ELECTRICAL TABLES AND ENGINEERING DATA

HAUSMANN AND TOUSLEY

Electrical Tables and Engineering Data

A Book of Useful Tables and Practical Hints for Electricians, Foremen, Salesmen, Solicitors, Estimators, Contractors, Architects and Engineers

By

HENRY C. HORSTMANN

and

VICTOR H. TOUSLEY

Authors of

"Modern Wiring Diagrams," "Modern Electrical Construction," "Practical Armature and Magnet Winding," "Electrician's Operating and Testing Manual," "Modern Illumination, Theory and Practice," "Alternating Current," "Motion Picture Operation, Stage Electrics and Illusions."

ILLUSTRATED

CHICAGO

FREDERICK J. DRAKE & CO.

Publishers

PREFACE

This book is an attempt to furnish electricians generally and others interested in electrical work with a reference and table book which can be conveniently carried in the pocket. It contains no theoretical discussions. Its scope is limited to practical information which is daily called for but seldom available at the time most needed. The matter is arranged in alphabetical order which enables one to find any item with a minimum of delay.

The tables provided assist in the calculation of almost every conceivable problem with which construction men have to deal, and by their use many hours of tedious calculations may be avoided.

THE AUTHORS.

ELECTRICAL TABLES AND ENGINEERING DATA

Acid Fumes.—In places where acid fumes or corrosive vapors may exist, the nature of the vapors will determine the insulation to be used. Consult chemists and Inspection Department having jurisdiction. Conduit work is not favored much in such places, but if it can be shown that the vapors in question are not harmful to the metal it is permissible.

Adapters.—There is no objection to the use of adapters, provided they are of approved type.

Adjusters.—The use of cord adjusters should be discouraged, but there is no very serious objection to the use of any that do not severely damage the cord.

Air Compressors.—Air compressors are usually driven by series wound motors and made to stop and start automatically. For a. c. work induction motors are used. Tanks should be of a capacity equal to about 50 per cent of the rated capacity of the compressor per minute. The air should be dry and cool, as most of the moisture will be precipitated. One H.P. will compress about 5½ cu. ft. of free air per minute to 90 lbs.

Alternating Current Wiring.—For alternating current systems the two or more wires must be run in the same metal conduit, armored cable or metal moulding. In open wiring the greater the separation of wires, the greater will be the inductive drop.

See also special tables for sizes of motor wires and wiring systems.

Alternators.—Alternating current generators and their exciters are not usually provided with fuse protection.

Aluminum.—Aluminum is used as a rule only for outside work and for bus-bars. It can be soldered, but soldering is more difficult than with copper wire and clamps are therefore much used. When used for bus-bars the current density ranges from 1,000 to 1,200 amperes per sq. in. for the smaller sizes, and about 500 for the heavy bars. See *Bus-Bars* for table. For insulated aluminum wire the safe carrying capacity is 84 per cent of that given for copper wire of same insulation. Aluminum is electropositive and must be tied with aluminum wire and no other metal must be allowed to touch it.

Comparison of Copper and Aluminum:

	Aluminum	Copper
Specific gravity	2.68	8.93
Relative specific gravity	1.00	3.33
Conductivity	61 to 63	96 to 99
Weight for equal area	47	100
Area for equal conductivity	160	100
Diameter for equal conductivity	126	100

It will be noted that an aluminum wire of equal conductivity is about two sizes larger by B. & S. gauge than a copper wire. The tensile strength of aluminum is from 20,000 to 35,000 pounds per square inch; that of copper from 20,000 to 65,000. For carrying capacity, etc., see *Wire Calculations.*

Ammeters.—It is customary to provide an ammeter for each generator connected to a switchboard, and only the very smallest and cheapest boards are ever put up without one. The cord sent out with shunt ammeters must always be used full length and need not be protected by fuses. Never place an ammeter in any lead that can be affected by equalizer current. An ammeter used for battery charging should indicate direction of current.

Ampere's Rule.—Imagine yourself swimming with the current and facing the center of the coil; the left hand will then point toward the north pole of the magnet.

Anode.—The anode is the positive pole.

Annunciators.—Unless the annunciator is known to be especially constructed for high voltage, no attempt should be made to operate it from light or power circuits. Use bell ringing transformers, motor generators or battery. Annunciators cannot be operated in parallel successfully.

Apartment Buildings.—If practicable, meters should be placed in basement. In some cities special rules for the wiring of apartment buildings exist. No cut-outs should ever be placed in closets; place them in kitchen if possible. To determine approximate size of mains necessary to supply lighting in apartment buildings, estimate one watt per square foot and consult table of carrying capacities.

Arcades.—The illumination of arcades should be kept low so as not to interfere with show windows.

Arc Lamps.—In laying out wiring for arc lamps the question of drop need not be considered unless incandescent lamps are also on the circuit. A wire smaller than No. 6 should not be used for theatre, or moving picture arc lamps. Two dissolving stereopticon lamps are usually rated as about equal to one stage or moving picture arc lamp.

Plugs used for arc and incandescent lamps should not be interchangeable. The light from direct current arc lamps is much better than that from alternating current. Series arc lamps are now operated almost entirely from constant current transformers; each transformer being limited to one circuit.

Arc Lamp Data

Type of lamp	Current in amperes	Voltage across arc	Color of light	Point of maximum intensity when used with clear glass globes	Watts per mean spherical candle power	Hours of life of pair of carbons
Open arcs						
Direct current series	6.5—7 9.6—10	45	Nearly white	45° below the horizontal	1.20—1.30	12—14
Direct current multiple	6—10	45	Nearly white	45° below the horizontal		12—14
Alternating current series	10—15	40	Blue white	Without reflectors 60° above and 60° below the horizontal	1.7—2	8—12
Alternating current multiple	10—15	28	Blue white			8—12
Enclosed arc						
Direct current series	6—6.6	75—80	Bluish white	45° below the horizontal	1.8—2	80—200
Direct current multiple	3—7	75—80	Bluish white	45° below the horizontal	2.60—3.50	80—200
Direct current multiple		140—160	Blue white to violet			80—150
Alternating current series	6—7	75—80	Bluish white	Without reflectors 60° above and 60° below the horizontal	2.40—2.60	80—150
Alternating current multiple	5—6	75—80	Bluish white		2.80—4	80—150
Intensified arc	3.5—5	80	White		1.8—2	80—100
Flaming arc series	6—12		Depends on the carbons used	With inclined carbons directly under lamp, with vertical carbons 20-30° below the horizontal	0.25—0.35	12—200
Flaming arc constant potential current	6—12	35—70			0.30—0.60	12—200
Regenerative flame arc series	5.5—7	70	Yellow	30° below the horizontal	0.30—0.45	60—70
Regenerative flame arc multiple		70	Yellow		0.40—0.60	60—70
Magnetite series	4—6	80	White	10° 20° below the horizontal	1.30—1.50	150—225
Magnetite multiple	4—6	80	White		1.60—1.80	150—225

Armored Cable and Cord.—Armored conductors are very suitable for "fish work." The radius of the curve of the inner edge of any bend must not be less than 1½ inches. Where moisture exists the conductors should be lead-covered under the armor. Armored cable is not nail proof under all circumstances.

TABLE I

Outside Diameters of Armored Cables and Weight Per 100 Ft. Greenfield Flexible, Steel Armored Conductors

		Solid			Stranded	
	B & S	Dia. in.	Wt. lbs.	B & S	Dia. in.	Wt. lbs.
Single conductors, type D..	14	.378	20	10	.450	23
	12	.384	21½	8	.469	28
	10	.434	26	6	.631	54
	8	.464	28	4	.717	63
	6	.609	54	2	.783	71
				1	.900	98
Twin conductors, BX......	14	.630	45	8	.830	77½
	12	.670	48	6	1.116	121
	10	.720	54	4	1.203	143
Three conductors, BX3....	14	.675	53	8	.890	93
	12	.715	56½	6	1.144	153
	10	.785	66			
Single conductors, DL.....				10	.506	53
				8	.564	72
Lead covered, and steel				6	.713	95
				4	.780	110
armored				2	.825	125
				1	.897	165
Twin conductors, BXL....	14	.730	68	8	.978	136
Steel armored and lead	12	.758	78	6	1.152	205
covered	10	.863	110			
Three conductors, BXL3...	14	.782	78	8	1.056	164
Lead covered and steel	12	.815	97			
armored	10	.933	129			
Steel armored, flexible				18	.414	20
cord, Type E...........				16	.447	22
				14	.625	38
Steel armored, flexible re-				18	.530	25
inforced cord, Type EM.				16	.540	26
				14	.652	48

Armory.—Armories are often classed with theatres and assembly halls, and must be wired accordingly. The most important part of an armory is the drill hall. This requires an illumination equal to about two or two and one-half foot candles. This is best obtained by placing large units high up out of the range of vision.

Artists.—Require an adjustable light and pendant drops are most serviceable.

Art Gallery.—Art galleries are also often classed with assembly halls. In illuminating statuary, the aim must be to produce some shadow effect because of the uniformity of color. Lights should be hung high. For white statuary an illumination of two-foot candles will be sufficient; for bronze statuary about four times as much should be provided. Paintings are often illuminated by *strips* and *reflectors,* and also by indirect lighting or Holophane globes. As many paintings must be viewed from a distance, a bright illumination of about five foot candles is recommended.

Asbestos.—This becomes a conductor when wet, and must not be used in damp places. Asbestos less than $\frac{1}{8}$ inch thick is not considered serviceable. Asbestos covered wires are much used for connecting arc lamps and rheostats where the wire is subject to much heat.

Assembly Halls.—The National Electrical Code prescribes that if any part of a building is "regularly or frequently used for dramatic, operatic, moving picture, or other performances or shows, or has a stage used for such performances used with scenery or other stage appliances," it must be classed as a theatre, and wired according to theatre rules. It is usual to specify that all wires must be in conduit and that there must be a separate system of lighting, independent of the main system, for use of the audience in leaving the building in case of fire, or other emergency.

Attachment Plugs.—Must be of approved type. They should be of the pull-out type, and the socket so placed that the plug can pull out in case strain is put upon it.

Automatic Cut-outs are required to protect every device, or wire, which is connected to any power circuit, except alternators and constant current generators. For details see *Cut-outs.*

Automobiles.—In wiring automobiles it is customary to disregard all ordinary construction rules. Electric motors are connected without any fuse protection. A fuse blowing on a heavy up-grade might cause disaster.

Auto-Starters.—As a general rule, auto-starters are not used with motors smaller than 5 H.P. Auto starters provided with overload release devices, and so arranged that the handle cannot be left in the starting position, are obtainable and should be used. Small auto-starters have usually three taps, and these are arranged to give about 50, 65 or 80 per cent of the line voltage. Larger starters usually have four taps arranged respectively for 40, 58, 70 and 80 per cent of the line voltage. Always make connections to the lowest voltage tap that will give the necessary starting torque. Wherever possible, place starter in sight of motor. For motors smaller than 5 H.P., throw-over switches are often used.

Bakeries.—In bakeries, hot places will be found in which rubber-covered wire is not suitable.

Balance Sets.—Balance sets are made up of motor generators or transformers, and exist for the purpose of obtaining a neutral wire and low voltage for a small lighting load operated in connection with a higher voltage two-wire generator. They are also used where motors operate at two voltages. The capacity of a balancing set is usually only a small percentage of the total load.

Balancing.—Three-wire systems are usually arranged so that a minimum of current may pass through the neutral wire. A good balance cannot always be obtained, and in some cases considerable judgment is required to determine which is the best arrangement of apparatus. Three wires should be carried to every center supplying more than one circuit. Safety rules require the neutral wire to be of same size as the outside wire, but in large systems this wire will seldom be called upon to carry more than 10 per cent of the current used at any time.

Ball Rooms.—Ball rooms are often classed with theatres. The illumination should be general, and lamps hung high. A general illumination of from two to four foot candles is recommended. Receptacles for musicians' use should be provided.

Banana Cellars.—These places are always hot and moist and the vapors are very corrosive. Conduits corrode very fast, and especially the small screws in outlet boxes; brass screws are often used. Open wiring, if it can be protected, is preferable.

Banks.—In that part of a bank occupied by the clerical force, a general illumination of from three to four foot candles is recommended. These lights are in use most of the time, and high efficiency lamps should be arranged for. In that portion used by the public the illumination is not so much used, and may be of a lower order. Numerous outlets for adding machines and fan motors should be provided. In some banks the private depositors' rooms are fitted with two lights, one above and one below desks, and provided with three-way switches so that only one light can be used at a time; this for convenience of customers who may have dropped things on the floor.

Barber Shops.—Good illumination of barber shops can be arranged for by placing clusters of fairly large candlepower close to the ceiling and a little to the rear of chairs. Placed in this manner, the light will not be forced directly into the line of vision of the customer, and yet give the desired illumination. The mirrors in front of chairs will reflect much of the light back to the chair. Often lights are placed along the mirrors, but this practice is not to be recommended. Outlets for cigar-lighters, curling-iron heaters, vibrators, etc., will be appreciated.

Barns.—The use of brass shell sockets should be avoided in horse barns. Avoid placing lights in front of horses, and keep all lights well up above horses' heads. Use weatherproof construction in wash rooms. Place lights in all dark corners.

Bases.—All electrical contacts must be mounted on non-combustible, non-absorbtive insulating material. Other materials than slate, marble, or porcelain are not favored much, and are allowed only when the first named are too brittle. Sub-bases are generally provided for all switches and other devices which would otherwise allow the wires to come against wood or plaster.

Base Frames.—Base frames are required under all generators and motors, and where the voltage is not in excess of 550 volts it is customary to use insulated base frames. If the motor operates at a voltage in excess of 550, it is better to ground the frame thoroughly. Where frames cannot be insulated they must be grounded.

Basements.—Basements are often damp, and must then be wired in accordance with rules for such places. As ceilings are usually low, protection against mechanical injury is often necessary.

Batteries, Primary.—Dry batteries are much used at the present time. They require no attention and when worn out are simply thrown away. The dry battery is at present made only for open circuit work. The wet battery used mostly for open circuit work consists of carbon and zinc elements immersed in a solution of sal-ammoniac. The carbon is the positive pole. This battery is charged by dissolving about four ounces of sal-ammoniac in sufficient water to fill the jar about three-fourths full. Never use more sal-ammoniac than will readily dissolve. It is preferable to make a saturated solution and, after filtering it through cloth, to add about 10 per cent of water. Keep jars in a cool place to prevent evaporation. Never allow water to freeze. Keep exposed parts covered with paraffiné. Do not allow battery to be short circuited or run down. If this has occurred, it will often pick up if left on open circuit for a few hours. If the solution appears milky, more sal-ammoniac is required. Impure zincs which do not eat away evenly facilitate the formation of crystals which greatly increase the resistance. The best known of the closed circuit batteries is the gravity type. The elements in this cell are zinc and copper, immersed in a solution of sulphate of copper (blue vitriol). The copper element rests on the bottom of the jar, and the blue vitriol is placed around it and the jar filled with clean water. The cell must be short circuited for a few hours to start the action. The blue solution should rise to about midway between the two elements. This cell must be kept in action or it will rapidly deteriorate.

Connect all batteries so that the resistance of the battery is nearest equal to the resistance of the devices it is to operate. Series connection should be used when the external resistance is higher than the internal battery resistance. If the external resistance is lower than that of the battery, group cells in multiple. When arranging small storage batteries to be charged from lighting or power circuits, provide double throw switches to entirely disconnect battery from power circuit while it is on the bell circuit. Install all wiring subject to power voltage in accordance with rules for that voltage.

Batteries, Secondary.—Small storage batteries may be carried about and used. The larger ones must remain stationary and are used as compensators for feeder drop, equalizers on three-wire systems, preventives against shut down and as a combination of all of these. Medium size storage batteries are also much used with automobiles. All storage batteries with exception of the Edison, use lead plates. The active material is sponge lead immersed in a weak solution of sulphuric acid. The positive plates when fully charged are of a chocolate color and the active material is quite solid. The negative plate is more of a slate color and softer. The unit of capacity is the ampere hour. A 60-ampere-hour battery, for instance, can deliver a current of three amperes for twenty hours, or seven and one-half amperes for eight hours. High voltages are obtained by connecting a number of cells in series. High amperage is obtained by connecting plates in parallel. The voltage is independent of the size of the cell, but the amperage capacity varies with the surface of the opposed plates. The efficiency is roughly about 75 per cent. The safe rate of charge and discharge varies from five to ten amperes per square foot of positive plate surface, both sides of plate being measured. The voltage should never be allowed to fall below 1.8, and when fully charged is about 2.6. The condition of full charge is indicated by both the positive and negative plates gassing freely.

Before manipulating or attempting to connect any storage battery, the instructions of the maker should be obtained. The following instructions form only a general guide: Keep electrolyte well above plates. See that the cells are kept clean and allow nothing that could short-circuit the plates to accumulate at the bottom. Keep whatever separators there may be in place. Allow no metal except lead in the battery room. Insulate cells from ground and from each other. See that battery is recharged as soon as possible after being used. Do not overcharge. When the negative plates begin to give off gas, it is time to quit. Never allow the voltage to fall below 1.75 per cell. The temperature of the battery should not rise above 110 degrees. The capacity of battery needed is governed by number of units in the generating plant. It is not likely that more than one unit will give out at a time.

Bells.—Bell-ringing transformers are much used in connection with alternating current in place of batteries. To operate bells in series, jump circuit breaker on all but one. If bells are to be operated from lighting circuits, the wiring must be installed in accordance with rules for the voltage used, and the bell must be specially approved for that service. The chief hazard that exists with low voltage bell wires is the possibility of coming in contact with other wires. If storage batteries of high amperage capacity are used, the wires should have fuse protection.

Belting.—Figure 1 is an illustration of a serviceable method of belt lacing. Thread lacing from left to right according to heavy lines, double up at ends and return to starting point; cross lacing on outside of belt only, and keep laces on inside parallel with length of belt.

Holes should be punched as nearly as possible according to the following table:

TABLE II

Width of Belt

Distance from edge of belt—	2 to 6 in.	6 to 12 in.	12 to 18 in.	18 to 24 in.
First row	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1
First row	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1
Second row	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{3}{8}$
Second row	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2
Distance apart of each row of holes	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2
Size of lace leather	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$

If pulleys are of same size, or far apart if of different sizes, the length of belt can be quite approximately found by the following rule: Add diameters

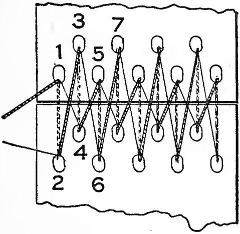


Figure 1.—Method of Belt Lacing.

of pulleys and multiply by 1.57; to this add 2 times the center-to-center distance. The length of belting contained in a roll can be found by reference to Table III. Multiply number of layers in roll by number found where outside diameter of roll and diameter of hole in center cross.

Example.—A roll of belting of 48 inches outside diameter has a hole in the center six inches in diameter, and there are 88 layers of belting. Where the line pertaining to 48 inches outside diameter crosses the line pertaining to 6-inch hole, we find the number 7.04, which multiplied by 88 gives 619.52 feet of belting. The width of a single belt necessary to perform a certain amount of work can be found by the formula $W = 1200 \times \text{H.P.} \div V$, where W stands for width, H.P. for horsepower, and V for velocity of belt in feet per minute. This formula will give a belt of ample size, and a smaller one can be made to do the work by giving it greater tension. Table IV is calculated from the above formula and shows the capacity of belts of various widths and operating at various velocities.

Belts should run horizontally and the pull should be on the under side. Tightener should be on slack side and close to main pulley. Belts running vertically must be kept very tight, especially if the lower pulley is small. The proportion between two pulleys close together should not be greater than 6 to 1. Double belting should not be used on pulleys less than 3 feet in diameter. Rubber belting is preferable in damp places. Thin belting is best for high speeds. Belts operating at high speeds should be cemented, not laced. Pulleys should be perfectly smooth.

Billboards.—A very bright illumination of from ten to twenty foot candles is often used. Lights must be encased in reflectors so as not to be visible to the observer. Install wiring according to rules for outside work.

Billiard Halls.—A general illumination of about one foot candle is recommended. Above each table there should be an illumination of four or five-foot candles. The light over the table should be uniform. At least two lamps should be provided for each table, and should be so encased that the lights are

TABLE III

Table for Calculating Length of Belting, Rope or Wire in Coils

Outside Diameter	Diameter of Hole in Inches 2	3	4	5	6	7	8	9	10	11	12
6 in.	1.05	1.17	1.30	1.44							
7 in.	1.17	1.31	1.44	1.57	1.70						
8 in.	1.31	1.44	1.57	1.70	1.83	1.96					
9 in.	1.44	1.57	1.70	1.83	1.96	2.09	2.23				
10 in.	1.57	1.70	1.83	1.96	2.09	2.23	2.46	2.49			
11 in.	1.70	1.83	1.96	2.09	2.23	2.36	2.49	2.62	2.75		
12 in.	1.83	1.96	2.09	2.23	2.36	2.49	2.62	2.75	2.88	3.01	
13 in.	1.96	2.09	2.23	2.36	2.49	2.62	2.75	2.88	3.01	3.14	3.27
14 in.	2.09	2.23	2.36	2.49	2.62	2.75	2.88	3.01	3.14	3.27	3.40
15 in.	2.23	2.36	2.49	2.62	2.75	2.88	3.01	3.14	3.27	3.40	3.53
16 in.	2.36	2.49	2.62	2.75	2.88	3.01	3.14	3.27	3.40	3.53	3.66
17 in.	2.49	2.62	2.75	2.88	3.01	3.14	3.27	3.40	3.53	3.66	3.79
18 in.	2.62	2.75	2.88	3.01	3.14	3.27	3.40	3.53	3.66	3.79	3.92
19 in.	2.75	2.88	3.01	3.14	3.27	3.40	3.53	3.66	3.79	3.92	4.06
20 in.	2.88	3.01	3.14	3.27	3.40	3.53	3.66	3.79	3.93	4.06	4.19
22 in.	3.14	3.27	3.40	3.53	3.66	3.79	3.92	4.05	4.19	4.32	4.45
24 in.	3.40	3.53	3.66	3.79	3.92	4.05	4.19	4.31	4.45	4.58	4.72
26 in.	3.66	3.79	3.92	4.05	4.18	4.31	4.45	4.57	4.71	4.84	4.97
28 in.	3.92	4.05	4.18	4.31	4.44	4.57	4.71	4.83	4.98	5.11	5.24
30 in.	4.18	4.31	4.44	4.57	4.70	4.83	4.98	5.09	5.23	5.36	5.50
32 in.	4.44	4.57	4.70	4.83	4.96	5.09	5.24	5.35	5.49	5.62	5.75
34 in.	4.70	4.83	4.96	5.09	5.22	5.35	5.50	5.62	5.75	5.88	6.01
36 in.	4.96	5.09	5.22	5.35	5.48	5.67	5.76	5.88	6.02	6.15	6.28
38 in.	5.22	5.35	5.48	5.61	5.74	5.88	6.02	6.14	6.28	6.41	6.54
40 in.	5.48	5.61	5.74	5.87	6.00	6.14	6.28	6.41	6.57	6.68	6.82
42 in.	5.74	5.87	6.00	6.13	6.26	6.40	6.54	6.67	6.81	6.94	7.08
44 in.	6.00	6.13	6.26	6.39	6.52	6.66	6.80	6.93	7.07	7.20	7.34
46 in.	6.26	6.39	6.52	6.65	6.78	6.92	7.06	7.19	7.33	7.46	7.60
48 in.	6.52	6.65	6.78	6.91	7.04	7.18	7.32	7.45	7.56	7.72	7.86

This table may also be used to estimate length of rope or wires in coils if number of turns can be determined.

TABLE IV

The table below is calculated from the above formula and shows the number of H. P. belts will transmit

Belt Speed in Ft. Per Min.	Width of Belt in Inches 1	2	3	4	5	6	7	8	9	10
200	.16	.33	.50	.66	.83	1.00	1.16	1.33	1.50	1.66
300	.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
400	.33	.66	1.00	1.32	1.66	2.00	2.33	2.66	3.00	3.32
500	.42	.84	1.25	1.67	2.10	2.50	2.95	3.34	3.75	4.20
600	.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
700	.58	1.14	1.75	2.33	2.90	3.42	4.08	4.67	5.25	5.80
800	.67	1.34	2.01	2.66	3.34	4.02	4.67	5.33	6.00	6.68
900	.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
1000	.83	1.66	2.49	3.33	4.15	4.98	5.83	6.66	7.50	8.30
1200	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.0
1400	1.16	2.32	3.50	4.67	5.80	7.00	8.13	9.34	10.5	11.6
1600	1.33	2.66	4.00	5.33	6.66	8.00	9.33	10.6	12.0	13.3
1800	1.50	3.00	4.50	6.00	7.50	9.00	10.5	12.0	13.5	15.0
2000	1.67	3.34	5.00	6.67	8.36	10.0	11.7	13.4	15.0	16.7
2200	1.83	3.66	5.50	7.32	9.15	11.0	12.8	14.6	16.5	18.3
2400	2.00	4.00	6.00	8.00	10.0	12.0	14.0	16.0	18.0	20.0
2600	2.16	4.32	6.50	8.66	10.8	13.0	15.1	17.3	19.5	21.6
2800	2.33	4.66	7.00	9.33	11.6	14.0	16.3	18.6	21.0	23.2
3000	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0
3200	2.66	5.32	8.00	10.6	13.3	16.0	18.6	21.2	24.0	26.7
3400	2.83	5.66	8.50	11.3	14.1	17.0	19.8	22.6	25.5	28.2
3600	3.00	6.00	9.00	12.0	15.0	18.0	21.0	24.0	27.0	30.0
3800	3.16	6.32	9.50	12.6	15.8	19.0	22.1	25.2	28.5	31.6
4000	3.33	6.66	10.0	13.3	16.6	20.0	23.3	26.6	30.0	33.2
4200	3.50	7.00	10.5	14.0	17.5	21.0	24.5	28.0	31.5	35.0
4400	3.67	7.34	11.0	14.6	18.3	22.0	25.6	29.2	33.0	36.6
4600	3.83	7.66	11.5	15.3	19.1	23.0	26.8	30.6	34.5	38.2
4800	4.00	8.00	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
5000	4.17	8.34	12.5	16.7	20.9	25.0	29.2	33.4	37.5	41.8

TABLE V

Table showing approximate lengths of material which must be cut out of belts to double the tension; sag on upper and lower sides assumed equal. Reducing sag by one-half approximately doubles the tension.

