentional ground fault, ***the protective devices has but one purpose - to interrupt the line, in case there is an excess current flow in the circuit.***

When the over current protective devices senses an excessive flow of current, it automatically open the circuit or simply

cut off the line to prevent the excessive flow of current in creating damages to the circuit or to the equipment. The over current device automatically opens the line to release the excessive current. The action of the over current protective device is called ***"Clearing"*** because it clears the circuit of the fault or over current load. It therefore acts in the same manner as the mechanical device to relieve the machine from excessive pressure.

The over current protective devices are installed in circuits to protect the following:

1. The wiring
2. The transformer
3. The lights
4. Appliances and other equipments

On the Protection of Conductors, the National Electrical Code provides that: ***"Conductors shall be protected against over current in accordance with their ampacities."***

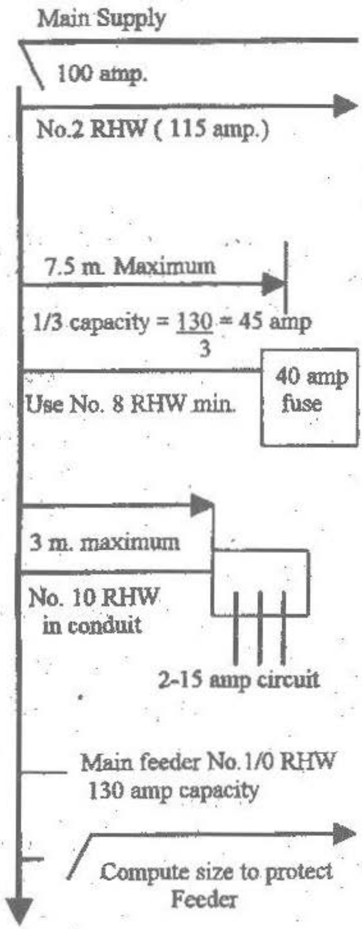
By definition, **Over *Current*** ***is any current in excess of the rated capacity of the equipment or the rated ampacity of the conductor.*** It was clear that both the equipment and the wire installation shall be protected from the over current flow.

Electrical equipment has its own rated ampacity. Similarly, electrical conductors have also their respective allowable ampacity. Thus, any load in excess of their rated or allowable ampacity, could damage the circuit or the equipment

Application of Over-current Protection is also Governed by the Following Rules:

1. That the over-current protection devices should be installed on the line or supply side of the equipment being protected.
2. The over-current protective devices shall be placed in all underground conductors of the protected circuits.

3. All equipment should be protected in accordance with its current carrying capacity.
4. That, the over-current protective devices should be readily assembled and protected from physical damages and away from easily ignited materials.
5. Conductors size should not be reduced in a circuit or tap unless the smallest wire is protected by the circuit over current devices.



Taps may be made if smaller conductor is protected by main feeder protection (100 amp. circuit breaker for No.2 wire)

Taps up to 7 m. long is allowed if tap conductors has minimum 1/3 ampacity of main and terminates in a single circuit breaker or set of fuses which limits the current on the tap to the wire capacity. 40 a. fuse limits current on 45 amp capacity wire.

Taps up to 3 m. long are allowed Provided they have sufficient capacity for the circuit they feed, say if the wiring feeds 2-15 amp. circuits, it must have 30 amp capacity and should be No. 10 AWG, RHW wire or equal rating.

Taps of any length may be made if conductor is protected at the tap point by and approximately sized overcurrent device.

FIGURE 3-5 PERMISSIBLE TAP ARRANGEMENTS

3-4 Fuse, Breaker and Panel Board

Fuse is defined as; ***an over all current protective device with a circuit opening fusible element which opens (break) when there is an over current in the circuit.***

The Fuse is a one time protective device to be replaced after the fault is cleared. It is the simplest and most common type of circuit protective device used in most house wiring installations. It is available in hundred design ratings and shapes but basically, the same in functions.

Generally, fuse consist of a fusible link or wire that easily melt at low temperature classified into two types:

1. The **Cartridge type** which is enclosed in an insulating fiber tube and
2. The **Plug Fuse type** enclosed in a porcelain cap.

TABLE 3-3 FUSE RATING AND CONSTRUCTION

Current Ratings	Remarks
0 to 10 15, 20, 25 to 30	Plug fuse construction mas. 150 v. to ground
0 to 10 35, 40, 45, 50 to 60	Cartridge type with ferrules single and dual element 250 and 600 volts
70, 80, 90,100, 110, 125, 150 175, 200, 225, 250, 300, 350 400, 450, 500, 600	Cartridge type, knife blade contacts: 250 and 600 volts
800, 1000, 1200, 1600, 2000 2500, 3000, 4000, 5000, 6000	Cartridge type bolted knife blade contacts; 600 volts

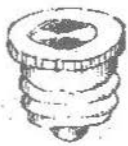
Circuit Breaker

The **Circuit Breaker** is an over-current protective device designed to function as a switch. Basically, a circuit breaker is equipped with an automatic tripping device to protect the branch circuit from overload and ground fault. Circuit breaker can be manually tripped, so that, in many cases, it also acts as circuit switch.

Trip or Tripping refers to the cutting-off or disconnection of the current supply.

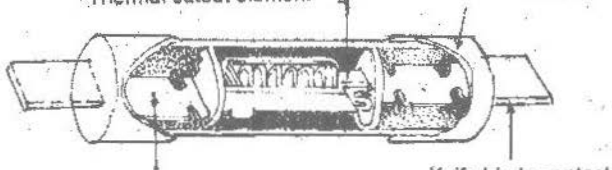
Advantages of Circuit Breaker Over the Fuse.

1. The circuit breaker act as switch aside from its being an over current protective device.
2. Unlike the fuse that has to be discarded after it was busted due to an over current flow, the circuit breaker trips off automatically and after correcting the fault, it is again readily available for switch on.



(a) Common Household Plug

(b) Single Element Knife Blade Fuse



Dual element - time delay fuse with Edison base, ferrule contacts and knife blade contacts respectively

FIGURE 3-5. STANDARD TYPE OF FUSE

Circuit breaker can be multiple pole installed with 1,2 or 3 poles which will simultaneously protect and switch one to three lines. The fuse on the other hand, is a single pole, installed on a single wire that could only protect a single electric line.

4. The circuit breaker position is easier to detect. It could be closed, tripped, or open right at the handle. On the contrary, the busted fuse could not be detected easily because the melted fusible element is inside the fuse casing.
5. The circuit breaker can be manually tripped so that in many cases, it also acts as the circuit switch.

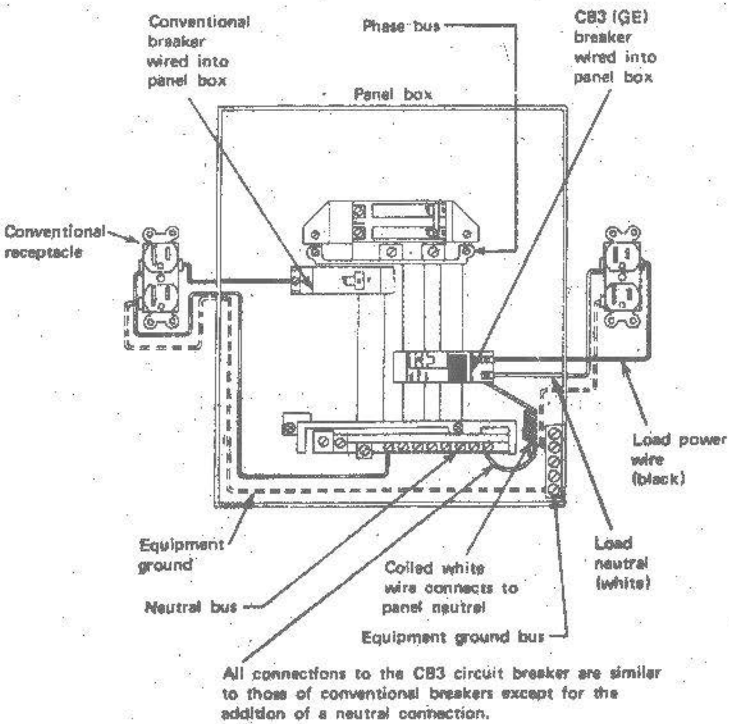
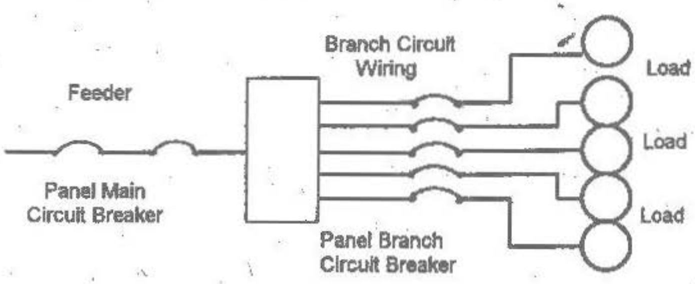


FIGURE 3-7 BRANCH CIRCUIT PROTECTION

Advantages of the Fuse over the Circuit Breaker

Despite the advantages of the circuit breaker over the fuse, the later has also some advantages over the circuit breaker enumerated as follows:

1. One major advantage of the fuse over the circuit breaker is its reliability and stability. The fuse can stay on its position for years and act when called on to act as designed.
2. The cost of the fuse is very much lower compared to that of the circuit breaker.
3. Circuit breakers has several moving parts which requires maintenance and periodic testing to be in good condition at all time.



THE BRANCH CIRCUIT RADIATE FROM THE PANEL TO THE LOADS

FIGURE 3-8 CONVENTIONAL RADIAL WIRING SYSTEM

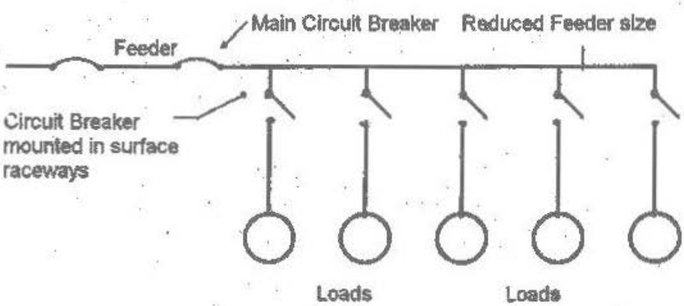


FIGURE 3-9 ALTERNATIVE WIRING METHODS

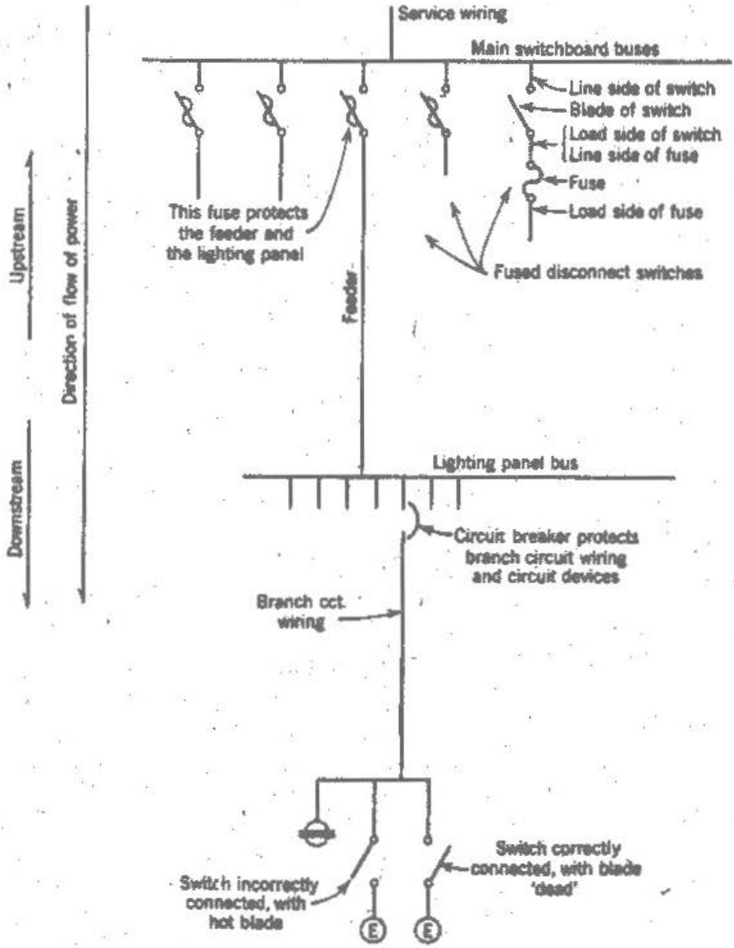
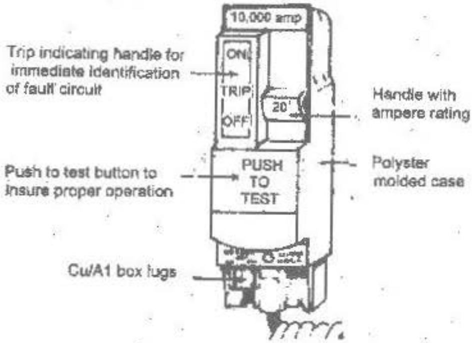


FIGURE 3-10

TYPICAL SINGLE WIRING DIAGRAM SHOWING

1. Relation of component to each other
2. Proper location of over current devices



Ground Fault Circuit Interrupters (GFCI) or (GFI). A unit that will provide ground fault protection in addition to functioning as an ordinary circuit breaker

FIGURE 3-11 MOLDED CASE CIRCUIT BREAKER

TABLE 3-4 TYPICAL MOLDED CASE CIRCUIT BREAKER CHARACTERISTICS

Frame Size Amperes *	Trip Setting (Amp)					Voltage	Remarks
50	15	20	30	40	50	240	1-3 poles
100	15	20	30	40		240	1-3 poles
	50	70	90	100		600	
225	70	90	100	125		600	1-3 poles
	150	175	200	225			
400 / 600	125	150	175	200	225	600	1-3 poles
	250	300	350	400	500	600	
800 / 1200	250	300	350	400	500	600	1-3 poles
	600	800	1000	1200			
1600	400	600	800	1000		600	2-3 poles
	1200	1600					3 poles

The Panel Board

The **Panel Board** is defined by the National Electrical Code as ***"A single panel or group panel limits designed for assembly in the form of a single panel."***

THE BRANCH CIRCUIT

This includes buses and automatic over-current protective devices with or without switches for the control of light, heat or power circuits. Panel board is designed for mounting in a cabinet or cutout box installed in or against a wall or partition accessible only to the front.

Panel board is popularly known as ***panel*** or ***electrical panel***. Panel board is simply the box wherein the protective devices are grouped from which they are fed. If the devices are of fuses, it is called ***Fuse Panel*** and if the devices are circuit breakers, it is called ***Breaker Panel.***

Fuse and breaker however, are very rarely mixed in a panel, except that a circuit breaker panel sometimes has a main switch and a fuse for overall protection of the panel. Basically, a panel consists of a set of electrical busbars where the circuit protective devices are connected.

A single phase, 3- wire panel is fed with two hot lines and a neutral line connected to the line buses and the neutral bus which varies in:

a. Ampere ratings of the buses
b. Type of protective devices installed

Regardless whether the panel is flush or surface mounted type, it is described in the following manner:

House panel circuit breaker type, surface mounting

120/240 volts 150 amperes main

100/80 amp. 2 pole main circuit breaker

Branch breakers all 80 amp. frame

10-20 amp. single pole 2-30 amp. 2 pole

1-20 amp. SP,GFI

There are as many different format of panel schedule as the numbers of technologists and every one believes that his work is the best. Hence, it will be called ***Schedule of Choice.***

Principles Applied in Installing Panel Board

1. The approach shall be accessible and more convenient.
2. The panel board is centrally located to shorten the home wiring runs.
3. It must be installed near the load center, as in most cases panel boards are mounted near the kitchen and the laundry where heavy duty loads are expected.
4. To limit voltage drop on the branch circuit, the panel board shall be located in such a manner that no circuit (wiring connections) exceed 35 meters long.
5. In the event that a circuit more than 35 meters long cannot be avoided, No.10 AWG wire shall be used for runs up to 50 meters long and No. 8 AWG wire for longer circuits.

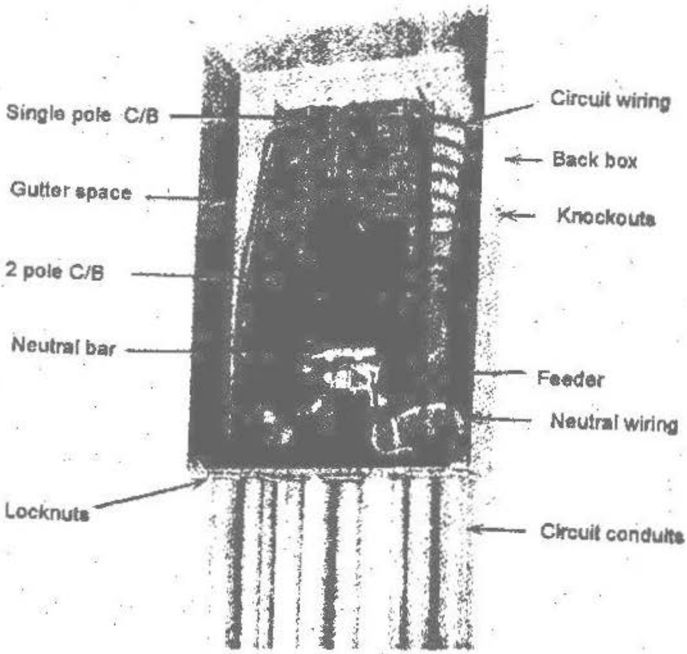
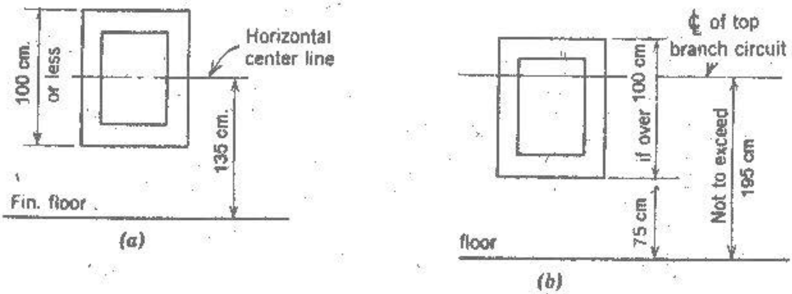
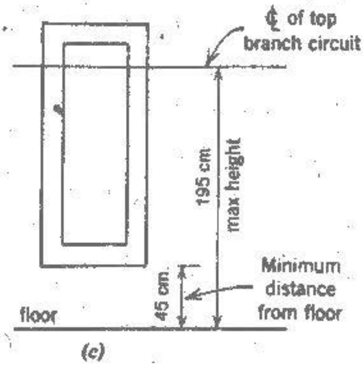


FIGURE 3-12 PANEL BOARD

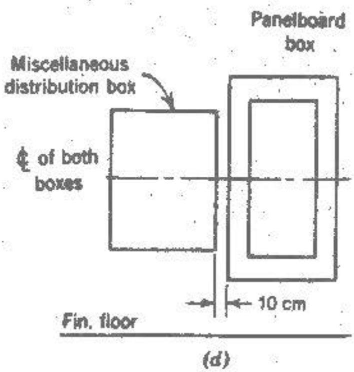




a) Panel board with 100 cm. high or less should be located 135 cm. from the floor to the center line of the box.

b) Panel board with boxes over 100 cm. high should be located 75 cm. from the floor to the bottom of the box, except that the highest branch circuit unit should not be more than 195 cm from the floor.

c) If necessary, the box maybe lowered to a distance not less than 45 cm. from the floor to the bottom of the box. However, where a maximum height of 195 cm above the floor to the upper circuit or a minimum distance of 45 cm. above the floor cannot be done, the panel should be divided into two sections.



d) If two or more boxes are adjacent on the same wall, they should be installed with the horizontal center line of each box equidistance from the floor. The center line distance of the higher box controlling the boxes should be installed with a minimum spacing of 10 cm. apart.

FIGURE 3-13 INSTALLATION OF THE PANEL BOARD

TABLE 3-5 WIRE GAUGE FOR COPPER WIRE CIRCUITS

		Maximum Distance of Circuit in Amperes and Watts (In Meters)					
Circuit AWG	Wire Amp.	5 A 375 w	10 A 1150 w	15 A 1725 w	20 A 2300 w	25 A 2875 w	35 A 4025 w
14	15	27	13	9			
12	20	42	21	13	10		
10	30	66	33	21	16	13	
8	40	108	52	36	27	21	15
6	55	168	84	54	42	33	24

Source: National Electrical Code

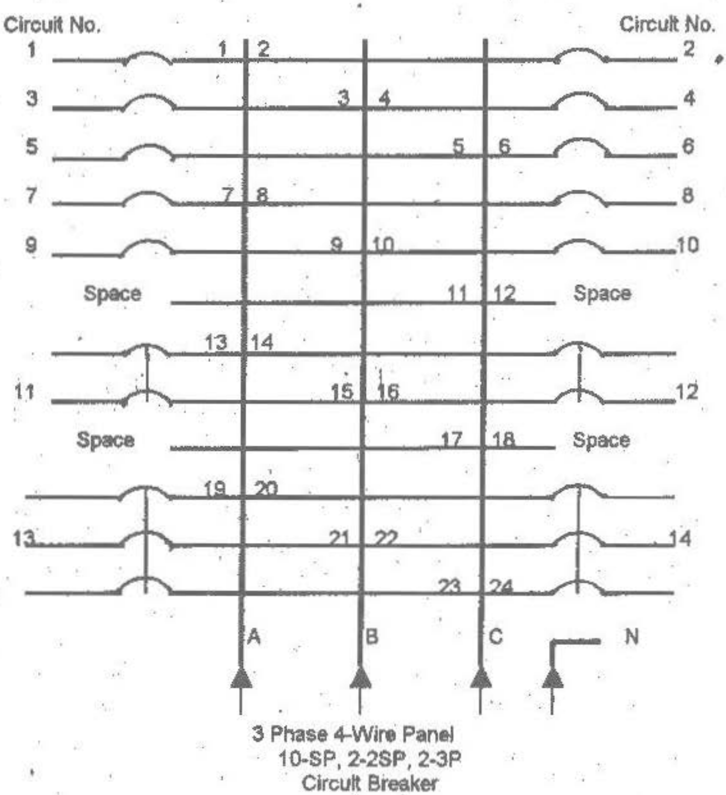


FIGURE 3-14 TYPICAL SCHEMATIC DIAGRAM OF A PANEL BOARD

Other Features of the Over Current Protective Device

1. The over current protective device is always upstream of the equipment being protected. Meaning, Electricity is ahead of the load.
2. Electric current flows downstream, and to cut off excess current, the protective device should be placed ahead of the protective items.
3. The panel is the source of current, the over current protective device of branch circuit is inside the electrical panel that supplies electric current.
4. The upstream side of the device is called ***Line Side***. The downstream side is called the ***Load Side***.

Switchboard and Switchgear

The Switchboard and Switchgear are free standing assemblies of switches, fuses and circuit breakers that provide switching and feeder protection to a number of circuits connected to the main source. It distribute large amount of power into small packages. In hydraulic analogy, the main buswork of the switchboard is equivalent to a main header supplying water. So far there is no clear distinction between the switchboard and the switchgear. Thus, a ***switchboard*** is a ***switchgear.***

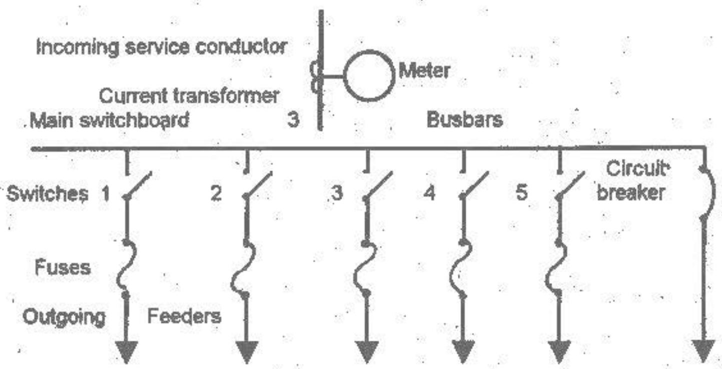


FIGURE 3-15 SINGLE DIAGRAM OF SWITCHBOARD REPRESENTING 3-PHASE CIRCUIT

3-5 Lamp Control and the Master Switch

Lamps are controlled by switch from a certain location illustrated as follows:

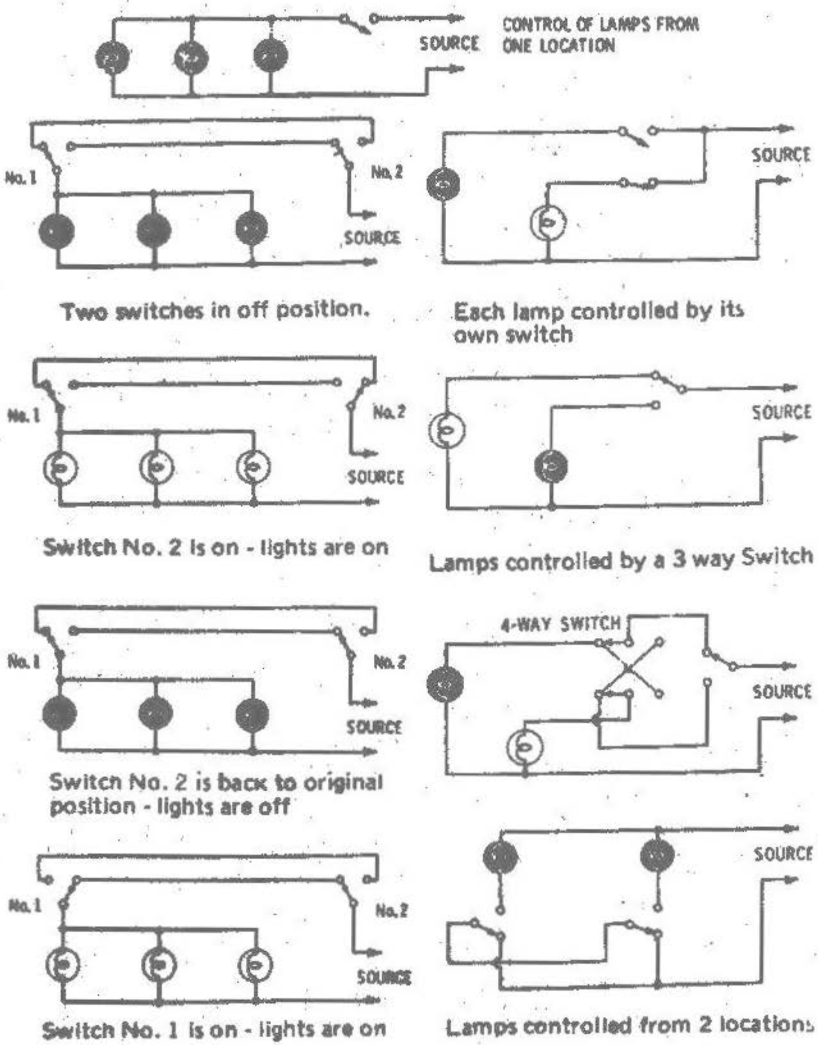
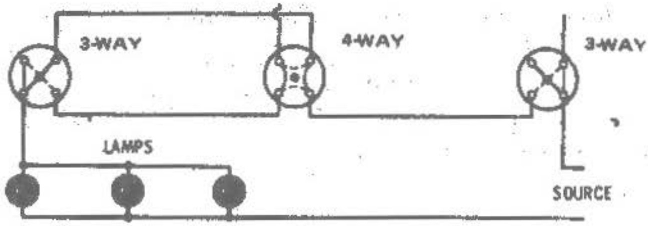
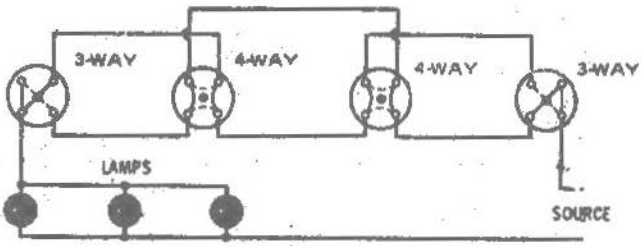


FIGURE 3-16

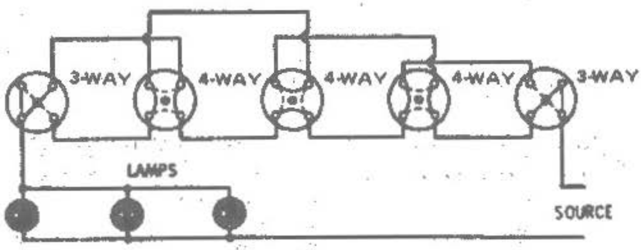


Two 3-way and one 4-way Switches
controlling lamps from 3 locations



Two 3 - way and two 4 - way
Switches controlling lamps from 4 locations

Four 4 - way switches to control lamps
from 4 locations



Two 3- way and three 4 - way
switches controlling lamps from 5 locations

FIGURE 3-17 LAMP CONTROL

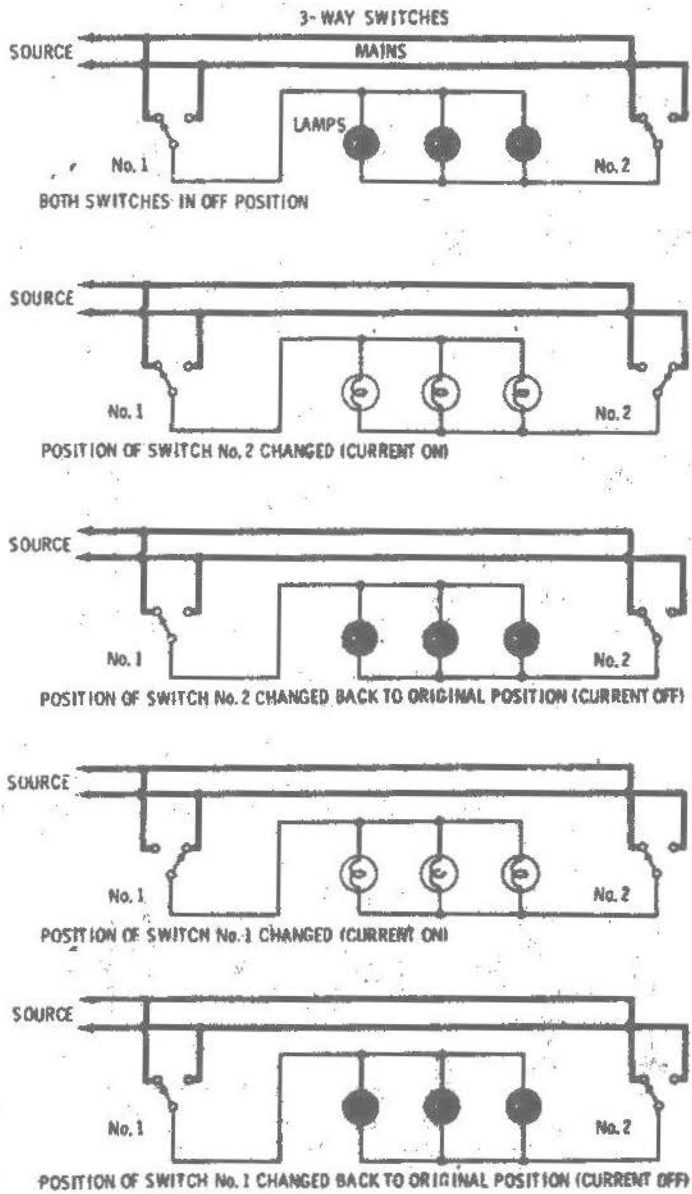


FIGURE 3-18 LAMP CONTROL

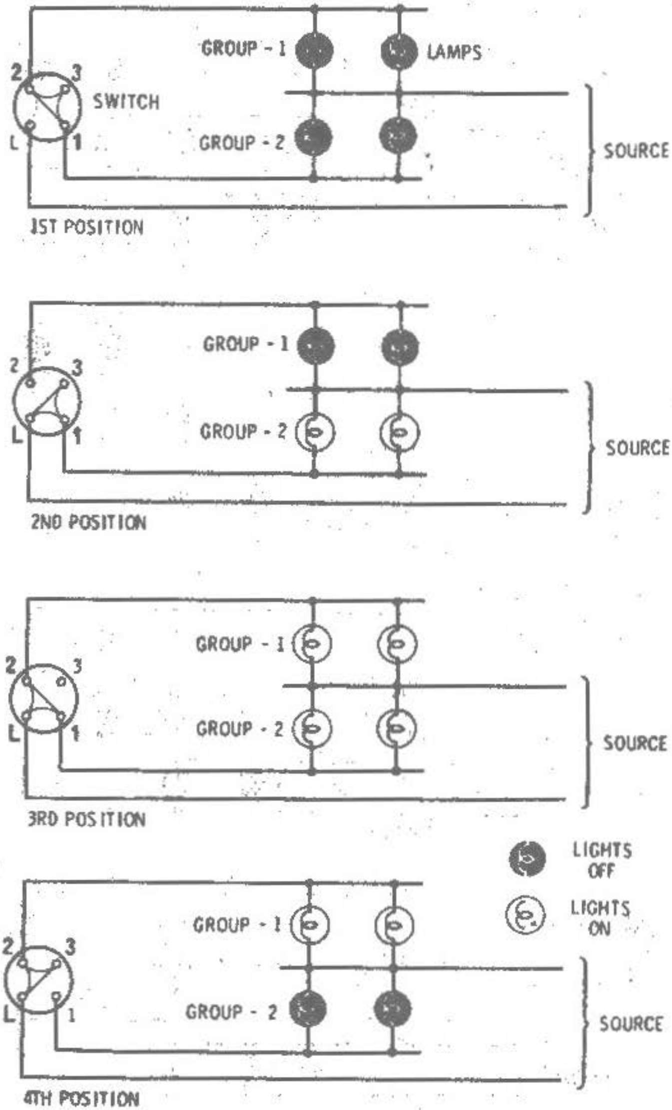


FIGURE 3-19 TWO ELECTROLOIR SWITCH ARRANGEMENT

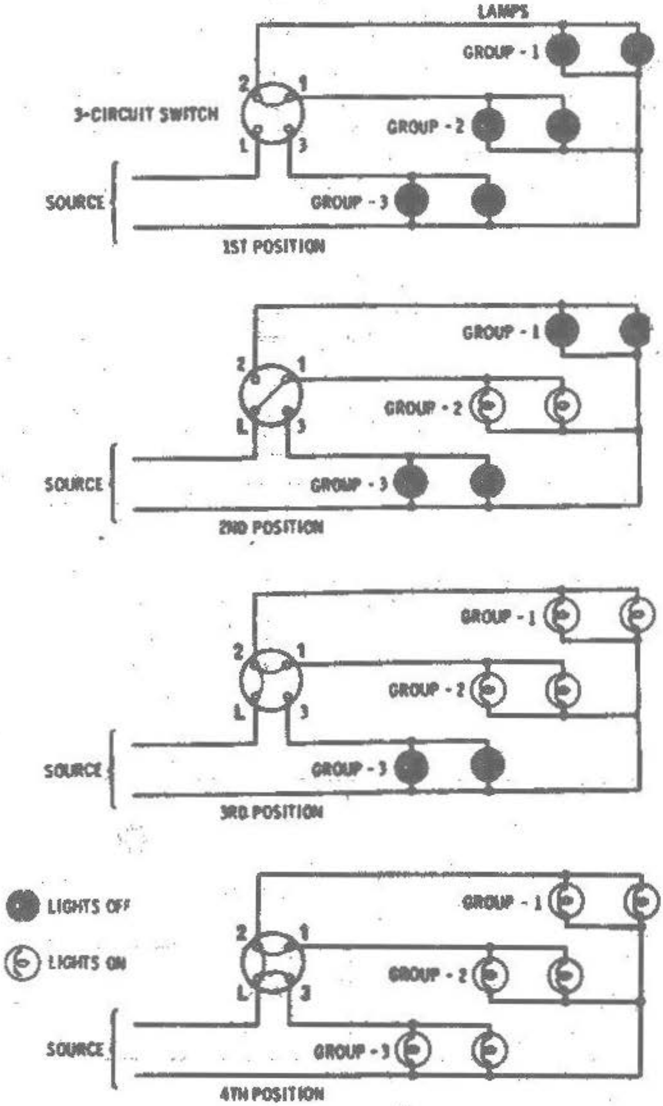
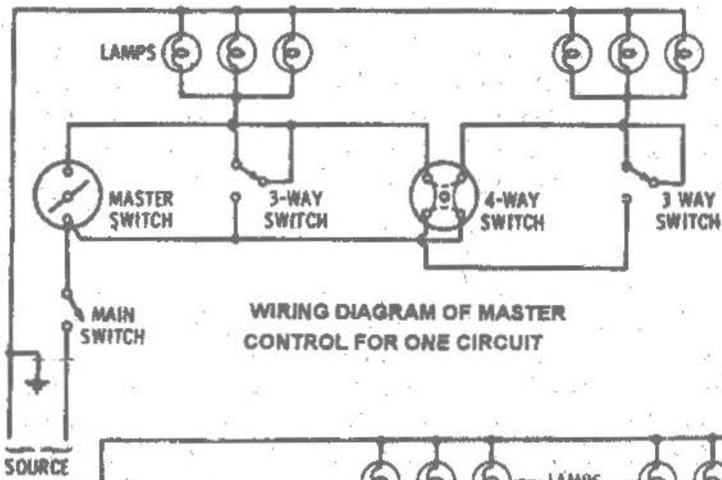
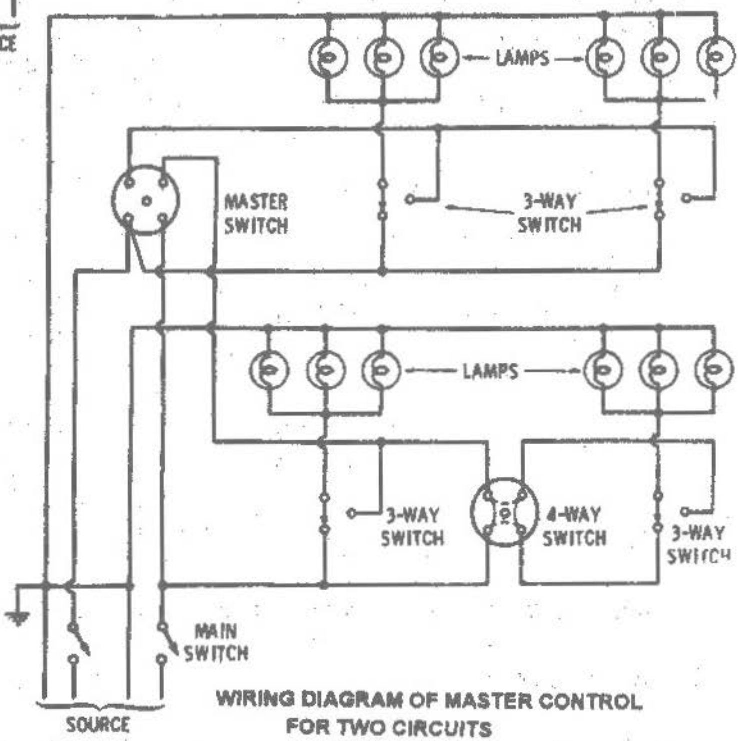


FIGURE 3-20 THREE CIRCUIT ELECTROLOIR SWITCH ARRANGEMENT



WIRING DIAGRAM OF MASTER CONTROL FOR ONE CIRCUIT



WIRING DIAGRAM OF MASTER CONTROL FOR TWO CIRCUITS

FIGURE 3-22 WIRING DIAGRAM OF MASTER CONTROL FOR 2 CIRCUITS

3-6 Emergency Electric Supply System

The National Electrical Code requires an entirely separate emergency standby electric supply system on commercial and industrial establishments. The concept of the emergency standby system is to replace normal power supply to selected or entire loads within the building in case of utility power outage.

The emergency standby source of electricity includes all devices, wirings raceways and other electrical equipment ready to supply electric power to the entire establishment or to a selected loads. These loads include egress light on stairs, doors, exit and lobby area. Signal equipment such as public address and fire alarm shall remain functional during the emergency and one or more elevators as required by the Code. The emergency electrical supply system could be arranged as follows:

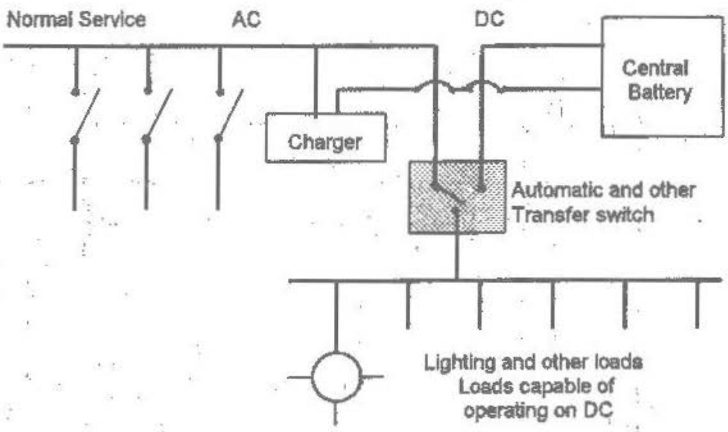


FIGURE 3-23 CENTRAL BATTERY BANK TO AC and DC LOAD

Battery Supplied

1. Storage batteries are connected to a converter to activate immediately in case of power outage to supply current to standby emergency lights.

2. Where all emergency loads could be supplied with direct current DC as in the following diagram, the same arrangement in Figure 3-23 could be adopted if alternating current AC is required.

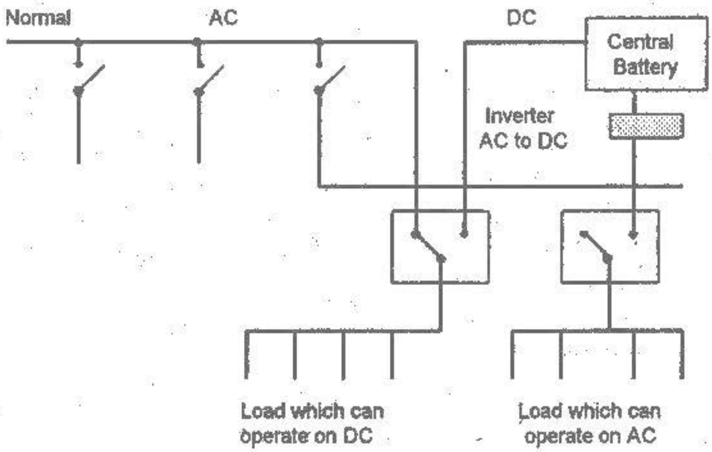


FIGURE 3-24 CENTRAL INVERTER IS USED WHEN AC AND DC CURRENT MUST BE SUPPLIED

3. When the emergency equipment is totally separated from the formal equipment and is normally de-energized, the following arrangement could be utilized.

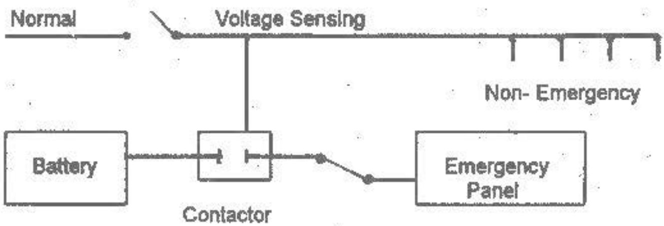
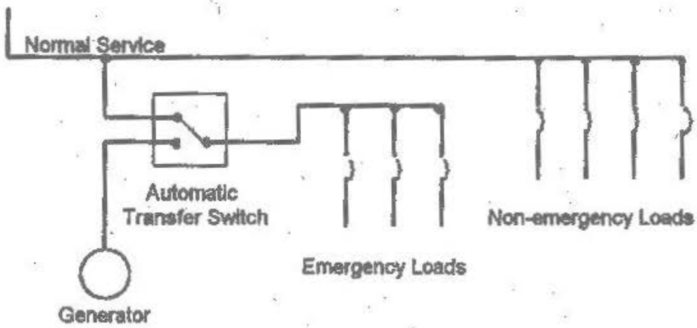


FIGURE 3-25

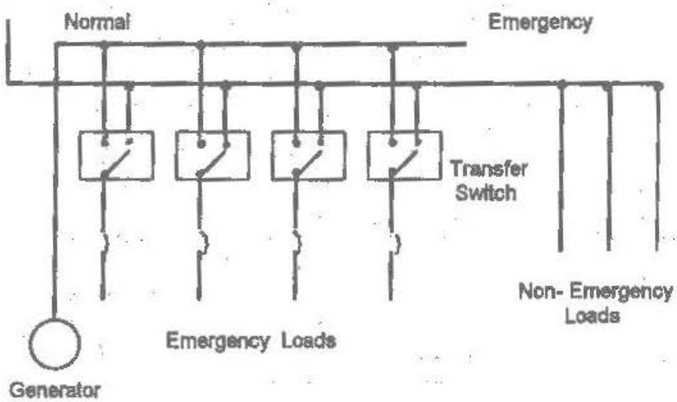
THE EMERGENCY LOADS ARE NORMALLY DE-ENERGIZED AND REACTIVATED THROUGH THE CONTACTOR WHEN IT SENSES POWER FAILURE

Current Supply by Generator

Where emergency loads are large enough that batteries could not be economically feasible, and where 8 to 15 seconds starting time is tolerable, a generator set is employed.



1. A single transfer switch serves the normal power transfer to the generator in case of power failure.

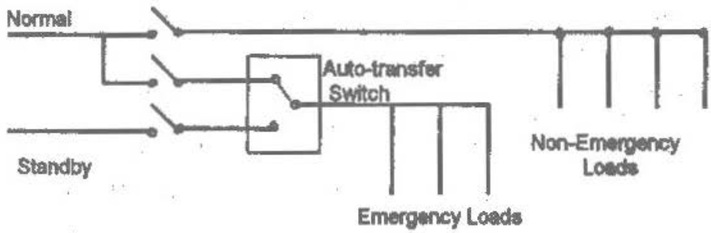


2. The entire emergency power system should be protected by adopting a smaller transfer switching device to reduce the chance of a single equipment failure faulting.

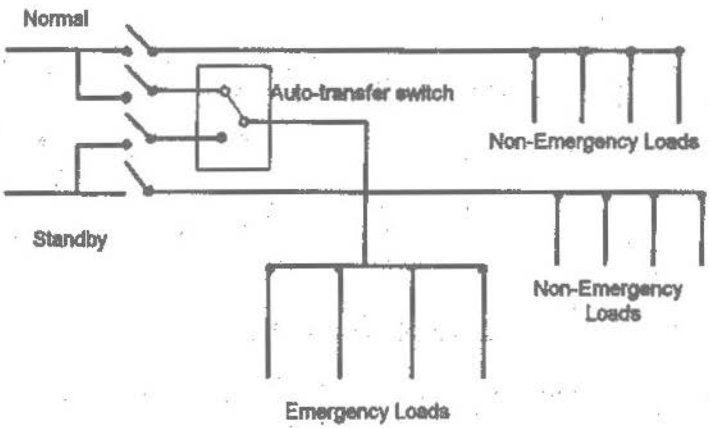
FIGURE 3-26 ALTERNATE ARRANGEMENT OF EMERGENCY NORMAL POWER SUPPLY

Two Separate Electric Services

The National Electrical Code allows the use of two separate electric services. One for normal, and the other for emergency source, provided that, they are independent coming from different utility transformers or feeders entering the building at different points and directions using separate service drops.



ONE SERVICE ACTS ONLY AS STANDBY



BOTH SUPPLY NORMAL LOADS AND EACH ACT AS STANDBY FOR EACH OTHER

FIGURE 3-27 EMERGENCY POWER SUPPLIED BY DUAL SERVICE

ELECTRICAL LAYOUT AND ESTIMATE

SYMBOL LIST

	Outlet and fluorescent fixture ceiling/wall mounted
	Outlet Box with blank cover
	Junction Box with blank cover
 2	Duplex Convenience Receptacle Outlet wall mounted .30 m. from floor line.
 3	Triple Outlet as above
 A	15 A 2P 2W or 3W GFCI Duplex outlet.
	20 A 2P 2W or 3W Single/ Duplex outlet
 B	30 A 125/250 V 3P 4W GND.
 C	60 A 125/250 V 3p 4W GND.
	Clock Hanger Outlet 2.25 m. from flr. line
Sa	Single Pole Switch 15 A 220 V 1.25 m. ht. Letter shows outlets controlled.
S_3	Three Way Switch 15A 220 V 2.25 m. from flr. line
S_4	Four Way Switch, as above
S_{DP}	Double Pole Switch, as above
S_K	Key Operated Switch, as above
S_T	Switch with Thermal Element suited for Motor.
	Combination Switch and Receptacle in 2 gang box
	Combination Switch and Dimmer

CHAPTER 4

ELECTRICAL CIRCUIT IN BUILDING

4-1 Service Entrance

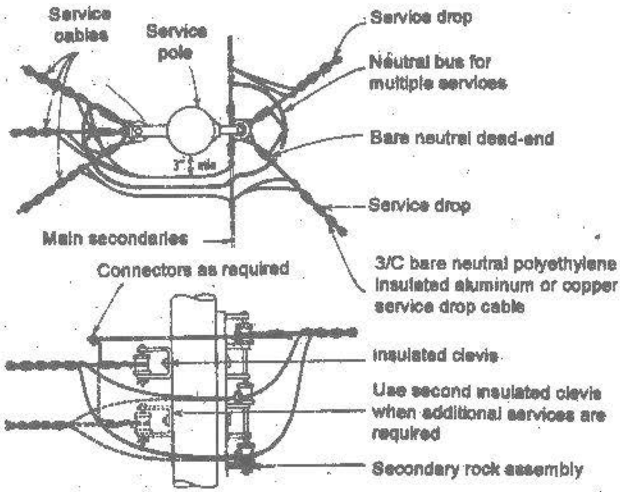
The **Service Entrance** is defined as that portion of the supply conductors which extends from the street main duct or transformer to the service or switchboard of the building supply. The National Electrical Code (NEC) defined service entrance as: ***"The conductor and equipment for delivering energy from the electricity supply system to the wiring system of the premises served."***

Service Entrance is either:

1. Overhead service
2. Underground service

The **Overhead Service Entrance** is the common type of service wire installed by electric power supply companies for industrial, commercial, and residential houses. A service drop, is connected from the nearest utility pole to the building service entrance point and enter the building through the weather head, down to the electric power meter.

The **Underground Service Entrance** consists of a raceway (conduit) extending from the building to the property line where it is tapped to the main. The cable recommended for underground service entrance is the USE type (*Underground Service Entrance)* cable. A low voltage cable is not advisable for installation in a concrete enveloped raceway, except, when the service equipment is not at the point at which the underground run meets the building.



ARRANGEMENT OF SECONDARY CABLE

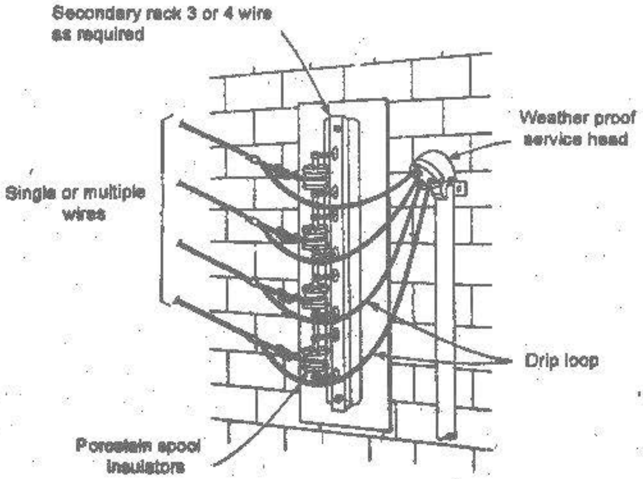
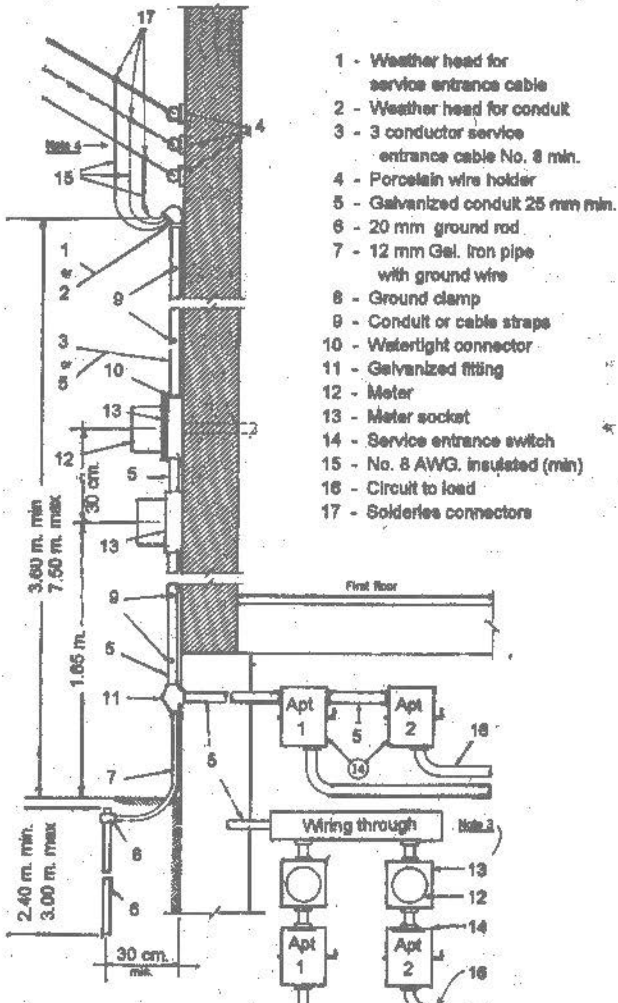


FIGURE 4-1 OVERHEAD SERVICE ENTRANCE



Notes:

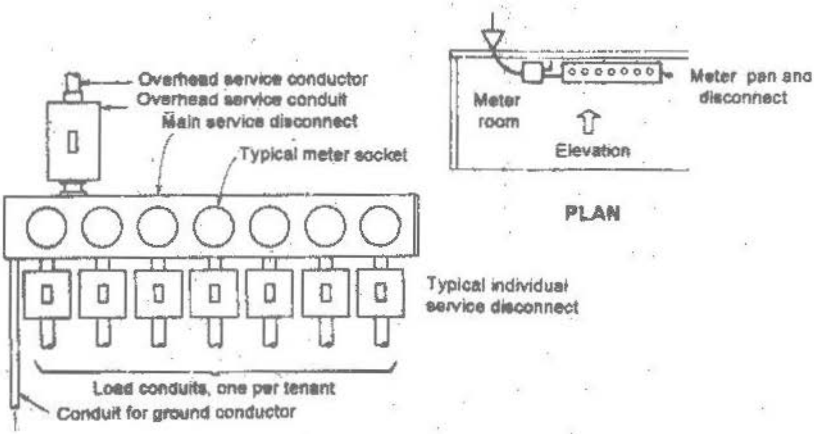
1. Omit item #10 if conduit is used.
2. Cold water pipe ground may be used in lieu of ground rod.
3. Meters may alternatively be placed inside the building.

FIGURE 4-2 UNDERGROUND SERVICE ENTRANCE

Most of buildings Service Entrances are connected to the secondary line low voltage below 600 volts. The Service entrance can be 2, 3, or 4 wires including a grounded neutral wire. Service entrance may be 2 wires of 120/240 volts or 4 wires with 120/208 or 277/480 volts for larger installations. In each case, the size of the service wire varies from 60, 100 or 200 amperes depending upon the demand load, but generally, the 2 wire service entrance, does not exceed 60 amperes.

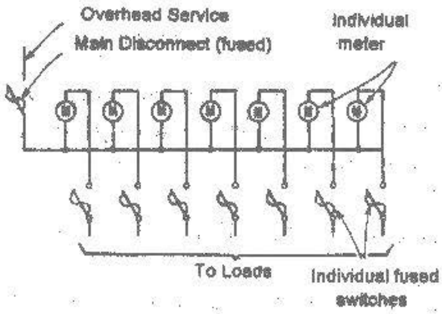
4-2 Electric Service Metering

Electric Meter is generally installed outside the building at the property line wall, or electric post for ready access to the meter reader, making it more difficult to tamper or to install jumpers. For multi-door services such as apartments and commercial establishments, the use of a master metering is preferred. A battery of meters are installed in a central meter room or reserved space, to facilitate the meter reading and making it a one stop affair.



ELEVATION OF PHYSICAL ARRANGEMENT

FIGURE 4-3 METERING FOR MULTI-OCCUPANCY BUILDING



ONE LINE DIAGRAM

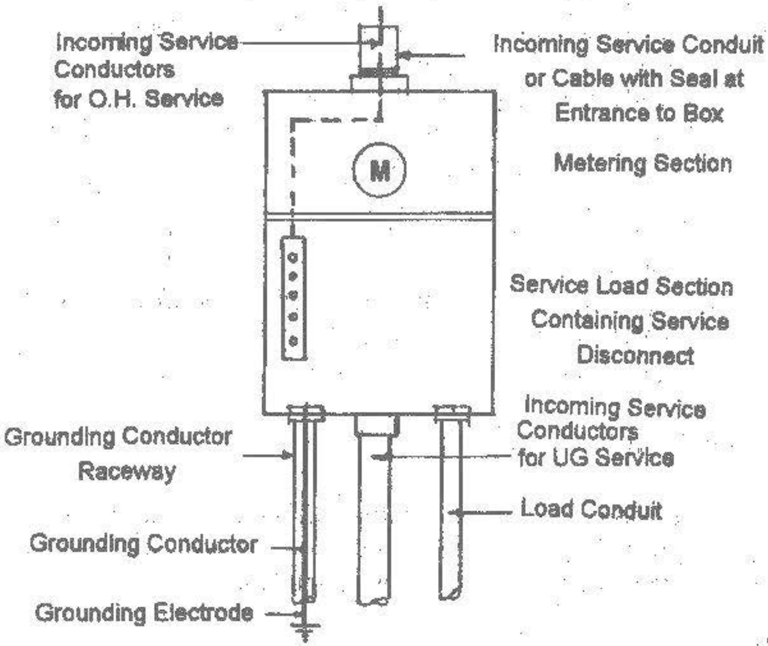


FIGURE 4-4 COMBINATION METER AND SERVICE CABINET FOR OVERHEAD OR UNDERGROUND SERVICE

The Feeder

The National Electrical Code define Feeder as;

"All circuit conductors between the service equipment or the generator switchboard of an isolated plant, and the final branch circuit over current device."

Feeder is installed under the following considerations:

1. On large installation, each floor is provided with one feeder.
2. In small installation, 1 or 2 feeders is satisfactory.
3. Feeder for electrical motor shall be independent and totally separated from the light circuits.
4. Feeders requiring more than 50mm (2") diameter conduit pipe should not be used.
5. Feeders shall be sub-divided if there are several bends or offsets on the line. A 50 mm conduit pipe is the largest diameter that could be economically used.
6. Feeders radiating from the distribution panel, shall be provided each with a properly rated switch and circuit breaker.
7. Good practice dictates that, feeders and main shall be installed inside a conduit pipe as it carries high voltage that requires special protection.

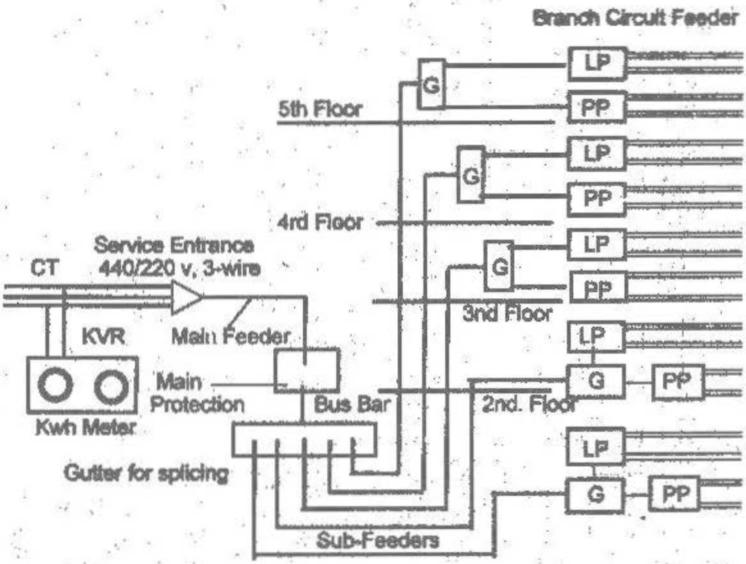
The Main

The Main is a feeder interior wiring extending from the service switch, generator bus, or converter bus, to the main distribution center or electric service equipments.

Location of the Service Equipment

1. The Service Equipment should be centrally located to shorten all home runs. Branch circuit run in excess of 30 meters will have an excessive voltage drop.

2. Accessible and convenient to approach.
3. In residential houses, it is located near the heaviest load center such as the kitchen and the laundry area.



LP - Lighting Panel
PP - Power Panel
G - Gutter
CT - Current Transformer

FIGURE 4-5

MAIN AND SUB-FEEDER

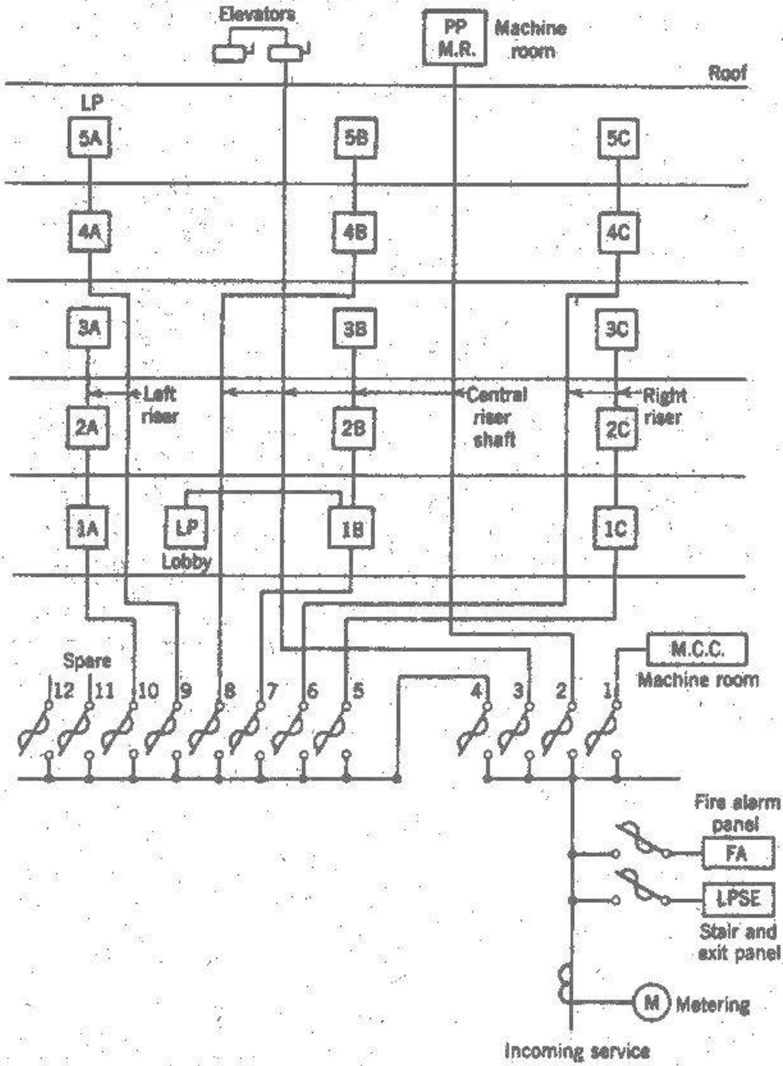


FIGURE 4-6 TYPICAL POWER RISER DIAGRAM

4-3 Single and Three Phase Electricity

The Three Phase AC electricity, is a **Triple Circuit**. The lighting and outlet loads are connected between any phase leg and a neutral line. Machineries and other bigger loads are connected to the phase leg only. The three phase system, is used in buildings where the loads exceed 50 Kva., or where it is required for bigger load such as motors and machineries.

The neutral conductor of a three phase system, although common to all three lines, only carries the *unbalanced current*. Thus, the ***neutral conductor carries no current when loads on both sides of it are balanced.*** Meaning, if the two legs carries the same load of say 120 volts, the neutral line is **zero** voltage.

A Single Phase alternating current (AC) can either be 2 or 3 wires. However, a 3 phase AC has 3 or 4 wires consisting of 3 hot legs designated as A, B and C plus a neutral wire designated with letter N. The common electrical circuit serving residential building is the two wires receptacle circuit that feeds the ceiling and the wall plug. The service entrance is sometimes 3 wires circuit written as, **3-wire 120/240 volt 60 hertz.**

Advantages of the Three Phase System

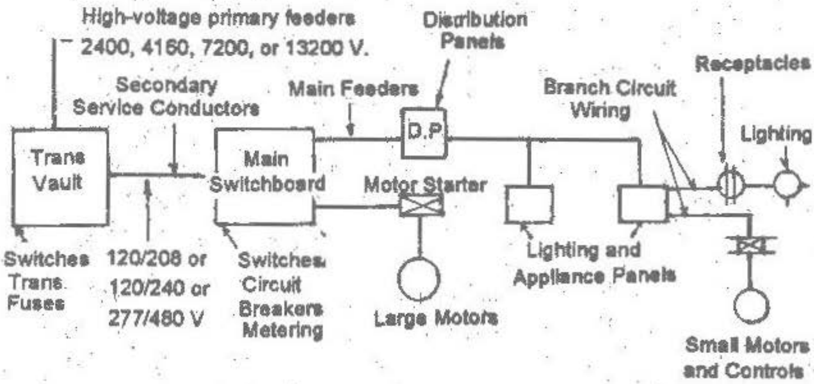
1. The 120 volt is for lighting and receptacles outlet only.
2. The 240 volt is for bigger loads.
3. Voltage drop is lower.
4. Smaller wire is used.

The size of a service conductor is based on the 240 volts rather than on 120 volts line. Smaller wire is used because the size of a conductor serving 240 volt is comparatively smaller than the 120 volts line serving the same amount of load.

The 3-Phase Conductor Wires are Color Coded

a) Neutral......................White or gray color
b) First Hot line A..............Black color
c) Second Hot line B...........Red color

The neutral conductor wire carries no current when the load on line A and B are equal. Since the neutral line is grounded, it is at a neutral zero potential being ½ way in voltage between the hot line A and B.



Typical one line diagram of a building electrical system from the incoming service to the utilization items.

