PDHonline Course E208 (4 PDH)

Electric Power Distribution for Industrial Plants

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Electric Power Distribution for Industrial Plants

Adolph A. Biss, P.E.

Introduction

Electric Power Distribution in Industrial Plants covers the fundamentals of motor wiring and elementary distribution system for low voltages 600 volts or less. Initially the course was sponsored by West Penn Power Company for industry personnel. The text will cover the plant electrical system with respect to design, reliability, safety and voltage selection. The course now has been modified to meet current requirements of the National Electric Code (NEC) and is designed especially for Engineers, Inspectors and others concerned with electric power distribution for industrial plants.

Specifically, the texts will enable one to design an entire plant electrical distribution system, covering (a) the installation of motors, furnaces and lighting equipment on branch circuits and feeders, (b) proper electric service entrance , (c) protective devices for the equipment and circuits, (d) proper voltages for equipment and plant distribution, and (e) system planning.

Course Content

Industrial plants receive electric power from the electric utility company through its Service Entrance at a voltage level available from the utility company and as determined by the plant electrical load. Included in the Service Entrance are the wire, bus, and switchgear necessary to control the electrical supply to the plant buildings. The design of the Service Entrance is covered in Section 2 and will be determined by the plant power requirements as covered in this Section.

An industrial plant operation to be good requires a safe and reliable power distribution system. Otherwise production suffers. In practically all plants, processes change, and equipment added so that electric loads are transferred from one circuit to another. Sooner or later an overload condition occurs. Wires may overheat causing insulation deterioration which finally results in a short circuit. Then fuses blow or breakers trip and the factory is shut down. Stop – gap emergency measures taken to get production rolling may cause breakers and switches to be patched or oversized, heedless of the fact that conductors are overheating and insulation deteriorating. Finally, ground faults occur and production again must wait until repairs are made. The tangled electrical distribution system has gotten a strangle hold on the operation. On the other hand, good adequate wiring makes it possible for a plant to enjoy flexibility and reliability not possible otherwise.

Wiring Fundamentals.

The analysis and design of a plant distribution system starts at the point of use, that is, at the motor or other electrical load. The following rules are fundamental for connections of motors:

Single Motor

1. The wire for the branch circuit must have a current-carrying capacity of not less than 125% of the rated full-load motor current.
2. The switch which serves as the motor controller and disconnecting device must be in sight of the motor or capable of being locked in the open position. This switch may be either fused or fuseless depending upon whether or not motor protection is desired. Use dual element fuses if protection is desired. The idea is to fuse as closely as possible to the rated full-load current and still allow the high starting currents to pass without blowing the fuse. If fused too high, the motor could burn up before the protective device opens. (Breakers may be substituted for switches and fuses).
3. A manual or automatic starter may also be added to the circuit, installed between the motor and the motor controller switch. The starter has a thermal overload relay for protection against excessive currents.
4 A combination starter including the starter and switch in one box may be used instead of a separate switch and separate starter.
If the motor switch is fuseless, the branch circuit switch may provide motor running protection as well as branch circuit protection.
5. If the motor switch is fused, then the branch circuit switch provides only branch circuit protection. If dual-element fuses are used in the branch circuit switch, they must be at least 25% to 40% larger than the dual-element fuses in the motor switch to prevent double blowing on short circuits.
6. If a starter is used, the branch circuit switch provides branch circuit protection only. If dual-element fuses are used they may be smaller than ordinary fuses.

Note:

These fundamentals are covered in the National Electric Code which specifies **minimum** wiring requirements. Following the NEC specifications will provide a safe wiring system because safety is the primary concern of the Code. However, **good wiring practice dictates that flexibility, reliability, provision for growth also must be considered**.

More Than One Motor on a Circuit.

1. Feeder must be capable of carrying 125% of the full-load current of the largest motor plus 100% of the full-load rating of all other motors connected to the circuit.

2. Fuses in the circuit switch must protect the feeder. Their size is determined by the sum of the fuse rating of motor branch circuit protection for the largest motor, plus the full-load currents of the other motors. Motor switches may be fuseless if starters are added to

provide thermal motor running protection. These switches should be in close proximity to the motor. (Must be less that 50 feet distant)

3. If motor switches are fuseless or have thermal protection, the fuse in the circuit switch must not be over four times the rating of the smallest motor on the circuit unless thermal cutouts or relays are approved for use with larger size fuses.
4. Smaller size Tap-offs. In the case of a circuit supplying a number of motors, it is permissible to tap off the branch circuit to the motor with a smaller size wire providing:
   a. The tap-off is correctly sized for the motor (125% full-load current), and
   b. The tap-off has an ampere rating at least 1/3 that of feeder, and
   c. The tap-off is protected against mechanical damage, and
   d. The tap-off is not over 25 feet long to motor or its protecting equipment. Exception is made in high-bay area where vertical length of drop exceeds 25 feet.
5. Growth. In the average plant, a 50% growth factor is commonly applied when determining sizes of the feeders in the electrical system for motor and heating loads. Additional lighting, however, normally requires a major revamp of lighting equipment. At that time a new feeder could be installed to carry the additional load. Therefore, we will not use a growth factor on lighting feeders.
6. Voltage Drop. In Systems serving most industrial loads, voltage drop in power feeders should not exceed 2% and in branch circuits not more than 1%. Lighting feeders to lighting panelboards should have a maximum of 1%. The reason for this is to assure satisfactory performance of the equipment. For example, in heating devices, heat output varies with the square of the voltage. A 10% voltage drop results in a 19% decrease in heat output.

Power Factor

The induction motors in the Circuit Design Problem which follows are assumed to have a lagging power factor of 80%. To understand just what this means, let's compare power factor with a mug of beer.

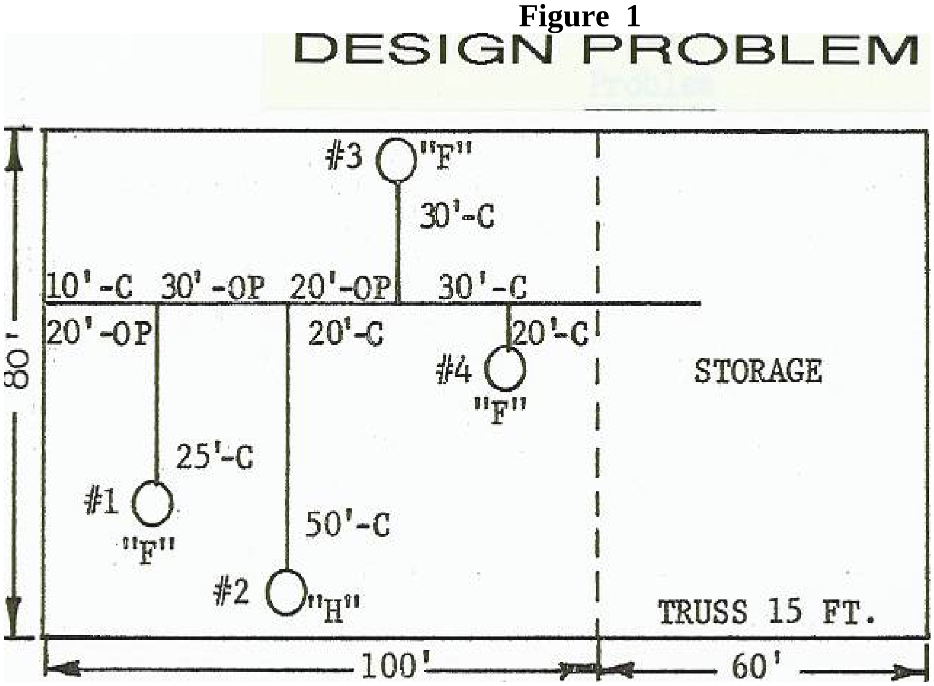
Just as a mug of beer is made up of both beer and foam, the power which we must supply to induction equipment, such as an induction motor, transformer, fluorescent light, is made up of real and reactive power. The real power, or the working power as it is sometimes called, may be compared to the beer. The unit of measurement of real power is the kilowatt (KW).

The reactive, or magnetizing power, is similar to the foam. The magnetizing power is the power which is required to produce the flux necessary for the operation of any induction equipment. Without magnetizing power, energy could not flow through the core of a transformer or across the gap of an induction motor. The unit of measurement of this power is the kilovar (KVAR).

The sum of the real and reactive power is the apparent power which is measured in kilovolt-amperes (KVA). Just as the mug must hold both beer and foam, so must wires and transformers carry total KVA power. Power factor is the ratio of the real or working power in

KW to the apparent power in KVA.

Figure 1



The problem is to determine the <u>sizes of the wire, conduit and protective equipment</u> required for installing the equipment in a metal working plant that has a 480 volt, 3-phase, distribution system.

Shown are the production and storage areas. The storage area will not be used for production for at least five years. There are four 80% power factor squirrel cage, across-the-line start motors which are to be connected, namely a 25hp – Code “F”, 15 hp – Code “H”, and two 5 hp – Code “F” motors. (The Code letter indicates starting current to be expected.)

We will use open wire for the feeder, since it can be mounted out-of-the-way up in the truss work. If this plant were a lumber mill, paint shop or similar operation having a possible fire hazard, the feeder would have to be in conduit or armored cable. Normally, for a plant over 50 feet in width, it would be best to run two feeders, one down each side of the plant, spaced about 5 feet in from the walls. For simplification we’ll use one feeder down the center of the building. Also it is best to supply power as near as possible to the center of the load. In this problem, however, we’ll run the feeder from one end of the plant to get a long feeder. The branch circuit distances shown on the sketch include the drops to the motors. The riser from the feeder switches and the motor taps will have to be in conduit.

<u>Solution:- Feeder Circuit.</u>

From Table #1, determine full-load current:-

Motor #1	25 hp	34 A
Motor #2	15 hp	21 A
Motor #3	5 hp	7.6 A
Motor #4	5 hp	7.6 A
Total		70.2 A

Minimum current –carrying capacity of feeder wires equals:-

125% full-load current of largest motor		42 A
100% ‘ ‘ ‘	Motor #2	21 A
100% “ “ “	Motor #3	7.6 A
100% ‘ ‘ ‘	Motor #4	7.6 A
Total		78.2 A

For recommended feeder current-carrying capacity, add 50% normal growth factor for future load:-

150% x 78.2 A = 117.3 A

(Since the storage area will not be used for production within five years, this future load need not be considered.)

From Table #3, the current-carrying capacity of #1 RHW wire in the Riser section of conduit is 130 A.

From Table #4, the conduit size required for 3 - #1 wires is 1 ½."

From Table #2, the current-carrying capacity of #4 RHW wire for the open wiring section is 125 A.

Motor Circuits:

Motor #1 – 25 hp switch located at motor.

Branch circuit current-carrying capacity, minimum required, equals

34 A x 125% = 42 A

From Table #3, wire Size is #8 RHW (45 A)

From Table #4, conduit size for 3 - #8 wires is ¾”.

A disconnect switch at tap-off point is not needed because 45 A (current-carrying capacity of #8 RHW wire) is greater that 1/3 feeder capacity (1/3 x 125 A = 42 A) and because branch is not longer than 25 ft.

Running protection required at motor switch equals:

40 A dual-element fuses in 60 A switch
(Table #5 – Column 2 – Table #6)

However, starters are used where large loads are encountered, where automatic features are required, or where repetitive starting is needed .