Distance Between Pulley Centers in Feet	Dimensions Below in 64th of an Inch								
4—Sag	31	46	62	77	92	108	123	138	154
Cutout ...	..	2	3	5	7	10	13	17	20
6—Sag	46	69	92	115	138	161	184	207	231
Cutout ...	1	3	5	7	11	15	19	25	30
8—Sag	62	92	123	154	185	216	246	277	308
Cutout ...	1	4	6	10	15	20	26	33	41
10—Sag	77	115	154	192	230	269	307	346	384
Cutout ...	1	4	8	12	18	25	32	41	50
12—Sag	92	138	184	230	276	322	368	415	462
Cutout ...	2	5	9	14	21	29	38	49	59
15—Sag	115	173	231	288	345	402	459	518	577
Cutout ...	2	7	12	18	28	37	48	62	76
18—Sag	138	207	277	346	415	485	554	623	693
Cutout ...	3	8	14	22	33	44	58	74	91
21—Sag	161	242	323	404	485	566	647	727	807
Cutout ...	3	9	16	26	39	51	70	87	106
25—Sag	192	288	384	480	576	672	768	864	960
Cutout ...	4	12	19	31	46	61	81	104	127
30—Sag	231	346	461	576	691	806	921	1036	1151
Cutout ...	4	14	23	37	55	74	97	124	152

The above table is based upon the ratio of deflection and elongation of wires in spans, and it is assumed that the additional strain produces no immediate elongation of the belt.

not visible to the players. A switch for each table will be a convenience. Outlets for cigar-lighters and fan motors should be provided.

Bonds.—Rail bonds should not be smaller than No. 000. The area of contact should be about eight times the cross section of the bond. In some instances the size of bond is determined by the size of supply wires, the total cross section of all bonds at any point being made equal to the cross section of the supply wires for that point. For a ratio of 1:12 the copper in circular mils necessary to equal the conductivity of steel rails can be found by multiplying the weight per yard of rail by 10,000.

Boosters.—Boosters may be in the form of transformers or motor generators, and are used to raise or lower voltage, also in some cases in return railway circuits to lessen electrolysis. The installation of boosters is not profitable except on long lines when the cost of copper to prevent the drop is greater than the cost of boosters. Boosters may be compounded so that the regulation becomes automatic.

Bowling Alleys.—The illumination should be arranged so that no light is visible to the players. An illumination equal to one and one-half or two foot candles is advisable for the alley, and about double that much for the pins.

Branch Blocks must always provide double pole fuse protection for each circuit.

Branch Circuits.—The term, "branch circuit," is here used to describe that part of the wiring between the last fuse and the lights, motors, heaters, or other translating devices. Branch circuits should be grouped as far as possible and arranged so that the cut-out cabinet may be in a safe and convenient place. It is advisable to place the switches outside of cut-out cabinets. In the best arranged theatres all branch circuits, except those for emergency lights, are carried to stage switchboards. By running mains as far as possible, and shortening the branch circuits, a much evener voltage at lamps will be secured than is possible from long branch circuits. The drop in voltage should never be over 2 per cent. Most lamps are marked for three voltages, top, middle, and bottom, and there is a difference of four volts between them. With a 4 per cent drop a 110-volt lamp will be at different times subject to all three voltages and the illumination will vary greatly.

For best location of cut-outs, see table on calculation of materials. The following table shows drop in voltage with different wires at different distances. A run of No. 14 wire 110 feet long feeding twelve lights evenly spaced ten feet apart will cause a drop of about one and one-quarter volts between first and last lamps. The table below shows the drop with wires from No. 14 to 6, carrying six amperes the distances given at top of table.

TABLE VI

Distance in feet; one leg

B & S	20	40	60	80	100	120	140	160	180	200
14 ..	.63	1.3	1.9	2.5	3.2	3.8	4.4	5.0	5.7	6.3
12 ..	.40	.80	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0
10 ..	.25	.50	.75	1.0	1.3	1.5	1.8	2.0	2.3	2.5
8 ..	.15	.30	.45	.60	.75	.90	1.1	1.2	1.4	1.5
6 ..	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0

Burglar Alarm.—A good burglar alarm is one so wired that it is under constant test, so as to give immediate notice when any part of it is out of order. The closed circuit system complies with this requirement. With open circuit systems it is best to provide "silent test" by which it can be tried out every night without causing an alarm. To guard against purposive incapacitating, some installations are mixed open and closed circuit system, so that it is impossible to know which wire to cut or short-circuit in order to prevent an alarm. In some systems "balanced" relays are used and the wires are interwoven so that it is impossible to interfere with them in any way without giving an alarm. Where either the simple open or closed circuit system is used, the wires and batteries should be protected against interference.

Bus-Bars.—The term, "bus-bar," refers, strictly speaking, only to those conductors on a switchboard which are connected directly to all of the machines. In common practice, however, it is understood that all of the current-carrying bars on a switchboard come under this classification. For high voltages it is usual to cover the bars with insulation, but for low voltages it is customary to leave them bare. The proper separation of bus-bars is $2\frac{1}{2}$ inches for voltages less than 300, and 4 inches for the higher, including 550 volts. Copper and aluminum are used. Systematize bus-bars by placing all positive poles at top or right-hand side of circuit. A current density of 1000 amperes per square inch is common practice for bus-bars, but is too high for the large ones.

Table number VII shows the current-carrying capacity of bus-bars calculated on a basis of 1000 amperes per square inch cross section. For very small bars $1\frac{1}{2}$ times as much current may be allowed, while for the very large ones not more than half the current given in the table should be used. The carrying capacity of aluminum is given as 84 per cent of that of copper.

Bushings.—In connection with very high voltages, specially constructed bushings must be used through walls. Ordinary bushings cause trouble. If possible the wires should be run in without touching anything.

TABLE VII

Table of Bus-Bar Data

Thickness	Width	Area in Sq. in.	Lbs. Per Foot Copper	Lbs. Per Foot Aluminum	Carrying Capacity 1000 Amp. Per Sq. In. Copper	Carrying Capacity 840 Amperes Per Sq. In. Aluminum
1/16	1/2	.0313	.1205	.0361	32	27
1/16	3/4	.0469	.1807	.0542	47	39
1/16	1	.0625	.2410	.0723	63	53
1/16	1 1/2	.0938	.3615	.1084	95	80
1/8	1/2	.0625	.2410	.0723	63	53
1/8	3/4	.0938	.3615	1084	95	80
1/8	1	.1250	.4820	.1446	125	105
1/8	1 1/2	.1875	.7230	.2169	188	158
1/8	2	.2500	.9640	.2892	250	210
1/4	3/4	.1875	.7230	.2169	188	158
1/4	1	.2500	.9640	.2892	250	210
1/4	1 1/4	.3125	1.205	.3615	315	265
1/4	1 1/2	.3750	1.446	.4338	375	315
1/4	1 3/4	.4375	1.687	.5061	435	365
1/4	2	.5000	1.928	.5784	500	420
1/4	2 1/4	.5625	2.169	.6507	565	475
1/4	2 1/2	.6250	2.410	.7230	625	530
1/2	3/4	.3750	1.446	.4338	375	310
1/2	1	.5000	1.928	.5784	500	420
1/2	1 1/4	.6250	2.410	.7230	625	525
1/2	1 1/2	.7500	2.892	.8676	750	630
1/2	1 3/4	.8750	3.374	1.1122	875	735
1/2	2	1.000	3.856	1.1568	1000	840
1/2	2 1/4	1.125	4.338	1.3014	1125	995
1/2	2 1/2	1.250	4.820	1.4460	1250	1050
1/2	2 3/4	1.375	5.304	1.5912	1375	1155
1/2	3	1.500	5.784	1.7352	1500	1260
1/2	3 1/4	1.625	6.266	1.8798	1625	1365
1/2	3 1/2	1.750	6.748	2.0244	1750	1470
1/2	3 3/4	1.875	7.230	2.1690	1875	1575
1/2	4	2.000	7.712	2.3136	2000	1680
3/4	1	.750	2.892	.8676	750	630
3/4	1 1/2	1.125	4.338	1.3014	1125	945
3/4	2	1.500	5.784	1.7352	1500	1260
3/4	2 1/2	1.875	7.230	2.1690	1875	1575
3/4	3	2.250	8.676	2.6118	2250	1890
3/4	3 1/2	2.625	10.122	3.0366	2625	2260
3/4	4	3.000	11.568	3.4704	3000	2520

The Aluminum Company of America recommends 1200 amperes per square inch for the smaller bars and 500 for the largest.

Cabinets.—Metal cabinets only are used in connection with conduit systems. Cabinets are obtainable in four thicknesses of steel, viz., 16, 14, 12, and 10 U. S. Standard gauge, equal to 1/16, 5/64, 7/64, and 9/64 inches respectively. The thin metal is used only for the smaller boxes, and the heavy for the large ones. The depth of cabinets is usually great enough to allow door to close with small switches in any position, and the large ones thrown way back. For necessary dimensions, see *Cut-outs, Panel Boards,* or *Switches.* Where conduits enter all from one end, a wiring gutter space equivalent to about ¼ square inch for each circuit of number 14 twin conductor should be allowed. Cabinets should be provided to enclose all cut-outs. If practicable, locate them so as to reduce likelihood of rubbish being stored in them to a minimum. To locate switches outside of cut-out cabinets is good practice. In ordering cabinets note the following points: Wood or metal. Wall or flush mounting. With or without lining. With or without wiring gutter. Thickness of steel desired. Over-all dimensions of cut-outs, panel board, or switch. Inches of back wiring pocket. Inches of side wiring pocket. Spring hinges or not. Type of handle or lock. Side on which hinge must be. Finish and nature of door.

Candle Power.—This term is rather loosely used and has no very definite meaning, unless qualified by one of the following terms: Apparent candle power; equivalent candle power; mean lower hemispherical candle power; mean horizontal candle power; maximum candle power. The candle power of no lamp is the same in all directions.

Canopies.—The number of lamps to be used for the illumination of outlines in canopies is usually governed by the design of the canopy. The best effect, where outline lighting is to be installed, is obtained from many small lamps of low intrinsic brilliancy. Keep lamps and sockets out of the weather. Fixture canopies must be insulated wherever an insulating joint is called for on fixture.

Carbons.—For life of carbons with various types of arc lamps, see *Arc Lamps.* The upper carbon is usually the positive, and for projecting arcs is larger than the lower. The positive carbon holds its heat longer than the negative. If carbons are too large, the arc will travel around them. With direct current, the upper or positive carbon is consumed twice as fast as the other. Flaming arc carbons contain special materials in the core, and the color of the arc is governed by this material.

Car Houses.—A main switch is usually provided by which all wires in the car house can be cut off. Where a car house contains many sections it is better to provide a switch for each section. The illumination of car houses is usually by series incandescent lighting.

Carriage Calls.—These are usually made up in the form of electric signs, and located above canopies of theatres and hotels. They consist of a large number of monograms and require a large number of wires to be run to them. Outdoor wires should be run in water-tight conduit system. If armored cable is used outdoors it must be lead-covered insulation.

Cathode.—The cathode is the negative pole. This term is used in connection with batteries and electrolytic devices, mostly.

Ceiling Fans.—These must never be fastened rigidly, but in such a manner as to allow them to find their own "centers" when running. Not more than 660 watts may be connected to one circuit. One fan to 400 or 500 square feet floor space is common practice.

Celluloid is highly inflammable, and must never be used exposed to heat or flame. Where a transparent medium of a similar appearance is needed, gelatine is used.

Cement when wet is a good conductor and may easily cause grounds.

Centers of Distribution.—In most cases the location of centers is governed by other conditions than economy of copper, and is dictated by the desire of the user. Where, however, free choice of location is given, the following tabulation showing the relative number of circular mils for each branch circuit of 660 watts at 110 volts will be of use. The table shows that with small mains, and especially three-wire systems, the amount of copper in the mains may be much less than in the branch circuits, and that it will be more profitable to run mains into the area to be served. This advantage grows less with larger mains. Branch circuits require 8214 circular mils per circuit of 660 watts.

The theoretical requirements per 660 watts for mains supplying centers is given below:

TABLE VIII

Mains B. & S.	2 Wire	3 Wire
14	3286	2460
12	3957	2968
10	5000	3752
8	5693	4270
6	6325	4744
5	7227	5426
4	7200	5397
3	7914	5934

Chandeliers.—No part of any chandelier should be less than six feet two inches above floor. The usual height ranges between this and seven feet. In theatres and similar places where chandeliers hang very high, arrangement should be made for either raising or lowering to admit of lamp renewals. For large chandeliers special permission to use 1320-watt circuits can usually be obtained.

Chemical Works.—Before undertaking work in such places, investigate the nature of fumes, and chemicals used, with reference to effect upon copper and insulating materials, especially metal conduits, if considered.

Choke Coils.—These are used mostly in connection with lightning arresters. They must be as well insulated as the circuit wires to which they are connected.

Churches.—Some of the large churches require a lighting equipment similar to that of theatres. In choir lofts and at altars, pockets for special lights are often required. Indirect lighting is very useful in churches, as the light should be kept out of the line of vision of the speaker as well as the audience. From two to three foot candles are necessary. Emergency lighting should also be provided.

Circuit Breakers are much more sensitive than fuses. Many of them are so constructed as to allow a considerable overload for a short time, and the length of this time is adjustable. Circuit breakers should ordinarily not be set more than 30 per cent above the rated carrying capacity of the wire they are to protect.

Coils.—The coils of a magnet must be connected so as to form a continuous spiral.

Coloring Lamps.—Coloring and frosting of lamps reduces the light from 30 to 50 per cent. Amber coloring reduces the light about 20 per cent, while green and red take up from 50 to 90 per cent, according to the density and shade. Prepared coloring materials can be had at all supply stores. A few amber-colored lamps are sometimes mixed in with white lights to give a warmer glow to the light.

Color of Light Sources.—

Moore tube (carbon dioxide gas)	White
Intensified arc	White
Magnetite arc	White
Open arc	Nearly white
Tungsten lamp	Nearly white
Tungsten lamp, gas-filled	White
Nernst lamp	Nearly white
Enclosed arc (short arc)	Bluish white
Tantalum lamp	Pale yellowish white
Gem lamp	Pale yellowish white
Carbon lamp	Pale yellowish white
Regenerative flame arc	Yellow
Flaming arc	Variable with different carbons
Mercury lamp (glass tube)	Bluish green
Enclosed arc (long arc)	Bluish white to violet
High sun	White
Low sun	Orange red
Skylight	Bluish white
Welsbach mantle	Greenish white
Common gas burner	Pale orange yellow
Kerosene lamp	Pale orange yellow
Candle	Orange yellow

TABLE IX

Comparison of Fahrenheit and Centigrade Thermometers

Fah.	Cent.	Fah.	Cent.	Fah.	Cent.	Fah.	Cent.	Fah.	Cent.
212	100	165	73.8	118	47.7	71	21.6	24	— 4.4
211	99.4	164	73.3	117	47.2	70	21.1	23	— 5.0
210	98.8	163	72.7	116	46.6	69	20.5	22	— 5.5
209	98.3	162	72.2	115	46.1	68	20.0	21	— 6.1
208	97.7	161	71.6	114	45.5	67	19.4	20	— 6.6
207	97.2	160	71.1	113	45.0	66	18.8	19	— 7.2

Fah.	Cent.	Fah.	Cent.	Fah.	Cent.	Fah.	Cent.	Fah.	Cent.
206	96.6	159	70.5	112	44.4	65	18.3	18	— 7.7
205	96.1	158	70.0	111	43.8	64	17.7	17	— 8.3
204	95.5	157	69.4	110	43.3	63	17.2	16	— 8.8
203	95.0	156	68.8	109	42.7	62	16.6	15	— 9.5
202	94.4	155	68.3	108	42.2	61	16.1	14	—10.0
201	93.8	154	67.7	107	41.6	60	15.5	13	—10.5
200	93.3	153	67.2	106	41.1	59	15.0	12	—11.1
199	92.7	152	66.6	105	40.5	58	14.4	11	—11.6
198	92.2	151	66.1	104	40.0	57	13.8	10	—12.2
197	91.6	150	65.5	103	39.4	56	13.3	9	—12.7
196	91.1	149	65.0	102	38.8	55	12.7	8	—13.3
195	90.5	148	64.4	101	38.3	54	12.2	7	—13.8
194	90.0	147	63.8	100	37.7	53	11.6	6	—14.4
193	89.4	146	63.3	99	37.2	52	11.1	5	—15.0
192	88.8	145	62.7	98	36.6	51	10.5	4	—15.5
191	88.3	144	62.2	97	36.1	50	10.0	3	—16.1
190	87.7	143	61.6	96	35.5	49	9.4	2	—16.6
189	87.2	142	61.1	95	35.0	48	8.8	1	—17.2
188	86.6	141	60.5	94	34.4	47	8.3	0	—17.7
187	86.1	140	60.0	93	33.8	46	7.7	— 1	—18.3
186	85.5	139	59.4	92	33.3	45	7.2	— 2	—18.8
185	85.0	138	58.8	91	32.7	44	6.6	— 3	—19.4
184	84.4	137	58.3	90	32.2	43	6.1	— 4	—20.0
183	83.8	136	57.7	89	31.6	42	5.5	— 5	—20.5
182	83.3	135	57.2	88	31.1	41	5.0	— 6	—21.1
181	82.7	134	56.6	87	30.5	40	4.4	— 7	—21.6
180	82.2	133	56.1	86	30.0	39	3.8	— 8	—22.2
179	81.6	132	55.5	85	29.4	38	3.3	— 9	—22.7
178	81.1	131	55.0	84	28.8	37	2.7	—10	—23.3
177	80.5	130	54.4	83	28.3	36	2.2	—11	—23.8
176	80.0	129	53.8	82	27.7	35	1.6	—12	—24.4
175	79.4	128	53.3	81	27.2	34	1.1	—13	—25.0
174	78.8	127	52.7	80	26.6	33	0.5	—14	—25.5
173	78.3	126	52.2	79	26.1	32	.0	—15	—26.1
172	77.7	125	51.6	78	25.5	31	—0.5	—16	—26.6
171	77.2	124	51.1	77	25.0	30	—1.1	—17	—27.2
170	76.6	123	50.5	76	24.4	29	—1.6	—18	—27.7
169	76.1	122	50.0	75	23.8	28	—2.2	—19	—28.3
168	75.5	121	49.4	74	23.3	27	—2.7	—20	—28.8
167	75.0	120	48.8	73	22.7	26	—3.3		
166	74.4	119	48.3	72	22.2	25	—3.8		

To convert degrees Centigrade into Fahrenheit, if the temperature given is above zero, multiply by 1.8

and add 32. If it is below zero multiply also by 1.8, but if this product is less than 32, subtract it from 32; if more, subtract 32 from it. To convert Fahrenheit into Centigrade, if the temperature given is above zero, subtract 32 and divide the remainder by 1.8; if below zero, add 32 and divide by 1.8.

Concentric Wire.—Concentric wires are seldom used except in mines and similar places. Such a wire fully insulated would require more insulating material and be more bulky than the ordinary duplex wire. The concentric wire recently put upon the market has only one wire insulated. The other wire is a metal sheath which entirely surrounds the inner wire and its insulation. The sheath must always be thoroughly grounded.

Condensers must be enclosed in noncombustible cases and installed with the same precautions as the wires of the system to which they attach. Condensers are usually rated in microfarads, and a condenser of two or three microfarads is considered quite large.

Conduits.—Conduit installations materially reduce the fire hazard, but to some extent increase the minor troubles. They produce many grounds and short circuits, but confine the trouble. Careful workmanship, especially at junction and outlet boxes, will reduce such troubles to a minimum. Install conduits so they will drain, and avoid their use in wet places unless lead-encased wires are used. Skilled conduit workers avoid the use of elbows with small wires as much as possible. The following tables (X and XI) give the sizes of conduits recommended by the National Electrical Contractors' Association of the United States in connection with various sizes and numbers of wires. These recommendations are based on actual tests and can be relied upon.

TABLE X

Standard sizes of conduits for the installation of wires and cables as adopted and recommended by The National Electrical Contractors' Association of the United States and the N. E. Code.

Conduit sizes are based on the use of not more than three 90° elbows in runs taking up to and including No. 10 wires; and two elbows for wires larger than No. 10. Wires No. 8, and larger, are stranded.

B. & S. Gauge	Approx. Diameter of Wire	One Wire in a Conduit — Diam. Int.	One Wire in a Conduit — Diam. Ext.	Two Wires in a Conduit — Diam. Int.	Two Wires in a Conduit — Diam. Ext.	Three Wires in a Conduit — Diam. Int.	Three Wires in a Conduit — Diam. Ext.	Four Wires in a Conduit — Diam. Int.	Four Wires in a Conduit — Diam. Ext.
14	18/64	½	.84	½	.84	½	.84	¾	1.05
12	20/64	½	.84	¾	1.05	¾	1.05	¾	1.05
10	24/64	½	.84	¾	1.05	¾	1.05	1	1.31
8	28/64	½	.84	1	1.31	1	1.31	1	1.31
6	30/64	½	.84	1	1.31	1¼	1.66	1¼	1.66
5	31/64	¾	1.05	1¼	1.66	1¼	1.66	1¼	1.66
4	32/64	¾	1.05	1¼	1.66	1¼	1.66	1½	1.90
3	34/64	¾	1.05	1¼	1.66	1¼	1.66	1½	1.90
2	36/64	¾	1.05	1¼	1.66	1½	1.90	1½	1.90
1	40/64	¾	1.05	1½	1.90	1½	1.90	2	2.37
0	44/64	1	1.31	1½	1.90	2	2.37	2	2.37
00	48/64	1	1.31	2	2.37	2	2.37	2½	2.87
000	52/64	1	1.31	2	2.37	2	2.37	2½	2.87
0000	55/64	1¼	1.66	2	2.37	2½	2.87	2½	2.87
250,000	58/64	1¼	1.66	2½	2.87	2½	2.87	3	3.50
300,000	62/64	1¼	1.66	2½	2.87	2½	2.87	3	3.50
400,000	67/64	1¼	1.66	3	3.50	3	3.50	3½	4.00
500,000	73/64	1½	1.90	3	3.50	3	3.50	3½	4.00
600,000	80/64	1½	1.90	3	3.50	3½	4.00		
700,000	86/64	2	2.37	3½	4.00	3½	4.00		
800,000	89/64	2	2.37	3½	4.00	4	4.50		
900,000	93/64	2	2.37	3½	4.00	4	4.50		
1,000,000	97/64	2	2.37	4	4.50	4	5.00		
1,250,000	109/64	2½	2.87	4½	5.00	4½	5.00		
1,500,000	117/64	2½	2.87	4½	5.00	5	5.56		
1,750,000	128/64	3	3.50	5	5.56	5	5.56		
2,000,000	133/64	3	3.50	5	5.56	6	6.62		
				Duplex Wires					
14	34/64	½	.84	¾	1.05	1	1.31	1	1.31
12	36/64	½	.84	¾	1.05	1	1.31	1¼	1.66
10	38/64	¾	1.05	1	1.31	1¼	1.66	1¼	1.66

TABLE XI

Standard sizes of conduits for the installation of wires and cables.

3 Wire Convertible System			3 Wire Convertible System		
2 Wires B. & S.	1 Wire	Size Conduit	2 Wires B. & S.	1 Wire	Size Conduit
14	10	¾	00	350,000	2½
12	8	¾	000	400,000	2½
10	6	1	0000	550,000	3
8	4	1	250,000	600,000	3
6	2	1¼	300,000	800,000	3
5	1	1¼	400,000	1,000,000	3½
4	0	1½	500,000	125,000	4
3	00	1½	600,000	1,500,000	4
2	000	1½	700,000	1,750,000	4½
1	0000	2	800,000	2,000,000	4½
0	250,000	2			

Single Wire Combination.

Number of single No. 14 wires in one conduit. Straight run; no elbows. Special permission is required.

	Conduit Size
3 No. 14 rubber covered double braid...........	½
5 No. 14 rubber covered double braid...........	¾
10 No. 14 rubber covered double braid...........	1
18 No. 14 rubber covered double braid...........	1¼
24 No. 14 rubber covered double braid...........	1½
40 No. 14 rubber covered double braid...........	2
74 No. 14 rubber covered double braid...........	2½
90 No. 14 rubber covered double braid...........	3

Signal Systems.

Straight runs; no elbows.

No. Wires	B.& S.		Conduit Sizes
10	16	Lt. ins. fixture wire..........	½
20	16	Lt. ins. fixture wire..........	¾
30	16	Lt. ins. fixture wire..........	1
70	16	Lt. ins. fixture wire..........	1¼
90	16	Lt. ins. fixture wire..........	1½

No. Wires	B.& S.		Conduit Sizes
150	16	Lt. ins. fixture wire..........	2
18	18	Lt. ins. fixture wire..........	½
30	18	Lt. ins. fixture wire..........	¾
40	18	Lt. ins. fixture wire..........	1
100	18	Lt. ins. fixtrue wire..........	1¼
130	18	Lt. ins. fixture wire..........	1½
200	18	Lt. ins. fixture wire..........	2

Telephone Circuits. Not more than two 90° Elbows.

No. 19 braided and twisted pair switchboard or desk instrument wires.

No. Pairs		Conduit
3	....	½
6	....	¾
10	....	1
16	....	1¼
25	....	1½
35	....	2

No. 20 braided and twisted pair switchboard or desk instrument wires.

No. Pairs.		Conduit
5	....	½
10	....	¾
15	....	1
25	....	1¼
35	....	1½
50	....	2

Conduits and Wires.—Two sides of the smallest rectangular enclosures that will contain a given number of wires are: $(D \times a) + \frac{D}{2}$ and $D \times b \times 86$. D being the diameter of the wire, a the number of wires in longest row, and b the number of rows.