FIGURE 4-7 BLOCK DIAGRAM

This type of presentation is called **Block Diagram** wherein the major components are represented by rectangles or blocks. When this type of data is presented showing the spatial relations between components, it is called **Riser Diagram.** When electrical symbols are used instead of blocks, it is called **One Line** or a **Single Line Diagram.**

Power Service

1. The 120 volts single phase, 2-wire up to 100 amperes is commonly used for small dwellings. The capacity of a 100 amperes service of this type is:

$$Kva = \frac{100 \text{ amp} \times 120v}{1000}$$

$$= 12 \text{ Kva maximum}$$

2. The 120/240 volt single phase, 3-wires up to 400 amperes is used for residential and small commercial services. The maximum power is:

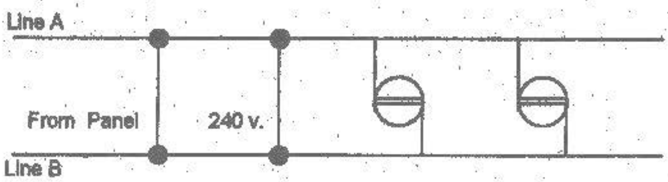
$$\text{Kva} = \frac{400 \text{ amp} \times 240 \text{ v}}{1000} = 96 \text{ Kva}$$

3. The 120/208 volt 3-phase 4-wires with a maximum load not to exceed 2,500 amperes is the normal urban 3-phase service for commercial buildings. The maximum power is:

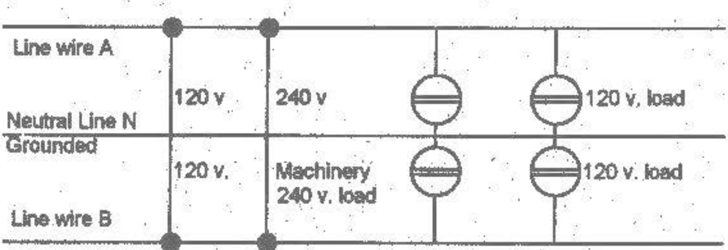
$$\text{Kva} = \frac{\sqrt{3} \times 208 \times 2500}{1000} = 900 \text{ Kva}$$

4. The 277/480 volt, 3-phase 4 wires with a load not to exceed 2500 amperes is a service for commercial and industrial buildings with larger loads and heavy motors. The maximum power is:

$$\text{Kva} = \frac{\sqrt{3} \times 480 \times 2500}{1000} = 2000 \text{ Kva}$$

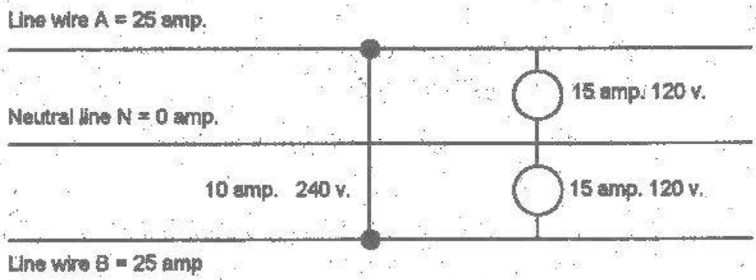


Typical convenience receptacle circuit wall plug



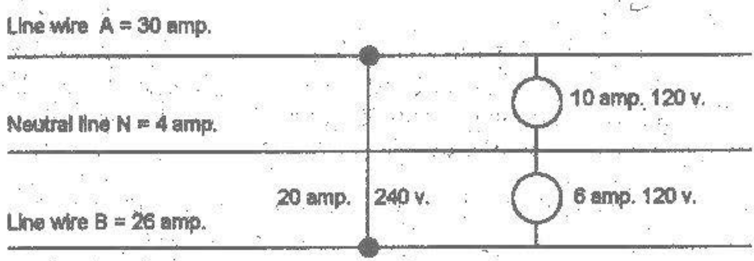
3- wire 120/240 v. arrangement common to residential and other small buildings. A combination of a 2120 v and 240 v. c.o.

FIGURE 4-8



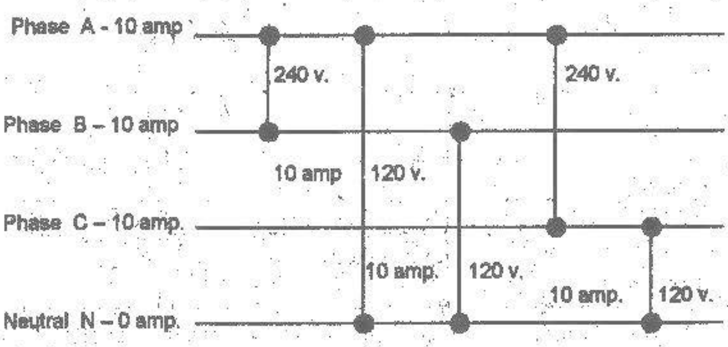
The neutral line carries no current when the 120 v. load of a 3-wire system are balanced. Line A and B carries the entire load.

FIGURE 4-9



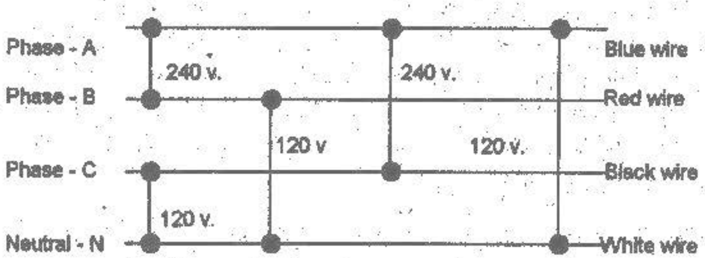
This is a single phase AC with 3-wires 120/240 volts circuit. The neutral line only carries the difference between the 120 v. loads on the 2 line wires.

FIGURE 4-10



In 3-phase system, the Neutral line carries the unbalance current only

FIGURE 4-11



This is a typical 3-phase wiring system indicating phase to neutral voltage. It has 3-single phase circuits with one common return wire.

FIGURE 4-12

System and Utilization Voltage

The **System Voltage** is the power supplied by company like Meralco and Electric Cooperative or what the transformer produces. **Utilization Voltage** on the other hand, is the current being utilized after some normal voltage drop.

Electric Motors are rated at Utilization Voltage. Transformer is rated at 240/480 volt and an electric motor is 230/460 volts respectively, and to indicate that a motor is rated at 480 volts is not correct. Motors for 208 and 240 volts systems are rated at 200 and 230 volts and so on. They cannot be used interchangeably without serious effect on the motor performance. Thus, ***when specifying transformer, use the system voltage.*** For ***electric motors use utilization voltage.*** The 4% utilizations voltage drop is within the normal motor tolerance.

TABLE 4-1 SYSTEM UTILIZATION STANDARD VOLTAGE

System Voltage Transformer		Utilization Voltage Motors	
Normal	With 4% drop	New Standard	Old Standard
120	115.2	115	110
208	199.7	200	208
240	230.4	230	220
480	460.8	460	440
600	575.0	575	550

The new trend in power supply system is to avail of a higher voltage level at all points. The old current supply system was lately improved by increasing the voltage. This improvement was due to the advance technology of insulating materials and the new technique of construction that permit the raising up of the voltage level.

The 345,000 volts (345 Kva) and the 500 Kv are now common, and the voltage up to 750 Kv are already much in used. With regards to the distribution level, the 13200 volts (13.2 Kv) is fast replacing the 4160 volts while the 46 Kv is replacing the 23 Kv. This higher voltage supply of current from the distribution line was improve to 120/240 volts replacing the 110/220 volts supply system for safety reasons of the house panel circuitry, appliances, and equipment. One example is the distribution line of the electric cooperative popularly known as Multi Ground System to be presented at the later part of this book.

4-4 Grounding and Ground Fault

The National Electrical Code (NEC) defines **Ground** as **Zero Voltage**. The purpose of grounding the circuit is to fix permanently a zero voltage point in the system. The grounded line of a circuit ***should not be broken nor fused*** to maintain a solid and uninterrupted connection to the ground. An established ground automatically becomes the reference for all voltage in the system.

Grounding Could be Accomplished by:

1. Connecting to a buried cold water main
2. Connecting to a ground rod
3. Connecting to a buried ground plate.

The Code requires that, ***"All new installations shall use grounded outlets such as; GFI and GFCI devices on all appliance circuits more particularly on outdoors and bathroom locations of outlets."***

Reasons for Grounding the Circuit System

1. To prevent a sustained contact between the low voltage secondary line and the high voltage primary line in case of insulation fire.
2. To prevent single grounds from being unnoticed or detected until a second ground occurs which could totally disable the secondary line.
3. To facilitate in locating the ground faults.
4. To protect against a short sudden rush of electric current in the circuit.
5. To establish a neutral at zero potential not to be interrupted by switches or other devices.
6. To connect the service entrance to ground only at one point and to use colored wires for easy identification.

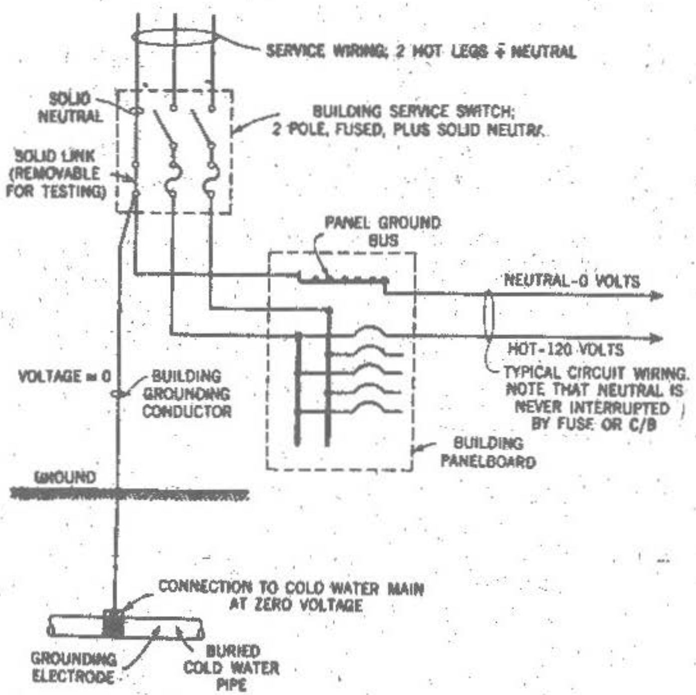


FIGURE 4-13 SERVICE GROUNDING

4-5 Circuit Safe Load

Branch Circuit is the technical term for the ***House Wiring Installation***. House wiring varies in sizes depending upon the kind of load it is to serve. **Load** refers to the electricity drawn or consumed by lighting fixtures, appliances, equipment etc.

The problem confronting the technologist is how to determine the types of wire to be used, their sizes and other appurtenances relative to its installation. These problems however, has been addressed by the National Electrical Code under the following specific provisions:

1. The Code provides that wirings for electrical circuitry shall be of the types RHW, T, THW, TW, THWN, XHHW in a raceway or cables as presented on Table 2-5
2. That, on a 15 amperes circuit, a single appliance shall not draw a maximum load of more than 12 amperes.
3. That, on a 20 amperes circuit, a single appliance shall not draw current in excess of 16 amperes.
4. That, if a branch circuit is combined with lighting or portable appliances, any fixed appliance shall not be allowed to draw more than 7.5 amperes on a 15 amperes circuit and 10 amperes on a 20 amperes circuit.
5. That, on a 30 amperes circuit, a single appliance draw shall not exceed 24 amperes.
6. That, a heavy lamp holders shall be rated not less than 750 watts.
7. That, a 30, 40 and 50 amperes circuit shall not be used for fixed lighting in residences.
8. That, when loads are connected for a long period of time, its actual load shall be computed not to exceed 80% of the fuse rating. Long period of time refers to

electric motors, air conditioner, and other similar units with a continuous loading.

9. That, a continuous type load shall be considered at 125% of the actual load in all load calculations.

10. That, a single receptacle on individual branch circuit shall have a rating of not less than the circuit.

11. Receptacles feeding portable and or steady appliance shall be limited to loads of 80% of their rating, that is:

    a. 12 amperes for a 15 amperes receptacle
    b. 16 amperes for a 20 amperes receptacle
    c. 24 amperes for a 30 amperes receptacle

12. The number of outlets in a circuit shall be limited to:

    6 outlets on a 15 ampere circuit
    8 outlets on a 20 ampere circuit

Comments:

A 15 or 20 amperes circuit refers to the branch circuit or wiring installation. The protective device has to open in case of over current or fault before the wiring circuitry is damaged. Thus, fuse rating should be lower than the allowable ampacity of the wire, except on No. 14, 12, and 10 AWG conductors were the load current rating and the over current protection shall not exceed 15, 20 and 30 amperes respectively.

If 16 amperes is allowed to be drawn by a single appliance on a 20 amperes circuit, it simply mean that, the 4 amperes difference is 20% safety factor provided by the Code. To find the wattage or maximum load equivalent to 16 amperes on an outlet for a single appliance load we have:

Watt or Power = Voltage x Ampere

W = 240 x 16 amp.

= 3,840 watts

TABLE 4-1 STANDARD AMPERE RATING FOR FUSES AND CIRCUIT BREAKER

Fuse / Breaker Rating	Receptacle Rating (Amp)	Maximum Load (Amperes)	
		Non-Continuous	Continuous
15	Not over 15	12	8
20	15 or 20	16	
25			
30	30	24	12
35			
40	40 or 50	32	
45			
50	50	40	20
60		48	24
70		56	28
80		64	32
90		72	36
100		80	40
110		99	44
125		100	50
150		120	60
175		140	70
200		160	80
225		180	90
250		200	100
300		240	120
350		280	140
400		320	160
450		360	180
500		400	200
600		480	240
700		560	280
800		640	320
1000		800	400
2000		1600	800
3000		2400	1200

* Continuous Load : Motor, Air Conditioning Unit etc.

TABLE 4-1a MAXIMUM NUMBER OF CONDUCTORS IN TRADE SIZES OF CONDUIT TUBING

Conduit Trade Size Millimeters		15	20	25	32	40	50	65	80	90	100	115	125	150
Type Letters	Conductor size mm^2 (mm dia.)													
TW, T, RUH, RUW, XHHW [2(1,6) thru 8(3.2)]	2.0 (1.6)	9	15	25	44	60	99	142						
	3.5 (2.0)	7	12	19	35	47	78	111	171					
	5.5 (2.6)	5	9	15	26	36	60	85	131	176				
	8.0 (3.2)	2	4	7	12	17	28	40	62	84	108			
RHW and RHH (without outer covering) THW	2.0 (1.6)	6	10	16	29	40	65	93	143	192				
	3.5 (2.0)	4	8	13	24	32	53	76	117	157				
	5.5 (2.6)	4	6	11	19	26	43	61	95	127	1673			
	8.0 (3.2)	1	3	5	10	13	22	32	49	66	85	106	133	
TW, T THW, RUH (14 - 30) RUW (14 -30)	14	1	2	4	7	10	16	23	36	48	62	78	97	141
	22	1	1	3	5	7	12	17	27	36	47	58	73	106
	30	1	1	2	4	5	9	13	20	27	34	43	54	78
	38		1	1	3	4	6	9	14	19	25	31	39	57
	50		1	1	2	3	5	8	12	16	21	27	33	49
FEPB (14 -30) RHW and RHH (without Covering)	60		1	1	1	3	5	7	10	14	18	23	29	41
	80		1	1	1	2	4	6	9	12	15	19	24	35
	100			1	1	1	3	5	7	10	13	16	20	29
	125			1	1	1	2	4	6	8	10	13	16	23
	150			1	1	1	2	3	5	7	9	11	14	20
	200				1	1	1	2	4	5	7	9	11	16
	250				1	1	1	1	3	4	6	7	9	14
	325					1	1	1	3	4	5	6	7	11
	400					1	1	1	2	3	4	5	6	9

TBLE 4-2 ALLOWABLE AMPACITIES OF INSULATED CONDUCTORS RATED 0-2000 VOLTS, 60^{O} TO 90^{O} C

Not more than three conductors in raceway or cable or directly burried based on Ambient Temperature

SIZE	TEMPERATURE RATING OF CONDUCTORS								SIZE
	60°C	75°C	85°C	90°C	60°C	75°C	85°C	90°C	
	TYPE	TYPE	TYPE	TYPE	TYPE	TYPE	TYPE	TYPE	
mm² mm (dia.)	RUW T TW UF	FEPW RH RHW RHU THW THWN XHHW USE ZW	V MI	TA TBS SA AVB SIS *FEP *FEPB *RHH *THHN *XHHW	RUW T TW UF	RH RHW RUH RHW THWN XHHW USE	V MI	TA TBS SA AVB SIS *RHH *THHN *XHHW	mm² mm (dia.)
	COPPER				ALUMINUM OR COPPER CLAD ALUMINUM				
2.0 (1.6)	15	15	25	25	-	-	-	-	-
3.5 (2.0)	20	20	30	30	15	15	25	25	3.5 (2.0)
5.5 (2.6)	30	30	40	40	25	25	30	30	5.5 (2.6)
8.0 (3.2)	40	45	50	50	30	40	40	40	8.0 (32)
14	55	65	70	70	40	50	55	55	14
22	70	85	90	90	55	65	70	70	22
30	90	110	115	115	70	85	90	90	30
38	100	125	130	130	80	95	100	100	38
50	120	145	150	150	95	115	120	120	50
60	135	160	170	170	105	125	135	135	60
80	160	195	205	205	125	150	160	160	80
100	185	220	225	225	145	170	180	180	100
125	210	255	265	265	170	200	210	210	125
150	240	280	295	295	190	230	240	240	150
200	280	330	355	355	225	270	290	290	200
250	315	375	400	400	260	305	330	330	250
325	370	435	470	470	295	355	380	380	325
400	405	485	515	515	330	395	420	420	400
500	445	540	580	580	370	440	475	475	500
	Correction Factor								
Ambient Temp °C	For Ambient temperature over 30o C, multiply by ampacities shown above by the appropriate correction factor to determine the maximum allowable load current.								
31°-40°	.82	.88	.90	.91	.82	.88	.90	.91	31°-40°
41-50	.58	.75	.80	.82	.58	.75	.80	.82	41-50
51-60		.58	.67	.71		.58	.67	.71	51-60
61-70		.35	.52	.58		.35	.52	.58	61-70
71-80			.30	.41			.30	.41	71-80

4-6 Sizing the Conductor Wires and the Over Current Protective Devices

Under this topic, the sizes of the branch circuit wires and its housing conduits plus the over current protective device or fuse will be determined based on the load it will serve. A sketch plan of the convenience outlets, lightings and their switches should be prepared. The expected load is computed, and the number of circuit necessary for the lights, convenience outlet, appliances and others are determined.

TABLE 4-3 GENERAL LIGHTING LOAD BY OCCUPANCY

Type of Occupancy	Unit Load Watts per Sq. M.
Armories and auditorium	8
Banks	40
Barber shop and beauty parlor	24
Churches	8
Clubs	16
Court rooms	16
Dwelling units	24
Garages-commercial storage	4
Hospitals	16
Hotels, motels and apartment (no provision for cooking by tenants)	16
Industrial commercial loft building	16
Lodge room	12
Office building	40
Restaurant	16
Schools	24
Stores	24
Warehouse (storage)	2
Assembly halls and auditorium	8
Halls, corridors, closets	4

All receptacles outlets of 20 amperes or less rating in one family and multi-family dwellings and in guest rooms of hotels and motels except those connected to the receptacle circuits specified in Sec. 3.3.13 (b) of the Code shall be considered as outlets for general illumination and no additional load calculations shall be required for such outlets

ILLUSTRATION 4-1

SINGLE FAMILY DWELLING

Type of Service – 230 Volts;
Single Phase – 2 Wire 60 Hz.
Line to Ground Current System

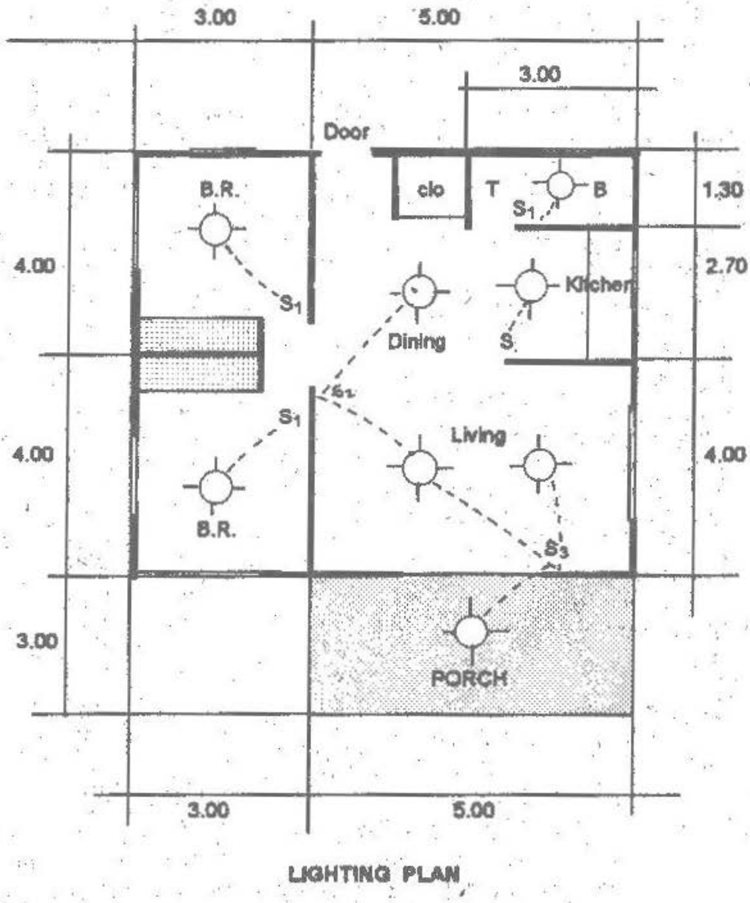


FIGURE 4-14 LIGHTING LAYOUT

PROBLEM 4-1

A single family dwelling is to be circuited with the following requirements as shown on Figure 4-14.Determine the :

a. Size of the branch circuit wire for lighting outlets.
b. Size of the conduit pipes.
c. Size or rating of the fuse protective device

SOLUTION

A. Circuit –1 for Lighting Load

1. From Figure 4-14, determine the number of lighting outlets. By direct counting, there are 8 light outlets.

The National Electrical Code provides that:

"100 watts shall be the maximum load for each household lighting outlet."

Adopting the 100 watts per lighting outlet we have:

8 outlets x 100 = 800 watts

2. *Determine the Total Current load*

$$\frac{800 \text{ watts}}{230 \text{ volts}} = 3.48 \text{ amperes}$$

3. ***Determine the Size of Conductor wire*** for Circuit -1. Refer to Table 2-5 or Table 4-2. Use 2 pieces 2.0 mm^2 or No.14 TW copper wire having an ampacity of 15 amperes that is much larger than the 3.48 amperes computed maximum load.

4. ***Determine the Size of the Conduit Pipe***. Refer to Table 2-9. The smallest diameter of a conduit pipe that could accommodate up to 3 pieces of No. 14 TW conductor wire is 13 mm diameter. Therefore, specify 13 mm diameter conduit pipe.

5. ***Determine the Size or Rating of the fuse protective device***. Refer to Table 4-1. ***Use 15 amperes fuse***.

The National Electrical Code provides that:

> *"Ampacity of the connected load shall not exceed 80% of the amperage capacity of the conductor and the fuse."*

In Table 2-5 and 4-2, the maximum ampacity load of a 2.0 mm^2 or No.14 AWG copper wire is 15 amperes. 80% of 15 amperes is 12, the maximum allowable load of the circuit sufficient enough to carry the 3.48 amperes computed load for a maximum 100 watts per light outlet. Therefore, the use of 2.0 mm^2 or No. 14 TW wire is safe.

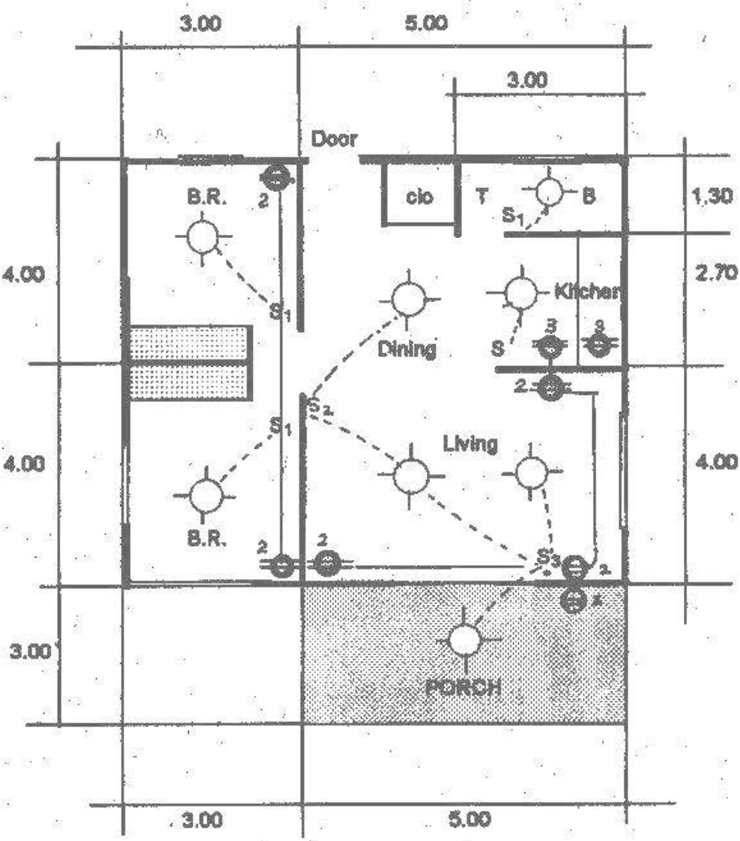


FIGURE 4-15 CONVENIENCE OUTLET LAYOUT

B. Circuit – 2 For Small Appliance Load

SOLUTION

The National Electrical Code provides that:

"For each single receptacle shall be considered at no less than 180 watts rating."

It simply mean that, ***each convenience outlet,*** is considered ***to have a maximum load of not less than 180 watts per plug or gang***. Thus:

1. From Figure 4-15, there are 6 convenience receptacles for small appliance load. Considering that there are two plug per outlet, the total number of plug will be:

   6 outlets x 2 plug = 12 pieces

2. Solve for the ***Total Estimated Load***.

   12 x 180 watts per outlet = 2,160 watts

3. Determine the ***Maxmum Expected Current Load***.

   $$\frac{2{,}160 \text{ watts}}{230 \text{ watts}} = 9.39 \text{ amperes}$$

4. Determine the ***Size of the Conductor Wire***. Refer to Table 4-2. For 9.39 amperes, use 2 pieces 3.5 mm^2 or No.12 TW copper wire for Circuit No 2.

5. Determine the ***Size of the Conduit Pipe*** for the 2-No. 12 TW wire, refer to Table 2-9.Use 13 mm conduit pipe.

6. Determine the ***Over Current fuse Protection***. Refer to Table 4-1. Under the column of fuse & breaker rating, the 20 amperes fuse can safely carry a maximum load of 16 amperes the 80% of 20 amperes load permitted by the National Electrical Code on No.12 circuit wire.

Comment:

1. On convenience outlet receptacle, the National Electrical Code provides that, "***Each single receptacle shall be considered at no less than 180 watts rating.***"

2. Examining the values given on Table 4-2, the 2.0 mm^2 or No.14 AWG, TW copper wire has an allowable ampacity rating of 15 amperes. Granting that only 80% of this 15 amperes is considered the derated value, still 12 amperes is very much larger than the 9.36 amperes computed as maximum load for the 6 convenience outlet. Why specify a bigger 3.5 mm^2 or No. 12 AWG conductor wire?

3. Although the 2.0 mm^2 or No. 14 AWG wire conductor could safety carry the 9.36 amperes computed load, considering its 15 amperes ampacity rating, yet, we cannot do so because the *Code specifically mandated* the use of a 3.5 mm^2 or No. 12 AWG copper wire as ***the minimum size for all types of convenience outlet wiring*** except, for an appliance with limited load wherein a 2.0 mm^2 or No.14 AWG wire is permitted

C. Circuit - 3 for Other Loads

SOLUTION

1. Examining Figure 4-15, other loads are:

   1- unit electric stove at 1.1 kw = 1,100 watts
   1- unit water heater at 2.5 kw = 2,500 watts
   Total load……3,600 watts

2. Compute for the ***current load***. Divide:

$$\frac{3{,}600 \text{ watts}}{230 \text{ volts}} = 15.65 \text{ amperes}$$

3. Determine the ***size of the service conductor wire***. Refer to Table 2-5 or 4-2.

4. For the 15.65 amperes load, use 2 pieces 3.5 mm^2 or No. 12 AWG, TW copper wire.

5. Determine the ***Size of the Conduit Pipe*** (if required). Refer to Table 2-9. Two pieces No. 12 AWG wire can be accommodated comfortably in a 13 mm diameter conduit pipe. Specify 13 mm diameter conduit pipe.

6. Determine the ***Size or Rating of the Over-current Protection***. Refer to Table 4-1. For the 15.65 amperes load use 20 amperes fuse rating.

Comment

The fuse rating is 20 amperes. Granting that it will be derated at 80% x 20, the 16 amperes derated value is still higher than the computed load of 15.65 amperes. Therefore, the 20 amperes fuse over current protection is accepted.

Finding the Size of Service Entrance

The size of service entrance being the supply conductor and equipment for delivering energy from the electricity supply to the wiring system of the building, is also computed based on the total load supplied by the branch circuit. Continuing the solution of illustration 4-1, we have the following:

1. Solve for the ***Total load of Circuit 1 to Circuit 3.***

$$\text{Total current load} = \frac{\text{Total connected load}}{\text{Voltage rating}}$$

$$\text{Total load} = \frac{800\text{ w} + 2{,}160\text{ w} + 3{,}600\text{ w}}{230\text{ volt}}$$

$$= 28.52\text{ amperes}$$

2. Apply 80% demand factor as permitted by the National Electrical Code.

28.52 x .80 = 22.8 amperes

3. Find the ***Size of the Service Wire***. Refer 22.8 amperes to Table 2-5. Use 2 - 8.0 mm^2 or No. 8 TW copper wire.

4. Determine the ***Size of Conduit Pipe*** for the service wire. Refer to Table 2-9, for No. 8 TW copper wire, use 20 mm diameter conduit pipe.

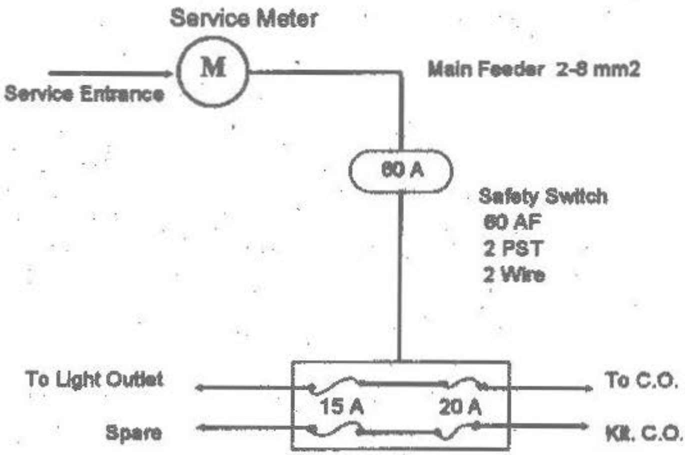


FIGURE 4-15 ONE LINE DIAGRAM

Comment

1. A demand factor of 80% was applied considering that ***not all receptacles and outlets are being used simultaneously*** (see Table 4-6).

2. These type of loads are classified as ***non-continuous load.*** From Table 4-2, the 5.5 mm^2 or No.10 AWG copper wire conductor has 30 amperes ampacity which is bigger than 22.8 amperes as computed. However, we do not specify the use of No.10 AWG wire because the ***Code limits the use of 8.0 mm^2 or No. 8 AWG, conductor as minimum size for Service Entrance.***

3. The National Electrical Code on Service Entrance provides that:

"Service entrance shall have sufficient ampacity to carry the building load. They shall have adequate mechanical strength and shall not be smaller than 8.0 mm² or 3.2 mm diameter except for installation to supply limited load of a single branch circuit such as small poly-phase power, controlled water heaters and the like and they shall not be smaller than 3.5 mm² or 2.0 mm diameter copper or equivalent."

The Main Disconnecting Means or Safety Switch

Find the total computed load.

Circuit – 1……	3.48 amperes
Circuit – 2……	9.39 amperes
Circuit – 3……	15.65 amperes
Total…….	28.52 amperes

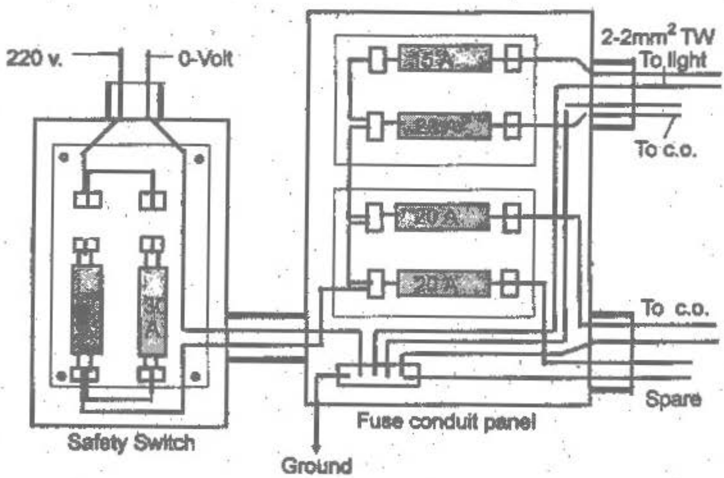


FIGURE 4- 17 SCHEMATIC RISER DIAGRAM

2. Use 2 pieces 30 amperes fuse parallel connection 60 amperes 2 pole single throw (PST) 250 volts safety switch.

3. Provide 2-double branch circuit cut out with two 15 and 2 - 20 amperes fuse respectively.

Multi-ground System and Line to Line Service

The protection of branch circuit is tapped to the hot line or live wire. The grounded line being neutral zero voltage, is not protected with fuse. This is one advantage of the ***Multi-ground System*** being adopted by the electric cooperative implemented by the Rural Electrification program of the government. The branch circuit and cutout could be doubled because the engaged voltage in the line is only 230 volts while the other is zero voltage being grounded (see figure 4-17).

Other electric service system on the other hand, are classified as ***Line to Line Service*** wherein the engaged voltage is 115/230 volts which ***requires fuse protection for both lines.***

Schedule of Load						Type of Service 230 volt, 2- wires 60 Hz.			
Ckt. No.	Load	No. of Outlets	Volts	Watts	Ampere per ckt.	No. of Pole	Protection in amp	wire size	Conduit in mm
1	Light load	8	230	800	3.48	2P	15	1-2.0 mm^2	13 mm
2	Small app.	6	230	2160	9.39	2P	20	2-3.5 mm^2	13 mm
3	Other load	2	230	3600	15.65	2P	20	2-3.5 mm^2	13 mm
4	Spare	-	230			2P			

I_t = 28.52 amp. x 80% Demand factor = 22.8 amp.

Use 2 pieces 8.0 mm^2 TW Cu. Wire @ 20 mm conduit pipe
RSC – Rigid Solid Conduit
IMT - Intermediate Metal Tube
PvcCP - Pvc Conduit pipe

RSC = Rigid Solid Conduit
IMT = Intermediate Metal Tube

THW - Thermoplastic moisture and heat resistance @ 45 amperes up.

TW - Thermoplastic moisture resistance @ 40 amp. below.

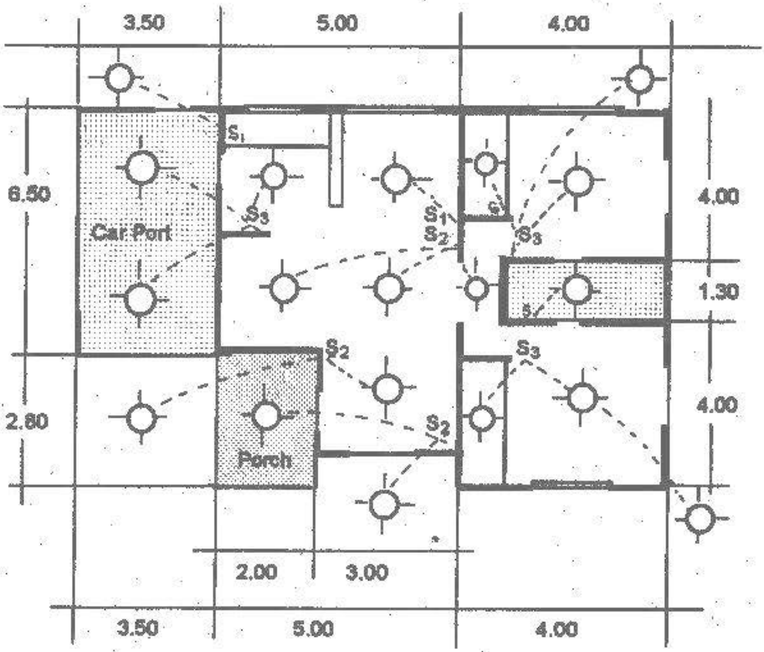
Materials	Quantity
Safety Switch, 30 amp. 2 DPST, 250 volts	1 pcs.
Fuse cutout, two branches	1 unit
30 amperes fuse	2 pcs.
20 amperes fuse	2 pcs.
15 amperes fuse	2 pcs.
8.0 mm^2 TW copper wire	50 mts.
3.5 mm^2 TW copper wire	1 roll
2.0 mm^2 TW copper wire	½ roll
13 mm diameter Pvc conduit pipe	18 pcs.
20 mm diameter conduit pipe Pvc.	5 pcs.
One gang switch with plate	4 pcs.
Two gang switch plate	2 pcs.
Two gang convenience outlet (small appliance)	6 pcs.
Cooking unit outlet	2 pcs.
Junction box with screw	7 pcs.
Receptacle with screw	8 pcs.
Utility box	14 pcs.
Incandescent lamp	4 pcs
Fluorescent lamp	4 pcs.
Meter base (to be provided by the owner)	1 pc.
Electrical tape (big)	2 pcs.

Note: The quantity of materials is subject to change depending upon the area and the choice of the designing engineers. For open wiring installation, conduit pipe can be change to split knobs or PDX wires.

ILLUSTRATION 4-2

SINGLE FAMILY DWELLING

Type of Service –115/ 230 volts
Single Phase – 3 wire 60 Hz.
Line to Line Service



There are 19 light outlets divided into two circuits.
Circuit 1; = 10 outlets
Circuit 2; = 9 outlets

FIGURE 4-18 LIGHTING LAYOUT

SOLUTION

Examining the lighting plan of Figure 4-18, there are 19 lighting outlets. Split the 19 outlets into two circuits A and B.

A. Circuit – 1 Lighting Load (10 light outlets)

1. The Philippine Electrical Code provides that ***100 watts be the maximum load per light outlet.*** Thus, for 10 light outlets at 100 watts, multiply:

   10 outlets x 100 watts = 1,000 watts

2. Compute the **Current Load**.

   $$\frac{1{,}000 \text{ watts}}{230 \text{ volts}} = 4.35 \text{ amperes}$$

3. Find the ***Size of Branch Circuit Wire***. Refer to Table 4-2. For 4.35 amperes, use 2.0 mm^2 TW copper wire.

4. Find the ***Rating of Overcurrent Protection.*** Refer to Table 4-1. For 4.35 amperes, use 15 amperes trip breaker.

5. Determine the ***Size of Conduit Pipe***. Refer to Table 2-9. For No.14 TW copper wire, use 13 mm conduit pipe.

B. Circuit – 2 Lighting Load (9 light outlets)

1. For 9 light outlets, find the ***Total load*** in watts.

   9 outlets x 100 watts per outlet = 900 watts

   Divide: $$\frac{900 \text{ watts}}{230 \text{ volts}} = 3.91 \text{ amperes}$$

2. Determine the ***Size of the Branch Circuit Wire.*** Refer to Table 2-5 or 4-2. For the 3.91 amperes load, use 2.0 mm^2 or No. 14 TW copper wire.

3. Determine the *Size of the Conduit Pipe*. Refer to Table 2-9. For 2 pieces No. 14 TW copper wire, use the 13 mm minimum size of conduit pipe.

4. Determine the *Size or Rating of the Overcurrent Protection*. Refer to Table 4-1. For the 3.91 amperes load, use 15 amperes fuse or trip breaker.

C. Circuit – 3 For Small Appliance Load

Section 3.3.1.2 of the Philippine Electrical Code specify ***180 watts load limit per convenience outlet***. Thus:

1. Find the number of appliance outlet and the current load.

   6 outlets x 2 gang per outlet x 180 watts

   12 x 180 = 2,160 watts

   Divide: $\frac{2{,}160 \text{ watts}}{230 \text{ volts}}$

   = 9.39 amperes

2. Determine the *Size of the Service Wire Conductor*. Refer to Table 2-5 or 4-2. For the 9.39 amperes load, specify the minimum wire gauge for convenience outlet.

   2 pieces 3.5 mm^2 or No. 12 TW copper wire

3. Determine the *Size of the Conduit Pipe*. Refer to Table 2-9. For 2 pieces No. 12 TW copper wire. Use 13 mm diameter conduit pipe.

4. Solve for the *Size or Rating* of the *Over Current Protection*. Refer to Table 4-1. For 9.39 amperes on No.12 TW copper wire specify:

   20 amperes fuse or trip breaker.

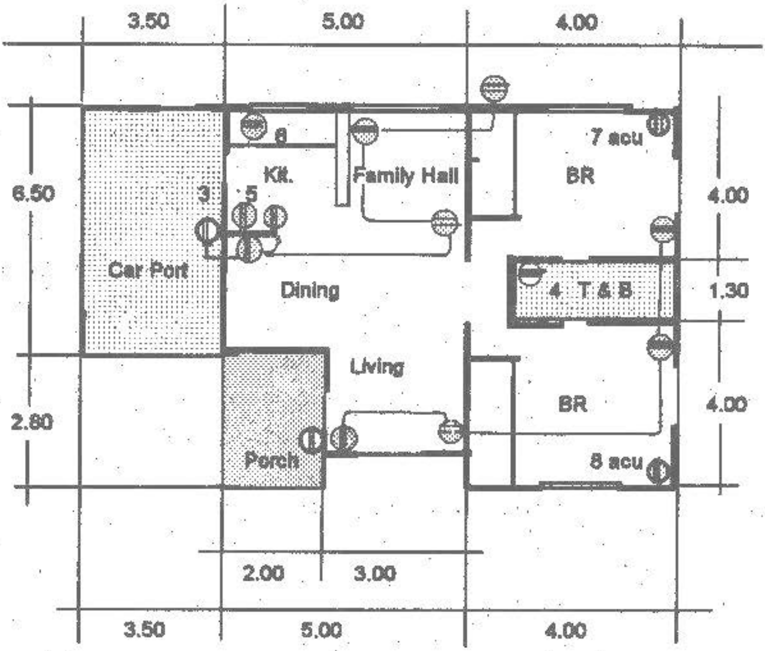


FIGURE 4-19 16 CONVENIENCE OUTLET LAYOUT

* Circuit-3 = 6 convenience outlet
* Circuit-4 = 6 convenience outlets
* Circuit-5 = 1- Range load
* Circuit-6 = 1- Water heater
* Circuit-7 = 1- Aircon Unit
* Circuit-8 = 1- Aircon Unit

D. Circuit – 4 for Small Appliance Load

1. The load of circuit 4 is identical with circuit 3. Use the same size of wire, conduit, and wire protection rating.

E. Circuit – 5 for Range Load

1. Range load (*appliance rating*) at 8.0 kw. = 8,000 watts.

2. Solve for the ***Line Current.***

$$\frac{8{,}000 \text{ watts}}{230 \text{ volts}} = 34.78 \text{ amperes}$$

3. Refer to Table 4-6, ***apply 80% demand load factor.***

34.78 x .80 d.f. = 27.82 amperes

4. Determine the ***Size of the Branch Circuit Wire***. Refer to Table 2-5 or 4-2. For the 27.82 amperes, use 8.0 mm^2 or No. 8.0 TW copper wire.

5. Determine the ***Size of Conduit Pipe***. Refer to Table 2-9, for 2 pieces No. 8 wire use 20 mm diameter pipe.

6. Find the ***Size or Rating of the Fuse or Trip Breaker***. Refer to Table 4-1. For appliance load, use 40 amperes fuse or trip breaker.

F. Circuit – 6 For Water Heater Load

1. One unit water heater at 2.5 kw. = 2,500 watts

2. The current load will be;

$$\frac{2{,}500 \text{ watts}}{230 \text{ volts}} = 10.86 \text{ amperes}$$

3. Solve for the ***Size of Branch Circuit Wire***. Refer to Table 2-5 or 4-2. For the 10.86 amperes convenience outlet use 2 pcs. 3.5 mm^2 or No. 12 TW copper wire.

4. Determine the ***Size of the Conduit Pipe***. Refer to Table 2-9. For 2- No.12 wire, use 13 mm conduit pipe.

5. Find the ***Size or Rating*** of the ***Overcurrent Protection***. Refer to Table 4-1. For the 10.86 amperes load, use 20 amperes fuse or trip breaker.

G. Circuit 7 and 8 with 1-Unit Air Conditioner each

1. One unit air conditioner at 1.5 horse power is:

   1.5 hp x 746 watts = 1,119 watts

   Article 6.7 of the Philippine Electrical Code (PEC) provides that: ***"Branch circuit conductor supplying a motor shall have an ampacity not less than 125% of the full load current."***

2. Current Load: $$\frac{1{,}119 \text{ watts}}{230 \text{ volts}} = 4.86 \text{ amperes}$$

   4.86 x 125% = 6.07 amperes

3. Fine the ***Size of the Branch Circuit*** service wire. Refer to Table 4-2. The 6.7 amperes can be served by a 2.0 No.14 TW copper wire, but ***the Code limits the size of convenience outlet to No. 12 AWG copper wire.*** Specify No. 12 THW copper wire for circuit 7 and circuit 8.

4. Find the ***Size of the Conduit Pipe.*** Refer to Table 2-9. For two No.12 wire, use 13 mm conduit pipe.

5. Find the ***Size and Rating of the Branch Circuit Protection***. The Code on branch circuit protection for a single motor provides that: ***"It shall be increased by 250% of the full load current of the motor."*** Thus:

   4.86 x 250% = 12.15 amperes. From Table 4-1 for a continuous load use 2- 30 amperes trip breaker

Calculating the Ampacity of the Service Entrance Conductor and the Main Disconnecting Means

1. Find the total current load of circuit 1 to Circuit 8:

Lighting Load Ct.-1 and Ct - 2	1,900 watts
Small appliance load Ct.-3 and Ct.-4	4,320 watts
Other loads Ct.-5 and Ct.-6	10,500 watts
Total load (except the Aircon unit)	16,720 watts

2. From Table 4-4, Optional Calculation for Dwelling Unit, apply demand factor (df).

   For the first 10,000 w. at 100% (df) .... 10,000 watts

   Subtract: 16,720 – 10,000 = 6,720 watts.

   For other load, multiply by 40% (SeeTable 4-4)

   6,720 x 40%.......................... 2,688 watts

   Aircon Unit at 100% demand factor (df)

   2- units at 1,119 watts.................... 2,238 watts

   Total................ 14,926 watts

Total Connected Load plus 25% of the Largest Motor

1. Amperes $I = \frac{14{,}926 \text{ w} + (25\% \text{ of } 1{,}119 \text{ w})}{230 \text{ volts}}$

   $I = 63.37$ amperes

2. Find the ***Size of Main Feeder and the Neutral Line.*** From Table 4-2, use 2 -38 mm^2 TW copper wire.

3. The Neutral conductor of a 3-wire line to line supply system shall have an ampacity of **not less than 70%** of the ungrounded (live wire) conductor or **Two Trade size smaller than the ungrounded conductor.** *(PEC Specifications).* Therefore use 1- 22 mm^2 TW copper wire for the Neutral line.

4. Determine the ***Size of the Conduit Pipe.*** Refer to Table 2-9, use 32 mm diameter pipe.

5. **For Main Breaker,** refer to Table 4-1. Use 2 -100 amp. 2-wires 250 volts, 2-pole molded ***air circuit breaker.***

Comment:

The total computed load is 63.37 amperes. From Table 4-2 the 30 mm^2 copper wire could be used considering its 90 amperes ampacity. However, the *National Electrical Code* (NEC) provides that:

"If the computed load exceeds 10,000 watts, the conductor and overcurrent protection shall be rated not less than 100 amperes".

Therefore, use 2-38 mm^2 TW wire for the Main Feeder, and 2- 100 amperes for the main breaker.

LOAD SCHEDULE TYPE OF SERVICE; 230 v. 3 WIRES 60 Hz. SINGLE PHASE

Ckt No.	Description	No. Outlet	Volts	Watts	Amp Ckt	Protection per Ckt.	Size of copper Wires	Conduit diameter
1	Light load	10	230	1000	4.35	15 AT	2-2.0 mm^2	13 mm
2	Light load	9	230	900	3.91	15 AT	2-2.0 mm^2	13 mm
3	Small App.	6	230	2160	9.39	20 AT	2-3.5 mm^2	13 mm
4	Small App.	6	230	2160	9.39	20 AT	2-3.5 mm^2	13 mm
5	Range-8 kw.	1	230	8000	34.78	60 AT	2-8.0 mm^2	20 mm
6	2.5 kw heater	1	230	2500	10.86	20 AT	2-3.5 mm^2	13 mm
7	Aircon 6.07 a.	1	230	1119	4.86	30 AT	2-3.5 mm^2	13 mm
8	Aircon 6.07 a.	1	230	1119	4.86	30 AT	2-3.5 mm^2	13 mm
9	Spare	-	-	-	-	-	-	-

It = 63.37 Amperes. Use 2-38 mm^2 TW copper wire and 1-8 mm^2 TW copper wire for Main and Neutral Feeder respectively, one 100 ampere 2 pole, 3 wire, 250 volts breaker

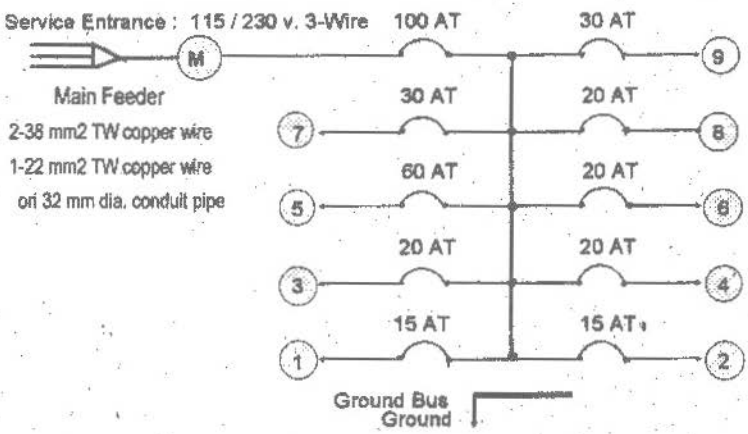


FIGURE 4-20 ONE LINE DIAGRAM

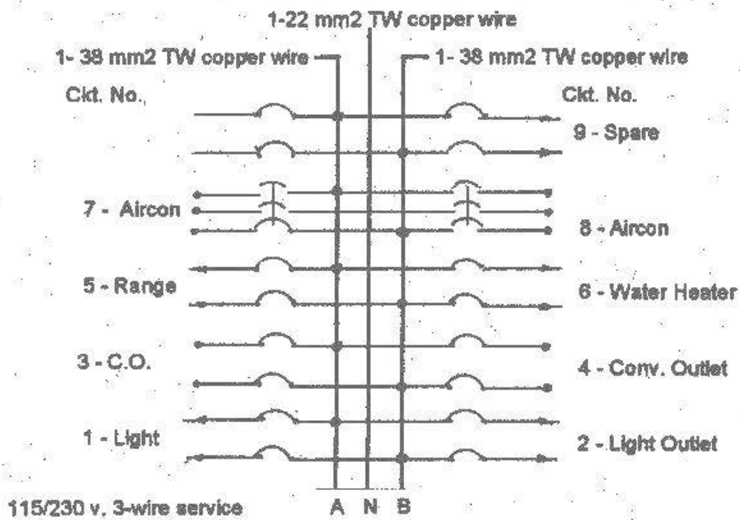


FIGURE 4-21 SCHEMATIC RISER DIAGRAM

ILLUSTRATION 4-3

SMALL FAMILY DWELLING
Type of Service – 230 volts; Two Wire Line to Ground System

A single family dwelling with a floor area of 80 square meters has the following receptacles and outlets load:

Lighting :

7 pcs. – 40 watts fluorescent lamp
2 pcs. – 20 watts Incandescent lamp

Convenience Outlet:

1-	Electric iron………………	1,000 watts
1-	Electric stove………………	1,100 watts
2-	Electric fan………………	500 watts
1-	7 cu. ft. Refrigerator……...	175 watts
1-	Portable stereo……………	100 watts
1-	20" TV set………………..	300 watts

SOLUTION

A. Circuit 1 - Lighting Load by the Area Method

1. Determine the wattage required per square meter area. From Table 4-3, the wattage required per square meter for dwelling unit is 24 watts. Multiply:

   80 sq. m. x 24 watts

   = 1,920 watts

2. Determine the *current load*. Divide:

   $$\frac{1{,}920 \text{ watts}}{230 \text{ volts}} = 8.35 \text{ amperes}$$

3. Compute for the *actual lighting load*. Multiply:

   7 - Flourescent lamp x 40 watts = 280 watts
   2 - Incandescent bulb x 60 watts = 120 watts
   Total.................400 watts

4. Solve for the *actual current load*. Divide:

   $$\frac{400 \text{ watts}}{230 \text{ volts}} = 1.74 \text{ amperes}$$

5. Determine the *Size of the Branch Circuit Wire*. From Table 2-5 or 4-2, the 1.74 amperes is very small load to be carried by 2.0 mm^2 or No. 14 TW copper wire. Therefore, the No. 14 wire is safe.

6. Determine the *Size of the Conduit Pipe*. Refer to Table 2-9, for 2 - No.14 wire, use 13 mm conduit pipe.

7. Determine the *Size or Rating of the Branch Circuit Protection*. Refer to Table 4-1. For 2.0 mm^2 No.14 copper wire conductor, use 15 amperes fuse or trip breaker.

TABLE 4-4 OPTIONAL CALCULATION FOR DWELLING UNIT

Load (KW or Kva)	Demand Factor
Air conditioning and cooling including .... heat pump compressors	100 %
Central electric space heating..................	65 %
Less than four separately controlled .... electric space heating units	65 %
First 10 Kw of all other load	100 %
Remainder of other load	40 %

TABLE 4-5 OPTIONAL CALCULATION-DEMAND FACTOR FOR THREE OR MORE MULTI-FAMILY DWELLING UNITS

Number of Dwelling Units	Demand Factor Percent
3 – 5	45 %
6 – 7	44 %
8 – 10	43 %
11	42 %
12 – 13	41 %
14 – 15	40 %
16 – 17	39 %
18 – 20	38 %
21	37 %
22 – 23	36 %
24 – 25	35 %
26 – 27	34 %
28 – 30	33 %
31	32 %
32 – 33	31 %
34 – 36	30 %
37 – 38	29 %
39 – 42	28 %
43 – 45	27 %
46 – 50	26 %
51 – 55	25 %
56 – 61	24 %
62 and over	23 %

B. Circuit – 2 For Small Appliance Load

1. Solve for the total appliance current load.

$$\text{Load Current} = \frac{1{,}000 + 1{,}100 + 500 + 175 + 300 + 100}{230 \text{ volts}}$$

$$= \frac{3{,}175 \text{ watts}}{230 \text{ volts}}$$

$$= 13.81 \text{ amperes}$$

2. Determine the ***Size of the Branch Circuit Wire*** conductor. Refer to Table 4-2. For a convenience outlet load of 13.81 amperes specify 3.5 mm^2 or No.12 TW copper wire, the minimum size required for convenience outlet.

3. Find the ***Size of the Conduit Pipe***. Refer to Table 2-9, for 2 pieces No.12 TW wire, use 13 mm pipe.

4. Find the ***Size or Rating of the Protective Device***. See Table 4-1, for 13.81 amperes, use1-20 amperes fuse.

Comment

It is interesting to note that only one 20 ampere fuse protection was used because the current is a ***Line to Ground or Multi-ground System*** where one line is zero voltage being grounded. Unlike the Line to Line System of current supply, it is necessary to provide 2 fuses to protect the two line branch circuit.

Finding the Size of the Service Entrance or Feeder

1. Get the sum total of connected load. Add:

Lighting load..............1,920 watts
Small Appliance load...3,175 watts
Total..................5,095 watts

2. Solve for the total connected load current. Divide:

$$\frac{5{,}095 \text{ watts}}{230 \text{ volts}} = 22.15 \text{ amperes}$$

3. Find the *Size of Service Entrance*. Refer to Table 4-2 or For 22.15 amperes, use No.8 TW copper wire, ***the minimum size for service entrance***.

4. Find the *Size of the Conduit Pipe*. Refer to Table 2-9 for No.8 TW wire, Use 20 mm diameter conduit pipe.

5. For ***Main Protection***, use 1- safety switch, 2-pole; 2-wires; 250 volts.

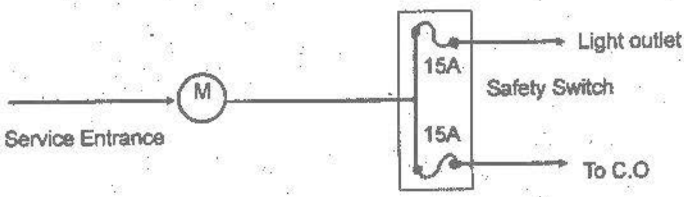


FIGURE 4-21 ONE LINE DIAGRAM

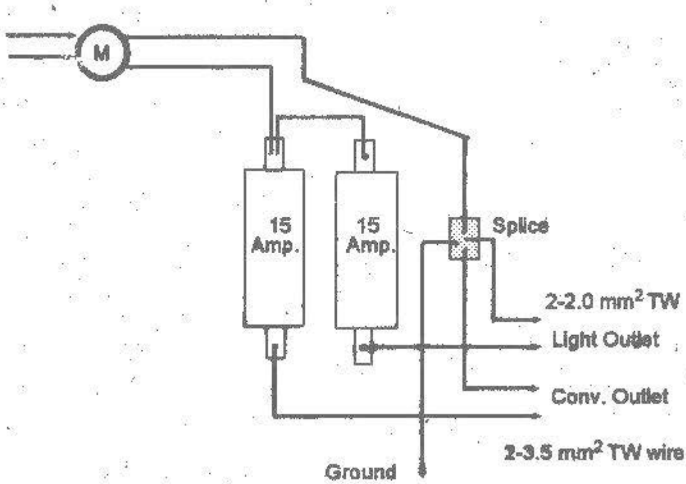


FIGURE 4-23 SCHEMATIC RISER DIAGRAM

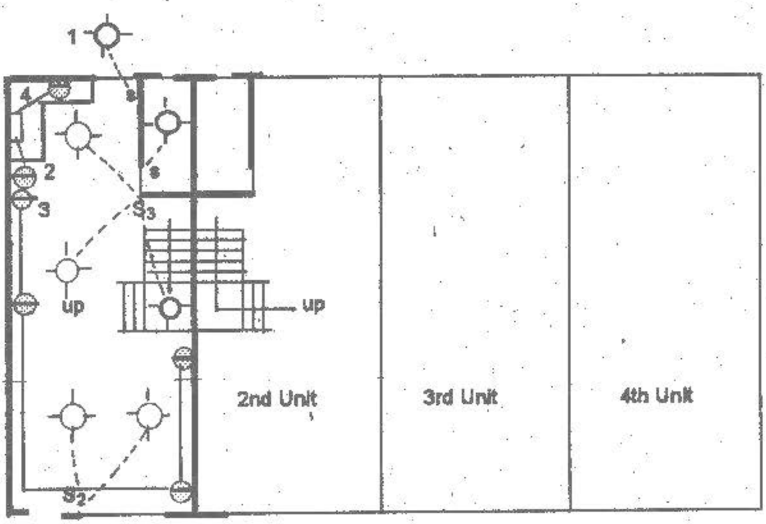
Under the preceding set-up, one safety switch could supply both lighting and convenience outlet at different branch circuit without the use of fuse cutout. This is only applicable to the ***line to ground*** or ***multi-ground supply system*** being used by the electric cooperative.

ILLUSTRATION 4-4

MULTI- FAMILY DWELLINGS
4 - DOOR APARTMENT

- **Type of Service – 230 Volts**
- **2-wire, Line to Ground System**
- **Floor Area per unit = 80 square meters**
- **Total Floor Area = 320 square meters**

Determine the branch circuit protection, size of conductor wires and the main feeder.



FLOOR PLAN

FIGURE 4-24 LIGHTING AND CONVENIENCE OUTLET LAYOUT

SOLUTION

Assume that the dwelling unit is equipped with one 5.1 kw cooking unit; one unit laundry circuit at 1.5 kw. (see appliance ratings)

A. Circuit – 1 For Lighting Load per Unit (see plan)

1. By the Area Method, refer to Table 4-3, ***General Lighting Load by Occupancy*** for Dwelling Units.

   80 sq. m. x 24 watts per square meter

   = 1,920 watts

2. Compute for the ***lighting load***. Divide:

   $$\frac{1{,}920 \text{ watts}}{230 \text{ volts}} = 8.35 \text{ amperes}$$

3. Determine the ***Size of the Branch Circuit conductor wire***. Refer to Table 2-5 or 4-2. For 8.35 amperes load, use 2 pieces 2.0 mm^2 or No. 14 AWG, TW copper wire.

4. Determine the ***Size of the Conduit Pipe*** (if required). Refer to Table 2-9. For number 14 AWG, TW wire use 13 mm the minimum size of conduit pipe.

5. Determine the ***Size or Rating*** of the ***Branch Circuit. Protection***. Refer again to Table 4-1, for 8.35 amperes load on a 2.0 mm^2 wire conductor size, use 15 amperes fuse or trip breaker.

B. Circuit - 2 For Convenience Outlet Load (see plan)

1. Solve for the ***total current load***. Multiply:

   8 receptacles x 2 gang per outlet x 180 watts.

   = 2,880 watts

2. Solve for the appliance *current load*. Divide:

$$I = \frac{2{,}880 \text{ watts}}{230 \text{ volts}}$$

$$= 12.52 \text{ amperes}$$

3. Determine the ***Size of the Branch Circuit*** conductor. Refer to Table 2-5 or 4-2. For a 12.52 amperes load, a 2.0 mm^2 or No. 14 AWG, TW, copper wire would be sufficient considering its 15 amperes ampacity that is bigger than 12.52 amperes as computed.

4. But the *National Electrical Code* limits the size of convenience outlet wire to a minimum of 3.5 mm^2 or No.12 AWG copper wire. The Code must prevail. Use No 12 TW wire rather than the No.14 as computed.

5. Determine the ***Size of the Conduit Pipe***. Refer to Table 2-9, for two No.12 TW wire, use 13 mm diameter pipe.

6. Find the ***Size of the Branch Circuit Fuse Protection***. Refer to Table 4-1. For 12.52 amperes non continuous load on convenience outlet, use 20 amperes trip breaker.

C. Circuit – 3 Other Load.

1. Laundry circuit at 1,500 watts per circuit (PEC provision).

$$\frac{1{,}500 \text{ watts}}{230 \text{ volts}} = 6.52 \text{ amperes}$$

2. Find the ***Size of the Branch Circuit Conductor***. From Table 4-2, use 2 pieces 3.5 mm^2 or No.12 TW copper wire, ***the minimum size for convenience outlet***

3. Find the ***Size of the Conduit Pipe*** if required. From Table 2-9, use 13 mm diameter pipe.

4. Find the ***Size of the Branch Circuit Fuse Protection.*** From Table 4-1, the 6.52 amperes load on *convenience outlet* requires 20 amperes fuse or trip breaker.

D. Circuit – 4 For Cooking Unit

1. Total load is 5.1 kw. = 5,100 watts

2. Refer to Table 4-6 *Demand Load for Household.* For electric range, apply 80% demand factor.

   Total load x demand factor (df)

   5,100 watts x .80 = 4,080 watts

3. Compute for the ***line current load***. Divide:

$$\frac{4{,}080 \text{ watts}}{230 \text{ volts}} = 17.74 \text{ amperes}$$

4. Find the ***Size of the Branch Circuit Wire***. Refer to Table 4-2, for the 17.74 ampere line current, use 5.5 mm^2 or No.10 TW copper wire.

5. Determine the ***Size of Conduit Pipe.*** From Table 2-9, for No.10 TW wire, Use 20 mm diameter pipe.

6. Find the ***Size of the Branch Circuit Fuse Protection***. Refer to Table 4-1, for 17.74 amperes current load, use 30 amperes fuse or trip breaker.

E. Determine the Sub-Feeder per Dwelling

1. Solve for the total connected load per dwelling.

Lighting load	1,920 watts
Convenience outlet load	2,880 watts
Other load 5.1 kw + 1.5 kw	6,600 watts
Total...........................	11,400 watts

2. Apply 80% Demand Factor (see Table 4-6).

$$\text{Total Line Current} = \frac{11{,}400 \text{ watts} \times 80\% \text{ d.f.}}{230}$$

$$= 39.65 \text{ amperes}$$

3. Determine the ***Size of the Sub-Feeder and Protection*** per dwelling for 39.65 amperes. From Table 2-5 or 4-2, use 8.0 mm^2 or No.8 THW cooper wire.

4. Find the ***Size of Conduit Pipe.*** From Table 2-9, for 8.0 mm^2 or No.8 wire, specify 25 mm diameter pipe.

5. Determine the ***Size or Rating of the Fuse Protection.*** From Table 4-1, use 60 amperes molded circuit breaker 2-wire 250 volts with solid bus.

F. Determine the Size of the Main Feeder

1. Solve for the ***Total Connected Load*** on 4 dwelling units at 11,400 watts each. Multiply:

   $$11{,}400 \times 4 = 45.600 \text{ watts}$$

2. Refer to Table 4-5. For 4 dwelling units apply 45% demand factor. Multiply:

   $$45{,}600 \times .45 = 20{,}520 \text{ watts}$$

3. Solve for the ***line current*** (amperes).

   $$I = \frac{20{,}520 \text{ watts}}{230 \text{ volts}}$$

   $$= 89.22 \text{ amperes}$$

4. Determine the ***Size of the Conductor Wire.*** Refer to Table 4-2. For 89.22 amperes, use 2 - 50 mm^2 TW copper wire or 2 - 38 mm^2 THW copper wire.

Comment:

It will be noted in Table 4-2 that the 89.22 amperes as computed does not exceed 80% of the 120 allowable ampacity of 50 mm^2 TW copper wire or 125 ampacity of 38 mm^2 THW copper wire. Therefore, any one of these two types of wire could be used for main feeder (See Art. 6.7 PEC).

5. Find the *Size of Conduit Pipe*. Refer to Table 2-9. Use 38 mm diameter RSC or IMT pipe.

6. Find the *Size or Rating of the over-current Protection*. Refer to Table 4-1. Use 125 amperes safety switch, 250 volts, 2 pole.