They also eliminate single phase operation since all three line contacts are opened together when current increases in one of the protected legs.

Since a magnetic starter is needed for this size motor, a combination starter including a switch will be selected, a NEMA size 2, with 100 A fuse clip (from manufacturer's catalogs). The over-load relay on the starter will provide the motor running protection. The 100 A fuse will provide the short circuit protection.

Motor #2 – 15 hp located in separate room.

Motor disconnect to be located near door to room, in sight of and within 50 ft. of motor, can have motor-running protection,

Branch circuit minimum capacity equals:

26 A (125% of full-load current)

Select #10 RHW (30 A) (From Table #3)

However, 30 A is less than 1/3 feeder capacity (1/3 x 125 A = 42 A). Therefore, we must either use #8 RHW wire (good for 45 A) or install a fused switch at the tap-off. We choose to use #8 RHW wire without a tap-off switch because the branch is only 20 ft long.

Conduit size – 3-#8 wires equals ¾" (Table 4)

This time a breaker type combination starter will be used, NEMA size 2, with 40 A breaker (from Manufacturer's catalogs). This 40 A is the continuous rating of the breaker. Again the overload relay on the starter provides motor running protection. The 40 A breaker provides the short circuit protection.

Beyond the 40 A breaker, current-carrying capacity of the remainder of the branch can be less than 1/3 that of the feeder so #10 RHW wire (30 A) can be used. ¾" conduit is required. This 40 A breaker also protects the #10 wire. The Code allows the next standard size protective device where the current-carrying capacity of a conductor does not correspond with the device rating.

Since some control should be located right at the motor, a push button station should be wired at the motor in parallel with the starter.

Motor #3 **–** 5 hp Code letter "F"

More than 25ft from feeder, starting and protective switch located at motor.

Branch circuit protection (because motor is more than 25 ft from feeder) equals:

25 A fuse in 30 A switch
(Table # 5 – Column 4 – Table #6)

Because we have a tap-off switch, the branch circuit size can be less than 1/3 that of the feeder. It need be only 125% of full-load current.

125% x 7.6 = 9.5 A

Although Table 1 shows that a smaller wire size would serve, it is recommended that no wire be used smaller than #12 in industrial work.

Conduit size for 3-#12 equals ½"

The 25 A fuse in the branch circuit switch will provide the short circuit protection for this circuit. Thus, only a starter need be installed at the motor. It could be a manual type if the motor were started infrequently or if low-voltage protection were not necessary. A manual starter, size 2, good for 7 ½ hp could be selected (from Manufacturer's catalogs)

Motor #4 – 5 hp, 20 ft from feeder**.**

Branch circuit switch is not needed if a circuit is used having a rating greater than 1/3 that of feeder. This is #8 RHW in ¾ " conduit as we determined for Motor #1.

We will assume that this 5 hp motor requires frequent starting so that a magnetic starter is required. We will also need a fused switch (or breaker) to provide short circuit protection. Let's select a switch type combination starter – NEMA size 0 with 30 A fuse clips with 30 A fuses (from manufacturer's catalogs). It is important to select the right size starter so that trouble can be localized at the motor and the feeder will remain operative.

Note: There is 30 ft of feeder between the tap-off for Motors #3 and #4. A branch circuit switch could have been put at tap-off for #3 and smaller wire run all the way to Motor #4. Because this would limit future growth, it was decided to run the #4 feeder all the way.

Voltage Drop – Feeder and Branch Circuit

Voltage drop of feeders should be not more than 2% equals:

2% x 480 V = 9.6 V maximum

We determine current flowing in each part of the feeder and apply the appropriate distances from the beginning of the feeder. The 50 % growth factor should be applied and, to allow for the worst condition, assume growth to be located at end of open-wire feeder.

Voltage drop "per A per 100 ft" - per Table 10 equals:

#2 wire in conduit = .0322 drop
#4 open wire = .0519 drop
Total full-load current of four motors equals:

34 A + 21 + 7.6 + 7.6 = 70 A

In Riser = (70 A + 35 A) x .0322 x 10/100 = 0.34 V

To Motor #1 Tap = (70 A + 35 A) x .0519 x 20/100 = 1.09 V

" " #2 Tap = (36 A + 35 A) x .0519 x 30/100 = 1.11 V
" " #3 Tap = (15 A + 35 A) x .0519 x 20/100 = 0.52 V
' ' #4 Tap = (7.6 A + 35 A) x .0519 x 30/100 = <u>0.64</u> V
3.72 V

Therefore, maximum voltage drop in the feeder as planned with use of #2 and #4 wire is 3.72 V, well below the 2% or 9.6 V limit.

Branch Circuit Drop

Voltage drop in branch circuits should be not more than 1% equals:

1% x 480 V = 4.8 V

Motor #1 (#8 RHW): 34 A x .1120 x 25/100 = .95 V

Motor #2 (#8 and #10 RHW): 21 A x .1120 x 20/100 = .47 V plus
21 A x .1733 x 50/100 = <u>1.82</u> V
2.29 V

Motor #3 (#12 RHW): 7.6 A x .2720 x 40/100 = .83 V

Motor #4 (#8 RHW): 7.6 A x .1120 x 20/100 = .17 V

We find all voltage drops in branch circuits within the allowable limit.

Feeder Protection

Maximum fuse size is sum of fuse rating of motor branch circuit protection for motor with largest starting load plus full load currents of other motors.

Largest starting load is 25 hp motor, code letter "F".
Fuse rating = 300% x 34 A =102 A (round at 100 A).

So the fuse size would be 100 A. (Table 7)

Sum of currents = 100 A + 21 + 7.6 + 7.6 = 136.2 A

Nearest standard fuse size is 150 A

Another rule: Overcurrent protective devices for loads continuing for long periods of time must have a rating not less than 125% of the circuit loading

Full load current including 50% growth equals:

70.2 A + 35.1 A = 105.3 A
125% x 105.3 A = 131 A,
(so the 150 A fuse selection is right)

These 150 A fuses must also protect the conductors.

Current-carrying capacity of #2 wire in conduit = 115 A
Current-carrying capacity of #4 wire in air = 125 A

This 150 A DE fuse is permissible under the code (Art 210.19), to protect the motor feeder. However, closer thermal protection will be obtained by the use of a 125 A DE fuse which will still allow the starting inrush of the motor.

Note**:** If starting in-rush current is abnormal, a 200 A fuse could be used. In some cases where two or more motors start together, larger feeder conductors my be required as well as larger fuses.

For Circuit Breaker

Rating = 250% x 34 A = 85 A (Table 7)

Sum of currents = 85 A + 21 + 7.6 + 7.6 = 121 A

Breaker size = 125 A

Heating Load Problem

Let's assume this same plant has an 80 KW, 3-phase furnace located 100 ft from the distribution panel (including 10 ft riser and 10 ft drop). It is planned to run a branch circuit from the distribution panel for this load using interlocked armor cable.

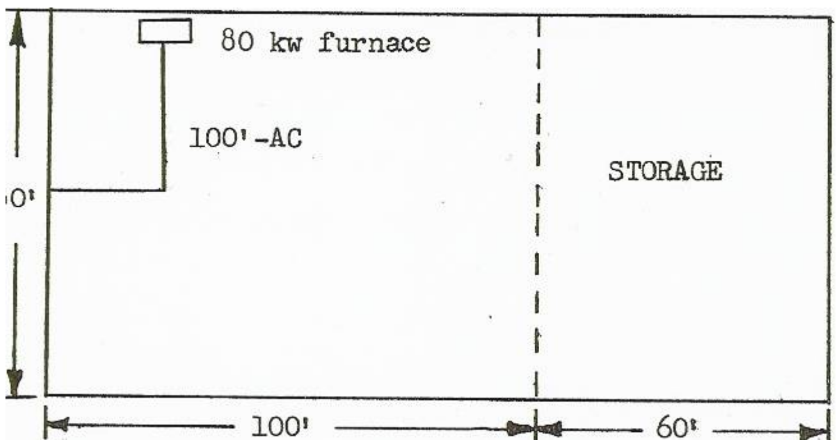


Figure 2

Solution

$$\text{Current per phase} = \frac{\text{Total Wattage}}{\text{Volts} \times 1.73} = \frac{80{,}000\ \text{W}}{440\ \text{V} \times 1.73} = 105\ \text{A}$$

150% x 105 A = 158 A (50% added for growth factor)

Assuming three conductor, varnished-cambric insulated cable with galvanized steel armor, #1/0 size has a current-carrying capacity of 155 A (Table #11) This matches the load plus 50% growth, close enough.

Voltage Drop

The voltage drop factor for three conductors in iron conduit can be used for the factor for galvanized wrapped armor cable. (If it had been aluminum wrapped, conductors in non-magnetic conduit would have been used.)

Drop = 158 A x .0208 x 100/100 = 3.28 V

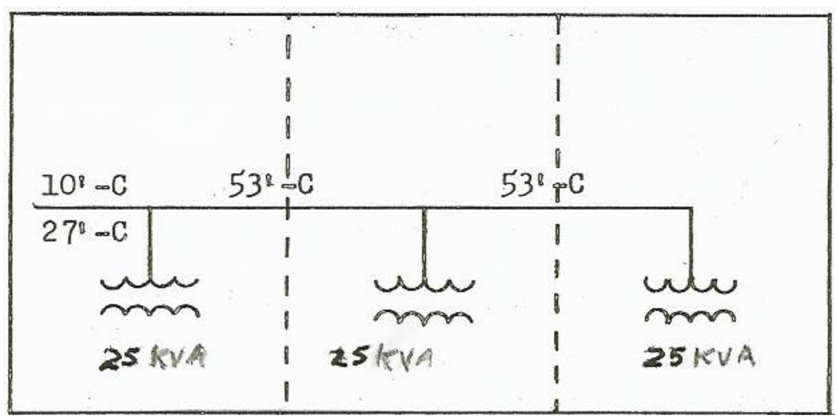
(Table #10, 100% power factor)

Allowable drop = 3% x 480 V = 14.4 V

Feeder Protection

There are no starting currents to consider so the circuit should be protected by a fuse or breaker set at rated current-carrying capacity (155 A) of the #1/0 RHW wire. Since the standard rating of the protective device doesn't correspond with the capacity of the wire, the next standard rating is permissible. This is a 175 A breaker or a 200 A switch fused at 175 A. Furnace protection calls for 125 A fuses in a 200 A switch or 125 A breaker

Lighting Load



0 54 107 160

Figure 3

Let's assume the manufacturing area will have about 50-60 FC of lighting requiring 32 KW and the storage area about 25 FC with 10 KW. However, because the storage area may be used for production purposes in five years, and because we have to wire the area for 25 FC, we might just as well wire it now for the 60-120 FC level. This would increase the storage area lighting load to 19.2 KW for a lighting total of 51.2 KW.

We will also want to supply about 5 FC for convenience outlets for small tools. These can be supplied from the lighting circuit. Three 25 KVA, 480/120/240 V single phase transformers will be supplied from one three-phase feeder. Incidentally, where at all possible, the lighting circuit should be kept separate from motor and heating circuits when the loads are of a fluctuating nature.

The transformer feeder will run down the center of the plant and each of the three transformers with their disconnect switches will be spotted to cover about 1/3 of the area. There will be a 10 ft riser section and a short 5 ft run to the transformers since they will be located up in the truss-work. Wire in conduit will be used.