The nearer square this enclosure can be made, the greater the economy of material. The greatest number of wires that can be placed in a rectangular enclosure is $\left(\frac{L}{D} - \frac{1}{2}\right) \times \left(\frac{H}{D \times .86}\right)$

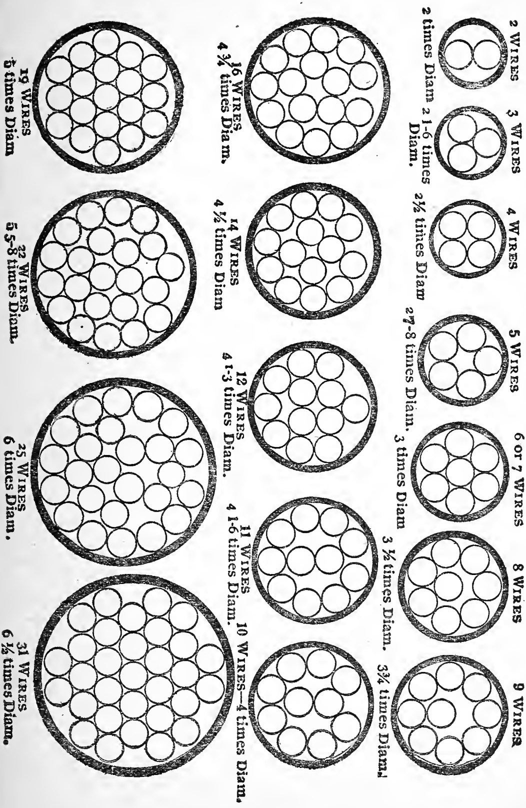
L being the length of the enclosure, H the height, and D the diameter of the wire.

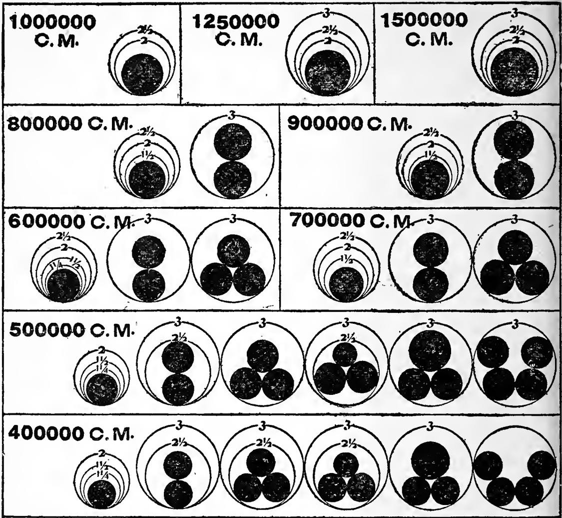
This formula is only approximate and in using it all fractions obtained by $\frac{L}{D}$ and $\frac{H}{D \times .86}$ must be dropped.

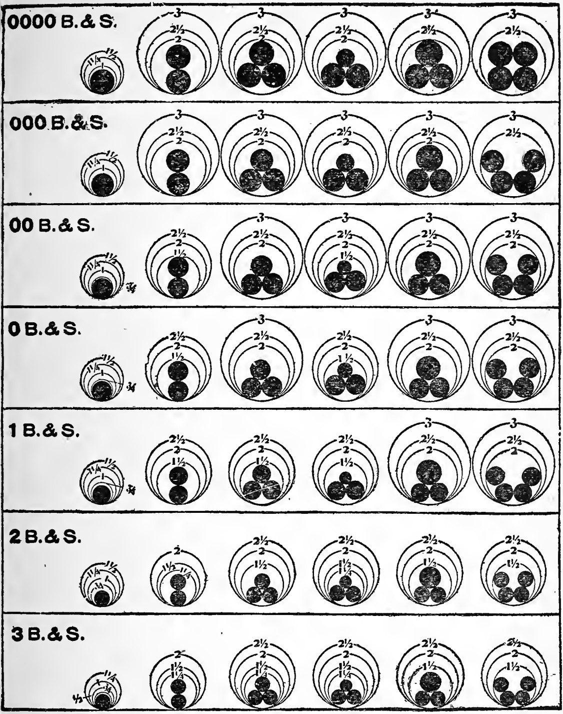
Example.—Given an enclosure 6 inches long and 2 inches high, how many wires can it hold, the diameter of each wire being .7? 6 divided by .7 equals 8.6. Dropping the .6 and subtracting $\frac{1}{2}$, we have 7.5 for the first factor. Next, .7 times .86 equals .602; 2 divided by this equals 3.3; dropping the .3, we now have to multiply the 7.5 by 3, which equals 22.5, or 22 wires.

For circular enclosures no general formula can be given because the percentage of waste space varies greatly with different wires. The first chart may be used to determine the smallest conduit that will enclose a certain number of wires. This chart shows graphically how nearly different numbers of wires fill out circular spaces. To use this chart, multiply diameter of wire by the number given in connection with circle containing the requisite number of wires. This will give the smallest diameter of tube or conduit that will receive these wires. How much larger the conduit to be used must be depends upon circumstances. The number and nature of bends, nature of insulation, flexibility of wire, as well as temperature and inspection requirements, must be taken into consideration.

The charts illustrate the relative spaces occupied by the different conduits, viz.: 3″, $2\frac{1}{2}$″, 2″, $1\frac{1}{2}$″, $1\frac{1}{4}$″, 1″, etc., and the wires considered. The sizes of conduits are marked in the various circles and each horizontal row pertains to one size of wire, with exception of the 4th and 5th in each row and a few at the top of one of the charts. The 4th shows a neutral wire of half the carrying capacity, and the 5th of double the carrying capacity of the outside wires. The different sizes of conduit given in each case will enable one to judge the most appropriate size to be used under different circumstances. The wires shown are all double braid stranded cables.


2 WIRES
2 times Diam
3 WIRES
2 1-6 times Diam.
4 WIRES
2½ times Diam
5 WIRES
2 7-8 times Diam.
6 or 7 WIRES
3 times Diam
8 WIRES
3½ times Diam.
9 WIRES
3¾ times Diam.
16 WIRES
4¾ times Diam.
14 WIRES
4½ times Diam
12 WIRES
4 1-3 times Diam.
11 WIRES
4 1-6 times Diam.
10 WIRES—4 times Diam.
19 WIRES
5 times Diam
22 WIRES
5 5-8 times Diam.
25 WIRES
6 times Diam.
31 WIRES
6½ times Diam.


1000000 C. M.
1250000 C. M.
1500000 C. M.
800000 C. M.
900000 C. M.
600000 C. M.
700000 C. M.
500000 C. M.
400000 C. M.
300000 C. M.
250000 C. M.


0000 B. & S.
000 B. & S.
00 B. & S.
0 B. & S.
1 B. & S.
2 B. & S.
3 B. & S.

In the preceding pages are given the conduit sizes recommended by the National Electrical Contractors' Association of the United States. These should be followed as far as they apply.

Contacts.—The standard materials for mounting contacts are slate, marble, porcelain, and glass. Where these are liable to breakage, other materials are allowed, but they should always be submitted to inspection departments for approval. A surface contact of one square inch for each 75 amperes is good practice for knife-switches and similar devices.

Controllers.—Methods of motor and light control are numerous. Lights are usually controlled by cutting resistance into the mains. A certain controller is suitable only for a certain number of lights requiring a certain amperage. The reduction of voltage is equal to the product of the amperes times the resistance, and the effect upon the lights is greater than indicated by the drop in voltage. The speed of motors may be altered by cutting resistance into the mains, altering the field connections, arranging taps of different voltages, and connecting armatures in multiple or series.

Cooking.—Almost any kind of cooking can be accomplished electrically, but the expense is higher than with gas. It is best to be honest and advise customers correctly about these things than to cause disappointment. The advantages are convenience and rapidity of results with many of the devices.

Cooper-Hewitt Lamps (Mercury Vapor).—These lamps may be obtained for either alternating or direct-current use, and for 110 or 220 volts. The light given out is of a greenish hue, and gives a ghastly effect to faces and hands. Many persons object to working under it, while others seem to like it. The efficiency of the lamp compares favorably with others; it is easy to operate, and the light is practically shadowless. With alternating currents the light flickers somewhat, and is said to give a deceptive appearance to some surfaces. Not more than one lamp should be installed on one circuit. Use double-pole switches and avoid plug cut-outs for 220 volts. Current sent through direct-current lamps in wrong direction will ruin tubes. Where inflammable gases exist, the sparking of some of the lamps is dangerous. The life of a tube is now claimed to be 5000 hours. The current ranges from 3.5 to 2.0 amperes for different types, and the efficiency is given as from 0.51 to 0.64 watts per mean lower hemispherical candle power. The light is mostly thrown downward.

Copper weighs about 556 pounds per cubic foot; its specific gravity is about 8.9, and it melts at 1196 degrees Fahrenheit. The tensile strength of annealed copper may be taken as about 35,000 pounds per square inch, and that of hard drawn copper as about 55,000.

Cross Currents pass between A.C. generators, and also between synchronous motors when they are operating in parallel and not perfectly in phase. These currents heat the wires and overload the machines unnecessarily.

Cut-outs.—In connection with installations served by central stations, the type of cut-out and fuse preferred by that company should be installed. This will usually obtain free fuse renewals. The installation of cartridge-type fuses is not advisable except in establishments where a competent electrician is always on duty.

The dimensions of several types of cut-outs are given below.

TABLE XII

Paiste Panel Cut-Outs (See Figure 2).

125 Volt Sizes. Capacity of Switches 30 Amperes

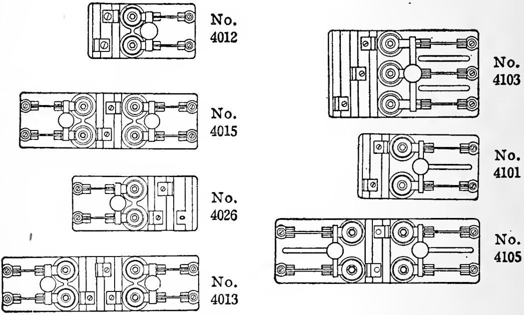


Figure 2.—Paiste Panel Cutouts.

Cat. No.	Main	Branches	Width (inches)	Length (inches)
4012	2-Wire	Single, 2-Wire	3⅛	5⅞
4015	2-Wire	Double, 2-Wire	3	10⅛
4026	3-Wire	Single, 2-Wire	3¼	7¼
4013	3-Wire	Double, 2-Wire	3⅛	10⅞
4103	3-Wire	Single, 3-Wire	5	8⅝
250 Volt Sizes. Capacity of Switches 30 Amperes				
=4101	2-Wire	Single, 2-Wire	3¾	7
=4105	2-Wire	Double, 2-Wire	3¾	11¾

TABLE XIII

Dimensions for Plug Cut-Outs (See Figure 3).

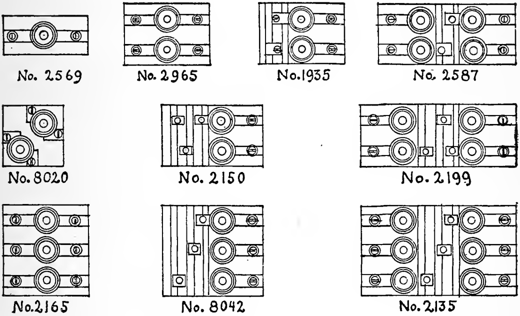


Figure 3.—Plug Cutouts.

Cat. No.	Length (inches)	Width (inches)	Height (inches)
2569	$2\frac{3}{4}$	2	$1\frac{31}{64}$
2965	$2\frac{1}{2}$	$3\frac{1}{16}$	$1\frac{29}{64}$
2165	$2\frac{9}{16}$	$4\frac{1}{2}$	$1\frac{29}{64}$
8020	$3\frac{3}{8}$	$3\frac{3}{8}$	$1\frac{1}{2}$
1935	$3\frac{19}{32}$	$3\frac{1}{16}$	$1\frac{29}{64}$
2587	$5\frac{3}{16}$	3	$1\frac{31}{64}$
2150	$4\frac{7}{8}$	3	$1\frac{17}{32}$
2199	$6\frac{5}{16}$	$2\frac{15}{16}$	$1\frac{31}{64}$
8042	$4\frac{13}{32}$	$4\frac{13}{32}$	$1\frac{23}{32}$
2135	$6\frac{7}{8}$	$4\frac{7}{16}$	$1\frac{21}{32}$

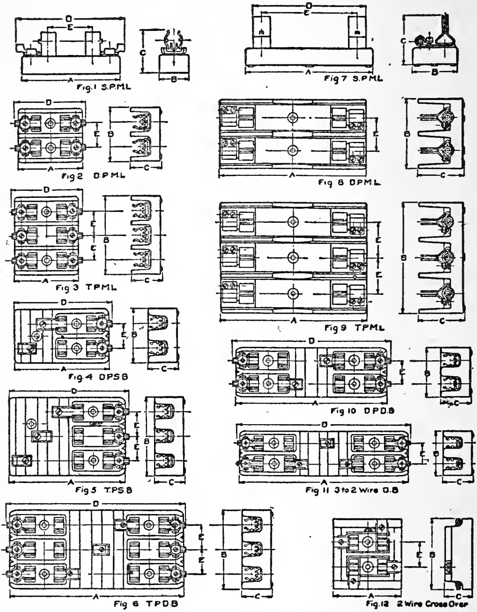


Figure 4.—D. & W. Cutouts.

TABLE XIV

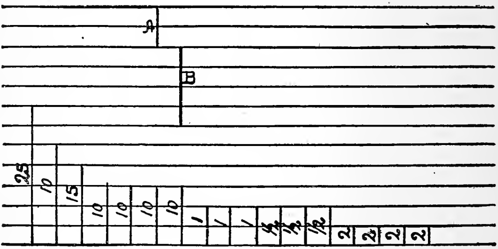
Dimensions of D. & W. 250 Volt Cut-Outs (See Figure 4).

Amperes	Fig.	A	B	C	D	E
0-30	1	$3\frac{3}{8}$	1	$1\frac{7}{16}$	$3\frac{3}{8}$	$1\frac{1}{2}$
0-30	2	$3\frac{5}{16}$	$2\frac{3}{4}$	$1\frac{9}{16}$	$3\frac{5}{16}$	$1\frac{1}{4}$
0-30	3	$3\frac{5}{16}$	4	$1\frac{9}{16}$	$3\frac{5}{16}$	$1\frac{1}{4}$
0-30	4	$4\frac{7}{8}$	$2\frac{3}{4}$	$1\frac{9}{16}$	$4\frac{7}{8}$	$1\frac{1}{4}$
0-30	5	6	4	$1\frac{9}{16}$	6	$1\frac{1}{4}$
0-30	10	$7\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{9}{16}$	$7\frac{3}{4}$	$1\frac{1}{4}$
0-30	6	$8\frac{15}{16}$	$4\frac{1}{16}$	$1\frac{9}{16}$	$8\frac{15}{16}$	$1\frac{1}{4}$
0-30	11	$8\frac{15}{16}$	$2\frac{7}{8}$	$1\frac{9}{16}$	$8\frac{15}{16}$	$1\frac{1}{4}$
0-30	12	$3\frac{1}{2}$	$3\frac{5}{8}$	$1\frac{7}{16}$	$3\frac{1}{2}$	$1\frac{1}{4}$
31-60	1	$4\frac{7}{8}$	$1\frac{3}{8}$	$1\frac{15}{16}$	$5\frac{9}{16}$	$2\frac{3}{8}$
31-60	2	$4\frac{3}{4}$	$3\frac{7}{16}$	$1\frac{7}{8}$	$5\frac{9}{16}$	$1\frac{9}{16}$
31-60	3	$4\frac{3}{4}$	5	$1\frac{7}{8}$	$5\frac{9}{16}$	$1\frac{9}{16}$
31-60	4	$6\frac{5}{8}$	$3\frac{7}{16}$	$1\frac{7}{8}$	$6\frac{15}{16}$	$1\frac{9}{16}$
31-60	5	8	5	$1\frac{7}{8}$	$8\frac{5}{16}$	$1\frac{9}{16}$
31-60	10	$10\frac{11}{16}$	$3\frac{5}{8}$	$2\frac{1}{4}$	$11\frac{5}{8}$	$1\frac{11}{16}$
31-60	6	12	$5\frac{5}{16}$	$2\frac{1}{4}$	$12\frac{7}{8}$	$1\frac{11}{16}$
31-60	11	12	$3\frac{11}{16}$	$2\frac{1}{4}$	$12\frac{7}{8}$	$1\frac{11}{16}$
61-100	7	$6\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{9}{16}$	$6\frac{5}{8}$	$4\frac{7}{8}$
61-100	8	$8\frac{1}{8}$	$4\frac{3}{16}$	$2\frac{5}{16}$	$8\frac{1}{8}$	$1\frac{15}{16}$
61-100	9	$8\frac{1}{8}$	$6\frac{1}{8}$	$2\frac{5}{16}$	$8\frac{1}{8}$	$1\frac{15}{16}$
101-200	7	$7\frac{3}{4}$	$2\frac{7}{8}$	$3\frac{1}{8}$	$8\frac{1}{4}$	$5\frac{3}{4}$
201-400	7	$9\frac{1}{4}$	$3\frac{3}{8}$	$4\frac{1}{16}$	$10\frac{1}{4}$	$6\frac{3}{4}$
401-600	7	11	$3\frac{1}{2}$	$4\frac{3}{8}$	$12\frac{3}{8}$	$8\frac{1}{8}$

Delta Connection.—This method of connection is used only with three-phase a.c. currents. If the connection of a generator is changed from "star" to "delta," its current will be increased 1.73 times for the same power delivery. If it is changed from "delta" to "star," its e.m.f. will be increased 1.73 times. A synonymous term for delta is "mesh."

Demand Factor.—At present it is customary among inspection bureaus to demand conductor capacity equivalent to the whole connected load operating at its maximum capacity. Experience, however, has shown that in many cases this leads to a great waste of copper.

In very many installations it has been found that not over 20 per cent of the connected load is ever in



Demand Factor Chart.

use at the same time. Tables of demand factors applicable to many classes of service have been worked out and are in existence. But as far as the authors are aware, these are all arranged from the standpoint of the central station engineer and are hardly applicable to individual installations. As a matter of fact, the authors have failed to find any two installations, even in the same line of business, quite alike.

INDIVIDUAL MOTORS

Many motors are now designed and rated to carry a certain overload, usually 25 per cent, for a short time. This fact should be taken into account wherever it seems necessary. Whenever motors are designed for a short time rating, instead of for continuous use, it seems but right that the conductors be chosen with the same length of time in view. Insofar as the heating of conductors is concerned, it is unnecessary to pay any attention to the ordinary starting current. The only justification for the excessive carrying capacity usually demanded for individual motors, lies in a possible necessity to take care of overloads.

GROUPS OF REGULARLY REVERSING MOTORS

A graphic representation of current values in a series of cycles of operation of a reversible motor operating a large washing machine is given in Figure 4b. In connection with such motors, it is quite usual to reverse without giving the armature time to come to rest. The reversed current through the armature must first bring the machinery to rest and then start it in the opposite direction. The majority of such motors reverse at intervals of 10 or 12 seconds and the average peak current lasts about one second.

In this connection it will be well to note that, in order to give this study a practical value, we must take a course about midway between absolute accuracy and haphazard guess work. The heating effect of various kinds of motor loads cannot be accurately determined without the use of graphic current charts and these are seldom available at the time the installation is made. The contractor and the inspector are thus, in the majority of cases, compelled to judge by the rated h. p. of the motors required. In order, therefore, to make these tables of general use to the public, the carrying capacity of conductors required

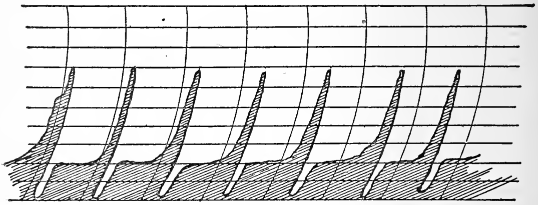


Figure 4b

must be based upon the h. p. intended to be installed. It is principally for this reason that the following table has been arranged in the form given.

The table gives factors which express the ratio of the h. p. equivalent of intermittent or fluctuating currents to the heating equivalent of the same currents. The h. p. value of a fluctuating current (voltage assumed constant) is proportional to the average sum of all the ordinates of a curve representing it. The heating effect of the same current is proportional to the r. m. s. value of the same ordinates. Thus, if we divide the r. m. s. value of a certain fluctuating current by its h. p. value, we shall obtain a factor by which we may multiply the h. p. delivered by a motor in such service in order to find the amperage for which conductor capacity should be provided to guard against overheating.

At the top of the table we have the various percentages of time of minimum and peak currents. In the first vertical row we have various percentages of peak currents expressed in terms of the minimum current used. In this form we may use the factors in connection with the rated h. p. of the motors, provided we know, in a general way, the approximate ratio of the minimum to the peak currents required by the fluctuating load.

As an example: If we have a motor reversing regularly and requiring a peak current five times as great as its running current, and this during half of the time of each cycle, we look where the lines pertaining to 50 per cent peak and minimum current time cross the line pertaining to the 500 per cent peak, and find there the factor 1.21, which indicates that the amperage to be provided for must be 1.21 times that called for by the h. p. rating of the motor.

TABLE

Percent time of peak current.		10	20	30	40	50	60	70	80	90
Percent time min. current....		90	80	70	60	50	40	30	20	10
Percent peak load in terms of min. load..	200%	1.04	1.05	1.06	1.06	1.05	1.04	1.04	1.04	1.01
	300%	1.12	1.15	1.15	1.14	1.12	1.10	1.07	1.05	1.02
	400%	1.22	1.25	1.23	1.21	1.17	1.13	1.10	1.07	1.03
	500%	1.31	1.34	1.30	1.26	1.21	1.16	1.11	1.07	1.03
	600%	1.41	1.42	1.37	1.29	1.23	1.18	1.12	1.08	1.04
	700%	1.50	1.50	1.40	1.32	1.25	1.19	1.13	1.09	1.04
	800%	1.59	1.54	1.44	1.35	1.27	1.20	1.15	1.09	1.04
	900%	1.67	1.59	1.47	1.37	1.28	1.21	1.15	1.09	1.04
	1000%	1.74	1.63	1.50	1.39	1.29	1.22	1.15	1.09	1.04

The factors here given are correct for single motors and are based on the worst possible condition under which a group of motors can operate; viz., all peaks superimposed. This is a condition which may at times be attained, but if a large group of motors is considered, the chance of its recurrence is exceedingly small.

With these considerations in view, we deduce the following formula to find the fraction of the total time during which the peaks of all the motors in use are likely to be superimposed:

$$A^b$$

In this formula, A represents the fraction of the time of a cycle of operation during which the peak is in use, and b the number of motors in use. In the case of laundry motors of the characteristics shown in Figure 4b, the peaks, when once coincident, will remain so for some length of time or until one or more have been stopped and the combination broken. In the case of elevator motors the combination will almost immediately be broken.

GROUPS OF REVERSING MOTORS WITH VARIABLE TIME INTERVALS

In many machine shops the planers are equipped with reversing motors. Some very clever systems of control have been worked out and in some of these the carriage is made to return at a high rate of speed after making the cut. The length of time during which such a motor moves in either direction is variable and the power required by the forward and return strokes is also variable. The periodicity, as well as the relative amount of current, vary and are governed by the work in hand.

Since there is no permanent regularity about any of the operations, no exact forecast as to what will happen at any particular time can be made. A study of the conditions as illustrated in Figure 4c will, however, assist materially in judging what the current demands of a group of such motors may be at times.

In the figure we have five motors, denoted by black circles, in operation and reversing regularly at intervals of 12, 6, 8, 4 and 9 seconds. An inspection of the figure will show at a glance that, with any num-

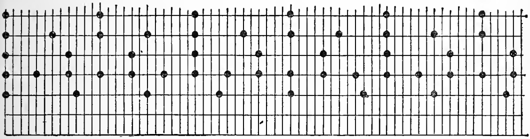


Figure 4c

ber of motors, if they start in synchronism, the time of coincidence of the peak of all of them will be proportional to the least common multiple of all of their time intervals. In this case that number is 72; hence, at intervals of 72 seconds these motors will all come into synchronism as far as their peaks are concerned. Their minima of current will, of course, also come into synchronism regularly.

If they do not start in synchronism, those starting at time intervals which form a multiple of their own time, remote from that of other motors, will work into synchronism and out of it in a perfectly regular manner, just as will those shown in the figure. Those that start at different time intervals, however, will not.

As an example, if the motor having a period of 6 seconds starts either 1, 2, 3, 4, 5, 7, 8, 9, 10 or 11 seconds after the other, it will never superimpose its peak entirely upon that of the other, although a part of it may overlap. It must, however, be borne in mind that the motor having the shortest periods governs the chances of falling into step. A motor having a period of 4, for instance, will have only one chance in 4 of missing regular synchronism of peaks with other motors having periods of 8 or 12. With motors on this kind of work then, we may be certain that there will be coincidence of peaks at times. In connection with motors of this kind it will be safe to use about the average multipliers given in the table, the average being determined from the characteristics of the different motors.

PASSENGER ELEVATOR AND SIMILAR MOTORS

In the kind of service here considered, the current is either entirely on or off. If calculations are to be based upon current or power charts the equivalent current of a cycle of operations should be determined by the r. m. s. method. The formulae and the tables herewith furnished, however, are so arranged that, for general purposes, we need merely know the rated h. p. of the whole group and the relative time of the on and off periods.

In the preliminary operation of finding the current required it is to be assumed that the motors are delivering their rated capacity continuously, regardless of the nature of their rating. The formula given below is also independent of the number of motors and the demand factor obtained is a function of the relative on and off times of the motors, which is assumed to be the same for all.