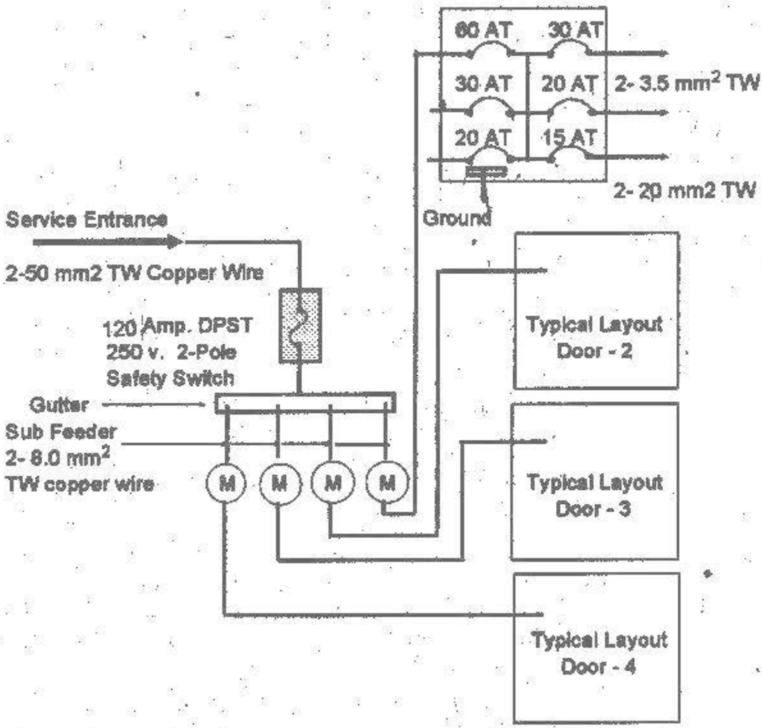


FIGURE 4-25 ONE LINE DIAGRAM

LOAD SCHEDULE TYPE OF SERVICE; 230 v. 3 WIRES 60 Hz. SINGLE PHASE

Ckt No.	Description	No. Outlet	Volts	Watts	Amp Ckt	Branch protection	Size of copper Wires	Conduit diameter
1	Light load	12	230	1,920	8.35	15 AT	2-2.0 mm^2	13 mm
2	Small App.	8	230	2,880	12.52	20 AT	2-3.5 mm^2	13 mm
3	Laundry load	*	230	1,500	6.52	20 AT	2-3.5 mm^2	13 mm
4	Cooking load	*	230	5,100	17.74	30 AT	2-5.5 mm^2	20 mm
5	Spare	-	-	-	-	-	-	-
	TOTAL				49.56			

AT – Ampere Trip
RSC – Rigid Solid Conduit

Current load per Dwelling $= \frac{11{,}400 \text{ watts}}{230 \text{ volts}} = 49.56$ amperes

Current Load per Dwelling: I = 49.56 x 80% d.f. = 39.65 amp.

Therefore: Use 8.0 mm^2 copper wire on a 20 mm RSC.
60 amp. molded circuit breaker, 2 wire 250 volts with 5 branch circuit

For Main Feeder: $\frac{\text{Total load} \times 45\%}{\text{Voltage}} = \frac{45{,}600 \text{ watts} \times .45}{230 \text{ v.}}$

Total load = 89.22

Therefore: Use 2 – 38 mm^2 TW copper wire or
2 – 30 mm^2 THW copper wire

Straight Pull

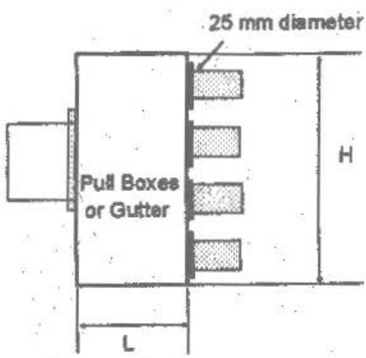


FIGURE 4-26 STRAIGHT PULL

In straight pulls, the length of the box should not be less than eight times the trade diameter of the largest conduit.

L = 40 mm x 8 = 320 mm. H = whatever height necessary to provide proper installation of the conduit lock nuts and bushing within the enclosure.

The depth of the box should be sufficient enough to permit installation of the largest lock nut and bushing of the conduit including the spacing between the adjacent conduit entries.

Angle or U Pull Box

For boxes where the conductors are pulled at an angle or in a "U" condition, the distance between each conduit entry inside the box, and the opposite wall of the box should ***not be less than six times the trade diameter of the largest conduit***, and the distance must be increased for additional conduit entries by ***the amount of the sum of the diameter of all other conduit entries on the same wall of the box.*** The distance between the conduit entries enclosing the same conductors should ***not be less than six times the trade diameter of the largest raceway.***

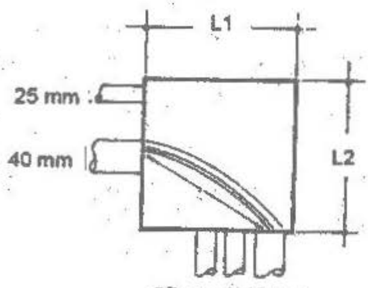


FIGURE 4-27 U-PULL BOX

The 40 mm diameter conduits = is the largest, thus:

L_1 = 6 x 40 mm + (25 mm + 25 mm) = 290 mm (min.)

L_2 = 6 x 40 mm + 25 mm.............. = 265 mm (min.)

D = 6 x 40 mm.......................... = 240 mm (min.)

D = Distance between raceway entries enclosing the same conductor.

TABLE 4-6 DEMAND LOAD FOR HOUSEHOLD APPLIANCES OVER 1.75 KW RATING

Number of Appliances	Maximum Demand	Demand Factor Percent	
	Column A Not over 12 kw Rating (kw)	Column B Less than 3 1/2 kw Rating %	Column C 3 1/2 kw to 8 3/4 kw Rating %
1	8	80	80
2	11	75	65
3	14	70	55
4	17	66	50
5	20	62	45
6	21	59	43
7	22	56	40
8	23	53	36
9	24	51	35
10	25	49	34
11	26	47	32
12	27	45	32
13	28	43	32
14	29	41	32
15	30	40	32
16	31	39	28
17	32	38	28
18	33	37	28
19	34	36	28
20	35	35	28
21	36	34	26
22	37	33	26
23	36	32	26
24	39	31	26
25	40	30	26
25-30	(15 kw +1 kw)	30	24
31-40	for each range	30	22
41-50	25 kw + 3/4 kw	30	20
51-60	for each range	30	18
61- over	"	30	16

TABLE 4-7 TYPE OF LSL CONTACTORS AND THERMAL OVERLOAD RELAYS OF VARIOUS MOTOR

Motor output Approx. KW	HP/CV	Motor current A	LSL Type contactor Type	Thermal O/L relay Type	Range	Back-up Type current delayed	Eff. n %	Power factor Cos.
For 3- ph operation at 220 v. 50/60 Hz.								
1.1	1.5	4.8	LS 6/L 11	b 7	4.0 to 6	16	74	0.80
1.5	2.0	6.4	LS 6/L 11	b 7	5.5 to 8	20	77	0.80
2.2	3.0	9.2	LS 6/L 11	b 7	8.0 to 12	25	77	0.80
3.0	4.0	12	LS 6/L 11	b 7	8.0 to 12	25	78	0.80
4.0	5.5	16	LS 8/L 14	b 27	11.0 to 16.5	40	80	0.80
5.5	7.5	21	LS 16/L 18	b 27	15.0 to 23	50	86	0.80
7.5	10	29	LS 20/L 24	b 27	21.0 to 32	63	86.5	0.85
11.0	15	39	LS 32/L 40	b 67	30.0 to 46	100	89	0.83
15.0	20	45	LS 36/L 44	b 67	42.0 to 63	125	90	0.84
18.5	25	63	LS 36/ L44	b 67	42.0 to 63	125	90.5	0.84
22.0	30	74	LS 60/L 84	b 207	55.0 to 80	160	91	0.84
30	40	99	LS 60/L 84	b 207	80.0 to 120	200	92	0.85
37	50	126	LS 100/L 144	b 207	120 to 180	300	92.5	0.86
45	60	151	LS 100/L 144	b 207	120 to 180	300	92.5	0.86
55	75	180	LS 100/L 144	b 207	120 to 180	300	93	0.86
75	100	249	LS 200/L 260	b 400	200 to 400	500	93.5	0.86
90	125	299	LS 330/L 410	b 400	200 to 400	630	94	0.86
100	150	356	LS 330/L 410	b 400	200 to 400	630	94	0.86
132	180	426	To suit cage induction motors on				95	0.86
160	220	514	AC 3 duty at 1800 min-1				95.5	0.86
200	270	626					95.5	0.86

KW	LSL Type Contactor Fuse 1 AA	Thermal O/L Relay A	Approx. Range			Back up Fuse 1 Delayed
For 3-ph Operation at 220 volts 50/60 Hz.						
2.4	LS 6/L 11	b 7	1.8	to	2.7	6
3.2	LS 6/L 11	b 7	2.7	to	4.0	10
4.6	LS 6/L 11	b 7	4.0	to	6.0	16
6.3	LS 6/L 11	b 7	5.5	to	8.0	20
8.0	LS 6/L 11	b 7	5.5	to	8.0	20
10.3	LS 6/L 11	b 7	8.0	to	12.0	25
14	LS 8/L 14	b 27	11.0	to	16.5	40
19	LS 16/L 18	b 27	15.0	to	23.0	50
27	LS 20/L 24	b 27.1	21.0	to	32.0	63
37	LS 32/L 40	b 67	30.0	to	46.0	100
49	LS 36/L 44	b 67	42.0	to	63.0	125
63	LS 36/L 44	b 67	42.0	to	62.0	125
75	LS 60/L 84	b 207	55.0	to	80.0	160
92	LS 60/L 84	b 207	80.0	to	120.0	200
124	LS 100/L 144	b 207	120.0	to	180.0	300
149	LS 100/L 144	b 207	120.0	to	180.0	300
177	LS 100/L 144	b 207	120.0	to	180.0	300
212	LS 200/L 260	b 400	200.0	to	400.0	500
255	LS 300/L 410	b 400	200.0	to	400.0	630
311	LS 330/L 410	b-400	200.0	to	400.0	630

ILLUSTRATION 4-5

COMMERCIAL LOAD
Type of Service; 230 Volts ; 3-Phase

PROBLEM

Determine the size of the main feeder of a 25 h.p. 3-pahse, 3-wire 230 volts with an efficiency of 90.5% and 84% power factor lagging to serve a rice mill with 12 lighting outlets plus convenience outlet for appliances.

For 25 h.p. motor 3-phase, 3-wire 230 volts 60 Hz. 91% efficiency and 84% power factor, refer to Table 4-7 Type of LSL Contactors and Thermal Overload Relays of Various Motors.

SOLUTION

A. Circuit – 1 For Lighting Load

1. For 12 light outlets at 100 watts per outlet.

   12 x 100 = 1,200 watts

2. Compute the *Lighting Current Load.*

   $$\frac{1{,}200 \text{ watts}}{230 \text{ volts}} = 5.22 \text{ amperes}$$

3. Find the ***Size of Conductor Wire***. Refer to Table 4-2, for 5.22 amperes load, use 2 pcs. 2.0 mm^2 TW copper wire.

4. Find the ***Size of Current Protection***. Refer to Table 4-1, use 1- 15 amperes trip breaker for 5.22 amperes load.

5. Find the ***Size of Conduit Pipe***. Refer to Table 2-9, use 13 mm diameter conduit pipe.

B. Circuit – 2 For Small Appliance Load

The Philippine Electrical Code (PEC) provides that *"the Branch Circuit and receptacles for small appliance load shall be rated at no less than 1,500 watts. However, if the number of receptacles were indicated and specified in the plan, the load is computed at 180 watts per outlet."*

In this example problem, there is no specific number of outlets given hence, adopt the 1,500 watts as mandated by the Philippine Electrical Code.

SOLUTION

1. Solve for the ***Total Current Load***.

$$\frac{1{,}500 \text{ watts}}{230 \text{ volts}} = 6.52 \text{ amperes}$$

2. Refer to Table 2-5 or Table 4-2, the 6.52 amperes could be safely served by No.14 AWG, TW conductor wire, but *the Code limits the use of No.12 for convenience outlet*. Therefore, specify No. 12 AWG, TW copper wire for Circuit-2.

3. If conduit pipe is required, refer to Table 2-9 and the pipe diameter for 2 pieces No.12 TW wire is 13 mm.

4. Determine the ***Over-current Fuse Protection***. Refer to Table 2-5 or 4-2. The 3.5 mm^2 or No. 12 TW branch circuit wire requires 20 ampere fuse protection.

C. Sub-Feeder for Circuit 1 and 2

1. Find the total sum of current load of Circuit 1 and 2.

$$\frac{1{,}200\text{w} + 1{,}500\text{w}}{230 \text{ volts}}$$

$$= 11.74 \text{ amperes}$$

2. Determine the ***Size of the Sub-Feeder Conductor Wire***. Refer to Table 4-2. For 11.74 amperes, use 8.0 mm^2 or No. 8 AWG, TW copper wire.

   On Table 4-2, the 11.74 amperes load for Circuit 1 and 2 could be safely carried by 2.0 mm^2 wire for having an allowable ampacity of 15 amperes, but the Code limits the Feeder Size to 8.0 mm^2 or No. 8 AWG copper wire. The Code must prevail, specify 8 mm^2 copper wire conductor for Sub-Feeder.

3. Find the ***Size of Conduit Pipe***. Refer to Table 2-9, for 2- 8 mm^2 or 2- No. 8 AWG TW wire, specify 20 mm diameter pipe Rigid Solid Conductor (RSC).

4. Find the ***Size or Rating of the Over-current Protection***. Refer to Table 4-1, for No.8 AWG wire, specify:

   60 amp. trip molded circuit breaker,
   2 pole, 250 volts with 3 branch circuit.

D. Circuit for Motor Load

Name plate of the motor

25 h.p., 220 volts, 3 phase; 3 wires 60 Hz. 0.84 power factor 90.5% efficiency

SOLUTION

1. Solve for the current load.

   1 horse power = 746 watts

$$I = \frac{\text{Load in hp} \times 746\text{ w}}{k \times E \times PF \times n}$$

Where: k - 1.0 for 2 wire single ø DC
1.73 for 3 - wire, 3-phase AC or $\sqrt{3}$
2.0 for 3 - wire single ø AC or DC
3.0 for 4 wires, 3 ø AC

E - Voltage between the neutral and live wire or between two live wire if no neutral line exist.
I - Current in any live wire except Neutral line.
PF - Power Factor
N - Efficiency

2. Applying the **Formula.**

$$I = \frac{25 \text{ hp} \times 746 \text{ watts}}{1.73 \times 220 \text{ volts} \times 0.84 \times 90.5\%}$$

$$= 64.45 \text{ amperes}$$

3. ***Determine the Motor Feeder***. The current load of a motor multiplied by 125% (*Code requirements*).

$$64.45 \times 1.25 = 80.56 \text{ amperes}$$

4. ***Find the Size of the Conductor Wire.*** Refer to Table 2-5 or 4-2, for 80.56 amperes, use any of the following:

   3-38 mm^2 THW or RHW copper wire
   3-50 mm^2 TW copper wire
   3-80 mm^2 TW aluminum or copper clad alum.
   3-50 mm^2 THW or RHW aluminum or copper clad aluminum

   The allowable ampacities of the above wires on Table 4-2 was derated by 80% to carry the 80.56 amperes current load.

5. ***Solve for the Size of Conduit Pipe***. Refer to Table 2-9, use 50 mm diameter pipe

6. ***Determine the Size or Rating of the Over-current Protection***. The Code provides "*The maximum over current protection for a single motor or a combination of motors should be, 250% of the ampacity of the largest motor, plus the sum of the full load current of the other motors.*

Therefore:

64.45 amp. x 250% = 161.12 amperes minimum

7. Refer to Table 4-1. ***Use 150 amperes fuse or trip breaker.*** It is the nearest standard rating which does not exceed the 161.12 amperes current load as computed.

E. Main Feeder

1. Find the ***Total Connected Current Load***

   a. For Circuit 1 and 2 load.......... 11.74 amp.
   b. Circuit for motor current load.... 64.45 amp.
   Total current load... 76.19 amp.

2. The 76.19 amperes plus 25% of the ***largest motor*** as required by the Code we have:

   76.19 + .25 (64.45)

   = 92.30 amperes

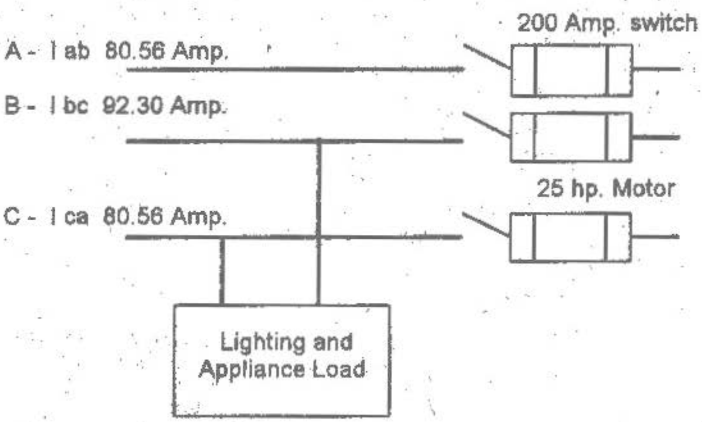


FIGURE 4-28

By inspection: A - 1 ab 80.56 amp.
B - 1 bc 92.30 amp.
C - 1 ca 80.56 amp.

The single phase B-C conductors that supplies both the motor and the lighting load has an amperage capacity of 92.30 amperes. The wire selected is adequate and safe to serve the motor and the lighting load.

However, if the phase current 1bc which is equal to 92.30 amperes exceeds the ampacity of the 38 mm^2 TW which is equals to 125 x 80% = 100 amperes, (see Table 4-2) then, select the next higher trade size for phase 1 bc.

Selection of the thermal and magnetic overload relay for various motor refer to Table 4-8 as specified by NEMA.

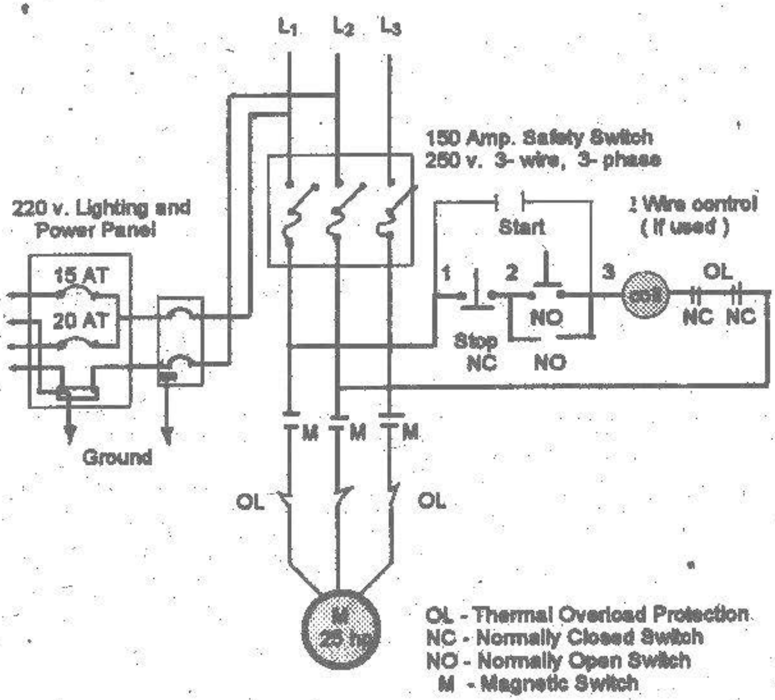


FIGURE 4-28 THREE LINE DIAGRAM

SCHEDULE OF LOAD TYPE OF SERVICE 3 PHASE, 3 WIRES, 60 Hz.

Ckt. No. Description	No. of outlet	volts	watts	Amp./ ckt.	Fuse	Size of Wire	Conduit
1 - Light Load	12	230	1200	5.22	15 AT	2-2.0 mm^2	13 mm
2 - Convenience outlet	-	230	1500	6.52	20 AT	2-3.5 mm^2	13 mm
3 - 25 hp Motor	1	230	18650	64.45	150 AT	3-38 mm^2	50 mm

I_1 = 92.30 amp, use 3-38 mm^2 THW copper wires 150 amperes safety switch, 250 volt, 3-poles single throw on 50 mm conduit pipe.

Materials for Motor Installation

1. 25 hp. Induction motor 230 volts, 3-phase, 1,800 5 rpm, 60 Hz. At 40° temperature rise.
2. Magnetic thermal overload control with contractors.
3. Service entrance cap 50 mm with locknut.
4. 38 mm^2 THW or RHW copper wire.
5. 50 mm^2 diameter IMT or RSC conduit pipe.
6. Conduit clamp with screw, 50 mm conduit pipe.
7. TPST safety switch or circuit breaker 150 a 250 volts.

The quantity of materials depends upon the area and choice of the designing Engineer

Calculation Procedures in Finding the Size of Feeder and the Overload Current Protection for a Group of Motors.

ILLUSTRATION 4-6

Four 3-phase motor 220 volts squirrel cage induction motor designed for 40° C temperature rise at 1,800 rpm. 60 Hz.

RATING	* APPROX. FULL LOAD CURRENT
20 hp	45 amp.
15 hp	39 amp.
10 hp	29 amp.
7.5 hp	21 amp.

* For Approximate Full Load Current values, see Table 4-7 Overload Relays of Various Motors.

RATING	* APPROX. FULL LOAD CURRENT
20 hp	45 amp.
15 hp	39 amp.
10 hp	29 amp.
7.5 hp	21 amp.

* For Approximate Full Load Current values, see Table 4-7 Overload Relays of Various Motors.

SOLUTION

1. Determine the main feeder of the motors. Apply ***25% of*** the ***biggest motor current load*** plus the <u>sum of the other motors.</u>

   (45 x 1.25) + 39 + 29 + 21

   = 145.25 amperes

2. Refer to Table 2-5 or 4-2. For the 145.25 amperes current load use any of the following conductor wires:

   3- 80 mm^2 THW or RHW copper wire
   3-100 mm^2 TW copper wire
   3-125 mm^2 THW or RHW aluminum or copper clad aluminum
   3-150 mm^2 TW clad aluminum

3. Determine the main *Overcurrent Protection*. The National Electrical Code provides that:

   " The protection rating or setting of a motor shall be 250% percent (maximum) of the full load current of the biggest motor being served plus the sum of the full load current of the other motors."

   (45 x 125%) x (250% + 39 + 29 + 21)

   140.625 + 89 = 229.625 amperes (maximum)

4. Refer to Table 4-8. Select a fuse or trip breaker that is nearest to standard rating that will not exceed 229.62 amperes. Use 200 amperes.

TABLE 4-9 SUMMARY OF BRANCH CIRCUIT REQUIREMENTS

Circuit Rating	15 amp.	20 amp.	30 amp.	40 amp.	50 amp
CONDUCTORS (Minimum size) Circuit Wires *	2 (1.6)	3.5(2)	5.5(2.6)	8(3.2)	14
Taps	2 (1.6)	2(1.6)	2(1.6)	3.5(2)	3.5(2)
OVERCURRENT PROTECTION	15 amp	20 amp	30 amp	40 amp	50 amp
OUTLET DEVICE Receptacle Amp.	15	15 or 20	30	40 or 50	50
MAXIMUM LOAD	15 amp	20 amp	30 amp	40 amp	50 amp

These Ampacities are for copper conductors where derating is not required.

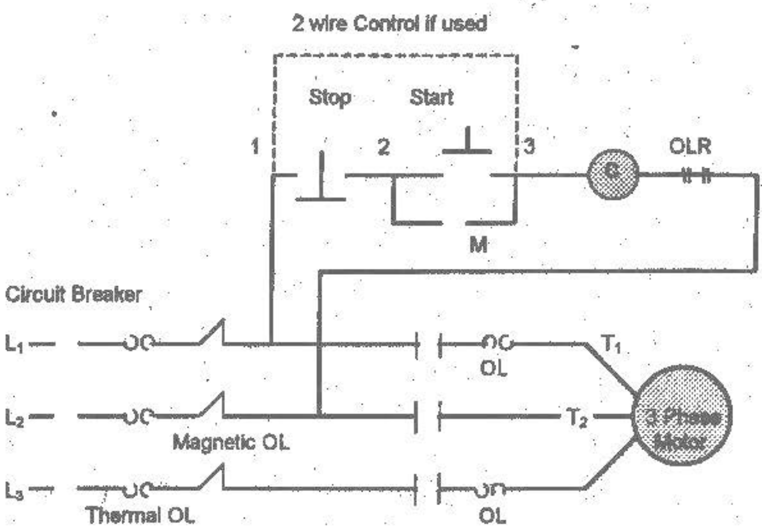


FIGURE 4-30
WIRING DIAGRAM FOR A TYPICL COMBINATION STARTER

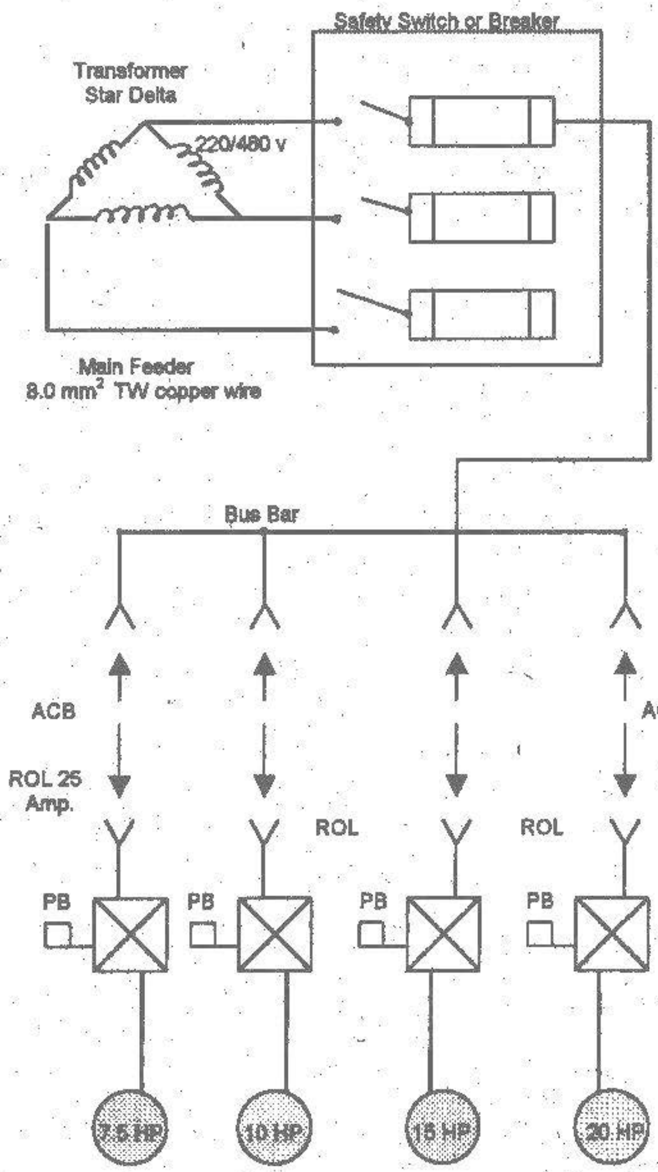


FIGURE 4-31
TYPCAL ONE LINE DIAGRAM OF A GROUP OF MOTORS AND CONTROLS

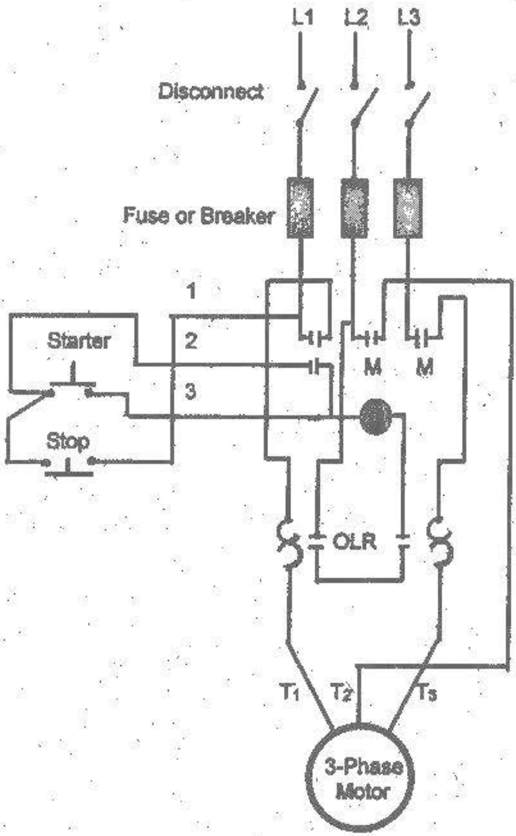
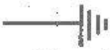
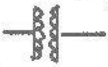
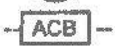
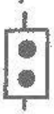
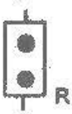
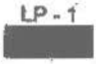
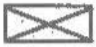
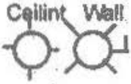
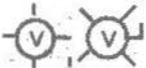
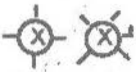
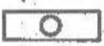
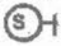
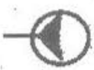


FIGURE 4-32

OTHER WIRING DIAGRAM FOR
TYPICAL COMBINATION STARTER

Electrical Symbols, Configurations and Figures for Electrical Plans, Panels, Circuits an Miscellaneous

Symbols	Description
----X--X---	Barbed wire fence
	Board Fence
---E--E---	Electrified Fence
	Antenna
	Lightning arrester. Indicate typeand Kv rating
	Circuit breaker, indicate rating and setting
	Fuse cutout, indicate rating.
	Ground
	Transformer. Indicate Kva. type, voltage & phase
	Service entrance. Indicate number of conductors, size type and voltage
	Service kilowatt-hour meter
	Air circuit breaker. Indicate rating and setting.
	Oil circuit breaker. Indicate rating and setting.
	Current Transformer cabinet
	Magnetic Starter
	Starter, Delta Wye
	Push button switch. Start and stop
	Push button switch. Remote control, start and stop.

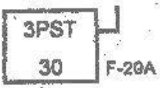
	Generator. Indicate Kva. phase, voltage and power factor
	Lighting panel. The number indicates lighting panel number
	Controller
	Incandescent light outlet
	Outlet for vapor discharge lamp
	Drop cord light outlet
	Exit light outlet
	Fluorescent light outlet
	Lamp outlet with pull switch
	Pull switch
	Outlet with blank P cover
	Fan Outlet
	Clock outlet
	Duplex convenience outlet
	Weatherproof convenience outlet
	Range outlet, 3-wire
	Switch and convenience outlet
	Radio and convenience outlet
	Special purpose outlet. Indicate rating in specifications
	Floor outlet

Junction box with J or Pull Box with P

Riser-down

Riser-up

Double throw safety switch. Indicate rating and number of poles NF (None Fused)



Safety switch. Indicate rating, number of poles (F-210-20 ampere fuse)


Knife switch. Indicate rating number of poles


Fused knife switch. Indicate number of poles

Lighting and or appliance circuit. The number indicates circuit number.

Load center. (Number indicates load center number)

Power panel. (Number indicates panel number)

Range. Indicate Kw. rating, phase and voltage.

Heater. Indicate Kva. rating, phase and voltage

Welder. Indicates Kva. or Kw. rating, type phase and voltage.


Ceiling fan


Wall fan

Motor. Indicate HP, phase, voltage and ampere rating

CHAPTER 5

ELECTRICAL LIGHTING MATERIALS

5-1 Incandescent Lamp

Incandescent lamp has a wide variety of forms, shapes and sizes. Likewise, its base is also made of different types and various designs. Incandescent lamps are critically dependent on the wattage supply that even for a small fluctuation of the current voltage, its life, output, and efficiency is materially affected. For instance:

1. Burning a 120 volt lamp with 115 volts current supply will mean approximately:

   15% less light of the lamp (**lumens**)
   7% lower power consumption (**watts**)
   8% lower efficacy (**lumens per hour**)
   72% more life (**burning hours**)

2. Burning a 120 volt lamp with 125 volts current supply will mean approximately:

   16% more light (**lumens**)
   6% more power consumption (**watts**)
   8% higher efficacy (**lumens per watt**)
   42% less life (**burning hours**)

Incandescent lamp is very sensitive to voltage change, and voltage change materially affects its life span. At an average 10% lower voltage supply, its life span is increased by 25% and reduces by 75% with 10% over voltage supply.

On the average, less than 10% of the wattage is utilized to produce light and the rest produces heat. In short, this type of lamp is considered as a poor choice for energy conversation because it produces poor and low level of lighting. However, incandescent lamp has also the following **Advantages:**

1. It is cheaper
2. Instant start and re-start
3. Simple inexpensive dimming
4. Simple and compact installation requiring no accessories
5. High power factor
6. It can be focused
7. Its life is independent of the number of start
8. It has good color.

Disadvantages of Incandescent Lamp

1. Has low efficacy
2. Has shorter life
3. Sensitive and critical to voltage changes or fluctuations.
4. High maintenance cost
5. More heat is produced than light

Due to its poor energy characteristics, incandescent lamp should be limited to the following applications:

1. Infrequent or short duration use.
2. Where low cost dimming is necessary
3. In focusing fixtures
4. Where minimum initial cost is required

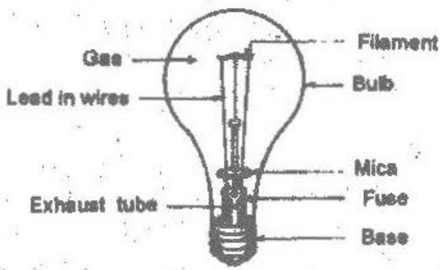


FIGURE 8-1 INCANDESCENT LAMP

ELECTRICAL LIGHTING MATERIALS

TABLE 6-1 EFFECTS OF OVERVOLTAGE AND UNDERVOLTAGE

	CONDITION	
LOAD	10% Undervoltage	10% Overvoltage
LIGHTING		
Incandescent	Output reduced by 30%	Life reduced by 67%
Fluorescent	Output reduced, poor start	Ballast overheating
Mercury lamp	Low output, poor start	Ballast overheating
MOTORS	20% Lower torque, hotter operation, reduce life, overloading	High starting current, excessive starting torque, higher noise
HEATERS	20% reduction in output	Overheat, short life.
SMALL TOOLS	Stalling, low power	Reduce life, burn windings

TABLE 6-2 TYPICAL DATA OF INCANDESCENT LAMPS

Lamp Watts	Ave. Rated Life (hrs.)	Initial Lumens	Lumens per watt	Size of base
60	1100	855	14.2	Med.
75	750	1180	15.7	Med.
100	750	1750	17.5	Med.
100	750	1710	17.1	Med.
150	750	2760	18.4	Med.
200	750	4000	20.4	Med.
100 SB	1000	1450	14.5	Med.
200 SBIF	1000	3300	16.5	Med.
300 SBIF	1000	5250	17.5	Mog.

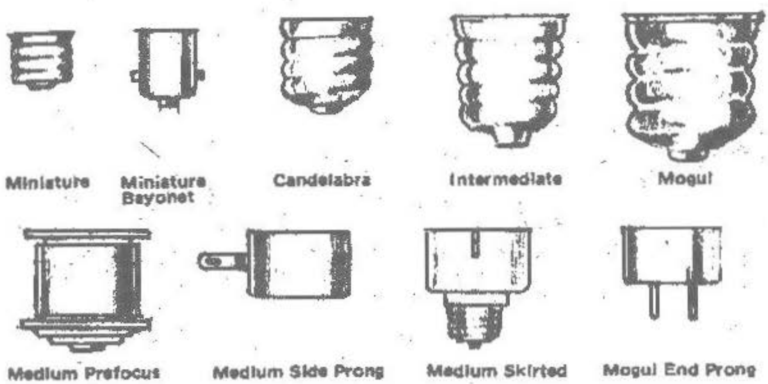
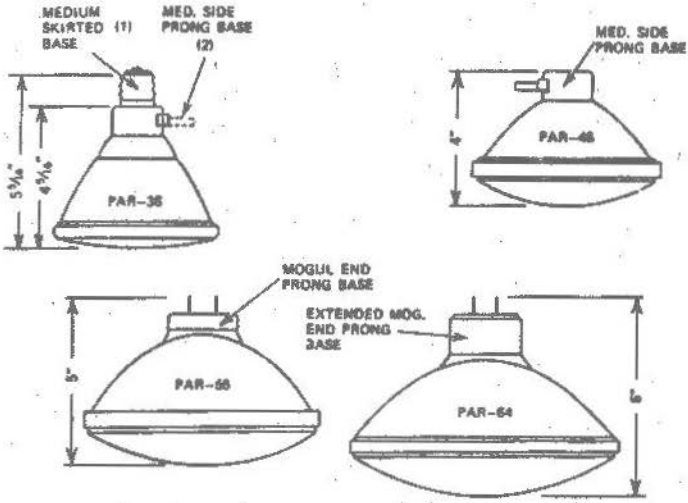


FIGURE 6-2 TYPES OF INCANDESCENT LAMP BASE



PROJECTOR	PAR-38				PAR-46	PAR-56	PAR-64
WATTS	75	100	150	150	200	300	500
BEAM TYPE	SP	FL	SP	FL	SP	MED. FL	MED. FL
DIAMETER"	$4^3/_4$	$4^3/_4$	$4^3/_4$	$4^3/_4$	5.6	7	8
M.O.L."	$5^5/_{16}$	$5^5/_{16}$	$5^5/_{16}$ (1) $4^5/_{16}$ (2)		4	5	6

SP = SPOTLIGHT
FL = FLOODLIGHT

Source: Architectural Lighting Graphics

FIGURE 5-3 REFLECTOR SPOT AND FLOOD LAMPS

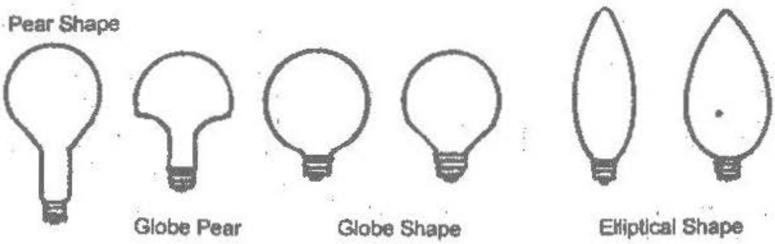
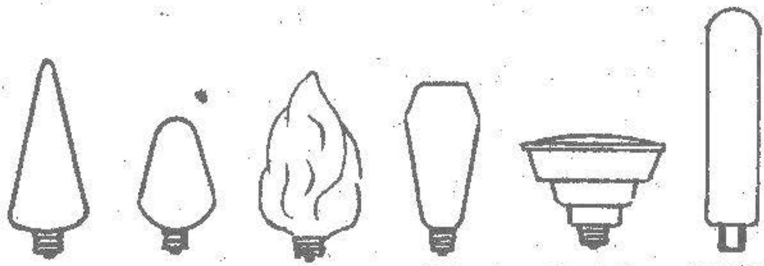


FIGURE 5-4 VARIOUS TYPES OF INCANDESCENT LAMP



5-2 Fluorescent Lamp

The **Fluorescent Lamp** was first introduced in 1937. It was considered the best, and most widely used type of lamp. Generally, it comes in varieties of sizes, wattages, colors, voltages and specific applications.

The **Cathode** fluorescent lamp is the most common type comprising of a cylindrical glass tube sealed at both ends, containing a mixture of an inert gas generally argon, and low pressure mercury vapor. At each end, is a cathode that supplies the electrons to start and maintain the mercury arc or gaseous discharge. The short wave ultra-violet light produced by the mercury arc is absorbed by the phosphors coating inside the tube and is re-radiated in the visible light range. The fluorescent lamp is so called because its phosphors radiate light when exposed to ultra violet rays.

Fluorescent lamp requires ballast in its circuit. The ballast is basically made of coil to limit the current in the circuit in which, if not controlled, will open the fuse or circuit breaker.

Characteristics of a Fluorescent Lamp

1. The fluorescent lamp efficacy is much higher than the incandescent lamp.
2. About 200% of its input energy becomes light, 80% is converted to heat including the ballast heat energy loss.

Efficiency - refers to the amount of energy converted to visible light.

Efficacy - is a measure of the lumens per watt produced by the lamp.

Life Span of Fluorescent Lamp

Fluorescent lamp has longer life span compared with the incandescent lamp. Its life span is materially affected by *the number of times the lamp is switched on and switched off.* Generally, switching wears out the lamp cathode and continuous burning of fluorescent lamp would last about 30,000 hours. With an average of 3 hours burning per start, fluorescent lamp could last for about 12,000 hours only.

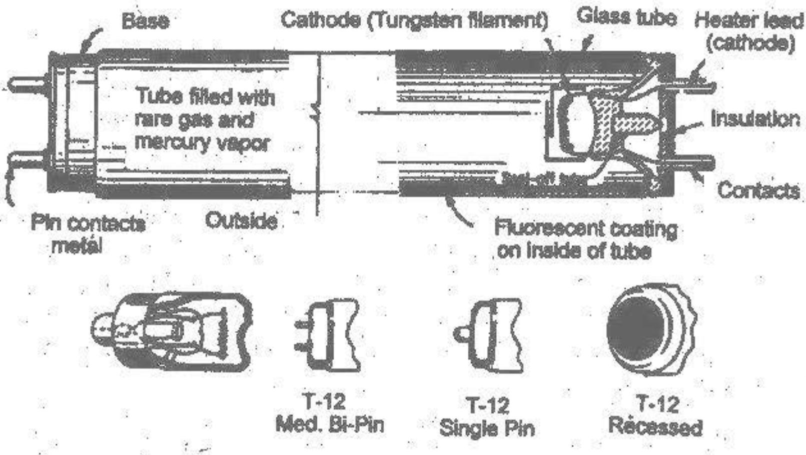


FIGURE 6-5 TYPICAL DETAIL OF A FLUORESCENT LAMP

Pre-Heat Lamp

The original fluorescent lamp is the preheated design. The circuit used is a separate starter. When the lamp circuit is closed, the starter energizes the cathode. After 2 to 5 seconds delay, it initiates a high voltage arc across the lamp causing it to start.

The preheat fluorescent lamp is ordered in the following specifications:

F 20 T 12 WW which means;
Fluorescent lamp 20 watts,
Tubular shaped bulb 12/8 inches diameter
Warm, White.

Rapid Start Lamp

The Rapid Start Lamp was introduced in 1952. It was typically the same in construction as the preheat lamp. The basic difference is the circuitry that eliminates the delay inherent in preheat circuit by constantly keeping the cathodes energized or preheated.

The 40W T12 is the most popular lamp represented by code name F40 T12 WW R/S. This high output lamp has a recessed contact base that requires special circuit and ballast that are not interchangeable with any other types of lamp. This type of lamp however, has shorter life span and is less efficient compared with the 4200 milli-ampere rapid start lamp. Most of the rapid start lamps operate at 425 milliamperes.

Another objection to this type of lamp, is the glare it produces aside from its very limited application. However, this particular type of lamp is specially used for outdoor sign lighting, street lighting, and merchandise display.

There are two special types of higher output rapid start lamps. Namely:

1. One that operates at 800 milli-amperes called High Output (HO)
2. One that operates at 1500 milli-amperes (1.5 amp.) called; Very High Output (VHO); Super High Output or Simply 1500 milliampere Rapid Start Lamp. In ordering this type of lamp, the abbreviation is:

F 48 T 12/CW/VHO which means:
Fluorescent 48 in. long, Tubular 12/8 in. diameter bulb
Cool White, Very High Output (1500 mla.) or

F 72 T 12/CW/HO which means:
Fluorescent 72 in. long, Tubular 12/8 in. diameter tube
Cool White, High Output (800 mla.)

Instant Start Fluorescent Lamp

This type of fluorescent lamp was introduced in 1944. It was called the ***Slim Lamp*** considered the best among the varieties of instant start fluorescent lamps. It has only one pin at each end acting as a switch to break the ballast circuit when the tube is removed. The lamp is operated in two lamp circuits at various current such as:

Normal current…200 and 425 milli-amperes (mla.)
Normal length….24 in., 36 in., 42, 48, 60, 64, 72, 84 and 96.

This lamp is a hot cathode, instant start lamp, different from the high voltage cold cathode type. Comparatively, this type lamp is more expensive than the rapid start type and somewhat less efficient. However, it has also the advantage of starting at a much lower ambient temperature than the rapid start circuit, This lamp is preferred on outdoor installations.

To Order this Type of Lamp it is Written as:

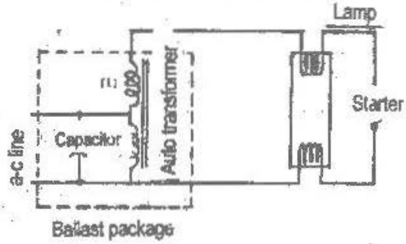
F 42 T 6 CW Slim line, meaning:
Fluorescent lamp 42 in. long,
Tubular 6/8 in. diameter tube
Cool White, Instant start

Take note that for Instant Start Lamp, the number following the letter F indicates the length of the tube, not the wattage. This is applicable to all lamps that operate at other than 425 milli-amperes which is the normal current.

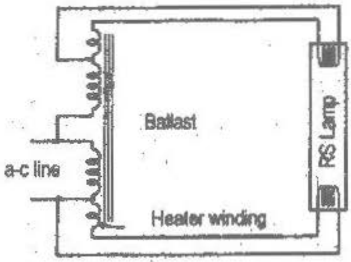
TABLE 5-3 FLUORESCENT LAMP DATA

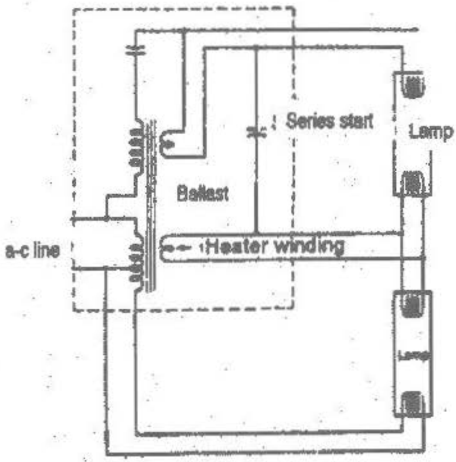
Lamp Code[a]	Watts	Lamp Current mil-amp.	Ballast Watts[bc]	Total Watts	Lamp Life hr [d]	Initial Output Lumens[e]	Actual Efficacy m/w [f]	Actual Efficacy lm/w[g]
Preheat Lamp								
F15 T8 CW	15	425	8	23	7500	870	38	58
F20 T12 CW	20	425	10	30	9000	1300	43	65
Rapid Start - Preheat Lamps [h]								
F40 T12 CW	40	425	6	46	18000	3150	68	79
F40 T12 WW	40	425	6	46	18000	3200	70	80
F40 T12 CWX	40	425	6	46	18000	2200	48	55
F40 T12 D	40	425	6	46	18000	2600	57	65
Rapid Start - High Output								
F48 T12 CW/HO	60	800	15	75	12000	4300	57	72
F60 T12 CW/HO	75	800	15	90	12000	5400	60	72
F72 T12 CW/HO	85	800	15	100	12000	6650	67	78
F96 T12 CW/HO	105	800	15	121	12000	9200	76	88
Rapid Start - Very High Output								
F48 T12 CW/VHO	110	1500	8	118	9000	6250	53	57
F72 T12 CW/VHO	165	1500	8	173	9000	9900	57	60
F96 T12 CW/VHO	215	1500	13	228	9000	14500	64	67
Instant Start (Slimline) Lamps								
F42 T6 CW	25	200	15	40	7400	1750	44	70
F64 T6 CW	40	200	10	50	7500	2800	56	70
F48 T12 CW	40	430	16	56	9000	3000	54	75
F64 T12 CW	55	430	16	71	12000	3600	51	65
F96 T12 CW	75	430	17	92	12000	6300	68	84

a Standard ordering abbreviation CW, cool white; WW, warm white; CWX, cool white de luxe; D, daylight
b Figures are for a two-lamp circuit per start
d Life figures are for 3 hours burning per start
e After 100 hours burning
f Includes ballast loss
g Excludes ballast loss
h Data given for lamps in a rapid start circuit



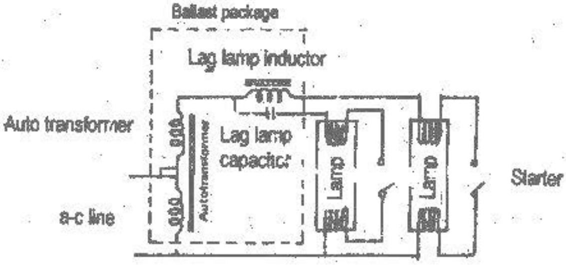
Preheat Circuit



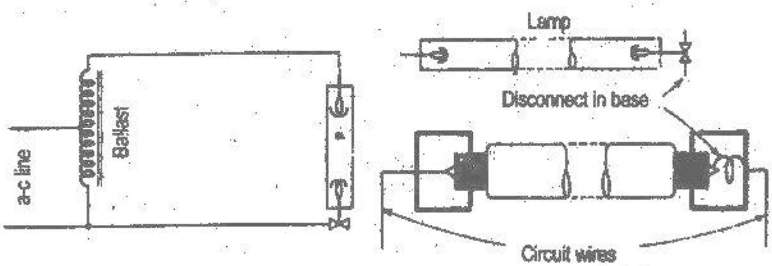


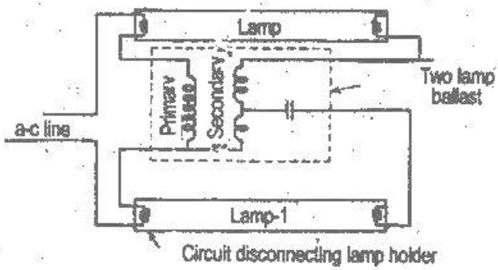
Rapid Start

FIGURE 5-6



Typical Two Lamp Instant Start Circuit





Two Lamp Preheat Circuit or Lead Lag Circuit

FIGURE 6-7

Cold Cathode Tube is another type of lamp that offers a very long life service compared with the hot cathode lamp. The lamp is not affected by the number of starting or switching of the lamp. It has a lower overall efficacy compared to the hot cathode lamp and is generally used where a long continuous burning is required.

Characteristics and Operation of Fluorescent Lamp

1. **Life Span** – depends on the burning hours per start.
2. **Lumen Output** – decreases rapidly during the first 100 hours of burning and thereafter much more slowly.
3. **Efficacy** – depends on the operating current and the phosphors utilized. Generally, the warm white lamp is more efficient than the white, cool white, daylight and colored lamps.

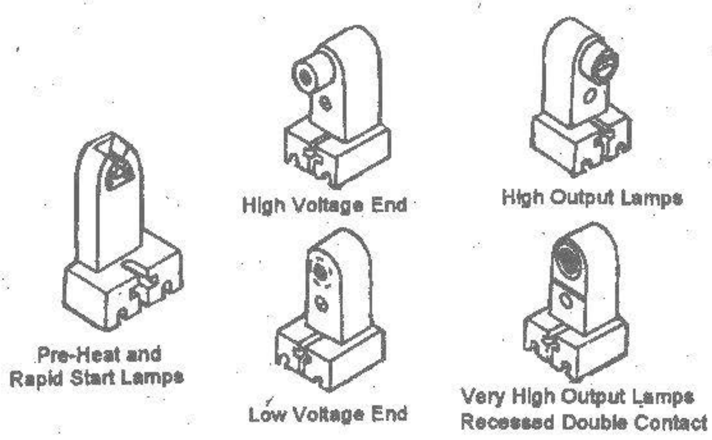


FIGURE 5-8 HIGH OUTPUT LAMPS

5-3 Mercury Lamp

Mercury lamp is a combination of the arc discharge characteristics of a fluorescent lamp and the compact focusable shape of an incandescent lamp. The combination effect is responsible for its efficiency and long life in various uses.

The American Standard Institute adopted a simplified code for the manufacture of mercury lamps containing five parts such as:

H38 MP 100DX which simply means;
H- Mercury lamp
38-Ballast number
MP- Lamp Physical characteristics
100- Lamp wattage
DX- Indicates phosphors, glass coating or coloring

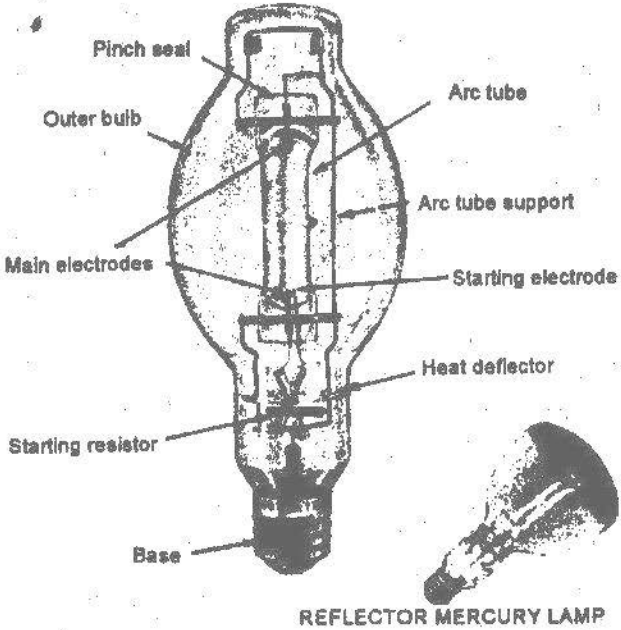
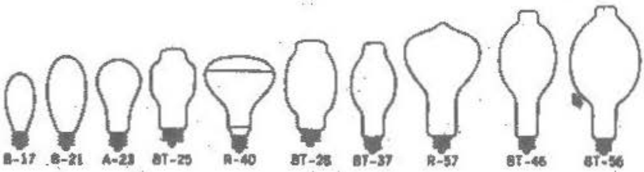


FIGURE 8-9 TYPICAL CONSTRUCTION OF A CLEAR MERCURY VAPOR LAMP

Special Features of Mercury Lamp

1. It is available in wide variety of shape, size and color with rating from 50 to 150 watts.

2. It requires ballast that could be mounted away from the lamp.
3. Because of its high efficiency, mercury lamp is a good replacement for incandescent lamp in the conservation of energy.
4. Dimming of mercury lamp is possible with a dimming ballast.



Explanation of color suffix in ordering abbreviation

Dx – Deluxe white R – Beauty lite
N – Style-Tone No suffix clear (non-phosphor coated)

Description Symbols

B - Black light RF – Reflector flood
FF – Froasted face S – Street lighting
G – General lighting VW – Very wide beam
W – Wide beam

FIGURE 6-10 TYPICAL FORMS OS MERCURY LAMPS

Lamp Life of a Mercury Lamp

1. The lamp life of a mercury lamp is extremely long with an average of 24,000 hours based on 10 burning hours per start.
2. Mercury lamp is not suitable for installation which is subject to constant switching. Thus, long period of burning per start is preferred.
3. The life of lamp if affected by:
   a. Ambient temperature
   b. Line voltage
   c. Ballast design

4. Lamp is replaced if accelerated lumens depreciation is near the end of its life span.
5. Clear lamp has the best lumen maintenance followed by the color improved and phosphors coated units.

The Ballast

Ballast is necessary to start the lamp, and thereafter, to control the arc. The basic ballast is a simple reactor that controls the arc after the discharge has been initiated. The lamp requires 3 to 6 minutes after switch on to reach the full output.

Types of Ballast

1. *Reactor Ballast* is a low power factor and does not require voltage regulation. This is only used where line voltage fluctuation does not exceed plus or minus 5%.
2. *Auto transformer Ballast* is a reactor unit with transformer to match line voltage to lamp voltage. It has a low power factor and non-regulating.
3. *High Power Factor Auto transformer Ballast* is the same as type 2 except the additional capacitor to improve the power factor.
4. *Constant Wattage Auto transformer Ballast* is also called Lead Circuit Ballast. A regulating high power factor unit that maintains lamp voltage making wattage and lumen output constant. The lamp wattage varies from 5% with a 10% voltage change.

Dimming Ballast

Dimming of mercury lamp is possible by using a dimmer ballast and a solid-state dimming control available for 400-700 and 1000 watts. A little use but effective and economical output reduction process, could be done by simply changing the circuit capacitance with an amount depending upon the lamp size and ballast type. As such, the lamp wattage and output can be reduced by approximately 50% with no adverse effect on lamp or ballast.

TABLE 5-4 MERCURY VAPOR LAMP DATA

Amp Watts	Bulb	Base	ANSI Ordering Abbreviation	Code	Rated Aver. Life hrs.	Approx Lumens Initial	Approx Lumens Mean
40	B-17	Med.	H46DL-40-50/DX	G	16000+	1100	800
50	B-17	Med.	H46DL-40-50/DX	G	16000 +	1550	1150
75	B-21	Med.	H43AZ-75	G,S	16000+	2800	2350
			H43AY-75/DX	G,S	16000+	2800	2200
			H43AY-75/N	G,S	16000+	2050	1600
			H43AY-75/R	G,S	16000+	2800	2200
100	A-23	Med.	H38LL-100	G	24000+	4100	3450
			H38MP-100/DX	G	24000+	4300	3200
			H38MP-100/N	G	24000+	3600	2650
	B-25	Mog.	H38HT-100	G,S,B	24000+	4100	3450
			H38JA-100R	G,S	24000+	4400	3300
	R-40	Med.	H38BP-100/DX	RF,FF,VW	24000+	2850	2280
			H38BP-100/N	RF,FF,VW	24000+	2450	1950
			H38BP-100/R	RF,FF,VW	24000+	2850	2280
175	BT-28	Mog.	H39KB-175	G,S,B	24000+	7700	6600
			H39KC-175/DX	G,S	24000+	8500	6800
			H39KC-175/N	G,S	24000+	7000	5600
			H39KC-175/R	G,S	24000+	2850	2280
	R-40	Med.	H39BM-175	RF,FF,W	24000+	6100	5150
			H39BP-175/DX	RF,FF,VW	24000+	5750	4800
250	BT-28	Mog.	H37KB-250	G, S, B	24000+	12100	9850
			H37KC-250/R	G,S	24000+	13000	9750
300	BT-37 (Econ-o-watt)	Mog.	H33CD-300	G,S	16000+	14000	
			H33GL-300/DX	G,S	16000+	15700	
400	BT-37	Mog.	H33CD-400	G,S,B	24000+	21000	18300
			H33GL-400/DX	G,S	24000+	23000	18400
	R-57	Mog.	H33FY-400	G,B,RF,FF W	24000*	18500	16400
			H33DN-400D/X	G	24000+	23000	18400
700	BT-46	Mog.	H35NA-700	G,S	24000+	41000	35700
1000	BT-56	Mog	H34GV-1000	G,B	16000+	55000	44000
			H34GW-1000/DX	G	16000+	56000	36400
			H36GV-1000	G,S,B	24000+	57500	47100
			H36GW-1000/DX	G,S	24000+	63000	44700

/DX - Deluxe White B - Black light S - Street Lighting FF - Frosted Face
R - Beauty Life VW - Very Wide Beam G - General Lighting W - Wide Beam
/N - Style Tone No suffix - means Clear RF - Feflector Flood

Special Type of Mercury Lamp

A small mercury lamp to replace interior incandescent lamps are available in 40; 50; 75 to 100 and 175 watts, sizes in deluxe white, and other color corrected design.

Self Ballast Lamp (un-ballasted) is available on where ballast mounting is impractical and inconvenient. Small size mercury lamps are also available to replace incandescent lamps. However, where a self-ballasted mercury lamp is contemplated, fluorescent lamp is a better choice considering the following advantages:

1. Lower in cost
2. Longer life
3. High efficiency
4. Good color
5. More attractive
6. Lower energy cost

5-4 Metal Halide Lamp

Basically, **Metal Halide Lamp** is **Mercury Lamp,** improved by the addition of halides of metal such as ***Thallium, Indium, or Sodium*** to the arc tube.

The addition of these salts, makes the light frequency radiate other than the basic mercury colors and at the same instance, increases its efficacy, but reduces the life and lumens maintenance to about 60% at two thirds life.

The color produced however is much warmer than the mercury light.

Brief Comparison of Mercury lamp and Metal Halide lamp

	Mercury Lamp	Metal Halide Lamp
Life span	16,000 to 24,000 hrs.	7,500 to 15,000 hrs.
Color	Poor to fair	Good to excellent
Lamp Efficacy	50 to 60 lpw.	80 to 100 lpw.

Recommended Applications

1. For exterior use, clear lamps are recommended.
2. For indoor use, the phosphor coated unit is recommended including lights for food display.

Other Characteristics of Metal Halide Lamp

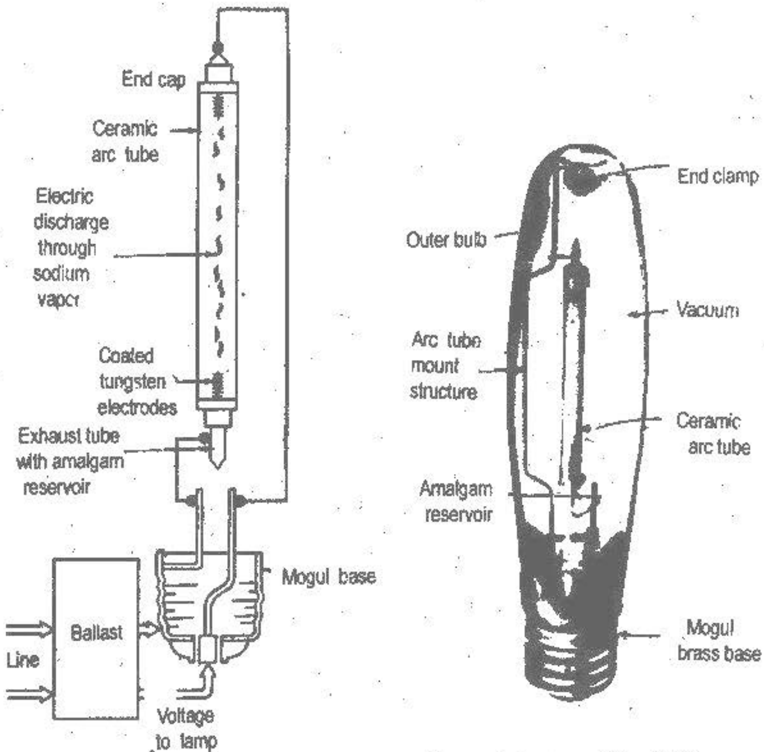
1. The color depends on the amount of iodized-halide salt in the arc. Its performance is extremely sensitive to voltage, temperature and burning position.
2. Strike time is shorter than that of the mercury lamp from 2 to 3 minutes.
3. The re-strike time is up to 10 minutes making little inconvenience in indoor areas that needs immediate light.
4. Certain metal halides are usable with mercury lamp ballast.

5-5 High Pressure Sodium Lamp

The High Pressure Sodium Lamp was first developed and introduced by General Electric Co. (GE). This is one of the latest developments in the high intensity discharge (HID) lamps. It is marked under the trade name Lucalux, Ceramalux and Analox.

One outstanding feature of this lamp is its output. The efficacy and ballast losses, is almost 100 lumen per watt, which is double that of a colored corrected mercury lamp. It has a yellowish color similar to a low wattage incandescent lamp, and a warm white fluorescent lamp. It is smaller in size, high output, and longer life. But like all high intensity discharge lamps, sodium lamps do not start instantaneously. The start and re-strike time required, is shorter than that of a mercury lamp. Unlike the metal halide lamp, the HPS is not sensitive to voltage changes. Its color is constant, and the ballast is different from that of the mercury or metal halide lamps that needs higher voltage.

Lamp efficacy	85 to 140 lpw
Life span	16,000 to 24,000 hours
Lumen maintenance	80 to 90%
Warm up time	3 to 4 minutes
Re-strike time	½ to 1 ½ minutes



Electrically, the HPS lamp is a simple device. The base contact and the internal wiring serves to provide a current connection to the ballast and arc tube electrodes.

The main feature of the HPS lamps are the alumina ceramic tube, amalgam reservoir and the rigid arc tube structure. This type is rated at 310 watts and yields 37,000 initial lumens and last for about 24,000 hr. life.

FIGURE 5-11 HIGH PRESSURE SODIUM LAMP

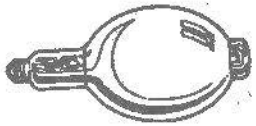
TABLE 5- 5 HIGH PRESSURE SODIUM LAMP (HPS) LUMALUX CLEAR LAMPS - Special Ballast Required

Watts	Bulb	Average Rated Hours Life [a]	Approx. Lumens Initial	Approx. Lumens Mean	L.C.L.	M.O.L	Lamp Efficacy (LPW)	Lamp & Ballast Efficacy
70	BT-25	20000	5800	5220	5	7-1/2	83	58
100	BT-25	20000	9500	8850	5	7-1/2	95	66
150	BT-25	24000	16000	14400	5	7-1/2	106	79
150	BT-28	24000	16000	14400	5	8-5/16	106	79
250	E 18	24000	27500	24750	5-3/4	9-3/4	110	90
400	E 18	240000	50000	45000	5-3/4	9-3/4	125	104
1000	E 25	24000	140000	126000	8-3/4	15-1/16	140	121

Watts	Bulb	Average Rated Hours Life [a]	Approx. Lumens Initial	Approx. Lumens Mean	L.C.L.	M.O.L	Lamp Efficacy (LPW)	Lamp & Ballast Efficacy
70	BT-25	200000	5400	4860	5	7-1/2	77	54
100	BT-25	20000	8800	7920	5	7-1/2	100	74
400	BT-37	24000	47500	42750	7	11-1/2	119	99

[a] Based on operation on proper auxiliary equipment for 10 hr .or more per start

Lumalux Coated Lamps are used in open bottom fixtures or where glare is a problem. Special ballast is required.



- Operate on existing Mercury lag type auto transformer ballasts or 240-277 volt reactors.
- Will operate on most mercury series circuits.

FIGURE 5-13 LUMALUX COATED LAMPS

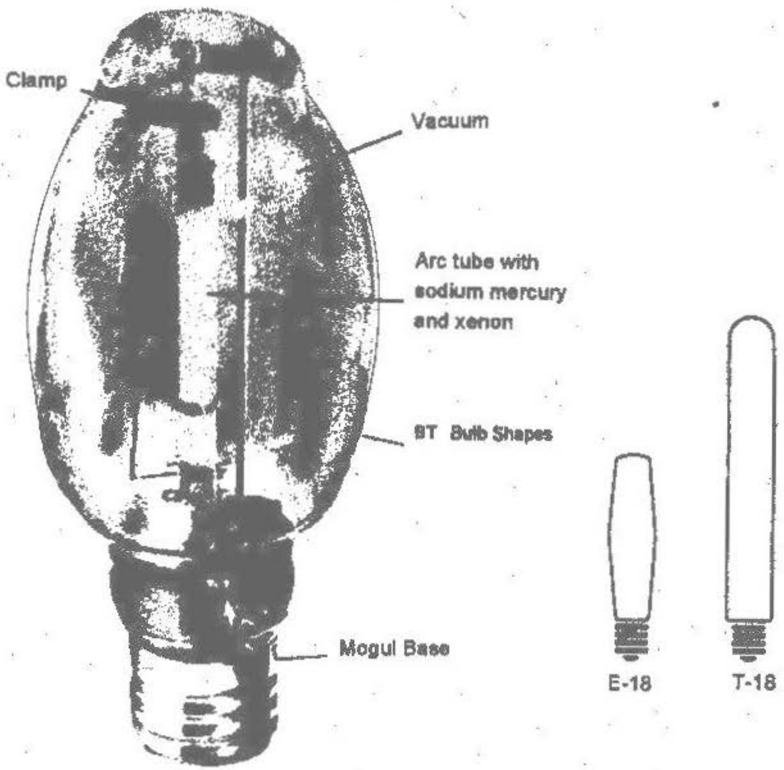
UNALUX CLEAR LAMPS

Watts	Bulb	Average Rated Hours Life*	Approx. Lumens Initial	Approx. Lumens Mean	LCL	MOL	Lamp Efficacy LPW	Lamp & Ballast Efficacy
150	BT-28	12000	12000	10800	5	8-5/16	80	65
360	BT-37	16000	36000	32400	7	11-1/2	100	88

UNALUX COATED LAMPS - Used in open bottom fixtures or where glare is a problem.