Solution

$$\text{Phase Current} = \frac{75{,}000 \text{ VA}}{440 \text{ V} \times 1.73} = 98.5 \text{ A}$$

(Remember we do not apply the 50% growth factor to lighting feeders. Should lighting levels be increased to say 120 FC for greater efficiency, a new feeder could be installed to carry additional load.)

#2 RHW will carry 115 A in conduit (Table #3)

#3 RHW wire carries 100 A, but the size is uncommon, so we choose #2.

Conduit size = 1 ¼" (Table #4)

Voltage Drop

For fluorescent lighting, use the 90% factor figures in the voltage drop table. Voltage drop for most distant transformer is –

Riser	98.5 A x .0339 x 10/100	= .33 V
To #1 Transformer Tap	98.5 A x .0339 x 27/100	= .90 V
To #2 " " "	98.5 A + 57 A x .0339 x 53/100	= 1.40 V
To #3 " " "	57 A x .0392 x 53/100	= 1.18 V
Tap to #3 Transformer	57 A x .0392 x 5/100	= .11V
		3.92V

Allowable voltage drop for this transformer feeder is 2% or 9.6 V (the same as any power or heating feeder). We are well within the limit with #2 RHW in conduit. It should be noted that the voltage drop for the 120/240 V conductors from the transformers to the lighting panelboards should be held to a maximum of 1%.

The feeder protective device should be fused for the capacity of the wire (115 A for #2 RHW in conduit). This requires a 125 A fuse in a 200 A switch. The breaker rating would be 125 A. The transformer tap-off switches will be 60 A with 60 A fuses (De-rate switch for 80% for continuous type load)

Note: There are tables available and special slide rules by use of which this problem could have been solved much easier and faster. This problem was solved arithmetically to gain an understanding of the fundamentals involved although in most instances it is more practical to use one of the shortcut methods.

Electric Service Entrance

Having determined the electric power, heating and lighting requirements, the service entrance equipment may now be considered. The service entrance may be defined as the entrance conductors and necessary equipment to control the electrical supply to a building. The necessary equipment includes the switchgear, supply bus, ad connectors. Equipment controlling the service must be located at the point of entry.

A maximum of six feeder circuit switches may be used at the service entrance, except that when a main disconnect is used, the number of feeder circuits may be increased. This main disconnect must be sized to provide adequate protection to the supply bus. The sixth switch may be used to feed a secondary bus from which additional feeders up to six may be fed without a main disconnect.

If one entrance supply bus is insufficient to meet growth needs, another similar bus may be added right beside the existing one. Main switches must be provided for both entrance circuits.

Circuit breakers are used for the service just as switches and fuses are. They provide more flexibility, safety, and better protection from such faults as undervoltage and single phasing. Frequently, they are combined in a built-up panelboard as part of the service entrance. They make a much neater installation and are preferred in most cases.

If, by necessity, the point of entry must be a distance away from the control device and the entrance conduit exposed, this conduit may be encased by two inches of cement or fireproof plaster.

Always plan service entrance requirements to include future expansion of power, heating and lighting loads.

The sum of cross sectional areas of all contained conductors at any cross section of a wireway or trough shall not exceed 20% of the interior cross sectional area of the wireway.

In addition to these rules, the diversity and demand which would be encountered in the system must also be considered

Diversity

Diversity means that **all** motors win **not** be running at full load at one time**. All** lights in the plant will probably **not** be on at one time. The heating load which is thermostatically controlled will be cycling. This is diversity.

Diversity Factor.

Average diversity figures have been developed for various types of equipment. These are expressed in percentages and are known as **diversity factors**. (Table #11) Lots of judgment must be used in applying diversity factors and the figures varied in the light of information on what actual practice will be.

Although there may be diversity between several feeders, this diversity factor is usually considered to be 100% to be on the safe side.

Demand

The estimated demand on the feeder is obtained by multiplying the diversity factor by the connected load. Load growth, however, must be included for sizing the service entrance or the substation.

Example:

Having considered the various plant loads earlier, we now must determine the service entrance requirements. The following data has already been determined:

	Load		Feeder			Protection		
		With 50%		Armor				
	Actual	Growth	Open	Cond,	Cable	Switch	Fuse	Breaker
Motors	70	105.3	#4	#2	---	200 A	150 A	125 A
Heating	105	158	---		#1/0	200 A	175 A	175 A
Lighting	98.5	98.5	---	#2	---	200 A	125 A	125 A
Total	273.5A	361.8A						

Applying diversity factors from Table 8 to these load figures (including growth):

Motors	105.3 A	x	50%	=	50 A	(rounded)
Heating	158 A	x	80%	=	126 A	
Lighting	98.5 A	x	80%	=	79 A	
					255 A	

255A would then be the load for which we should size the service entrance, assuming there will be no plant expansion within five years.

Referring to Table #3, we see that 250 MCM or 350 MCM RHW cable will do the job. However, we choose 3-500 MCM. Here's why:- we have used only three spaces on the supply bus and we are permitted six. Three 500 MCM's provide spare capacity of 125 A or 49%. This is food practice since industrial use of power has been doubling every 10 years.

Conduit size is the same 3" for 3-500 MCMs as it is for 3-350 MCMs.

Installation cost would be the same and the difference in material cost would not be significant compared to the rest of the system.

Wire Trough should be 6" x 8" for either 3-#500 MCM or 3-#350 MCM.

Length of the Trough wireway should be 6' to 8' long depending n switch frame sizes.

Instead of a Trough, a preferred service entrance installation consists of a bus duct and a built-up panelboard. A six-position cabinet would allow three spaces for future feeders.

One-Line Diagram

When it comes time to modernize an existing electrical system or to design an entirely new system, an invaluable tool is a good up-to-date **one-line diagram** of the system. It will be especially valuable when planning additions to an existing system or modernizing it step by step. A one-line diagram indicates by single lines and standard symbols the course and component parts of an electric circuit of system of circuits.

The following items, if given special attention during preparation will help to insure complete, accurate, and easily interpreted diagrams:

1. Maintain Relative Geographic Relations

   As far as practical, approximate relative position of components should be maintained.

2. Avoid Duplication

   A one-line diagram is a sort of diagram shorthand and for this reason every line, symbol, figure, and letter has a definite meaning. Therefore, the duplication of names should be carefully avoided.

3. Use Standard Symbols:- Table #9
4. Show all known facts

   No detail within the scope of the diagram should be considered as unimportant, and the rule to be followed should be – when in doubt, show it. Use of the following check list may help avoid the omission of some important details:

   a. Manufacturer's type and rating of devices
   b. Ratios of current and potential transformers, taps to be used on multi-ratio transformers, and connections of double current transformers.
   c. Connections of power transformer windings.
   d. Circuit breaker ratings in volts and amperes, the interrupting rating, type and number of trip coils on circuit breaker.
   e. Switch and fuse ratings in volts and amperes.
   f Functions of relays.
   g. Ratings of machines and power transformers.
   h. Size and type of conductors.

i. Voltage, phase, and frequency of all incoming circuits, indicate wye or delta system , grounded or ungrounded.

5. Show Future Plans

Future plans should be set forth in the diagram, either diagrammatically or by explanatory notes.

6. Include Correct Title Data

Care should be exercised in the assignment of titles to one-line diagrams to assure that they accurately identify the intallation without confusing it with another job.

One other important point concerning one-line diagrams which is actually a warning to anyone responsible for preparing them:- Tell what you know on the one-line sketch, but nothing which you do not know.

Voltage Selection

Nominal System and Equipment Voltage Ratings.

It may be confusing that there are differences between the voltage ratings of electrical systems and various types of electrical equipment; i.e., a 440 V motor is used on a 480 V system. System voltages are no-load voltages. This voltage is decreased by the drop through the transformer and conductor which varies with load so that slightly lower voltage is available at the point of use. Data on Table 12 helps to clarify the ratings.

Delta and Wye Voltage Systems.

In the delta connection, (Figure 4), which is the most common three-phase three-wire system, the voltage between each pair of line wires is the actual transformer winding volts

An attempt should be made to balance single-phase loads across all three phase of the system to avoid the necessity of increasing the ratings of one of the three transformers. If one three-phase transformer is used, the entire transformer must be larger to accommodate unbalanced loading than when a balanced condition exists.

In a three-phase, three –wire connection, the voltage between each pair of line wires equals square-root-of-3 times the transformer winding voltage. Individual single-phase loads can be balanced across the three phases. However, this is not recommended because one of the loads might be removed, causing a current unbalance which would probably open the protective fuses.

When unbalanced loads are expected, the three-phase, four-wire wye system is used as in Figure 5. This system also provides a line to neutral voltage which equals the line voltage divided by the square-root-of-3. This is also the transformer winding voltage. The grounded neutral carries any unbalance in the system.

Selection of Proper Plant Voltages.

Advantage should be taken of decreased circuit investment, lower electrical losses, and better voltage regulation by power as close to actual loads as possible at relatively higher voltages.

When low-voltage feeder lengths are short so that voltage drops are not excessive and when foreseeable loads do not exceed approximately 1,000 KVA at 480 V (1200 A) or 500 KVA at 240 V (1200 A), the system can be supplied direct from the power company service. However, 240 V is not desirable as will shown later.

240 Volts Versus 480 Volts

Probably the two most common secondary voltages to compare are 240 and 480. A majority of smaller industries and larger plants with small or medium size motor loads can utilize either 240 or 480 systems.

Economics favor the selection of a 480 V system over a 240 V system in a typical plant. Motor costs are the same and unit-substation costs will not differ greatly; however, starters and wiring favor the 480 V system. This indicates that a 480 V system is the most economical system to select. A 600 V system would probably show a greater economy. However, 550 V or 575 V equipment is not as readily available as 480 V, thus it is seldom used except in certain industries such as paper and textile.

How To Shift From 240 Volts To A 480 Volt system

Many plants now have 240 V and are faced with the question of shifting to 480 V. Before converting or modernizing a system, consideration should be given to existing and obsolete equipment, plant processes, and possible expansion. A study may indicate changing only portions of a plant to 480 V while maintaining 240 V until such time as the conversion can take place. In this case, the 240 V equipment can be supplied through step-down transformers. This is especially true where primary distribution is involved.

If the motors are of recent vintage, they are reconnectable for 440 V. In general, motor starters can be converted by the installation of new thermal trips and new operating coils on the contactor as long as the hp rating is unchanged.

Making this conversion is a good time to replace overloaded motors and to change the underloaded motors which contribute to poor system power factor.

If the plant has 120 V lighting, then 4/1 transformers would be required. If the lighting were 240 V, then a decision would have to be made whether to use 2/1 transformers or the center tap of the 480 V power transformer.

Heating loads create another problem. Sometimes 240 V heating elements can be placed in series for 480 V. Otherwise, 2/1 step-down transformers are required.

Conductors, safety switches, and breakers can utilize 480 V without change and it will be possible to carry twice the load thus permitting expansions at no additional cost. This saving will help offset a portion of the motor control cost.

The major reason for converting to the 480 V system is to reduce future costs of equipment such as unit-substations, control, wiring , and to get better voltage regulation of the present system at minimum cost.

Wye Voltages

So far, we have considered the 240 and 480 V delta secondary voltages. The wye voltages that can be obtained are shown if Figure 7.