A conductor is used to the best advantage with reference to heating when subjected to a steady current flow. Hence, if another conductor be called upon to transmit an equivalent amount of energy with intermittent service, the carrying capacity of the second conductor must be correspondingly increased. If the load is of such a nature that the conductor is idle half of the time, it must carry double current during the other half of the time. As the heating is proportional to the square of the current, it follows that a double current during half time is equivalent in heating effect to $\sqrt{2}$ times the normal current used continuously. The same relation holds for all other time divisions and this will allow us to find the value of a steady current, to be denoted by I, which will be the equivalent of any regularly intermittent current of the nature here considered by the formula as given below:

$$\sqrt{\frac{t}{t'}} \times i = I$$

where i is the theoretical current based on the total motor rating, t the fraction or percentage of time in a cycle of operation during which the motor is using this current, and t' the time of a complete cycle of operation. This formula will give us a multiplier, virtually a demand factor, by which we can find the current having an equivalent heating effect to that required by the motors under the assumption that they are all working under the worst possible condition, i. e., all motors taking their maximum current at the same instant.

The factors calculated according to the formula as applying to the various percentages of time during which the current is in use, are given below. The upper line gives the percentage of time during which current is used, and the lower line gives the multiplying factors.

Percentage of Time.......	10	20	30	40	50	60	70	80	90
Factors	.32	.45	.55	.66	.71	.78	.84	.89	.95

GROUPS OF MOTORS OF INDISCRIMINATE CHARACTERISTICS

This classification embraces all kinds of motors as usually found in shops and factories. There are two ways of arriving at the probable demand factor of such groups. One way consists of consulting tables made up from experiences with similar installations. This method has the great disadvantage that it is almost impossible to find two installations near enough alike to warrant very accurate comparisons. Such tables are given further on, but should be used only as general guides and the final determination made only after making a careful analysis of the installation.

A simple method of analyzing a motor installation and determining its demand factor is as follows: Take any piece of ordinary ruled paper and number as many lines as there are hours of the day to be considered. Let these lines be horizontal. Next draw as many lines vertically across them as there are motors to be considered. Also place each line so that in position and length it may cover the hours of the day during which the motors are thought to be in use.

There are two ways in which such a representation can be made. If the motors have no fixed time at which they run, their running time may be laid out at the bottom of the figure; the main point being that the lines give a fair idea of the proportionate running time per day. If the stopping and starting intervals are not too short, a series of such lines, representing the estimated number of starts, may be used.

If any of the motors are used only during certain hours of the day, the line pertaining to these motors may be placed in the horizontal lines pertaining to the hours of the day, as for instance *A* and *B* in the figure. These two motors never interfere with each other, but do occasionally come in at the same time with some of the other motors plotted at the bottom of the line.

Department Stores.—Such places usually require large quantities of power for illumination, electric signs, and motors. The demand factor for lighting is very close to 100 per cent. If economy is not too much insisted upon, a bountiful circuit capacity should be provided. This will allow brilliant illumination wherever it is needed. As department stores contain nearly all of the goods handled in other stores, hints on illumination of special places should be looked up under the corresponding headings—dry goods stores, jewelry, etc. As there are usually large areas visible from any one place, good appearance demands some uniform arrangement of fixtures. If this does not provide sufficient light for certain goods in show cases, local illumination is provided in the cases. If branch circuit capacity for five watts per square foot is provided, it will enable very brilliant illumination of spots without overloading circuits and not interfere with the frequent changes which are made. The capacity of general mains need not be greater than two watts per square foot on the most important flows.

Depreciation.—Depreciation must be duly considered in dealing with any form of apparatus. The depreciation is governed entirely by the useful life of the device, but this in turn is governed by the amount of wear and tear which cannot be repaired for from time to time; obsolescence, possibly inadequacy after a time, or probable cessation of business. Depreciation should not be confused with maintenance, to which should be charged all mishaps which do not permanently lessen the natural useful life of the apparatus. From 10 to 20 per cent is often charged to depreciation, but it is better to estimate it carefully in each case unless a parallel case is well understood.

Desk Lighting.—The illumination of desks by individual lamps is never to be advised, except in the case of individuals with very poor eyesight or in locations where desks are far apart or used but a few hours per day. Where individual desk lighting is provided, the cost of energy may sometimes be lower, but the first cost of installation, and also maintenance, is always high. There is, further, always a considerable fire hazard, and all of these offset the saving in energy to a large extent. A general and fairly shadowless illumination also adds much to the efficiency of clerks. The following table shows the comparative cost of proper general illumination as compared with local for desks of various spacing. It is assumed that a general illumination of $1\frac{1}{4}$ watts per square foot is provided, and that at each desk a 25-watt lamp is also used, while the general illumination with which this desk lighting is compared is obtained through the medium of the most efficient large wattage lamps at present on the market. One watt per square foot will give good general illumination, which will need to be helped out by local lighting only for persons with weak eyes. Where local desk lighting is resorted to the wattage requirements will be about as follows:

Av. sq. ft. per desk....	20	25	30	35	40	45	50
Total watts per sq. ft..	1.5	1.25	1.08	0.96	0.87	0.80	0.75

It will be noted that where desks are close together the general illumination is not only the easiest installed but also the cheapest to operate. If the desks are used only a small part of the time the local illumination will be the cheaper. Lamps used for desk lighting should either be frosted or encased in diffusing globes.

Diamagnetic.—Zinc, antimony, bismuth, and certain other metals are repelled when placed between the poles of strong magnets, and are said to be diamagnetic. Metals which are attracted by magnetism are said to be paramagnetic.

Dielectric.—Any substance which is an insulator and allows electrostatic induction to take place through its mass. Usually taken as synonymous with insulation.

Dry Kilns.—Such places are too hot for rubber-covered wire. Use asbestos-covered. Place cut-outs and switches outside.

Eddy Currents.—Useless currents which are produced in the iron of pole pieces, etc., subject to motion in a magnetic field, or to the influence of coils in which a fluctuating current exists. They cause a waste of energy and heat the metal.

Efficiency.—The efficiency of motors, transformers, and other similar translating devices is found by dividing the output by the input. In connection with sources of electric illumination the term *efficiency* has an entirely different meaning. The efficiency of such devices is spoken of as a certain number of watts per candle power. In this case, the higher the efficiency, the more uneconomical is the lamp. See *Motors* and *Illumination* for practical applications.

Egg Candling.—One light must be provided for each workman, and it should be located about waist high. The wires should be run at this height so as to avoid use of long cords. The light is always made adjustable, and is encased in a small metallic hood with a small opening.

Electric Braking.—This is also sometimes termed "dynamic braking." If an electric motor is disconnected from its source of supply, and its armature circuit closed while the armature is still in motion, it will generate current and consume power, and may be brought to rest very quickly in this manner. Where the necessary provisions for this purpose are installed this method of braking is very successful.

Electrolysis.—Nearly all electrolysis is due to the fact that piping and other metallic structures near a ground return system of electrical distribution afford a return circuit of such low resistance as compared to the return circuit provided, that a large part of the current returns over the piping. It is impossible to prevent electrolysis entirely except by insulating the return wires. The troubles may, however, be materially reduced. The current does damage only where it leaves the pipes or other structures which it has entered, and the damage is in proportion to the amperes carried. The methods used for lessening electrolysis are the following:

1. Protection of structures by concrete or other forms of insulation, or keeping them as far as possible from ground return circuits. Insulation of piping is not advisable; it is likely to concentrate the trouble at spots where it is poor.

2. Bonding pipes, etc., so as to prevent current which has once entered them from leaving, except at predetermined places, and then never to earth.

3. Negative boosters have been suggested, but have not been extensively tried. A negative booster is a low-voltage dynamo connected into the return circuit in such a manner as to draw current from the rails and earth and deliver it back to the station.

4. Reinforcing the rails, etc., by large conductors, thus increasing the conductivity of the return, and lowering the p.d. between the rails and the station.

In most cities ordinances mention the difference in potential which may be allowed to exist between any two points on the return wires. In Chicago it is provided that all uninsulated electrical return circuits must be of such current-carrying capacity and so arranged that the difference of potential between any two points on the return circuit will not exceed the limit of twelve volts, and between any two points on the return 1000 feet apart within a one-mile radius of the City Hall will not exceed the maximum limit of 1 volt, and between any two points on the return 700 feet apart outside of this one-mile radius limit will not exceed the limit of 1 volt. In addition thereto, a proper return conductor system must be so installed and maintained as to protect all metallic work from electrolysis damage. The return current amperage on pipes and cable sheaths must not be greater than 0.5 amperes per pound-foot for caulked cast iron pipe, 8.0 amperes per pound-foot for screwed wrought iron pipe, and 16.0 amperes per pound-foot for standard lead or lead alloy sheaths of cables.

All insulated return current systems must be equipped with insulated pilot wire circuits and voltmeters, so that accurate chart records will be obtainable daily, showing the difference of potential between the negative bus-bars in each station and at least four extreme limits on the return circuit in its corresponding feeding district. Also with recording ammeters, insulated cables, and automatic reverse load and overload circuit breakers which will record and limit the maximum amperes drained from all the metallic work (except the regular return feeders) to less than 10 per cent of the total output of the station. Figuring on the basis of the average resistance of cast iron, wrought iron, and lead, the above amperages will exist with the following difference of potential per running foot, and will be independent of the thickness or size of pipe: Cast iron, 0.000711 volt per foot; measurements must be taken on solid pipe and not across any joint. Wrought iron, 0.001568 volt per foot; measurement to be taken as above. Lead sheaths, 0.007497 volt per foot; as joints in lead sheaths are always soldered and wiped, no attention need be paid to them. The lower amperage for the iron piping is specified because joints will usually be found of higher resistance than the piping, and at each joint current is likely to leave piping and enter it again just beyond.

The proper treatment of electrolysis may require all four methods outlined above. The method most to be recommended in a general way is that of reinforcing the return conductors sufficiently to limit the difference of potential as prescribed.

The following table shows the size of copper conductors necessary with rails of various weights per yard to reduce electrolysis to $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{1}{4}$, etc.; the specific resistance of the rails being taken as 10 times that of copper, and the resistance of bonds as negligible.

TABLE XV.

Showing c. m. of copper necessary to reduce p. d. of electrolysis to the fraction of its original value given.

Weight of Rails Per Yard	Circular Mils of Rail	1-2	1-3	1-4
40	4,950,000	495,000	990,000	1,485,000
45	5,600,000	560,000	1,120,000	1,680,000
50	6,230,000	623,000	1,246,000	1,869,000
60	7,500,000	750,000	1,500,000	2,250,000
70	8,770,000	877,000	1,754,000	2,631,000
80	9,900,000	990,000	1,980,000	2,970,000
90	11,200,000	1,120,000	2,240,000	3,360,000
100	12,500,000	1,250,000	2,500,000	3,750,000

Weight of Rails Per Yard	Circular Mils of Rail	1-5	1-6	1-7	1-8
40	4,950,000	1,980,000	2,475,000	2,970,000	3,465,000
45	5,600,000	2,240,000	2,800,000	3,360,000	3,920,000
50	6,230,000	2,492,000	3,115,000	3,738,000	4,361,000
60	7,500,000	3,000,000	3,750,000	4,500,000	5,250,000
70	8,770,000	3,508,000	4,385,000	5,262,000	6,039,000
80	9,900,000	3,960,000	4,950,000	5,940,000	6,930,000
90	11,200,000	4,480,000	5,600,000	6,720,000	7,840,000
100	12,500,000	5,000,000	6,250,000	7,500,000	8,750,000

For a comprehensive treatment of electrolysis a map of the return circuits and adjacent piping should be made. Tests determining p. d. and direction of current should be made, and results marked upon the map. In many cases currents will be found in opposite direction at the same point at different times. In estimating the current strength from p. d. noted between track and piping the distance of the latter from the track must be taken into consideration. If this is small a low p. d. may deliver considerable current. Often the trouble can be reduced sufficiently by running comparatively short lengths of heavy copper. In testing p. d.'s it is best to use a sensitive galvanometer. Such an instrument may be calibrated with reference to a milli-volt meter.

TABLE XVI

The table below shows the approximate amperage per milli-volt p.d. per foot which will be found in the various kinds and sizes of piping and sheaths given.

Cast Iron, Inside Diam.	Wt., Per Ft.	Average Amperes	Wrought Iron, Inside Diam.	Wt., Per Ft.	Average Amperes	Lead Sheaths, ⅛" Outside Diam.	Amperes Approx.
3	16	12	½	.87	4½	1.26	5
4	22	15	¾	1.15	5½	1.50	6
6	35	25	1	1.70	8	1.58	6
8	50	37	1¼	2.25	11	1.65	6.6
10	67	50	1½	2.75	14	1.68	6.9
12	87	65	2	3.60	18	1.72	7.0
14	110	82	2½	5.80	30	1.78	7.1
16	135	102	3	7.65	40	1.84	7.2
18	165	123	3½	9.00	48	1.90	7.5
20	190	141	4	11.0	57	1.95	7.7
24	255	190	4½	12.5	66	1.98	7.9
30	370	275	5	15.0	80	2.00	8.0
36	500	375	6	19.0	100	2.05	8.2
42	665	500	7	24.0	125	2.10	8.4
48	850	635	8	29.0	155	2.15	8.6
54	1,050	775	9	34.0	180	2.19	8.8
60	1,300	970	10	41.0	220	2.21	8.9
72	1,575	1,200	11	46.0	250	2.24	9.0
84	1,850	1,400	12	51.0	275	2.32	9.3

Electrolyte is the name given to the solution used in storage batteries and other batteries.

Electromagnets.—The magnetic flux is equal to the magnetomotive force divided by the reluctance. The magnetomotive force is the product of current times number of turns of wire and is known as ampere turns. The reluctance of the iron of all well designed magnets is very low but that of the air gap is high, so that roughly speaking we can judge the total reluctance by the air gap. In any given case the magnetic flux is approximately proportional to the current strength up to a point at which the iron becomes nearly saturated. After this the increase is slow until the point of full saturation is reached and after this it is very slow.

To increase the magnetization (e. m. f. being fixed) we must increase the size of wire; winding more turns of the same wire upon a spool simply decreases the current required for a given magnetization but does not alter the magnetization itself. The self-induction and the sparking are proportional to the square of the number of turns of wire. The heating is proportional to the square of the current used. The heating of the coils sets the limit of the current which may be used. A radiating surface of from 1 to 3 square inches per watt consumed in the coil is usually provided. One watt per square inch will heat the coil very much if it is in use continuously. The possible traction of electromagnets is about 200 lbs. per square inch for good annealed wrought iron, and 75 for cast iron. This, however, varies widely with the quality of iron used. In laboratory experiments as high as 1,000 lbs. per square inch has been obtained. Single phase a-c. magnets do not give a constant pull but two and three phase magnets are very serviceable. The "chattering" of single phase magnets can be lessened by a "shading coil." Lifting magnets are extensively used. They are built with the two poles concentric and the material to be lifted constitutes the armature. Permanent magnets are used only in small sizes.

USEFUL FORMULAS AND TABLES

In the following formulas it is assumed that the wires lie squarely over one another in the coil, each wire fully occupying a space equal to the square of its diameter. As in most coils some insulating medium is placed between the different layers, this is about the condition which exists in practice.

The symbols used in the formulas are as follows:

d = diameter of wire, in inches, over insulation.
l = length of wire, on spool, in inches.
nt = number of turns.
r = resistance of one foot of wire.
rs = radiating surface.
B = diameter of core and insulation, in inches.
D = diameter over outside of completed winding, in inches.
L = length of winding space on spool, in inches.
N = depth of winding from core to outside, in inches.
W = weight of wire.
a, c, k = constants for use in the formula, given in the tables below. Each constant has a different value for each size and kind of wire used.

Number of turns in a given spool (see Figure 5):

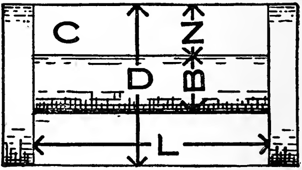


Figure 5.

$$nt = \frac{L \times N}{d^2}$$

Diameter of wire to give a certain number of turns:

$$d = \sqrt{\frac{L \times N}{nt}}$$

Cross-section of winding space, or $L \times N$, necessary to accommodate a certain number of turns of a given wire:

$L \times N = d^2 \times nt.$

Length of wire on a given spool:

$l = (D^2 - B^2)\, L \times k.$ See table below for value of k.

Weight of wire on a given spool:

$W = (D^2 - B^2)\, L \times c.$ See table below for value of c.

Resistance of wire on a given spool:

$R = (D^2 - B^2)\, L \times a.$ See table below for value of a.

Radiating surface for a given spool:

$rs = D \times 3.14 \times L.$

TABLE XVII

CONSTANTS.

	k — Constant for Length			c — Constant for Weight			a — Constant for Resistance		
B. & S. Gauge	Double Cotton	Single Cotton	Single Silk	Double Cotton	Single Cotton	Single Silk	Double Cotton	Single Cotton	Single Silk
20	40.9	50.4	56.7	.137	.162	.177	.415	.512	.576
21	50.4	64.1	72.7				.638	.812	.920
22	60.2	78.0	89.7				.97	1.257	1.445
23	68.3	89.7	104.7				1.387	1.82	2.08
24	83.6	113.5	135.	.1115	.149	.169	2.14	2.91	3.46
25	97.2	135.	163.				3.14	4.36	5.27
26	114.	163.	202.				4.65	6.65	8.24
27	135.	202.	255.				6.94	11.75	13.1
28	148.	226.	291.	.0845	.122	.148	9.60	14.62	18.82
29	182.	291.	387.				14.85	23.7	31.6
30	201.	334.	454.				20.7	34.4	46.8
31	226.	387.	542.				29.36	50.25	70.4
32	255.	454.	655.	.0687	.1045	.132	41.8	74.4	107.2
33	291.	542.	812.				60.33	114.5	168.
34	334.	655.	1023.				87.1	170.5	266.5
35	354.	712.	1140.				116.2	234.	374.8
36	387.	811.	1340.	.0492	.0825	.1115	160.	335.5	555.
37	422.	897.	1582.				220.5	468.	806.
38	457.	1023.	1825.				308.	674.	1192.
39	496.	1170.	2165.				412.	972.	1795.
40	532.	1300.	2525.	.038	.0615	.0888	557.	1360.	2645.

Depreciation.—Depreciation must be duly considered in dealing with any form of apparatus. The depreciation is governed entirely by the useful life of the device, but this in turn is governed by the amount of wear and tear which cannot be repaired for from time to time; obsolescence, possibly inadequacy after a time, or probable cessation of business. Depreciation should not be confused with maintenance, to which should be charged all mishaps which do not permanently lessen the natural useful life of the apparatus. From 10 to 20 per cent is often charged to depreciation, but it is better to estimate it carefully in each case unless a parallel case is well understood.

Desk Lighting.—The illumination of desks by individual lamps is never to be advised, except in the case of individuals with very poor eyesight or in locations where desks are far apart or used but a few hours per day. Where individual desk lighting is provided, the cost of energy may sometimes be lower, but the first cost of installation, and also maintenance, is always high. There is, further, always a considerable fire hazard, and all of these offset the saving in energy to a large extent. A general and fairly shadowless illumination also adds much to the efficiency of clerks. The following table shows the comparative cost of proper general illumination as compared with local for desks of various spacing. It is assumed that a general illumination of 1¼ watts per square foot is provided, and that at each desk a 25-watt lamp is also used, while the general illumination with which this desk lighting is compared is obtained through the medium of the most efficient large wattage lamps at present on the market. One watt per square foot will give good general illumination, which will need to be helped out by local lighting only for persons with weak eyes. Where local desk lighting is resorted to the wattage requirements will be about as follows:

Av. sq. ft. per desk....	20	25	30	35	40	45	50
Total watts per sq. ft..	1.5	1.25	1.08	0.96	0.87	0.80	0.75

It will be noted that where desks are close together the general illumination is not only the easiest installed but also the cheapest to operate. If the desks are used only a small part of the time the local illumination will be the cheaper. Lamps used for desk lighting should either be frosted or encased in diffusing globes.

Diamagnetic.—Zinc, antimony, bismuth, and certain other metals are repelled when placed between the poles of strong magnets, and are said to be diamagnetic. Metals which are attracted by magnetism are said to be paramagnetic.

Dielectric.—Any substance which is an insulator and allows electrostatic induction to take place through its mass. Usually taken as synonymous with insulation.

Dry Kilns.—Such places are too hot for rubber-covered wire. Use asbestos-covered. Place cut-outs and switches outside.

Eddy Currents.—Useless currents which are produced in the iron of pole pieces, etc., subject to motion in a magnetic field, or to the influence of coils in which a fluctuating current exists. They cause a waste of energy and heat the metal.

Efficiency.—The efficiency of motors, transformers, and other similar translating devices is found by dividing the output by the input. In connection with sources of electric illumination the term *efficiency* has an entirely different meaning. The efficiency of such devices is spoken of as a certain number of watts per candle power. In this case, the higher the efficiency, the more uneconomical is the lamp. See *Motors* and *Illumination* for practical applications.

Egg Candling.—One light must be provided for each workman, and it should be located about waist high. The wires should be run at this height so as to avoid use of long cords. The light is always made adjustable, and is encased in a small metallic hood with a small opening.

Electric Braking.—This is also sometimes termed "dynamic braking." If an electric motor is disconnected from its source of supply, and its armature circuit closed while the armature is still in motion, it will generate current and consume power, and may be brought to rest very quickly in this manner. Where the necessary provisions for this purpose are installed this method of braking is very successful.

Electrolysis.—Nearly all electrolysis is due to the fact that piping and other metallic structures near a ground return system of electrical distribution afford a return circuit of such low resistance as compared to the return circuit provided, that a large part of the current returns over the piping. It is impossible to prevent electrolysis entirely except by insulating the return wires. The troubles may, however, be materially reduced. The current does damage only where it leaves the pipes or other structures which it has entered, and the damage is in proportion to the amperes carried. The methods used for lessening electrolysis are the following:

1. Protection of structures by concrete or other forms of insulation, or keeping them as far as possible from ground return circuits. Insulation of piping is not advisable; it is likely to concentrate the trouble at spots where it is poor.

2. Bonding pipes, etc., so as to prevent current which has once entered them from leaving, except at predetermined places, and then never to earth.

3. Negative boosters have been suggested, but have not been extensively tried. A negative booster is a low-voltage dynamo connected into the return circuit in such a manner as to draw current from the rails and earth and deliver it back to the station.

4. Reinforcing the rails, etc., by large conductors, thus increasing the conductivity of the return, and lowering the p. d. between the rails and the station.

In most cities ordinances mention the difference in potential which may be allowed to exist between any two points on the return wires. In Chicago it is provided that all uninsulated electrical return circuits must be of such current-carrying capacity and so arranged that the difference of potential between any two points on the return circuit will not exceed the limit of twelve volts, and between any two points on the return 1000 feet apart within a one-mile radius of the City Hall will not exceed the maximum limit of 1 volt, and between any two points on the return 700 feet apart outside of this one-mile radius limit will not exceed the limit of 1 volt. In addition thereto, a proper return conductor system must be so installed and maintained as to protect all metallic work from electrolysis damage. The return current amperage on pipes and cable sheaths must not be greater than 0.5 amperes per pound-foot for caulked cast iron pipe, 8.0 amperes per pound-foot for screwed wrought iron pipe, and 16.0 amperes per pound-foot for standard lead or lead alloy sheaths of cables.

All insulated return current systems must be equipped with insulated pilot wire circuits and voltmeters, so that accurate chart records will be obtainable daily, showing the difference of potential between the negative bus-bars in each station and at least four extreme limits on the return circuit in its corresponding feeding district. Also with recording ammeters, insulated cables, and automatic reverse load and overload circuit breakers which will record and limit the maximum amperes drained from all the metallic work (except the regular return feeders) to less than 10 per cent of the total output of the station. Figuring on the basis of the average resistance of cast iron, wrought iron, and lead, the above amperages will exist with the following difference of potential per running foot, and will be independent of the thickness or size of pipe: Cast iron, 0.000711 volt per foot; measurements must be taken on solid pipe and not across any joint. Wrought iron, 0.001568 volt per foot; measurement to be taken as above. Lead sheaths, 0.007497 volt per foot; as joints in lead sheaths are always soldered and wiped, no attention need be paid to them. The lower amperage for the iron piping is specified because joints will usually be found of higher resistance than the piping, and at each joint current is likely to leave piping and enter it again just beyond.

The proper treatment of electrolysis may require all four methods outlined above. The method most to be recommended in a general way is that of reinforcing the return conductors sufficiently to limit the difference of potential as prescribed.

The following table shows the size of copper conductors necessary with rails of various weights per yard to reduce electrolysis to $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{1}{4}$, etc.; the specific resistance of the rails being taken as 10 times that of copper, and the resistance of bonds as negligible.

TABLE XV

Showing c. m. of copper necessary to reduce p. d. of electrolysis to the fraction of its original value given.

Weight of Rails Per Yard	Circular Mils of Rail	1-2	1-3	1-4
40	4,950,000	495,000	990,000	1,485,000
45	5,600,000	560,000	1,120,000	1,680,000
50	6,230,000	623,000	1,246,000	1,869,000
60	7,500,000	750,000	1,500,000	2,250,000
70	8,770,000	877,000	1,754,000	2,631,000
80	9,900,000	990,000	1,980,000	2,970,000
90	11,200,000	1,120,000	2,240,000	3,360,000
100	12,500,000	1,250,000	2,500,000	3,750,000

Weight of Rails Per Yard	Circular Mils of Rail	1-5	1-6	1-7	1-8
40	4,950,000	1,980,000	2,475,000	2,970,000	3,465,000
45	5,600,000	2,240,000	2,800,000	3,360,000	3,920,000
50	6,230,000	2,492,000	3,115,000	3,738,000	4,361,000
60	7,500,000	3,000,000	3,750,000	4,500,000	5,250,000
70	8,770,000	3,508,000	4,385,000	5,262,000	6,039,000
80	9,900,000	3,960,000	4,950,000	5,940,000	6,930,000
90	11,200,000	4,480,000	5,600,000	6,720,000	7,840,000
100	12,500,000	5,000,000	6,250,000	7,500,000	8,750,000

For a comprehensive treatment of electrolysis a map of the return circuits and adjacent piping should be made. Tests determining p. d. and direction of current should be made, and results marked upon the map. In many cases currents will be found in opposite direction at the same point at different times. In estimating the current strength from p. d. noted between track and piping the distance of the latter from the track must be taken into consideration. If this is small a low p. d. may deliver considerable current. Often the trouble can be reduced sufficiently by running comparatively short lengths of heavy copper. In testing p. d.'s it is best to use a sensitive galvanometer. Such an instrument may be calibrated with reference to a milli-volt meter.