Watts	Bulb	Average Rated Hours Life*	Approx. Lumens Initial	Approx. Lumens Mean	LCL	MOL	Lamp Efficacy LPW	Lamp & Ballast Efficacy
150	BT-28	12000	13000	11700	5	8-5/16	87	70
360	BT-37	16000	38000	34200	7	11-1/2	106	93

Unalux Coated Lamps is used in open bottom fixtures or glare is a problem. Operates on existing Mercury lag type auto transformer ballasts or 240-277 volt reactors. This type of lamp operates on most mercury series circuits.



WATTS	BULB	BASE	LCL	MOL	LIFE HRS. 10 BURNING HRS PER START	LUMENS INITIAL	LUMENS MEAN
150	BT-28	Mog.	5"	8 5/16"	15000	16000	14400
250	E - 18	Mog.	5 3/4"	9 3/4"	15500	25500	23200
400	E - 18	Mog.	5 3/4"	9 3/4"	20000	50000	45000
1000	T - 18	Mog.	8 3/4"	15 1/16	100000	130000	119600

SOURCE: General Electric Company

FIGURE 5-14 HIGH PRESSURE SODIUM LAMPS (HPS)

5-6 Low Pressure Sodium Lamp

This type of lamp is also called SOX. It produces light of sodium characteristics monochromatic deep yellow color. This is not applicable for general lighting purposes because of its very high efficacy over 150 lumens per watt including ballast loss. It can be used wherever color is not an important criteria.

SOX is widely used on streets, roads, area lighting and for emergency or after hours indoor lighting. SOX has 100% lumen maintenance, long life which could last for 18,000 or more hours making it the most economical source in terms of cost per million lumens produced.

Choice of Light Source

Cost study should be based on:

1. Annual and life cycle of the lamp
2. Impact on the heating/cooling system
3. Quantity of lumens produced
4. Re-lamping which includes labor
5. Energy cost
6. Capital investment

5-7 Tungsten-Halogen Lamp

The Tungsten-Halogen Lamp is popularly called Quartz Lamp. It is a special type of incandescent lamp. One advantage it has over the normal incandescent lamp is its ability to maintain a constant level of light output throughout its life.

The life span of a quartz lamp is about three to four times that of the normal incandescent lamp. According to the result of experiments made, 13% of its wattage, produces light and 87% produces heat. Comparatively, it was proven after sufficient time of use that the quartz lamp has longer life and more efficient than the incandescent lamp.

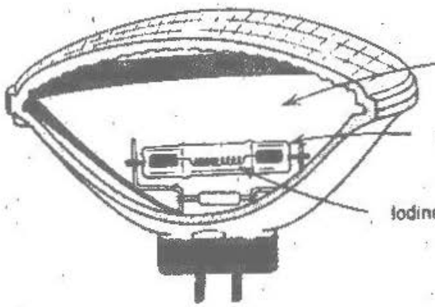


FIGURE 5-14 TUNGSTEN-HALOGEN LAMP OR QUARTZ LAMP

TABLE 5-6 TYPICAL DATA FOR TANGSTEN-HALOGEN LAMP

Watts	Bulb	Max Overall Length Inches	mm	Rated life Hours	Approx In'l Total lumens	Mean Lumen Through life %
250	PAR-38	5.31	135	4000	3220	94
500	PAR-56	5.00	125	4000	8000	94
1000	PAR-64	6.00	150	4000	19400	94
1000	R-60	10.12	257	3000	17000	95
250	T-4	3.00	75	2000	4850	95
300	T-4	3.12	80	2000	5650	95
400	T-4	3.62	92	2000	7970	95
500	T-4	6.00	150	2000	10750	95
750	T-6	6.00	150	2000	15750	95
1000	T-6	5.62	143	4000	19800	95

5-7 Lighting Fixtures

Lighting fixtures are electrical devices designed to hold and connect the lamps to power supply as well as control and distribute the light, and to position and protect the lamp.

Not all lighting fixtures however, possess all these functions. For instance, lamp holder only serves as holder of the lamp, or as a connection of the lamp and some others fixtures that are utilized as aid in the distribution or control of light.

Considering the various types and design of lighting fixtures serving a definite and specific purpose, lighting fixtures are classified into: lampholders, reflectors or shields and diffusers. Lampholders are either cord or box-mounted sockets for the incandescent lamps or wiring strips for the fluorescent lamps which is provided with wiring channel and mounting for the ballast. Aside from holding the lamp and connecting it to the power supply it is also designed to protect the lamp itself. Some lampholders are even provided with reflectors and others are designed for focusing the light.

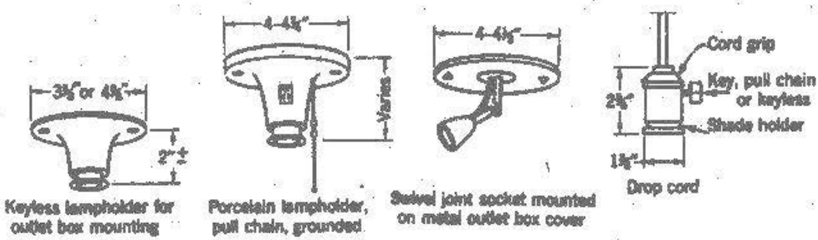


FIGURE 6-16 LAMPHOLDERS

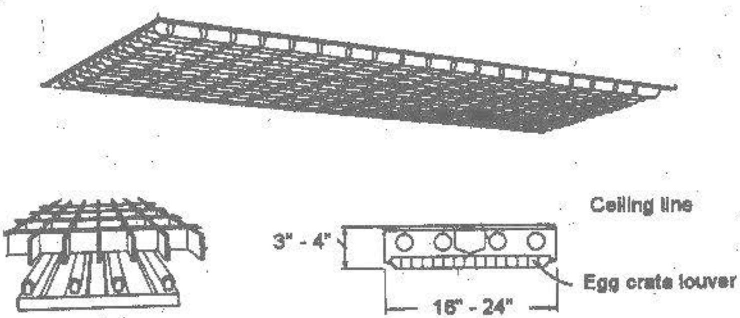
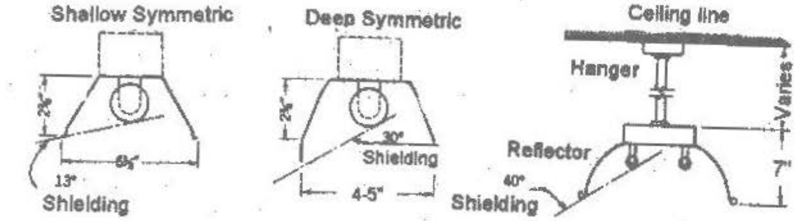
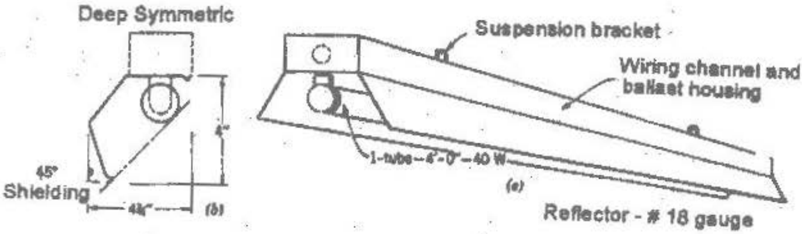


FIGURE 6-17 LIGHTING REFLECTORS AND DIFFUSERS





Diameter	Lamp
12"	60-100 w
14"	150 w
16"	200 w
18"	300-500 w

FIGURE 5-18

LIGHTING REFLECTORS AND DIFFUSERS

CHAPTER 6

PRINCIPLES OF ILLUMINATION

6-1 Definition of Terms

Illumination is defined as the intensity of light per unit area. When we talk of illumination, or simply lighting, we are referring to man made lighting. Daylight being excellent is not included. Indeed, we assume a night time condition.

Electric Illumination is the production of light by means of electricity and its applications to provide efficient, comfortable and safe vision. Specifically, when one speaks of lighting design, he refers to only two things:

1. The quantity of light and
2. The quality of light

Quantity of Light refers to the amount of illumination or luminous flux per unit area. Quantity of light can be measured and easily handled because it deals with the number of light fixtures required for a certain area.

Quality of Light refers to the distribution of brightness in the lighting installation. It deals with the essential nature or characteristics of light. In short, quality of light is the mixture of all the items related to illumination other than the quantity of light which includes several elements such as:

1. Brightness
2. Glare
3. Color
4. Psychological reaction to color and fixtures
5. Brightness ratio or contrast
6. Diffuseness
7. Aesthetics
8. Economics

There are four factors that affect illumination:

1. Brightness	3. Glare
2. Contrast	4. Diffuseness

Brightness is the light that seems to radiate from an object being viewed. Brightness or luminance is the luminous flux *(light)* emitted, transmitted or reflected from a surface.

Contrast is the difference in brightness or the brightness ratio between an object and its background. The recommended brightness ratio between an object being viewed and its background is normally 3:1.

If a print on a white paper can be clearly seen on a light background, it is due to the effect called **contrast.** Likewise, if a light object is placed on a dark background, the light object reflects more light and look brighter although both have equal illumination. It is for this reason that office furniture is generally light colored, tan or light green for eye comfort.

Glare is a strong, steady, dazzling light or reflection. The quality of the lighting system must also include the visual comfort of the system, that is, the absence of glare. An excessive luminance and or excessive luminance ratio in the field of vision is referred to as glare.

There are two types of glare:

1. *Direct Glare* is an annoying brightness of light in a person's normal field of vision.
2. *Indirect or Reflected Glare* is much more serious and difficult to control. Technically, reflected glare is a glossy object.

When the discomfort glare is caused by light sources in the field of vision, it is known as *direct or discomfort glare*. When the glare is caused by reflection of a light source in a viewed surface it is called ***reflected glare*** or ***veiling reflection***.

Diffuseness refers to the control of shadows cast by light. Diffuseness is the degree to which light is shadowless, and is therefore a function of the number of directions to which light collides with a particular point and the comparative intensities.

Perfect Diffusion is an equal intensity of light clashing from all directions producing no shadows. A single lamp will cast sharp and deep shadows. The color of lighting and the corresponding color of the object within a space is an important consideration in producing a quality of light. A luminous ceiling provides a satisfactory diffused illumination and less shadows.

There are three characteristics that define a particular coloration, they are:

a. **Hue** – is the quality attribute by which we recognize and describe colors as red, blue, yellow, green, violet and so on.
b. **Brilliance or Value** – is the difference between the resultant colors of the same hue, such as: white is the most brilliant of the neutral colors while black is the least.
c. **Saturation or Chromate** – is the difference from the purity of the colors. Colors of high saturation must be used in a well lit spaces.

6-2 Estimating Illumination and Brightness

In many respect, it is more important to know luminance measurements and illumination because the eye is more sensitive to brightness than simple illumination. It is more difficult to measure luminance than illumination. However, there are three types of luminance meter available:

1. **The Comparator** type requires the operator to make a brightness equivalence judgment between the target and the background.

2. **The Direct Reading type** is basically an illumination meter equipped with a hooded cell arranged to block oblique light.
3. **The Accurate Laboratory Instrument** that is unsuitable for fieldwork.

The quantity of light or level of illumination can be measured or calculated with the aid of a portable foot-candle meter.

Footcandle (fc) is the amount of ***light flux density***. It is the unit of measure used when describing the amount of light in a room and is expressed in ***lumens per square foot.***

Footlambert (fl) is defined as ***"the luminance of a surface reflecting, transmitting or emitting one lumen (lm) of illumination per square foot of area in the direction being viewed or the conventional unit of brightness or luminance.*** In the same manner, the lumens (lm) is the light output generated continuously by a standard wax candle.

In our study of light, we are interested in the amount of light that falls on the areas we want to illuminate. We also want to know the lumens per square foot or square meter in a particular space. This quantity called ***Light Flux Density*** is the common term ***Foot-candle (fc)*** represented by the formula:

$$\textbf{Footcandle} = \frac{\textbf{Lumens}}{\textbf{Area}}$$

ILLUSTRATION 6-1

A 40-watt fluorescent lamp 120 centimeters (48 in.) long produces 3,200 lumens of light in a room having a general dimensions of 10 x 20 ft. Find the illumination on the floor.

SOLUTION

1. $\text{Footcandle (fc)} = \frac{\text{Lumens}}{\text{Area}}$

$$Fc = \frac{3{,}200 \text{ lm}}{10 \times 20 \text{ ft.}}$$

$$= 16 \text{ footcandle}$$

The Footcandle is an important unit of measure in calculating the desired illumination and layout of fixtures. In the absence of footcandle table of equivalent for a particular fixture, a rule of thumb of 10-30-50 illumination level is here presented.

10 – footcandle is adequate for halls and corridors.
30 – footcandle is sufficient for areas between work stations such as in offices other than desk areas.
50 – footcandle is satisfactory on spaces where office work is being done.

However, providing an adequate quantity of light alone is not a guarantee for an efficient and comfortable vision. In fact, the quality of light is very important especially where difficult visual needs are required. The luminance or brightness of a diffusely reflecting surface is equal to the product of the illumination and the reflectance. Thus;

Luminance = Illumination x Reflectance factor or

Footlambert = Footcandle x Reflectance factor

ILLUSTRATION 6 -2

From illustration 5-1, find the luminance if the reflectance factor of the wall is 40%.

SOLUTION

$$\text{Footlambert} = \text{Footcandle} \times \text{Reflectance factor}$$

$$= 16 \times 40\%$$

$$= 6.4$$

Lighting Units in Metric Measures

In the English System of measure, the distance is expressed in feet and the area is in square feet. Under the Metric System (SI) the distance and area are expressed in meters and square meters respectively. Meanwhile;

Lumens flux remains in **Lumens;** but

Illumination or light flux is expressed in **Lux.** Thus:

$$\text{Lux} = \frac{\text{Lumens}}{\text{Area (sq. m.)}}$$

TABLE 6-1 APPROXIMATE REFLECTANCE FACTOR

Medium Value Color	Percent
White	80-85
Light gray	45-70
Dark gray	20-25
Ivory white	70-85
Ivory	60-70
Pearl gray	70-75
Buff	40-70
Tan	30-50
Brown	20-40
Green	25-50
Olive	20-30
Azure blue	35-40
Sky blue	35-40
Pink	50-70
Cardinal red	20-25
Red	20-40

In the Metric System, **Luminance** or **Brightness** is expressed in **Lambert** which is defined as *"the luminance or brightness of a surface reflecting, transmitting or emitting one lumen per square centimeter.*

Millilambert is more conveniently used than the lambert because the value of lambert is greater than what is usually encountered.

TABLE 6-2 TABLE OF COMPARISON

Description	English	Metric (SI)
Length	Feet	Meter
Area	Square foot	Square meter
Luminous Flux	Lumens	Lumens
Illumination Flux Density	Footcandles	Lux
Luminance	Footlamberts	Lamberts or Milli-lamberts

ILLUSTRATION 6-3

A 40 watts x 120 centimeters long fluorescent lamp produces 3,200 lumens of light in a room having a general dimension of 10 ft x 20 ft. Compute the illumination on the floor comparing the English and the Metric units.

SOLUTION by Comparison

		Engllish	Metric (SI)
Light Flux	=	3,200 lm.....	..3,200 lm.
Area	=	10' x 20'	... $\frac{10 \times 20}{10.76}$
	=	200 sq. ft....	...18.59 sq. m.
Illumination	=	$\frac{3{,}200 \text{ lm}}{200 \text{ sq. ft.}}$	.. $\frac{3{,}200 \text{ lm}}{18.59 \text{ sq. m.}}$
	=	16 fc........	. 172.16 lux

ANOTHER SOLUTION

Convert : 10 feet to meter = 3.048 m.
20............. = 6.097 m.

$$\text{Lux} = \frac{3{,}200}{3.048 \times 6.097}$$

$$= 172.19 \text{ Lux}$$

ILLUSTRATION 6-4

Compute the brightness of a fixture with a 1'x 4' plastic diffuser having a transmittance of 0.6 and illuminated by 2 pcs. 3,200 lumen lamp assuming 100% use of light flux.

SOLUTION

1. $$\text{Luminance} = \frac{\text{Total lumens} \times \text{Transmission factor}}{\text{Area of diffuser}}$$

$$= \frac{2 \text{ pcs.} \times 3{,}200 \times 6}{1' \times 4'}$$

$$= 960 \text{ footlambert}$$

2. To obtain the metric equivalent, multiply:

$$\text{Millilambert} = \text{Footlambert} \times 1.076$$

$$= 960 \times 1.076$$

$$= 1{,}032.96 \text{ millilambert}$$

The Watts per Square Meter

Another methods used in determining the illumination, is the ***watts per square meter***. The floor area is computed from the outside dimensions of the building excluding open porches.

Depending upon the size of the room, colors of wall and ceiling, types of lighting units, and methods of lighting used, the watts per square meter method may produce 50 to 100 lux that is approximately 5 to 10 footcandles.

1. For industrial areas, twenty (20) watts per square meter will provide an illumination of 100 to 150 lux which is approximately 10 to 15 footcandles.
2. For commercial areas, two (2) watts per square foot or 22 watts per square meter will provide from 80 to 120 lux when used with standard quality equipment.
3. Forty (40) watts per square meter will provide about 200 lux that is approximately 20 fc wherein greater illumination is required.
4. Sixty (60) watts per square meter will provide about 300 lux or approximately 30 fc usually recommended for many conventional, industrial and commercial requirements.
5. Eighty (80) watts per square meter will provide from 300 to 350 lux. In excess of 350 lux, supplementary lightings are necessary.

6-3 Coefficient of Utilization and Maintenance Factor

The usable **Initial** footcandle or lux is equal to the footcandle produced by the coefficient of utilization (cu).

Initial was emphasized, because the output of the light fixture is reduced with time as the lamp fixture becomes old and dirty. Lamp output normally drops and it is termed as ***Maintenance Factor*** (mf). And to find the average maintained illumination, we reduce the initial illumination by the maintenance factor.

The ***efficiency of a light fixture is equals the ratio of fixture output lumens to lamp output lumens***. What we need is to determine a number indicating the efficiency of the fixture room combination, or how a particular light fixture lights a particular room. This number is normally expressed in decimal values called **coefficient of utilization (cu).**

The **usable initial footcandle** is equal to the footcandle produced by the coefficient of utilization (cu).

a) **Initial footcandle** = $\dfrac{\text{footcandle x cu.}}{\text{Area}}$

b) **Maintenance illumination** = $\dfrac{\text{lamp lm x cu. x mf.}}{\text{Area}}$

* *Lamp lumen therefore is simply the rated output of the lamp.*

TABLE 6-3 COEFFICIENT OF UTILIZATION

Fixture Description	cu
Efficient fixture, large unit colored room	0.45
Average fixture, medium size room	0.35
Inefficient fixture, small or dark room	0.25

TABLE 6-4 MAINTENANCE FACTOR

Enclosed fixture, clean room	0.80
Average conditions	0.70
Open fixture or dirty room	0.60

ILLUSTRATION 6-5

A school classroom with general dimensions of 24 x 30 feet is lighted with 10 fluorescent lamp 4F 40 T12 WW rapid start lamp. Calculate the initial and maintained illumination in foot candle (*English*) and Lux (*Metric*), assuming that the coefficient of utilization (cu), is 0.35 and the maintenance factor (mf) is 0.70.

SOLUTION – 1 (English Measure)

1. Refer to Table 5-3. The F 40 T 12 WW watts fluorescent lamp has 3,200 lm. output. Multiply:

$$\text{Lamp lumens} = 10 \text{ fixtures} \times 4 \text{ lamps per fixture}$$
$$= 40 \times 3{,}200 \text{ lumens per lamp}$$
$$= 128{,}000 \text{ lumens}$$

$$\textbf{Initial Foot Candle} = \frac{\text{Lumens} \times \text{cu} \times \text{mf}}{\text{Area}}$$

$$= \frac{128{,}000 \times 0.35 \times 0.70}{24\text{ft.} \times 30\text{ft.}}$$

$$= 62.22 \text{ fc.} \times 0.70 \text{ mf}$$

$$= 43.55 \text{ foot candle}$$

SOLUTION – 2 By the Metric Measure (SI)

Convert feet to meter: 24 ft. = 7.32 m.
30 ft. = 9.14 m.

$$\textbf{Lux} = \frac{\text{Lumens} \times \text{cu} \times \text{mf}}{\text{Area}}$$

$$= \frac{128{,}000 \times 0.35 \times 0.70}{7.32 \text{ m.} \times 9.14 \text{ m.}}$$

$$= 468.75 \text{ Lux}$$

Check the answer:

One lux = .09294 foot candle

468.75 x .09294 = 43.56 fc

When the size of the room and the foot candle are given, the problem is how to find the number of lamps required in each fixture. The following example is presented.

ILLUSTRATION 6-6

An office room with general dimensions of 8 x 20 meters is to be lighted at an average maintained foot candle of 50. How many 3-lamp fixtures of 120 centimeters long F40 T12 WW rapid start fluorescent lamps are required assuming 0.38 cu and 0.75 mf ?

SOLUTION

1. **Lamp lumens** $= \dfrac{\textbf{maintained footcandle x area}}{\textbf{cu x mf}}$

$$= \frac{50 \text{ fc x } (8 \text{ m. x } 20 \text{ m.})}{0.38 \times 0.75}$$

$$= 28{,}070 \text{ lumens}$$

2. Each 40 watt fluorescent lamp has an output of 3,200 lumen, the number of lamps will be:

$$\text{Number of lumens} = \frac{28{,}070}{3{,}200}$$

$$= 8.77 \text{ lamps}$$

3. Since there are 3 lamps for each fixture, divide:

$$\frac{8.77}{3} = 2.93 \text{ say 3 lamps in each fixture}$$

Calculation involving a wide area is sometimes confusing than by computing the number of lamp fixtures per bay or per row which is found to be simple and interesting. This could be done easily by using the following formula:

$$\text{Number of fixtures} = \frac{\text{Illumination x area}}{\text{lamp per fixture x lumens x cu x mf}}$$

This means that, the area lighted by a single fixture is:

$$\text{Area per fixture} = \frac{\text{lamp per fixture x lumens per lamp x cu x mf}}{\text{Illumination}}$$

TABLE 6-6 EFFICACY OF VARIOUS LAMPS

Source	Lumens per Watt
Candle	0.10
Oil Lamp	0.30
Original Edison Lamp	1.40
1910 Edison Lamp	4.50
Modern Incandescent Lamp	14-20
Tungsten Halogen Lamp	16-20
Fluorescent Lamp (including ballast losses)	50-80
Mercury Lamp (including ballast losses)	40-70
Metal Halide Lamp (including ballast losses)	60-80
High Pressure Sodium Lamp	90-100

ILLUSTRATION 6-7

An entire office floor is lighted at an average maintained 538 lux or 50 fc. The floor measures 20 meters by 50 meters and is divided into bays measuring 4 m. x 5 m. Using 2-lamp of F40 T12 CW rapid start preheat lamp, find the number of fixtures required. Assume an economy grade fixture with a low cu of 0.35 and mf of 0.70.

SOLUTION – 1

1. Solve for the number of fixtures per bay. Refer to Table 5-3.

   for F40 T12 CW, lumens = 3,150

2. $$\text{No. of fixtures} = \frac{\text{Illumination x Area}}{\text{Lamp per fixture x lumens x cu x mf}}$$

   $$= \frac{538 \text{ lux x } (4 \text{ m. x } 5 \text{ m.})}{2\text{-lamps x } 3{,}150 \text{ lm. x } 0.35 \text{ x } 0.70}$$

$$= \frac{10,760}{1,543} = 6.9 \text{ fixtures}$$

Accept 6 pieces of fixture per bay to make it symmetrical.

SOLUTION – 2

1. From the following Formula, substitute the values:

$$\text{Area per Fixture} = \frac{\text{Lamp per fixture x lumen/lamp x cu x mf}}{\text{Illumination}}$$

$$= \frac{\text{2-lamps per fixture x 3,150lm. x 0.35 x 0.70}}{\text{538 lux}}$$

$$= \frac{1,543.5}{538} = 2.87 \text{ sq. m. per fixture}$$

2. Therefore, the number of fixtures per bay is:

$$\frac{4 \text{ m. x } 5 \text{ m.}}{2.87} = 6.9 \text{ say 6 pcs. per bay for symmetry}$$

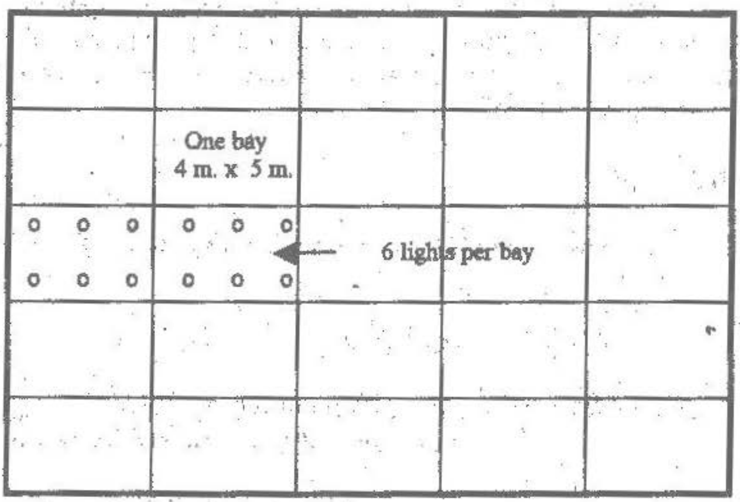


FIGURE 6-1 DISTRIBUTION OF LIGHTS PER BAY

6-4 Measuring Footcandle

The unit of measure for illumination is the footcandle, or lux. This unit is frequently used when describing the amount of light inside a room. It is not just enough how to calculate the illumination level but is also equally important how to measure them in an enclosed space. In measuring illumination level, the footcandle meter is held horizontally with its sensitive surface at least 30 centimeters from the body of the person holding the meter, or it could be placed on a table and read from a distance to avoid obstructing the light.

In conducting general illumination check inside a room, the meter is held about 80 centimeters above the floor. Reading is undertaken throughout the room and the results are recorded on the plan of each room.

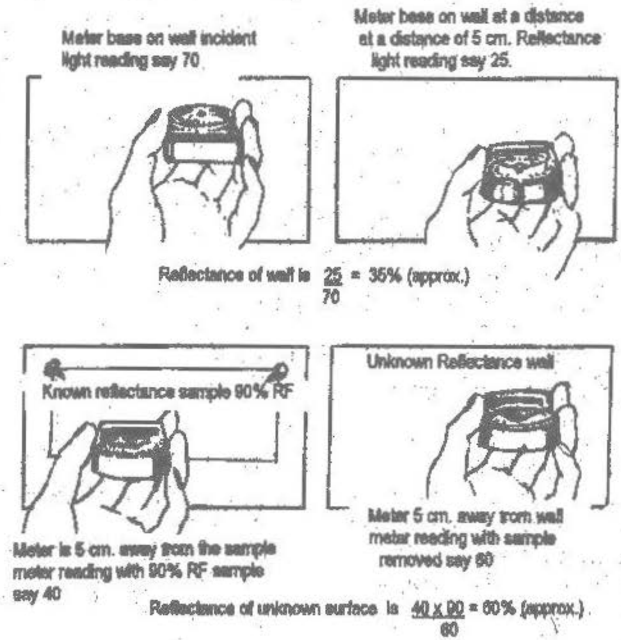
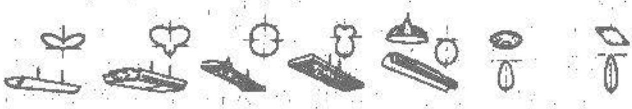


FIGURE 6-2 MEASURING REFLECTANCE

TABLE 6-7 SPACING AND MOUNTING HEIGHT RELATIONSHIP OF LUMINAIRES FOR ILLUMINATION UNIFORMITY[a]

LIGHT DISTRIBUTION



	Indirect	*Semi-indirect*	*General Diffusing*	*Direct-Indirect*	*Spread Direct*	*Semiconcentrating Direct*	*Concentrating Direct*
Ceiling Height	*Distance[b] from Walls*	*Maximum[c] Spacing of Luminaires*	*Mounting[d] Height of Luminaires*	*Distance[b] from Walls*	*Maximum[c] Spacing of Luminaires*	*Maximum[c] Spacing of Luminaires*	*Maximum[c] Spacing of Luminaires*
2.40	.60	2.70	2.40	.60	2 25	1.65	.75
2.70	.60	3.15	2.70	.60	2.70	1.80	.90
3.00	.75	3.75	3.00	.75	3.15	2.10	1.20
3.30	.75	4.00	3.30	.75	3.60	2.40	1.35
3.60	.90	4.50	3.60	.90	4.00	2.70	4.50
3.90	1.20	5.10	3.90	1.20	4.50	3.00	1.65
4.20	1.50	5.70	4.20	1.50	4.95	3.30	1.80
4.50	1.50	6.00	4.50	1.50	5.40	3.60	1.95
4.80	1.80	6.60	4.80	1.80	6.00	3.90	2.10
5.40	1.80	7.20	5.40	1.80	6.60	4.65	2.40
6.00+	2.10	8.40	6.00+	2.10	7.50	5.25	2.70

a All dimensions in meters.

b These spacings apply where desks and benches are next to wall, otherwise, one third the spacing between units is satisfactory.

c The actual spacing of luminaires is usually less than the maximum spacing to suit bay or room dimensions.

d For mounting height of general diffusing and direct -indirect fixtures

6-5 Uniformity of Light

The purpose of lighting calculation, by the footcandle or lux, is to determine the average illumination in a room to a working level condition. This working level condition refers to the height of about 75 centimeters above the floor being the approximate height of the table. The average illumination at the working level is directly related to the maximum spacing of the light to the mounting height ratio represented by the formula:

$$\frac{S}{mh}$$

where:

S = Spacing of light fixtures
mh = mounting height

Normally, the manufacturer of light fixtures provides data with respect to spacing and mounting ratio. However, in the event that the manufacturer failed to provide these data, Table 6-8 was presented showing the spacing and mounting height ratio for a particular lighting conditions.

TABLE 6-8 SPACING AND MOUNTING HEIGHT RATIO

System	S/m Ratio
Direct Concentrating	0.40
Direct Spreading	1.20
Direct Indirect Diffusing	1.30
Semi - Direct - Indirect	1.50

ILLUSTRATION 6-8

A room with a ceiling height of 3 meters is to be lighted with direct concentrating fluorescent light. What is the maximum fixture spacing?

SOLUTION

1. For spacing and mounting ratio, refer to Table 6-8. The mounting height ratio of a direct concentrating light is 0.40. Therefore:

$$\frac{S}{mh} = 0.40$$

2. Substituting the given values, wherein mh is the ceiling height,

$$\frac{S}{3\ m.} = 0.40$$

$$S = 0.40 \times 3.00$$

Spacing: S = 1.20 meters maximum side to side of the fixtures.

ILLUSTRATION 6-9

A warehouse will install pendant dome incandescent lamps at a mounting height ratio of 1.50 meters. The lamp will be mounted on a grid measuring 5.00 x 5.00 meters. What is the minimum mounting height of the lamps?

SOLUTION

Mounting height is; $mh = \frac{\text{Spacing}}{\text{Ratio}}$

$$mh = \frac{5.00\ m.}{1.50} = 3.30\ \text{meters}$$

6-6 Classification of Lighting System

Lighting system is classified into four types, namely:

1. Direct lighting 2. Semi-direct lighting

3. Semi-indirect-lighting 4. Indirect lighting

Direct Lighting. When the light on an illuminated area is focused downward coming directly from the lighting fixture.

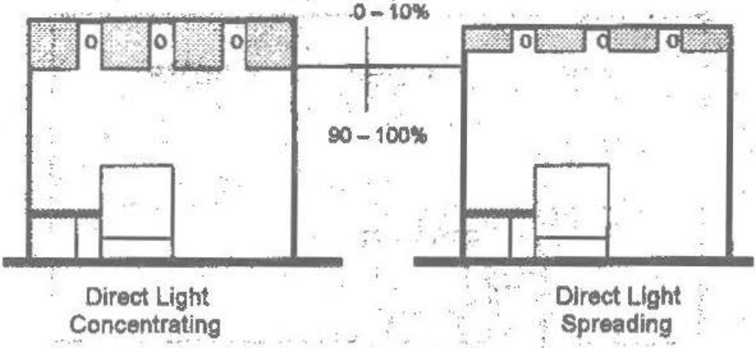


FIGURE 6-3

Semi-Direct Lighting. When the predominant light on the illuminated area is fed directly from the lighting units wherein the greater amount of light is obtained from the ceiling through reflection.

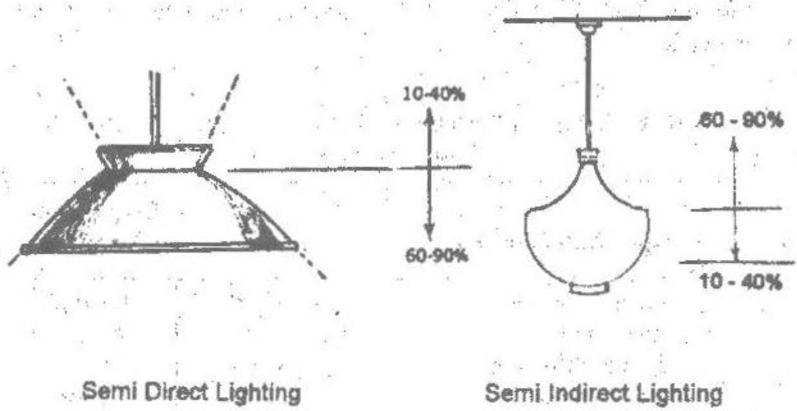


FIGURE 6-4

Semi-Indirect-Lighting. A lighting arrangement wherein 5% to 25% of the light is directed downward with more than half of the light focused upward and reflected from the ceiling.

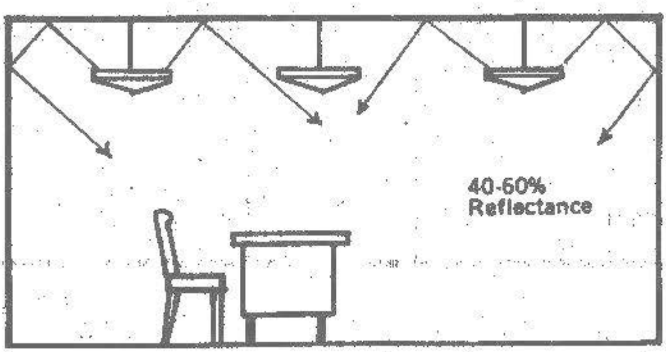


FIGURE 6-8 INDIRECT LIGHTING

Indirect Lighting – when the light is diffused and reflected from a wide ceiling area. This kind of lighting produces a soft and subdued effect due to low brightness and absence of sharp shadows.

TABLE 6-9 LIGHT DISTRIBUTION OF VARIOUS TYPES OF LIGHTING SYSTEMS

Type of Illumination	Percent of Distribution	
	Upward	Downward
Direct	1-10	90-100
Semi-direct	10-40	60-90
General diffusing	40-60	40-60
Semi- indirect	60-90	10-40
Indirect	90-100	1-10

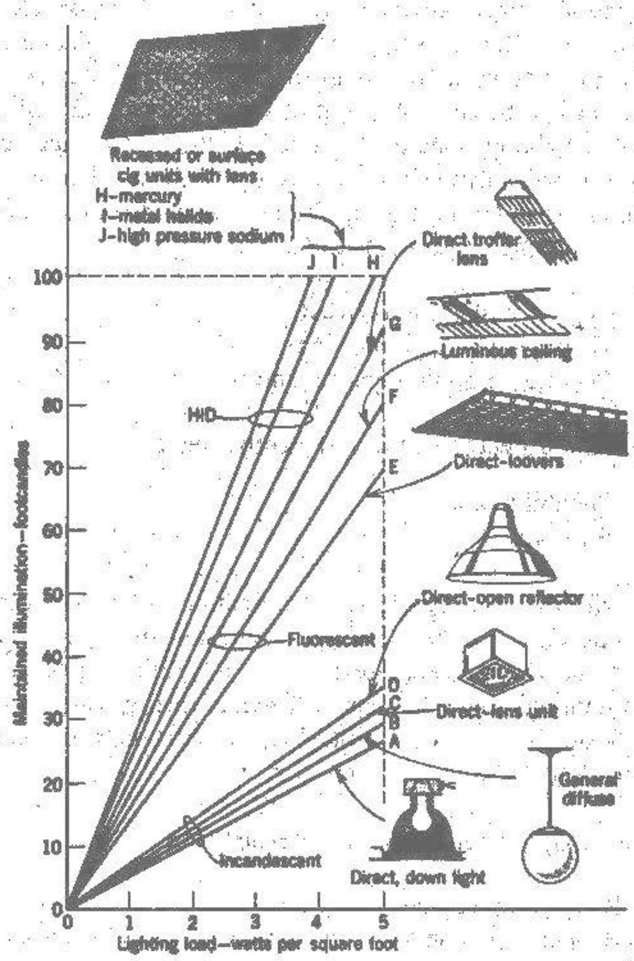


FIGURE 6-6

CHART FOR ESTIMATING LIGHTING LOAD AND ILLUMINATION LEVEL CALCULATED FOR FAIRLY LARGE ROOM

6-7 Lighting Control

Lighting control includes all techniques necessary for the operation of lighting system covering both manual and automatic control. The control plan must be incorporated with the lighting design, because the control scheme should be appropriate to the lighting source. As a result, the system accessories and arrangement depends on the control scheme. For instance, if dimming is to be used using fluorescent light source, then the range of dimming control determines the:

1. Type of ballasts to be used
2. Their switching points, and
3. The degree of dimming flexibility.

The main objectives of lighting control are:

1. Flexibility and
2. Economy

Flexibility to provide the modifications of brightness and pattern as viewed by the designer, and Economy of both energy sources and cost considerations. Comparatively, a properly designed lighting control system will reduce energy usage by 10% to 50% against the uncontrolled installation without reducing lighting effectiveness.

Financial Operating Costs will Result from:

1. Reduced energy consumption
2. Reduced air conditioning costs as a result of lower lighting waste heat.
3. Longer lamp and ballast life due to lower operating temperatures and lower output.
4. Lower labor costs due to control automation.

In view of the overlapping terminologies, it is necessary to differentiate the term: ***control functions; control devices, and control system*** for clarity.

a.) For lighting, the only ***control functions*** are switching and dimming.
b.) The ***control devices*** are the means by which the switching and dimming functions operates. It includes from simple wall switches, through time switches and dimmers of all sorts, Also included in this category are control initiation devices, such as occupancy sensors and photocells.
c.) ***Control System*** is the entire assembly of control and signal initiating equipment together with their interconnections plus the microprocessors and programmable controllers. The system can be a stand alone arrangement or alternatively part of an energy management system EMS or a building automation system BAS or both.

Switching

Basically, there are two types of control functions: *switching* and *dimming*. Switching is an On and Off function. The designer can select the number of lighting elements to be switched in each switching control. He can establish the number of control levels, the more levels the finer the control. In a space that requires several levels of uniform illumination for different functions, the designer has many control alternatives.

For example, taking three-lamp fluorescent fixtures, the designer can obtain better uniformity and four levels of illumination by switching the ballasts.

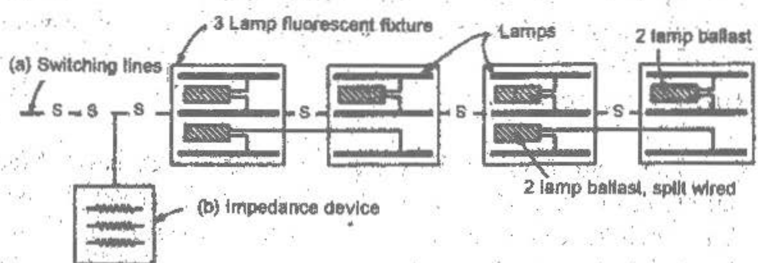


FIGURE 6-7 SWITCHING ARRANGEMENT

1. All ballasts on	100% illumination
2. Two lamp ballast on	66% illumination
3. ½ of two-lamp ballast on	33% illumination
4. All ballast off	0 illumination

Figure 6-12 is an schematic diagram of switching arrangements to achieve multiple discreet lighting levels with three lamp fluorescent lighting fixtures. Two lamp ballasts are used in the interest of energy conservation and financial economy.

Scheme (a) ballasts are switched, thus removing either one or two lamps from service. Finer control is achieved by using two level ballasts or by introducing impedance (b) into the circuit either in a block for an entire circuit or distributed in each fixture. The use of automatic controls has been encouraged because it is the only proven method of attaining significant energy conservation.

Dimming

Fluorescent lamp with conventional ballasts dimming reduces down the output to approximately 40% without reducing efficacy. Considering that below 40% output efficacy drops off is an economical and efficient control scheme, combines dimming and switching of multi-lamp fluorescent fixtures to yield an almost lower output range of 13 to 100% output, the continuous dimming over a 10 to 100% range is practicable with special dimming ballasts or with electronic ballasts. Electronic ballasts are much more energy efficient than conventional ones and must be considered for all new installations dimmed or not.

Initiated Control

The control operation is either manual or automatic. Manual operation is applicable only to small number of simple functions such as on and off or level switching. Even then, the tendency is to leave lights on at the maximum level and not to shut them off when leaving a room.

According to studies, there is no lasting energy economy is possible with the control initiation entirely operated manually that relies on a facilities personnel.

A small portion of energy conservation is possible when the turn-off function is automated by the use of *"time out"* switches that open after a pre-set interval. Long term energy reduction can only be achieved with automatic control initiation.

Automatic controls are of two types: the *open circuit* and the *closed loop feedback type*. It is otherwise known as *static* and *dynamic control* respectively. The open circuit type is a control function that is independent of the actual lighting condition. The dynamic control type reacts to the condition of the lighting situation it controls via a feedback loop.

Static Control

The most common type of open circuit lighting control is the programmable time controller. These devices are available in a myriad of designs and capacities, but all perform the same basic function – *remote control* of loads and circuits on a pre-programmed time basis. It is programmed with tight energy savings up to 50% over an uncontrolled installation.

These devices act only on a time base minus actual field or special conditions. If the timer is arranged to shut off during non-working hours, provision must be made for persons working overtime. In general, programmable time controls are best applied to facilities with regular, repetitive schedules and few exceptional situations.

Dynamic Control

This type of automatic control initiation responds to sensor indicated field conditions via an information feedback loop. The initiation of control function depends not on a fixed programmed parameter such as time, but on real time field parameters. The control device in its entirety is called ***programmable controller*** which in combination with the field sensors and the interconnecting wiring constitute the control system. Some systems are wireless using high frequency signals impressed on the power wiring system to transmit control signals. This arrangement is known as power line carrier system (PLC). In addition to its microprocessor (CPU) the programmable controller contains input/output interfaces, memory and means for programming and reprogramming.

Lighting Design

Lighting design is a combination of applied art and applied science. There are countless solutions to the same lighting problem and all of which will satisfy the minimum requirements. However, some will be poor while others will display ingenuity and resourcefulness. Considering the large number of interrelated factors in lighting, no single design is the correct one. A good lighting designer solve each problem again and once more by introducing a knowledge of current technology and years of background and experience, yet, rarely being satisfied with a xerox copy of a previous design.

Objectives of a Lighting Design

The objectives of a lighting design is to create an efficient and pleasing interior. In short, it should be utilitarian and aesthetic demonstrated by every good lighting design. Light can and should be used as a primary architectural material.

1. Lighting level should be adequate for efficient seeing of the particular object involved. Variations within acceptable luminance ratios in a given field of view are desirable to avoid monotony and to create perspective effects.
2. Lighting equipment should be unobtrusive, but not necessarily invisible. Fixtures can be chosen and arranged in various ways to complement the architecture or to create dominant or minor architectural features or patterns. Fixtures may be decorative to enhance the interior design.

3. Lighting must have the proper quality. Accent lighting, directional lighting, and other highlighting techniques increase the utilitarian as well as architectural quality of a space.
4. The entire electrical design must be accomplished efficiently in terms of capital and energy resources, the former determined principally by life cycle costs and the latter by operating energy costs and resource-energy usage. Both the capital and energy limitations are, to a large extent, outside the control of the designer, who works within constraints in these areas.

6-8 Street Lighting

The Institute of Integrated Electrical Engineers instituted guidelines for adequate and acceptable illumination of the streets in order to promote safety. This concept was brought about by the continuously increasing speed of motor vehicles using the roads.

The Philippine Electrical Code Committee prepared the guidelines for a standard practice on design of street lighting installation recommending the proper quantity and quality of light for traffic routes.

Definition of Terms

Lighting Installation - is defined as the whole of the equipment provided for lighting the roadway comprising the lamps luminaires, means of support and electrical installations including other auxiliaries.

Lighting System - refers to an array of luminaires having a characteristic of light distribution.

Luminaire - is a housing for one or more lamps comprising a body and any refractor, diffuser or enclosure associated with the lamps.

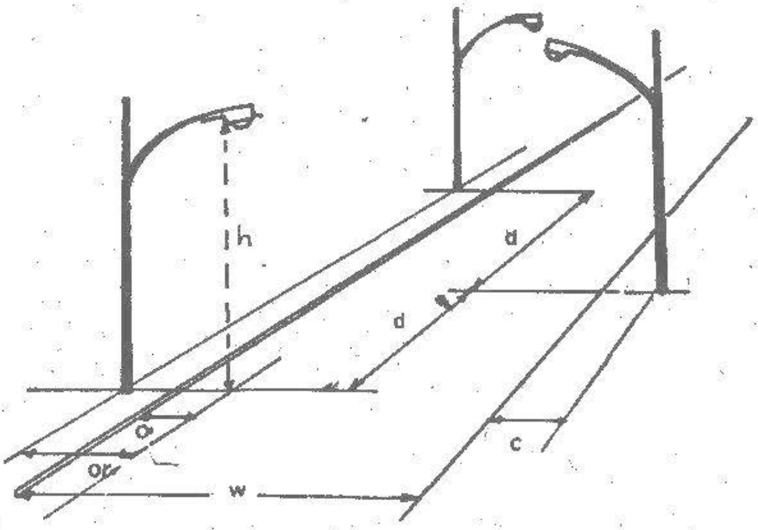
Road Width - is the distance between the edges of the road curbs measured at right angles to the length of the roadway.

Outreach - is the distance measured horizontally between the outer of the column or wall face or lamp post and the center of the luminaires.

Overhang - is the horizontal distance between the center of luminaires and the adjacent edge of the road.

Mounting Height - refers to the vertical distance between the center of the luminaire and the surface of the roadway.

Spacing - is the distance between the successive luminaires in an installation.



o = Overhang d = Distance spacing
c = Clearance w = Width of the roadway
h = Mounting height or Outreach

FIGURE 6-8 STREET LIGHTING

Maximum Light Utilization - In order to attain the maximum utilization of light from the fixtures, the luminaires should be mounted under the following specifications

Road width	Outreach
1.50 to 3.00 m.	.60 m.
3.00 to 9.15 m.	1.60 m.
9.15 to 15.25 m.	3.00 m.

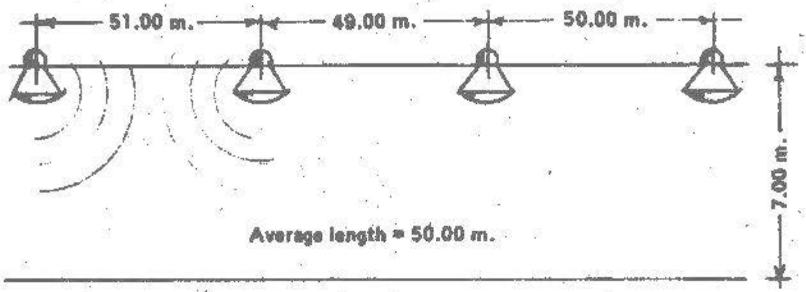


FIGURE 8-9 STREET LIGHT AVERAGE SPACING DISTANCE

Working Voltage

Luminaires are properly selected and mounted on a location most feasible and effective with minimum cost. For a 230 volt system, a voltage drop of 5% is allowed although in extreme cases 15 % voltage drop is sometimes tolerated. For street illumination, the following formula is used:

$$E = \frac{Al \times (cu \times mf)}{w \times d}$$

$$Al = \frac{E \times w \times d}{cu \times mf}$$

where:

E = The illumination in Lux
Al = Average lumens with a typical value of:

20500 lumens for 400 watts
11500 lumens for 250 watts
5400 lumens for 125 watts

The value of Al however, varies depending upon the type of lamp specified.

mf = the maintenance factor which depends on the following:

a. Maintenance practice of the company.
b. Operation of light sources at rate current and voltage.
c. Regular replacement of depreciated lamps.
d. Periodic cleaning of the luminaires either 0.8-0.9.

w = Width of the roadway
d = Distance between luminaires
cu = Coefficient of utilization dependent on the type of fixtures, mounting height, width of roadway and the length of mast arm or outreach.

TABLE 6-10 RECOMMENDED AVERAGE HORIZONTAL ILLUMINATION LEVEL, LUX

	Vehicular Traffic Classification			
Pedestrian	Very light	Light	Medium	Heavy to Heaviest
Traffic	Under 150	150-500	500 to 1200	1200 up
Heavy	9.68	12.91	16.14	21.52
Medium	6.46	8.61	10.26	12.91
Light	2.15	4.30	6.46	9.68

The values given are based on favorable reflectance for asphalt road, the recommended illumination should be increased by 50%. For concrete road, the recommended value could be decreased by 25%.

In designing street illumination, consider the modern lighting of the present that will not be obsolete tomorrow when the minimum light levels are raised. The increasing motor vehicles speed, and the increasing congestions on the street, requires higher level of highway lighting. Thus, future needs for light should be considered in the design.

ILLUSTRATION 6-10

Considering the data presented on Figure 6-8 when the night pedestrian traffic is estimated to be light, and the night vehicular traffic is to be medium, determine the required lumens if the road is a concrete pavement.

SOLUTION

1. Referring to Table 6-9, E = 6.46 for light pedestrian medium traffic classifications. For concrete road, the reflectance will be higher but let us accept the value of 6.46 lumens.

2. Determine the average pole distance.

E = 6.46 lumens per sq. m.
w = 7.00 meters
d = 50 meters
mf = 0.9
cu = 0.29 (type A fixture)

$$Al = \frac{E \times w \times d}{cu \times mf}$$

$$Al = \frac{6.46 \times 7.00 \times 50 \text{ m.}}{0.29 \times 0.9}$$

Al = 8,662.83 average lumens

Under the **Working Voltage**, the mean lamp lumens of a 250 watts lamp is 11,500 lumens, this is the nearest value to 8,662.83 average lumens. Therefore, a 250 watts lamp is acceptable.

Computing for the new actual illumination E

$$E = \frac{Al \times cu \times mf}{w \times d}$$

$$E = \frac{11{,}500 \times 0.29 \times 0.9}{7.00 \times 50}$$

$$E = 8.57 \text{ lumens per sq. m.}$$

This is higher than the 6.46 recommended in Table 6-11. Therefore, the road is considered as adequately lighted.

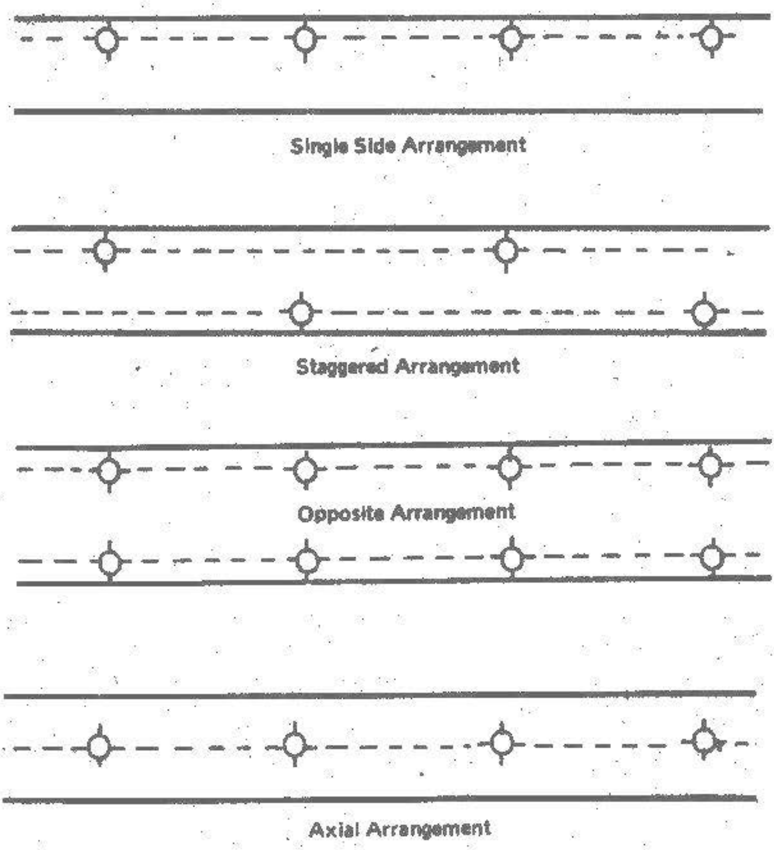


FIGURE 6-10 BASIC ARRANGEMENT OF PUBLIC LIGHTING

Classification of Pedestrian Traffic

a.) *Light or No Pedestrian Traffic* streets in residential or warehouse areas and on express or elevated depressed roadways.

b.) *Medium Pedestrian Traffic* on a secondary business street and some industrial roads.

c.) *Heavy Pedestrian Traffic* as in business streets.

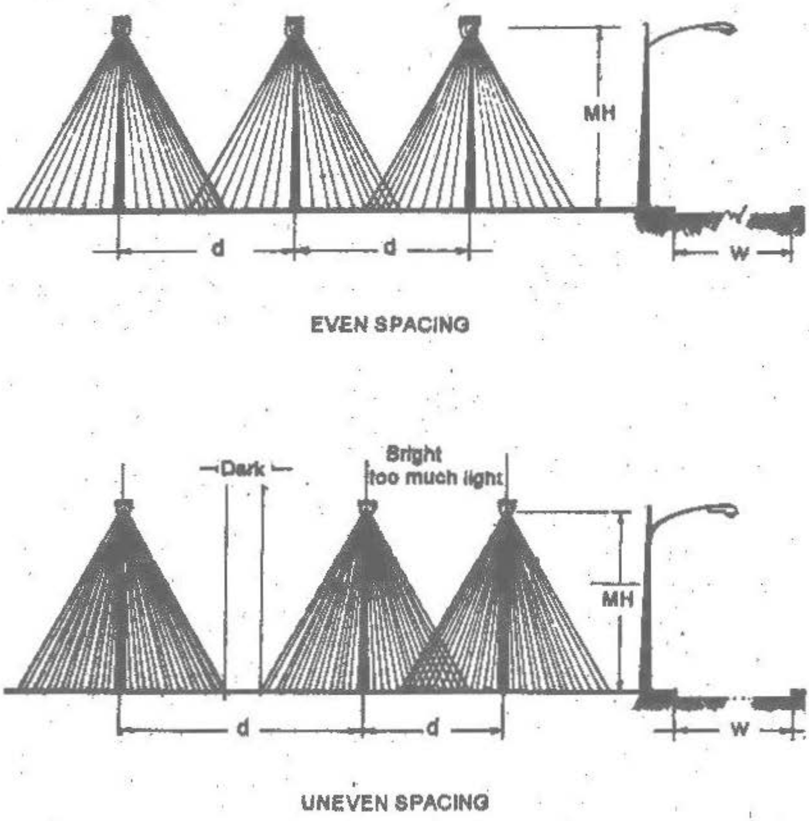
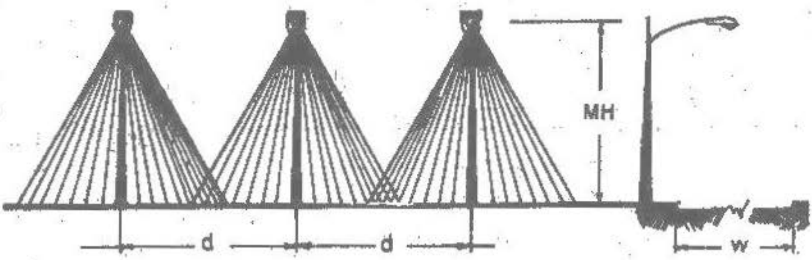


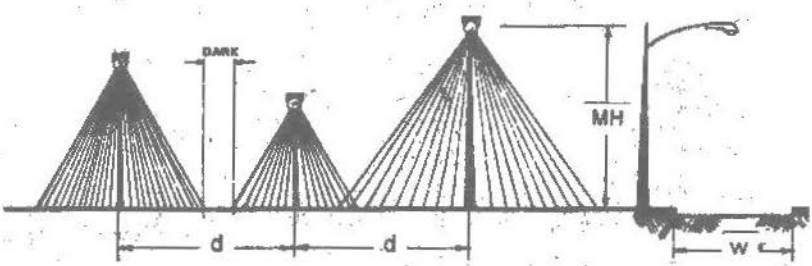
FIGURE 6-11 STREET LIGHT MOUNTING ARRANGEMENTS

TABLE 6-10 ROADWAY CLASSIFICATIONS

Classification Number	Number of Vehicles per Hour	
	Maximum Night Hour	Both Direction
Very light traffic	Under	150
Light traffic	150	500
Medium traffic	500	1200
Heavy traffic	1200	2400
Very heavy traffic	2400	4000
Heaviest traffic	over	4000



EVEN MOUNTING HEIGHT



UNEVEN MOUNTING HEIGHT

FIGURE 6-12 STREET LIGHT MOUNTING ARRANGEMENTS

TABLE 6-11 COEFFICIENT OF UTILIZATION

Fixture	Average Coefficient of Utilization	
	Roadwidth 3.00 m. to 9.15 m	Roadwidth 9.15 m. to 15.25 m.
C	33.0 %	35.0%
A	29.0%	34.6%
B	38.9%	44.0%

TABLE 6-12 LIGHT DISTRIBUTION DATA

Desired light level	Lamp wattage w	Type of fixture	Coefficient of utilization	Arrangement of luminaire	Nominal spacing
10.76	250	A	36.3%	Opposite	46
				Staggered	23
10.76	250	B	45.5%	Opposite	58
				Staggered	29
10.76	250	A	31.6%	Opposite	67
				Staggered	34
10.76	250	B	42.5%	Opposite	88
				Staggered	44
5.38	125	A	31.6%	Opposite	61
				Staggered	30
5.38	125	B	42.5%	Opposite	84
				Staggered	41
5.38	125	C	36.2%	Opposite	72
				Staggered	35
5.38	250	A	31.6%	One side	67
5.38	250	B	42.5%	One side	90
5.38	125	A	31.6%	One side	30
5.38	125	B	42.5%	One side	43
5.38	125	C	36.2%	One side	35
3.23	125	A	26.2%	One side	64
3.23	125	B	35.6%	One side	88
3.23	125	C	29.7%	One side	73

Residential (Road width 3 to 9 m.) Traffic (Road width 9 to 15 m.)

SOURCE: Philippine Electrical Code part II

TABLE 6-13 LEVEL OF ILLUMINATION FOR VARIUS TYPES OF APPLIANCES

TYPE OF OCCUPANCY	LUX
A. RESIDENTIAL	
1. Living rooms	
General lighting	150
Locally (reading, writing etc.)	500-1000
2. Bedrooms	
General lighting	150
Locally (mirrors, dressing tables, bed lighting)	250-500
3. Kitchen	
General lighting	150
Locally (stove, dresser, table)	250-500
4. Hallways, Staircases, Lofts, Garages	
General lighting	150
Locally (workbenches, hobby tables)	250-500
B. SCHOOLS	
1. Nursery schools	150
2. Classrooms	
General (Elementary, High School, Lecture room)	250-500
Workshops, science room	250-500
Drawing rooms	500-1,000
3. Gymnasiums, Assembly Halls, Canteen, Corridors	150
4. Offices, Library etc.	250-500
C. HOSPITALS	
1. Doctors room	
General lighting	150
Work table	500-1,000
2. Dispensary	
General lighting	150
Dispensing table	500-1,000
Store room	150
3. First Aid Department	
General lighting	500-1,000
Locally	10,000- 20,000
4. Laboratory	
Research room	250-500
Work table	500-1,000
5. Diagnostic and Therapeutics room	
General lighting	250-500
Diagnostic table	500-1,000

6. Surgical Department Sterilizing room, operating theater	
General lighting	500-1,000
Operating table	20,000- 40,000
7. Maternity Department	
Delivery bed	5,000-10,000
Delivery room general	250-500
Nursery	150
8. Dental Department	
Dental room, general	250-500
Patient's chair	5,000-10,000
Laboratory	150
9. Private Rooms for Patients	
General	150
Bed lighting	250-500
10. Kitchen, Library	250-500
12. Assembly halls, Waiting room, Corridors	
Hallways and bathroom	150
D. COMMERCIAL BUILDINGS	
1. Shops and Store	
Large town shopping centers	
Shop windows, general	1,000-2,000
Supplementary spot lighting	5,000-10,000
2. Others, general	
Supplementary spot lighting	2,500-5,000
3. Shop interior, large town shopping center	500-1,000
4. Other places	250-500
5. Railways and Bus Station	
Waiting rooms, platform, lavatories and refreshment	150
Ticket halls and office	500-1,000
Luggage depot	250-500
6. Hotels and Restaurants	
Restaurant, lounge, bar, hallways, staircases	150
Larger rooms	
Conference room	150
Platform, exhibition and demonstration	250-500
Kitchen	250-500
Hotel bedrooms, general	150
Bed lighting, writing desk, dressing table	250-500
7. Offices	
Managers room, conference room	250-500
Typical pools, records and accounts bookkeeping	500-1,000
Drawing offices, land registry offices, cartography	over 2,000

Designing, Architectural and Engineering offices	1,000-2,000
Decorative drawing and sketching	500-1,000
Canteen, parlor, filling rooms	150
8. Storage	
General stores (used frequently)	150
Factory (used frequently)	150
Bulk storage, small items	150
Very small items	250-500
E. INDUSTRIAL BUILDINGS	
1. Milk factory	
Sterilizing rooms, storage, cooling halls pasteurization cream preparation, weighing room	150
Sorting of bottles	250-500
Bottle washing machines, inspections, filling, lab.	500-1,000
2. Food Processing Plants and Canneries	
Cleaning and washing	250-500
Color sorting	1,000-2,000
Canning general	250-500
Inspection of filled cans	1,000-2,000
Sealing of cans	250-500
Packing in cartons	150
3. Garment Factories	
Inspection of materials	
Light fabrics	500-1,000
Dark fabrics	over 1,000
Cutting and pressing	
Light fabrics	500-1,000
Dark fabrics	1,000-2,000
Sewing and Trimming	
Light fabrics	1,000-2,000
Dark fabrics	over 2,000
4. Soap Factories	
Boiling, cutting, manufacture of powder and flakes	150
Stamping, wrapping and packing.	250-500
5. Textile Plants	
Cotton	
Bale breaking, mixing sorting, carding, drawing sizing, spool winding, spinning	250-500
Weaving	500-1,000
Inspection	
Stationary pieces	500-1,000
Fast moving pieces	over 2,000

3. Silk and Synthetic Fibers	
degumming, dyeing , drying	150
Bobbin winding, spool winding	250-500
Spinning, light color red yarns dark color	1,000-2,000
Weaving	500-1,000
4. Wool	
Bale breaking, blending, sorting	150
Inspection	500-1,000
Carding, drawing, sizing, twisting, spool winding	250-500
Spinning	
White	250-500
Colored	500-1,000
Weaving	
White	500-1,000
Colored	1,000-2,000
F. STEEL MANUFACTURING PLANT	
1. Rolling Mills	
Primary rolling, flat rolling, hot rolling of strip and sheets	150
Drawing of tubes, rods and wire	250-500
2. Plate Mills	
Tinning, galvanizing, cold rolling	250-500
Engine room	150
3. Inspection	
Black sheets, rolled slabs	500-1,000
G. OTHERS	
1. Museum, Art Galleries	
General	150
On pictures supplementary lighting	250-500
On sculptures and other objects	250-1,000
2. Sports	
Stadium	250-500
Training field	75-150
Horse race tracks	125-250
Tennis courts etc.	225-450
3. Garage	
Garage accommodation	150
Greasing bay	150
Workshop, greasing pit, washing place	250-500
Work benches, show room	500-1,000

CONSTRUCTION OF THE DISTRIBUTION LINE

THE DISTRIBUTION LINE CONSTRUCTION

Introduction

Prior to the declaration of Martial Law in the Philippines on September 21, 1972, the supply and sales of electric current in various parts of the country was under the monopoly of several franchise holders. Thus, electric services in the country were controlled by private capital. This set up however, resulted to non-uniformity of electric rates and services because of the different electric companies operating business in different provinces, cities and municipalities nationwide.

When Martial Rule was impose by President Ferdinand E. Marcos, on September 1972, the privileges being enjoyed by these franchise holders were totally scrapped and abolished by virtue of Presidential Decree No. 269 creating the National Electrification Administration (NEA) and the Electric Cooperatives. These two agencies of the government were then saddled with the responsibility of implementing the Rural Electrification Program. The Rural Electrification program was among the priority program of the Marcos Administration towards industrialization and extending efficient services to the remotest rural areas at a reasonable lower rate of electricity.

In order to carry out this ambitious program of the government, the Marcos administration embarked on foreign borrowings to support the financial needs of the National Power Corporation and the Electric Cooperatives. The blue print of the master plan is to construct various power generating plants and distribution lines in Luzon and then consolidate and interconnect all generated power to the main system called Luzon Grid.

The Luzon Grid will then supply electricity to the different electric cooperatives whose business is to retail electricity to the end users from industrial, commercial and residential consumers.

The Electric Distribution System

Under the present set-up, electricity will be supplied by:

1. The National Power Corporation
2. The Meralco
3. The Electric Cooperatives Inc.

The Meralco has its own poser generating plant but also depends on the National Power Corporation for its power deficiency. On the other hand, Electric Cooperatives that serves as the retail outlet of electricity outside Metro Manila are mostly dependent on the current supplied by the National Power Corporation. A handful number of electric cooperatives however, generates power through their own mini hydro electric plants, powered generating plants or dendro thermal plant but is not enough for the growing demand of their consumers.