120/208 Volt Wye

The 120/208 V system is generally applied for commercial use, as 120 V single phase is available for lighting and 208 V three phase can be used for small motors. This system is used rather infrequently in industry because 440 V equipment is more economical for large motor loads.

240/416 Volt Wye

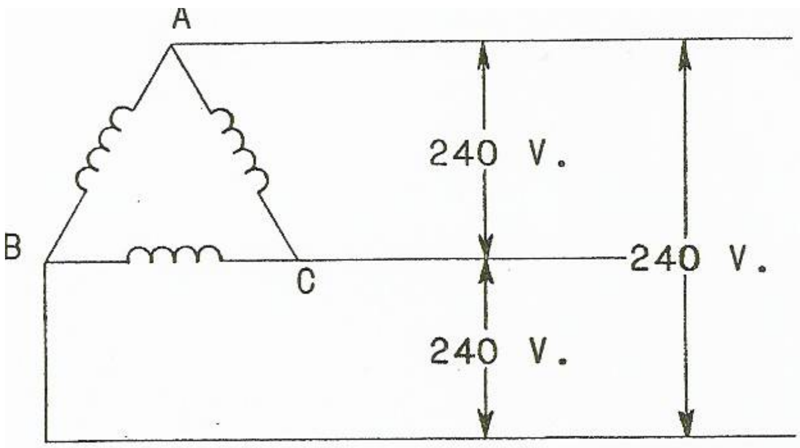
The 240/416 V system has the advantage of being able to handle twice the load compared with the 120/208 V system for the same size conductors, switches and breakers. It finds its use in offices which have large 240 V lighting loads and not much motor load at 440 V. Standard 240 V transformers are used. Of course, 120 V convenience outlets must be served from 240-120/240 V step-down transformers.

265/460 Volt and 277/480 Volt Wye

The 265/480 V Wye and the 277/480 V wye systems are practically the same, the only difference being that 265/460 V is supplied by standard 240 V transformers, using two 5% taps to raise the voltage to 265, whereas the 277/480 V is supplied by a transformer designed for that voltage. The system fits industrial plants very well because of its ability to adequately operate large 440 V motors. The cost of this system may be about 25% less than that of a 120/240c system.

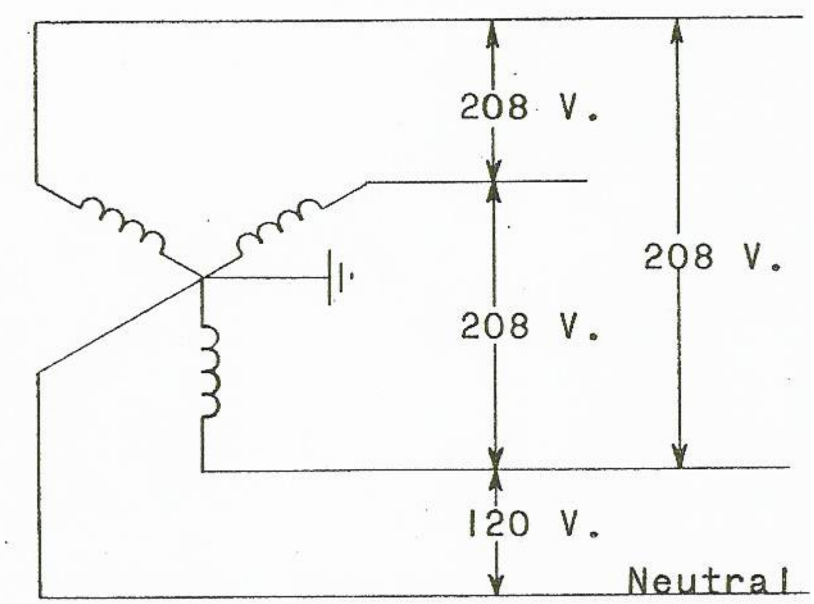
Voltage Summary

The savings and improved voltage regulation using 480 V over 208 V and 240 v indicates that 480 V is the preferred voltage for low voltage in industrial plants. As a result, equipment manufacturers are standardizing more and more on 480 V



240 Volts, 3 Phase, 3 Wire

FIGURE 4



120/208 Volts, 3 Phase, 4 Wire

FIGURE 5

Power Factor Improvement.

As mentioned earlier, power factor is the ratio of actual power to apparent power, or watts to volt-amperes expressed as a percentage. A high power factor is very important for efficient operation of electrical systems.

Improvement of power factor may be divided into two classifications:

- one in which equipment operates at unity power factor, and the
- second in which devices are used which supply leading current.

Unity Power Factor Equipment

!. Unity power factor synchronous motors.

2. Unity power factor capacitor motors.
3. Incandescent lamps.
4. Resistance heaters and other non-inductive loads.

Adding this type of equipment to the system improves the power factor of the system. The magnetizing current remains the same, but the total actual power becomes greater in proportion to the total apparent power.

Leading Power Factor Equipment

This type of power equipment, capable of supplying leading current to the system to which it is connected, includes:

1. Synchronous motor, overexcited to give a leading power factor.

2. Synchronous condenser which is the same as a synchronous motor except that is used only for power factor correction and does not carry any mechanical load.

3. Synchronous or rotary converter to supply direct current from an alternating current circuit. When the converter is lightly loaded it can be operated at leading power factor by overexciting the fields.

4. Capacitor, a device that has the property of supplying magnetizing current to the load. Efficiency of capacitors is high, having losses less than one-half of 1% of their KVA rating.

Capacitors can be applied at various points throughout the system. The most effective location is at the motor or point of use. If they are installed at a central location, overvoltage then the load drops should be guarded against.

Sizing of Capacitors

To improve power factor it is necessary to determine the size of capacitors needed. This can be done by calculation, by graphic determination, or by tables. As proposed in this Course, the simpler and accurate method of determining the required capacitors can be found in Table 13.

In addition, Tables 13a and 13b shows the maximum capacitor rating that should be switched with motors.

For example, what amount of capacitors is needed to raise the power factor of a 20 KW load from 80% to 90%?

The factor from Table 13 is .266, which when multiplied by 20 KW gives 5.32 KVAR. The standard capacitor size selected is 5 KVAR which will result in slightly less than 90%(close enough)

Capacitor Economics

The installation of capacitors at the point of use, reduces the current drawn from the system. This results in lower voltage drop, less conductor size required, and less transformer capacity required, as well as a reduction in the power cost (depending on the power rate applied).

Table 430.249 Full-Load Current, Two-Phase Alternating-Current Motors (4-Wire)

The following values of full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Current in the common conductor of a 2-phase, 3-wire system will be 1.41 times the value given. The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

	Induction-Type Squirrel Cage and Wound Rotor (Amperes)				
Horsepower	115 Volts	230 Volts	460 Volts	575 Volts	2300 Volts
½	4.0	2.0	1.0	0.8	—
¾	4.8	2.4	1.2	1.0	—
1	6.4	3.2	1.6	1.3	—
1½	9.0	4.5	2.3	1.8	—
2	11.8	5.9	3.0	2.4	—
3	—	8.3	4.2	3.3	—
5	—	13.2	6.6	5.3	—
7½	—	19	9.0	8.0	—
10	—	24	12	10	—
15	—	36	18	14	—
20	—	47	23	19	—
25	—	59	29	24	—
30	—	69	35	28	—
40	—	90	45	36	—
50	—	113	56	45	—
60	—	133	67	53	14
75	—	166	83	66	18
100	—	218	109	87	23
125	—	270	135	108	28
150	—	312	156	125	32
200	—	416	208	167	43

TABLE 1

Table 430.250 Full-Load Current, Three-Phase Alternating-Current Motors

The following values of full-load currents are typical for motors running at speeds usual for belted motors and motors with normal torque characteristics.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

	Induction-Type Squirrel Cage and Wound Rotor (Amperes)							Synchronous-Type Unity Power Factor* (Amperes)			
Horsepower	115 Volts	200 Volts	208 Volts	230 Volts	460 Volts	575 Volts	2300 Volts	230 Volts	460 Volts	575 Volts	2300 V
½	4.4	2.5	2.4	2.2	1.1	0.9	—	—	—	—	—
¾	6.4	3.7	3.5	3.2	1.6	1.3	—	—	—	—	—
1	8.4	4.8	4.6	4.2	2.1	1.7	—	—	—	—	—
1½	12.0	6.9	6.6	6.0	3.0	2.4	—	—	—	—	—
2	13.6	7.8	7.5	6.8	3.4	2.7	—	—	—	—	—
3	—	11.0	10.6	9.6	4.8	3.9	—	—	—	—	—
5	—	17.5	16.7	15.2	7.6	6.1	—	—	—	—	—
7½	—	25.3	24.2	22	11	9	—	—	—	—	—
10	—	32.2	30.8	28	14	11	—	—	—	—	—
15	—	48.3	46.2	42	21	17	—	—	—	—	—
20	—	62.1	59.4	54	27	22	—	—	—	—	—
25	—	78.2	74.8	68	34	27	—	53	26	21	—
30	—	92	88	80	40	32	—	63	32	26	—
40	—	120	114	104	52	41	—	83	41	33	—
50	—	150	143	130	65	52	—	104	52	42	—
60	—	177	169	154	77	62	16	123	61	49	12
75	—	221	211	192	96	77	20	155	78	62	15
100	—	285	273	248	124	99	26	202	101	81	20
125	—	359	343	312	156	125	31	253	126	101	25
150	—	414	396	360	180	144	37	302	151	121	30
200		552	528	480	240	192	49	400	201	161	40
250	—	—	—	—	302	242	60	—	—	—	—
300	—	—	—	—	361	289	72	—	—	—	—
350	—	—	—	—	414	336	83	—	—	—	—
400	—	—	—	—	477	382	95	—	—	—	—
450	—	—	—	—	515	412	103	—	—	—	—
500	—	—	—	—	590	472	118	—	—	—	—

*For 90 and 80 percent power factor, the figures shall be multiplied by 1.1 and 1.25, respectively

TABLE 2

Article 310 - Conductors for General Wiring

Table 310.17 Allowable Ampacities of Single-Insulated Conductors Rated 0 Through 2000 Volts in Free Air, Based on Ambient Air Temperature of 30°C (86°F)

	Temperature Rating of Conductor (See Table 310.13.)						
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
Size AWG or kcmil	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			Size AWG or kcmil
18	—	—	18	—	—	—	—
16	—	—	24	—	—	—	—
14*	25	30	35	—	—	—	—
12*	30	35	40	25	30	35	12*
10*	40	50	55	35	40	40	10*
8	60	70	80	45	55	60	8
6	80	95	105	60	75	80	6
4	105	125	140	80	100	110	4
3	120	145	165	95	115	130	3
2	140	170	190	110	135	150	2
1	165	195	220	130	155	175	1
1/0	195	230	260	150	180	205	1/0
2/0	225	265	300	175	210	235	2/0
3/0	260	310	350	200	240	275	3/0
4/0	300	360	405	235	280	315	4/0
250	340	405	455	265	315	355	250
300	375	445	505	290	350	395	300
350	420	505	570	330	395	445	350
400	455	545	615	355	425	480	400
500	515	620	700	405	485	545	500
600	575	690	780	455	540	615	600
700	630	755	855	500	595	675	700
750	655	785	885	515	620	700	750
800	680	815	920	535	645	725	800
900	730	870	985	580	700	785	900
1000	780	935	1055	625	750	845	1000
1250	890	1065	1200	710	855	960	1250
1500	980	1175	1325	795	950	1075	1500
1750	1070	1280	1445	875	1050	1185	1750
2000	1155	1385	1560	960	1150	1335	2000
	CORRECTION FACTORS						
Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp. (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–77
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	—	0.58	0.71	132–140
61–70	—	0.33	0.58	—	0.33	0.58	141–158
71–80	—	—	0.41	—	—	0.41	159–176

See 240.4D

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TABLE 3

Table 310.16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size AWG or kcmil	Temperature Rating of Conductor (See Table 310.13.)						Size AWG or kcmil
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14*	20	20	25	—	—	—	—
12*	25	25	30	20	20	25	12*
10*	30	35	40	25	30	35	10*
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000
	CORRECTION FACTORS						
Ambient Temp. (°C)	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp. (°F)
21–25	1.08	1.05	1.04	1.08	1.05	1.04	70–77
26–30	1.00	1.00	1.00	1.00	1.00	1.00	78–86
31–35	0.91	0.94	0.96	0.91	0.94	0.96	87–95
36–40	0.82	0.88	0.91	0.82	0.88	0.91	96–104
41–45	0.71	0.82	0.87	0.71	0.82	0.87	105–113
46–50	0.58	0.75	0.82	0.58	0.75	0.82	114–122
51–55	0.41	0.67	0.76	0.41	0.67	0.76	123–131
56–60	—	0.58	0.71	—	0.58	0.71	132–140
61–70	—	0.33	0.58	—	0.33	0.58	141–158
71–80	—	—	0.41	—	—	0.41	159–176

* See 240.4(D).