TABLE XVI

The table below shows the approximate amperage per milli-volt p.d. per foot which will be found in the various kinds and sizes of piping and sheaths given.

Cast Iron, Inside Diam.	Wt., Per Ft.	Average Amperes	Wrought Iron, Inside Diam.	Wt., Per Ft.	Average Amperes	Lead Sheaths, ⅛" Outside Diam.	Amperes Approx.
3	16	12	½	.87	4½	1.26	5
4	22	15	¾	1.15	5½	1.50	6
6	35	25	1	1.70	8	1.58	6
8	50	37	1¼	2.25	11	1.65	6.6
10	67	50	1½	2.75	14	1.68	6.9
12	87	65	2	3.60	18	1.72	7.0
14	110	82	2½	5.80	30	1.78	7.1
16	135	102	3	7.65	40	1.84	7.2
18	165	123	3½	9.00	48	1.90	7.5
20	190	141	4	11.0	57	1.95	7.7
24	255	190	4½	12.5	66	1.98	7.9
30	370	275	5	15.0	80	2.00	8.0
36	500	375	6	19.0	100	2.05	8.2
42	665	500	7	24.0	125	2.10	8.4
48	850	635	8	29.0	155	2.15	8.6
54	1,050	775	9	34.0	180	2.19	8.8
60	1,300	970	10	41.0	220	2.21	8.9
72	1,575	1,200	11	46.0	250	2.24	9.0
84	1,850	1,400	12	51.0	275	2.32	9.3

Electrolyte is the name given to the solution used in storage batteries and other batteries.

Electromagnets.—The magnetic flux is equal to the magnetomotive force divided by the reluctance. The magnetomotive force is the product of current times number of turns of wire and is known as ampere turns. The reluctance of the iron of all well designed magnets is very low but that of the air gap is high, so that roughly speaking we can judge the total reluctance by the air gap. In any given case the magnetic flux is approximately proportional to the current strength up to a point at which the iron becomes nearly saturated. After this the increase is slow until the point of full saturation is reached and after this it is very slow.

To increase the magnetization (e.m.f. being fixed) we must increase the size of wire; winding more turns of the same wire upon a spool simply decreases the current required for a given magnetization but does not alter the magnetization itself. The self-induction and the sparking are proportional to the square of the number of turns of wire. The heating is proportional to the square of the current used. The heating of the coils sets the limit of the current which may be used. A radiating surface of from 1 to 3 square inches per watt consumed in the coil is usually provided. One watt per square inch will heat the coil very much if it is in use continuously. The possible traction of electromagnets is about 200 lbs. per square inch for good annealed wrought iron, and 75 for cast iron. This, however, varies widely with the quality of iron used. In laboratory experiments as high as 1,000 lbs. per square inch has been obtained. Single phase a-c. magnets do not give a constant pull but two and three phase magnets are very serviceable. The "chattering" of single phase magnets can be lessened by a "shading coil." Lifting magnets are extensively used. They are built with the two poles concentric and the material to be lifted constitutes the armature. Permanent magnets are used only in small sizes.

USEFUL FORMULAS AND TABLES

In the following formulas it is assumed that the wires lie squarely over one another in the coil, each wire fully occupying a space equal to the square of its diameter. As in most coils some insulating medium is placed between the different layers, this is about the condition which exists in practice.

The symbols used in the formulas are as follows:

d = diameter of wire, in inches, over insulation.
l = length of wire, on spool, in inches.
nt = number of turns.
r = resistance of one foot of wire.
rs = radiating surface.
B = diameter of core and insulation, in inches.
D = diameter over outside of completed winding, in inches.
L = length of winding space on spool, in inches.
N = depth of winding from core to outside, in inches.
W = weight of wire.
a, c, k = constants for use in the formula, given in the tables below. Each constant has a different value for each size and kind of wire used.

Number of turns in a given spool (see Figure 5):

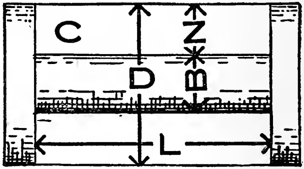


Figure 5.

$$nt = \frac{L \times N}{d^2}$$

Diameter of wire to give a certain number of turns:

$$d = \sqrt{\frac{L \times N}{nt}}$$

Cross-section of winding space, or $L \times N$, necessary to accommodate a certain number of turns of a given wire:

$L \times N = d^2 \times nt.$

Length of wire on a given spool:

$l = (D^2 - B^2)\, L \times k.$ See table below for value of k.

Weight of wire on a given spool:

$W = (D^2 - B^2)\, L \times c.$ See table below for value of c.

Resistance of wire on a given spool:

$R = (D^2 - B^2)\, L \times a.$ See table below for value of a.

Radiating surface for a given spool:

$rs = D \times 3.14 \times L.$

TABLE XVII

CONSTANTS.

	k Constant for Length			c Constant for Weight			a Constant for Resistance		
B. & S. Gauge	Double Cotton	Single Cotton	Single Silk	Double Cotton	Single Cotton	Single Silk	Double Cotton	Single Cotton	Single Silk
20	40.9	50.4	56.7	.137	.162	.177	.415	.512	.576
21	50.4	64.1	72.7				.638	.812	.920
22	60.2	78.0	89.7				.97	1.257	1.445
23	68.3	89.7	104.7				1.387	1.82	2.08
24	83.6	113.5	135.	.1115	.149	.169	2.14	2.91	3.46
25	97.2	135.	163.				3.14	4.36	5.27
26	114.	163.	202.				4.65	6.65	8.24
27	135.	202.	255.				6.94	11.75	13.1
28	148.	226.	291.	.0845	.122	.148	9.60	14.62	18.82
29	182.	291.	387.				14.85	23.7	31.6
30	201.	334.	454.				20.7	34.4	46.8
31	226.	387.	542.				29.36	50.25	70.4
32	255.	454.	655.	.0687	.1045	.132	41.8	74.4	107.2
33	291.	542.	812.				60.33	114.5	168.
34	334.	655.	1023.				87.1	170.5	266.5
35	354.	712.	1140.				116.2	234.	374.8
36	387.	811.	1340.	.0492	.0825	.1115	160.	335.5	555.
37	422.	897.	1582.				220.5	468.	806.
38	457.	1023.	1825.				308.	674.	1192.
39	496.	1170.	2165.				412.	972.	1795.
40	532.	1300.	2525.	.038	.0615	.0888	557.	1360.	2645.

TABLE XVIII

Round Cotton-covered Magnet Wire

American Steel & Wire Co.

Coarse Sizes

Size B. & S.	Diameter Inches	Allowable Variation Either Way in Per Cent.	Rated Area in Cir. Mils.	Single Cotton Covered Approximate Values Outside Diameter Inches	Single Cotton Covered Approximate Values Feet per Pound	Double Cotton Covered Approximate Values Outside Diameter Inches	Double Cotton Covered Approximate Values Feet per Pound
0	0.3249	½ of 1	105,625	.333	3.1	.339	3.1
1	.2893	½ of 1	83,694	.297	3.9	.303	3.9
2	.2576	½ of 1	66,358	.266	5.	.272	4.9
3	.2294	¾ of 1	52,624	.237	6.2	.243	6.2
4	.2043	¾ of 1	41,738	.212	7.8	.218	7.8
5	.1819	¾ of 1	33,088	.190	9.9	.196	9.9
6	.1620	¾ of 1	26,244	.170	12.5	.176	12.4
7	.1443	¾ of 1	20,822	.152	15.7	.158	15.6
8	.1285	1	16,512	.136	19.8	.142	19.6
9	.1144	1	13,087	.121	24.9	.125	24.7
10	.1019	1	10,384	.108	31.4	.113	31.1
11	.0907	1	8,226	.097	39.5	.102	39.1
12	.0808	1¼	6,528	.087	49.6	.092	49.2
13	.0720	1¼	5,184	.078	62.5	.083	61.7
14	.0641	1¼	4,108	.070	78.6	.075	77.5
15	.0571	1½	3,260	.063	98.9	.068	97
16	.0508	1½	2,580	.056	125	.060	122
17	.0453	1½	2,052	.050	157	.054	153
18	.0403	1½	1,624	.045	198	.050	192
19	.0359	1¾	1,288	.041	248	.045	240

ENAMELED MAGNET WIRE

Enamel insulation has a dielectric strength far in excess of silk or cotton covered wire. It will also withstand a much greater heat, as silk and cotton insulation will char at 270° Fahr., whereas enamel insulation will withstand 450° Fahr. without the slightest deterioration.

Another decided feature about enamel insulation is the economy of space where this material is used for coil windings, and it takes up much less space than the single silk insulation. This feature is a very important one, especially to manufacturers of electrical instruments and apparatus where space economy is essential.

TABLE XIX

Size B. & S.	Diam. Enam. Wire	Approx. Feet per Lb.	Approx. Turns per Sq. In.	Size B. & S.	Diam. Enam. Wire	Approx. Feet per Lb.	Approx. Turns per Sq. In.
16	....	126	359	29	.0122	2570	7900
17	....	159	447	30	.0109	3240	10000
18	....	201	567	31	.0097	4082	12620
19	....	253	715	32	.0087	5132	16020
20	.0337	320	885	33	.0077	6445	20400
21	.0302	404	1126	34	.0069	8093	25200
22	.0269	509	1400	35	.0062	10197	31900
23	.0241	642	1736	36	.0055	12813	40000
24	.0215	810	2160	37	.0049	16110	51600
25	.0192	1019	2770	38	.0044	20274	65700
26	.0171	1286	3460	39	.0039	25519	81600
27	.0153	1620	4270	40	.0035	32107	104000
28	.0136	2042	5400	..	....	....	....

TABLE XX

Table for Insulated Copper Wire. (Belden Manufacturing Co.)

B. & S. Gauge	Single Cotton, Total Insulation Thickness 4 Mils.		Double Cotton, Total Insulation Thickness 8 Mils.		Single Silk, Total Insulation Thickness 1¾ Mils.		Double Silk, Total Insulation Thickness 4 Mils.	
	Ohms per pound	Feet per pound	Ohms per pound	Feet per pound	Ohms per pound	Feet per pound	Ohms per pound	Feet per pound
20	3.15	311	3.02	298	3.24	319	3.18	312
21	4.99	389	4.72	370	5.12	403	5.03	389
22	7.88	488	7.44	461	8.15	503	7.96	493
23	12.44	612	11.7	584	12.92	636	12.65	631
24	19.55	762	18.25	745	20.50	800	19.95	779
25	30.8	957	28.45	903	32.50	1005	31.5	966
26	48.6	1192	44.3	1118	51.29	1265	49.7	1202
27	76.45	1488	68.8	1422	82.00	1590	78.3	1542
28	120.	1852	106.5	1759	129.00	1972	123.5	1917
29	188.5	2375	164.	2207	205.00	2570	194.	2485
30	294.6	2860	252.	2534	328.5	3145	306.5	2909
31	460.5	3800	384.5	2768	512.3	3943	477.	3683
32	716.	4375	585.	3737	810.0	4950	747.	4654
33	1117.	5390	880.	4697	1277.5	6180	1165.	5689
34	1720.	6580	1315.	6168	2018.	7740	1810.	7111
35	2642.	8050	1960.	6737	3175.	9680	2820.	8534
36	4060.	9820	2890.	7877	4970.	12000	4340.	10039
37	6190.	11860	4230.	9309	7940.	15000	6660.	10666
38	9440.	14300	6150.	10666	12320.	18660	10250.	14222
39	14420.	17130	8850.	11907	19200.	23150	15600.	16516
40	22600.	21590	12500.	14222	30200.	28700	23650.	21333

TABLE XXI

Table of Diameters (d) and Square of Diameters (d^2) for Insulated Copper Wire.

B. & S.	Double Cotton		Single Cotton		Single Silk	
	d	d^2	d	d^2	d	d^2
20	.040	.0016	.036	.001296	.034	.001156
21	.036	.0013	.032	.00102	.030	.0009
22	.033	.00109	.029	.00084	.027	.00073
23	.031	.00096	.027	.00073	.025	.000625
24	.028	.000784	.024	.000576	.022	.000484
25	.026	.000675	.022	.000484	.020	.0004
26	.024	.000575	.020	.0004	.018	.000324
27	.022	.000484	.018	.000324	.016	.000256
28	.021	.000441	.017	.000289	.015	.000225
29	.019	.00036	.015	.000225	.013	.000169
30	.018	.000324	.014	.000196	.012	.000144
31	.017	.000289	.013	.000169	.011	.000121
32	.016	.000256	.012	.000144	.010	.000100
33	.015	.000225	.011	.000121	.009	.000081
34	.014	.000196	.010	.000100	.008	.000064
35	.0136	.000185	.0096	.000092	.0076	.0000576
36	.013	.000169	.009	.000081	.007	.000049
37	.0124	.000155	.00845	.000073	.00645	.0000415
38	.012	.000143	.008	.000064	.006	.0000362
39	.0115	.000132	.0075	.000056	.0055	.0000303
40	.0111	.000123	.0071	.0000504	.0051	.000026

Elevators.—Electric motors are used direct connected or belted; in some cases they are used to pump water for hydraulic elevators. Motors should be capable of exerting a strong starting torque, and are generally compounded. Means are usually provided for cutting out the compound winding, or otherwise weakening the field to obtain high speeds. To prevent sparking at the brushes, commutating poles are frequently used. The ordinary commercial motor is seldom used for elevator service.

The methods of speed control with d. c. motors consist in weakening the field and cutting resistance out or in; dynamic braking is also used in some cases for slowing down. With a. c. motors wound rotors are often used.

Single phase as well as two and three phase motors are practicable, and variable speed motors are often employed. Hydraulic elevators require about 1.7 as much power as direct connected. A.-c. elevator motors under the same conditions require about 20 to 30 per cent more power than d. c. motors.

The H. P. required can be found by the formula

$$\text{H. P.} = \frac{l \times s}{33{,}000 \times e}$$

where l = unbalanced load in pounds, s = speed in feet per minute, e = combined efficiency of motor and elevator machinery. This is usually about 0.50.

The speed of freight elevators often runs as low as 65 to 85 feet per minute, while some passenger elevators run as fast as 700 feet per minute. As the load is always intermittent motors may be rated high, and the starting torque is from two to two and one-half times running torque.

The following table gives the H. P. required to lift various loads at speeds given; a combined efficiency of 50 per cent being assumed.

TABLE XXII

Table showing H. P. required to lift unbalanced loads at speeds given. Efficiency of 50 per cent assumed.

	Speed in Feet Per Minute								
Lbs.	75	100	125	150	200	250	300	400	500
1000....	4.5	6.1	7.6	9.1	12.1	15.1	18.2	24.2	30.2
1250....	5.7	7.6	9.5	11.4	15.2	19.0	22.8	30.4	38.0
1500....	6.8	9.1	11.4	13.6	18.2	22.8	27.2	36.4	45.6
1750....	7.9	10.5	13.3	15.8	21.0	26.6	31.6	42.0	53.2
2000....	9.1	12.1	15.2	18.2	24.2	30.4	36.4	48.4	60.8
2500....	11.3	15.1	19.0	22.6	30.2	38.0	45.2	60.4	76.0
3000....	13.6	18.2	23.7	27.2	36.4	47.4	54.4	72.8	94.8
3500....	15.9	21.2	27.5	31.8	42.4	55.0	63.6	84.8	110.0
4000....	18.2	24.2	30.4	36.4	48.4	60.8	72.8	96.8	121.6
4500....	20.4	27.3	34.2	40.8	54.6	68.4	81.6	109.2	136.8
5000....	22.7	30.3	38.0	45.4	60.6	76.0	90.8	121.2	152.0
6000....	27.2	36.4	45.4	54.4	72.8	90.8	108.8	145.6	181.6

Emergency Lighting.—This is usually required in churches, theatres and other places where large numbers of people congregate. The purpose is to provide a system of illumination which shall be in service if the main system should fail. In large cities the emergency lighting is supposed to be used during the entire time the audience is in the building. An entirely independent and separate service should be provided for it, and there should be no switches or fuses except those absolutely necessary.

Equalizers.—Equalizer wires are used in connection with two or more compound generators operated in parallel. All connections must be to the same terminal with series field. Wires should be led to switchboard, and connected to middle blade of switch. Arrange switch blades so that equalizer will be connected slightly ahead of other wire. The lower the resistance of the equalizer, the closer will be the regulation of the machines. Never connect ammeter on same side with equalizer.

Factors.—*Assurance Factor.*—This is the ratio of the voltage at which a wire or cable is tested to that at which it is to be used.

Demand Factor. (See *Demand Factor*).—This is the ratio or the maximum demand of any system, or part of a system, to the total connected load of the system, or of the part of the system under consideration.

Diversity Factor.—The diversity factor of any part of a system of distribution is the ratio of the sum of the maxima of the subdivisions to the maximum demand on the source of supply during some given time.

To find the diversity factor we divide the sum of the maxima of the consumers during a given period of time by the maximum registered at the source of supply during the same time. If all consumers use their maximum energy at the same instant the diversity factor is 1. A large diversity factor is a distinct advantage. In a central station system a certain diversity factor will be found to exist between the consumers maxima, and the transformer serving them; between the various transformers and the main serving them there will be another diversity factor; between the mains and their feeder still another will exist, and so on between mains, substations, transmission lines, and central station. The diversity factor of the last station is found by multiplying together all the other diversity factors.

Average diversity factors for a large central stations as given by Gear & Williams are:

Residence lighting. Diversity factor from 3.32 to 3.40. Commercial lighting. Diversity factor from 1.40 to 1.51. General power. Diversity factor from 1.39 to 1.60.

Load Factor.—The load factor is the ratio of the average load to the maximum load demanded by a consumer, a group of consumers connected to a single transformer, a group of transformers, feeders, mains, transmission lines, substations, generators, or central stations. For each of these on the same system it has a different value which is found by dividing the average load by the maximum load. A low load factor is a disadvantage.

The following data are condensed from tables published by Gear & Williams in "Electric Central Station Distributing Systems."

Residence lighting.

Individual consumer's average load factor = 7%.

Transformer load factor = 23% to 24%.

Commercial lighting.

Average consumer's load factor = 10% to 13%.

Transformer load factor = 15% to 19%.

General power.

Average consumer's load factor = 15% to 21%.

Transformer load factor = 21% to 30%.

Plant Factor.—This is the ratio of the average load to the rated capacity of the power plant.

Power Factor.—The power factor is the ratio of the true power to the volt-amperes. In the case of sinusoidal voltage and current, the power factor is equal to the cosine of their difference in phase. The power factor is always less than unity and may be either lagging or leading.

Reactance Factor.—This is the ratio existing between the reactance of a circuit, and its ohmic resistance.

Reactive Factor.—The reactive factor expresses the ratio of the wattless volt-amperes to the total volt-amperes. It is equal to the reactance divided by the impedance, which is equal to the sine of the angle between the impressed voltage and the current.

Safety Factor.—The ratio of the strength of material to the load to which it is to be subjected. It is common practice to use a safety factor of 4 or 5.

Saturation Factor.—The saturation factor of a machine is the ratio of a small percentage increase in the field excitation, to the corresponding increase in voltage thereby produced.

Factories.—It is an old custom to illuminate factories by means of small c. p. lamps distributed among machinery so as to give each workman in need of it one lamp. Since the advent of the large wattage tungsten, or Mazda lamps, this has been somewhat changed. The change has been further helped along by individual drive machinery which has eliminated the belting and shafting. Where the work is not particular, one 100 watt tungsten lamp, if kept clean, to every 200 or 300 square feet of floor surface will give good results. Where particular work is done this illumination must be helped out by a 15 watt local lamp. A general illumination has the advantage that it will not have to be changed every time a machine is moved, which frequently happens. Where individual lighting for machinery is to be provided it will be well to avoid placing lamps before the machinery is located; plans are seldom reliable. The mercury vapor lamp gives a very serviceable illumination for some purposes, but it is said that fine machine work is not well done under it; also because of the ghastly appearance is gives faces, many men do not like to work under it. Oil dissolves rubber very fast, and when flexible cord is used around machinery it is well to encase it in loom.

To avoid interference with open wires run them as far as possible between joists or along beams. Drop all lights from ceiling and never use floor pockets or side wall outlets. Make ample provision for glue pots and small portable motors.

(For hints on motors, see *Motors.*)

Fans.—(See *Ventilation.*)

Farad.—The practical unit of capacity. A condenser or conductor in which a charge of one coulomb (1 ampere for 1 second) produces a p. d. of one volt has a capacity of one farad. The farad is much too large for practical work, and micro-farads are used. A condensor of two or three micro-farads is quite large.

Faradic Current.—This term is used in therapeutics, and designates the current taken from an induction coil as distinguished from a galvanic or direct current.

Faure Plate.—In this type of storage battery plate, the active material is pasted onto the supporting material, instead of being *formed* there. This type of plate is used mostly for vehicles. It gives a maximum of capacity with a minimum of weight.

Feeders.—These are the wires which start from a central station, substation, or other center and feed a group or center from which mains supply translating devices. The term is always rather loosely used. There may be feeders and sub-feeders. A voltage of about 1,000 per mile of feeder length is customary.

Festoons.—Festoons to be strung across streets are usually wired with number 8 or 10 wire, and weather-proof sockets. As a rule they are supported in the center of the street, and swung from pulleys which allow of lowering for lamp renewals, etc. In order to allow for graceful hanging the wires should be from 1.3 to 1.6 times the width of street. Lights are usually spaced from 18 inches to two feet apart. At street intersections two festoons are often swung diagonally across, and in such a case the length of wire should be two times the width of street. The supporting cables from which the festoons are swung are attached to buildings and poles on opposite side of street and in many cases they must be run diagonally to find attachments which will allow the festoon to come in its proper place. This often necessitates very long spans and requires strong cables. Three-eighths and half-inch steel cables are often used. Where festoons are swung over trolley lines strain insulators are used. Festoons for theatre work are made up of stage cable and weatherproof sockets; joints are staggered, and taped to prevent strain on joints.

Fiber.—This, in general, is a serviceable insulating material, but on account of the fact that it does not resist moisture, and swells and warps when wet, it is not approved for light and power voltages.

Field.—This term describes either a magnetic, or an electrostatic field. Field magnets are the electromagnets which produce the electric field in which the armature revolves. Field coils are the coils in which the magnetizing current circulates. A field rheostat is one which regulates the current in the field coils. A field of force is the space traversed by an electrostatic, or magnetic flux. The field windings of induction motors are those in which the rotating field is produced.

Fire Alarms.—May be either automatically, or manually operated. In the manual system a glass disk is usually broken to send in an alarm. In the automatic system a fuse opens, or closes a circuit and sends in the alarm. A system in which the current is constantly flowing is always preferable because it is always under test, and failure of any kind will send in an alarm. Means of testing without sending in alarms should be provided. The common fire alarm telegraph system consists of boxes containing notched wheels which are released when the box is pulled, and send in the code signal.

Fish Work.—For light and power voltages armored cable, or single rubber covered wires in circular loom are used; never use twin wire. When one is alone on a fish job, a bell and battery connected to the fish wire with one pole, and to a coil of wire inserted in the hole at the other end with the other, is very useful. When the fish wire touches the other wire the bell will ring. Use a small chain for dropping and a spring wire for other work.

Fixtures.—The height of hanging varies from 6 feet 2 inches to 7 feet. The so-called art-domes are hung much lower, but they are a passing fad.

Memorandum of Fixture Work

	Name....................... Address.....................	Room or Circuit Number					
Chandeliers	No. lights on each circuit	....	....	....	....	....	....
	No. of beam lights	....	....	....	....	....	....
	No. of electric lights	....	....	....	....	....	....
	No. of gas lights	....	....	....	....	....	....
	Style of finish	....	....	....	....	....	....
	Catalogue number	....	....	....	....	....	....
	Sketch number	....	....	....	....	....	....
	Kind of glassware	....	....	....	....	....	....
	Catalogue number	....	....	....	....	....	....
	Size of holders	....	....	....	....	....	....
	Kind of sockets	....	....	....	....	....	....
	Height lowest point above floor	....	....	....	....	....	....
	Size of gas stub	....	....	....	....	....	....
Brackets	No. of elec. lights	....	....	....	....	....	....
	Kind of sockets	....	....	....	....	....	....
	No. gas lights	....	....	....	....	....	....
	Style of finish	....	....	....	....	....	....
	Catalogue number	....	....	....	....	....	....
	Sketch number	....	....	....	....	....	....
	Kind of glassware	....	....	....	....	....	....
	Catalogue number	....	....	....	....	....	....
	Height above floor	....	....	....	....	....	....
	Size gas stub	....	....	....	....	....	....
	No. switches	....	....	....	....	....	....
	Kind of switch	....	....	....	....	....	....
	Style of finish	....	....	....	....	....	....

The standard height of brackets is from $5\frac{1}{2}$ to 6 feet above floor.

No fixture should ever be selected except with reference to the room in which it is to be hung, and it should be neither conspicuous for its expensiveness or cheapness.

Elaborate fixtures made up of cheap material should never be used; pretense is always abominable. Before installing, test each fixture for continuity, short circuits and grounds; move wires while

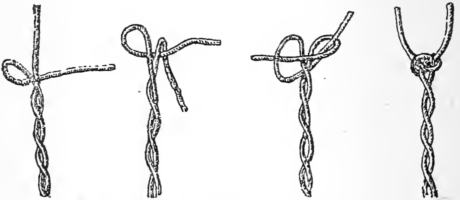


Figure 6.—Method of Tying Knots in Flexible Cord.

testing. The following memoranda will be of use in ordering fixtures:

Flashers on branch circuits usually operate single pole. In such a case one-half of the cut-outs may be located at flasher, the other half, if more convenient, in the sign. Although the flasher allows the use of only a part of the lights at a time, it is customary to run mains for the full requirements of all the lights.