One probable disadvantage of this synchronized supply of current through the Luzon Grid is in case of power plant or transmission line failure or break down. In such a case, black out may be felt through out the entire supply coverage area.

At present there are two systems being adopted in the service of electricity, they are:

1. The Line to Line service by the Meralco
2. The Multi-Ground system by the Electric Cooperatives.

The line to line service has an engaged voltage of 115/230 volts, while the multi ground system of the electric cooperatives has an engaged voltage of 230 volts only or 230/0 which means only one wire is carrying voltage and the other which is grounded is zero voltage.

Presented in this chapter is the Multi-Ground system used by no less than 120 electric cooperatives in the country today. The actual construction of the 7.62/13 Kv. distribution line including the materials required for ready reference of the engineers, electricians and linemen in the field of construction.

Distribution Line Construction

The distribution line construction is divided into three parts:

1. Construction of the Distribution Line
   a. Single Phase
   b. Two Phase
   c. Three Phase
2. The Different Assemblies of the Distribution Line
   a. Primary
   b. Secondary
   c. Grounding
3. Protection of the Line and Metering
   a. Fuse Cutout
   b. Lighting Arrester
   c. Recloser
   d. Voltage Regulator and Capacitor
   e. Transformer

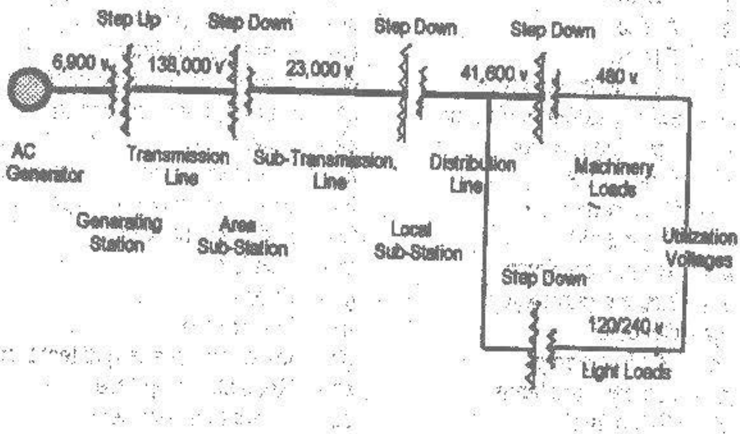


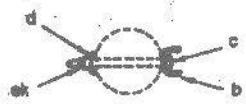
FIGURE II – A

ELECTRIC POWER FROM GENERATION TO UTILIZATION VOLTAGE

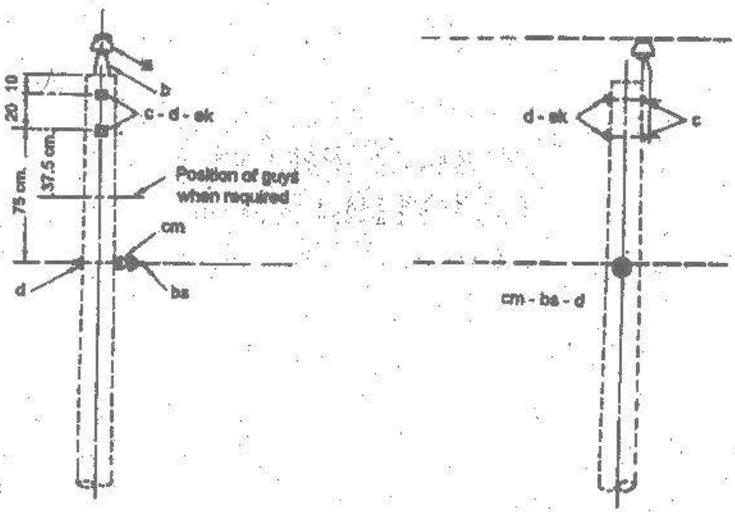
STANDARD ALPHABETICAL CODING FOR MATERIALS USED BY ALL ELECTRIC COOPERATIVES SPECIFIED BY THE NATIONAL ELECTRIFICATION ADMINISTRATION

Item	Materials	Item	Materials
a -	Pin type insulator	bj -	Guy hook
b -	Pole top pin	bk -	Guy plate
c -	Machine bolt	bm -	Guy thimble
d -	Washer	bn -	Loop clamp dead end
e -	Bolt	bo -	Anchor shackle
f -	Cross arm steel pin	bp -	Galvanized nail
g -	Cross arm	br -	Chain, link
h -	Brace	bs -	Single post bolt
i -	Carriage bolt	bt -	Wire holder
j -	Lag screw	bu -	Connector solderies
k -	Suspension insulator	bv -	Armor rod, (tapping)*
l -	Dead end clamp	bv-1	Armor rod (single support)
m -	Suspension clamp	bv-2	Armor rod (double support)
n -	Double arming bolt	cc -	Neutral dead end assembly
o -	Eye bolt	cj -	Ground wire
p -	Compression connector	ck -	Clamp, anchor and bonding
s -	Swinging clevis (secondary)	cm -	Spool insulator
t -	Armor tape	cr -	Angle bracket
u -	Guy clamp	cu -	Wood brace
v -	Guy attachment	da -	Bracket
x -	Anchor rod	dl -	Pipe spacer
y -	Guy wire	dm -	Transformer bracket
z -	Anchor	dt -	Dead end service
aa -	Eye nut	ea -	Post type insulator
ab -	Eye nut, thimble type	eb -	Bracket for post type insulator
ac -	Brace (side arm diagonal)	ec -	Bracket, offset, neutral insulator
ae -	Lightning arrester	ek -	Locknut
af -	Fuse cutout	fo -	Transformer secondary bracket
ag -	Ground wire	fk -	Extension, bracket L-type
ai -	Ground rod	fc -	Hot line connector
aj -	Ground rod clamp	gc -	Conduit
al -	Staple ground wire	gd -	Straps
ge -	Condulet	an -	Transformer
ap -	Hot line clamp	gh -	Meter box, meter and test block
aq -	Jumpers and leads	se -	Regulator, step type
at -	Guy guard	sd -	Current transformer
ax -	Cutout arrester (combination)	sk -	By-pass switch
bb -	Brace, side arm vertical angle	tw -	Tie wire
be -	Recloser		

SINGLE PHASE CONSTRUCTION



POLE TOP PIN ASSEMBLY



ELEVATION

SIDE VIEW

FIGURE 11 -1

7.62 / 13.2 KV. PRIMARY SINGLE PHASE 0° TO 5° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin Insulator	1	Tw -	Tie wire*	16'
b -	20" Pole top pin	1	ek -	5.8" Locknut	2
c -	5/8" x 8" Machine bolts	2	bs -	8" Single upset bolt	1
d -	3/16" x 2¼ -13/16" hole washer	3	cm-	1 ¾" dia. groove spool insulator	1
bv -	1 Armor rod (single support)	2			

** Conductor Accessories*

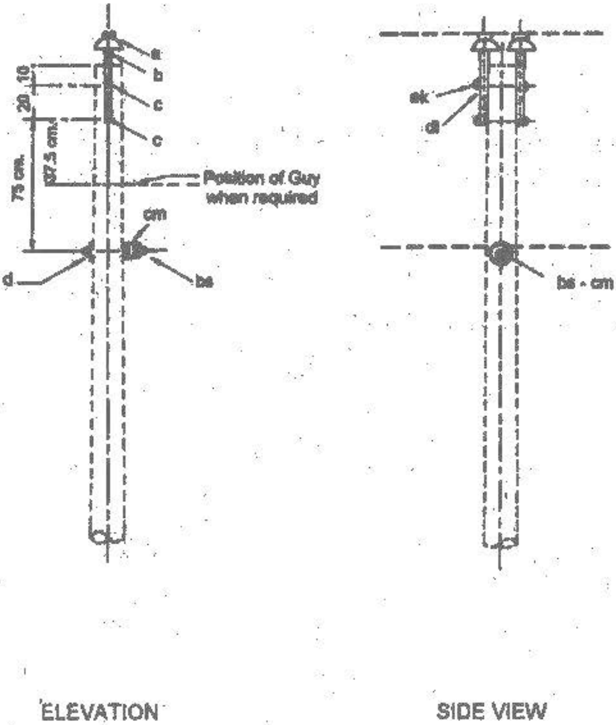


FIGURE 11-2

7.62 / 13.2 KV. PRIMARY, SINGLE PHASE 0° TO 5° ANGLE
DOUBLE PRIMARY SUPPORT

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	32	cm-	1 ¾" dia.x 1 ½" pipe spacer	1
b -	20" Pole top pin	2	dl -	¾" dia. x 1 ½" pipe spacer	2
c -	5/8" x 12" Machine bolts	2	ek -	5/8" Locknut	2
d -	3/16" x 2 ¼"- 13/16" hole washer	1	bv-1	Armor rod (single support) *	1
bs -	9" Single upset bolt	1	bv-2	Armor rod (double support) *	1
Tw -	Tie wire*	24'			

**Conductor Accessories*

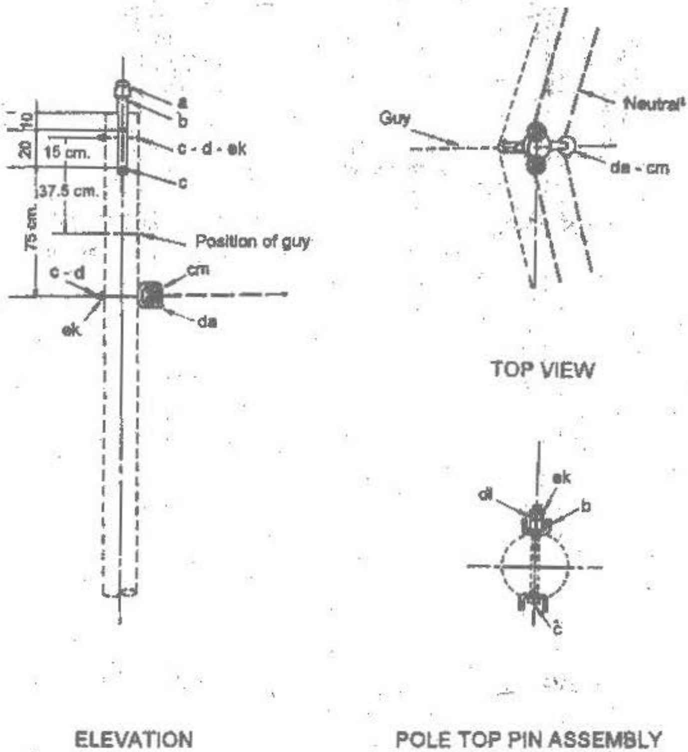


FIGURE 11-3

7.62 / 13.2 KV. SINGLE PHASE DOUBLE PRIMARY SUPPORT MAXIMUM TRANSVERSE LOADING 227 KG. (500 LBS.) PER PIN 5° TO 30° MAXIMUM ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	2	da -	Bracket	1
b -	20" Pole top pin	2	dl -	¾" dia. Groove pipe spacer	2
c –	5/8" x 10" Machine bolts	2	ek -	5/8" Locknuts	4
c -	5/8" x 12" Machine bolts	2	bv-1	Armor rod (single support)*	1
d -	3/16" x 2 ¼ -13/16 Hole washer	3	bv-2	Armor rod (double support)*	1
cm -	1 ¾" Groove spool insulator	1	tw -	Tie wire*	24'

** Conductor accessories*

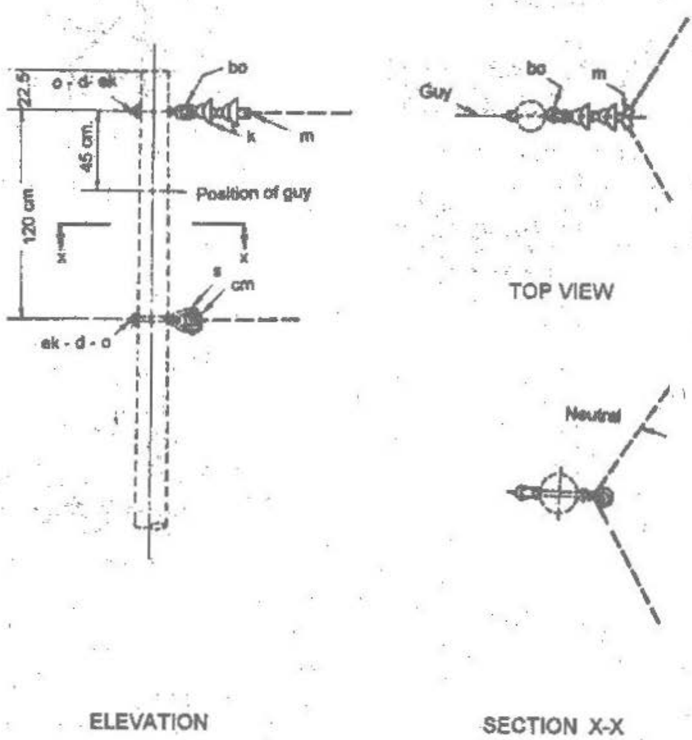


FIGURE 11-4

7.62 / 13.2 KV. PRIMARY, SINGLE PHASE 30° TO 60° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	2 ¼" x 3/16" Hole washer	2	cm -	1¾" dia groove spool insulator	1
k -	Suspension insulator	2	bo -	Anchor shackle	1
o -	5/8" x 9" Eye bolt	2	ek -	5/8" Locknuts	2
m -	Suspension clamp	1	tw -	Tie wire*	8'
s -	Secondary swinging clevis	1	bv -	Armor rod (single support)*	2

** Conductor Accessories*

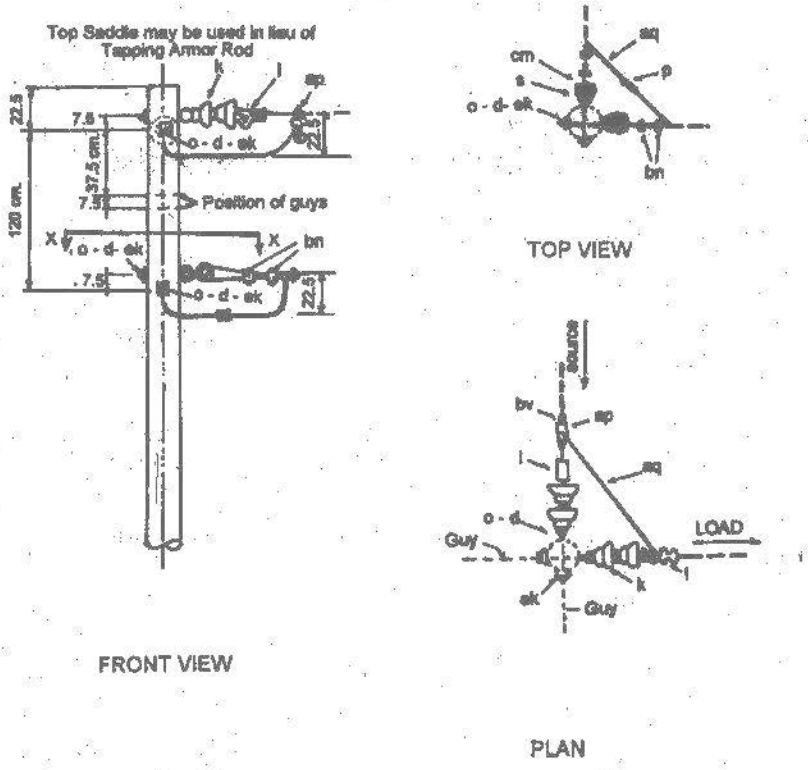


FIGURE 11-5

7.62 / 13.2 KV. PRIMARY, SINGLE PHASE 60° TO 90° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	2 ¼" x 3/16-13/16 Hole washer	4	cm -	1 ¾" dia groove spool insulator	2
k -	Suspension Insulator	4	bn -	Loop dead end clamp	4
o -	5/8" x 9" Eye bolt	4	ek -	5/8" Locknuts	4
p -	Compression connector	1	aq -	Jumpers (as required)	
ap -	Hot line clamp	1	t -	Armor tape*	2'
l -	Dead end clamp	2	bv -	Armor rod (tapping)	1
s -	Secondary swinging clevis	2			

** Conductor Accessories*

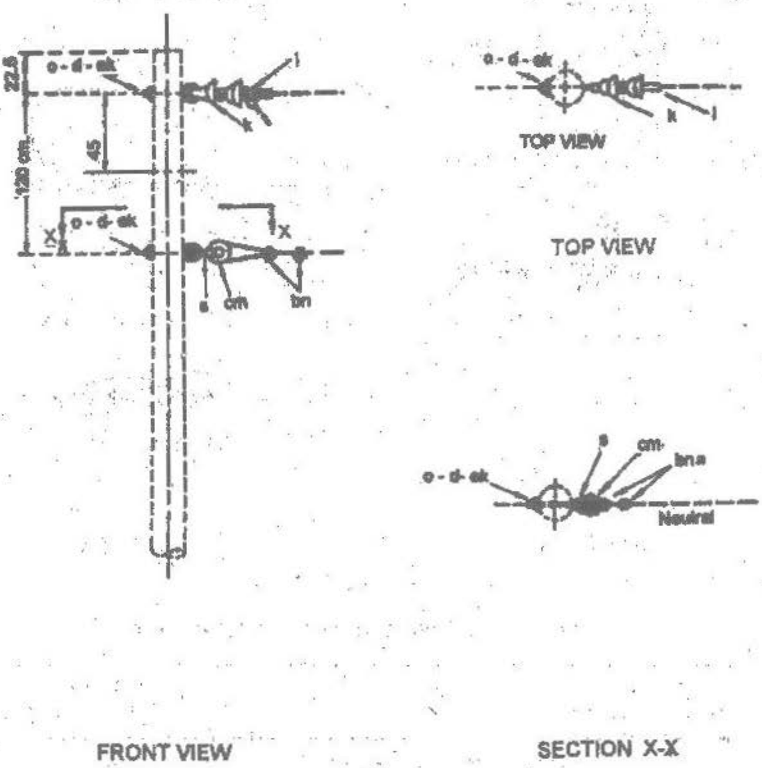
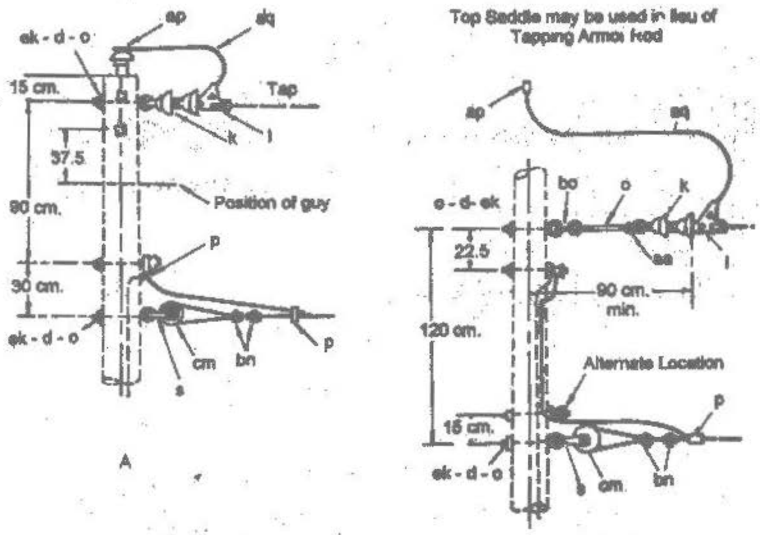


FIGURE 11-6

7.62 / 13.2 KV. PRIMARY, SINGLE PHASE DEADEND (SINGLE)

Item	Materials	Quantity	Item	Materials	Quantity
d -	2 ¼ x 3/16 - 13/16" hole washer	2	bn -	Loop dead end clamp	2
k -	Suspension insulator	2	cm -	11/3 dia groove spool insulator	1
l -	Dead end clamp	1	ek -	5/8" Locknuts	2
o -	5/8" x 9" Eye bolts	2	t -	Armor tape *	12"

** Conductor Accessories*



FRONT VIEW   FRONT VIEW

FIGURE 11-7

7.62 / 13.2 KV. PRIMARY, SINGLE PHASE TAP

Item	Materials	No. Required A	B	C
d -	2 ¼" x 2 ¼ "x 3/16", 13/16" Hole washer	2	2	0
k -	Suspension Insulator	2	2	2
o -	5/8" x required length Eye bolt	2'-9"	2'-9"	1'-18"
p -	Compression connectors	2	2	2
aa -	5/8" Eye nut	0	1	3
aq -	Jumpers and leads (as required)			
bo -	Anchor shackle	0	1	1
bv -	Armor rod (tapping)*	1	1	1
ek -	5/8" Locknuts	2	2	0
ap -	Hot line clamp	1	1	1
l -	Dead end clamp	1	1	1
s -	Secondary swinging clevis	1	1	1
cm -	1 ¼" dia. groove spool insulator	1	1	1
bn -	Dead end loop clamp	2	2	2
t -	Armor tape*	1'	1'	1'

* *Conductor Accessories*

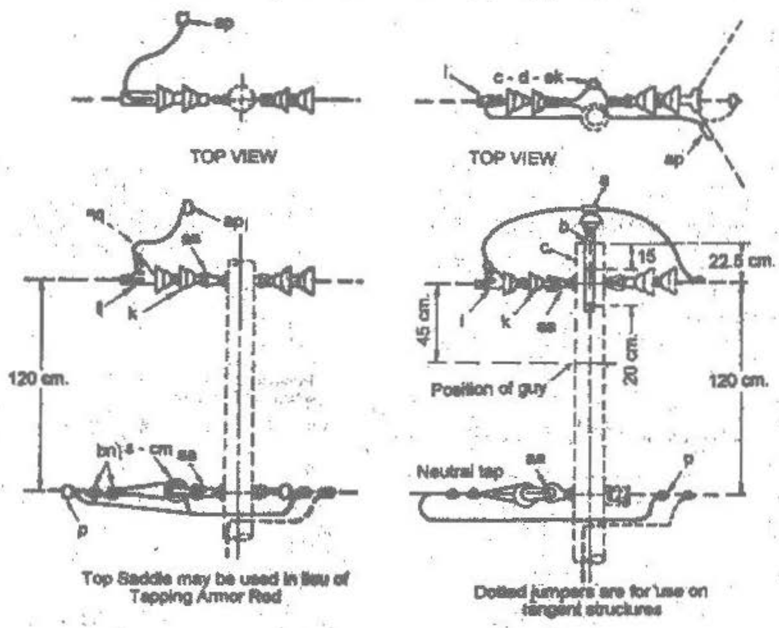


FIGURE 11-8

7.62 / 13.2 KV, PRIMARYSINGLE PHASE TAP

Item	Materials	No. Required A	B
a -	Pin type Insulator	0	1
d -	insulator 2 ¼" x 2 ¼" x 3/16" Hole diameter	0	2
k -	Suspension Insulator	2	2
b -	20" Pole top pin	0	1
p -	Compression connectors	2	2
aa -	5/8" diameter Eye nut	2	2
aq -	Jumpers and leads (as required)		
t -	Armor tape*	1'	1'
bv -	Armor rod tapping*	1	1
c -	5/8" x 9" Machine bolt		2
ek -	5/8" Locknuts		2
ap -	Hot line clamp	1	1
l -	Dead end clamp	1	1
cm -	1 ¾" diameter groove spool insulator	1	1
bn -	Dead end loop clamp	2	2
s -	Secondary swinging clevis	1	1

* *Conductor Accessories*

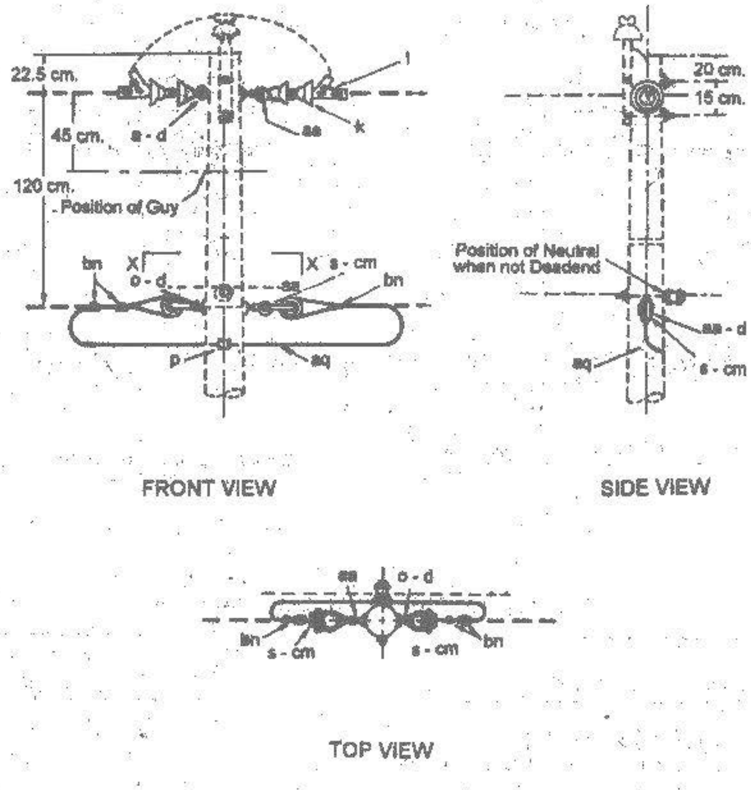
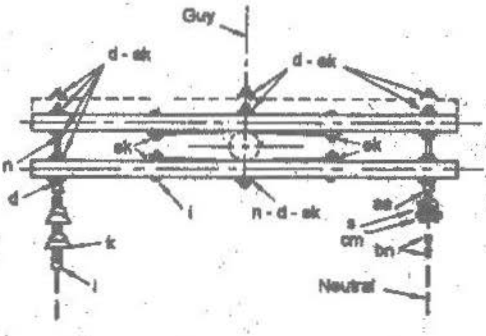


FIGURE 11-9

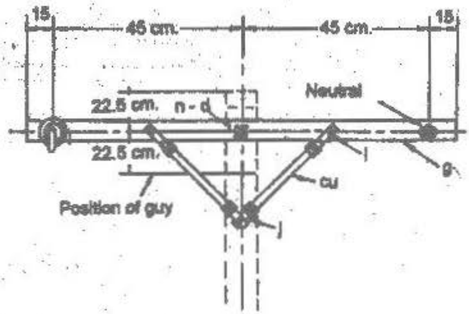
7.32 / 13.2 KV. PRIMARY, SINGLE PHASE VERTICAL DEADEND (DOUBLE)

Item	Materials	Quantity	Item	Materials	Quantity
d -	2 ¼" x 3/16"-13/16" Hole washer	4	aa -	5/8" Eye nut	2
k -	Suspension insulator	4	aq -	Jumpers (as required)	
l -	Dead end clamp	2	bn -	Loop dead end clamp	4
o -	5/8" x 9" Eye bolt	2	cm -	1 ¾" dia. groove spool insulator	2
p -	Compression connector	1	t -	Armor tape*	24"
s -	Secondary swinging clevis	2			

** Conductor Accessories*



TOP VIEW



FONT VIEW

FIGURE 11-10

7.62 / 13.2 KV. SINGLE PHASE, CROSS-ARM CONSTRUCTION
(DEADEND SINGLE)

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16"x 2 ¼"- 13/16 Hole washer	10	s -	Secondary swinging clevis	1
g -	3/1/2"x 4 ½ x 8' Crossarm	2	cu -	28" Wood brace	4
i -	3/8" x 4 ½" Carriage bolts	4	cm -	1 ¾" dia. groove spool insulator	1
j -	½" x 4" Lag screw	2	bn -	Dead end loop clamp	2
k -	Suspension insulator	2	ek -	5/8" Locknuts	8
l -	Dead end clamp	1	ek –	3/8" Locknuts	4
n -	5/8" x 18" Double arming bolt	3	t -	Armor tape *	12"
aa -	5/8" Eye nut	2			

* *Conductor Accessories*

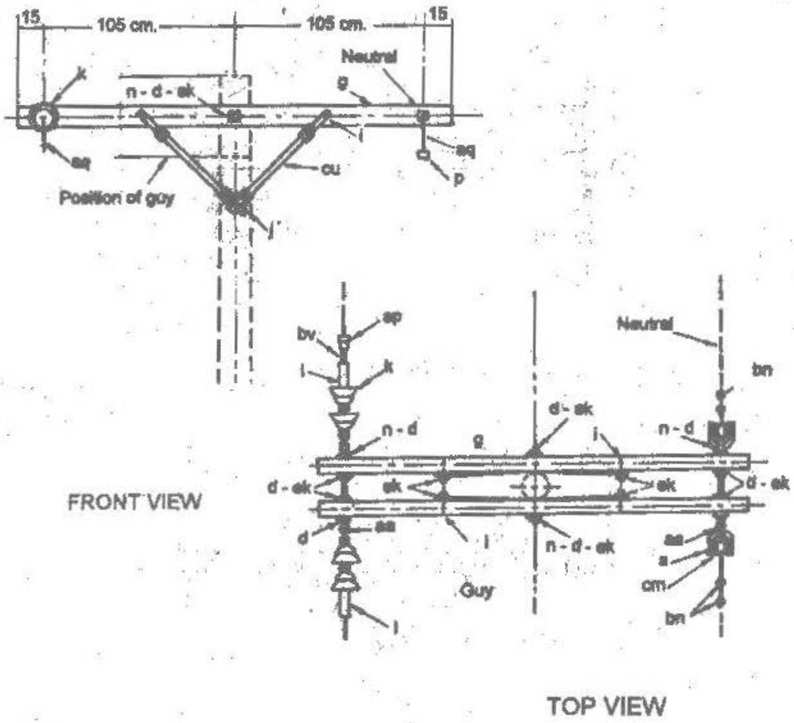
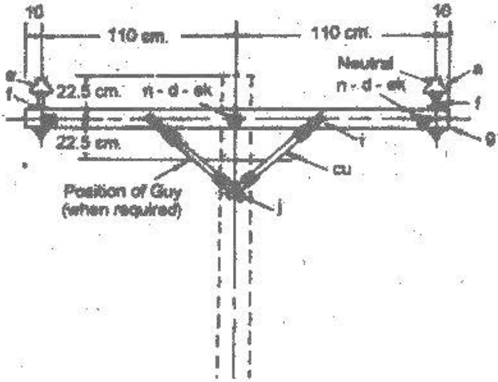


FIGURE 11-11

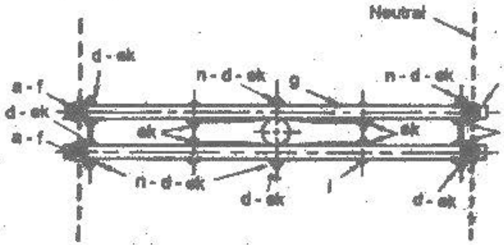
7.62 / 13.2 KV. SINGLE PHASE CROSS-ARM CONSTRUCTION (DEADEND DOUBLE)

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼"-13/16" Hole washer	10	p -	Compression connector	1
g -	3 ½" x 4 ½ x 8' Crossarm	2	aa -	5/8" Eye nut	4
cu -	28" Wood brace	4	aq -	Jumpers (as required)	
i -	3/8" x 4 ½" Carriage bolt	4	ek -	5/8" Locknuts	6
j -	¼" x 4" Lag screw	2	ek -	3/8" Locknuts	4
k -	Suspension insulator	4	cm –	1 ¾" dia. groove spool insulator	2
n -	5/8" x 18" Double arming bolt	3	ap -	Hot line clamp	1
l -	Dead end clamp	2	bv -	Armor rod (tapping) *	1
s -	Secondary swinging clevis	2	t -	Armor tape *	24"
bn -	Loop dead-end clamp	4	tw –	Tie wire*	40'

** Conductor Accessories*



FRONT VIEW



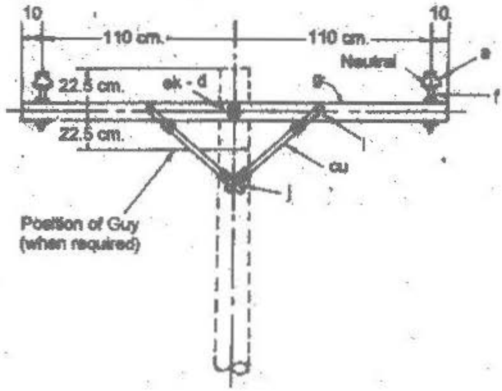
TOP VIEW

FIGURE 11-12

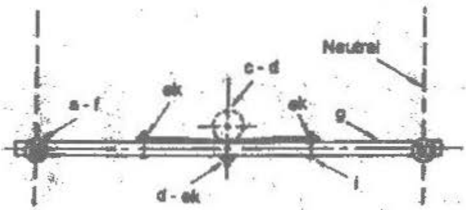
7.62 / 13.2 KV. SINGLE PHASE CROSSARM CONSTRUCTION DOUBLE LINE ARM

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	4	j -	½" x 4" Lag screw	2
d -	3/16" x 2 ¼" Washer	10	n -	5/8" x 18" Double arm bolt	3
f -	5/8"x 10"x ¾" Crossarm steel pin	4	ek -	5/8" Locknuts	10
g -	3 ½" x 4 ½" x 8' Crossarm	2	ek -	3/8" Locknuts	4
cu-	28" Wood brace	4	bv-2	Armor rod *	2
i -	3/8" x 4 ½" Carriage bolts	4	tw -	Tie wire*	32"

* *Conductor Accessories*



FRONT VIEW



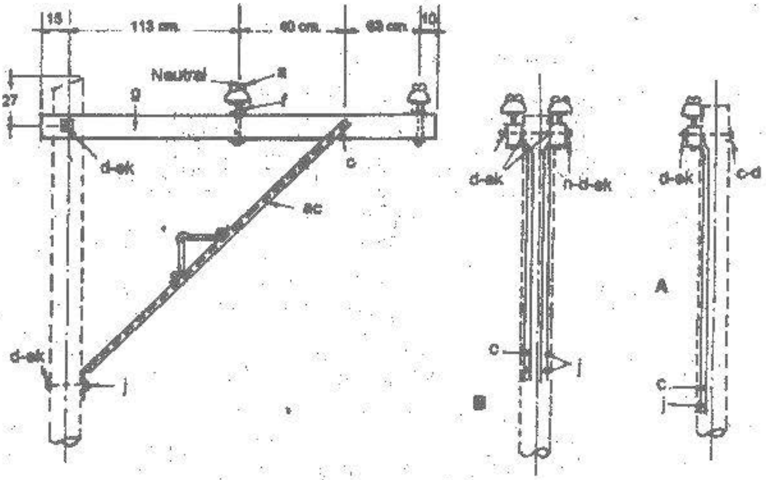
TOP VIEW

FIGURE 11-13

7.62 / 13.2 KV. SINGLE PHASE CROSSARM CONSTRUCTION SINGLE LINE ARM

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	2	j -	½" x 4" Lag screw	1
c -	5/8" x 12" Machine bolt	1	cu -	28" Wood brace	2
d -	3/16" x 2 ¼"-13/16" Hole washer	2	ek -	5/8" Locknuts	1
f -	5/8" x 10 ¾" Crossarm steel pin	2	ek -	3/8" Locknut	2
g -	3 ½" x 4 ½" x 8' Crossarm	1	bv- l	Armor rod (single support)*	2
i -	3/8" x 4 ½" Carriage bolts	2	tw -	Tie wire *	16'

** Conductor Accessories*



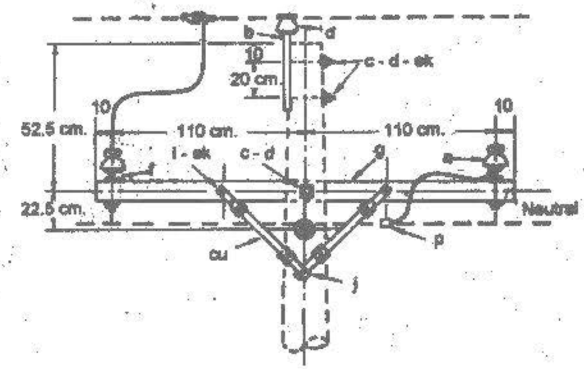
FRONT VIEW SIDE VIEW SIDE VIEW

FIGURE 11-14

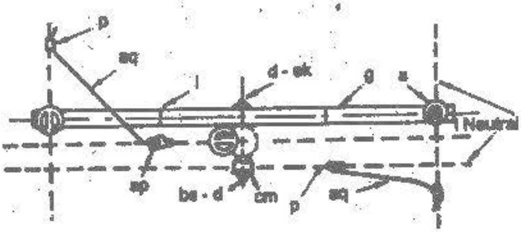
7.62 / 13.2 KV. PRIMARY, SINGLE PHASE SIDE ARM TANGENT

Item	Materials	Quantity A	Quantity B	Item	Materials	Quantity A	Quantity B
a -	Pin type insulator	2	4	c -	5/8" x 12" Machine bolt	1	0
c -	½" x 6" Machine bolt	1	2	c -	½" x 10" Machine bolt	1	2
d -	2 ¼" x 3/16"-13/16" Washer	2	6	d -	1 3/8" x 9/16" Hole washer	2	6
n -	5/8" x 18" dbl. Arming bolt	0	2	f -	5/8" x 10 ¾" C. arm steel pin	2	4
g -	3 ½" x 4 ½" x 8' Crossarm	1	2	j -	½" x 4" Lag screw	1	2
ac -	84" Side arm diag. Brace	1	2	ek -	½" Locknuts	2	4
ek -	5/8" Locknuts	1	6	bv-l	Armor rod single support*	2	0
tw -	Tie wire*	16'	32'	bv-2	Armor rod double support*	0	2

** Conductor Accessories*



FRONT VIEW



TOP VIEW

FIGURE 11-15

7.62 / 13.2 KV. SINGLE PHASE CROSSARM CONSRUCTION
SINGLE PHASE JUNCTION AT 6° TO 15°

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin insulator	3	i -	3/8" x 4 ½" Carriage bolt	2
b -	20" Pole top pin	1	j -	½" x 4" Lag screw	1
c -	5/8" x 10" Machine bolts	2	p -	Compression connector	3
c -	5/8" x 14" Machine bolt	1	aq -	Jumpers and leads (as required)	
d -	3/16" x 2 ¼"-13/16" hole washer	5	bs -	10" Single upset bolt	1
f -	5/8" x 10 ¾" Crossarm steel pin	2	ek -	5/8" Locknuts	3
g -	3 ¾" x 4 ¼" x 8' Crossarm	1	ek -	3/8" Locknuts	2
cu -	28" Wood brace	2	bv-1	Armor rod (single support)*	4
cm -	Spool insulator 1 ¾" dia. groove	1	tw -	Tie wire*	32"
ap -	Hot line clamp	1	bv -	Armor rod tapping *	1

** Conductor Accessories*

TWO-PHASE CONSTRUCTION

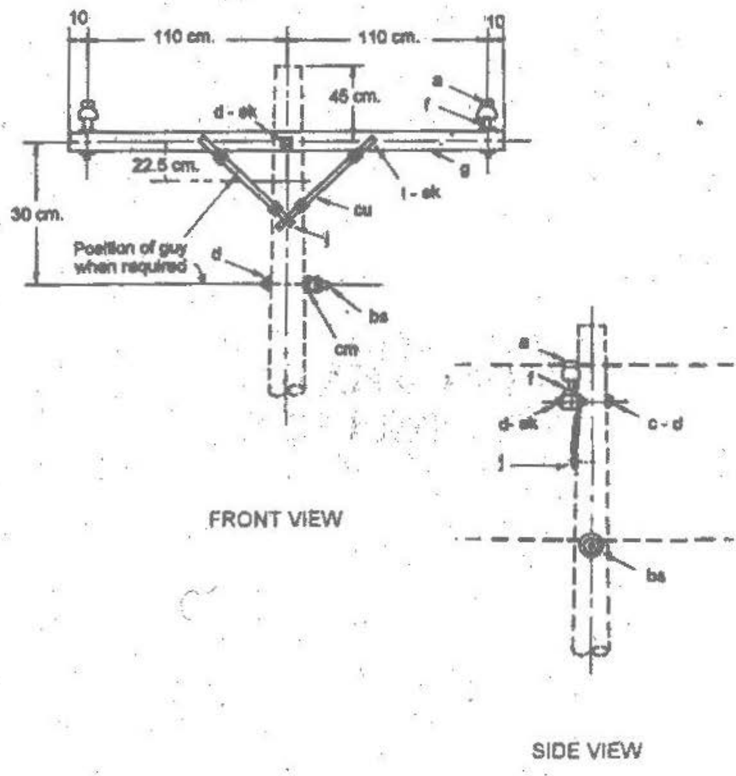


FIGURE 11-16

7.62 / 13.2 KV. TWO PHASE CROSSARM CONSTRUCTION
0° TO 5° ANGLE SINGLE PRIMARY SUPPORT

Item	Materials	Quantity	Item	Materials	Quantity
à -	Pin type insulator	2	ek -	5/8" Locknuts	1
c -	5/8" x 14" Machine bolt	1	i -	5/8"x 4 ½" Carriage bolt	2
d -	3/16" x 2 ¼"-13/16" Hole washer	3	bs -	10" Single upset bolt	1
f -	5/8" x 10 ¾" Crossarm steel pin	2	j -	2/2" x 4" Lag screw	1
g -	3 ½" x 4 ½" x 8' Crossarm	1	cm -	1 ¾" dia. groove spool insulator	1
cu -	28" Wood brace	2	bv-1	Armor rod single support *	3
ek -	3/8" Locknuts	2	tw -	Tie wire *	24'

** Conductor Accessories*

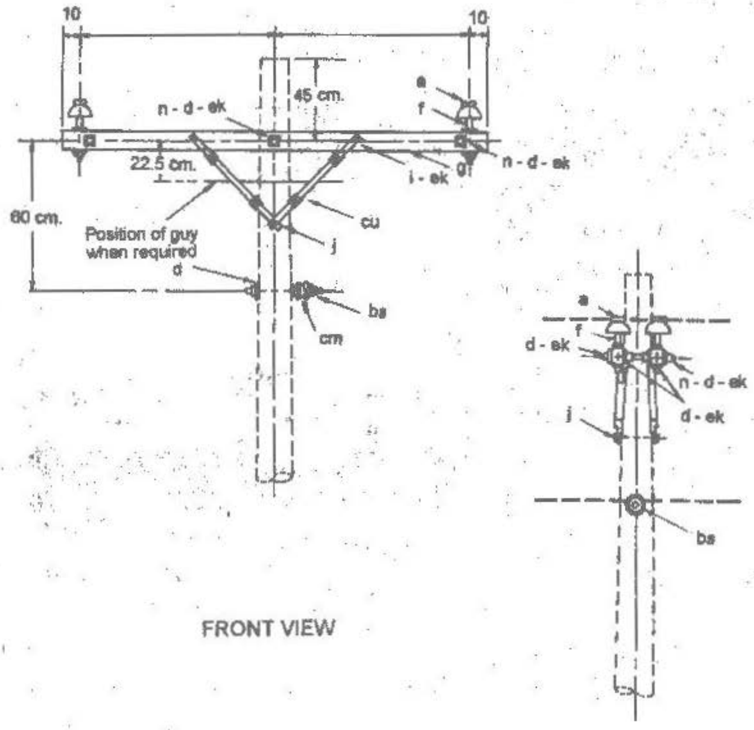
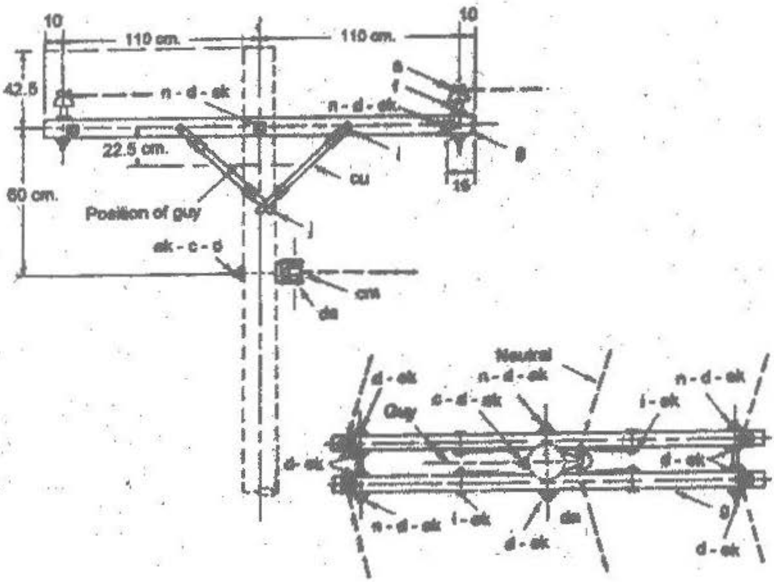


FIGURE 11-17

7.62 / 13.2 KV. TWO PHASE, CROSSARM CONSTRUCTION DOUBLE PRIMARY SUPPORT AT 0° TO 5° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	4	j -	½" x 4" Lag screw	2
d -	3/16" x 2 ¼"-13/16 Hole washer	11	n -	5/8" x 20" double arming bolt	3
f -	*5/8" x 10 ¾" Crossarm steel pin	4	bs -	10" Single upset bolt	1
g -	3 ½" x 4 ½" x 8' Crossarm	2	cm -	1 ¾" dia. groove spool insulator	1
cu -	28" Wood brace	4	bv-1	Armor rod single support *	1
ek -	3/8" Locknuts	4	bv-2	Armor rod double support *	2
ek -	5/8" Locknuts	10	tw -	Tie wire*	40'
i -	3/8" x 4 ½" Carriage bolts	4			

*Conductor Accessories



FRONT VIEW

TOP VIEW

FIGURE 11-18

7.62 / 13.2 TWO PHASE CROSSARM CONSTRUCTION
DOUBLE PRIMARY SUPPORT, MAX. TRANSVERSE
LOADING 500 LBS / PIN 5° TO 30° MAXIMUM ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	4	j -	½" X 4" Lag screw	2
c -	5/8" x10" Machine bolt	1	i -	3/8" x 4 ½" Carriage bolts	4
d -	3/16 x 2 ¼ - 13/16" Hole washer	4	n -	5/8" x 20" Double arming bolt	4
f -	5/8" x 10 ¾" Crossarm steel pin	4	da -	Bracket	1
g -	3 ½' x 4 ½" x 8' Crossarm	2	cm -	1 ¾" dia. groove spool insulator	1
cu -	28" Wood brace	4	bv-3	Armor rod (single support) *	1
ek -	3/8" Locknuts	4	tw -	Tie wire*	40'
ek -	5/8" Locknuts	11			

* Conductor Accessories

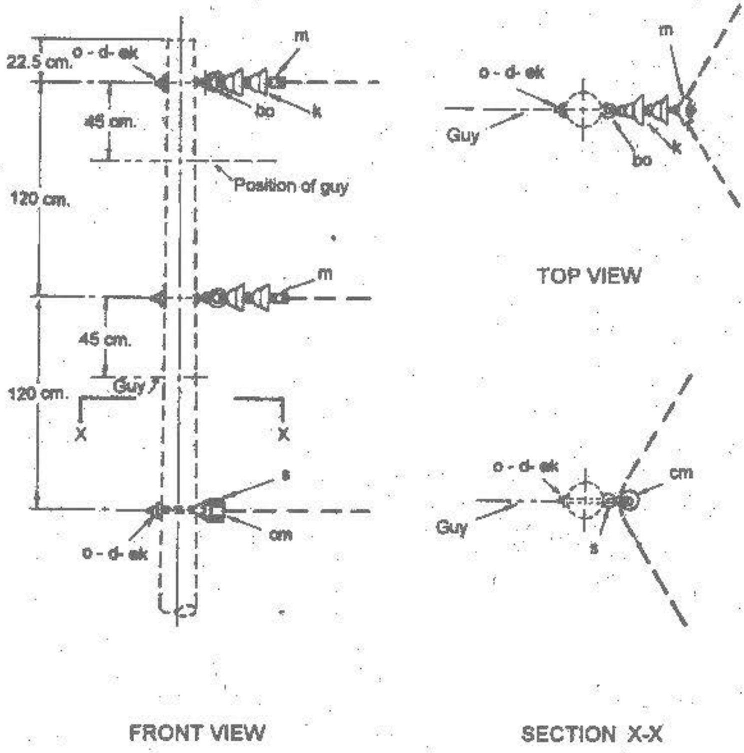


FIGURE 11-19

7.62 / 13.2 KV. TWO PHASE VERTICAL CONSTRUCTION
30° TO 60° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼"- 13/15" Hole washer	3	cm-	1 ¾" dia. groove spool insulator	1
k -	Suspension insulator	4	bo -	Anchor shackle	2
o -	5/8" x 10" Eye bolt	3	ek -	5/8" Locknuts	3
m -	Suspension clamp	2	bv-1	Armor rod (single support) *	3
s -	Secondary swinging clevis	1	tw -	Tie wire *	8'

** Conductor Accessories*

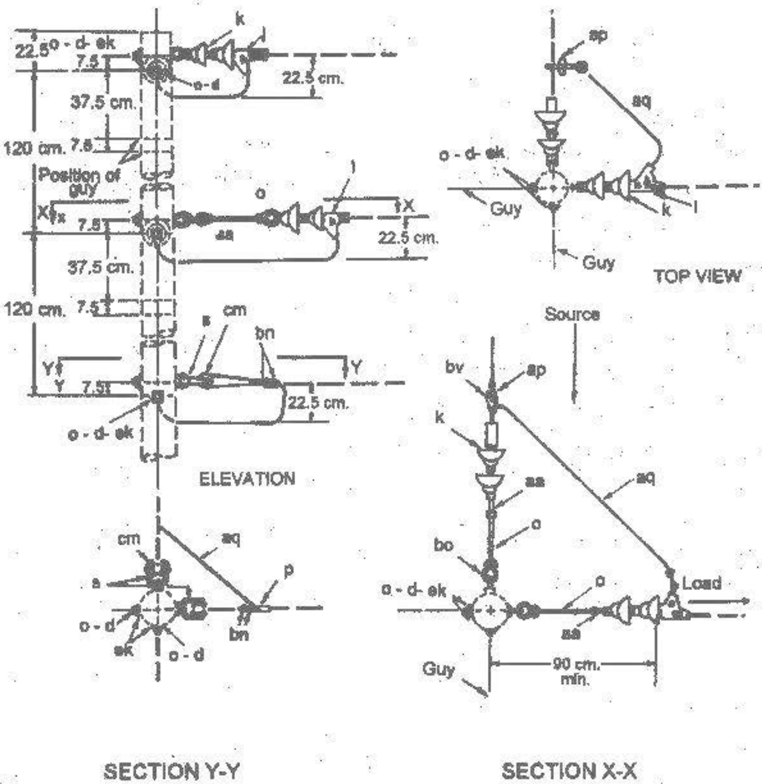
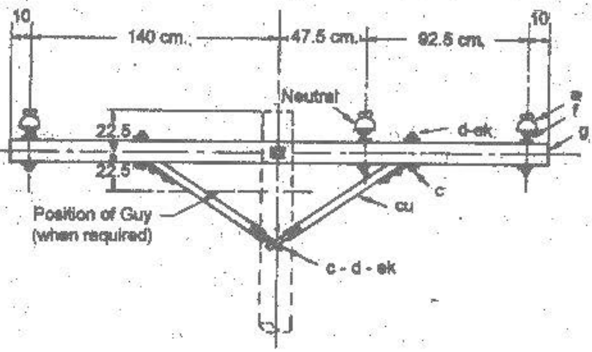


FIGURE 11-20

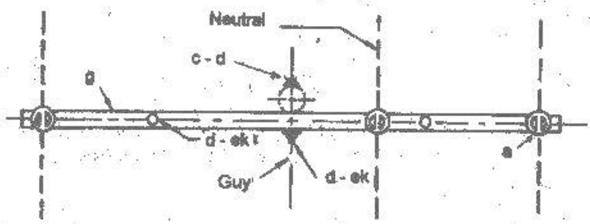
7.62 / 13.2 KV. TWO PHASE, VERTICAL CONSTRUCTION
60° TO 90° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼" - 1316" Hole washer	6	cm -	1 ¾" dia. groove spool insulator	2
k -	Suspension insulator	8	bn -	Dead end loop clamp	4
o -	5/8" x 10" Eye bolt	6	bo -	Anchor shackle	2
o -	5/8" x 8" Eye bolt	2	ek -	5/8" Locknuts	6
p -	Compression connectors	2	ap -	Hotline clamp	2
aa -	5/8" Eye nut	2	l -	Dead and clamp	4
aq -	Leads and jumpers (as required)		bv-	Armor rod (tapping) *	2
s -	Secondary swinging clevis	2	t -	Armor type *	2'

** Conductor Accessories*



FRONT VIEW



TOP VIEW

FIGURE 11-21

**7.62 / 13.2 KV. TWO PHASE CROSSARM CONSTRUCTION
SINGLE LINE ARM**

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	3	g -	3 ¾" x 3 ¾" x 10' Crossarm	1
c -	5/8" x 10" Machine bolt	1	cu -	60" Span wood brace	1
c -	½" x 6" Machine bolt	2	ek -	½" Locknut	2
c -	5/8" x 14" Machine bolt	1	ek -	5/8" Locknut	2
d -	3/16" x 2 ¼" x 13/16 Hole washer	3	bv-1	Armor rod (single support) *	3
d -	1 3/8" dia. x 9/16 Hole fd. washer	2	tw -	Tie wire *	24'
f -	5/8" x 10 ¾" Crossarm steel pin	3			

** Conductor Accessories*

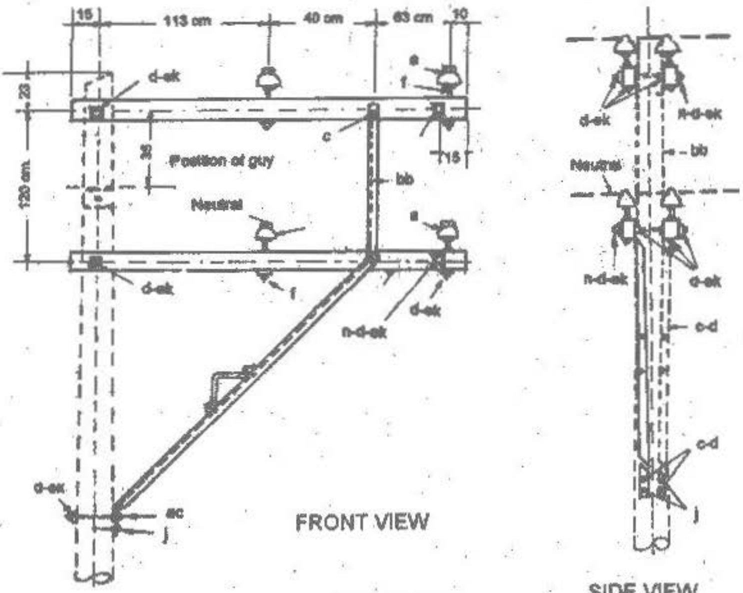


FIGURE 11-22

7.62 / 13.2 KV. TWO PHASE SIDE ARMS CONSTRUCTION FOR SINGLE AND DOUBLE PRIMARY SUPPORTS

Item	Materials	No. Required A	No. Required B
a -	Pin type insulator	3	6
c -	5/8" x 14" Machine bolts	2	0
c -	½" x 6" Machine bolts	2	4
c -	½" x 10" Machine bolts	1	2
d -	2 ¼" x 2 ¼" - 3/16" hole - square washer	4	12
d -	1 3/8" diameter x 9/16" hole round washer	3	6
f -	5/8" x 10 ¾" Crossarm steel pin	3	6
g -	3 ½" x 4 ½" x 8' Crossarm	2	4
j -	½" x 4" Lag screw	1	2
n -	5/8" x 20" Double arming bolt	0	4
ac -	1 ¾" angle 3/16" x 7' Side arm diagonal brace	1	2
bb -	50 " Side arm vertical angle brace	1	2
ek -	5/8" Locknuts	2	12
ek -	½" Locknuts	3	6
bv -	Armor rod (single support)*	3	-
bv-2	Armor rod (double support)*	-	3
tw -	Tie wire*	7.5 m.	15 m.

* *Conductor Accessories*

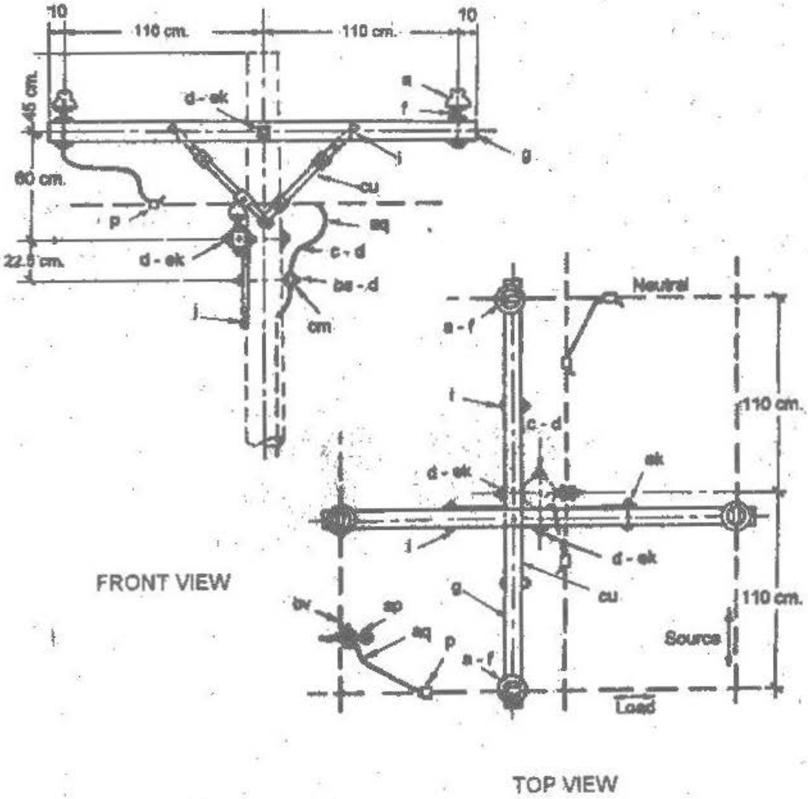


FIGURE 11-23

7.62 / 13.2 KV. TWO PHASE CROSSARM CONSTRUCTION
SINGLE PHASE JUNCTION AT 0° TO 5° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	4	bv -	Armor rod tapping *	1
c -	5/8" x 14" Machine bolts	2	bv-1	Armor rod (single support)*	5
d -	3/16" x 2 ¼" – 13/16 hole washer	5	tw -	Tie wire*	40'
f -	5/8" x 10 ¼" Crossarm steel pin	4	i -	3/8" x 4 ½" Carriage bolt	4
g -	3 ½" x 4 ½" x 8' Crossarm	2	j -	½" x 4" Lag screw	2
cu -	28" Wood brace	4	p -	Compression connectors	4
ek -	3/8" Locknuts	4	aq -	Jumpers and leads (as required)	
ek -	5/8" Locknuts	2	cm -	1 ¾" dia. groove spool insulator	1
ap -	Hot line clamp	1	bs -	3/8" x 10" single upset bolt	1

** Conductor Accessories*

THREE-PHASE CONSTRUCTION

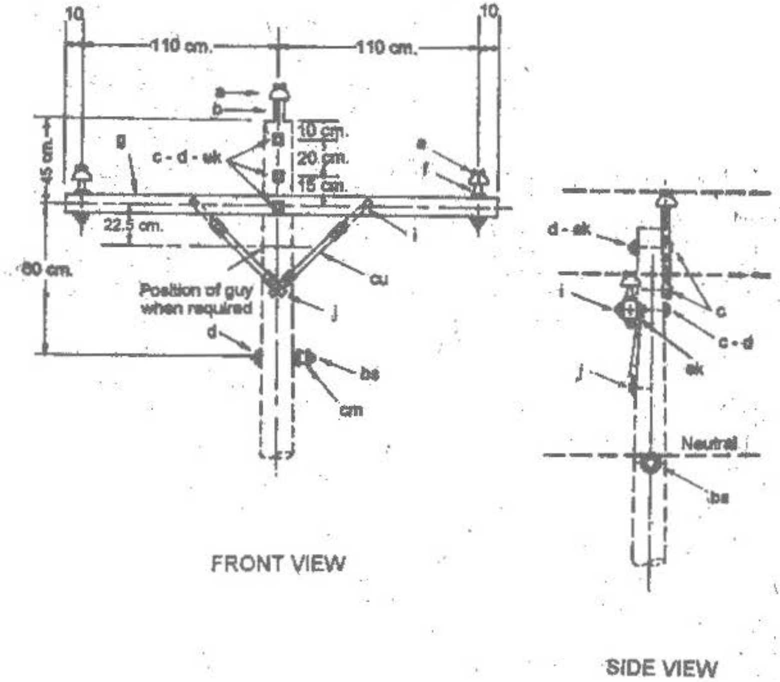
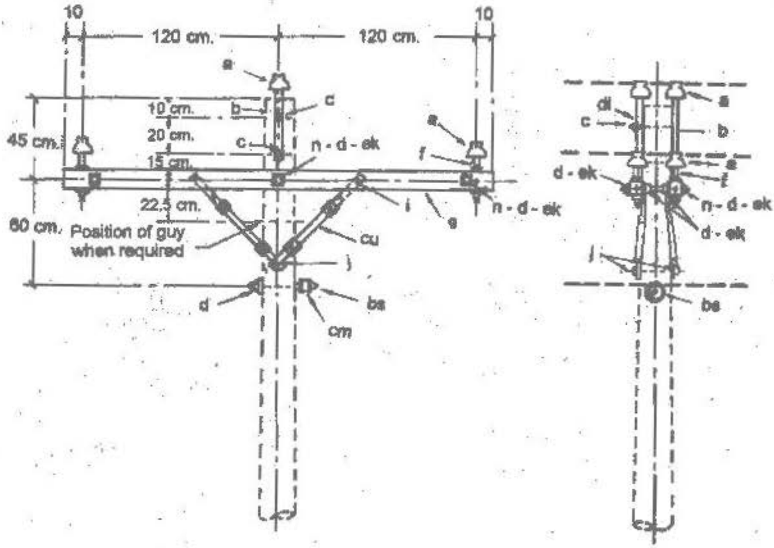


FIGURE 11-24

7.62 / 13.2 KV. THREE PHASE CROSSARM CONSTRUCTION
SINGLE PRIMARY SUPPORT AT 0° TO 5° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	3	I -	3/8" x 4 ½" Carriage bolt	2
b -	20" Pole top pin	1	j -	½" x 4" Lag screw	1
c -	5/8" x 10" Machine bolts	2	bs -	5/8" x 10" Single upset bolt	1
c -	5/9" x 14" Machine bolt	1	cm -	1 ¾" dia. groove spool insulator	1
d -	3/16" x 2 ¼" – 13/16 hole washer	5	ek -	3/8" Locknut	2
f -	5/8" x 10 ¾" Crossarm steel pin	2	ek -	5/8" Locknut	3
g -	3 ½" x 4 ½" x 8' Crossarm	2	bv-1	Armor rod (single support)*	4
cu -	28" Wood brace	2	tw -	Tie wire *	32'

Conductor Accessories



FRONT VIEW

SIDE VIEW

FIGURE 11-26

7.62 / 13.2 KV. THREE PHASE CROSSARM CONSTRUCTION
DOUBLE PRIMARY SUPPORT AT 0° TO 5° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	6	bs -	5/8" x 10" single upset bolt	1
b -	20" Pole top pin	2	ek -	5/8" Locknut	13
c -	5/8" x 12" Machine bolts	2	ek -	3/8" Locknut	4
d -	3/16" x 2 ¼" –13/16" hole washer	11	cu -	28" Wood brace	4
f -	5/8" x 10 ¾" Crossarm steel pin	4	cm -	1 ¾" spool insulator	1
g -	3 ½" x 4 ½" x 8' Crossarm	2	dl -	¾" dia. x 1 ½" pipe spacer	2
i -	3/8" x 4 ½" Carriage bolt	4	bv-1	Armor rod (single support) *	1
j -	½" x 4" Lag screw	2	bv-2	Armor rod (double support) *	3
n -	5/8" x 18" double arming bolt	3	tw -	Tie wire*	56'

* *Conductor Accessories*

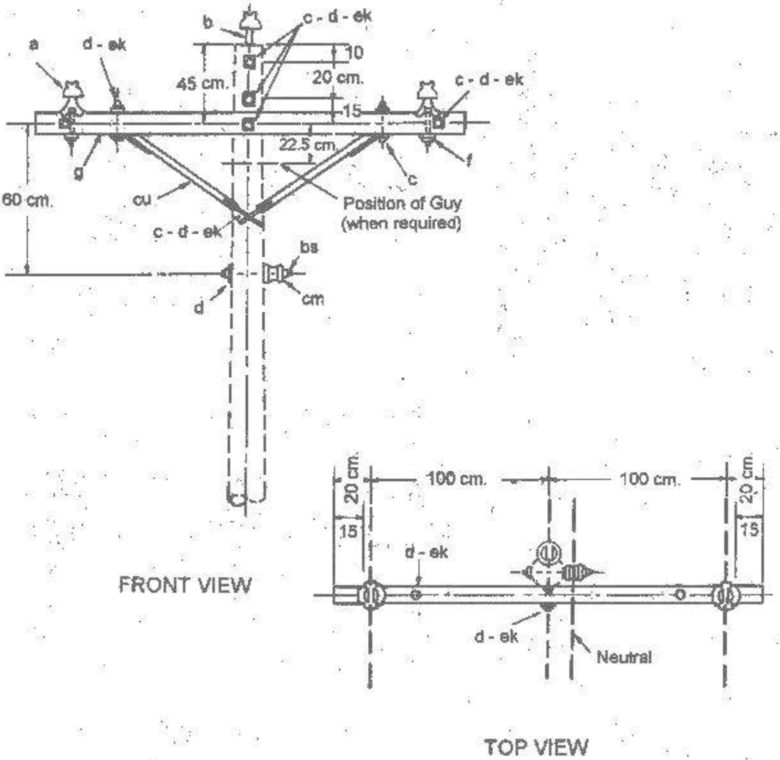
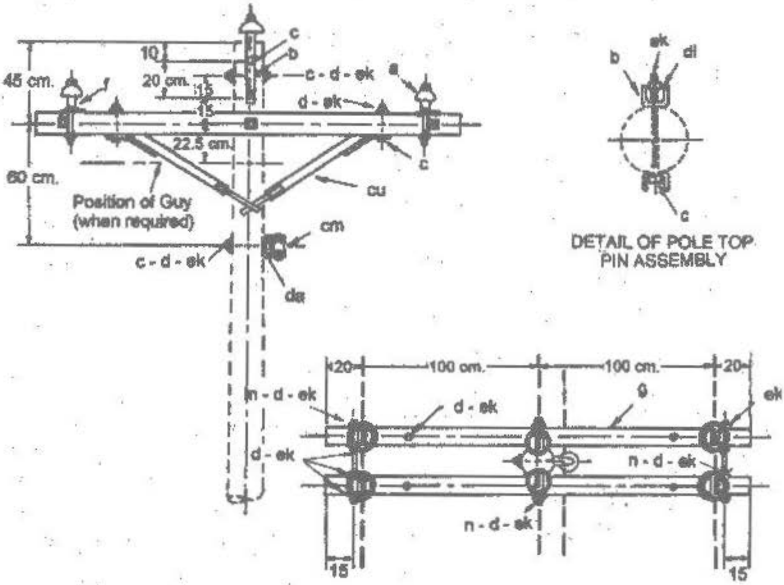