TABLE 4

ANNEX C AnnexC: Tables

Table C.8 Maximum Number of Conductors or Fixture Wires in Rigid Metal Conduit (RMC)
(Based on Table 1, Chapter 9)

		CONDUCTORS											
	Conductor Size	Metric Designator (Trade Size)											
Type	(AWG/ kcmil)	16 (½)	21 (¾)	27 (1)	35 (1¼)	41 (1½)	53 (2)	63 (2½)	78 (3)	91 (3½)	103 (4)	129 (5)	155 (6)
RHH, RHW, RHW-2	14	4	7	12	21	28	46	66	102	136	176	276	398
	12	3	6	10	17	23	38	55	85	113	146	229	330
	10	3	5	8	14	19	31	44	68	91	118	185	267
	8	1	2	4	7	10	16	23	36	48	61	97	139
	6	1	1	3	6	8	13	18	29	38	49	77	112
	4	1	1	2	4	6	10	14	22	30	38	60	87
	3	1	1	2	4	5	9	12	19	26	34	53	76
	2	1	1	1	3	4	7	11	17	23	29	46	66
	1	0	1	1	1	3	5	7	11	15	19	30	44
	1/0	0	1	1	1	2	4	6	10	13	17	26	38
	2/0	0	1	1	1	2	4	5	8	11	14	23	33
	3/0	0	0	1	1	1	3	4	7	10	12	20	28
	4/0	0	0	1	1	1	3	4	6	8	11	17	24
	250	0	0	0	1	1	1	3	4	6	8	13	18
	300	0	0	0	1	1	1	2	4	5	7	11	16
	350	0	0	0	1	1	1	2	4	5	6	10	15
	400	0	0	0	1	1	1	1	3	4	6	9	13
	500	0	0	0	1	1	1	1	3	4	5	8	11
	600	0	0	0	0	1	1	1	2	3	4	6	9
	700	0	0	0	0	1	1	1	1	3	4	6	8
	750	0	0	0	0	0	1	1	1	3	3	5	8
	800	0	0	0	0	0	1	1	1	2	3	5	7
	900	0	0	0	0	0	1	1	1	2	3	5	7
	1000	0	0	0	0	0	1	1	1	1	3	4	6
	1250	0	0	0	0	0	0	1	1	1	1	3	5
	1500	0	0	0	0	0	0	1	1	1	1	3	4
	1750	0	0	0	0	0	0	1	1	1	1	2	4
	2000	0	0	0	0	0	0	0	1	1	1	2	3
TW	14	9	15	25	44	59	98	140	216	288	370	581	839
	12	7	12	19	33	45	75	107	165	221	284	446	644
	10	5	9	14	25	34	56	80	123	164	212	332	480
	8	3	5	8	14	19	31	44	68	91	118	185	267
RHH*, RHW*, RHW-2*, THHW, THW, THW-2	14	6	10	17	29	39	65	93	143	191	246	387	558
RHH*, RHW*, RHW-2*, THHW, THW	12	5	8	13	23	32	52	75	115	154	198	311	445
	10	3	6	10	18	25	41	58	90	120	154	242	350
RHH*, RHW*, RHW-2*, THHW, THW, THW-2	8	1	4	6	11	15	24	35	54	72	92	145	209

(continued)

TABLE 5

For running protection of motors, see Section 430-32. For setting of motor-branch-circuit protective devices, see Tables in Sections 430-152 and 430-153. For grouping of small motors under the protection of a single set of sizes, see Section 430-53. These values are in accordance with Sections 430-6, 430-22, 430-32, 430-34, 430-52, 430-59, except as follows: The current values in Column 1 are to be taken from Tables 430-147 through 430-150, including footnotes, but the values shown for running protection in Columns 2 and 3 must be modified if nameplate full load current values are different, as vided in Section 430-6. The current values shown in Columns 2 and 3 be reduced by 8 per cent for all motors other than open type motors mark have a temperature rise not over 40°C. as required by Section 430-32. certain exceptions to the values in Columns 4, 5, 6, and 7, see Sections 43 and 430-59. See Section 430-53 for values to be used for several motor one branch circuit.

Col. No. 1	2	3	4		5		6		7	
			Maximum Allowable Rating or Setting of Branch Circuit Protective Devices							
Full load current rating of motor amperes	For Running Protection of Motors		**With Code Letters** Single phase, squirrel cage and synchronous. Full voltage, resistor or reactor starting, Code letters F to V inclusive. **Without Code Letters** Same as above.		**With Code Letters** Single phase, squirrel cage and synchronous. Full voltage, resistor or reactor start, Code letters B to E inclusive. Auto transformer start, Code letters F to V inclusive. **Without Code Letters** (Not more than 30 Amperes) squirrel cage and synchronous, auto transformer start, high reactance squirrel cage.*		**With Code Letters** Squirrel cage and synchronous auto transformer start, Code letters B to E inclusive. **Without Code Letters** (More than 30 amperes) Squirrel cage and synchronous auto transformer start, high reactance squirrel cage.*		**With Code Letters** All motors code letter A. **Without Code Lette** DC and wound rotor motors.	
	Maximum rating of nonadjustable protective devices. Amperes	Maximum setting of adjustable protective devices. Amperes	Fuses	Circuit Breakers (Non-adjustable Overload Trip)	Fuses	Circuit Breakers (Non-adjustable Overload Trip)	Fuses	Circuit Breakers (Non-adjustable Overload Trip)	Fuses	Circu Break (Non-ad able O load T
1	2	1.25	15	15	15	15	15	16	15	15
2	3	2.50	15	15	15	15	15	16	15	15
3	4	3.75	15	15	15	15	15	15	15	15
4	6	5.0	15	15	15	15	15	15	15	15
5	8	6.25	15	15	15	15	15	15	15	15
6	8	7.50	20	15	15	15	15	15	15	15
7	10	8.75	25	20	20	15	15	15	15	15
8	10	10.0	25	20	20	20	20	20	15	15
9	12	11.25	30	30	25	20	20	20	15	15
10	15	12.50	30	30	25	20	20	20	15	15
11	15	13.75	35	30	30	30	25	30	20	20
12	15	15.00	40	30	30	30	25	30	20	20
13	20	16.25	40	40	35	80	30	30	20	20
14	20	17.50	45	40	35	30	30	30	25	30
15	20	18.75	45	40	40	80	30	30	25	30
16	20	20.00	50	40	40	40	35	40	25	30
17	25	21.25	60	50	45	40	35	40	30	30
18	25	22.50	60	50	45	40	40	40	30	30
19	25	23.75	60	50	50	40	40	40	30	30
20	25	25.00	60	50	50	40	40	40	30	30
22	30	27.50	70	70	60	50	45	50	35	40
24	80	30.00	80	70	60	50	50	50	40	40
26	35	32.50	80	70	70	70	60	70	40	40
28	35	35.00	90	70	70	70	60	70	45	50
30	40	37.50	90	100	80	70	60	70	45	50
32	40	40.00	100	100	80	70	70	70	50	50
34	45	42.50	110	100	90	70	70	70	60	70
36	45	45.00	110	100	90	100	80	100	60	70
38	50	47.50	125	100	100	100	80	100	60	70
40	50	50.00	125	100	100	100	80	100	60	70
42	50	52.50	125	125	110	100	90	100	70	70
44	60	55.00	125	125	110	100	90	100	70	70
46	60	57.50	150	125	125	100	100	100	70	70
48	60	60.00	150	125	125	100	100	100	80	100
50	60	62.50	150	125	125	100	100	100	80	100
52	70	65.00	175	150	150	125	110	125	80	100
54	70	67.50	175	150	150	125	110	125	90	100
56	70	70.00	175	150	150	125	125	125	90	100
58	70	72.50	175	150	150	125	125	125	90	100
60	80	75.00	200	150	150	125	125	125	90	100
62	80	77.50	200	175	175	125	125	125	100	100
64	80	80.00	200	175	175	150	150	150	100	100
66	80	82.50	200	175	175	150	150	150	100	100
68	90	85.00	225	175	175	150	150	150	110	125
70	90	87.50	225	175	175	150	150	150	110	125
72	90	90.00	225	200	200	150	150	150	110	125
74	90	92.50	225	200	200	150	150	150	125	125
76	100	95.00	250	200	200	175	175	175	125	125

TABLE 6

List of Fuses, Switches and Breakers

Fuses			Switches	Non-Adjustable Trip Circuit Breakers	
15 A	100 A	500 A	30 A	15 A	200 A
20 A	110 A	600 A	60 A	20 A	225 A
25 A	125 A	800 A	100 A	30 A	250 A
30 A	150 A	1000 A	200 A	40 A	300 A
35 A	175 A	1600 A	400 A	50 A	350 A
40 A	200 A	2000 A	600 A	70 A	400 A
45 A	225 A	2500 A	800 A	100 A	500 A
50 A	250 A	3000 A	1200 A	125 A	600 A
60 A	300 A	4000 A		150 A	700 A
70 A	350 A	5000 A		175 A	800 A
80 A	400 A	6000 A			
90 A	450 A				

TABLE 7

MAXIMUM RATING OR SETTING OF MOTOR-BRANCH-CIRCUIT PROTECTIVE DEVICES FOR MOTORS MARKED WITH A CODE LETTER INDICATING LOCKED ROTOR KVA

Type of Motor	Per Cent of Full-Load Current		
	Fuse Rating (See also NEC Table 20, Columns 7, 8, 9, 10)	Circuit-Breaker Setting: Instantaneous Type	Circuit-Breaker Setting: Time Limit Type
All AC single-phase and polyphase squirrel cage and synchronous motors with full-voltage, resistor or reactor starting:			
Code Letter A	150	...	150
Code Letter B to E	250	...	200
Code Letter F to V	300	...	250
All AC squirrel cage and synchronous motors with auto-transformer starting:			
Code Letter A	150	...	150
Code Letter B to E	200	...	200
Code Letter F to V	250	...	200

For certain exceptions to the values specified see NEC sections 4342 and 4349. The values given in the last column also cover the ratings of non-adjustable, time-limit types of circuit-breakers which may also be modified as in section 4342.