Flat Irons constitute a considerable fire hazard and every precaution should be taken to install them safely. A pilot lamp is very useful. Provide extra flexible cord to help out the cord furnished with iron so the two will be long enough to allow iron to fall to the floor without straining fixture or other attachment. The common domestic flat irons weighing from 3 to 8 lbs. require from 250 to 635 watts. A substantial metal stand should always be provided and should separate the iron about $2\frac{1}{2}$ inches from cloth on board.

Flexible Cord improperly used causes the majority of electrical fires. The common cord should always hang free in air; should never be spliced, and should be soldered only where it connects to line wires. In sockets, rosettes, and outlet boxes it must be knotted to prevent strain from coming on the joints. The best method of tying knots is shown in Figure 6.

Foundries.—The general illumination of foundries is commonly effected by means of arc lamps or clusters of incandescent lamps. The flaming arc is very effective. Strong shadows are useful, as all objects soon assume the same color. Cleaning of lamps is an important item and for this reason clusters of incandescent lamps are often encased in outer globes, which are more easily cleaned. In addition to the general illumination, each molder requires an individual lamp for his own use.

Frequencies.—A frequency of 25 cycles per second is generally used for rotary converter work, and power transmission. Arc and incandescent lamps do not operate well with such low frequencies, hence a frequency of 60 cycles is generally used for illumination. In any given circuit, the higher the frequency, the greater will be the reactance. If the frequency is too high for a given device the current will be insufficient, if too low it will be excessive. A frequency changer is a machine usually installed in substations. A frequency indicator is usually installed upon switchboards, or used in connection with a large motor installation.

Fuses.—Fuses are divided into three general classes: open, enclosed, and expulsion. The fuse metal itself is never hard enough to stand up well under binding screws, hence copper tips are necessary. If these are not used there will be much unnecessary blowing. All fuses should be placed in cabinets not only to prevent molten metal from causing fires, but to insure greater reliability of the fuse by protecting it against drafts. The fusing of branch, and main circuits inside of buildings is thoroughly covered by the National Electrical Code. The rule in general is to provide fuse protection wherever the size of wire changes. The fuse to be of such size as to prevent current rise above the safe carrying capacity of wires as given in the Code. Each motor or other translating device also requires separate fuse protection except that small devices aggregating not more than 660 watts capacity may be grouped under one fuse.

All plans of fusing are a compromise between the desire to obtain adequate protection on the one hand, and escape the trouble caused by the many accidental breaks and uncalled for operations of fuses.

Overhead systems as a rule are not fused where they leave the switchboard, but are equipped with switches or disconnectives.

Feeders leaving the transmission lines are also usually left without fuse protection, but equipped with disconnectives.

Fuse protection is fully demanded only where the chances of short circuits or grounds are quite great, and this point is not reached until the transformers are reached. It must be borne in mind that all consumers devices are protected by service fuses and switches, and these protect the outer lines fully against everything except what occurs on the poles. The primary side of transformers of small and medium capacity is usually protected by fuses, but the fuses are made large enough so that ordinary overloads will not cause them to blow.

TABLE XXIII

The following table gives fuse sizes often used with transformers of the capacities given.

K.W. Capacity	Size Fuse Amperes	K.W. Capacity	Size Fuse Amperes
1	3	15	15
2	3	20	15
3	3	25	20
4	3	30	20
5	5	40	30
7½	10	50	40
10	10		

On the secondary side of transformers, fuses are not ordinarily used and it is not advisable to have them. In case a number of transformers feed a network the blowing of one fuse may cause the blowing of another, etc., until all are out. Under such circumstances fuses cannot well be replaced until the load on the main is sufficiently reduced to allow one transformer to carry it, or until the feeder supplying the network has been opened; in this case the feeder must be left open until all fuses have been replaced. In connection with underground circuits the case is different. Here short circuits and grounds are much more likely to occur. Such systems also always supply a much larger number of customers within a given space, and more care is necessary. Underground networks are usually fused at each junction point so that, if an overload causes one fuse to blow, the other will follow and clear the balance of the circuits from trouble. Wherever parallel lines are run they should be equipped with reverse current circuit breakers. Three phase four wire systems are usually provided with a single pole switch in each leg, thus any phase can be disconnected without interfering seriously with the others. For three phase three wire systems three pole switches are used. All telephone circuits should be protected by fuse and in addition with "sneak coils" and air gap arresters. Heat coils are arranged to open the circuit when a small or "sneak current" has passed through them for a considerable time, or a large current in an instant. Air gap arresters are supposed to open the circuit whenever unduly high potentials come to exist at their terminals.

TABLE XXIV

Tested Fuse Wire from ½ to 100 Amperes

Safe Carrying Capacity Amperes	Best Lengths for Use and Fusing Currents for such Lengths: Inches	Amperes	Length Per Lb.: Ft.	In.	Mils. Diam.
½	1	1½	2550		10
¾	1	2¼	1516		13
1	1¼	3	993		16
2	1½	5	407		25
3	1½	7	265		31
4	1¾	9	207		35
5	1¾	10	167		39
6	2	12	144		42
7	2	13	120		46
8	2	15	106		49
9	2	16	94		52
10	2¼	17	84		55
12	2¼	20	68		61
14	2¼	23	58		66
15	2¼	24	55		68
16	2½	25	49		72
18	2½	28	43		77
20	2½	30	37	10	82
25	2¾	37	28	9	94
30	2¾	43	24		103
35	3	49	20		113
40	3	56	17	2	122
45	3	62	15	4	129
50	3	69	13	6	137
60	3¼	81	10	3	158
70	3¼	93	8	10	170
75	3½	99	7	9	182
80	3½	106	7	2	189
90	3½	118	5	8	212
100	4	129	5		226

Tested Fuse Strip from 50 to 600 Amperes

Safe Carrying Capacity Amperes	Best Lengths for Use and Fusing Currents for such Lengths — Inches	Amperes	Weight Per Foot Ounces
50	3	69	1⅛
60	3¼	81	1⅜
70	3¼	93	1¾
75	3½	99	1⅞
80	3½	106	2⅛
90	3¾	118	2½
100	4	129	3
125	4¼	158	3⅞
150	4½	187	4⅞
175	4½	215	6
200	4¾	243	6⅞
225	4¾	270	7⅞
250	4¾	298	8⅞
275	4¾	325	9¾
300	5	351	10¾
350	5¼	402	12¾
400	5¼	450	14⅝
450	5½	500	17
500	6	550	20½
600	6½	675	35

The current required to fuse metals can be found by the well known Preece formula:

$$I = a\sqrt{d^3},$$

where I = current in amperes, d = diameter of wire, and a = a constant for different kinds of metal as given below:

Copper 10244	Iron 3148
Aluminum 7585	Lead 1379
German Silver........5230	

The table below is calculated from the above formula and constants, and gives the current required to fuse wires of various sizes.

TABLE XXV

B. & S.	Copper	Aluminum	German Silver	Iron	Lead
4	942	698	481	290	127
6	666	493	339	204	90
8	471	349	240	145	63
10	334	247	171	103	50
12	235	174	120	72	32
14	165	122	84	51	22
16	117	86	60	35	16
18	82	60	42	25	11
20	58	43	29	18	8
21	49	36	25	15	6
22	40	29	21	12	5
23	36	26	19	11	5
24	29	21	15	9	4
25	25	18	13	8	3
26	20	15	11	6	3
27	17	12	9	5	2
28	14	10	7	4	2
29	12	9	6	4	1.5
30	10	8	5	3	1.2
31	8.5	6	4	2.6	1.0
32	7.0	5	4	2.2	0.9

The strands of which flexible cord is made up range from No. 26 to 36.

Galvanic.—A term much used in therapeutics to denote continuous, or direct current.

Garages.—The gasoline vapors so prevalent in garages do not ordinarily rise more than 4 feet above the floor. Avoid all possibility of electric sparks at this level, especially in pits. Electric lights should be well guarded with elastic lamp-guards which will protect the lamp against breakage even when it falls.

Gas Lighting may be effected by pilot flame, a small quantity of sponge platinum on mantle, or by high-tension electric sparks jumping a number of spark gaps in the gas jets, or low-tension sparks applied to jets in multiple. A spark coil is required and it should be connected with a tell-tale relay and bell which will ring in case the system becomes grounded. Electric gas lighting wires must not be used on same fixtures with electric light.

Gauges.—The American, or Brown & Sharp wire gauge, abbreviated respectively A. W. G. or B. & S., is the one commonly used for measuring copper, aluminum, and resistance wires in general. The U. S. steel wire gauge is commonly used for steel and iron wire. This is also known as the Washburn and Moen; Roebling, and American Steel and Wire, and is generally abbreviated Stl. W. G.

The Birmingham or Stubs' Wire Gauge is sometimes used for brass wire. It is commonly abbreviated B. W. G. This, although spoken of as Stubs, is not identical with the Stubs' Steel Wire Gauge. The British Standard Wire Gauge, the Edison Wire Gauge and the Stubs' Steel Wire Gauge are not much used in this country in electrical work. A comparison of the different wire gauges is given below, diameters being given in mils (thousandths of an inch).

CIRCULAR OF THE BUREAU OF STANDARDS

TABLE XXVI

Tabular Comparison of Wire Gauges. Diameters in Mils.

Gauge No.	American Wire Gauge (B. & S.)[22]	Steel Wire Gauge[23]	Birmingham Wire Gauge (Stubs')	Old English Wire Gauge (London)	Stubs' Steel Wire Gauge	(British) Standard Wire Gauge	Gauge No.
7-0		490.0				500.	7-0
6-0		461.5				464.	6-0
5-0		430.5				432.	5-0
4-0	460.	393.8	454.	454.		400.	4-0
3-0	410.	362.5	425.	425.		372.	3-0
2-0	365.	331.0	380.	380.		348.	2-0
0	325.	306.5	340.	340.		324.	0
1	289.	283.0	300.	300.	227.	300.	1
2	258.	262.5	284.	284.	219.	276.	2
3	229.	243.7	259.	259.	212.	252.	3
4	204.	225.3	238.	238.	207.	232.	4
5	182.	207.0	220.	220.	204.	212.	5
6	162.	192.0	203.	203.	201.	192.	6
7	144.	177.0	180.	180.	199.	176.	7
8	128.	162.0	165.	165.	197.	160.	8
9	114.	148.3	148.	148.	194.	144.	9
10	102.	135.0	134.	134.	191.	128.	10
11	91.	120.5	120.	120.	188.	116.	11
12	81.	105.5	109.	109.	185.	104.	12
13	72.	91.5	95.	95.	182.	92.	13
14	64.	80.0	83.	83.	180.	80.	14
15	57.	72.0	72.	72.	178.	72.	15
16	51.	62.5	65.	65.	175.	64.	16
17	45.	54.0	58.	58.	172.	56.	17
18	40.	47.5	49.	49.	168.	48.	18
19	36.	41.0	42.	40.	164.	40.	19
20	32.	34.8	35.	35.	161.	36.	20
21	28.5	31.7	32.	31.5	157.	32.	21
22	25.3	28.6	28.	29.5	155.	28.	22

Gauge No.	American Wire Gauge (B. & S.)[22]	Steel Wire Gauge[23]	Birmingham Wire Gauge (Stubs')	Old English Wire Gauge (London)	Stubs' Steel Wire Gauge	(British) Standard Wire Gauge	Gauge No.
23	22.6	25.8	25.	27.0	153.	24.	23
24	20.1	23.0	22.	25.0	151.	22.	24
25	17.9	20.4	20.	23.0	148.	20.	25
26	15.9	18.1	18.	20.5	146.	18.	26
27	14.2	17.3	16.	18.75	143.	16.4	27
28	12.6	16.2	14.	16.50	139.	14.8	28
29	11.3	15.0	13.	15.50	134.	13.6	29
30	10.0	14.0	12.	13.75	127.	12.4	30
31	8.9	13.2	10.	12.25	120.	11.6	31
32	8.0	12.8	9.	11.25	115.	10.8	32
33	7.1	11.8	8.	10.25	112.	10.0	33
34	6.3	10.4	7.	9.50	110.	9.2	34
35	5 6	9.5	5.	9.00	108.	8.4	35
36	5.0	9.0	4.	7.50	106.	7.6	36
37	4.5	8.5		6.50	103.	6.8	37
38	4.0	8.0		5.75	101.	6.0	38
39	3.5	7.5		5.00	99.	5.2	39
40	3.1	7.0		4.50	97.	4.8	40
41		6.6			95.	4.4	41
42		6.2			92.	4.0	42
43		6.0			88.	3.6	43
44		5.8			85.	3.2	44
45		5.5			81.	2.8	45
46		5.2			79.	2.4	46
47		5.0			77.	2.0	47
48		4.8			75.	1.6	48
49		4.6			72.	1.2	49
50		4.4			69.	1.0	50

The American Wire Gauge sizes have here been rounded off to about the usual limits of commercial accuracy.

The Steel Wire Gauge is the same gauge which has been known by the various names: "Washburn and Moen," "Roebling," "American Steel and Wire Co.'s." Its abbreviation should be written "Stl. W. G.," to distinguish it from "S. W. G.," the usual abbreviation for the (British) Standard Wire Gauge.

Generators.—*Alternating Current* generators may be of the revolving field or revolving armature type. The revolving field type is easier to insulate and less troublesome to maintain, hence is most widely used. There is another, known as an *inductor* type, in which usually all electrical parts are stationery and an iron spider is caused to revolve, it being so arranged as alternately and regularly to alter the magnetic flux and thus cause induction of e. m. f. This type is not much used.

The so-called *Induction* generator is another type, and is similar to an induction motor; in fact, an induction motor, when driven above the speed of synchronism becomes an induction generator, and delivers current to the line. This type of generator cannot operate unless other alternators provide it with the necessary exciting current. The capacity in generators for field excitation must be nearly equal to one-third of the capacity of the induction generators. This type of generator is well suited for fluctuating speeds such as are given by gas engines, but it can never constitute an entire plant. Alternating current generators are made to operate single-phase, two-phase and three-phase. The single-phase machine is not well suited for power work, and is more expensive per unit of output than polyphase machines. The two-phase generators are, as a rule, used only on old direct current installations which have been adapted to a.-c. operation. The three-phase system is the most economical and is almost universally used. It is well suited for either light or power transmission. Alternators may be built to be self-exciting, but this is not often done. Most of them require a direct current exciter.

Efficiency.—Approximate efficiencies of generators of various sizes are given about as follows: 100 K. V. A., 91 per cent; 500, 94; 1,000, 95; 2,000, 96;

3,000, 96 to 97; 5,000, 97 or better. These efficiencies vary of course with the power factor, load, voltage, etc.

Frequency.—The common frequencies are 25 and 60 cycles per second, the lower being used for transmission to substations and for power alone. The higher frequency is used for mixed lighting and power, and also for lighting alone. In a single-phase machine the current and voltage per phase have but one meaning. The power is equal to $I \times E \times$ power factor, and the product of volts and amperes gives the volt-ampere rating of the machine. In a two-phase alternator each half supplies half of the current and power. The usual four transmission wires are sometimes combined into three wires, and in such a case the voltage between the two outside wires is 1.41 times the phase voltage, and the current in the middle wire is 1.41 times the current in the outside wires. The power in such a combination may be found in two ways. Measuring current in the middle wire and the voltage across both phases, the power is equal to $I \times E \times$ power factor. Measuring current in one of the outside wires, and using phase voltage, the power is equal to $I \times E \times 2 \times$ power factor. Three-phase generators are always connected by means of 3 main wires, and sometimes a neutral, but may be either delta or star. If the delta connection is used, the phase voltage is the same as the voltage between any two wires, but the current in any phase is 1.73 times the current in any one of the wires. If the star connection is used, the voltage between any two wires is 1.73 times the voltage of any phase winding, and the current to deliver the same power will be only 0.58 of the former current in the line wires. The power with either connection is equal to $I \times E \times 1.73 \times$ power factor.

Frequencies.—The common frequencies are 60 and

25 cycles. The higher frequency is used for light, and mixed light and power loads. The lower is used for power alone and also for transmission lines to substations or converters. The frequency of any generator depends upon the speed and number of poles and may be found by the formula:

$$f = \frac{\text{r.p.m.}}{60} \times \frac{\text{number of poles}}{2}$$

The table below shows the speeds at which generators provided with a certain number of poles must operate to deliver current at the frequencies given.

TABLE XXVII

60 Cycles.

No. Poles........	4	8	12	16	20	24
R. P. M..........	1,800	900	600	450	360	300

25 Cycles.

No. Poles........	4	8	12	16	20	24
R. P. M..........	750	375	250	187½	150	125

Operation of Alternators in Parallel.—In order that alternators may be operated in parallel they must be identical in four respects. The frequency must be the same. The voltage must be the same. The current and voltages must be in phase, i.e., their maxima and minima must occur at the same instant. The wave form of the machines should be as near as possible alike.

The frequency is governed by the speed, and if it is not correct, the speed must be adjusted either by adjusting the engine, or diameters of pulleys. The voltage can be determined by a voltmeter test.

Whether the machines are in or out of phase can be determined only by properly connected synchronizing lamps, or synchronizing instruments.

The synchronizing and keeping in step of alternators will be made easier by synchronizing the piston strokes of engines as far as possible if they are separately driven, or, if driven from a common shaft, by running one of the machines with a slack belt, which will allow it to fall in step more readily. Where synchroscopes are used the pointer will indicate which machine is running too fast or too slow: Where the synchronizing is done with lamps they may be connected so as to indicate synchronism either by darkness or light. If the machines are not in phase there will be alternations of darkness and light in the lamps which will alternate with great rapidity if the machines are much out of synchronism, but will be at longer and longer intervals as they are brought more nearly into step. The proper time to close the switch is just a moment before the period of full darkness. If the machines are nearly in synchronism when thrown together, there will be cross current which will help to bring them together, but it is best to have them synchronized perfectly before connecting.

The load cannot be divided among alternators by increasing the field excitation as with direct-current machines; it is necessary to give more steam to the engine of the light running generator. This tends to advance the generator and causes it to take more current. The power factor can be improved or altered by adjusting the field excitation. Adjust fields so that power factor of each machine is the same.

Single Machine, Operation of.—See that machine is entirely disconnected from the load. Inspect all bearings and see that they are well oiled and that oil rings work properly. Adjust field rheostat so that all resistence is in circuit and close exciter circuit. Start machine, bringing it gradually up to speed and cutting out resistance in field rheostat until generator voltage comes to its proper value. Next throw in switches, bringing load on gradually if possible, and adjust rheostat to maintain voltage properly. Test speed to see that it is at its proper value; the speed is of greater importance with alternators than with direct current generators.

Rating.—For full details as to rating, the reader is referred to the Standardization Rules of the A. I. E. E., which are too lengthy to be given here.

The maximum, or continuous, rating of an alternator is commonly taken as the load in kilowatts it can carry at 100 per cent power factor with a maximum rise in temperature of any part of 50° C. (122° F.) above the surrounding air when that is 25° C. (77° F). Corrections for other surrounding temperatures to be made according to A. I. E. E. Standardization Rules. Another rating, used mostly in connection with street railway work, allows a temperature rise of 45° C. (113° F.) under the same conditions as above, and requires that 50 per cent more than the rated load used for two hours shall not cause a temperature rise of more than 55° C. (131° F.).

Voltage.—A voltage in excess of 12,000 or 13,000 is rarely generated direct; higher line voltages are obtained mostly by step-up transformers.

Direct Current Generators, Compound Machines.—This is a combination of shunt and series dynamo, and a distinct improvement over the shunt machine. The compound winding can be adjusted to regulate the voltage as desired. It requires the same instruments as the shunt, and in addition heavy equalizing wires run between each pair of machines. These should be carried to the board and the main switch should be triple pole. The machine may be connected either long shunt (shunt winding bridging compound fields as well as armature), or short shunt (shunt field bridging only armature); it is merely a question of convenience. All these machines may be bi-polar or multi-polar, direct or belt connected and provided with commutating or interpoles.

Rating.—Machines are commonly rated on the basis of their continuous output in kilowatts with a maximum rise in temperature of 50° C. (122° F.) above the surrounding air at 25° C. (77° F.). For full information see A. I. E. E. Standardization Rules. The common voltages are 110 volts for lighting and small power (used mostly in isolated plants); 220 to 250 also for lighting and power, but used mostly in larger plants, and for short distance distribution; 500 to 600 volts, used almost exclusively for street railway work; 2,000 to 6,000, or more, used for series arc lighting by direct current.

The *Series Machine* is used only for constant current work. It requires the following instruments and fittings:

Short circuiting switch for fields.

Ammeter, a switchboard equipped with plugs and jacks.

A polarity indicator is often advisable.

The Shunt Machine is used for all variable current work. Its voltage regulation is poor, and requires constant attention. It requires a field rheostat, fuses, main switch or circuit breaker, volt meter, ammeter, ground detector, switchboard and pilot lamps. The voltage of this machine is variable and automatically decreases with an increase in the devices it supplies.

Greek Alphabet.—Greek letters have become the standard symbols for many quantities dealt with in electrical and mechanical calculations. The letters and their pronunciations are given below:

A α — Alpha.	I ι — Iota.	P ρ — Rho.
B β — Beta.	K κ — Kappa.	Σ σ — Sigma.
Γ γ — Gamma.	Λ λ — Lambda.	T τ — Tau.
Δ δ — Delta.	M μ — Mu.	Υ υ — Upsilon.
E ϵ — Epsilon.	N ν — Nu.	Φ ϕ — Phi.
Z ζ — Zeta.	Ξ ξ — Xi.	X χ — Chi.
H η — Eta.	O σ — Omicron.	Ψ ψ — Psi.
Θ θ — Theta.	Π π — Pi.	Ω ω — Omega.

Gram or Gramme.—The gramme is the mass of a cubic centimeter of water at the temperature of its greatest density. It is the unit of mass and is equal to 15.43235 grains; 7,000 grains equal 1 lb. av.

Gravity Cell.—This is a cell in which copper and zinc immersed in a solution of blue vitriol are the active elements. It is used for continuous work and where small constant currents only are required.

Ground Detectors.—It is customary to provide ground detectors on all switchboards from which entirely insulated circuits are run. Tests should be made quite frequently, so as to catch a ground as soon as it comes on. When grounds exist on both sides of a system, detectors are not reliable and the part to be tested must be disconnected from the board. Continuously indicating detectors are preferable; static instruments are made which can be so used even on high voltage lines with perfect safety.

Grounding.—Any connection of any part of a current carrying conductor, or live metal part of any device which has become connected to a foreign conducting medium so as to deliver current or potential to it, is spoken of as being *grounded.* Some devices and circuits are purposely grounded, the frame or the earth being relied upon as return conductors.

The purposive grounding of wires used in connection with electrical work may be divided into two classes: The grounding of frames, conduits, etc., which are not supposed to become alive except through a breakdown of the insulation, and the grounding of wires, or devices which usually do carry current. The life and fire hazard from electrical sources may be greatly reduced by improving the insulation, so that the chance of any person or material being affected by the current is small, or by arranging a bypath which shall carry the current safely away in case live parts of the conductors come in contact with it. To provide such a shunt is the object of all grounding.

Wherever a ground connection is provided, it increases the liability of a breakdown in the insulation of the device, but at the same time reduces the possibility of serious damage from that source. Connecting the frame of any device to ground weakens the natural insulation of that device, but protects persons and property otherwise liable to injury to a considerable extent. Good cause for the grounding of live parts of electrical circuits for the purpose of protection exists only in cases where two or more voltages exist in such close proximity that there is liability of the higher voltage becoming impressed upon parts normally intended only for the lower voltage. And even under these conditions the N. E. C. authorizes the grounding only when, normally, no current is supposed to be flowing over the ground connections. The grounding of any part of a live circuit under the above conditions increases the chances of trouble but confines the trouble to that which may be possible with the lower voltage. If, for instance, the ground on the secondary of a transformer is in perfect condition, it will give positive assurance that the primary voltage cannot be impressed upon any part of the secondary system, but it will also give assurance that any workman who may come in contact with live parts on the ungrounded side, while making a ground himself, will receive the full benefit of the secondary voltage. In general, since the grounding takes away the natural insulation, which is often relied upon to some extent but quite often does not exist at all, it will force upon manufacturers a higher standard of construction, and the net result will be increased safety in all respects except life. In order to keep the life hazard within bounds it is not customary to ground live wires operating with a potential above 250.

As a general rule, all metallic structures or pipes not normally connected to electrical sources, but liable to be accidentally so connected, should be grounded. Connection to an extensive water pipe system makes the best possible ground. Steam and hot water piping is not so reliable even if connected to water pipe systems. The steel frames of buildings are useful only with supposedly small currents confined to the same building. Gas piping is likely to cause fires if contacts work loose, or if there is any electrolytic action. Where the above means of making ground connections are not available the most economical connection is made with a galvanized iron pipe driven into the ground. The practice of one large company is to use a $1\frac{1}{2}$-inch pipe 8 feet long, and drive its full length into the ground, burying the connection with it. Another company uses a $\frac{1}{2}$- or $\frac{3}{4}$-inch pipe. The resistance of the ground itself is so much higher than that of the pipe that the conductivity of the larger pipe is not much better than that of the smaller, but it is more reliable for driving purposes. Where the ground is of very great importance, it is advisable to use several pipes. The pipe should enter the earth at least 6 feet, and it is probable that an additional foot or two will more than double the usefulness in dry seasons. The resistance of the earth varies with its composition, its degree of moisture, and distance from piping, etc. Gravel and sand, because so easily drained, make very poor grounds, and rock cannot be used at all.

Overhead cables and messenger wires are provided with about one ground per mile. Ground connections may be tested with an ammeter and a voltmeter.

Connect one pole of current source to nearest hydrant or other available piping and the other to the ground. The voltage divided by the current will equal the resistance of the ground, since the piping itself may be considered as comparatively without resistance.

Hanger Boards are required for incandescent lamps indoors on series circuits, but are not necessary with arc lamps, although advisable.

Heat Coils are usually installed in connection with signaling circuits. They are arranged to open the circuit when a large current flows through them for a short time or a small current for a longer time. Their office is to guard against SNEAK CURRENTS too small to blow fuses.