FIGURE 11-26

7.62 / 13.2 KV. 3 PHASE CROSSARM CONSTRUCTION AT 0° TO 2° ANGLE (LARGE CONDUCTORS)

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	3	ek -	5/8" Locknuts	6
b -	20" Pole top pin	1	f -	Crossarm clamp type pin	2
c -	½" x 6" Machine bolts	2	g -	3 ¾" x 4 ¾" x 8' Crossarm	1
c -	5/8" x 5" Machine bolts	2	bs -	12" Single upset bolt	1
c -	5/8" x 12" Machine bolts	3	cu -	60" Wood brace	1
c -	5/8" x 16" Machine bolt	1	cm -	1 ¾" dia. groove spool insulator	1
d -	3/16" x 2 ¼" –13/16" hole washer	10	bv-1	Armor rod (single support) *	4
d -	3/8" dia. 9/16" hole round washer	2	tw -	Tie wire*	32'
ek -	½" Locknuts	2			

** Conductor Accessories*



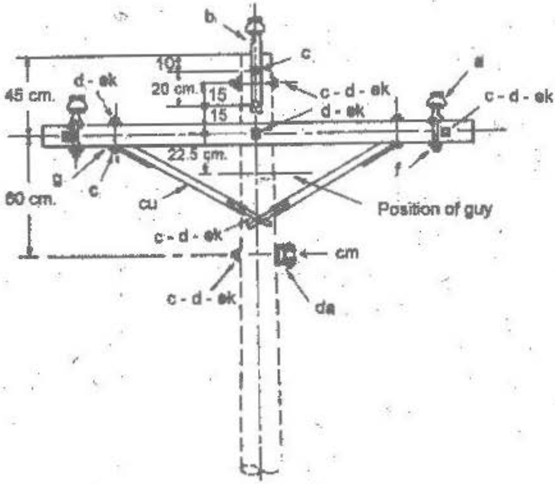
FRONT ELEVATION TOP VIEW

FIGURE 11-27

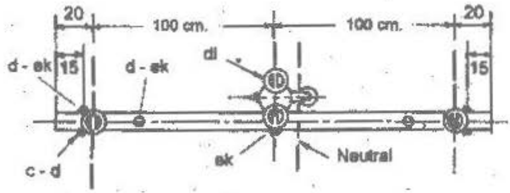
7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION, DOUBLE PRIMARY SUPPORT 0° TO 5° ANGLE (LARGE CONDUCTORS)

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	6	g -	3 ¾" x 4 ¾" x 8' Crossarm	2
b -	20" Pole top pin	2	n -	5/8" x 24" Double arming bolt	3
c -	5/8" x 12" Machine bolt	3	cu -	60" Span wood brace	2
c -	½" x 6" Machine bolt	4	da -	Bracket	1
c -	5/8" x 14" Machine bolt	2	ek -	5/8" Locknut	15
d -	3/16" x 2 ¼"-13/16" hole washer	13	ek -	½" Locknut	4
d -	1 3/8" dia. 9/16" hole rd. washer	4	bv-1	Armor rod (single support) *	1
dl -	¾" dia. x 1 ½" Pipe spacer	2	bv-2	Armor rod (double support) *	3
f -	Crossarm steel clamp pin type	4	tw -	Tie wire*	56'

* Conductor Accessories



FRONT ELEVATION



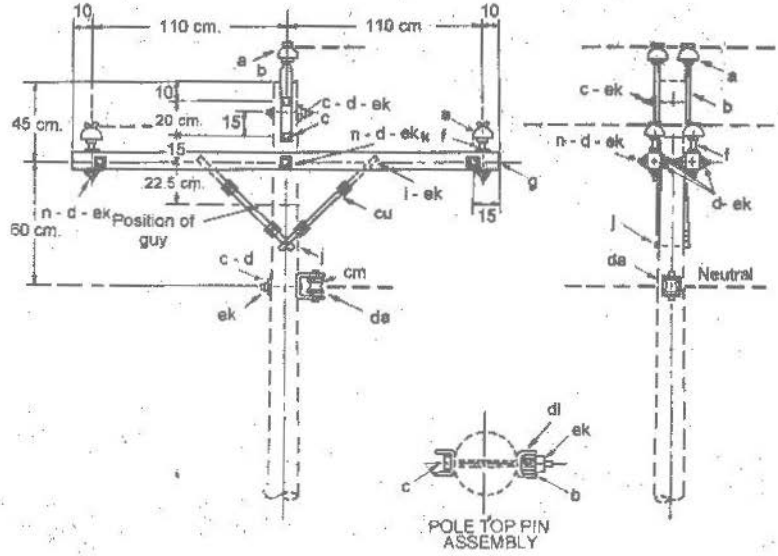
TOP VIEW

FIGURE 11-28

7.62 / 13.2 KV. 3-PHASE CROSS ARM CONSTRUCTION
2° TO 6° ANGLE (LARGE CONDUCTORS)

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type Insulator	4	cm -	3" dia. groove spool insulator	1
b -	20" Pole top pin	2	g -	3 ¾" x 4 ¾" x 8' Crossarm	1
c -	5/8" x 12" Machine bolts	3	cu -	60" Span wood brace	1
c -	½" x 6" Machine bolts	2	da -	Bracket	1
c -	5/8" x 14" Machine bolts	2	di -	¾" dia. x 1 ½" Pipe spacer	2
c –	5/8" x 16" Machine bolt	1	ek -	5/8" Locknut	7
c -	5/8" x 5" Machine bolts	2	ek –	½" Locknut	2
d -	3/16" x 2 ¼" - 13/16" hole washer	10	bv-1	Armor rod (single support) *	3
d -	1 3/8" dia. 9/16" hole rd. washer	2	bv-2	Armor rod (double support) *	1
f -	Crossarm pin, clamp type	2	tw -	Tie wire*	40'

** Conductor Accessories*



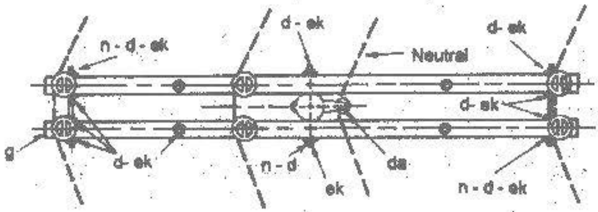
FRONT ELEVATION SIDE VIEW

FIGURE 11-29

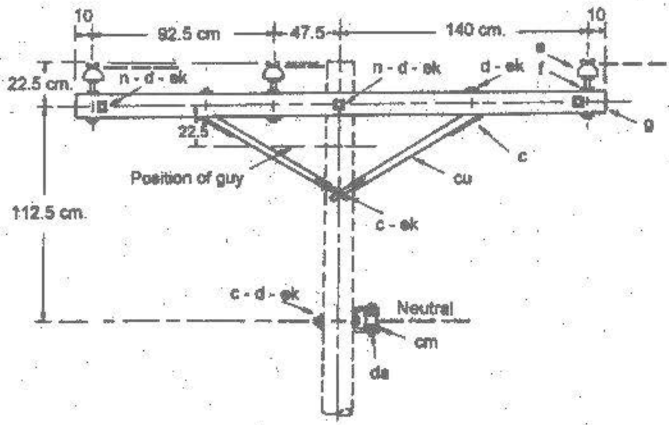
7.62 / 13.2 KV. 3-PHASE CONSTRUCTION DOUBLE PRIMARY SUPPORT MAXIMUM TRAVERSE LOADING – 227 KG. (500 LBS) PER PIN 5° TO 30° MAXIMUM ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	6	cm -	3" dia. groove spool insulator	1
b -	20" Pole top pin	2	cu -	28" Wood brace	4
c -	5/8" x 12" Machine bolt	2	da -	Bracket	1
c -	5/8" x 14" Machine bolt	2	dl -	¾" dia.x 1 2/2" Pipe spacer	2
d -	3/16" x 2 ¼"- 13/16" hole washer	13	ek -	5/8" Locknuts	13
f -	5/8" X 10 ¾" Crossarm steel pin	4	ek -	3/8" Locknuts	4
g -	3 ½" x 4 ½" x 8' Crossarm	2	bv-1	Armor rod (single support) *	1
i -	3/8" x 4 ½" Carriage bolt	4	bv-2	Armor rod (double support) *	3
j -	½" x 4" Lag screw	2	tw -	Tie wire *	56'

** Conductor Accessories*



TOP VIEW



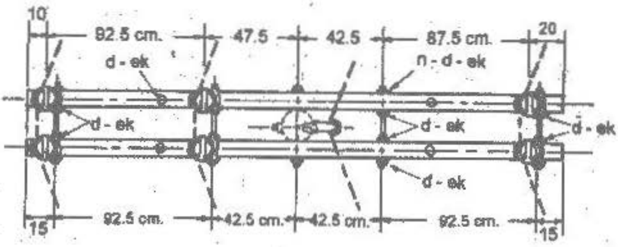
FRONT ELEVATION

FIGURE 11-30

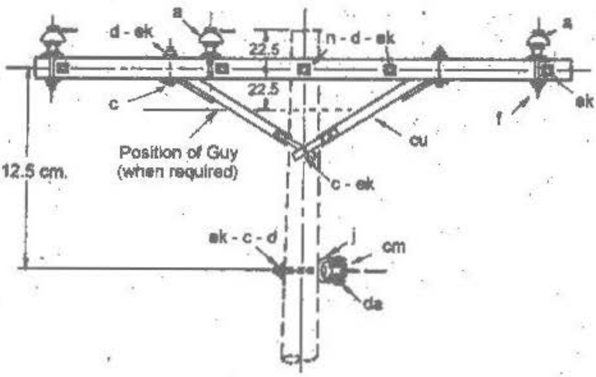
7.62 / 13.2 KV. 3- PHASE CONSTRUCTION DOUBLE PRIMARY SUPPORT MAX. TRANSVERSE LOADING 750° LBS. / PIN 5° TO 30° MAX. ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	6	cm -	3" dia. groove spool insulator	1
c -	5/8" x 12" Machine bolt	2	cu -	60" Span wood brace	2
c -	½" x 6" Machine bolt	4	da -	Bracket	1
d -	3/16" x 2 ¼"- 13/16" hole washer	11	ek -	5/8" Locknut	12
d -	1 3/8" dia. x 9/16: hole rd. washer	4	ek -	½" Locknuts	4
f -	5/8" x 10 ¾" Crossarm steel pin	6	bv-1	Armor rod (single support) *	1
g -	3 ¾" x 4 ¾" x 10' Crossarm	2	bv-2	Armor rod (double support) *	3
n -	5/8" x 22" Double arming bolt	3	tw -	Tie wire *	56'

** Conductor Accessories*



TOP VIEW



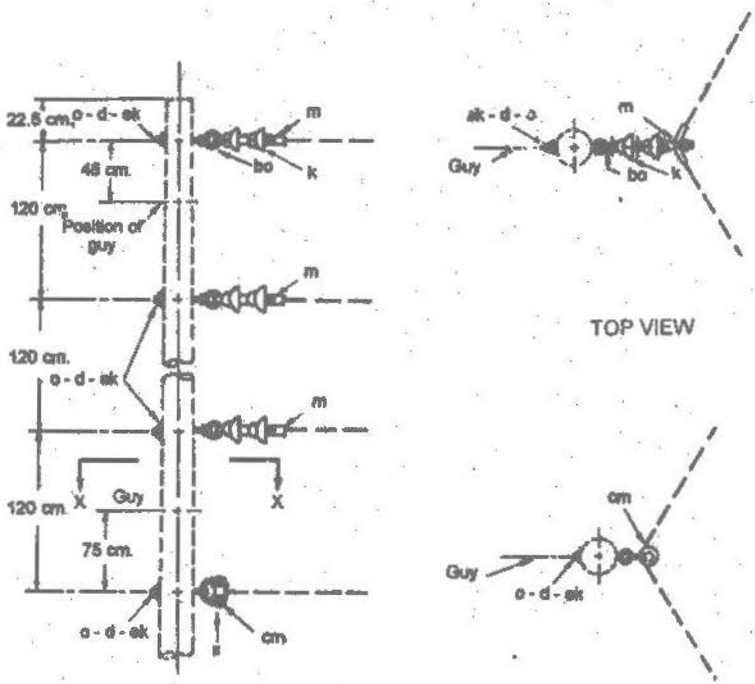
FRONT ELEVATION

FIGURE 11-31

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION, DOUBLE PRIMARY SUPPORT (LARGE CONDUCTOR) MAXIMUM TRAVERSE LOADING 1,000 LBS. / PIN

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	6	da -	Bracket	1
c -	5/8" x 12" Machine bolts	2	cm -	3" dia. groove spool insulator	1
c -	½" x 6" Machine bolts	4	cu -	60" Span wood brace	2
d -	3/16" x 2 ¼" - 13/16" hole washer	19	ek -	5/8" Locknut	19
d -	1 3/8" di. 9/16" hole rd. washer	4	ek -	½" Locknut	4
f -	Crossarm steel pin, clamp type	6	bv-1	Armor rod (single support) *	1
g -	3 ¾" x 4 ¾" x 10' Crossarm	2	bv-2	Armor rod (single support) *	3
j -	½" x 4" Lag screw	2	tw -	Tie wire *	56'
n -	5/8" x 22" Double arming bolt	5			

** Conductor Accessories*



FRONT ELEVATION

SECTION X-X

FIGURE 11-32

7.62 / 13.2 KV. 3-PHASE VERTICAL CONSTRUCTION 30° TO 60° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼" - 13/16" hole washer	4	bo -	Anchor shackle	3
k -	Suspension insulator	6	o -	5/8" x 12" Eye bolt	4
ek -	5/8" Locknut	4	cm -	3" dia. groove spool insulator	1
m -	Suspension clamp	3	bv-1	Armor rod (single support) *	4
s -	Secondary swinging clevis	1	tw -	Tie wire *	8'

** Conductor Accessories*

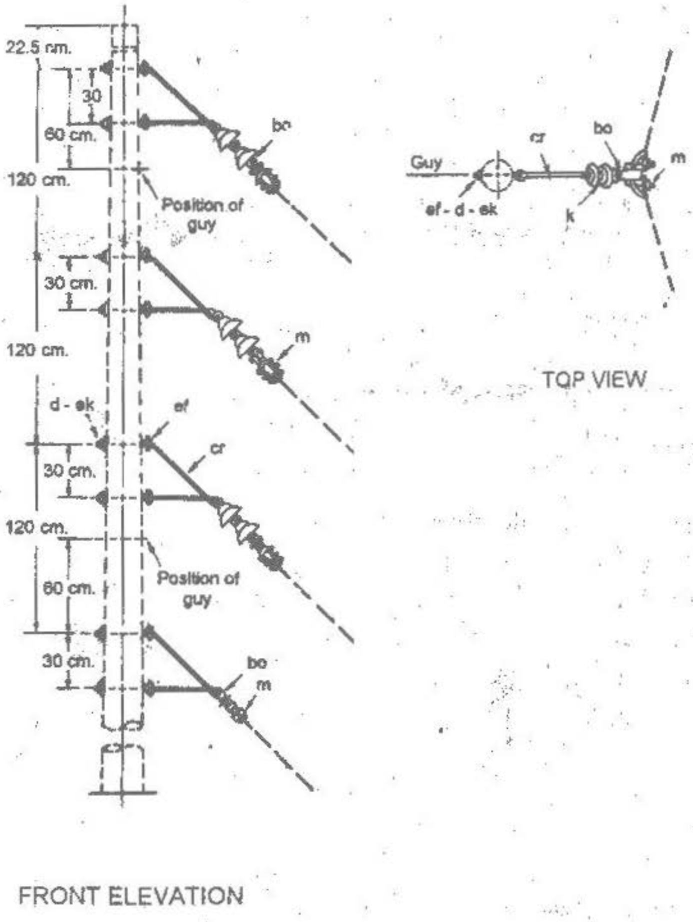


FIGURE 11-33

7.62 / 13.2 KV. VERTICAL CONSTRUCTION 10O TO 20O ANGLE (LARGE CONDUCTORS)

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼" x 13/16" hole washer	8	cr -	5/8" Angle bracket	4
k -	Suspension insulator	6	ef -	5/8" x 12" clevis bolt	8
m -	Suspension clamp	4	ek -	5/8" Locknut	8
bo -	Anchor shackle	4	bv-1	Armor rod (single support)	4

* *Conductor Accessories*

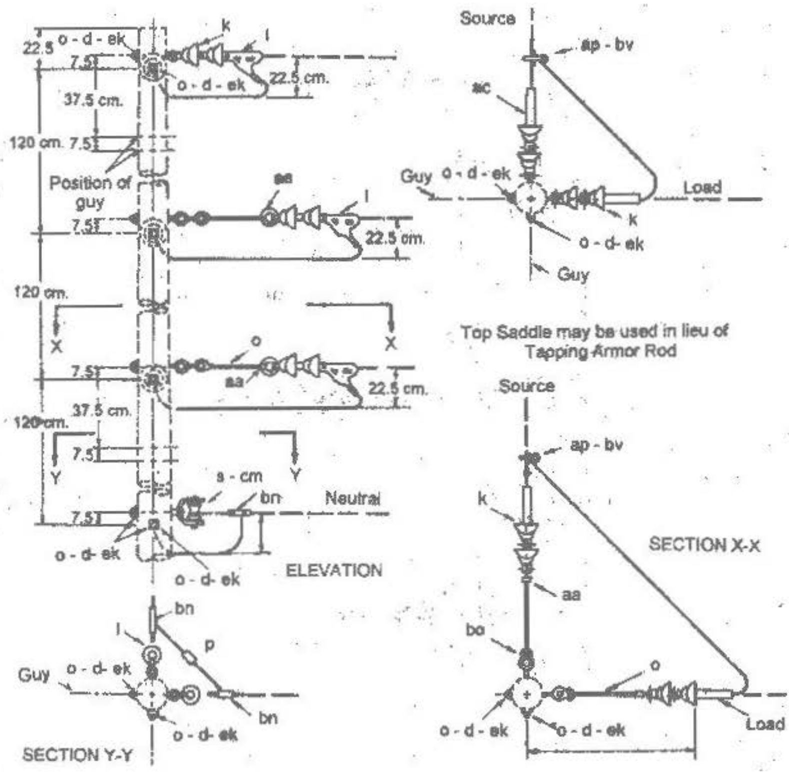
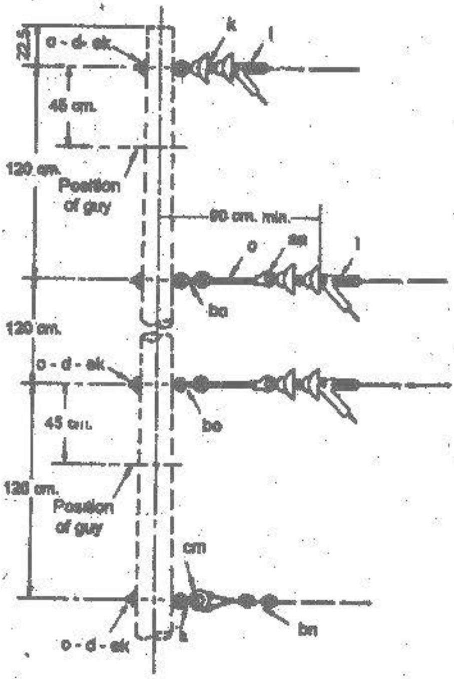


FIGURE 11-34

7.62 / 13.2 KV. 3-PHASE VERTICAL CONSTRUCTION 60° TO 90° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼"- 13/16" hole washer	8	bo -	Anchor bracket	4
k -	Suspension insulator	12	cm -	3" dia. groove spool insulator	2
o -	5/8" x 12" Eye bolt	8	aa -	5/8" Eye nut	4
o -	5/8" x 18" Eye bolt	4	bn -	Dead end loop clamp	4
p -	Compression connector	1	l -	Dead end clamp	6
ek -	5/8" Locknut	8	s -	Secondary swinging clevis	2
ap -	Hotline clamp	3	bv -	Armor rod (tapping) *	3
aq -	Jumpers (as required)		t -	Armor tape *	4'

* Conductor Accessories



FRONT ELEVATION

FIGURE 11-35

7.62 / 13.2 KV. 3-PHASE VERTICAL CONSTRUCTION DEAD END SINGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼" – 13/16" hole washer	4	aa -	5/8" Eye nut	2
k -	Suspension Insulator	6	bn -	Dead end loop clamp	2
l -	Dead end clamp	3	bo -	Anchor shackle	2
o -	5/8" x 12" Eye bolt	4	cm -	3" dia. groove spool insulator	1
o -	5/8" x 18" Eye bolt	2	ek -	5/8" Locknut	4
s -	Secondary swinging clevis	1			

** Conductors Accessories*

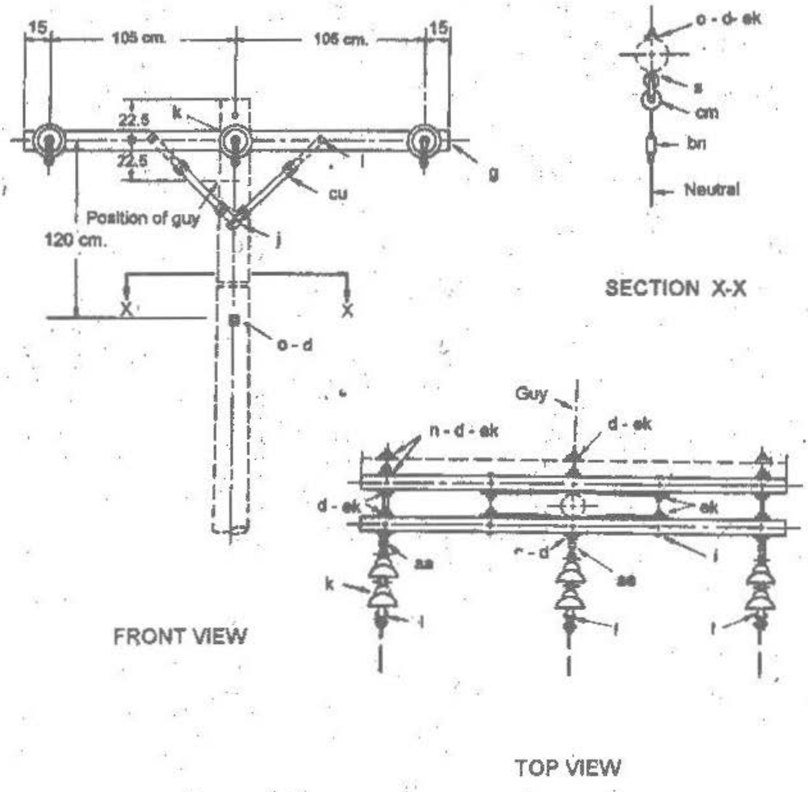


FIGURE 11-36

7.62 / 13,2 KV. 3-PHASE CROSSARM CONSTRUCTION
DEAD END SINGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼ - 13/16" hole washer	11	s -	Secondary swinging clevis	1
g -	3 ½" x 4 ½" x 8' Crossarm	2	aa -	5/8" Eye nut	3
1-	3/8" x 4 ½" Carriage bolt	4	bn -	Dead end loop clamp	2
j -	1/2" x 4" Lag screw	2	cu -	28" Wood brace	4
k -	Suspension insulator	6	ek -	3/8" Locknut	4
l -	Deadend clamp	3	ek -	5/8" Locknut	11
n -	5/8 x 22" Double arming bolt	3	cm -	3" dia. groove spool insulator	1
o -	5/8" x 12" Eye bolt	1	t -	Armor tape *	2'

** Conductor Accessories*

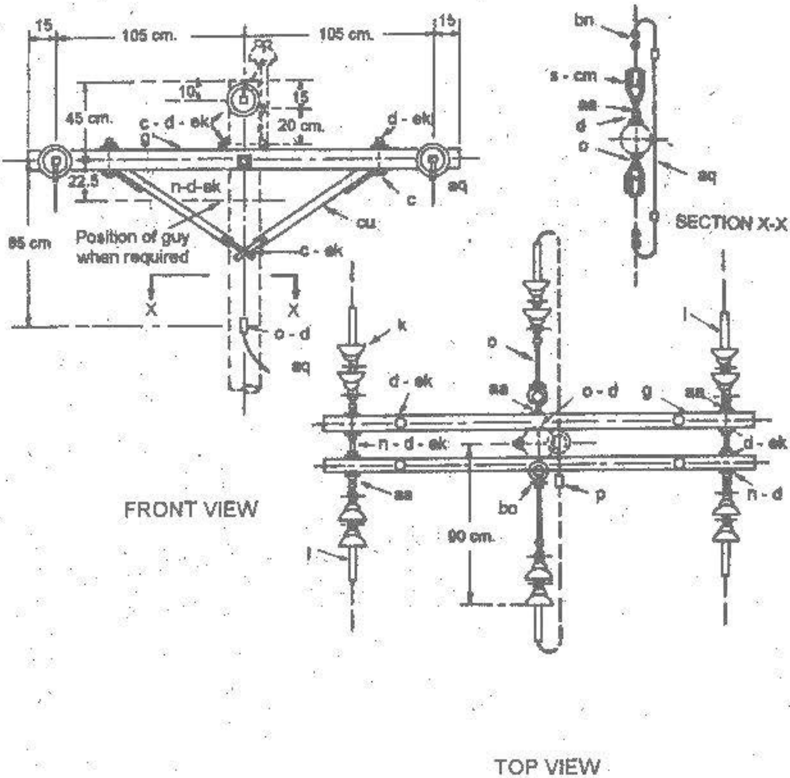
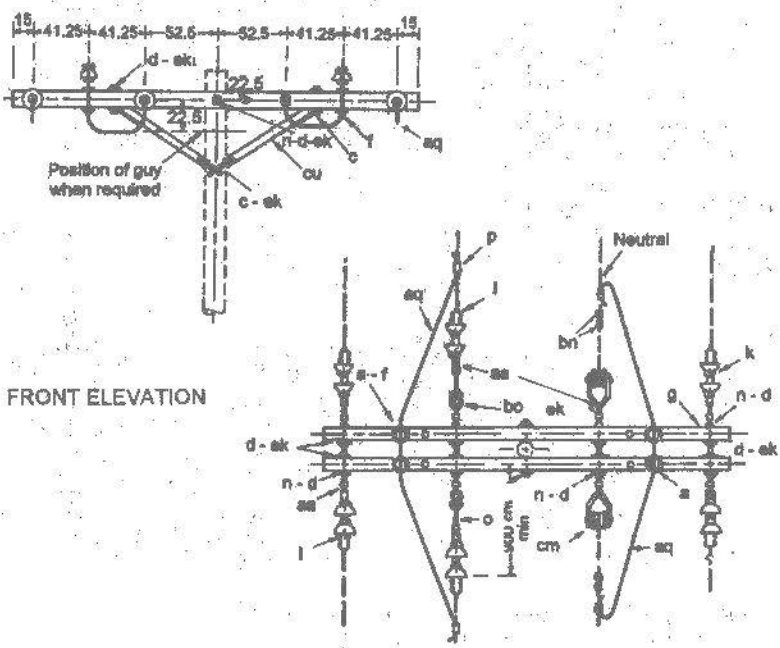


FIGURE 11-37

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION DEAD END DOUBLE

Item	Materials	Quantity	Item	Materials	Quantity
c -	5/8" x 12" Machine bolt	1	ek -	5/8" Locknut	12
c -	½" x 6" Machine bolts	4	o -	5/8" x 12" Eye bolt	2
d -	3/16" x 2 ¼"-13/16" hole washer	14	o -	5/8" x 18" Eye bolt	2
d -	1 3/8" round, 9/16" hole washer	4	p -	Compression connector	5
cm-	3" dia. groove spool insulator	2	aa -	5/8" Eye nut	8
g -	3 ½" x 4 ½" x 8' Crossarm	2	aq -	Jumper and leads (as required)	
k -	Suspension insulator	12	bo -	Anchor shackle	2
n -	5/8" x 24" Double arming bolt	3	cu -	60" Span wood brace	2
l -	Dead end clamp	6	bn -	Dead end loop clamp	4
s -	Secondary swinging clevis	2	t -	Armor tape	2'
ek -	½" Locknut	4			



TOP VIEW

FIGURE 11-38

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION
DEAD END DOUBLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin Type insulator	4	p -	Compression connector	4
c -	5/8" x 12" Machine bolt	1	o -	5/8" x 18" Eye bolt	2
c -	½" x 6" Machine bolt	4	aa -	5/8" Eye nut	10
d -	3/16" x 2 ¼"-13/16" hole washer	18	aq -	Jumper and leads (as required)	
d -	1 3/8" dia. 9/16" hole rd. washer	4	bo -	Anchor shackle	2
f -	5/8" x 10 ¾" Crossarm steel pin	4	cu -	60" span wood brace	2
g -	3 ¾" x 4 ¾" x 10' Crossarm	2	ek -	5/8" Locknut	11
k -	Suspension insulator	12	ek -	½" Locknut	4
l -	Dead end clamp	6	s -	Secondary swinging clevis	2
cm-	3" dia. groove spool insulator	2	n -	5/8" x 24" Double arming bolt	5
bn -	Dead end clamp	4	t -	Armor tape	4'

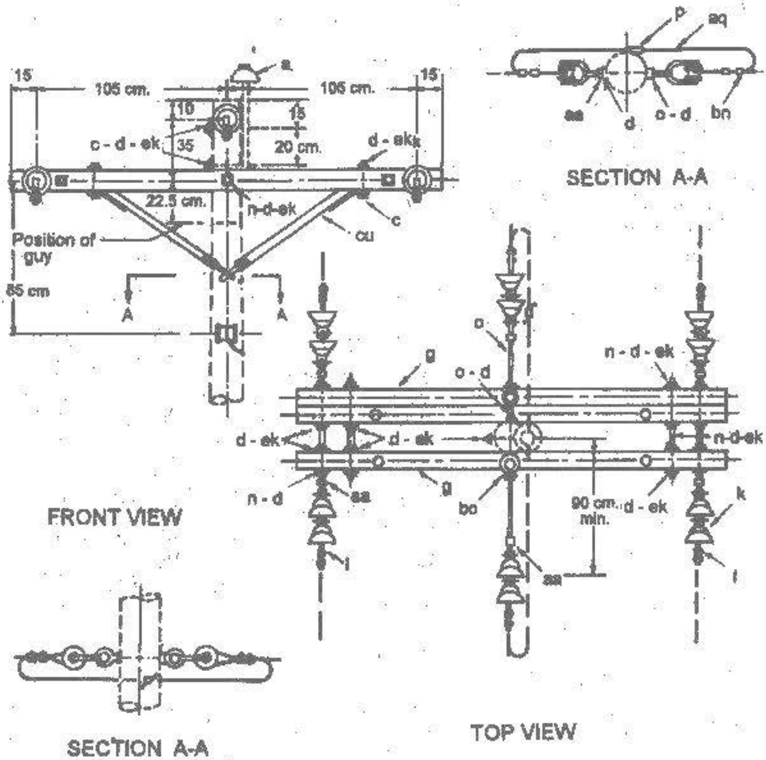


FIGURE 11-39

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION
DEAD END LARGE CONDUCTORS WITH UNBALANCED LOAD

Item	Materials	Quantity	Item	Materials	Quantity
c -	5/8" x 12" Machine bolt	1	s -	Secondary swinging clevis	2
c -	½" x 6" Machine bolt	4	aa -	5/8" Eye nut	8
d -	3/16" x 2 ¼"-13/16" hole washer	22	aq -	Jumper (as required)	
d -	1 3/8" dia. 9/16" hole rd. washer	4	bn -	Dead end loop clamp	4
g -	3 ¾" x 4 ¾" x 8' Crossarm	3	bo -	Anchor shackle	2
k -	Suspension insulator	12	cm -	3" dia. groove spool insulator	2
n -	5/8" x 26" double arming bolt	5	cu -	60" span wood brace	2
o -	5/8" x 12" Eye bolt	2	ek -	½" Locknut	4
o -	5/8" x 18" Eye nut	2	ek -	5/8" Locknut	14
p -	Compression connector	4	t -	Armor tape	4'
l -	Dead end clamp	6			

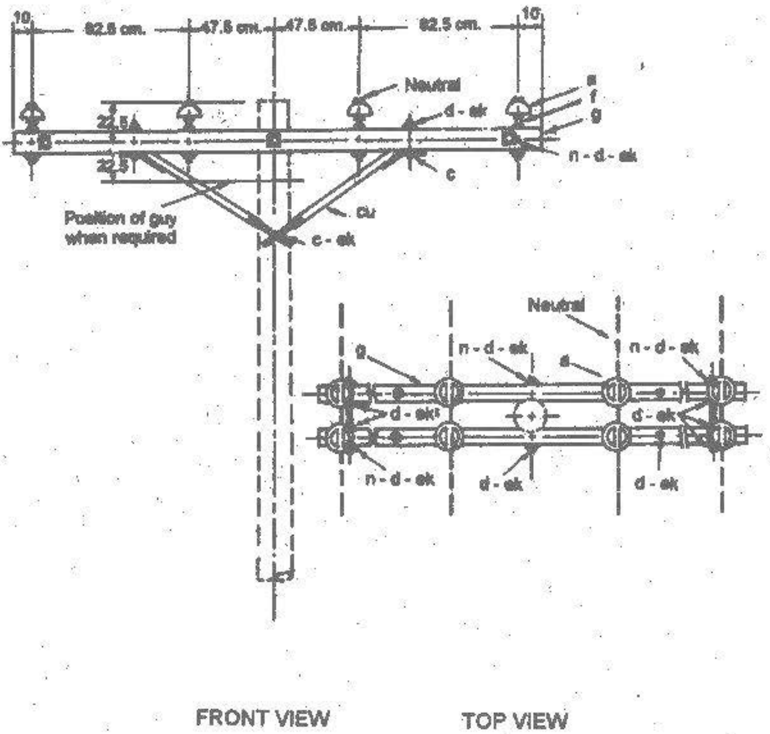
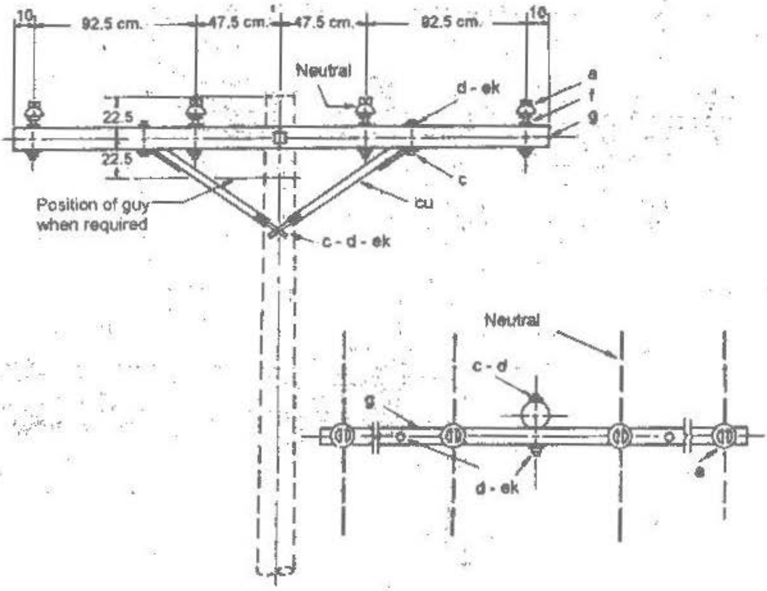


FIGURE 11- 40

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION
DOUBLE LINE ARM

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	8	n -	5/8" x 20" double arming bolt	3
c -	5/8" x 12" Machine bolt	1	cu -	60" span wood brace	2
c -	½" x 6" Machine bolt	4	ek -	½" Locknut	4
d -	3/16" x 2 ¼"-13/16" hole washer	10	ek -	5/8" Locknut	11
d -	1 3/8" dia. 9/16" hole rd. washer	4	tw -	Tie wire *	64'
f -	5/8" x 10 ¾" Crossarm steel pin	8	bv-2	Armor rod (double supporting)*	4
g -	3 ¾" x 4 ¾" x 10' Crossarm	2			

** Conductor Accessories*



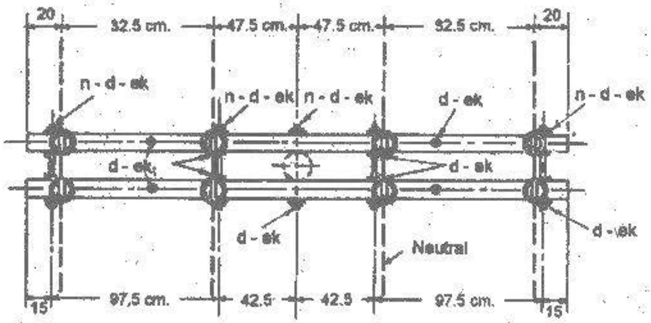
FRONT ELEVATION TOP VIEW

FIGURE 11-41

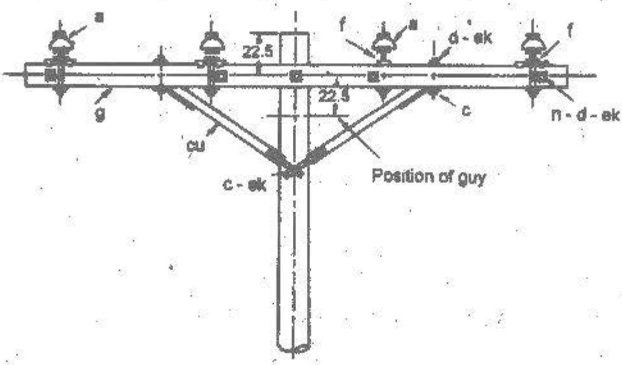
7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION
SINGLE LINE ARM

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type Insulator	4	g -	3 ¾" x 4 ¾" Crossarm	1
c -	5/8" x 12" Machine bolt	1	cu -	60" span wood brace	1
c -	½" x 6" Machine bolts	2	ek -	½" Locknut	2
c -	5/8" x 16" Machine bolt	1	ek -	5/8" Locknut	2
d -	3/16" x 2 ¼"-13/16" hole washer	3	bv-1	Armor rod (single support) *	4
d -	1 3/8" dia. 9/16" hole rd. washer	2	tw -	Tie wire*	32'
f -	5/8" x 10 ¾" Crossarm steel pin	4			

** Conductor Accessories*



TOP VIEW



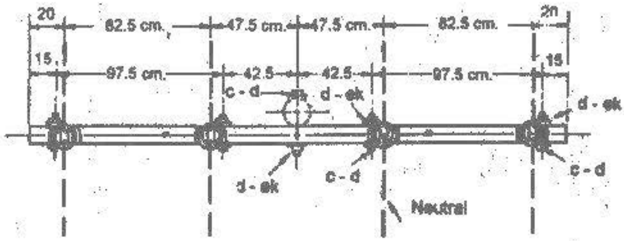
FRONT ELEVATION

FIGURE 11- 42

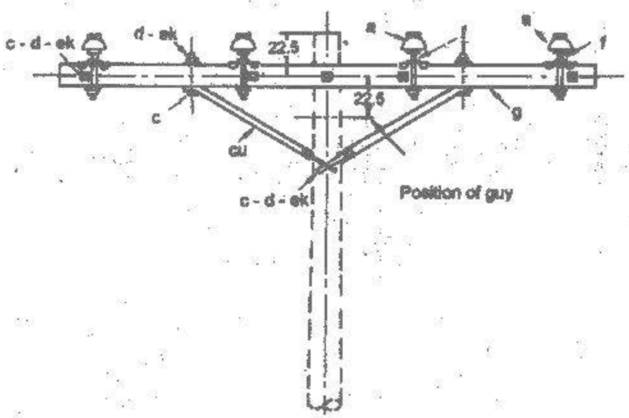
7.62 / 13.2 kv. 3-PHASE CROSSARM CONSTRUCTION DOUBLE LINE ARM AT 0° TO 15° ANGLE CONDUCTORS

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	8	g -	3 ¾" x 4 ¾" x 10' Crossarm	2
c -	5/8" x 12" Machine bolt	1	cu -	60" span wood brace	2
c -	½" x 6" Machine bolt	4	ek -	½" Locknut	4
d -	3/16" x 2 ¼" –13/16 hole washer	18	ek -	5/8" Locknut	19
d -	1 3/8" dia. 9/16" hole rd. washer	4	tw -	Tie wire *	64'
t -	Crossarm steel pin clamp type	8	bv-2 –	Armor rod (double support) *	4
n -	5/8" x 22" double arming bolt	5			

** Conductor Accessories*



TOP VIEW



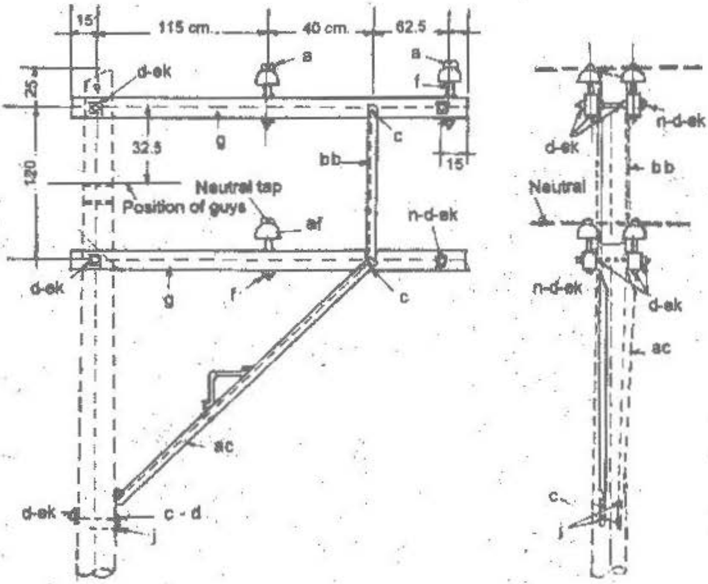
FRONT VIEW

FIGURE 11- 43

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION
SINGLE LINE ARM LARGE CONDUCTORS

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	4	f -	Crossaarm steel pin clamp type *	4
c -	5/8" x 5" Machine bolt	4	g -	3 ¾" x 4 ¾" x 10' Crossarm	1
c -	½" x 6" Machine bolt	2	cu -	60" span wood brace	1
c -	5/8" x 12" Machine bolt	1	ek -	½" Locknut	2
c -	5/8" x 16" Machine bolt	1	ek -	5/8" Locknut	8
d -	3/16" x 2 ¼"-13/16" hole washer	11	bv-1	Armor rod (single support)*	4
d -	1 3/8" dia. 9/16" hole rd. washer	2	tw -	Tie wire *	32'

** Conductor Accessories*



FRONT ELEVATION SIDE ELEVATION

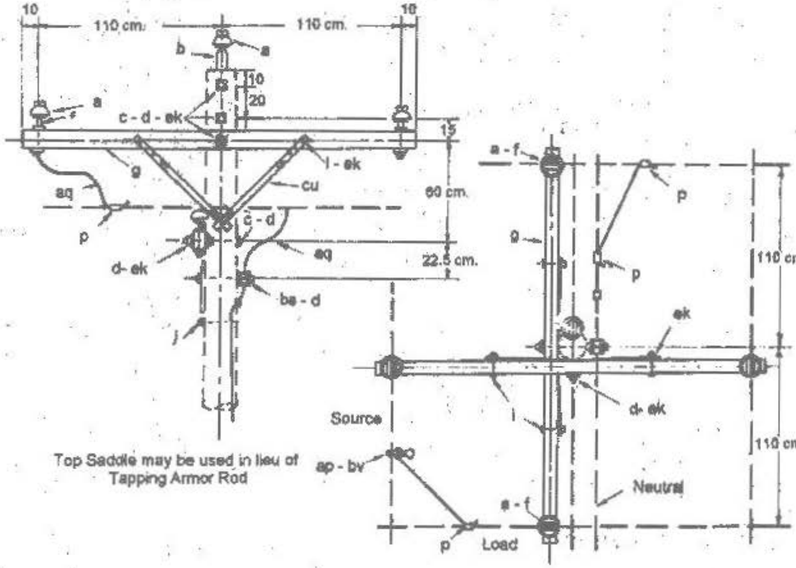
FIGURE 11- 44

7.62 / 13.2 KV. 3-PHASE SIDE ARM CONSTRUCTION
FOR SINGLE (DOUBLE PRIMARY SUPPORT)

Item	Materials	Quantity A	Quantity B	Item	Materials	Quantity A	Quantity B
a -	Pin type insulator	4	8	c -	5/8" x 16" Machine bolts	2	-
c -	½" x 6" Machine bolts	2	4	c -	½" x 10" & 12" Machine bolts	1	2
j -	½" x 4" Lag screw	1	2	ek -	5/8" Locknt	2	12
ek -	½" Locknut	3	6	tw -	Tie wire*	32'	64'

Item	Materials	A	B
d -	3/16" x 2 ¼" x 13/16" hole square washer	4	12
d -	1 3/8" diameter 9/16" hole round washer	3	6
f -	5/8" x 10 ¾" Crossarm steel pin	4	8
g -	3 ¾" x 4 ¾" Crossarm	2	4
n -	5/8" x 22" double arming bolt		4
ac -	1 ¾" angle, 3/16" x 7" diagonal side arm brace	1	2
bb -	50" side arm vertical angle brace	1	2
bv-1	Armor rod (single support) *		4
bv-2	Armor rod (double support) *		4

** Conductor Accessories*



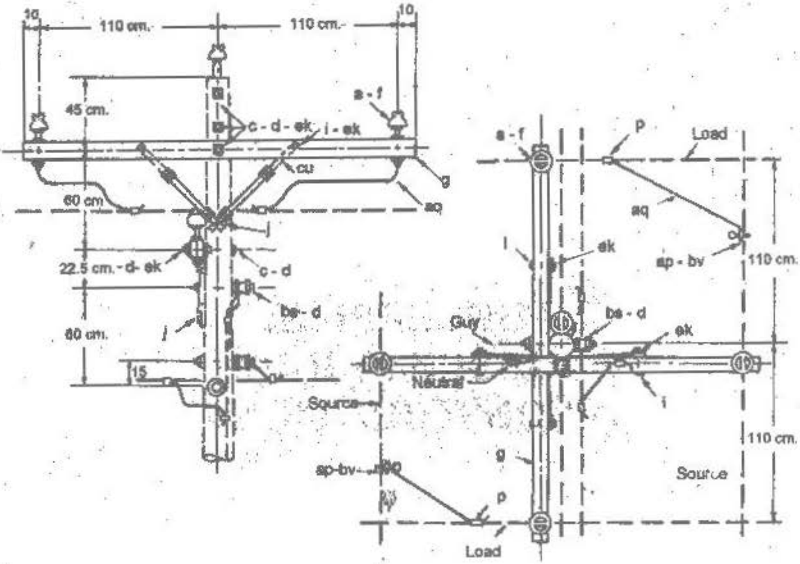
FRONT VIEW TOP VIEW

FIGURE 11-46

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION SINGLE PHASE JUNCTION AT 0° TO 5° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	5	ap -	Hotline clamp	1
b -	20" Pole top pin	1	aq -	Jumper and leads (as required)	
c -	5/8" x 12" Machine bolt	2	bs -	5/8" x 12" single upset bolt	1
c -	5/8" x 16" Machine bolt	2	bv -	Armor rod (tapping) *	1
d -	3/16" x 2 ¼" - 13/16 hole washer	7	bv-1	Armor rod (single support) *	6
f -	5/8" x 10 ¼" Crossarm steel pin	4	cu -	28" wood brace	4
g -	3 ½" x 4 ½" x 8' Crossarm	2	cm -	1 ¾" dia. groove spool insulator	1
l -	3/8" x 4 ½" Carriage bolt	4	ek -	5/8" Locknut	4
j -	½" x 4" Lag screw	2	ek -	3/8" Locknut	4
p -	Compression connector	3	tw -	Tie wire *	48'

* *Conductor Accessories*



FRONT ELEVATION

TOP VIEW

FIGURE 4-46

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION TWO PHASE JUNCTION AT 0° TO 5° ANGLE

Item	Materials	Quantity	Item		Quantity
a -	Pin type insulator	5	aq -	Jumpers (as required)	
b -	20" Pole top pin	1	ap -	Hot line clamp	2
c -	5/8" x 12" Machine bolt	2	bs -	5/8" x 12" single upset bolt	2
c -	5/8" x 16" Machine bolt	2	cm -	1 ¾" dia groove spool insulator	2
d -	3/16" x 2 ¼"-13/16" hole washer	8	cu -	28" wood brace	4
f -	5/8" x 10 ¾" Crossarm steel pin	4	ek -	5/8" Locknut	4
g -	3 ½" x 4 ½" x 8' Crossarm	2	ek -	3/8" Locknut	4
i -	3/8" x 4 ½" Carriage bolt	4	tw -	Tie wire *	56'
j -	½" x 4" Lag screw	2	bv -	Armor rod (tapping) *	2
p -	Compression connector	6	bv-1	Armor rod (single support) *	7

** Conductor Accessories*

THREE-PHASE DOUBLE CIRCUIT CONSTRUCTION

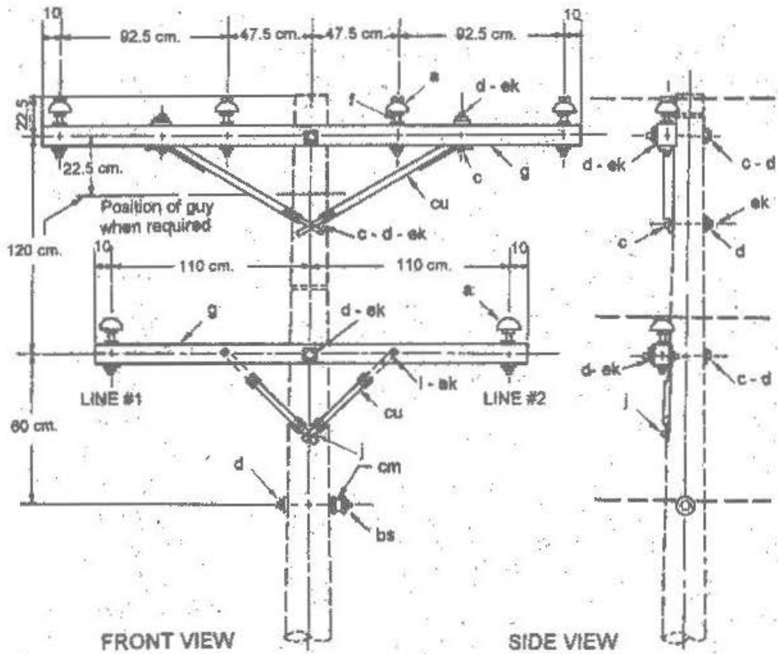
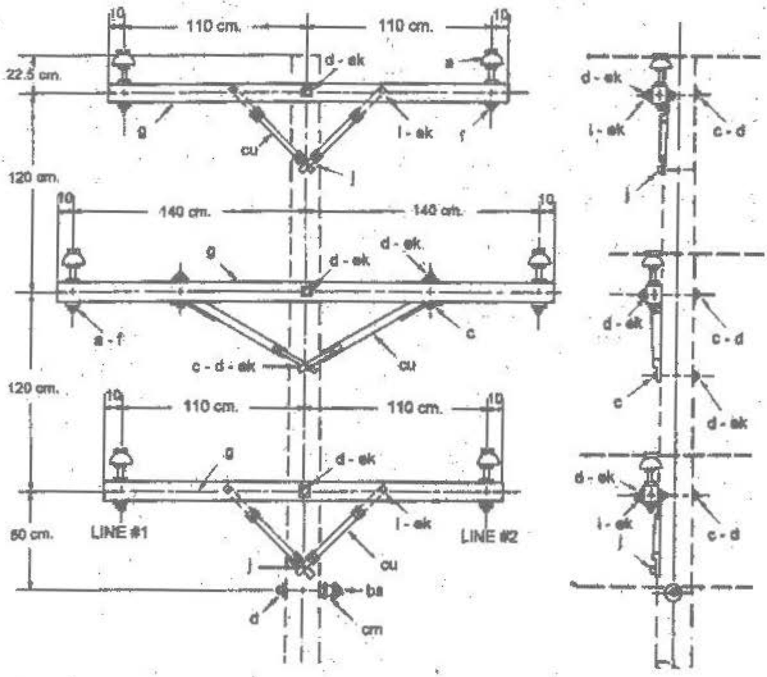


FIGURE 11- 47

7.32 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION
DOUBLE CIRCUIT SINGLE PRIMARY SUPPORT
AT 0° TO 5° ANGLE (2 X ARM TYPE)

Item	Materials	No.	Item	Materials	No.
a -	Pin type insulator	6	c -	5/8" x 12" Machine bolt	1
c -	½" x 6" Machine bolt	2	c -	5/8" x 16" Machine bolt	2
l -	3/8" x 4 ½" Carriage bolt	2	j -	½" x 4" Lag screw	1
bs -	5/8" x 12" single upset bolt	1	bv-1	Armor rod single support	7
cu -	28" wood brace	2	cu -	60" span wood brace	1
ek -	½" locknut	2	ek -	3/8" locknut	2
ek -	5/8" locknut	3	tw -	Tie wire	56'
d -	2 ¼" x 2 ¼" x 3/16" x 13/16" hole square bolts	6			
d -	1 3/8" diameter 9/16" hole round washer	2			
f -	5/8" x 10 ¾" crossarm steel pin	6			
g -	3 ¾" x 4 ¾" x 10' crossarm	1			
g -	3 ½" x 4 ½" x 8' crossarm	1			
cm -	1 ¾" diameter groove spool insulator	1			



FRONT ELEVATION

SIDE VIEW

FIGURE 11-48

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION DOUBLE CIRCUIT, SINGLE PRIMARY SUPPORT AT 0° TO 5°

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	6	j -	½" x 4" Lag screw	2
c -	5/8" x 12" Machine bolt	1	bs -	5/8" x 14" single upset bolt	1
c -	½" x 6" Machine bolt	2	cm -	1 ¾" dia. groove spool insulator	1
c -	5/8" x 16" Machine bolt	3	cu -	28" wood brace	4
d -	3/16" x 2 ¼"-13/16" hole washer	8	cu -	60" span wood brace	1
d -	1 3/8"x 9/16" hole round washer	2	ek -	½" Locknut	2
f -	5/8" x 10 ¾" Crossarm steel pin	6	ek -	3/8" Locknut	4
g -	3 ¾" x 4 ¾" x 10' Crossarm	1	ek -	5/8" Locknut	4
l -	3/8" x 4 ½" Carriage bolt	4	tw -	Tie wire *	56'

* *Conductor Accessories*

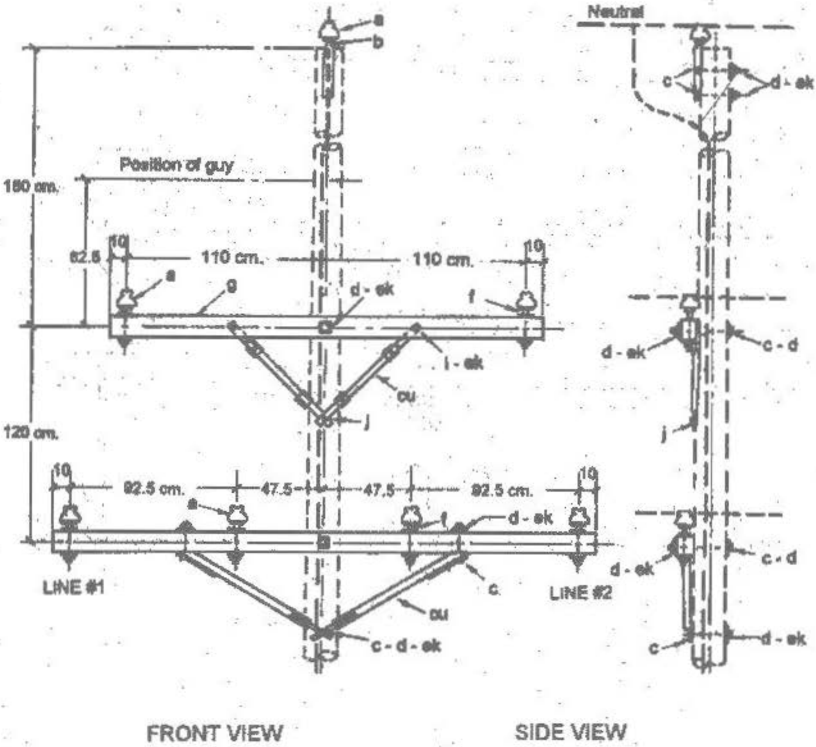


FIGURE 11- 49

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION DOUBLE CIRCUIT SINGLE PRIMARY SUPPORT WITH OVERHEAD NEUTRAL AT 0° TO 5° ANGLE

Item	Materials	Quantity	Item		Quantity
a -	Pin type insulator	7	g -	3 ¾" x 4 ¾" x 10' Crossarm	1
b -	Pole top pin	1	g -	3 ½" x 4 ½" x 8' Crossarm	1
c -	5/8" x 12" Machine bolt	2	i -	3/8" x 4 ½" Carriage bolt	2
c -	½" x 6" Machine bolt	2	j -	½" x 4" Lag screw	1
c -	5/8" x 14" Machine bolt	1	cu -	28" wood brace	2
c -	5/8" x 18" Machine bolt	2	cu -	60" span wood brace	1
d -	3/16" x 2 ¼"-13/16" hole washer	7	ek -	5/8" Locknut	5
d -	1 3/8" dia. 9/16" hole rd. washer	2	ek -	3/8" Locknut	2
ek -	½" Locknut	2	bv-1	Armor rod (single support) *	7
f -	5/8" x 10¾" Crossarm steel pin	6	tw -	Tie wire *	56'

* *Conductors Accessories*

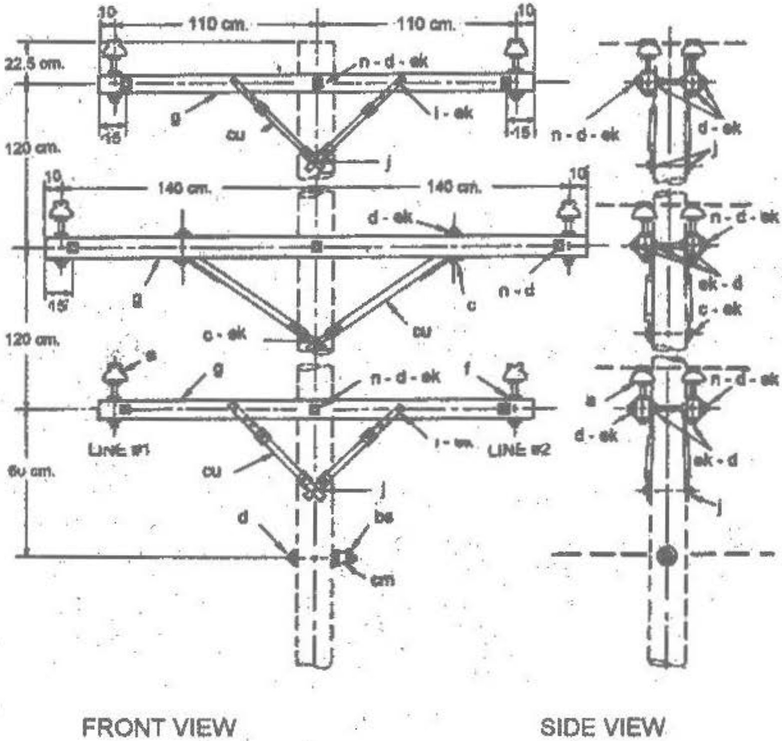


FIGURE 11-50

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION DOUBLE CIRCUIT, DOUBLE PRIMARY SUPPORT AT 0° TO 5° ANGLE (3X- ARM TYPE)

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	12	bs -	5/8" x 14" single upset bolt	1
c -	5/8" x 12" Machine bolt	1	cm -	1 ¾" dia. groove spool insulator	1
c -	½" x 6" Machine bolt	4	cu -	60" span wood brace	2
d -	3/16" x 2 ¼"-13/16" hole washer	31	cu -	28" wood brace	8
d -	1-3/8" dia. 9/16" hole rd. washer	4	ek -	1.2" Locknut	4
f -	5/8" x 10 ¾" Crossarm steel pin	12	ek -	5/8" Locknut	31
g -	3 ¾" x 4 ¾" x 10' Crossarm	2	ek -	3/8" Locknot	8
g -	3 ½' x 4 ½" x 8' Crossarm	4	bv-1	Armor rod (single support)*	1
i -	3/8" x 4 ½" Carriage bolt	8	bv-2	Armor rod (double support)*	6
n -	5/8" x 24" double arming bolt	9	tw -	Tie wire *	104'

** Conductor Accessories*

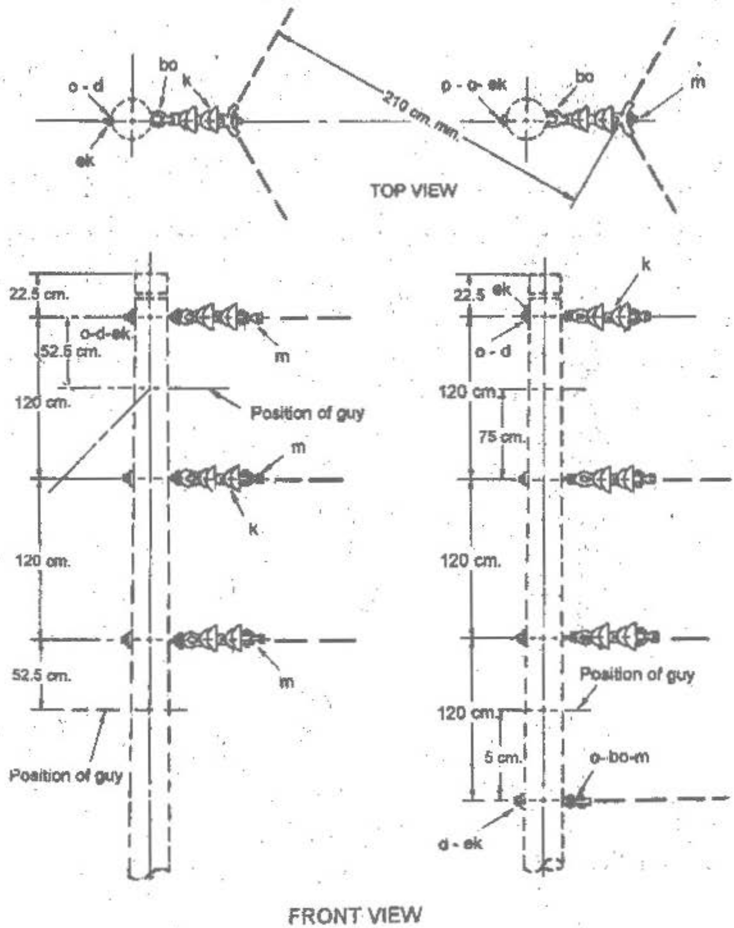


FIGURE 11-51

7.62 / 13.2 KV. 3-PHASE DOUBLE CIRCUIT VERTICAL CONSTRUCTION 30° TO 60° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16" x 2 ¼"- 13/16" hole washer	7	bo -	Anchor shackle	6
k -	Suspension insulator	12	ek -	5/8" Locknut	7
o -	5/8" x 14" Eye bolt	7	bv-1	Armor rod (single support) *	7
m -	Suspension clamp	7	tw -	Tie wire *	8'

* *Conductor Accessories*

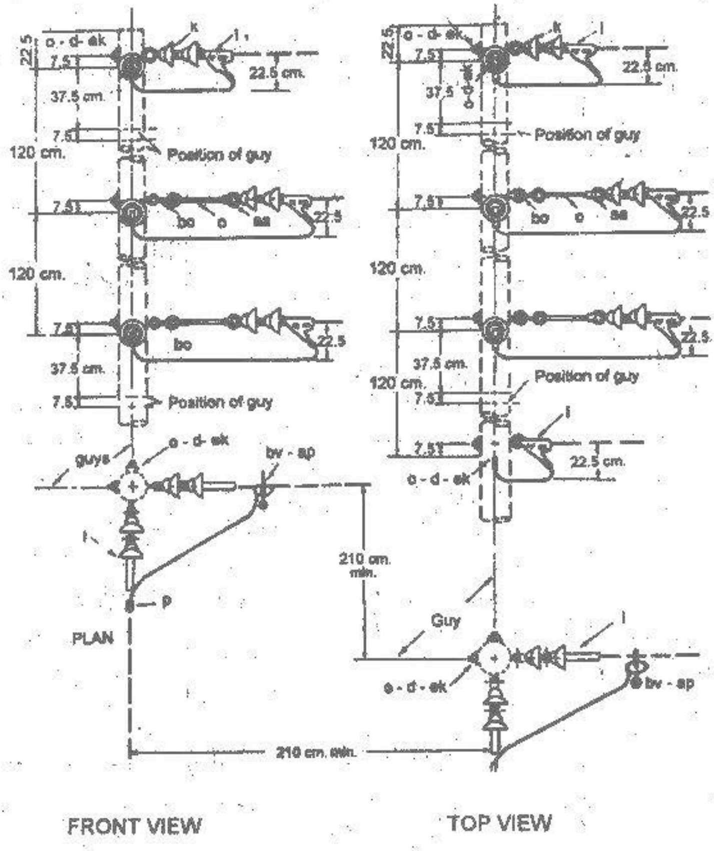


FIGURE 11-62

7.62 / 13.2 KV. 3-PHASE, DOUBLE CIRCUIT VERTICAL CONSTRUCTION 60° TO 90° ANGLE

Item	Materials	Quantity	Item	Materials	Quantity
d -	3/16"x 2 ¼"-13/16" hole washer	14	ap -	Hot line clamp	6
k -	Suspension insulator	24	bv -	Armor rod (tapping) *	6
o -	5/8" x 14" Oval eye bolt	14	aq -	Jumpers as required *	
o -	5/8" x 18" Oval eye bolt	8	bo -	Anchor shackle	8
ek -	5/8" Locknut	14	p -	Compression connector	8
aa -	Eye nut	8	l -	Dead end clamp	14

** Conductor Accessories*

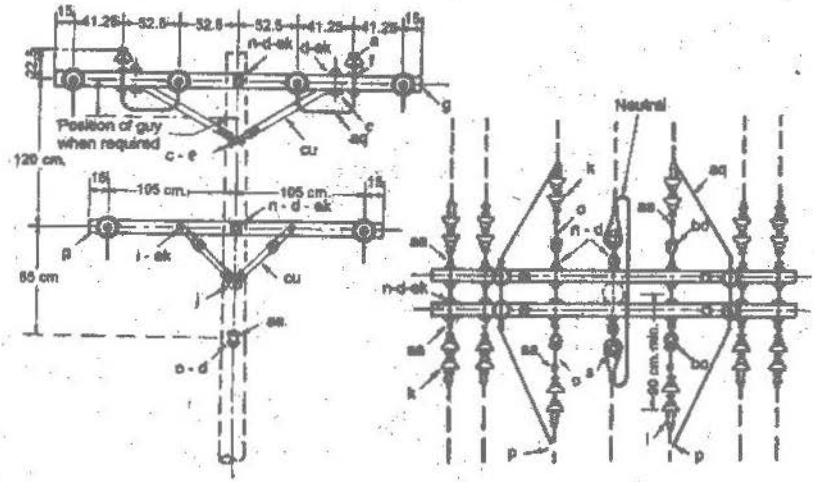


FIGURE 11-53

7.62 / 13.2 KV. 3-PHASE CROSSARM CONSTRUCTION DOUBLE CIRCUIT DEAD END (DOUBLE 2X-ARM TYPE)