Synchronous motors of the low-torque, low-speed type (usually 450 RPM or lower), such as are used to drive reciprocating compressors, pumps, etc., which start up unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 per cent of full-load current.

MAXIMUM RATING OR SETTING OF MOTOR-BRANCH-CIRCUIT PROTECTIVE DEVICES FOR MOTORS NOT MARKED WITH A CODE LETTER INDICATING LOCKED ROTOR KVA

Type of Motor	Per Cent of Full-Load Current		
	Fuse Rating (See also NEC Table 20, Columns 7, 8, 9, 10)	Circuit-Breaker Setting: Instantaneous Type	Circuit-Breaker Setting: Time Limit Type
Single-phase, all types	300	...	250
Squirrel-cage and synchronous (full-voltage, resistor and reactor starting)	300	...	250
Squirrel-cage and synchronous (auto-transformer starting)			
Not more than 30 amperes	250	...	200
More than 30 amperes	200	...	200
High-reactance squirrel-cage			
Not more than 30 amperes	250	...	250
More than 30 amperes	200	...	200
Wound-rotor	150	...	150
Direct-current			
Not more than 50 H.P.	150	250	150
More than 50 H.P.	150	175	150

For certain exceptions to the values specified see NEC sections 4342 and 4349. The values given in the last column also cover the ratings of non-adjustable, time-limit types of circuit-breakers which may also be modified as in section 4342.

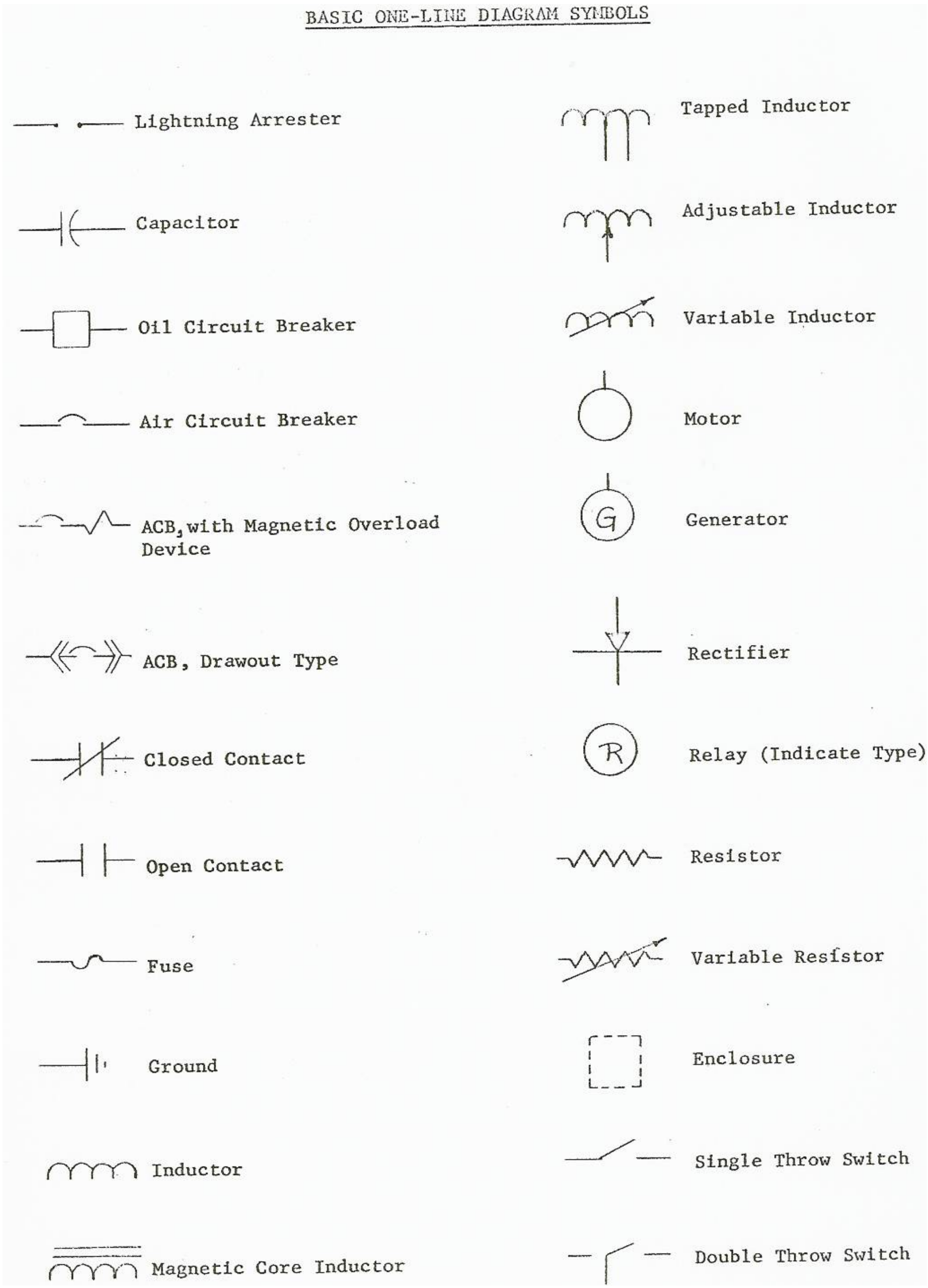
Synchronous motors of the low-torque, low-speed type (usually 450 RPM or lower), such as are used to drive reciprocating compressors, pumps, etc., which start up unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 per cent of full-load current.

TABLE 8

Diversity Factors

Motors General Purpose	30%
Motors Semi-continuous Processes	60%
Motors Continuous Operations	90%
Resistance Heating	80%
Induction Furnaces	80%
Arc Furnaces	100%
Lighting	80%
Arc Welders	30%
Resistance Welders	20%

TABLE 9


BASIC ONE-LINE DIAGRAM SYMBOLS
Lightning Arrester
Capacitor
Oil Circuit Breaker
Air Circuit Breaker
ACB, with Magnetic Overload Device
ACB, Drawout Type
Closed Contact
Open Contact
Fuse
Ground
Inductor
Magnetic Core Inductor
Tapped Inductor
Adjustable Inductor
Variable Inductor
Motor
G
Generator
Rectifier
R
Relay (Indicate Type)
Resistor
Variable Resistor
Enclosure
Single Throw Switch
Double Throw Switch

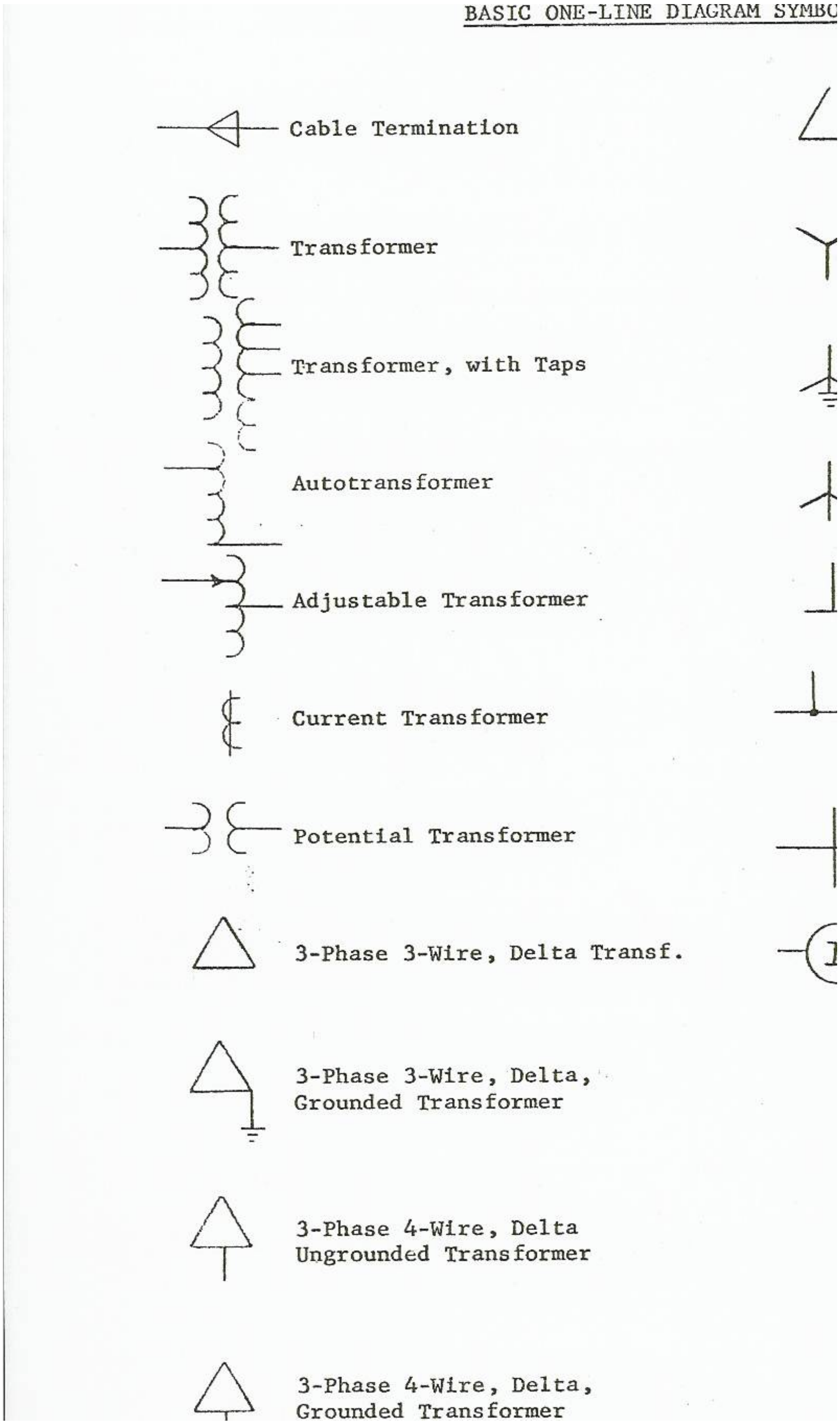

BASIC ONE-LINE DIAGRAM SYMBC
Cable Termination
Transformer
Transformer, with Taps
Autotransformer
Adjustable Transformer
Current Transformer
Potential Transformer
3-Phase 3-Wire, Delta Transf.
3-Phase 3-Wire, Delta,
Grounded Transformer
3-Phase 4-Wire, Delta
Ungrounded Transformer
3-Phase 4-Wire, Delta,
Grounded Transformer