Heating by Electricity.—The heating of buildings by electricity is not commercially practicable, except on a small scale, or under particularly favorable cirsumstances. It is used on a large scale only in connection with street cars. In residences, offices, factories, etc., it is used only for small spaces, or where a limited quantity of heat is required for a short time only. Since there is practically no heat wasted, no air vitiated, little space occupied, no dirt caused, the fire hazard greatly reduced and the heaters are easily portable, it compares under suitable conditions, very favorably with other means of heating. One watt hour will raise the temperature of 1 cubic foot of air about 200 degrees Fahrenheit.

The heat represented by one B. T. U. is sufficient to raise the temperature of 1 lb. of water or 55 cubic feet of air 1 degree Fahrenheit. One watt equals 3.412 B. T. U.s.

In order to heat a room properly we must first supply sufficient heat to raise the temperature the required amount; next, furnish a steady supply of heat to make up for the absorption of walls, floor and ceiling; third, heat the fresh air which must be admitted for ventilating purposes. For a rough estimate it is customary to require from one to two watts per cu. ft. in room.

The wattage necessary to raise the temperature of a room may, however, be more accurately found by the formula:

$$W = \frac{C \times t}{200} \times \frac{60}{m}$$

where W = watts

C = cubic feet of air in room

t = number of degrees F. that temperature must be raised

m = the number of minutes in which this rise must take place.

The above formula makes no allowance for radiation or ventilation.

Under average conditions it may be assumed that every square foot of wall, ceiling, and floor space will absorb heat as given in Table XXX for various temperatures. If we multiply the surfaces by the numbers given we shall obtain the rate at which watts must be supplied to maintain the temperature in a hermetically sealed room after the desired temperature has been secured.

Every human being should be provided with 3,000 cubic feet of fresh air per hour, although it is possible to do comfortably with 2,000 feet. If the allowance per hour, however, is as low as 1,000 feet, conditions will be decidedly injurious to health and also immediately uncomfortable. Since all rooms electrically heated are small, fresh air requirements demand that the air must be changed several times per hour. In order to facilitate the calculations three tables are provided. Table XXVIII shows the number of cubic feet of air contained in rooms of various dimensions likely to be warmed with electrical heat, the height of rooms being assumed as 9 feet. This table also shows the number of square feet of radiating surface, including ceiling and floor. There is further given, in connection with each size of room, the number of times the air should be changed per hour for each occupant to afford fair ventilation. The figures given are such as it is believed the occupants will naturally provide by opening windows or doors.

In Table XXIX we have constants by which the cubic contents of rooms must be multiplied to find the number of watts necessary to raise the temperature of rooms the number of degrees given at top, in the number of minutes given at the left. To find the watts necessary to provide for air changes per hour we must multiply the cubic contents by the constants given for 60 minutes and by the number of times per hour the air is to be changed.

To find the watts lost in radiation we multiply the wall surface by the figures given in Table XXX.

Example.—A bathroom 6 by 8 feet is to be heated 20 degrees F. above the temperature of the surrounding rooms and the rise in temperature must be brought about in five minutes and then maintained for an hour afterward. What size of heater will be required? There are 432 cu. ft. in such a room and by Table XXIX for 20 degrees and five minutes we find 1.20 and multiplying this by 432 we have 518 watts required to heat the air without allowing for conduction or ventilation. From Table XXVIII we also see that there are 348 feet of surface which, multiplied by 2.5, taken from Table XXX, for twenty degrees, give us 870 watts to make up for conduction through walls. Table XXVIII further shows that the air ought to be changed five times per hour; hence, taking the constant 0.10 from Table XXIX for 60 minutes and 20 degrees and multiplying this by 5, we have 0.50, and this, multiplied by the number of cu. ft., gives us 216 watts for air changes, and this, added to 870 watts for conduction, gives us a total of 1,088 watts to keep up the temperature of our bathroom 20 degrees above that of the surrounding rooms. A 1,500-watt heater would serve such a room very nicely.

Every occupant of such a room will contribute about 125 watts of this.

With all doors and windows closed the average house is supposed to allow a change of air at least once per hour.

If a room is to be used only for a short time, a change of once per hour may thus be calculated upon. In laying out heating plants in residences where comfort of the user is the main desideratum, it is advisable to err on the side of plentiful capacity; in commercial installations where the installation is more for the benefit of workmen it may be more judicious to err in the interest of a somewhat small capacity.

In small rooms a heater should always be placed as near as possible where the cold air enters, but in large rooms, if only a portion of the room is to be heated, it should be located out of the way of drafts. The coils should be divided into proportional sections equal to 1 and 2. This will enable 1/3d, 2/3ds or the full capacity of the heater to be used as desired. Electric heating has one advantage over other forms, and this consists in its ability to give instantaneous results, and these are best attained with heaters of comparatively large capacity, so that there will be no temptation to keep up the temperature except when it is actually needed.

TABLE XXVIII

Showing number of cu. ft.; wall surfaces (including ceiling and floor) and necessary changes of air per occupant per hour in room of dimensions given; height of ceiling 9 ft.

Width		Length in Feet. 5	6	7	8	9	10	11	12
5	Cu. feet	225	270	315	360	405	450	495	540
	Wall surface	230	258	286	314	342	370	398	426
	Air changes	9	8	7	6	5	5	4	4
6	Cu. feet	270	324	378	432	486	540	594	648
	Wall surface	258	288	318	348	378	408	438	468
	Air changes	8	6	6	5	4	4	4	3
7	Cu. feet	315	378	441	504	567	630	693	756
	Wall surface	286	318	350	382	414	446	478	510
	Air changes	7	6	5	4	4	3	3	3
8	Cu. feet	360	432	504	576	648	720	792	864
	Wall surface	314	348	382	416	450	484	518	552
	Air changes	6	5	4	4	3	3	3	3
9	Cu. feet	405	486	567	648	729	810	891	972
	Wall surface	342	378	414	450	486	522	558	594
	Air changes	5	4	4	3	3	2.5	2.2	2
10	Cu. feet	450	540	630	720	810	900	990	1,080
	Wall surface	370	408	446	484	522	560	598	636
	Air changes	4.4	4	3.2	3	2.5	2.3	2	2
11	Cu. feet	495	594	693	792	891	990	1,089	1,188
	Wall surface	398	438	478	518	558	598	638	678
	Air changes	4	3.2	3	2.6	2.2	2.0	1.9	1.7
12	Cu. feet	540	648	756	864	972	1,080	1,188	1,296
	Wall surface	426	468	510	552	594	636	678	720
	Air changes	4	3	2.6	2.3	2	2	1.8	1.7

TABLE XXIX

To find watts required to heat air in room (no allowance for radiation or changes) multiply cubic feet of air by factor in table below.

Minutes in which rise is to take place	Rise in Temperature, F. 10	15	20	25	30	35	40
5	0.60	0.90	1.20	1.50	1.80	2.10	2.40
10	0.30	0.45	0.60	0.75	0.90	1.05	1.20
15	0.20	0.30	0.40	0.50	0.60	0.70	0.80
30	0.10	0.15	0.20	0.25	0.30	0.35	0.40
45	0.07	0.10	0.14	0.17	0.20	0.23	0.27
60	0.05	0.07	0.10	0.12	0.15	0.18	0.20

TABLE XXX

To find watts needed to make up for conduction multiply wall surface by factors below.

Temperature Rise

10	15	20	25	30	35	40
1.5	2.0	2.5	3.1	3.6	4.3	5.0

To find watts necessary for ventilation, multiply watts required to heat air in 60 minutes by number of changes of air required per hour.

DOMESTIC HEATING DEVICES

(Westinghouse Electric & Mfg. Co.)

Apparatus	Watts
Broilers, 3 ht.	300 to 1,200
Chafing dishes, 3 ht.	200 to 500
Cigar lighters	75
Coffee percolators	380
Coil heaters	110 to 440
Corn poppers	300
Curling irons	15
Curling iron heaters	60

Apparatus	Watts
Double boilers for 6 in. 3 ht. stove	100 to 440
Flat irons, 3 to 8 lbs., domestic sizes	250 to 635
Foot warmers	50 to 400
Frying kettle, 8 in.	825
Frying pan	250 to 500
Griddle cake cookers, 9x12, 3 ht.	330 to 880
Griddle cake cookers, 12x18, 3 ht.	500 to 1,500
Grill	600
Heating pads	50
Instantaneous flow water heaters	2,000
Kitchenettes (complete), average	1,500
Nursery milk warmers	500
Ornamental stoves	250 to 500
Ovens	1,200 to 1,500
Plate warmers	300
Radiators	500 to 6,000
Ranges, three heats, 4 to 6 people	1,000 to 4,515
Ranges, three heats, 6 to 12 people	1,100 to 5,250
Ranges, three heats, 12 to 20 people	2,000 to 7,200
Samovar	500
Saute pans	165 to 660
Shaving mugs	150
Stoves (plain) 4 in.	50 to 220
Stoves (plain) 6 in., 3 ht.	125 to 500
Stoves (plain) 7 in., 3 ht.	120 to 600
Stoves (plain) 8 in., 3 ht.	165 to 825
Stoves (plain) 10 in., 3 ht.	275 to 1,100
Stoves (plain) 12 in., 3 ht.	325 to 1,300
Stoves, traveler's	200
Toaster stoves, 5 in. by 9 in.	500
Toasters, 9 in. by 12 in., 3 ht.	330 to 880
Toasters, 12 in. by 18 in., 3 ht.	500 to 1,500
Urns, 1 gal., 3 ht.	110 to 440
Urns, 3 gal., 3 ht.	220 to 440
Urns, 3 gal., 3 ht.	330 to 1,320
Urns, 5 gal., 3 ht.	400 to 1,700
Waffle irons, two waffles	770
Waffle irons, three waffles	1,150
Water cup	500
Water heater, bayonet type	700 to 1,500

ELECTRIC HEATING DEVICES FOR INDUSTRIAL PURPOSES

Apparatus	Watts
Annealing furnaces	200
Bar or barbers' urns, 1 to 5 gal., 3 ht.	200 to 1,700
Bakers' ovens, 30 to 80 loaves	6,000 to 10,000
Branding tool	10 to 500
Button dye heater	100
Chocolate warmers	55 to 250
Coffee urns, 1 to 20 gal.	200 to 4,000
Corset irons	350
Dental furnaces	450
Embossing head	100 to 1,000
Glue pot, ½ pt. to 25 gal.	150 to 5,000
Glue pots	110 to 880
Hat irons (small)	200
Hatters' iron, 9 to 15 pounds	450
Instrument sterilizers	350 to 500
Japanning oven	1,000 to 10,000
Laboratory apparatus flask heaters	500
Linotype pots	485
Machine irons, 2 to 18 lbs.	770
Matrix dryer	28,000
Melting pot	13,000 to 30,000
Oil tempering bath	6,000 to 20,000
Pitch kettles, 12 and 15 in. 3 ht.	300 to 1,500
Polishing irons, 3.5 to 5.5 lbs.	330 to 550
Radiators, various sizes	700 to 6,000
Sealing wax pots, .5 to 1.5 pt.	175 to 300
Shoe irons	200
Soldering irons (various sizes)	100 to 450
Soldering pots, 4 to 15 lbs. capacity	200 to 440
Tailors' iron, 12 to 25 lbs.	660 to 880
Vulcanizers for automobile tires	100 to 450

High Tension.—The N. E. C. classifies as "high potential" all voltages above 550 and below 3500, allowing a 10 per cent additional in the case of 550 volt motors. Voltages above 3500 are classed as "extra high potential." Special points to be noted with very high potentials are the Corona effect and the fact that ordinary bushings must not be used where wires enter buildings. It is best to enter wires through large open spaces.

Horsepower.—746 watts equal 1 horsepower, abbreviated H. P. One H. P. is sufficient to raise 33,000 lbs. 1 foot per minute or 1 lb. 33,000 feet per minute.

Hospitals.—In the corridors, only an indifferent illumination of about 0.5 watts per square foot is needed. Good exit and emergency lighting is usually insisted upon and as most of the inmates are helpless every possible precaution against the fire hazard should be taken. Good ventilation is also essential.

In the public wards inverted lighting or lights encased in strongly diffusing globes would give the best results. By no means should direct lighting from the ceiling be favored. A plentiful supply of outlets for heating pads, etc., will be found convenient.

In the private wards the illumination should be by means of lights placed at the head of bed and never by ceiling lights. Each lamp should be controllable by pendant switch, so as to enable patient to operate it. Separate receptacle for heating pads and other devices should be provided. In the operating rooms a very bright shadowless illumination should be provided, and this should be fitted with ample switching facilities so as to adjust it to the special needs of any operating physician. Arrange the operating lights so that no one fuse can put all of them out, or at least provide throw over switch to another set of fuses. Signaling circuits are usually also provided for all patients.

Hotels.—Exit and emergency lights should be provided in all large hotels. It is a good plan to arrange the lighting so that two circuits enter each room or apartment which contains more than one outlet. Where floors are alike this can sometimes be done by running branch circuits straight up and down, and locating all cut-outs in basement. Hall circuits should always be independent of room circuits, so as to reassure guests in case of a blowout of large fuse, or other accident which darkens a large part of the house. Door switches will be found useful for closets as well as for rooms. Vacuum cleaner circuits should be provided in all halls, close enough together to avoid the use of very long cords. In the case of hotels planned for families, a large number of outlets with which to supply lights for illumination of pictures, lamps in cozy corners, etc., will be useful. If these are not provided, the rooms will likely soon be found strung full of flexible cord, which will introduce a considerable fire risk. Special systems of wiring enabling one to turn on lights in rooms even though they be switched off there, will be very serviceable in case of fire or panic, but will add considerable to the expense. In large hotels equipped with banquet halls, carriage calls are often provided. In such halls a special outlet for moving picture arc, or stereopticon should be provided.

Hunting.—Whenever anything causes fluctuations in the speed of an alternator operating in parallel with others, it will either deliver current to the others or draw current from them. Under certain circumstances this condition may become fixed and the machines are then said to be hunting or phase swinging. This condition is liable to be most severe with machines having a large number of poles. To prevent hunting the prime mover should have a governor which is not too sensitive. The connections between the machines should not have too much resistance, and the machines should be equipped with damping coils. To prevent excessive short circuits, reactances are sometimes cut into the external circuit. To prevent overheating, thermometers or pyrometers electrically connected are sometimes embedded in the hottest parts of machines and arranged to indicate temperatures at the outside.

Hysterisis.—This is the term which describes the lagging of the magnetism behind the magnetizing force. It causes heating of the iron and loss of energy, and is much greater with steel than with soft iron.

Illumination.—Illuminating engineering is more an art than a science, and to master it properly requires considerable experience and knowledge of many factors which can only be hinted at in a work of this kind. By means of the hints given out and the tables following, anyone, however, should be able to design a pretty satisfactory installation where ordinary commercial effects are desired. Where special effects in illumination of statuary, altars, etc., is desired, experiments with temporary lights should be made. The main requisite, where economy is not too much insisted upon, is plenty of capacity. It is never advisable to figure illumination for light colors, since colors are apt to be changed. If there is plenty of circuit capacity, a wide choice as to candle power of lamps is possible and many experiments may be made until the most satisfactory effects are obtained. In addition to the matter contained in this chapter, practical hints on the illumination of special places are given in the alphabetical order of locations referred to, and it is advisable to consult these before deciding upon any work.

The circuit capacity necessary to be installed to arrange for any degree of illumination can be determined readily by reference to Table XXXI. Multiply the floor area to be illuminated by the number of watts per square foot recommended with the various illuminants and by the foot candles desired. The result will give the number of watts for which provision should be made. Except in special cases (see *National Electrical Code Rules*) one circuit at least should be provided for each 660 watts. If large units are used, the first cost will be less, but evenness of illumination will be sacrificed unless lamps can be hung high.

The intensity of illumination obtainable from a given source varies with the height and distribution of lamps; condition, type and kind of reflectors or enclosing globes; nature and color of ceilings and walls; also with the voltage maintained, and is never quite the same at all parts of the working plane.

The figures given below are intended as approximations and for quick determination of the number of lamps required. The watts per square foot given in connection with the various illuminants are thought to be sufficient to provide an illumination of one foot candle; for greater intensities they must be multiplied by the number of foot candles desired.

Table XXXII is prepared to illustrate the difference in the quantity of wiring material required for illumination brought about by the use of large and small units or clusters of lamps. The line "Wire used per sq. ft." refers only to the wire (one leg) used between lamps. The wire needed to feed the circuits must be separately calculated. In case of arc lamps, or large incandescent lamps using one per circuit, no wire between lamps will be used. No allowance is made for switches or drops to brackets and it is assumed that circuits are run according to N. E. C. rules, never more than 660 watts per circuit. The table is not quite accurate unless the space illuminated is of such size as to allow of the use of full circuits.

TABLE XXXI

Kind of illuminant—	Watts per sq. ft. — With proper reflectors — Light	Dark	Indirect frosted or inclosed		Color of light
Nitrogen (large units).........	0.12	0.18	0.18	0.27	White
Mazda	0.20	0.30	0.30	0.45	Nearly white
Tantalum	0.31	0.46	0.46	0.69	Pale yellowish white
Gem	0.42	0.63	0.63	0.95	Pale yellowish white
Carbon	0.53	0.80	0.79	1.2	Yellowish white
Nernst	0.28	0.42	0.42	0.63	Nearly white
Mercury vapor................	0.11	0.16			Bluish green
Mercury vapor, quartz tube....	0.04	0.06			
Direct Current Arcs					
Open arc; series; clear globes..	0.17	0.25	0.25	0.38	Nearly white
Enclosed arc; series; clear globes	0.26	0.40	0.39	0.58	Bluish white
Enclosed arc; multiple; opal inner and clear outer globes...	0.36	0.54	0.54	0.81	Long arcs may be bluish white, or run into violet
Enclosed arc; multiple; opal inner and outer globes.........	0.42	0.63	0.63	0.95	

TABLE XXXI—Continued

Kind of illuminant	Watts per sq. ft. — With proper reflectors, Light	Dark	Indirect frosted or inclosed		Color of light
Alternating Current Arcs					
Open arc; clear globes	0.23	0.35	0.34	0.51	Nearly white
Enclosed arc; multiple; opal inner and clear outer globes	0.38	0.57	0.57	0.85	Bluish white
Enclosed arc; multiple; opal inner and outer globes	0.47	0.70	0.70	1.05	Long arcs may be bluish white, or run into violet
Special Arc Lamps					
Intensified arc; opal outer globe	0.25	0.38	0.38	0.57	White
Luminous arc; series; clear globe	0.20	0.30	0.30	0.45	
Luminous arc; multiple; clear globe	0.22	0.33	0.33	0.49	White
Flaming arc; series; clear globe	0.04	0.06	0.06	0.09	White
Flaming arc; multiple; clear globe	0.05	0.07	0.07	0.10	Depends upon carbons
Regenerative flaming arc; series; opal outer globe	0.05	0.07	0.07	0.10	Yellow
Regenerative flaming arc; multiple; opal outer globe	0.07	0.10	0.10	0.15	Yellow

TABLE XXXII

The table below shows the quantity of wire (one leg) required to connect between lamps for full circuits of lamps of wattages given; not more than 660 watts on any circuit.

Wattage of Lamps	Number Per Circuit		Watts to Be Used Per Square Foot									
			.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.50	3.00
25	16	Diam. of space per lamp	10.	7.1	5.7	5.	4.5	4.	3.7	3.5	3.2	2.9
		Wire used per sq. ft...	0.09	0.14	0.18	0.20	0.23	0.25	0.27	0.29	0.32	0.35
40	16	Diam. of space per lamp	12.6	8.9	7.5	6.3	5.7	5.1	4.8	4.5	4.0	3.6
		Wire used per sq. ft...	0.08	0.11	0.14	0.16	0.18	0.20	0.21	0.23	0.25	0.28
50	13	Diam. of space per lamp	14.1	10.0	8.1	7.1	6.3	5.7	5.4	5.0	4.5	4.1
		Wire used per sq. ft...	0.07	0.10	0.13	0.14	0.16	0.18	0.19	0.20	0.22	0.24
60	11	Diam. of space per lamp	15.5	10.9	8.9	7.7	6.9	6.3	5.8	5.5	4.9	4.5
		Wire used per sq. ft...	0.06	0.09	0.11	0.13	0.15	0.16	0.17	0.19	0.21	0.22
100	6	Diam. of space per lamp	20.0	14.1	11.5	10.	8.9	8.1	7.6	7.1	6.3	5.7
		Wire used per sq. ft...	0.05	0.07	0.09	0.10	0.11	0.13	0.14	0.15	0.16	0.18
150	4	Diam. of space per lamp	24.5	17.3	14.1	12.2	10.9	10.0	9.3	8.7	7.7	7.1
		Wire used per sq. ft...	0.04	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.15
200	3	Diam. of space per lamp	28.3	20.0	16.3	14.1	12.6	11.5	10.7	10.0	8.9	8.2
		Wire used per sq. ft...	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13
250	2	Diam. of space per lamp	31.7	22.4	18.3	15.8	14.1	12.9	11.9	11.2	10.0	9.1
		Wire used per sq. ft...	0.03	0.04	0.06	0.07	0.07	0.08	0.09	0.10	0.11	0.1[illegible]

Average illumination, if made up of spots of very bright light alternating with low illumination, is no criterion of the value of illumination. The very bright spots only make the others appear less brilliant. The eye has great powers of adjustment and can get along with low illumination if it is even, but with elderly persons it cannot rapidly and often change its adjustment without causing pain and injury. The quantity of illumination should be adjustable, for not all persons can be comfortable with the same intensity. The source of light should never be visible, especially if it is of high intrinsic brilliancy. The best light is one sufficiently diffused to cast but a slight shadow. In offices, however, where one source of light must serve many persons, an absolutely shadowless inverted light is desirable. It is good practice to space outlets so that the space between lamps is from one to two times the height of lamps above the working plane. This rule requires large units for high ceilings and small ones for low places. Special reflectors, however, have a certain ratio of spacing to height which should be obtained from the maker. Buildings containing many windows require more artificial light for night work than the ordinary building.

The following tables are based on Holophane Intensive, or medium reflectors, and will give fair approximations of results to be expected from other reflectors. Holophane reflectors are of high efficiency and in some cases allowance must be made for this.

Incandescent Lamps.—These lamps are operated mostly in multiple, and when so used never at a higher voltage than 250. On series circuits the voltage used runs into the thousands, but special lamps are required. Most lamps are built marked with three voltages: top, middle, and bottom. The top voltage is preferably used; with this voltage the efficiency is the highest but the life shortened; with botton voltage

TABLE XXXIII

TABLE SHOWING ILLUMINATION IN FOOT CANDLES FROM 25, 40 AND 60 WATT MAZDA OR TUNGSTEN LAMPS ARRANGED IN ONE ROW AT HEIGHTS AND DISTANCES APART GIVEN IN TABLE. BOWL FROSTED LAMPS EQUIPPED WITH HOLOPHANE INTENSIVE CLEAR HIGH EFFICIENCY REFLECTORS, NOS. 106,125, 106,130 AND 106,150 RESPECTIVELY.

Height of lamps in feet above plane to be illuminated.		Distance Apart of Lamps															
		3 Ft.		4 Ft.		5 Ft.		6 Ft.		7 Ft.		8 Ft.		10 Ft.		12 Ft.	
	Wattage	Under lamps	Between lamps	Under lamps	Between lamps	Under lamps	Between lamps	Under lamps	Between lamps	Under l'mps	Betw'en l'mps	Under l'mps	Betw'en l'mps	Under l'mps	Betw'en l'mps	Under l'mps	Betw'en l'mps
4	25	4.22	4.16	3.15	3.2	2.7	2.4	2.4	1.9	2.2	1.5	2.1	1.1	2.0	0.6	2.0	0.4
	40	7.31	6.43	5.53	5.0	4.7	3.9	4.3	3.1	4.1	2.3	3.9	1.6	3.8	0.9	3.8	0.5
	60	11.22	10.83	8.24	8.2	7.0	6.5	6.3	5.1	5.9	3.8	5.7	2.6	5.6	1.5	5.5	0.8
5	25	3.3	3.3	2.5	2.5	2.0	2.0	1.8	1.6	1.6	1.3	1.5	1.1	1.4	0.7	1.3	0.4
	40	5.2	5.2	4.0	3.9	3.1	3.2	2.7	2.7	2.4	2.2	2.3	1.8	2.1	1.0	2.1	0.6
	60	8.9	8.7	6.7	6.6	5.3	5.4	4.6	4.4	4.2	3.6	3.9	2.8	3.7	1.6	3.6	1.0
6	25	2.7	2.7	2.1	2.1	1.7	1.7	1.4	1.4	1.2	1.2	1.1	1.0	1.0	0.7	0.9	0.5
	40	4.3	4.2	3.2	3.2	2.7	2.6	2.2	2.2	1.9	1.8	1.7	1.5	1.5	1.1	1.5	0.7
	60	7.2	7.1	5.5	5.3	4.4	4.4	3.6	3.7	3.2	3.1	2.9	2.6	2.6	1.8	2.5	1.1
7	25	2.3	2.3	1.8	1.8	1.4	1.4	1.2	1.2	1.0	1.0	0.9	0.9	0.8	0.6	0.7	0.5
	40	3.6	3.6	2.8	2.7	2.2	2.2	1.9	1.8	1.6	1.6	1.4	1.4	1.2	1.0	1.1	0.8
	60	6.1	6.0	4.7	4.7	3.8	3.7	3.1	3.1	2.7	2.7	2.4	2.3	2.1	1.7	2.0	1.2
8	25	2.0	2.0	1.6	1.5	1.2	1.3	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.6	0.6	0.4
	40	3.1	3.1	2.4	2.4	1.9	2.0	1.6	1.6	1.4	1.4	1.2	1.2	1.0	0.9	0.9	0.7
	60	5.3	5.3	4.1	4.1	3.3	3.3	2.8	2.7	2.4	2.3	2.1	2.1	1.7	1.6	1.6	1.2
10	25	1.5	1.5	1.2	1.2	1.0	1.0	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4
	40	2.5	2.4	2.1	1.9	1.6	1.6	1.3	1.3	1.1	1.1	1.0	1.0	0.8	0.8	0.7	0.6
	60	4.2	4.0	3.2	3.2	2.6	2.6	2.2	2.2	1.9	1.9	1.6	1.6	1.3	1.3	1.1	1.1
12	25	1.2	1.2	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4
	40	1.9	1.9	1.6	1.5	1.3	1.3	1.1	1.1	0.9	0.9	0.8	0.8	0.6	0.6	0.5	0.5
	60	3.3	3.2	2.6	2.5	2.1	2.1	1.8	1.8	1.6	1.5	1.3	1.4	1.1	1.1	0.9	0.9

TABLE XXXIV

Table Showing Illumination in Foot Candles from 25, 40 and 60 Watt Mazda or Tungsten Lamps Arranged in Two Rows at Heights and Distances Apart as Given in Table. Bowl Frosted Lamps Equipped with Holophane Intensive Clear High Efficiency Reflectors Nos. 106,125, 106,130 and 106,150, Respectively.