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	4	p -	Compression connector	7
c -	5/8" x 12" Machine bolt	1	s -	Secondary swinging clevis	2
c -	½" x 6" Machine bolts	4	aa -	Eye nut	17
d -	3/16"x 2 ¼"-13/16" hole washer	30	aq -	Jumpers or leads (as required)	
d -	1 3/8" dia. 9/16" hole washer	4	bn -	Deadend loop clamp	4
f -	1-5/8"x10 ¾" Crossarm steel pin	4	bo -	Anchor shackle	4
g -	3 ¾"x 4 ¾" x 10' Crossarm	2	cm -	3" dia. groove spool insulator	2
g -	3 ½" x 4 ½" x 8' Crossarm	2	cu -	28" wood brace	4
i -	3/8" x 4 ½" Carriage bolts	4	cu -	60" span wood brace	2
j -	½" x 4 ½" Lag screw	2	ek -	½" Locknut	4
k -	Suspension insulator	24	ek -	5/8" Locknut	17
l -	Dead end clamp	12	ek -	3/8" Locknut	4
o -	5/8" x 18" Oval eye bolt	4	tw -	Tie wire *	32'
o -	5/8" x 12" Oval eye bolt	1	t -	Armor tape *	4'
n -	5/8" x 24" double arming bolt	8			

** Conductor Accessories*

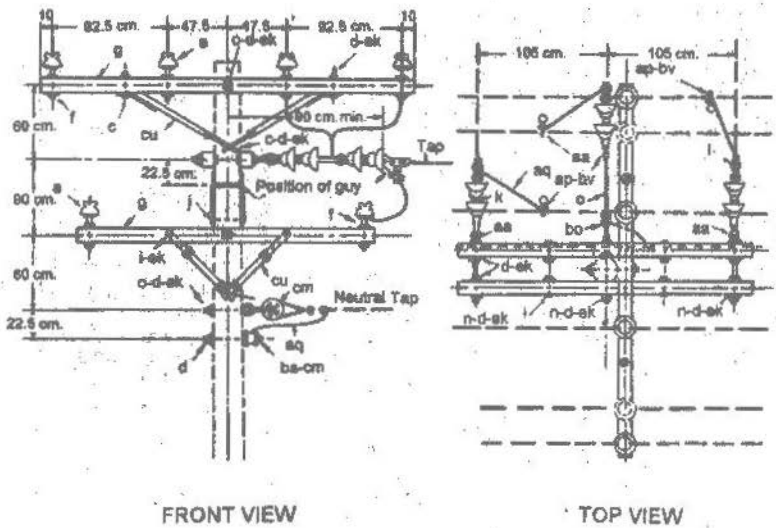


FIGURE 11- 54

7.62 / 13.2 KV. 3-PHASE CROSSAARM CONSTRUCTION DOUBLE CIRCUIT 3-PHASE TAP AT 0° TO 5° ANGLE 2X-ARM TYPE

Item	Materials	Quality	Item	Materials	Quantity
a -	Pin type insulator	6	aa -	5/8" Eye nut	4
c -	5/8" x 12" Machine bolt	1	aq -	Jumpers or leads (as required)	
c -	½" x 6" Machine bolt	2	bn -	Dead end loop clamp	2
c –	5/8" x 14" Machine bolt	2	bo -	Anchor shackle	1
d -	3/16"x 2 ¼"-13/16" hole washer	17	bs -	5/8" x 12" Single upset bolt	1
d -	1-3/8"dia. 9/16" hole rd. washer	2	cm-	1 ¾"dia. groove spool insulator	1
f -	5/8" x 10 ¾" Crossarm steel pin	6	cm-	3" dia. groove spool insulator	1
g -	3 ¾" x 4 3/4:" x 10' Crossarm	1	cu -	28" wood brace	6
g -	3 ½" x 4 ½" x 8' Crossarm	3	cu -	60" span wood brace	1
i -	3/8" x 4 ½" Carriage bolt	6	ek -	½" Locknut	2
j -	½" x 4" Lag screw	3	ek -	5/8" Locknut	11
k -	Suspension insulator	6	ek -	3/8" Locknut	6
l -	Dead end clamp	3	ap -	Hot line clamp	3
n -	5/8" x 24" double arming bolt	3	t -	Armor tape *	1
o -	5/8" x 12" Oval eye bolt	1	bv -	Armor rod (tapping) *	3
p -	Compression connector	2	bv-1	Armor rod (single support) *	7
s -	Secondary swinging clevis	1	tw -	Tie wire *	56'

** Conductor Accessories*

GUY ASSEMBLIES

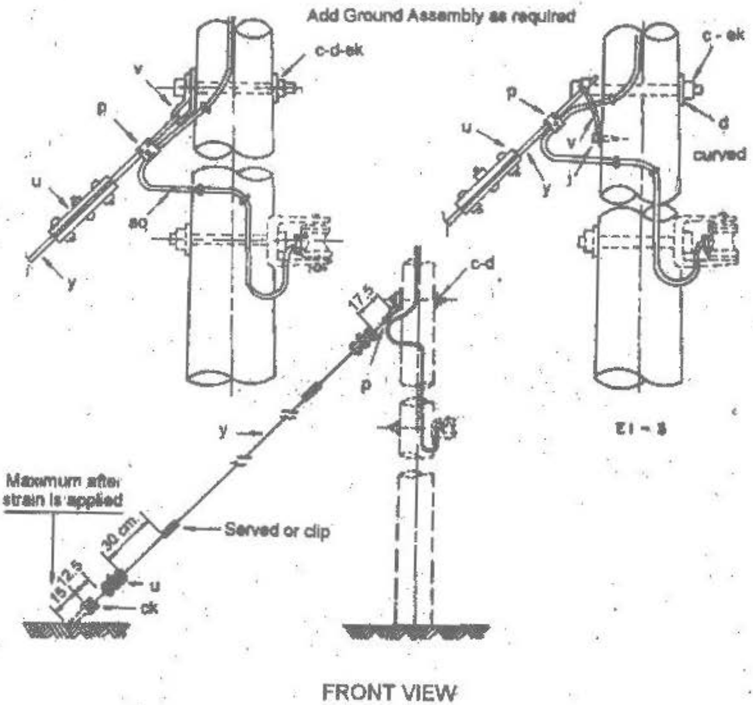


FIGURE 11- 55

SINGLE DOWN GUY, THROUGH BOLT TYPE

Item	Materials	Guy Assembly Unit 1/4"	3/8"	7/16"
c -	5/8" Machine bolt	1"-8"	1"-8"	1"-9"
d -	3/16" x 2 ¼" – 13/16" Hole washer	1	1	
d -	5/16" x 3" x 3" x 11/16" Hole curved washer			1
j -	¼" x 4" Lag screw			1
p -	Parallel groove compression connector	2	2	2
u -	3 bolt, 6" long guy clamp	2 L-duty	2 L-duty	2 L-duty
v -	Guy attachment	1	1	1
y -	Guy wire, SM T-strand	50'	50'	50'
ck -	Anchor rod bonding clamp	1	1	1
aq -	Jumper # 4, 3-strand aluminum aloy	5'	5'	5'
ek -	5/8" Locknut	1	1	1

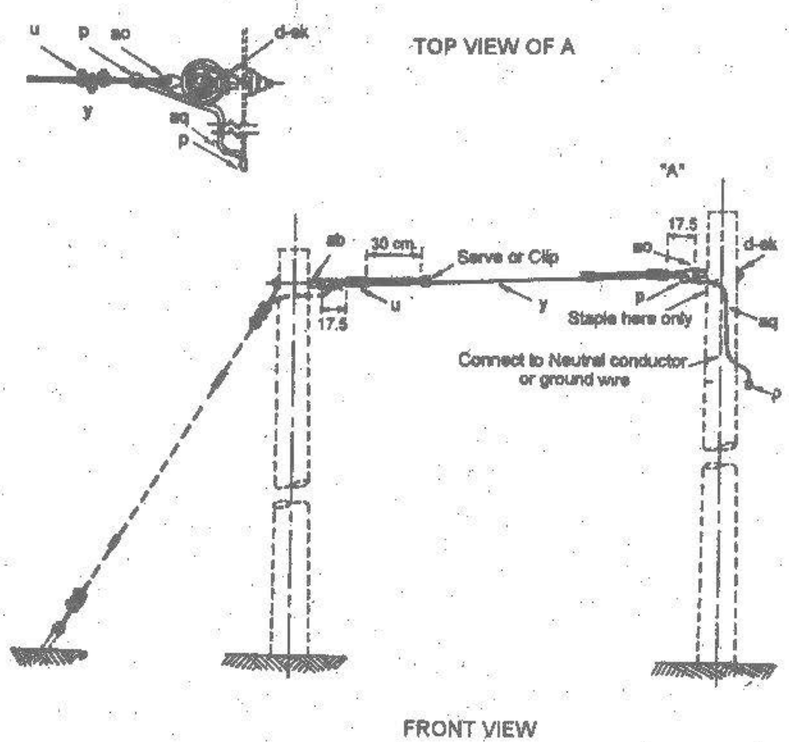


FIGURE 11-56

7.62 / 13.2 KV. SINGLE OVERHEAD GUY, THROUGH BOLT TYPE

Item	Materials	Guy Wire Assembly Unit 1/4"	3/8"	7/16"
d -	3/16" x 2 ¼"- 13/16" Hole washer	1		
d -	5/16"x 3" 3" – 11/16" Hole curved washer	1	1	
y -	7 Strand SM guy wwire	70'	70'	70'
ab -	1/2" Thimble type eye bolt	1 - 8"	1 – 9"	1 –10"
u -	3-bolt buy clamp	2L-duty	2L-duty	2L-duty
oo-	5/8" Thimble type eye bolt	1 – 8"	1 – 9"	1 – 10"
aq -	Jumper #4 AWG 3 strand aluminum alloy	5'	5'	5'
p -	Compression connector	2	2	2
ek -	5/8" Locknut	1	1	1

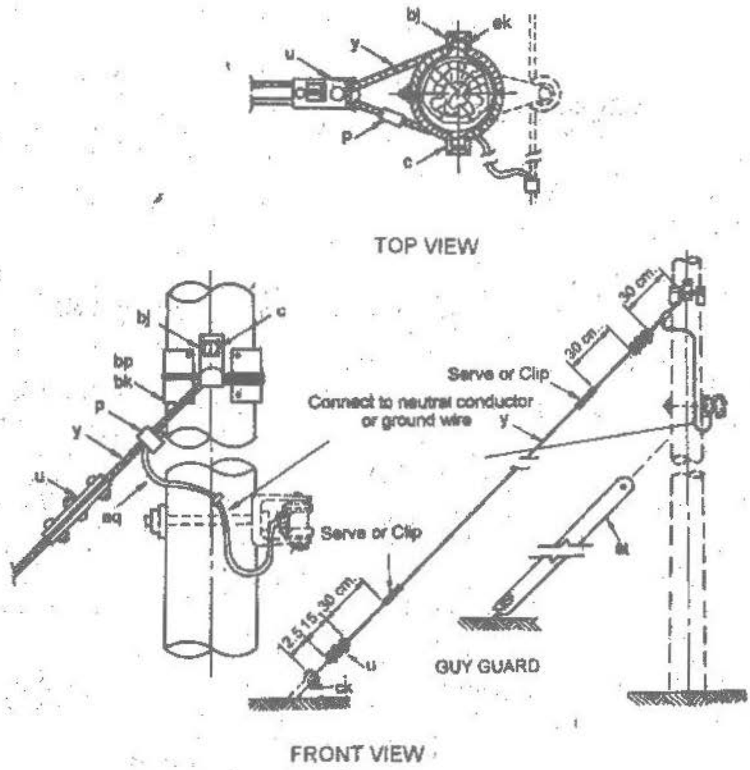


FIGURE 11-67

7.62 / 13.2 KV. SINGLE DOWN GUY, WRAPPED TYPE

Item	Materials	Guy Wire Assembly Unit 3/8"	7/16"	Guard
c -	3/8" x 10" Machine bolt	1	1	
p -	Compression connector	2	2	
u -	6" long guy clamp, 3 bolt	2 h-duty	2 h-duty	
y -	Guy wire SM, 7 strand	50'	50'	
ag -	Jumper #4 AWG, 3 strand aluminum alloy	5'	5'	
at -	8' minimum length Guy guard			1
bj -	J Guy hook	2	2	
bk -	4" x 8", gauge 14 Guy plate	2	2	
bp -	Nail, 8 penny, galvanized	8	8	
ck -	Clamp, anchor rod bonding	1	1	
ek -	5/8" Locknut	1	1	

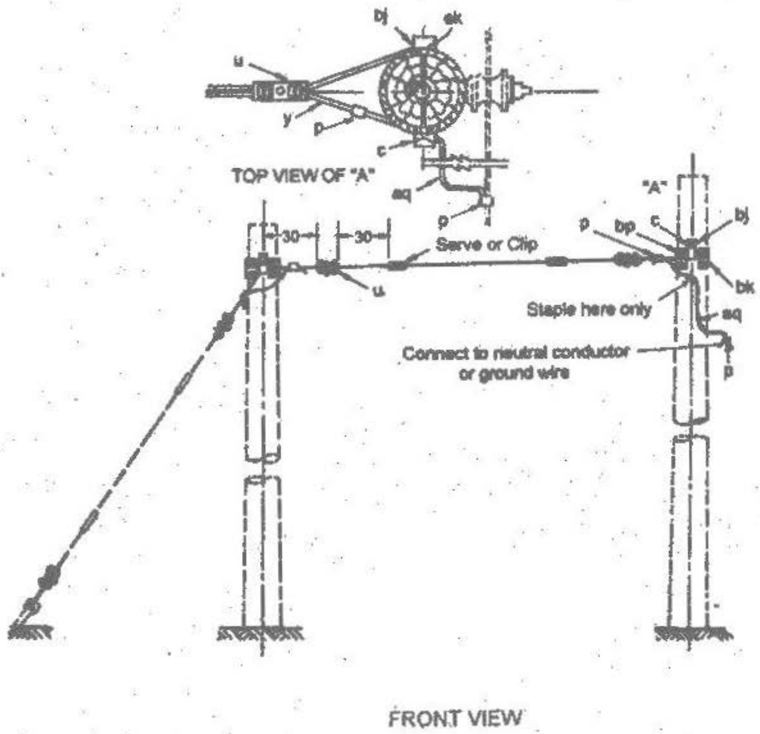


FIGURE 11-68

7.62 / 13.2 KV. SINGLE OVERHEAD GUY, WRAPPED TYPE

Item	Materials	Guy Wire Assembly Unit 3/8"	7/16"
c -	5/8" Machine bolt	1 – 10"	1 – 12"
p -	Compression connector	2	2
u -	Dead end for Guy strand	2 h-duty	2 h-duty
y -	7 Strand SM Guy wire	70'	70'
aq-	Jumper # 4 AWG 3 stranded aluminum alloy	5'	5'
bj -	Guy hook	2	2
bk -	4" x 8" gauge 14 Guy plate	2	2
bp -	8 penny galvanized nail	8	8
ek -	Locknut	1	1

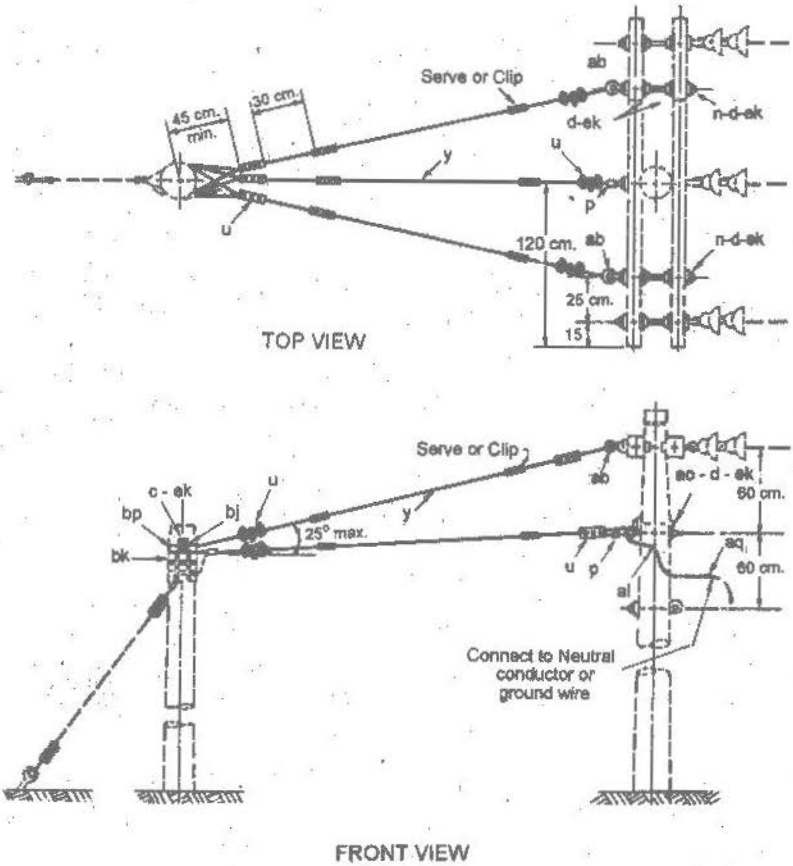
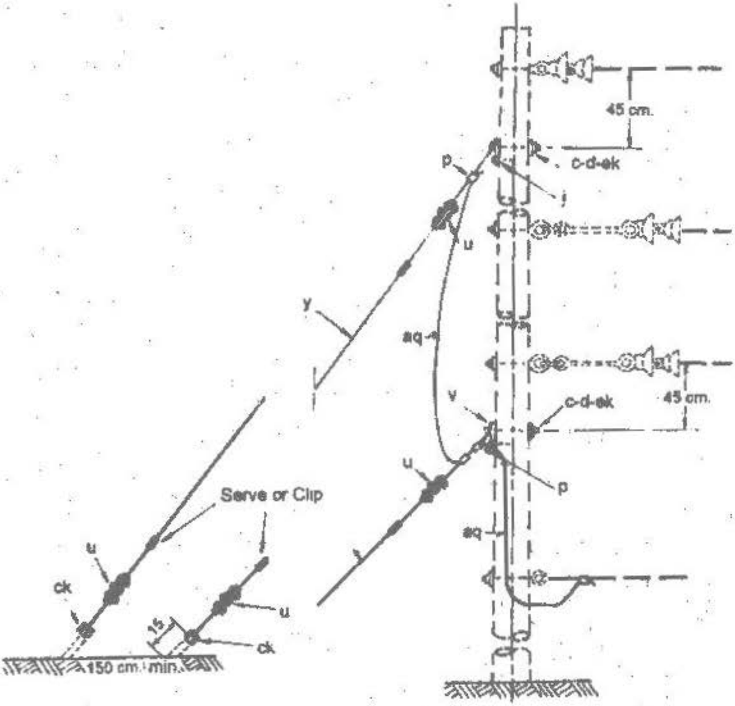


FIGURE 11-59

7.62 / 13.2 KV. DEAD END GUY CROSSARM CONSTRUCTION WRAPPED TYPE

Item	Materials	Quantity	Item	Materials	Quantity
a -	3/16" x 2 ¼"-13/16" hole washer	9	bp -	Penny nail galvanized	8
n -	5/8" x 24" double arming bolt	2	ab -	5/8" Thimble type eye nut	2
p -	Compression connector	4	ao -	5/8"x 12" Thimble type eye nut	1
u -	3/8" bolt, 6" long Guy clamp	6	aq -	Jumper # 4; 3 strand al. alloy	5'
y -	7 Strand SM Guy wire*	100'	al -	Staple ground wire	1
c -	5/8" x 10" Machine bolt	1	bk -	4" x 8" gauge 14 guy plate	2
ak -	5/8" Locknut	8	bj -	Guy hook J	2



FRONT VIEW

FIGURE 11-60

7.62 / 13.2 KV. DOUBLE DOWN GUY

Item Materials	Guy Wire Assembly Unit 3/8"	7/16"
c - 5/8" Machine bolt	2 – 10"	2 – 12"
d - 3" x 3" x 5/16" curved washer		2
d - 2 ¼" x 2 ¼" – 13/16" hole washer	2	
j - ½" x 4" Lag screw		2
p - Compression connector	4	4
u - 3 bolts heavy duty guy clamp	4	4
v - Malleable iron heavy duty guy attachment		2
v - Guy attachment through bolt type	2	
y - 7 Strand, S.M. guy wire	100'	100'
aq- Jumpers # 4 AWG; 3 wire strand aluminum alloy	10'	10'
ck - Guy bond clamp	2	2
ek - 5.8" Locknut	2	2

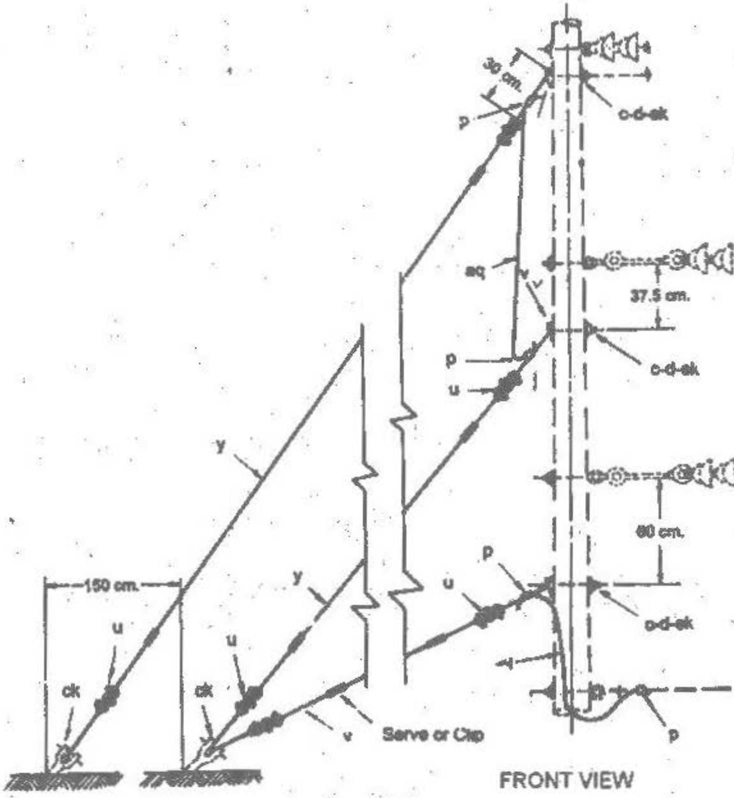
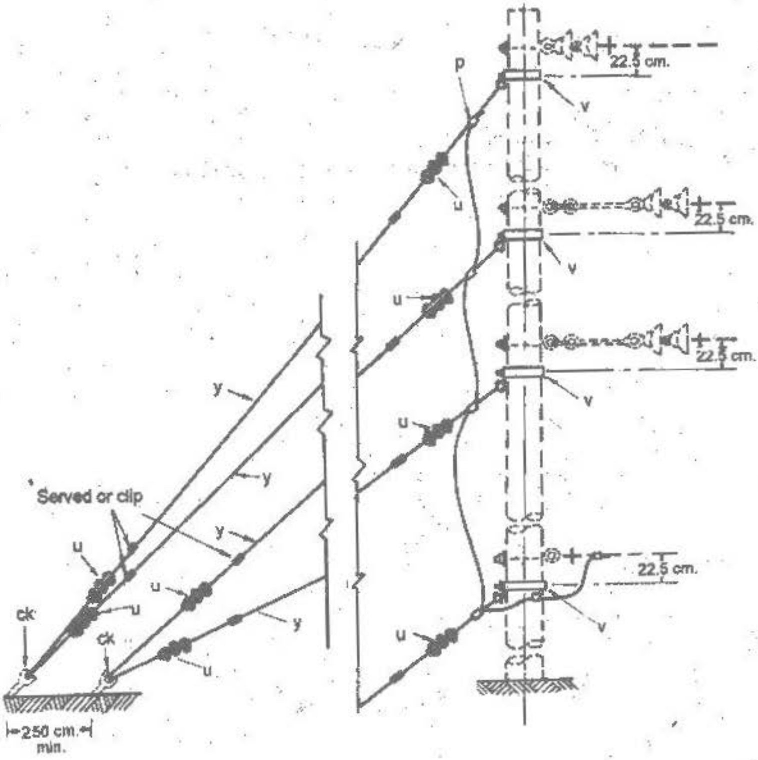


FIGURE 11-61

7.62 / 13.2 KV. 3- DOWN GUYS FOR LARGE CONDUCTORS

Item	Materials	Guy Assembly Unit 3/8"	Guy Assembly Unit 7/16"
c -	5/8" x 12" Machine bolts	3	3
d -	5/16" x 3" x 3" Curved washer	3	3
j -	½" x 4" Lag screw	3	3
p -	Compression connectors	4	4
u -	Guy clamp heavy duty	6	6
v -	Malleable iron heavy duty guy attachment	3	3
y -	7 Strand S.M. guy wire	150'	150'
aq -	# 4 AWG jumpers 3 strand aluminum alloy	15'	15'
ck-	Anchor rod bond single & double rod clamp	1	1
ek-	Locknut	3	3



FRONT VIEW

FIGURE 11-62

7.62 / 13.2 KV. FOUR DOWN GUYS FOR LARGE CONDUCTORS

Item	Materials	Guy Assembly Unit 3/8"	Guy Assembly Unit 7/16"
p -	Compression connector	4	4
u -	3-bolt heavy duty guy clamp	8	8
v -	Guy attachment pole bond type	4	4
y -	SM – 7 Strand guy wire	200'	200'
aq-	# 4 AWG Jumpers 3 strand aluminum alloy	20'	20'
ck-	Clamp guy bonding for twin eye rod	2	2

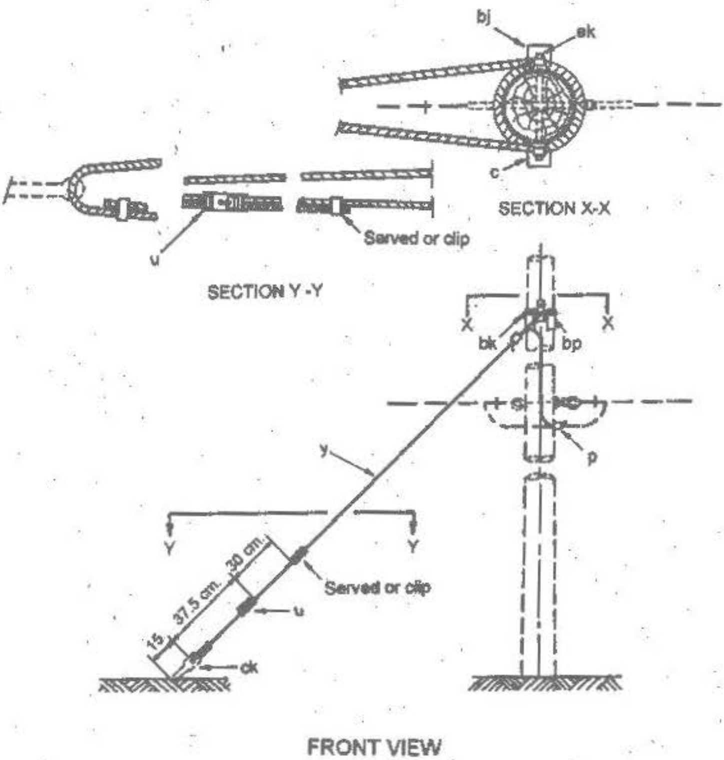


FIGURE 11-63

7.62 /13.2 KV. SINGLE LOOP GUY, WRAPPED TYPE

Item	Materials	Guy Wire Assembly 1/4"	3/8"
c -	5/8" Machine bolt	1 – 10'	1 – 12'
u -	3-bolt guy clamp	1 L-duty	1 L-duty
y -	s-m Guy wire	80'	80'
p -	Compression connector	2	2
ek -	Clamp anchor rod bonding	1	1
bk -	4" x 8" Gauge # 4 guy plate	2	2
bj -	J guy hook	2	2
bp -	8 Penny galvanized nail	8	8
aq -	# 4 AWG 3 strand aluminum alloy	5'	5'
ek -	5/8" Locknut	1	1

ANCHOR ASSEMBLIES

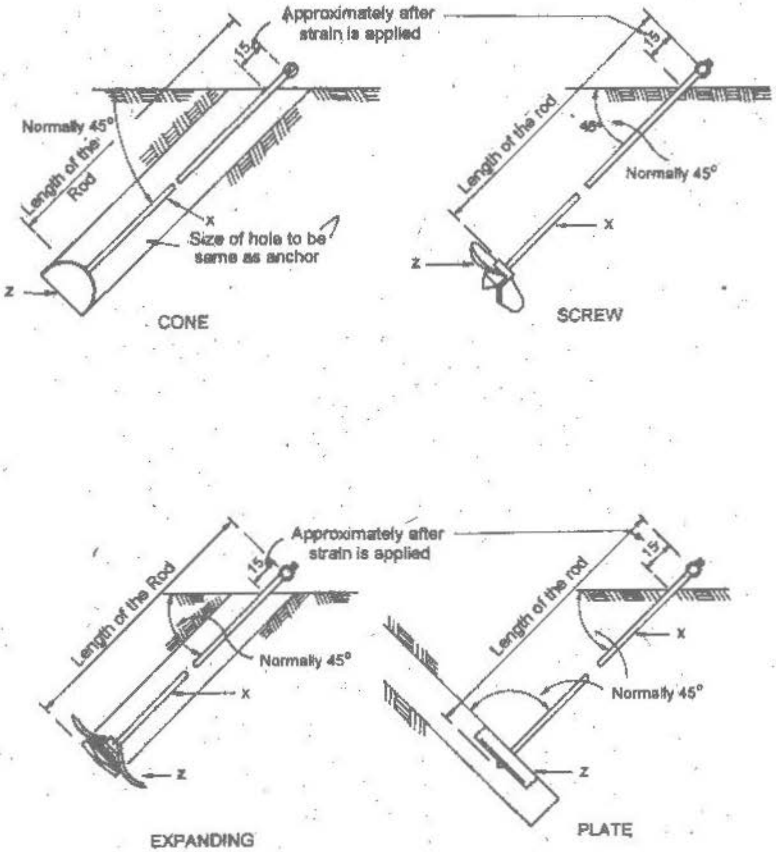


FIGURE 11-64

LINE ANCHOR ASSEMBLIES

Holding Power in Ordinary Soil lbs.		Assembly Unit 6,000		8,000		10,000	
Item	Materials	A	No.	B	No.	C	No.
x -	Rod, anchor, thimble eye	5/8" x 7'	1	5/8" x 7'	1		
x -	Rod, anchor, twin eye					¾" x 8'	1
z -	Anchor, expanding type	2 way	1	4 way	1	8 way	1

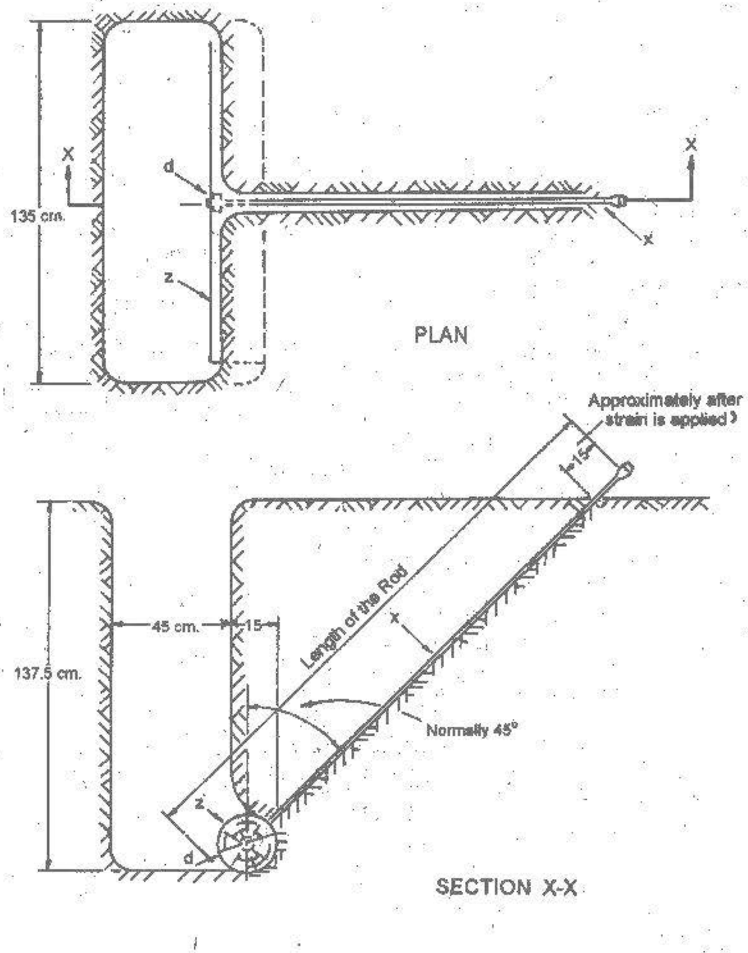


FIGURE 11-66
LOG ANCHOR ASSEMBLY

	Assembly Unit in Inches			
Item Materials	A No. &Type	B No.& Type	C No. & Type	D No. & Type
d - 13/16" Hole washer	1- ½ x 4 x 4	1- ½ x 4x4	1- ½ x4x4	1- ½ x4x4
x - Anchor rod thimble type	1- 5" x 8" x 7'	1- ¾ x 8'	1- ¾"x 8'	1- 1"x 10'
z - Anchor (created log)	1- 8" x 4'	1 9" x 4.5'	1-10" x 5'	1-12" x 5'
Holding power in ordinary soil	8,000 lbs.	10,600 lbs.	12,000 lbs	16,000 lbs

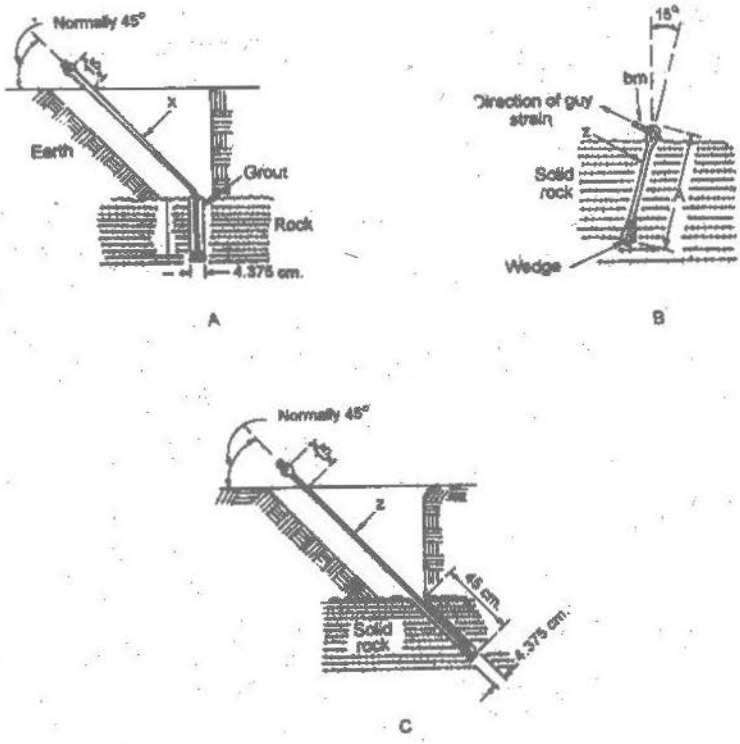
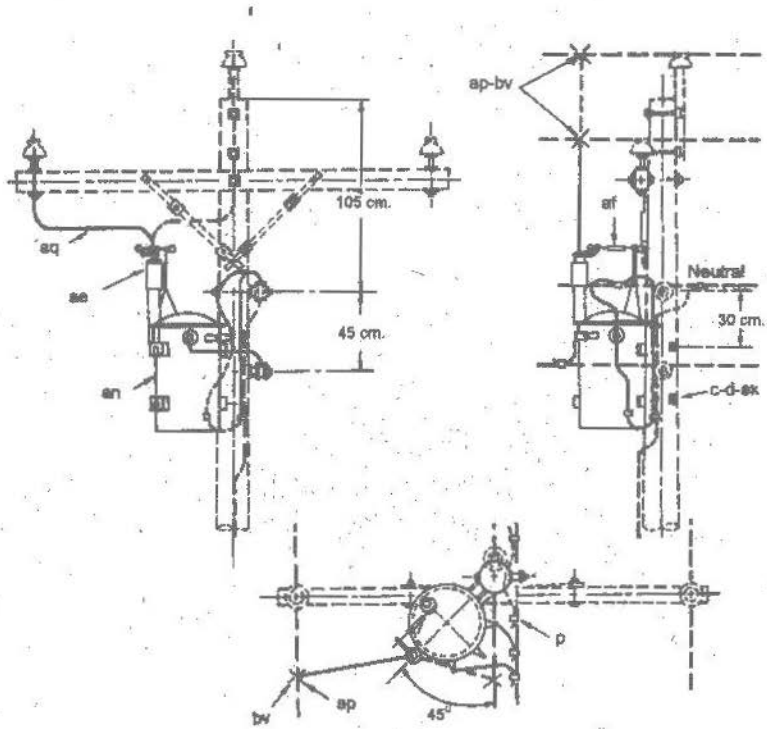


FIGURE 11-66

ROCK ANCHOR ASSEMBLIES

Item	Materials	No. Required A	B	C
x -	Anchor or thimble type rod	1		
z -	Rock anchor		1	1
bm-	Guy thimble		1	

TRANSFORMER ASSEMBLIES

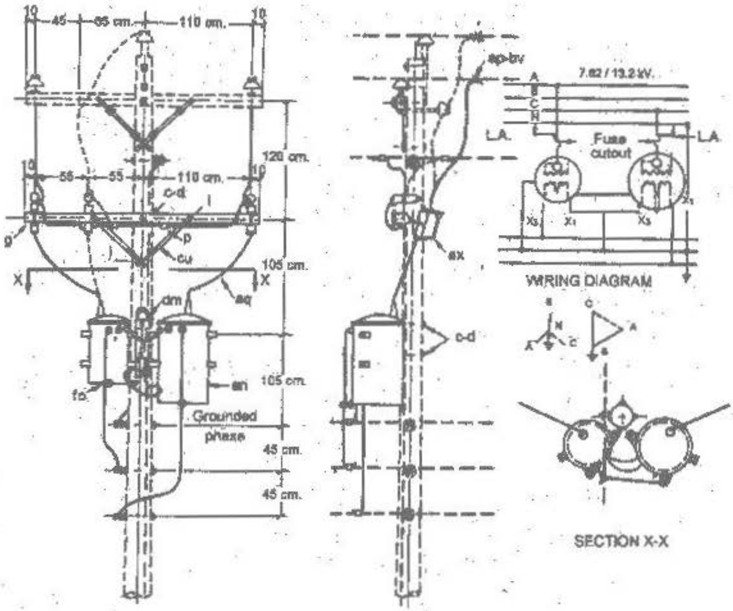


FRONT VIEW　　TOP VIEW　　SIDE VIEW

FIGURE 11-67

7.62 / 13.2 KV. SINGLE PHASE TRANSFORMER ON 3-PHASE CIRCUIT FOR CONVENTIONAL TRANSFORMER WITH TANK MOUNTED COUTOUT AND ARRESTER

Item	Materials	Quantity	Item		Quantity
a -	5/8" x 12" Machine bolt	2	aq -	# 4 ACSR primary jumper	1 m.
d -	3/16"x 2 ¼"-13/16" hole washer	2	aq -	Secondary insulated jumper	2 m.
p -	Compression connector	4	af -	Cutout fuse open link	1
an -	Pole type transformer	1	ae -	Lightning arrester	1
ap -	Hot line clamp	1	ek -	5/8" Locknut	2
p -	Split bolt connector	1	bv -	Armor rod (tapping) *	1
ag -	Ground wire # 4 AWG; 3 strand	6'			



FRONT VIEW SIDE VIEW

FIIGURE 11- 68

7.62 / 13.2 KV. TWO TRANSFORMERS CLUSTER MOUNTED OPEN WYE OPEN DELTA FOR 240 VOLT POWER LOADS CORNER GROUNDED

Item	Materials	Quantity	Item	Materials	Quantity
c -	5/8" x 14" Machine bolt	3	ax -	Combination cutout arrester	2
d -	3/16"x 2 ¼"-13/16" hole washer	4	cu -	28" wood brace	2
g -	3-5/8" x 4-5/8" x 8' Crossarm	1	dm -	Transformer bracket	1
i -	3/8" x 4 ½" Carriage bolt	2	ek -	5/8" Locknut	3
j -	½" x 4" Lag screw	1	ek -	3/8" Locknut	2
p -	Compression connector	3	cm -	1 ¾" dia. groove spool insulator	3
p -	Split bolt connector	5	bv -	Armor rod (tapping) *	2
an -	25 kvg. Max. conventional trans	2	aq -	# 4 AWG 3 strand alum. Alloy ground wiring	20'
ap -	Hot line clamp	2	fo -	Transformer secondary bracket	3
aq -	Secondary insulated jumper	15 m.	al -	Ground wire staple	30
aq -	Primary # 4 ACSR jumper	10 m.			

** Conductor Accessories*

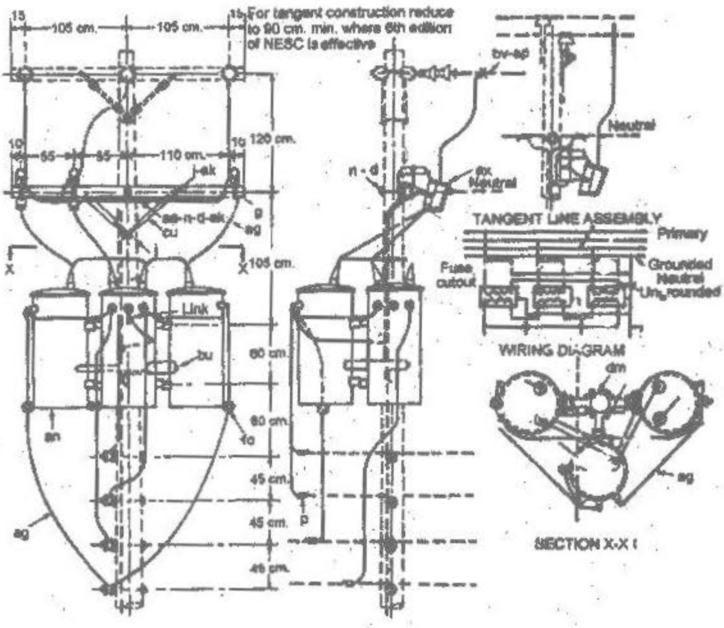


FIGURE 11-69

7.62 / 13.2 KV. THREE TRANSFORMERS CLUSTER MOUNTED UNDERGROUNDED WYE DELTA FOR 240/480 VOLT POWER LOADS

Item	Materials	Quantity	Item	Materials	Quantity
d -	2 ¼" x 13/16" hole washer	2	g -	3 ½ x 4 ½" x 8' Crossarm	1
i -	3/8" x 12 Carriage bolt	2	j -	½" x 4" Lag screw	4
p -	Compression type connector	3	an-	100 kv. Max. conv. Transformer	3
p -	Split bolt connector	2	aq -	Secondary insulated jumper	15 m.
ax -	Cutout & arrester combined	3	aq -	Primary jumpers # 4ACSR	12m.
bu -	Solderless connector	4	cc -	Neutral dead end assembly	1
cu -	28" wood brace	2	dm	Bracket, transformer cluster	1
	link grounding	1	fo -	Transformer 2ndary bracket	3
n -	5/8" x 18" double arming bolt	1	ap -	Hot line connector	3
ek -	5/8" Locknut	2	ek -	3/8" Locknut	2
cm	1 ¾" dia. groove spool insulator	3	bv -	Armor rod; (tapping) *	3
d -	2 ¼" x 2 ¼" x 13/16" washer	2			

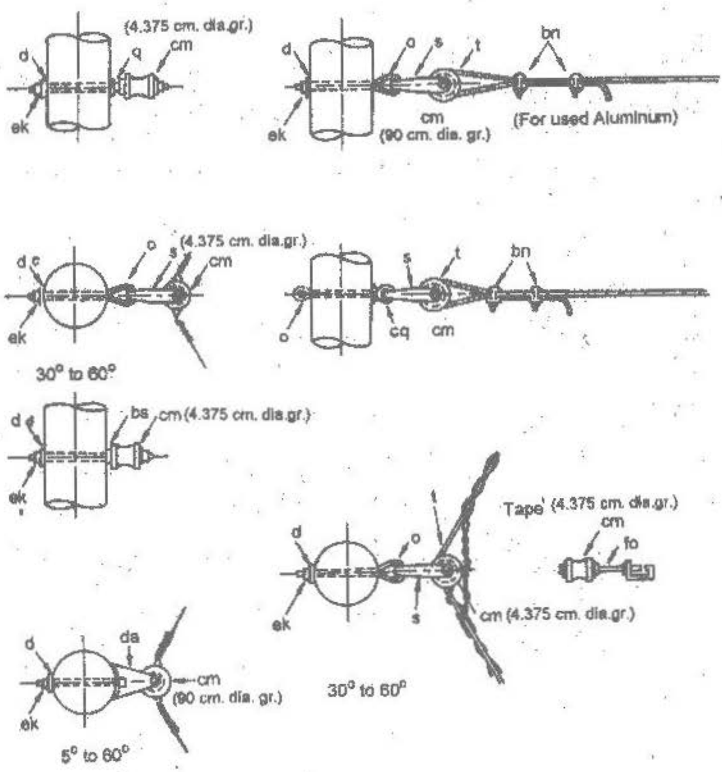


FIGURE 11-73

SECONDARY ASSEMBLIES

Item	Materials	Quantity	Item	Materials	Quantity
c -	5/8" x 10" Machine bolt		tw -	Tie wire	4'
d -	2 ¼"x 2 ½"x 3/16"-13/16 hole washer		t -	Armor tape*	1'
o -	5/8" x 10" Eye bolt		ca -	5/8" Eye nut	
p -	Connector (as required)		bn -	Dead end loop clamp	
q -	5/8" x 10" Double upset bolt		cq -	Sleeve, offset, splicing	
s -	Secondary swinging clevis insulated		da -	Bracket	
cm-	1 ¾" dia. groove spool insulator		fo -	Transformer secondary bracket	
cm-	3" dia. groove spool insulator		ek -	5/8" Locknuts	
bv-1	Armor rod (single support)*				

** Conductor Accessories*

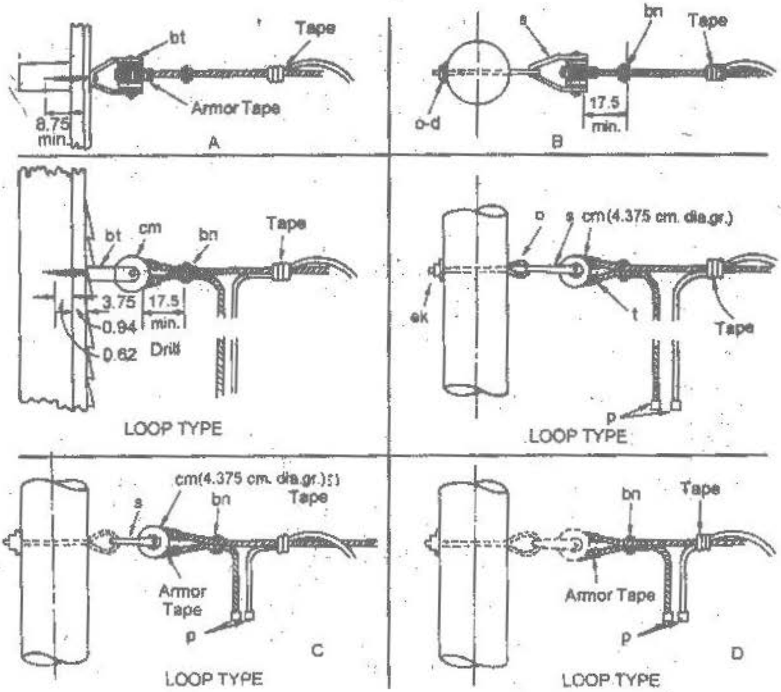


FIGURE 11-74

SERVICE ASSEMBLIES

Item	Materials	Quantity A	B	C	D
bt -	Wire holder, clevis type, # 24 wood screw		1	1	
o -	5/8" x 9" Eye bolt		1		
p -	Compression connector		2	2	2
t -	Armor tape	1'	1'	1'	1'
cm-	1 ¾" dia. groove spool insulator	1	1		
bn -	Dead end loop clamp	1	1	1	1
bt -	Wire holder, clevis type, # 24 wood screw	1			
ek -	5/8" locknut		1		
d -	2 ¼" x 2 ¼" x 3/8" – 13/16" hole washer		1		

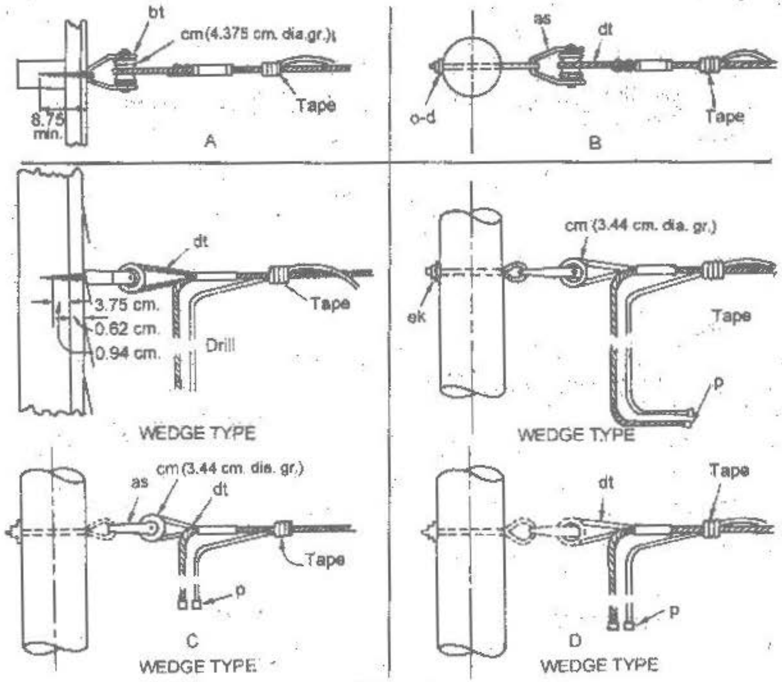
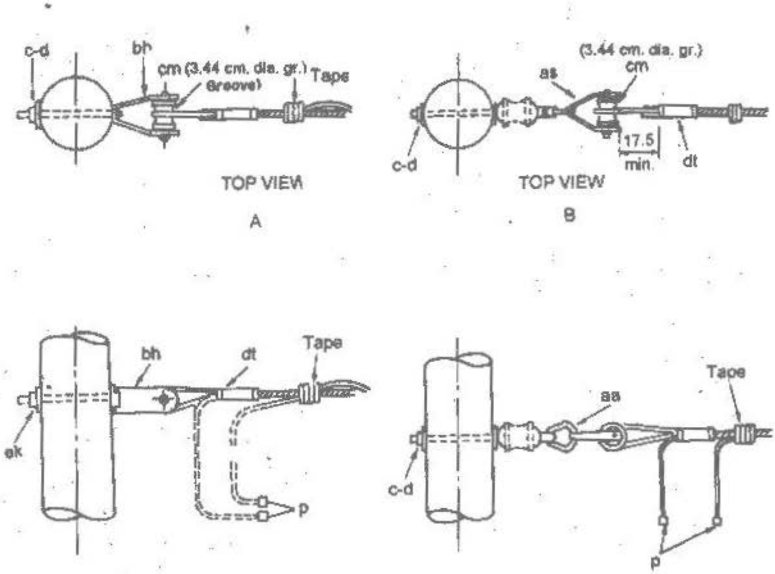


FIGURE 11-75

SERVIECE ASSEMBLIES

Item	Materials	Quantity A	B	C	D
cm -	1 3/8" dia. groove spool insulator		1	1	
cm -	1 ¾" dia. groove spool insulator	1			
as -	Clevis, service swinging		1	1	
bt -	Wire holder, clevis type # 24 wood screw	1			
dt -	Service dead end, wedge type	1	1	1	1
o -	5/8" x 9" Eye bolt		1		
d -	2 ¼" x 2 ¼" x 3/8"-13/16" hole washer		1		
ek -	5/8" Locknut		1		
p -	Compression connector		2	2	2



WEDGE TYPE

WEDGE TYPE

SIDE VIEW

FIGURE 11-76

SERVICE ASSEMBLIES

Item	Materials	Quantity A	Quantity B
c -	5/8" X 10" Machine bolt	1	
d -	2 ¼" x 2 ¼ x 3/8" – 13/16" hole washer	1	
p -	Compression connector	2	2
s -	Secondary swinging clevis		1
t -	Armor tape	1'	1'
aa -	5/8" Eye nut		1
da -	Secondary bracket	1	
ek -	5/8" Locknut	1	
cm-	3" diameter groove spool insulator	1	
cm-	1 ¾" diameter groove spool in sulator		1
bn -	Dead end loop clamp	2	1

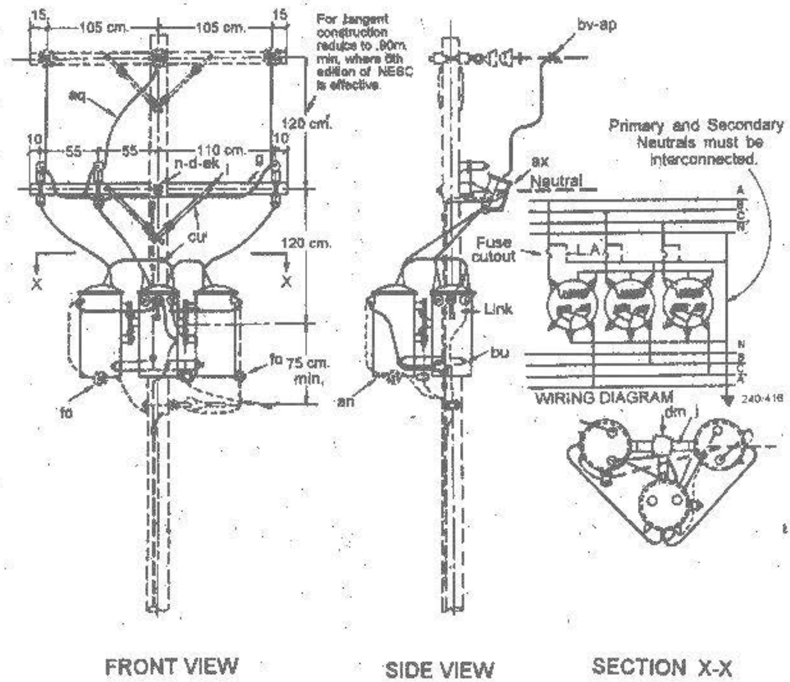
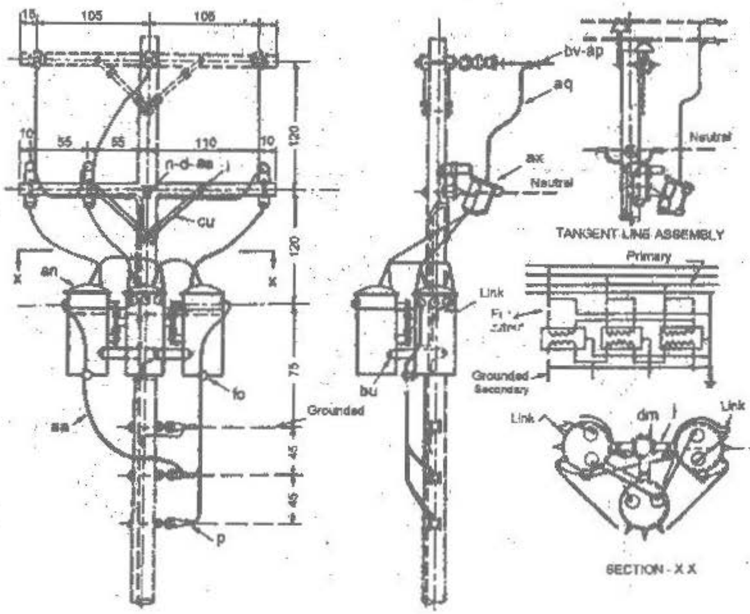


FIGURE 11-70

7.62 / 13.2 KV. THREE TRANSFORMERS CLUSTER MOUNTED FOUR WIRE GROUNDED WYE FOR 240/480 VOLT POWER LOADS

Item	Materials	Quantity	Item	Materials	Quantity
g -	3 ¼" x 4 ½" x 8' Crossarm	1	i -	3/8" x 41/2" Carriage bolt	2
j -	½" x 4" Lag screw	4	p -	Compression connector type	3
p -	Split bolt connector	3	ap -	Hot line connector	3
an -	100 kva. Max. Transformers	3	aq -	Secondary Insul. Jumpers	15 m
ax -	Cutout- Arrester combined	3	aq -	Bare # 4 ACSR Jumpers	12m
bu -	Solderless connector	3	cu -	28" wood brace	2
ek -	3/8" Locknut	2	ek -	5/8" Locknuts	2
bv -	Armor rod (tapping) *	3	n -	5/8" x double arming bolt	1

d -	2 ¼" x 2 ¼" x 3/16" hole square washer	2
dm	Bracket, transformer, cluster & adapter plates	as required
fo -	Transformer secondary bracket	3
	Link grounding *	3
cm-	1 ¾" diameter groove spool insulator	3



FRONT VIEW SIDE VIEW

FIGURE 11-71

7.62 / 13.2 KV. THREE TRANSFORMERS, CLUSTER MOUNTED 3-WIRE GROUNDED DELTA FOR 240 / 480 VOLT POWER LOAD

Item	Materials	Quantity	Item	Materials	Quantity
c -	3/16" x 2 ¼"-13/16" hole washer	2	ax -	Cutout and arrester combined	3
g -	3 ½" x 4 ½" x 8' Crossarm	1	cu -	28" wood brace	2
i -	3/8" x 4 ½" Carriage bolt	2	fo -	Secondary bracket transformer	2
j -	½" x 4" Lab screw	4	bu -	Solderless connector *	5
n -	5/8" double arming bolt	4	dm-	Bracket, transformer cluster * and adapter plates as required 2- link grounding	**
p -	Compression type connector	3	ek -	3/8" Locknut	2
p -	Split bolt connector	3	ek -	5/8" Locknut	2
ap -	Hotline connector	3	ag -	# 4 grd. Wire 5005 alum. alloy	8'
an -	100 kva max. transformer	3	bv -	Armor rod (tapping) *	3
aq -	Jumper prim. Bare ACSR #4	12m			
aq -	Jumper secondary insulated	15m			
cm-	Spool insulator 1 ¾" groove	3			

SECONDARY AND SERVICE ASSEMBLIES

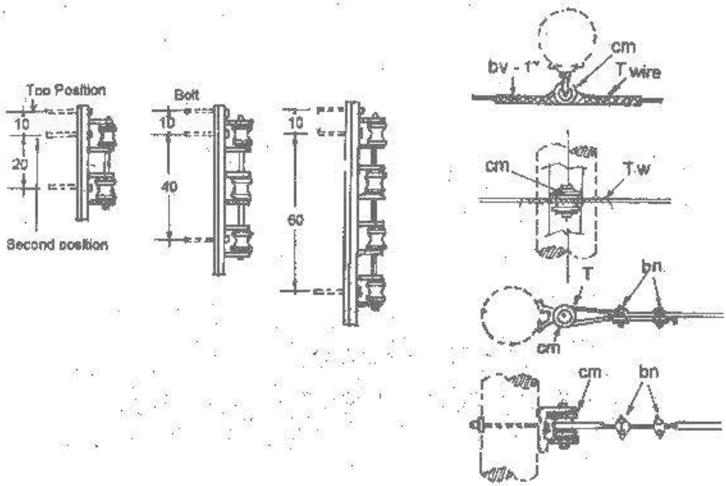


FIGURE 11-72

SECONDARY RACK ASSEMBLY

Item	Materials	Assembly Unit									
		Bolted			No Bolt			Bare		Insul.	
		A	B	C	A	B	C	A	B	A	B
2 -	Wire rack	1			1						
3 -	Wire rack		1			1					
4 -	Wire rack			1			1				
c -	5/8" x 9" Machine bolt	2	2	2							
d -	2 ¼" x 2 ¼" x 3/16" –13/16" hole square washer	2	2	2							
ek -	5/8" Locknut	2	2	2							
cm -	1 ¾" dia. ground spool insulator							1	1	1	1
bv-1	Armor rod (single support) *							1			
tw -	Tie wire *							4'		4'	
t -	Armor tape *								1		
bn -	Dead end loop clamp								2		2

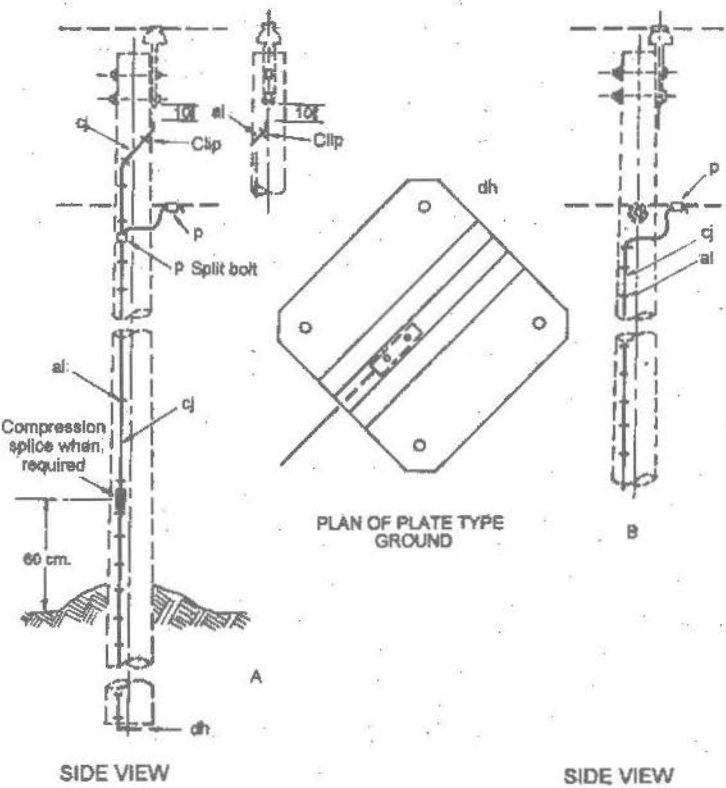
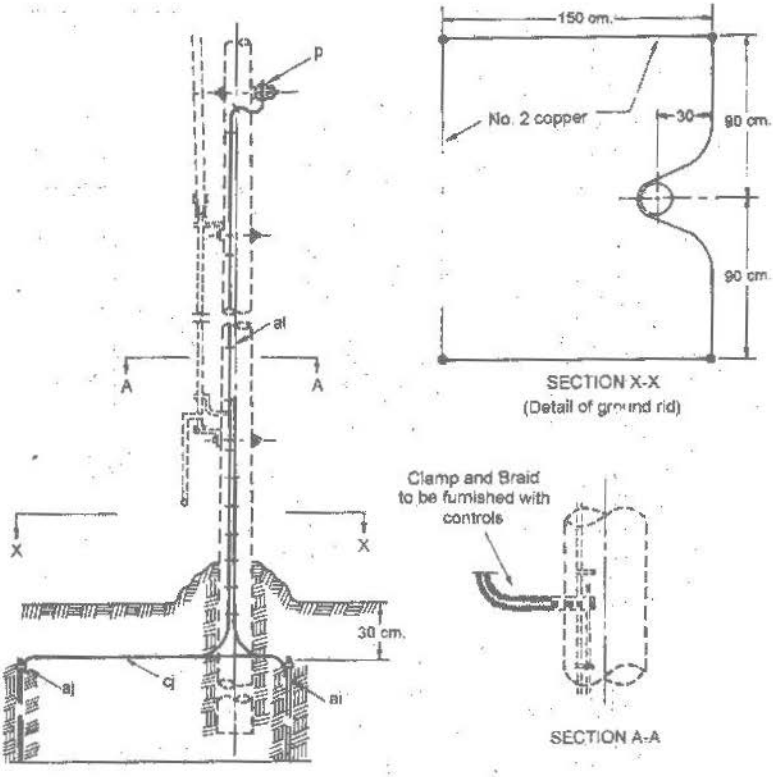


FIGURE 11-80

POLE PROTECTION ASSEMBLY- BUTT TYPE

Item	Materials	Assembly Unit A	Assembly Unit B
al -	Staple, ground wire, 2 ½", 8 gauge	40'	35'
al -	Ground wire clip	1	
cj -	Ground wire jumper, # 4 AWG, strand aluminum alloy	3'	
cj -	Ground wire iron 5/8" dia. 3 strand galvanized	40'	38'
dh-	Butt type grounding device plate	1	1
p -	Compression connector	1	1
p -	Split bolt type connector	1	
bp -	Nails, 1 inch roofing, galvanized	4	4



FRONT VIEW SECTION A-A

FIGURE 11-81

GROUNDING ASSEMBLY- GROUND ROD TYPE FOR SECTIONALIZING AIR BREAK SWITCH

Item	Materials	Quantity	Item	Materials	Quantity
ai -	5/8" dia. x 10' ground rod	4	cj -	Ground wire, soft annealed iron 5/8" dia. 3 strand galvanized	60'
aj -	Clamp, ground rod	4			
al -	Staple grd. wire 2" x ½" # 8	50'	p -	Compression connector	1

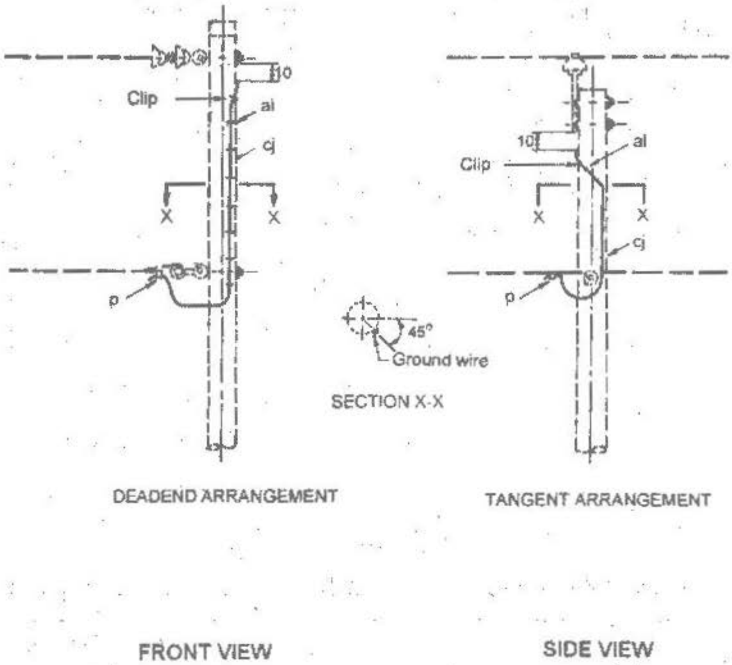


FIGURE 11-82

POLE TOP PROTECTION ASSEMBLY

Item	Materials	Quantity	Item	Materials	Quantity
p -	Compression connector	1	cj -	Grd. Wire # 4 AWG, 3 strand aluminum alloy	60'
al -	Staple, ground wire, 2" x ½" 8 gauge	8	al -	Ground wire clip	1