TABLE 10

	WIRE SIZE	AMPERE RATING: Type R, RW, RU, T, TW (60° Wire)	AMPERE RATING: Type RH, RHW (75° Wire)	VOLT LOSS: Direct Current	THREE PHASE - 60 Cycle, lagging power factor					SINGLE PHASE - 60 Cycle, lagging power factor				
					100%	90%	80%	70%	60%	100%	90%	80%	70%	60%
IRON CONDUIT	14	15	15	.6100	.5280	.4800	.4300	.3780	.3260	.6100	.5551	.4964	.4370	.3772
	12	20	20	.3828	.3320	.3030	.2720	.2400	.2080	.3828	.3502	.3138	.2773	.2404
	10	30	30	.2404	.2080	.1921	.1733	.1540	.1340	.2404	.2221	.2003	.1779	.1547
	8	40	45	.1520	.1316	.1234	.1120	.1000	.0880	.1520	.1426	.1295	.1159	.1017
	6	55	65	.0970	.0840	.0802	.0735	.0665	.0590	.0970	.0926	.0850	.0769	.0682
	4	70	85	.0614	.0531	.0530	.0487	.0445	.0400	.0614	.0613	.0562	.0514	.0462
	3	80	100	.0484	.0420	.0425	.0398	.0368	.0334	.0484	.0491	.0460	.0425	.0385
	2	95	115	.0382	.0331	.0339	.0322	.0300	.0274	.0382	.0392	.0372	.0346	.0317
	1	110	130	.0306	.0265	.0280	.0270	.0254	.0236	.0306	.0323	.0312	.0294	.0274
	0	125	150	.0241	.0208	.0229	.0224	.0214	.0202	.0241	.0265	.0259	.0247	.0233
	00	145	175	.0192	.0166	.0190	.0188	.0181	.0173	.0192	.0219	.0217	.0209	.0199
	000	165	200	.0152	.0132	.0157	.0158	.0155	.0150	.0152	.0181	.0183	.0179	.0173
	0000	195	230	.0121	.0105	.0131	.0135	.0134	.0132	.0121	.0151	.0156	.0155	.0152
	250 M	215	255	.0102	.0089	.0118	.0123	.0125	.0123	.0103	.0136	.0142	.0144	.0142
	300 M	240	285	.0085	.0074	.0104	.0111	.0112	.0113	.0086	.0120	.0128	.0130	.0131
	350 M	260	310	.0073	.0063	.0094	.0101	.0105	.0106	.0073	.0108	.0117	.0121	.0122
	400 M	280	335	.0064	.0055	.0087	.0095	.0098	.0100	.0064	.0100	.0110	.0113	.0116
	500 M	320	380	.0051	.0045	.0076	.0085	.0090	.0092	.0052	.0088	.0098	.0104	.0106
	600 M	355	420	.0043	.0038	.0069	.0079	.0085	.0087	.0044	.0080	.0091	.0098	.0101
	700 M	385	460	.0036	.0033	.0064	.0074	.0080	.0084	.0038	.0074	.0086	.0092	.0097
	750 M	400	475	.0034	.0031	.0062	.0072	.0079	.0082	.0036	.0072	.0083	.0091	.0095
	800 M	410	490	.0032	.0029	.0061	.0071	.0076	.0081	.0033	.0070	.0082	.0088	.0093
	900 M	435	520	.0028	.0026	.0057	.0068	.0074	.0078	.0030	.0066	.0078	.0085	.0090
	1000 M	455	545	.0026	.0023	.0055	.0066	.0072	.0076	.0027	.0063	.0076	.0083	.0088
NON-MAGNETIC CONDUIT Lead covered cables or installation in fibre or other non-magnetic conduit, etc.	14	15	15	.6100	.5280	.4790	.4280	.3760	.3240	.6100	.5530	.4936	.4336	.3734
	12	20	20	.3828	.3320	.3020	.2700	.2380	.2055	.3828	.3483	.3112	.2742	.2369
	10	30	30	.2404	.2080	.1910	.1713	.1513	.1311	.2404	.2202	.1978	.1748	.1512
	8	40	45	.1520	.1316	.1220	.1100	.0976	.0851	.1520	.1406	.1268	.1128	.0982
	6	55	56	.0970	.0840	.0787	.0715	.0641	.0562	.0970	.0908	.0825	.0740	.0648
	4	70	85	.0614	.0531	.0517	.0466	.0422	.0374	.0614	.0596	.0538	.0486	.0431
	3	80	100	.0484	.0420	.0410	.0379	.0344	.0308	.0484	.0474	.0438	.0397	.0355
	2	95	115	.0382	.0331	.0326	.0303	.0278	.0250	.0382	.0376	.0350	.0321	.0288
	1	110	130	.0306	.0265	.0266	.0251	.0232	.0211	.0306	.0307	.0289	.0267	.0243
	0	125	150	.0241	.0208	.0216	.0206	.0192	.0176	.0241	.0249	.0237	.0221	.0203
	00	145	175	.0192	.0166	.0176	.0170	.0160	.0148	.0192	.0203	.0196	.0184	.0171
	000	165	200	.0152	.0132	.0145	.0141	.0134	.0126	.0152	.0167	.0163	.0155	.0145
	0000	195	230	.0121	.0105	.0119	.0118	.0114	.0108	.0121	.0137	.0136	.0131	.0125
	250 M	215	255	.0102	.0089	.0105	.0106	.0104	.0100	.0103	.0121	.0122	.0120	.0115
	300 M	240	285	.0085	.0074	.0092	.0094	.0093	.0091	.0086	.0106	.0109	.0107	.0105
	350 M	260	310	.0073	.0063	.0082	.0085	.0084	.0083	.0073	.0094	.0098	.0097	.0096
	400 M	280	335	.0064	.0055	.0075	.0078	.0079	.0078	.0064	.0086	.0090	.0091	.0090
	500 M	320	380	.0051	.0045	.0064	.0069	.0071	.0070	.0052	.0074	.0080	.0082	.0081
	600 M	355	420	.0043	.0038	.0057	.0063	.0066	.0066	.0044	.0066	.0073	.0076	.0076
	700 M	385	460	.0036	.0033	.0053	.0058	.0061	.0063	.0038	.0061	.0067	.0070	.0073
	750 M	400	475	.0034	.0031	.0051	.0056	.0060	.0061	.0036	.0059	.0065	.0069	.0070
	800 M	410	490	.0032	.0029	.0049	.0055	.0058	.0060	.0033	.0057	.0064	.0067	.0069
	900 M	435	520	.0028	.0026	.0046	.0052	.0055	.0057	.0030	.0053	.0060	.0064	.0066
	1000 M	455	545	.0026	.0023	.0043	.0050	.0054	.0056	.0027	.0050	.0058	.0062	.0064
OPEN WIRING INSTALLATIONS (4" SEPARATION)	14	20	20	.6100	.5280	.4840	.4350	.3840	.3338	.6100	.5593	.5022	.4438	.3849
	12	25	25	.3828	.3320	.3070	.2765	.2460	.2150	.3828	.3543	.3195	.2841	.2480
	10	40	40	.2404	.2080	.1970	.1780	.1590	.1400	.2404	.2258	.2054	.1838	.1614
	8	55	65	.1520	.1316	.1260	.1158	.1050	.0930	.1520	.1457	.1338	.1221	.1075
	6	80	95	.0970	.0840	.0827	.0770	.0707	.0635	.0970	.0955	.0889	.0816	.0734
	4	105	125	.0614	.0531	.0554	.0519	.0483	.0443	.0614	.0640	.0599	.0558	.0512
	3	120	145	.0484	.0420	.0448	.0429	.0405	.0375	.0484	.0517	.0496	.0467	.0433
	2	140	170	.0382	.0331	.0362	.0354	.0337	.0316	.0382	.0418	.0408	.0389	.0365
	1	165	195	.0306	.0265	.0300	.0298	.0286	.0274	.0306	.0347	.0344	.0331	.0316
	0	195	230	.0241	.0208	.0248	.0250	.0245	.0236	.0241	.0287	.0289	.0283	.0273
	00	225	265	.0192	.0166	.0209	.0214	.0211	.0207	.0192	.0241	.0247	.0244	.0239
	000	260	310	.0152	.0132	.0175	.0184	.0185	.0183	.0152	.0202	.0212	.0213	.0211
	0000	300	360	.0121	.0105	.0148	.0158	.0162	.0163	.0121	.0171	.0183	.0187	.0188
	250 M	340	405	.0102	.0089	.0133	.0145	.0150	.0152	.0103	.0154	.0167	.0173	.0175
	300 M	375	445	.0085	.0074	.0119	.0132	.0137	.0140	.0086	.0137	.0152	.0158	.0162
	350 M	420	505	.0073	.0063	.0108	.0121	.0127	.0132	.0073	.0125	.0140	.0147	.0152
	400 M	455	545	.0064	.0055	.0100	.0114	.0120	.0125	.0064	.0116	.0131	.0139	.0145
	500 M	515	620	.0051	.0045	.0089	.0103	.0112	.0115	.0052	.0103	.0119	.0129	.0133
	600 M	575	690	.0043	.0038	.0081	.0095	.0104	.0109	.0044	.0093	.0110	.0120	.0126
	700 M	630	755	.0036	.0033	.0075	.0089	.0098	.0106	.0038	.0087	.0103	.0113	.0121
	750 M	655	785	.0034	.0031	.0074	.0087	.0095	.0102	.0036	.0085	.0100	.0111	.0118
	800 M	680	815	.0032	.0029	.0071	.0086	.0094	.0100	.0033	.0082	.0099	.0108	.0116
	900 M	730	870	.0028	.0026	.0068	.0081	.0091	.0097	.0030	.0078	.0094	.0105	.0112
	1000 M	780	935	.0026	.0023	.0064	.0079	.0087	.0093	.0027	.0074	.0091	.0101	.0108

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TABLE 11

INTERLOCKED ARMOR CABLE CURRENT-CARRYING CAPACITY

Wire Size	Varnished Cambric N.E.C. Rating 30° C.	Thermoplastic Jacket IPCEA Rating 40° C.	Geoprene* IPCEA Rating 40° C.	AVAI* IPCEA Rating 60° C.
12	30	-	-	-
10	40	-	38	-
8	50	52	50	-
6	70	69	65	-
4	90	91	86	92
2	120	121	113	122
1	140	139	129	141
1/0	155	161	147	163
2/0	185	185	171	187
3/0	210	213	194	216
4/0	235	244	221	247
250	270	270	245	273
350	325	334	303	338
500	405	417	374	423
750	500	529	480	-

* G. E. Trade Names: Geoprene - Wet or dry locations
AVAI - High temperature applications in dry locations

TABLE 12

VOLTAGE RATINGS

Nominal System Voltage	Other Designations of Identical Systems	No-Load Transformer Secondary Rated Voltage	EQUIPMENT NAMEPLATE RATING: Motors and Control	LAMPS: Incandescent	LAMPS: Fluorescent and Mercury	Capaci-tors	Industrial Heating Devices
Single-Phase Systems							
120 or 120/240	110, 115, or 125 110/220 or 115/230	120 or 120/240	115	120 or 125	118	-	120
	220 or 230, 110/220 or 115/230	240 or 120/240	230	230	236	230	240
Three-Phase Systems							
120	110, 115, 125	120	110	120 or 125	118	-	120
120/208 Y	125/216 Y	120/208 Y	208	120 or 208	118	-	-
240	220 or 230	240	220	230 or 250	236	230	240
240/416 Y	-	240/416 Y	440	230	220 or 236	230	240
277/480 Y	-	277/480 Y	440	-	277	460	480
480	440 or 460	480	440	-	480/440	460	480
600	550 or 575	600	550	-	-	575	550

TABLE 13

HOW MANY CAPACITORS DO YOU NEED?