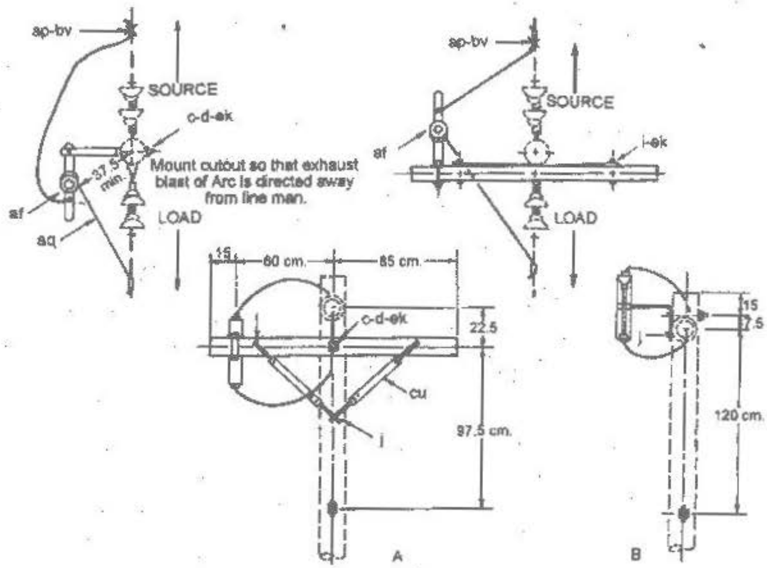
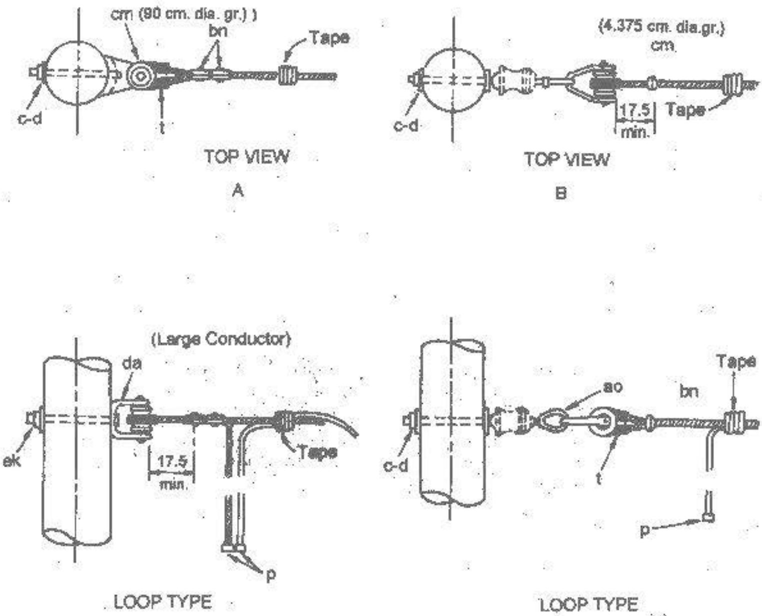


FIGURE 11-63

7.62 / 13.2 KV. SINGLE PHASE ONE SECTIONALIZING FUSE CUTOUT

Item	Materials	Quantity A	Quantity B
c -	5/8" x 14" Machine bolt	1	1
d -	2 ¼" x 2 ¼" x 3/16" – 13/16 hole washer	1	2
g -	3 ½" x 4 ½" x 4' Crossarm		1
i -	3/8" x 4 ½" Carriage bolt		2
j -	½" x 4" Lag screw	1	1
p -	Compression connector	2	2
af -	Fuse cutout, single shot	1	1
aq-	Lead or jumpers, ACSR	3 m.	3 m.
cu -	28" wood brace		2
fk -	Extension bracket L type	1	
ek -	5/8" Locknut	1	1
ek -	3/8" Locknut		2
bv -	Armor rod (tapping)*		
ap -	Hotline clamp (as required)		



SIDE VIEW

FIGURE 11-77

SERVICE ASSEMBLIES

Item	Materials	Quantity A	Quantity B
c -	5/8" X 10" Machine bolt	1	
d -	2 ¼" x 2 1/4 " x 3/8" – 13/15" hole washer	1	
p -	Compression connector	2	2
s -	Secondary swinging clevis		1
t -	Armor tape	1'	1'
aa-	5/8" Eye nut		1
da-	Secondary bracket	1	
ek -	5/8" Locknut	1	
cm-	3" diameter groove spool insulator	1	
cm-	1 ¾" diameter groove spool insulator		1
bn -	Dead end loop clamp	2	1

MISCELLANEOUS ASSEMBLIES

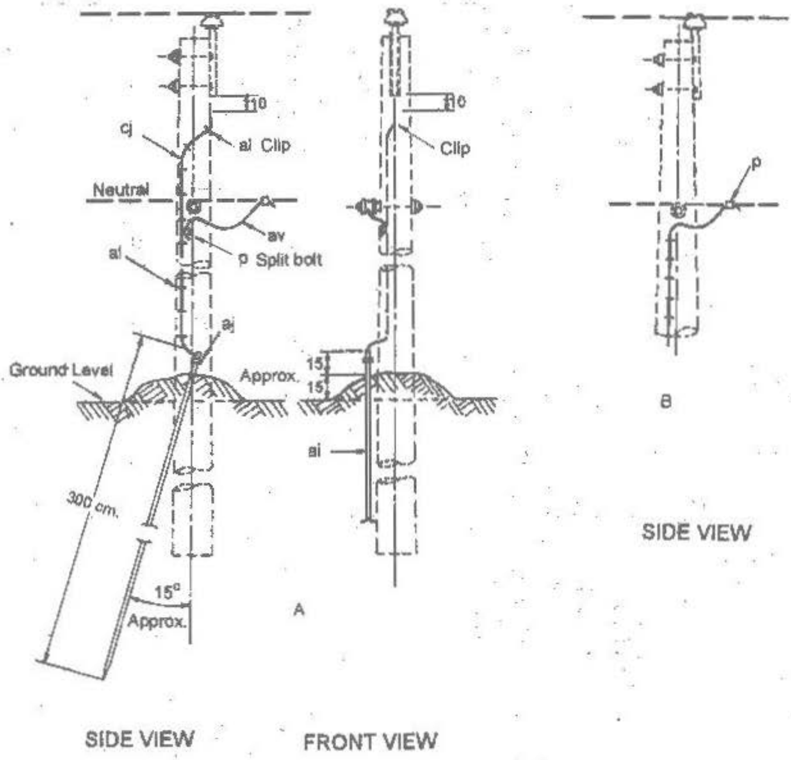


FIGURE 11-78

GROUNDING ASSEMBLY- GROUND ROD TYPE

Item	Materials	Assembly Unit A	B
p -	Compression connector	1	1
ai -	5/8" diameter min. 10' long galvanized steel rod	1	1
aj -	Clamp, ground rod, tamper roof	1	1
al -	Ground wire clip	1	
al -	2" x ½" 8 gauge ground wire staple	35	35
av-	Jumper, No. 4 AWG aluminum alloy, stranded	3'	
cj -	# 4 AWG, aluminum ground wire	30'	30'
p -	Split connector, bolt type	1	

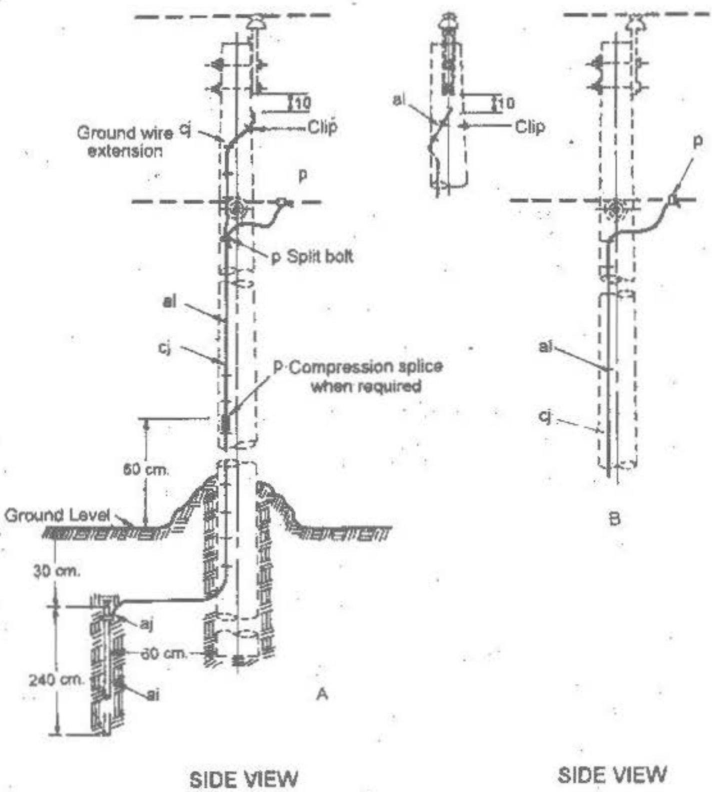
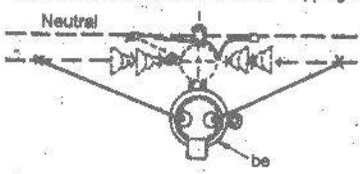


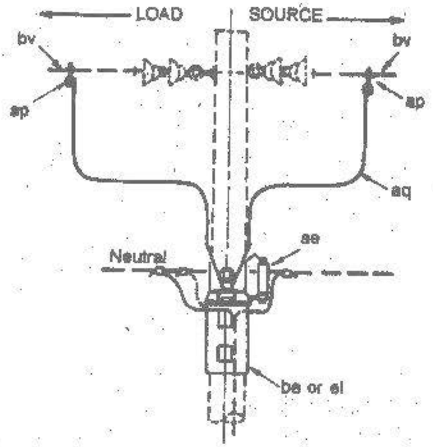
FIGURE 11-79

GROUNDING ASSEMBLY – GROUND ROD TYPE

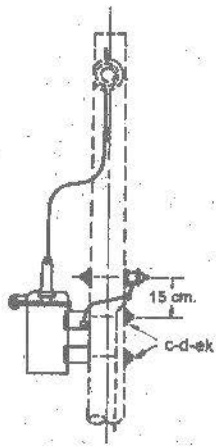
Item	Materials	Assembly Unit A	Assembly Unit B
p -	Split connector, bolt	1	
ai -	5/8" diameter x 8' steel grounding rod	1	1
aj -	Clamp, ground rod for 5/8" steel rod	1	1
al -	Staple ground wire, 2" x ½" # 8 gauge	40'	35'
al -	Ground wire clip	1	
cj -	Ground wire # 4 AWG 3 strand aluminum alloy	3'	
p -	Compression connector	1	1
cj -	5/16 dia. iron grounding wire	35'	33'



PLAN



FRONT VIEW

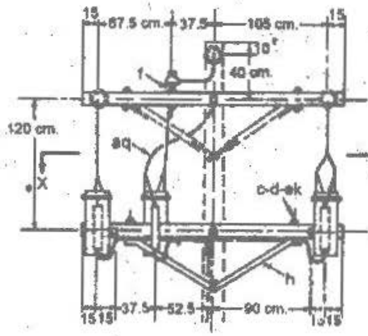


SIDE VIEW

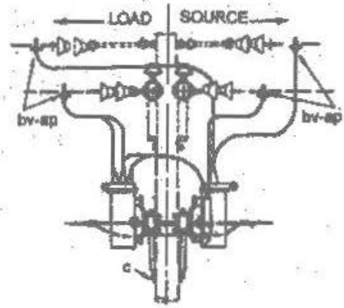
FIGURE 11-84

ONE SECTIONALIZER OR OIL CIRCUIT RECLOSER

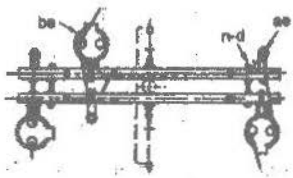
Item	Materials	Quantity	Item		Quantity
c -	5/8" x 10" Machine bolt	1	cj -	Grd. wire # 4 AWG alum. alloy	4
d -	2 ¼" x 2 ¼" x 3/16" hole washer	2	ae-	Lightning arrester	1
p -	compression connector	2	el -	Sectionalizer (M3-41 only)	1
ap -	Hotline clamp	2	ek -	5/8" Locknut	2
aq -	Leads or Jumpers	5m	bv -	Armor rod (tapping)*	2
be -	Oil circuit recloser (M3-10 only)	1			



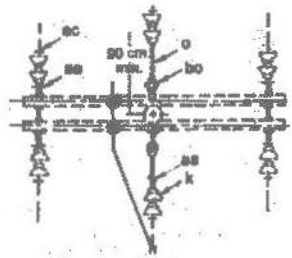
FRONT VIEW



FRONT VIEW



TOP VIEW



TOP VIEW

FIGURE 11-86

7.62 / 13.2 KV. 2 OR 3- PHASE SECTIONALIZING OIL CIRCUIT RECLOSER

Item	Materials	Quantity A	Quantity B	Item	Materials	Quantity A	Quantity B
a -	Pin type insulator	2	2	aa -	5/8" Eye nut	2	2
c -	5/8" x 12" Machine bolt	1	1	p -	Compression connector	2	3
c -	½" x 6" Machine bolts	4	4	ae -	Lightning arrester	2	3
bv -	Armor rod (tapping)	4	6	be -	Oil circuit recloser	2	3
bo -	Anchor shackle	-	2	ek -	5/8" Lock nut	11	11
ap -	Hot line clamp	4	6	ek -	½" Lock nut	4	4
d -	1 3/8" diameter 9/16" hole diameter washer					4	4
d -	2 ¼" x 2 ¼" x 3/16" – 13/16" hole washer					10	10
g -	3 ¾" x 4 ¾" x 8' Cross arm					2	2
f -	5/8" x 10 ¾" Cross arm steel pin					2	2
h -	1 ¼" x 1 ¼" x 13/16" x 24" span brace					2	2
n -	5/8" x 20" Double arming bolt					3	3
s -	Secondary swinging clevis					2	2
eq-	Jumpers or leads ACSR (meters)					15	15
cm-	3" diameter groove spool insulator					2	2
	Cross arm OCR mounting					2	3

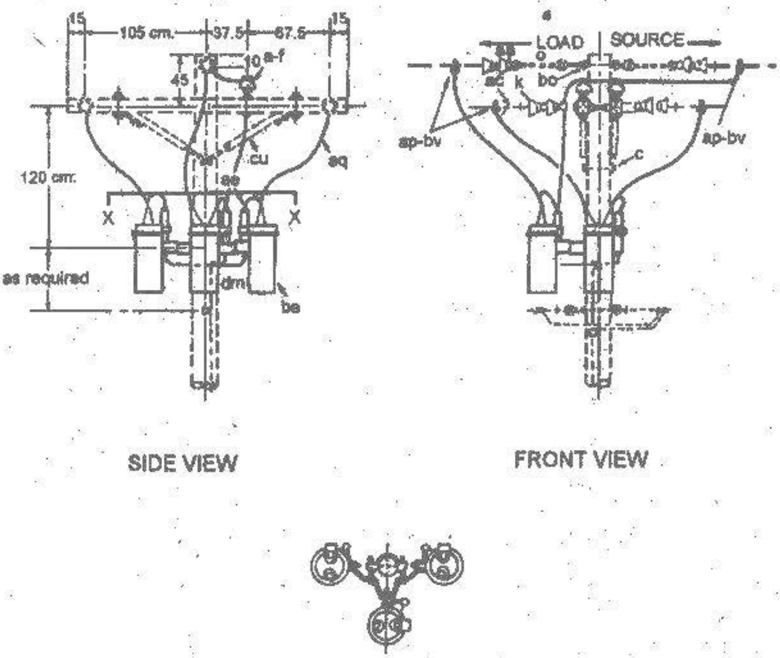


FIGURE 11-86

7.62 / 13.2 KV. 2 OR 3-SECTIONALIZING OIL CIRCUIT RECLOSER

Item	Materials	Quantity A	Quantity B
f -	5/8" x 10 ¾" Cross arm steel pin		2
p -	Compression connector	2	3
ae -	Lightning arrester	2	3
aq -	Jumpers or leads (as required)	15m	25m
be -	Oil circuit recloser	1	3
bv -	Armor rod (tapping)*	4	6
dm-	Bracket, cluster type	1	1
ek -	Locknut (as required)		
ap -	Hotline clamp, top assembly	4	6
a -	Pin type insulator		2

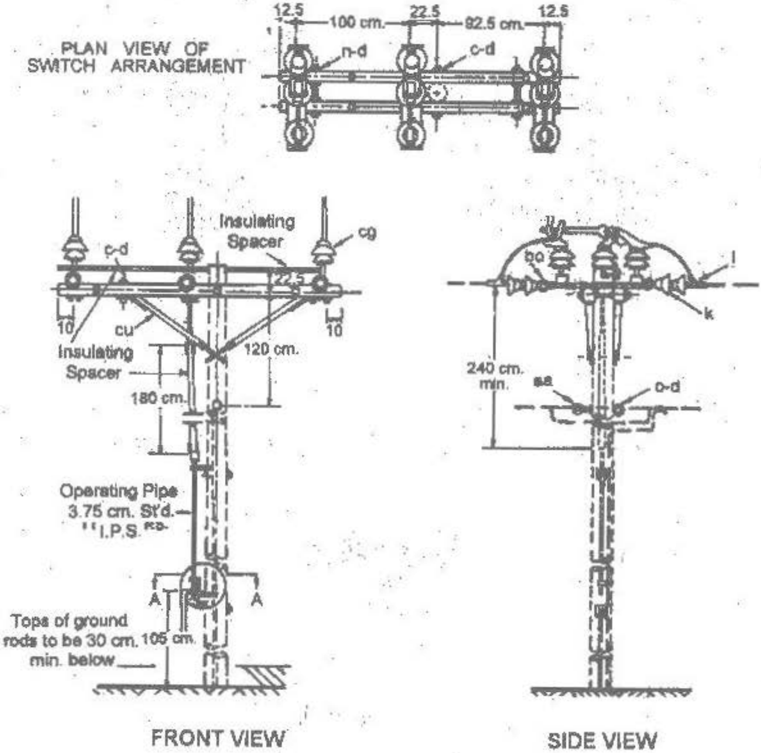


FIGURE 11-87

7.62 / 13.2 KV. SECTIONALIZING AIR BREAK SWITCH

Item	Materials	Quantity	Item		Quantity
c -	5/8" x 18" Machine bolt	16	ek	- ½" Locknut	4
c -	½" x 6" Machine bolt	4	p -	compression connector	2
c -	5/8" x 12" Machine bolt	3	s -	Secondary swinging clevis	2
d -	2 ¼"x 2 ¼"x 3/16"-13/16 hole washer	25	bo-	Anchor shackle	6
d -	1-3/8"x 9/16" hole round washer	4	cg -	switch, air break, 3 pole unit 15kv. operating mechanism 8" spacers	1
g -	3 ¾"x 4 ¾" x 8' Cross arm	2	aa -	5/8" Eye nut	1
k -	Suspension insulator	12	cm-	3" dia. groove spool insulator	2
l -	Dead end clamp	6	ek -	5/8" Locknut	24
n -	5/8" x 22" Double arming bolt	3	t -	Armor tape*	4
o -	5/8" x 12" Eye bolt	1			

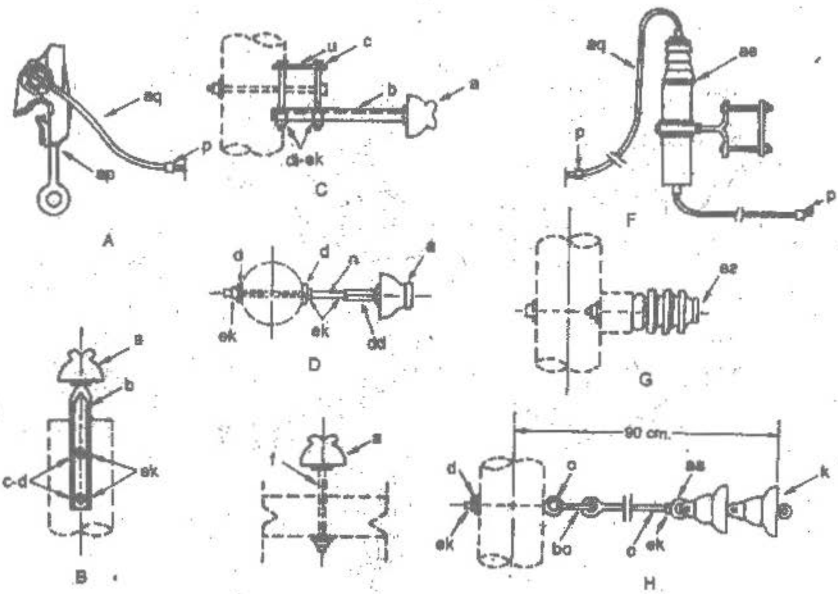


FIGURE 11-88

7.62 / 13.2 KV. MISCELLANEOUS PRIMARY ASSEMBLIES

Item	Materials	Number Required							
		A	B	C	D	E	F	G	H
a -	Pin type insulator	1	1	1	1				
b -	20" Pole top pin insulator		1	1					
c -	5/8" x 8" Machine bolts		2	2					
d -	2 ¼" x 2 ¼ x 3/16 hole washer		2		2			1	1
f -	5/8" x 10 ¾" Cross arm steel pin					1			
k -	Suspension insulator								2
n -	5/8"x 14" Double arming bolt				1				2
o -	5/8" x 12" and 18" Eye bolt								2
p -	Compression connector	1					2		
u -	3" Guy clamp bolt type			1					
aa -	5/8" Eye nut								1
ae -	Lighting arrester						1		
ap -	Hot line clamp	1							
aq -	Jumper	1					2		
bo -	Anchor shackle								1
dd -	Insulator adapter				1				
df -	Pipe spacer, pole pin			2					
ea -	7" stud post type insulator							1	
ek -	5/8" Locknuts	2	2	2	3				2
bv -	Armor rod (tapping)*	1							

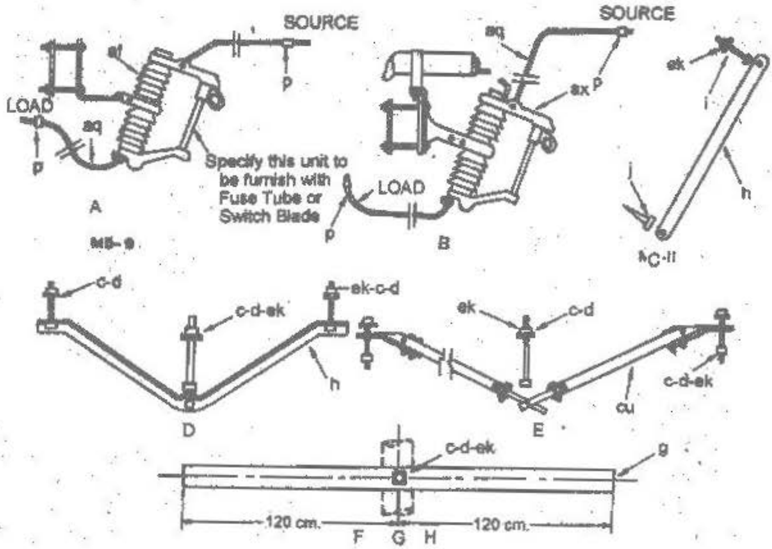


FIGURE 11-89

MISCELLANEOUS PRIMARY ASSEMBLIES

Item	Materials	Number Required							
		A	B	C	D	E	F	G	H
c -	5/8" X 12" and 16" Machine bolts				1	1	1	1	1
c -	½" x 6" Machine bolt				2	2			
d -	2 ¼" x 2 ¼" x 3/16" square washer				1	1	2	2	2
d -	1 3/8" diameter 9/16" hole round washer				2	2	1		
g -	3 ½" x 4 ½" x 8' Cross arm						1		
g -	3 ¾" x 4 ¾" x 10' Cross arm								1
g -	3 ¾" x 4 ¾" x 8' Cross arm							1	
h -	1 ¼" x 1 ¼" x 28" Flat brace			1.					
h -	1 ½" x 1 ½" x 3/16" Angle brace				1				
i -	3/8" x 4 ½" Carriage bolt			1					
j -	½" x 4" Lag screw			1					
p -	Compression connector	2	2						
af -	Single shot cutout	1							
ag -	Jumper	2	2						
ax -	Cutout and arrester combination		1						
cu -	60" span wood brace					1			
ek -	1.2" and 5/8" Lock nut			1	3	3	1	2	1

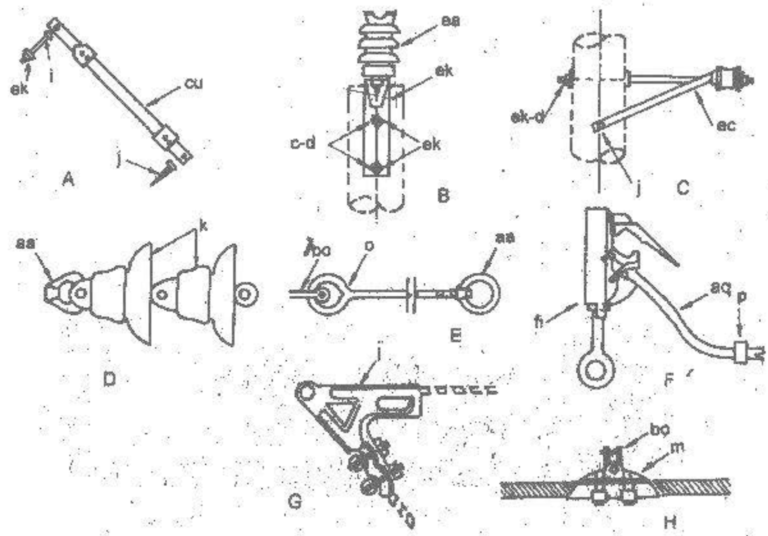
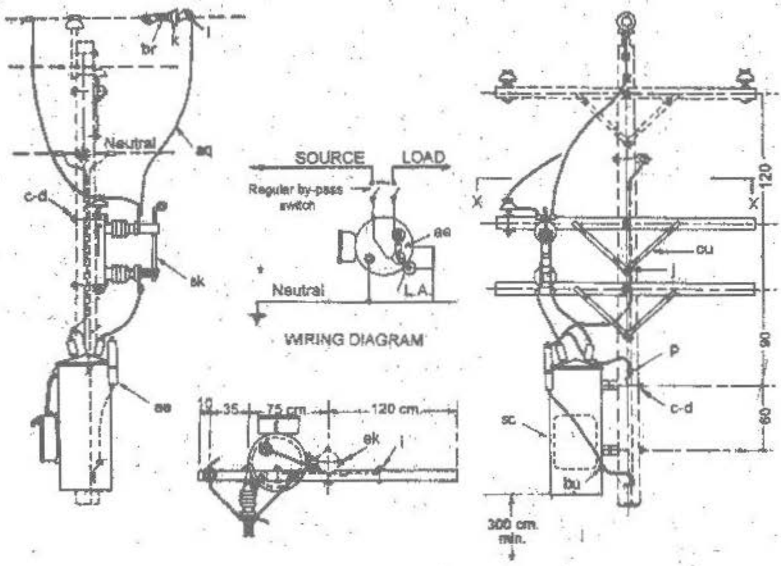


FIGURE 11-90

MISCELLANEOUS PRIMARY ASSEMBLIES

Item	Materials	Number Required							
		A	B	C	D	E	F	G	H
a -	5/8" x required length machine bolt		2						
d -	2 ¼" square washer		2	1					
i -	3/8" x 4 ½" Carriage bolt	1							
j -	½" x 4" Lag screw	1		1					
k -	Suspension insulator				2				
ea -	1 ¾" stud post type insulator		1						
eb -	Insulator type post bracket		1						
ec -	Insulated neutral offset bracket			1					
ek -	3/8" Locknut	1	2	1					
cu -	28" wood brace	1							
aa -	5/8" Eye nut				1	1			
bo -	Anchor shackle					1			1
o -	5/8" x 18" Eye bolt					1			
fj -	Hot line connector						1		
aq -	Jumper						1		
p -	Compression connector						1		
l -	Dead end clamp							1	
m -	Suspension clamp								1

REGULATORS CAPACITORS AND METERING ASSEMBLIES



SIDE VIEW SECTION X-X FRONT VIEW

FIGURE 11-81

7.62 / 13.2 KV. ONE VOLTAGE REGULATOR POLE MOUNTED

Item	Materials	Quantity	Item	Materials	Quantity
a -	Pin type insulator	1	ek -	½" Locknut	4
c -	½" x 6" Machine bolt	4	ek -	5/8" Locknut	4
c -	3/8" x 5" Machine bolt	4	l -	Dead end clamp	2
c -	5/8" x 16" Machine bolt	2	p -	Compression connector	4
d -	1 3/8" dia. 9/16" hole rd. washer	4	ca -	Lightning arrester	1
d -	3/16" x 2 ¼"-13/16" hole washer	9	aq -	Leads or jumpers ACSR	10m
f -	5/8" x 10 ¾" Cross arm pin	1	br -	5/8" x 3 ¼" Chain link	1
g -	3 ½" x 4 ½" x 8' Cross arm	2	bu -	Solderless connectors	1
i -	3/8" x 4 ½" Carriage bolt	4	cu -	28" wood brace	4
j -	½" x 4" Lag screw	2	sc -	Step type regulator	1
k -	Suspension insulator	1	sk -	By pass switch regulator	1
ek –	3/8" Locknut	4	ae -	By pass arrester	1

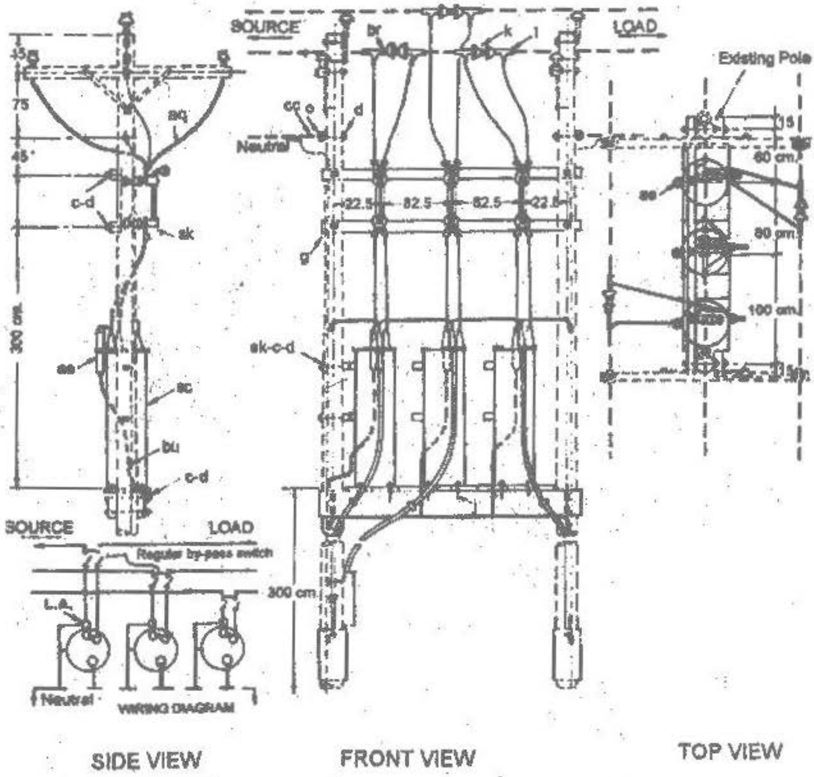


FIGURE 11-62

7.62 / 13.2 KV. THREE VOLTAGE REGULATOR PLATFORM MOUNTED

Item	Materials	Quantity	Item	Materials	Quantity
c -	5/8" x reqd. length machine bolt	6	ae -	By-pass arrester	3
c -	¾" x reqd. length machine bolt	4	aq -	Jumpers (as required)	
d -	3/16" x 2 ¼"-13/16" hole washer	20	br -	5/8" x 3 ¼" chain link	3
g -	3 ¾" x 3 ¾" x 10' Cross arm	2	bu -	Solderless connectors	8
i -	5/8" x 6" length reqd. lag screw	8	cc -	Dead end assembly	2
j -	½" x 5" (as required)		sc -	Step type regulator	3
k -	Suspension insulator	6	sk -	By-pass switch	3
d -	Dead end clamp	6		4" x 4" x 10' structural timber	2
o -	5/8" x required length eye bolt	2		2" planks, length (as required)	
p -	Connectors (as required)		ek -	Locknuts (as required)	
ae -	Lightning arrester	3			

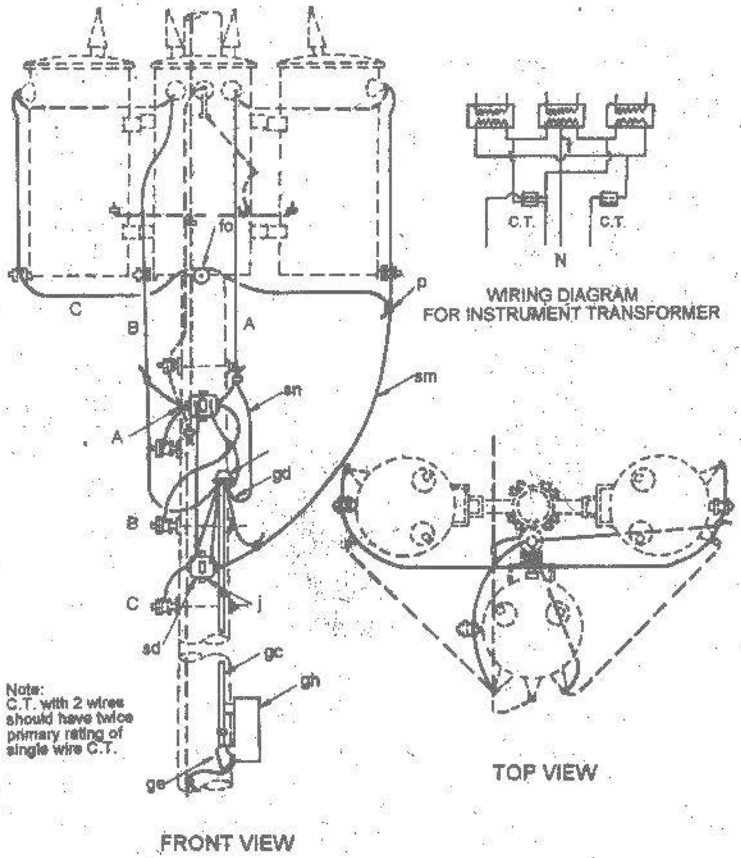
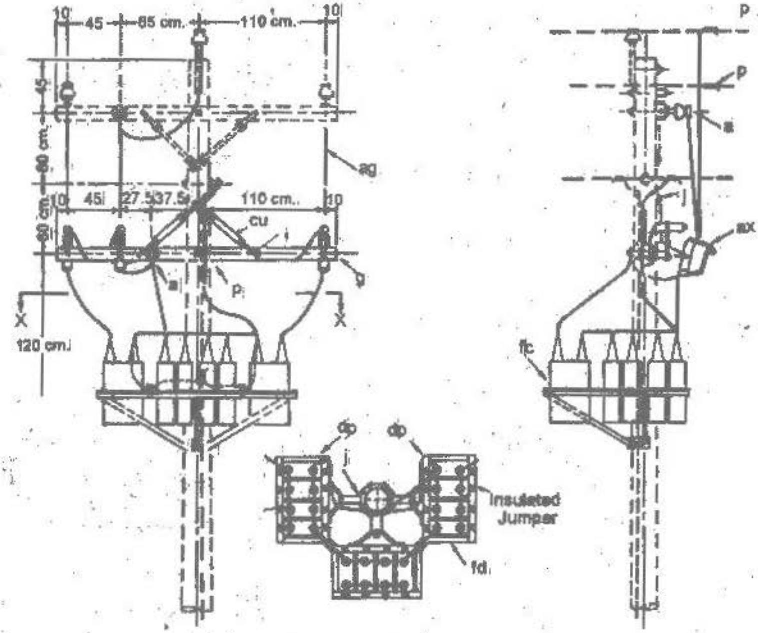


FIGURE 11-93

SECONDARY METERING GUIDE 3-PHASE 120/240 OR 240/480 VOLTS 4-WIRE DELTA

Item	Materials	Quantity	Item	Materials	Quantity
j -	½" x 4" Lag screw	4	gh -	Meter box, and test block	1
p -	Compression connector	5	sd -	Current transformer	2
gc -	1 ¼" Conduit	15		Service head	1
ge -	Conduit type LB	1	sm -	Wire No.12 insul. for current	80'
gd -	Conduit straps	6	sn -	Wire No.14 insul. for potential	80'
fo -	Transformer, secondary bracket	1			



SECTION X-X

FRONT VIEW

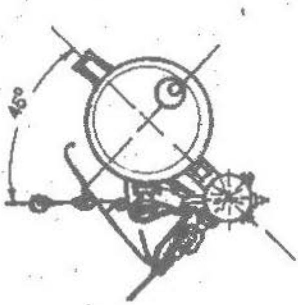
SIDE VIEW

FIGURE 11-94

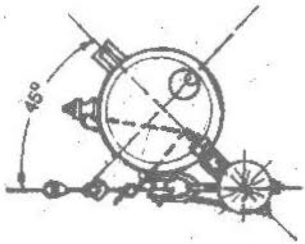
7.62 / 13.2 KV. 2 OR 3-PHASE CAPACITOR ASSEMBLY

Item	Materials	Quantity	Item		Quantity
a -	Pin type insulator	1	ax -	Cutout- arrester combination	3
c -	5/8" x 14" Machine bolt	1	cu -	28" wood brace	2
d -	3/16" x 2 ¼"-13/16 hole washer	2	dp -	Ground wire clamp	2
g -	3 ½" x 4 ½"x 8' Cross arm	1	ea -	Post type insulator w/7" stud	2
i -	3/8" x 4 ½" Carriage bolt	2	fc -	Capacitor KVA each	
j -	½" x 4" lag screw	4	fd -	Hanger cluster type	1
p -	Compression type connector	3	ek -	5/8" Locknut	2
p -	Connector (as required)		ek -	3/8" Locknut	2
aq -	Jumpers (as required)		f -	5/8"x 10 ¾" Cross arm steel pin	2

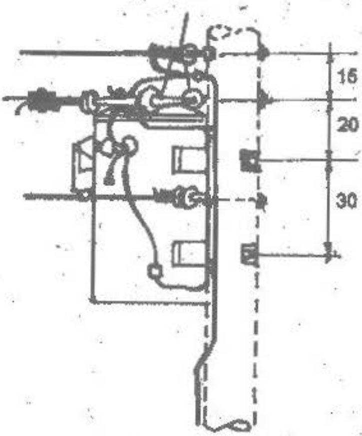
TRANSFORMER CONNECTION GUIDE



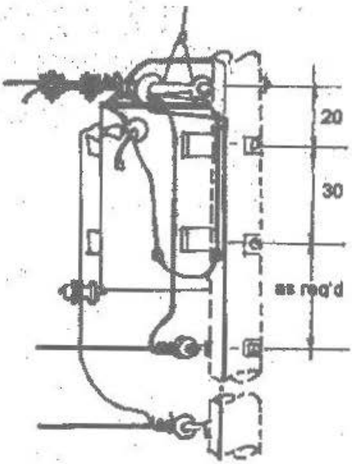
PLAN



PLAN



PRIMARY DEADEND
SERVICE TAKE OFF
AT TRANSFORMER
LEVEL



PRIMARY DEADEND
SERVICE TAKE OFF
BELOW TRANSFORMER

FRONT VIEW

FIGURE 11- 95

TRANSFORMER CONNECTION GUIDE OPEN WIRE SERVICES

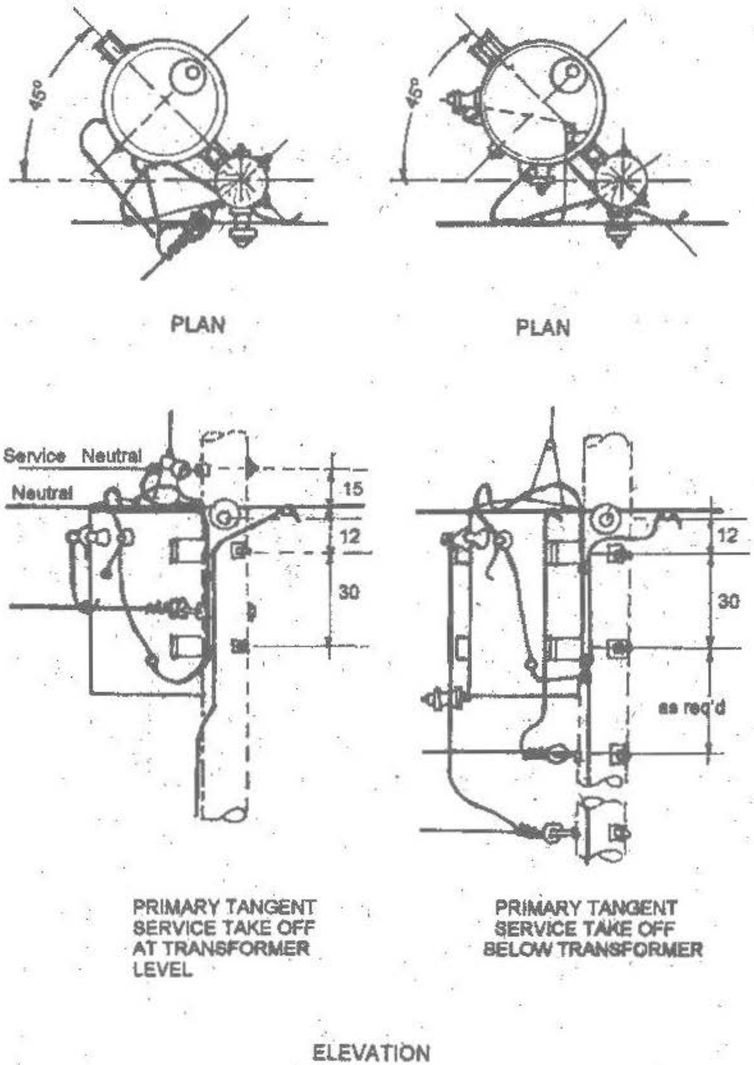
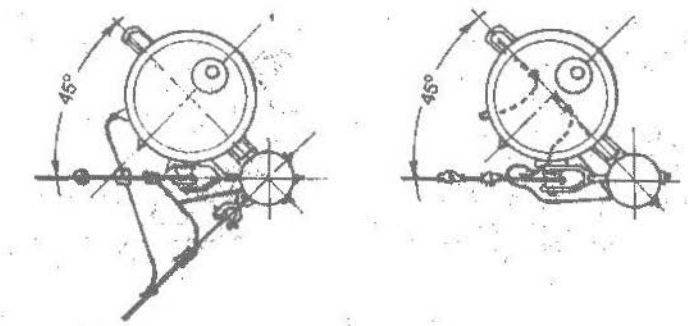
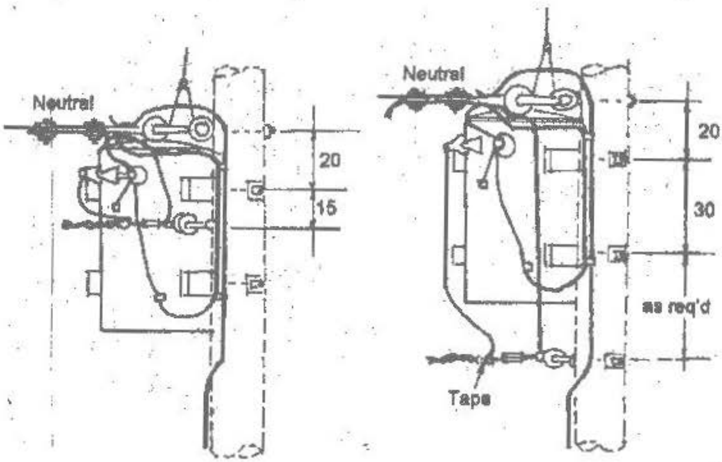


FIGURE 11-96

TRANSFORMER CONNECTION GUIDE OPEN WIRE SERVICES



PLAN PLAN



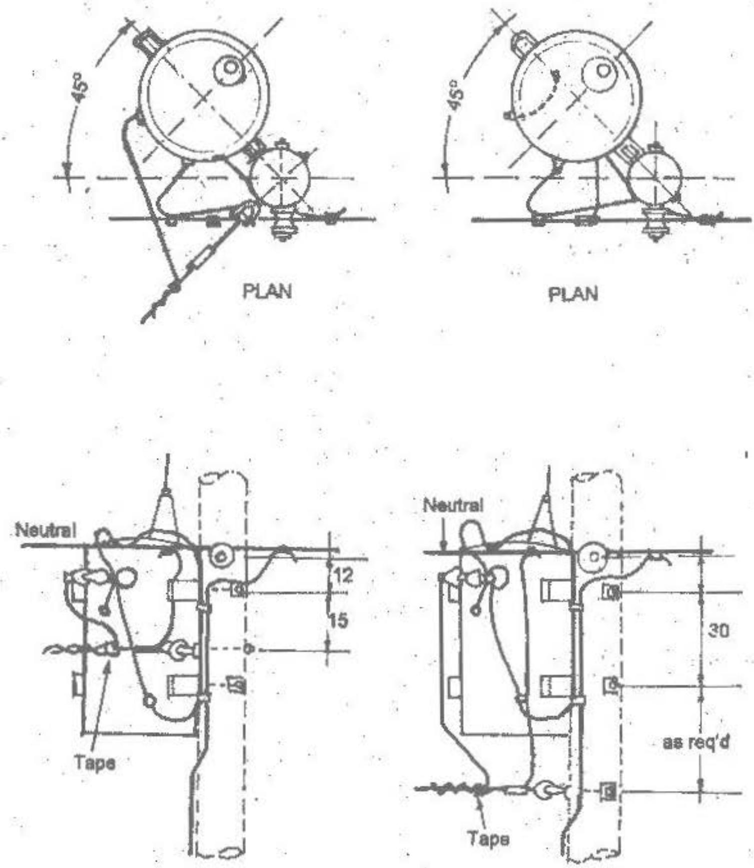
Primary deadend service
Take off at transformer

Primary deadend service
take off below transformer

FRONT VIEW

FIGURE 11- 97

TRANSFORMER CONNECTION GUIDE TRIPLEX CABLE SERVICES



FRONT VIEW

Primary tangent service take off at transformer

Primary tangent service take off below transformer

FIGURE 11-98

TRANSFORMER CONNECTION GUIDE TRIPLEX CABLE SERVICES

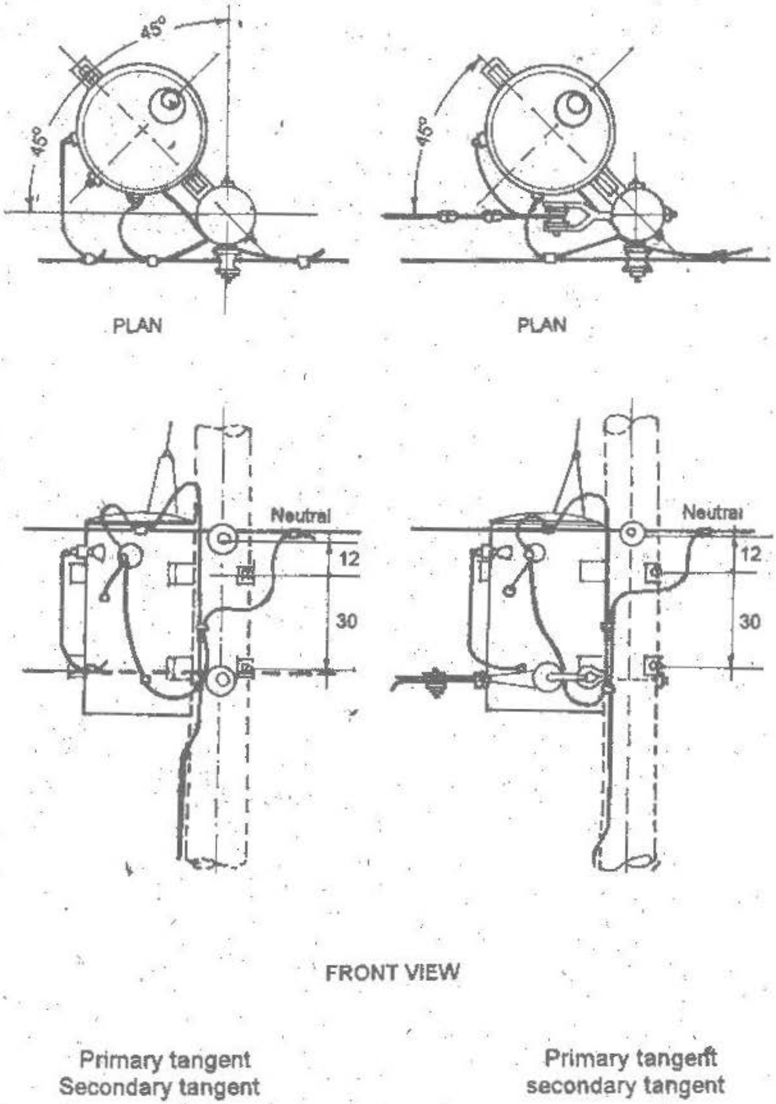
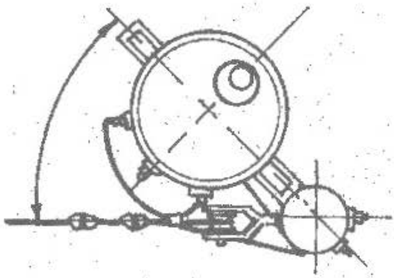
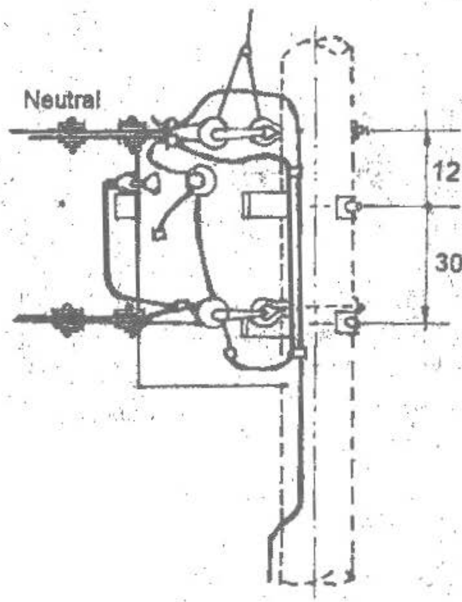


FIGURE 11- 99

TRANSFORMER CONNECTION GUIDE SECONDARY UNDERBUILD



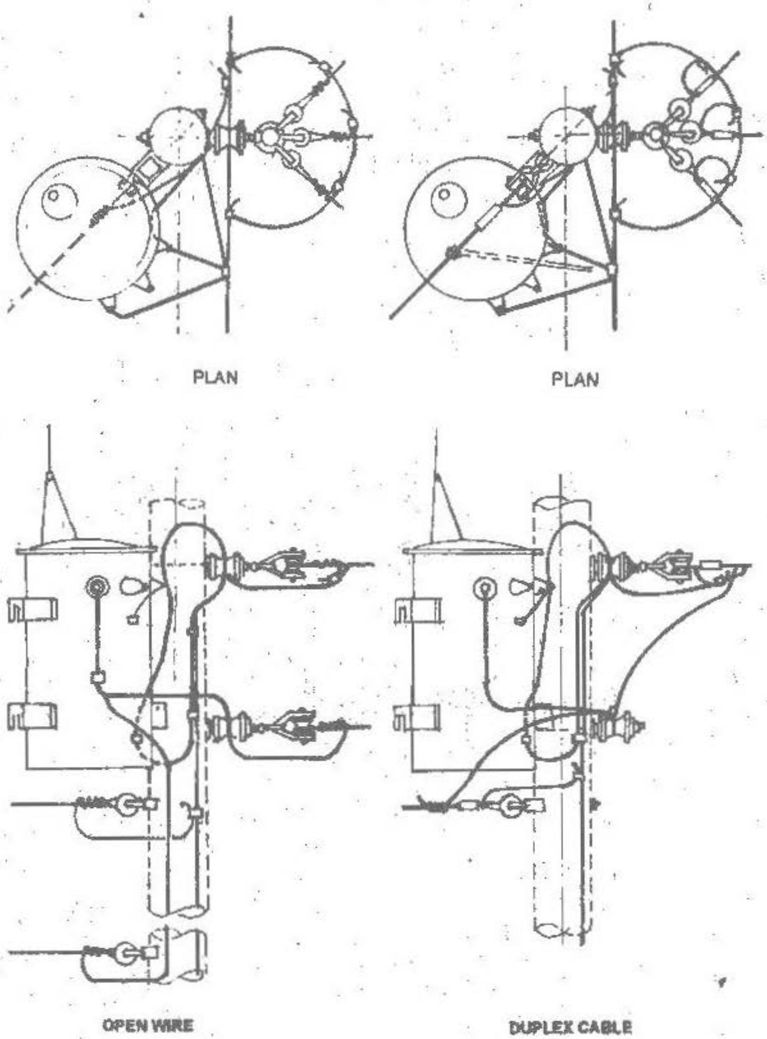
PLAN



ELEVATION

FIGURE 11 - 100

PRIMARY DEADEND SECONDARY DEADEND



ELEVATION

FIGURE 11 – 101

TRANSFORMER CONNECTION AND SERVICE

DISTRIBUTION LINE CONSTRUCTION

Primary Voltage	750 - 15,000 volts
Secondary Voltage	0 - 750 volts
Service Drop Voltage	0 - 750 volts

Site Condition	Primary without Neutral	Primary with multi grounded neutral	Secondary	Service drops
Over Railroad tracks	8.50 m.	8.00 m.	8.00 m.	8.50 m.
Over Public street	6.00 m.	5.50 m.	5.50 m.	5.50 m.
Over Pedestrian ways	4.50 m.	4.50 m.	4.50 m.	
Along Urban streets	6.00 m.	5.50 m.	5.50 m.	
Along Rural roads	5.50 m.	4.50 m.	4.50 m.	
Over Commercial driveways				4.50 m.
Over Residential pedestrian ways				3.60 m.

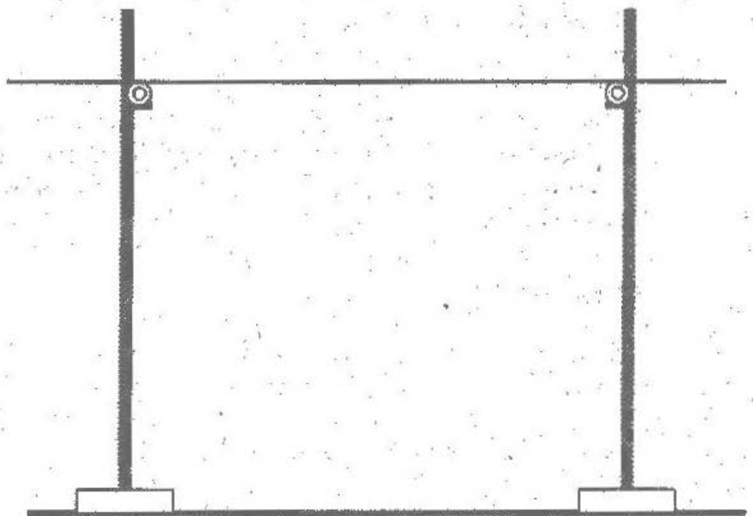


FIGURE 11-102

BASIC MINIMUM HEIGHT OF DISTRIBUTION LINE

Specifications for Construction

1. General

All construction work shall be done in a thorough and workmanlike manner in accordance with the Staking Sheets, Plans and Specifications, and the Construction Drawings.

2. Distribution of Poles

In distributing the poles, large choice, closed grain poles shall be used for transformers, deadend, angle and corner poles.

3. Setting of Poles

The minimum depth for setting of poles shall be as follows:

"Setting in Soil" – Specifications shall be:

a. Where poles are to be set in soil
b. Where there is a layer of soil of more than 60 centimeters in depth over solid rock
c. Where the hole in solid rock is not substantially vertical or the diameter of the hole at the surface of the rock exceeds approximately twice the diameter of the pole at the same level.

" Setting in Solid Rock"

Specifications shall apply where poles are to be set in solid rock and where the hole is substantially vertical, approximately uniform in diameter and large enough to permit the use of tamping bars through the full depth of the hole.

Where there is a layer of soil 60 centimeters or less in depth over the solid rock, the depth of the hole shall be the depth of the soil in addition to the depth specified under *"Setting in all Solid Rock"* provided that such depth shall not exceed the depth specified under *"Setting in Soil"*.

On sloping ground, the depth of the hole shall be measured from the low side of the hole.

Pole shall be set so that alternating cross arm gains face in opposite directions, except at terminals and dead ends where the gains of the last two poles shall be on the side facing the terminal or dead end. On long spans, the poles shall be set so that the crossarm comes on the side of the pole away from the long span. Where pole top pins are used, they shall be on the opposite side of the pole from the gain, with the flat side against the pole.

Poles shall be set in alignment and plumb except at corners, terminals, angles, junctions, or other points of strain, where they shall be set and raked against the strain so that the conductors shall be in line.

Poles shall be raked against the conductor strain not less than 2.5 centimeters for each 3.00 meter of pole length nor more than 7.60 centimeters for each 3.00 meters pole length after conductors are installed at the required tension. Pole backfill shall be thoroughly tamped to the full depth. Excess dirt must be banked around the pole.

4. Grading of Line

When using high poles to clear obstacles such as buildings, foreign wire crossings, railroads, etc., there shall be no upstream on the pin type insulators in grading the line each way to lower poles.

5. Guys and Anchors

Guys shall be placed before the conductors are strung and shall be attached to the pole as shown in the construction drawings. All anchors and rods shall be in line with the strain and shall be so installed that approximately 15 centimeters of the rod remain out of the ground. In cultivated fields or other locations, as deemed necessary, the projection of the anchor rod above earth may be increased to maximum of 30 centimeters to prevent burial of the rod eye. The back fill of all anchor holes shall be thoroughly tamped to the full depth.

When a cone anchor is used, the hole, after the anchor has been set in place, shall be backfilled with coarse crushed rocks for 60 centimeters above the anchor, tamping during the filling with the remainder of the hole to be backfilled and tamped with dirt.

6. Locknuts

A Locknut shall be installed with each nut, or other fastener on all bolts or threaded hardware such as insulator pins, upset bolts, double arming bolts, etc.

7. Conductors

Conductors shall be handled with care. Conductors shall not be tramped on nor run over by vehicles. Each reel shall be examined and the wire shall be inspected for cuts, kinks, or other injuries. Injured portion shall be cut and the conductor spliced. The conductors properly mounted on pulled over suitable rollers or stringing blocks shall be carefully mounted on pole or crossarm if necessary to prevent binding while stringing.

The neutral conductor shall be maintained on 9ne side of the pole (preferably the road side) for tangent construction and for angles not exceeding 30°.

With pin-type insulators, the conductors shall be tied on the top groove of the insulator on tangent poles and on the side of the insulator away from the strain at angles. Pin type insulators shall be tight on the pin and on the tangent. The top groove must be in line with the conductor after tying it.

For neutral and secondary conductors on poles, insulated brackets may be substituted for the single and double upset bolts on angles of 0° to 5° in locations known to be subject to considerable conductor vibration.

All conductors shall be cleaned thoroughly by wire brushing before splicing of the installation of connectors, clamps or tapping armor rods. A suitable inhibitor shall be used on aluminum conductors before splicing, before applying connectors, clamps or before installing tapping armor rods.

8. Splicing and Deadends

Conductors shall be spliced and deadend as shown on the construction drawings. There shall be not more than one splice per conductor in any span and splicing sleeves shall not be located near conductor support. Maintain 3.00 meters or more separation between the splice and the conductor support. No splices shall be located in Grade B crossing spans and preferably not in the adjacent spans.

9. Taps and Jumpers

Jumpers and other leads connected to line conductors shall have sufficient slack to allow free movement of the conductors. Where slack is not shown on the construction drawings, it shall be provided by at least two bends in a vertical plane, or one in a horizontal plane, or the equivalent. In areas where vibrations occurs, special measures to minimize the effects of jumper breaks shall be used as specified.

All leads on equipment such as transformers, reclosers, etc., shall be a minimum of No. 6 copper conductivity.

10. Hot Line Clamps and Connectors

Connectors and hot line clamps suitable for the purpose shall be installed as shown on guide drawings.. On all hot line clamp installations, the clamp and jumper shall be so installed so that they are permanently bonded to the load side of the line, allowing the jumper to be energized when the clamp is disconnected. This applies in all cases, even where the line layout is such that the tap line is in actuality the main back to the power source. Do not install hot line clamps directly to ACSR conductors.

Use tapping armor rods on tap saddles. Before installing hot line clamps to the surface of tapping armor rods, clean thoroughly by wire brushing and apply a suitable inhibitor to the area of the tapping armor rod coming in contact with the hot line clamp.

11. Lighting Arrester Gap Settings

The external gap electrodes of lightning arresters, combination arrester cutout units, and the transformer mounted arresters shall be adjusted to the manufacturer's recommended spacing. Care shall be taken that the adjusted gap is not disturbed when the equipment is installed.

12. Conductor Ties

Ties shall be in accordance with Construction Drawings. Hot line ties shall not be used at Grade B crossings.

13. Sagging of Conductors

Conductors shall be sagged in accordance with the conductor manufacturers recommendations except that a maximum increase of 7.6 centimeters of the specified sag in any span will be acceptable but in no circumstances shall a decrease in the specified sag be allowed.

All conductors shall be sagged evenly. The air temperature at the time and place of sagging shall be determined by a certified etched glass thermometer.

14. Secondary and Service Drops

Secondary conductors may be bare or covered wires or multi-conductor service cable. Conductors for secondary under build on primary lines is normally bare except in those instances where prevailing conditions may limit primary span length to the extent that covered wires or service cables may be used. Service drops shall be covered wire or service cable type. Secondary and service drops shall be so installed as not to obstruct climbing space. There shall not be more than one splice per conductor in any span, and splicing sleeves shall not be located near the conductor support. Maintain 3 meters or more separation between the splice and the conductor support. Where the same covered conductors or service cables are to be used for the secondary and service drop, they may be installed in one continuous run.

15. Ground

Ground rods shall be driven in undistributed earth in accordance with the construction drawings. Where aluminum ground wire is used, it must be terminated above ground at a galvanized ground rod or splice by a compression connector to a copper steel ground wire extension to the ground rod of which the top of the ground rod shall be 30 cm. or more below the surface of the earth. The ground wire shall be attached to the rod with a clamp and secured to the pole with staple. Staples on the ground wire shall be spaced two feet apart except for a distance of 2.40 meters above the ground rod and 2.40 meters down from the top of the pole where they shall have at least two connections from the frame case or tank to the multi-grounded neutral conductor. The equipment shall be interconnected and attached to a common ground wire.

MINIMUM DEPTH FOR SETTING POLES

Length of Pole in Meter	Setting in Soil in Meter	Setting in Solid Rock in Meter
6.00	1.20	0.90
7.50	1.50	1.05
9.00	1.65	1.05
10.00	1.80	1.20
12.00	1.80	1.20
13.50	1.95	1.35
15.00	2.10	1.35
16.50	2.25	1.40
18.00	2.40	1.50

FIRST AID INSTRUCTION IN CASE OF ACCIDENT CAUSED BY ELECTROCUTION

Preliminary Precautions

Switch off the line or have it done by the power company, then remove the victim from contact with the electric conductor. Remember that in removing a victim from a live wire, the rescuer is exposed to danger of electrocution. In such a case, adopt any of the following procedures:

In case of Low Voltage Installation

1. Insulate yourself from the ground by several layers of dry boards, beams, wooden boxes or rubber insulators.
2. Remove the line from the victim by means of a long dry wooden sticks, dry ladder etc. Metal objects should not be used. If this does not work:
3. Wrap several layers of dry cloth around your hands and push or pull the victim away from the line while standing on insulating boards, rubber shoes etc. Do not touch the victim except by his clothing.

In Case of High Voltage Installation

1. Only experts should be permitted to remove the victim.
2. If the victim is hanging on the wires, spread straw, hey or bedding underneath.
3. Notify the power company and call a doctor.
4. Post a guard at the site of the accident.

Treatment in case of Unconsciousness

1. After the victim has been removed from the contact with the power line, start immediate attempt to restore his breathing.
2. Place the unconscious person on his back, with the head to one side with a pillow under his shoulder open his

collar, scarf, belt and tight clothing etc.

3. Carefully open the mouth of the patient and place some hard object preferably a piece of wood, between his teeth and remove any dentures.
4. Slowly but with sufficient strength pull out his tongue using a handkerchief. Let somebody hold it or tie it to the chin of the victim.
5. Try to get him to breath spontaneously by tickling his nose and throat.
6. If no immediate success is achieved, start at once with artificial breathing. Kneel down behind the head of the victim grasp his arms under the elbows, press them firmly against his chest and then draw them slowly apart in a circle over his head.
7. After two seconds, bring the arms back to their initial position.
8. Repeat the exercise at the rate of 16 to 20 times a minute. If necessary for several hours until the doctor arrives. More rapid movements are harmful and needlessly tiring.
9. Stop the artificial respiration as soon as the victim starts breathing.
10. Activate the blood circulation by sprinkling his head and chest with cold water and rubbing hard.
11. If the victim recovers, cover him up and let him sip warm drinks from a teaspoon as soon as he is able to swallow.
12. Leave any further aid to the doctor.

REFERENCES

Philippine Electrical Code Part-I & Part II
Electrical System by W.J. Mc. Guinness and B. Stein
National Electrification Administration (NEA) Catalogue 1975
Electric Wiring and Lighting for Home and Office by Saffordl
Audels Practical Electricity
Readers Digest Home Improvement Manual
Making Electrical Calculations by J.F. Mc Partland
IIEE Technical Guide on Electrical and Electronic Products 1981 Edition.
Columbia Wires and Cables Technical Data.
Architectural Graphic Standards AIA, CG. Ramsey and H.R. Sleeper.
Electrical Fundamentals for Technicians R.L. Shrader, Mc Graw Hill
National Electrical Code (NEC)
Simplified Electrical Wiring Handbook, Sears Roebuck & Co.
NEC Article 210 and Table 210-24.