The table below makes it simple for you to find the amount of capacitors needed to improve your power factor from its present level to any desired value.

EXAMPLE

A small machine tool plant used an average of 100 kw at a power factor of 80 percent. The kvar of capacitor necessary to raise the power factor to 95 percent i found by multiplying the factor .421, taken from th table, by 100 kw to get 42 kvar. The nearest standar 460 volt equipment is rated 40 kvar. Of course, tw 20 kvar units could also be used.

POWER-FACTOR IMPROVEMENT

Figures below × kilowatt input = kvar of capacitors required to improve from one power factor to another.

DESIRED POWER FACTOR IN PER CENT

ORIGINAL POWER FACTOR IN PER CENT	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	10
50	0.982	1.008	1.034	1.060	1.086	1.112	1.139	1.165	1.192	1.220	1.248	1.276	1.306	1.337	1.369	1.403	1.442	1.481	1.529	1.590	1.73
51	.937	.962	.989	1.015	1.041	1.067	1.094	1.120	1.147	1.175	1.203	1.231	1.261	1.292	1.324	1.358	1.395	1.436	1.484	1.544	1.68
52	.893	.919	.945	.971	.997	1.023	1.050	1.076	1.103	1.131	1.159	1.187	1.217	1.248	1.280	1.314	1.351	1.392	1.440	1.500	1.64
53	.850	.876	.902	.928	.954	.980	1.007	1.033	1.060	1.088	1.116	1.144	1.174	1.205	1.237	1.271	1.308	1.349	1.397	1.457	1.60
54	.809	.835	.861	.887	.913	.939	.966	.992	1.019	1.047	1.075	1.103	1.133	1.164	1.196	1.230	1.267	1.308	1.356	1.416	1.55
55	.769	.795	.821	.847	.873	.899	.926	.952	.979	1.007	1.035	1.063	1.090	1.124	1.156	1.190	1.228	1.268	1.316	1.377	1.51
56	.730	.756	.782	.808	.834	.860	.887	.913	.940	.968	.996	1.024	1.051	1.085	1.117	1.151	1.189	1.229	1.277	1.338	1.48
57	.692	.718	.744	.770	.796	.822	.849	.875	.902	.930	.958	.986	1.013	1.047	1.079	1.113	1.151	1.191	1.239	1.300	1.44
58	.655	.681	.707	.733	.759	.785	.812	.838	.865	.893	.921	.949	.976	1.010	1.042	1.076	1.114	1.154	1.202	1.263	1.40
59	.618	.644	.670	.696	.722	.748	.775	.801	.828	.856	.884	.912	.939	.973	1.005	1.039	1.077	1.117	1.165	1.226	1.36
60	.584	.610	.636	.662	.688	714	.741	.767	.794	.822	.850	.878	.905	.939	.971	1.005	1.043	1.083	1.131	1.192	1.33
61	.549	.575	.601	.627	.653	.679	.706	.732	.759	.787	.815	.843	.870	.904	.936	.970	1.008	1.048	1.096	1.157	1.29
62	.515	.541	.567	.593	.619	.645	.672	.698	.725	.753	.781	.809	.836	.870	.902	.936	.974	1.014	1.062	1.123	1.26
63	.483	.509	.535	.561	.587	.613	.640	.666	.693	.721	.749	.777	.804	.838	.870	.904	.942	.982	1.030	1.091	1.23
64	.450	.476	.502	.528	.554	.580	.607	.633	.660	.688	.715	.744	.771	.805	.837	.871	.909	.949	.997	1.058	1.20
65	.419	.445	.471	.497	.523	.549	.576	.602	.629	.657	.685	.713	.740	.774	.806	.840	.878	.918	.966	1.027	1.16
66	.388	.414	.440	.466	.492	.518	.545	.571	.598	.626	.554	.682	.709	.743	.775	.809	.847	.887	.935	.996	1.13
67	.358	.384	.410	.436	.462	.488	.515	.541	.568	.596	.624.	.652	.679	.713	.745	.779	.817	.857	.905	.966	1.10
68	.329	.355	.381	.407	.433	.459	.486	.512	.539	.567	.595	.623	.650	.684	.716	.750	.788	.828	.876	.937	1.07
69	.299	.325	.351	.377	.403	.429	.456	.482	.509	.537	.565	.593	.620	.654	.866	.720	.758	.798	.840	.907	1.04
70	.270	.296	.322	.348	.374	.400	.427	.453	.480	.508	.536	.564	.591	.625	.657	.691	.729	.769	.811	.878	1.02
71	.242	.268	.294	.320	.346	.372	.399	.425	.452	.480	.508	.536	.563	.597	.629	.663	.701	.741	.783	.850	.9
72	.213	.239	.265	.291	.317	.343	.370	.396	.423	.451	.479	.507	.534	.568	.600	.634	.672	.712	.754	.821	.9
73	.186	.212	.238	.264	.790	.316	.343	.369	.396	.424	.452	.480	.507	.541	.573	.607	.645	.685	.727	.794	.9
74	.159	.185	.211	.237	.263	.289	.316	.342	.369	.397	.425	.453	.480	.514	.546	.580	.618	.658	.700	.767	.9
75	.132	.158	.184	.210	.236	.262	.289	.315	.342	.370	.398	.426	.453	.487	.519	.553	.591	.631	.673	.740	.8
76	.105	.131	.157	.183	.209	.235	.262	.288	.315	.343	.371	.399	.426	.460	.492	.526	.564	.604	.652	.713	.8
77	.079	.105	.131	.157	.183	.209	.236	.262	.289	.317	.345	.373	.400	.434	.466	.500	.538	.578	.620	.687	.8
78	.053	.079	.105	.131	.157	.183	.210	.236	.263	.291	.319	.347	.374	.408	.440	.474	.512	.552	.594	.661	.8
79	.026	.052	.078	.104	.130	.156	.183	.209	.236	.264	.292	.320	.347	.381	.413	.447	.485	.525	.567	.634	.7
80	.000	.026	.052	.078	.104	.130	.157	.183	.210	.238	.266	.294	.321	.355	.387	.421	.459	.499	.541	.608	.7
81	....	.000	.026	.052	.078	.104	.131	.157	.184	.212	.240	.268	.295	.329	.361	.395	.433	.473	.515	.582	.7
82	....	....	.000	.026	.052	.078	.105	.131	.158	.186	.214	.242	.269	.303	.335	.369	.407	.447	.489	.556	.6
83	....	....	....	.000	.026	.052	.079	.105	.132	.160	.188	.216	.243	.277	.309	.343	.381	.421	.463	.530	.6
84	....	....	....	....	.000	.026	.053	.079	.106	.134	.162	.190	.217	.251	.283	.317	.355	.395	.437	.504	.6
85	....	....	....	....	....	.000	.027	.053	.080	.108	.136	.164	.191	.225	.257	.291	.329	.369	.417	.478	.6
86	....	....	....	....	....	....	....	.026	.053	.081	.109	.137	.167	.198	.230	.265	.301	.343	.390	.451	.5
87	....	....	....	....	....	....	....	....	.027	.055	.082	.111	.141	.172	.204	.238	.275	.317	.364	.425	.5
88	....	....	....	....	....	....	....	....	....	.028	.056	.084	.114	.145	.177	.211	.248	.290	.337	.398	.5
89	....	....	....	....	....	....	....	....	....	....	.028	.056	.086	.117	.149	.183	.220	.262	.309	.370	.5
90	....	....	....	....	....	....	....	....	....	....	....	.028	.058	.089	.121	.155	.192	.234	.281	.342	.4
91	....	....	....	....	....	....	....	....	....	....	....	....	.030	.061	.093	.127	.164	.206	.253	.314	.4
92	....	....	....	....	....	....	....	....	....	....	....	....	....	.031	.063	.097	.134	.176	.223	.284	.4
93	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.032	.066	.103	.145	.192	.253	.3
94	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.034	.071	.113	.160	.221	.3
95	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.037	.079	.126	.187	.3
96	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.042	.089	.150	.2
97	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.047	.108	.2
98	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.061	.2
99	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.1

Recommended Maximum Capacitor Rating When Capacitor and Motor Are Switched as a Unit

MOTOR TYPE K, 440 Volts, Enclosure Open — Including Dripproof and Splashproof, NEMA Design "B" (Normal Starting Torque and Current)

Induction Motor Horse-power Rating	Nominal Motor Speed in RPM and Number of Poles											
	3600 2		1800 4		1200 6		900 8		720 10		600 12	
	KVAR	% AR	KVAR	% AR	KVAR	% AR	KVAR	% AR	KVAR	% AR	KVAR	% AR
2	1	16	1	20	1	22	1	24	..	..	..	..
3	1	10	1	16	1	21	2	24	..	..	..	..
5	1	9	2	16	2	21	2	21	..	..	..	..
7½	1	8	2	13	2	15	4	21	5	29	..	..
10	2	8	2	13	4	15	5	21	5	25	5	30
15	4	8	4	13	5	15	5	13	5	25	5	25
20	4	7	5	9	5	12	5	13	10	25	10	25
25	4	7	5	9	5	11	5	11	10	25	10	25
30	5	7	5	7	5	11	10	11	10	15	10	19
40	5	5	5	7	10	11	10	11	10	15	10	19
50	5	5	10	7	10	9	15	11	20	15	25	19
60	5	5	10	7	10	9	15	11	20	15	30	19
75	10	5	10	7	15	9	15	9	30	15	40	19
100	15	5	20	7	25	9	30	9	40	15	45	17
125	15	5	20	7	30	9	30	9	45	15	50	17
150	15	5	25	6	30	9	40	9	50	13	60	17
200	40	5	40	6	45	8	50	9	70	13	75	17
250	45	5	50	6	50	8	70	9	75	12	90	17
300	50	5	50	6	70	8	70	9	75	11	105	17
350	50	5	50	5	70	8	80	9	80	11	105	17
400	60	5	60	5	70	8	100	9	100	11	110	17
450	60	5	70	5	70	6	100	9	100	11	110	17
500	70	5	90	5	90	6	110	9	120	11	120	17

TABLE 13A

MOTOR TYPE KG, 440 Volts, Enclosure Open — Including Dripproof and Splashproof, NEMA Design "C" (High Starting Torque and Normal Starting Current)

Induction Motor Horse-power Rating	Nominal Motor Speed in RPM and Number of Poles							
	1800 4		1200 6		900 8		720 10	
	KVAR	% AR	KVAR	% AR	KVAR	% AR	KVAR	% AR
3	..	..	2	19	2	30	..	..
5	1	15	2	19	4	26	..	..
7½	2	15	2	15	4	22	..	..
10	2	12	4	12	5	15	..	..
15	4	12	4	12	5	15	..	..
20	4	12	5	12	5	15	..	..
25	5	9	5	9	10	15	..	..
30	5	9	5	9	10	15	..	..
40	10	9	10	9	10	13	..	..
50	10	9	10	9	15	13	..	..
60	10	8	15	9	20	13	20	18
75	15	8	15	9	20	12	30	18
100	20	8	25	9	30	12	40	18
125	20	7	30	8	30	12	50	*18
150	35	7	35	8	45	12	..	..
200	40	7	50	8	70	12	..	..
250	50	7	50	8	80	12	..	..
300	60	7	80	8	80	10	..	..
350	60	7	80	8	80	9	..	..

TABLE 13B