Distance Apart of Lamps Each Way

Height of lamps in feet above plane illuminated	Wattage	3 Ft. Under lamps	3 Ft. Between lamps	4 Ft. Under lamps	4 Ft. Between lamps	5 Ft. Under lamps	5 Ft. Between lamps	6 Ft. Under lamps	6 Ft. Between lamps	7 Ft. Under l'mps	7 Ft. Betw'en l'mps	8 Ft. Under l'mps	8 Ft. Betw'en l'mps	10 Ft. Under l'mps	10 Ft. Betw'en l'mps	12 Ft. Under l'mps	12 Ft. Betw'en l'mps
4	25	6.4	6.9	4.3	4.1	3.3	3.1	2.7	2.2	2.4	1.3	2.3	1.0	2.1	0.5	2.0	0.2
	40	10.8	11.0	7.2	6.9	5.6	4.9	4.8	3.4	4.4	1.9	4.3	1.5	3.9	0.6	3.8	0.4
	60	16.8	18.3	10.8	10.8	8.3	7.9	7.0	5.3	6.4	3.0	6.0	2.3	5.8	1.0	5.6	0.6
5	25	5.5	5.8	3.8	3.7	2.7	2.9	2.2	2.3	1.9	1.5	1.7	1.2	1.5	0.6	1.4	0.4
	40	8.8	9.1	5.9	5.9	4.2	4.7	3.3	3.7	2.8	2.2	2.8	1.7	2.2	0.8	2.1	0.5
	60	14.6	15.1	9.8	9.8	6.9	7.6	5.5	5.8	4.7	3.4	4.3	2.7	3.8	1.3	3.7	0.7
6	25	4.7	4.8	3.3	3.2	2.5	2.6	1.9	2.1	1.6	1.5	1.3	1.2	1.1	0.7	1.0	0.4
	40	7.4	7.7	5.1	5.1	3.8	4.0	2.9	3.3	2.4	2.4	2.2	1.9	1.7	1.0	1.5	0.6
	60	12.4	12.9	8.6	8.4	6.3	6.8	4.7	5.5	3.9	3.8	3.4	3.0	2.9	1.5	2.7	0.9
7	25	4.1	4.1	2.9	2.9	2.2	2.3	1.7	1.9	1.4	1.4	1.2	1.2	0.9	0.7	0.8	0.5
	40	6.5	6.7	4.7	4.4	3.4	3.6	2.7	3.0	2.1	2.3	2.0	1.9	1.4	1.1	1.2	0.7
	60	10.8	11.2	7.7	7.3	5.6	6.0	4.4	5.0	3.5	3.6	3.0	3.1	2.4	1.7	2.1	1.0
8	25	3.6	3.6	2.7	2.6	2.0	2.1	1.6	1.8	1.3	1.3	1.1	1.1	0.8	0.8	0.7	0.5
	40	5.7	5.8	4.2	4.1	3.2	3.3	2.5	2.8	1.9	2.0	1.9	1.8	1.2	1.2	1.0	0.8
	60	9.7	9.5	7.0	6.8	5.3	5.5	4.1	4.6	3.3	3.4	2.8	3.0	2.1	1.9	1.7	1.2
10	25	2.8	2.8	2.2	2.1	1.68	1.8	1.3	1.4	1.1	1.1	1.0	1.0	0.7	0.7	0.5	0.5
	40	4.5	4.6	3.6	3.3	2.7	2.7	2.1	2.3	1.8	1.8	1.6	1.6	1.1	1.1	0.8	0.8
	60	7.6	7.9	5.8	5.4	4.5	4.5	3.6	3.8	2.9	3.0	2.6	2.6	1.7	1.8	1.4	1.3
12	25	2.2	2.2	1.8	1.7	1.4	1.4	1.2	1.2	0.9	1.0	0.8	0.9	0.5	0.6	.04	0.5
	40	3.6	3.8	2.8	2.8	2.3	2.3	1.9	1.9	1.5	1.6	1.4	1.4	0.9	1.0	.07	0.8
	60	6.1	6.4	4.8	4.6	3.8	3.8	3.1	3.4	2.5	2.6	2.3	2.2	1.5	1.6	1.2	1.2

TABLE XXXV

TABLE SHOWING ILLUMINATION IN FOOT CANDLES FROM 25, 40 AND 60 WATT MAZDA OR TUNGSTEN LAMPS ARRANGED IN 3 ROWS AT HEIGHTS AND DISTANCES APART EACH WAY AS GIVEN IN TABLE. BOWL FROSTED LAMPS EQUIPPED WITH HOLOPHANE INTENSIVE CLEAR HIGH EFFICIENCY REFLECTORS NOS. 106,125, 106,130 AND 106,150 RESPECTIVELY.

DISTANCE APART OF LAMPS

Height of lamp in feet above plane to be illuminated.	Wattage	3 Ft. Under lamps	3 Ft. Between lamps	4 Ft. Under lamps	4 Ft. Between lamps	5 Ft. Under lamps	5 Ft. Between lamps	6 Ft. Under lamps	6 Ft. Between lamps	7 Ft. Under l'mps	7 Ft. Betw'en l'mps	8 Ft. Under l'mps	8 Ft. Betw'en l'mps	10 Ft. Under l'mps	10 Ft. Betw'en l'mps	12 Ft. Under l'mps	12 Ft. Betw'en l'mps
4	25	8.6	8.1	5.4	4.6	3.9	3.4	3.1	2.4	2.6	1.4	2.4	1.1	2.1	0.5	2.1	0.3
	4	14.3	12.6	8.8	7.4	6.5	5.3	5.2	3.6	4.7	2.1	4.3	1.6	4.0	0.7	3.9	0.4
	60	22.4	20.8	13.4	11.8	9.6	8.4	7.7	5.6	6.8	3.2	6.3	2.4	5.9	1.0	5.7	0.5
5	25	7.6	7.1	5.0	4.3	3.5	3.3	2.7	2.5	2.1	1.6	1.9	1.3	1.6	0.6	1.4	0.4
	40	12.3	11.0	7.8	6.8	5.1	5.1	3.9	3.9	3.2	2.1	3.1	1.6	2.3	0.9	2.2	0.5
	60	20.3	18.0	12.5	11.1	8.4	8.2	6.4	6.2	5.3	3.6	4.7	2.8	4.0	1.4	3.8	0.7
6	25	6.6	6.2	4.5	3.9	3.2	3.0	2.4	2.4	1.9	1.6	1.5	1.4	1.2	0.7	1.0	0.4
	40	10.6	9.8	7.0	6.1	5.0	4.6	3.6	3.6	2.9	2.5	2.4	2.1	1.9	1.1	1.6	0.6
	60	17.7	16.3	11.7	9.9	8.1	7.6	5.8	6.0	4.5	4.1	3.9	3.2	3.0	1.6	2.8	0.9
7	25	5.8	5.5	4.1	3.6	3.0	2.7	2.2	2.2	1.7	1.6	1.4	1.3	1.0	0.8	0.9	0.5
	40	9.3	8.8	6.5	5.5	4.6	4.3	3.4	3.4	2.6	2.5	2.2	2.0	1.5	1.1	1.3	0.7
	60	15.6	14.6	10.7	9.0	7.5	6.9	5.6	5.5	4.3	3.9	3.5	3.3	2.6	1.8	2.3	1.1
8	25	5.2	4.9	4.0	3.3	2.8	2.6	2.1	2.1	1.7	1.5	1.4	1.3	1.0	0.8	0.8	0.5
	40	8.3	7.9	5.9	5.3	4.4	4.0	3.3	3.3	2.6	2.3	2.1	2.0	1.4	1.3	1.1	0.8
	60	14.0	12.9	9.8	8.7	7.2	6.6	5.4	5.3	4.2	3.8	3.4	3.2	2.4	2.0	1.9	1.3
10	25	4.0	4.0	3.1	2.8	2.4	2.3	1.8	1.8	1.4	1.3	1.3	1.1	0.9	0.7	0.7	0.6
	40	6.6	6.5	5.2	4.5	3.8	3.5	3.0	2.8	2.4	2.1	1.9	1.9	1.3	1.2	1.1	0.9
	60	11.1	10.9	8.3	7.3	6.3	5.7	4.9	4.6	3.8	3.5	3.1	2.9	2.1	1.9	1.6	1.4
12	25	3.2	3.2	2.6	2.4	2.0	1.9	1.7	1.6	1.3	1.2	1.1	1.0	0.8	0.7	0.6	0.5
	40	5.2	5.4	4.1	3.8	3.3	3.1	2.6	2.4	2.2	1.9	1.7	1.6	1.2	1.1	0.9	0.9
	60	8.8	9.0	6.9	6.4	5.5	5.0	4.3	4.3	3.5	3.1	2.9	2.6	2.0	1.8	1.5	1.3

TABLE XXXVI

Table Showing Illumination in Foot Candles from 25, 40 and 60 Watt Mazda or Tungsten Lamps Arranged in Four Rows at Heights and Distances Apart Each Way as Given in Table. Bowl Frosted Lamps Equipped with Holophane Intensive Clear High Efficiency Reflectors Nos. 106,125, 106,130 and 106,150 Respectively.

Distance Apart of Lamps.

Height of lamp above plane illuminated.	Wattage	3 Ft. Under lamps	3 Ft. Between lamps	4 Ft. Under lamps	4 Ft. Between lamps	5 Ft. Under lamps	5 Ft. Between lamps	6 Ft. Under lamps	6 Ft. Between lamps	7 Ft. Under l'mps	7 Ft. Betw'en l'mps	8 Ft. Under l'mps	8 Ft. Betw'en l'mps	10 Ft. Under l'mps	10 Ft. Betw'en l'mps	12 Ft. Under l'mps	12 Ft. Betw'en l'mps
4	25	9.2	9.2	5.7	5.1	4.0	3.6	3.2	2.5	2.7	1.5	2.4	1.2	2.1	0.5	2.1	0.3
	40	15.2	14.2	9.2	9.0	6.7	5.6	5.3	3.8	4.8	2.2	4.3	1.7	4.0	0.8	3.9	0.4
	60	23.6	23.2	13.9	12.8	9.9	8.9	7.9	5.8	6.9	3.4	6.3	2.6	5.9	1.1	5.7	0.6
5	25	8.4	8.4	5.4	4.9	3.7	3 6	2.8	2.7	2.2	1.7	1.9	1.4	1.6	0.7	1.4	0.4
	40	13.3	12.8	8.3	7.6	5.3	5.6	4.0	4.2	3.3	2.5	3.1	1.9	2.3	1.0	2.2	0.6
	60	21.8	20.9	13.1	12.4	8.7	8.9	6.6	6.5	5.4	3.8	4.8	3.0	4.0	1.4	3.8	0.7
6	25	7.5	7.6	4.9	4.6	3.4	3.4	2.5	2.6	2.0	1.8	1.5	1.5	1.2	0.8	1.0	0.4
	40	11.8	11.9	7.6	7.1	5.3	5.0	3.7	3.8	3.0	2.7	2.4	2.2	1.9	1.2	1.6	0.6
	60	19.6	19.6	12.6	11.5	8.5	8.4	6.0	6.4	4.6	4.3	4.0	3.3	3.0	1.7	2.8	1.0
7	25	6 7	6.8	4.5	4.4	3.2	3.1	2.3	2.5	1.8	1.7	1.4	1.4	1.0	0.8	0.9	0.5
	40	10.6	10.9	7 1	6.6	4.9	4.9	3.6	3.8	2.7	2.7	2.3	2.2	1.5	1.2	1.3	0.7
	60	17.6	18.0	11.7	10.8	8.0	7.9	5.9	6.1	4.5	4.2	3.6	3.5	2.7	1.9	2.3	1.1
8	25	6.4	6.2	4.5	4.1	3.1	3.0	2.3	2.4	1.8	1.7	1.4	1.4	1.0	0 9	0.8	0.6
	40	9.8	9.9	6.7	6.5	4.8	4.8	3.5	8.6	2.7	2.5	2.2	2.1	1.4	1.4	1.1	0.9
	60	16.3	16.3	11.0	10.6	7.9	7.7	5.7	5.9	4.4	4.2	3.5	3.5	2.5	2.1	1.9	1.3
10	25	4.9	5.1	3.7	3.6	2.7	2.8	2.0	1.4	1.5	1.5	1.4	1.3	0.9	0.8	0.7	0.6
	40	8.0	8.3	6.0	5.7	4.3	4.3	3.3	3.3	2.6	2.4	2.0	2.1	1.4	1.3	1.0	1.0
	60	13.4	14.0	9.7	9.2	7.1	7.0	5.3	5.4	4.0	4.0	3.1	3.2	2.2	2.1	1.6	1.4
12	25	4.0	4.2	3.1	3.0	2.3	2.4	1.9	1.2	1.4	1.4	1.2	1.2	0.8	0.8	0.6	0.6
	40	6.4	6.9	4.9	4.8	3.8	3.9	2.9	2.9	2.4	2.3	1.8	1.8	1.3	1.2	0.9	0.9
	60	10.9	11.6	8.3	8.2	6.3	6.3	4.8	5.2	3.8	8.7	2.9	8.0	2.1	2.0	1.5	1.4

TABLE XXXVII

TABLE SHOWING ILLUMINATION IN FOOT CANDDLES FROM 100, 150 AND 250 WATTS MAZDA LAMPS ARRANGED IN ONE ROW AT HEIGHTS AND DISTANCES APART GIVEN IN TABLE. BOWL FROSTED LAMPS EQUIPPED WITH HOLOPHANE INTENSIVE CLEAR HIGH EFFICIENCY REFLECTORS NOS. 106,180, 106,185 AND 106,190 RESPECTIVELY.

DISTANCE APART OF LAMPS IN FEET.

Height of unit above plane illuminated.		6 Ft.		8 Ft.		10 Ft.		12 Ft.		14 Ft.		16 Ft.		18 Ft.		20 Ft.	
	Wattage	Under lamps	Be tween lamps	Under lamps	Be-tween lamps	Under lamps	Be-tween lamps	Under lamps	Be-tween lamps	Un-der l'mps	Be-tw'en l'mps	Un-der l'mps	Be-tw'en l'mps	Un-der l'mps	Be-tw'en l'mps	Un-der l'mps	Be-tw'en l'mps
6	00	5.4	5.3	4.3	3.7	3.8	2.7	3.7	1.8	3.6	1.2	3.5	0.8	3.5	0.5	3.4	0.4
	150	9.5	9.4	7.5	6.7	6.7	4.6	6.4	3.2	6.2	2.1	6.0	1.5	6.0	1.0	6.0	0.7
	250	16	16	13	11	12	8.0	11	5.4	11	3.8	11	2.7	10	1.9	10	1.3
7	100	4.6	4.7	3.6	3.4	3.0	2.6	2.8	1.9	2.7	1.4	2.6	1.0	2.6	0.7	2.6	0.5
	150	8.0	8.2	6.2	6.0	5.3	4.4	4.9	3.2	4.7	2.4	4.5	1.7	4.5	1.3	4.4	0.9
	250	14	14	11	10	9.2	7.6	8.5	5.4	8.2	4.1	8.0	3.0	7.9	2.2	7.7	1.6
8	100	4.0	4.0	3.2	3.0	2.5	2.4	2.3	1.9	2.1	1.4	2.0	1.1	2.0	0.8	2.0	0.6
	150	7.0	7.1	5.3	5.3	4.4	4.1	4.0	3.1	3.7	2.4	3.5	1.8	3.5	1.4	3.4	1.0
	250	12	12	9.4	9.2	7.7	7.0	6.9	5.3	6.5	4.1	6.3	3.2	6.2	2.5	6.0	1.8
9	100	3.5	3.6	2.7	2.6	2.2	2.1	1.9	1.7	1.7	1.4	1.6	1.1	1.6	0.9	1.6	0.7
	150	6.2	6.3	4.6	4.7	3.8	3.7	3.4	2.9	3.1	2.3	2.9	1.9	2.8	1.5	2.7	1.1
	250	11	11	8.2	8.2	6.6	6.5	5.8	5.0	5.4	4.0	5.1	3.2	5.0	2.6	4.8	1.9
10	100	3.2	3.2	2.4	2.4	2.0	1.9	1.7	1.6	1.5	1.3	1.4	1.1	1.3	0.9	1.3	0.7
	150	5.6	5.6	4.1	4.2	3.4	3.4	3.0	2.7	2.6	2.2	2.4	1.8	2.3	1.5	2.3	1.2
	250	9.6	9.8	7.3	7.4	5.9	5.9	5.0	4.7	4.6	3.8	4.4	3.2	4.2	2.6	4.0	2.0
12	100	2.6	2.6	2.0	2.1	1.6	1.6	1.4	1.4	1.2	1.1	1.0	1.0	1.0	0.8	0.9	0.7
	150	4.5	4.6	3.4	3.5	2.7	2.8	2.4	2.3	2.1	2.0	1.8	1.7	1.7	1.5	1.7	1.2
	250	7.9	8.0	6.0	6.0	4.8	4.9	4.0	4.0	3.7	3.4	3.4	3.0	3.2	2.6	2.9	2.1
14	100	2.2	2.2	1.8	1.7	1.4	1.4	1.2	1.2	1.0	1.0	0.9	0.9	0.8	0.8	0.7	0.7
	150	3.8	3.9	2.8	2.9	2.3	2.4	2.1	2.0	1.8	1.7	1.5	1.6	1.4	1.4	1.3	1.1
	250	6.6	6.8	5.1	5.0	4.0	4.1	3.4	3.4	3.1	3.0	2.8	2.7	2.6	2.4	2.3	2.0

TABLE XXXVIII

Table Showing Illumination in Foot Candles from 100, 150 and 250 Watts Mazda Lamps Arranged in Two Rows at Heights and Distances Apart Given in Table. Bowl Frosted Lamps Equipped with Holophane Intensive Clear High Efficiency Reflectors Nos. 106,180, 106,185, and 106,190 Respectively.

Distance Apart of Lamps.

Height of lamps in feet above plane illuminated	Wattage	6 Ft. Under lamps	6 Ft. Between lamps	8 Ft. Under lamps	8 Ft. Between lamps	10 Ft. Under lamps	10 Ft. Between lamps	12 Ft. Under lamps	12 Ft. Between lamps	14 Ft. Under l'mps	14 Ft. Betw'en l'mps	16 Ft. Under l'mps	16 Ft. Betw'en l'mps	18 Ft. Under l'mps	18 Ft. Betw'en l'mps	20 Ft. Under l'mps	20 Ft. Betw'en l'mps
6	100	7.03	7.88	5.01	4.66	4.19	2.46	3.95	1.34	3.69	0.76	3.59	0.60	3.52	0.34	3.49	0.30
	150	12.6	14.1	8.81	8.18	7.33	4.44	6.74	2.54	6.36	1.56	6.20	1.12	6.10	0.68	6.03	0.50
	250	21.6	24.2	15.4	14.0	12.9	7.94	11.6	4.56	11.15	2.80	10.9	1.98	10.7	1.15	10.5	0.84
7	100	6.53	7.16	4.45	4.64	3.45	2.79	3.10	1.66	2.84	0.90	2.72	0.70	2.66	0.43	2.63	0.35
	150	11.4	12.9	7.72	8.06	6.09	4.89	5.36	2.98	4.93	1.88	4.73	1.34	4.59	0.77	4.51	0.62
	250	19.6	22.3	13.7	13.7	10.6	8.52	9.28	5.24	8.57	3.32	8.30	2.40	8.07	1.40	7.82	1.04
8	100	6.01	6.60	4.14	4.32	3.00	2.95	2.55	1.86	2.29	1.10	2.16	0.86	2.07	0.47	2.04	0.39
	150	10.5	11.6	7.03	7.72	5.34	4.94	4.52	3.24	4.01	2.16	3.77	1.60	3.62	0.94	3.53	0.70
	250	18.2	20.2	12.4	13.3	9.4	9.04	7.80	5.64	6.98	3.84	6.68	2.80	6.40	1.66	6.10	1.20
9	100	5.46	6.00	3.77	4.06	2.72	2.83	2.17	1.94	1.89	1.26	1.77	0.98	1.65	0.55	1.63	0.43
	150	9.7	10.6	6.49	7.22	4.85	4.86	3.98	3.34	3.40	2.36	3.13	1.76	2.95	1.06	2.84	0.82
	250	16.8	18.3	11.5	12.5	8.47	8.54	6.85	5.80	5.95	4.12	5.59	3.10	5.27	1.87	4.92	1.40
10	100	5.12	5.48	3.52	3.82	2.62	2.72	2.04	1.96	1.71	1.40	1.52	1.08	1.42	0.64	1.39	0.52
	150	9.00	9.6	6.05	6.76	4.49	4.71	3.62	3.36	2.99	2.48	2.71	1.90	2.49	1.19	2.37	0.90
	250	15.6	16.6	9.63	11.7	7.88	8.26	6.21	5.80	5.26	4.36	4.87	3.34	4.50	2.09	4.11	1.56
12	100	4.46	4.52	3.16	3.26	2.25	2.44	1.82	1.82	1.40	1.36	1.20	1.20	1.10	0.76	1.01	0.60
	150	7.73	8.00	5.30	5.84	4.00	4.29	3.18	3.22	2.52	2.56	2.19	2.02	1.92	1.33	1.78	1.06
	250	13.5	13.8	9.35	10.2	6.98	7.56	5.39	5.52	4.43	4.44	4.01	3.48	3.55	2.36	3.07	1.84
14	100	3.86	3.88	2.83	2.92	2.11	2.14	1.65	1.68	1.31	1.32	1.11	1.20	0.93	0.82	0.87	0.74
	150	6.76	6.68	4.67	5.12	3.61	3.79	2.92	2.96	2.25	2.48	1.90	1.98	1.64	1.43	1.45	1.14
	250	11.7	11.7	8.35	8.8	6.30	6.82	4.85	5.14	3.93	4.32	3.51	3.46	3.05	2.47	2.48	1.96

the opposite will be the case. See Table XXXIX for approximate effects.

The efficiency of all lamps decreases with use. Incandescent lamps will not give good results with frequencies lower than 40; for outdoor illumination they have, however, been used with 25 cycles. The fluctuations are less noticeable with heavy filaments.

Circuit Limitations.—Not more than 660 watts are generally allowed on circuits, but where small fixture wire and fiber lined sockets and flexible cords are not used there is no serious objection to 1320 watts per circuit, or 32 lights instead of the usual 16.

Frosting.—Lamps are frosted to reduce the intrinsic brilliancy and through it become less harmful to the eye. Ordinary frosting reduces the c. p. from 5 to 10 per cent, but shortens the life from 25 to 50 per cent. Bowl frosting has no appreciable effect upon the life. The effect of coloring upon the life of the lamp is about the same as that of frosting. The effect upon the c. p. varies with the color and its density. Amber, opal and yellow absorb the least; blue, green and purple the most; blue and red are the most used colors. Not much illumination can be expected from colored lamps. In some cases lamps are merely bowl colored. The efficiency of incandescent lamps increases with the voltage, but the length of life decreases. To a certain extent, therefore, what is gained on the one hand is lost on the other.

Table XXXIX is prepared to facilitate the calculations necessary to be made in order to determine the most economical voltage at which to operate lamps. In the column "K. W. wasted" we give the K. W. wasted by the use of the middle or bottom voltage during the length of life corresponding to top voltage, which is considered the standard. In the column headed "Saving in lamp renewals" we give the percentage of lamp renewals avoided by the use of lamps at the lower voltages. In order to find the money value of the watts wasted by any lamp we must multiply the figure given in the table by the c.p. of the lamp and the rate per K.W. In order to find how much the same combination will save us in lamp renewals we must multiply the cost of lamp by the figure in the column on "Saving in lamp renewals." If our calculation shows a net saving it will be more profitable to use the lower voltage, otherwise use the higher. Example: With energy at 5 cents per K.W. and 25 watt tungsten lamps costing 20 cents each, is it more economical to use the middle voltage than the top voltage? A 25 watt lamp gives 20 c.p. and the K.W. wasted at middle voltage is 0.050; we have therefore $20 \times 0.050 \times 0.05$, which equals 0.05, or 5 cents wasted during 1,000 hours. On the other hand, we save 0.23×0.20, which equals 0.046. The saving in cost of lamp renewals does not quite offset the loss by the lower voltage, hence the higher voltage is more economical.

In many cases such a calculation has merely an academic value. As long as the parties using the light are satisfied with that obtainable from the use of the lower voltage there is no economy in using the higher.

Smashing Point.—The useful life of a lamp is generally considered to be over when its c.p. has dropped to 80 per cent of its original value.

The following table is based on average values. The improvement in lamps is at times very rapid and in case great accuracy is required the manufacturers' guaranteed data should be obtained and used instead of values here given.

Inductance.—This is that property of an electric circuit which causes a current in it to create lines of force and thus produce a counter e.m.f. proportional to the rate of change of that current.

TABLE XXXIX

Comparative cost of illumination and lamp renewals.

Name of Lamp	Voltage Rating	Watts Per C.P.	Hours of Life	K.W. Wasted	Saving in Lamp Renewals
Mazda or Tungsten	Top........	1.22	1,000	.....	....
	Middle.....	1.27	1,300	0.050	0.23
	Bottom.....	1.33	1,700	0.110	0.41
Tungsten Gas Filled	Top........	In large units the type "C" or gas filled lamp is fully twice as efficient as the common tungsten lamp but in connection with small units there is no saving, but a whiter light is obtained.			
	Middle.....				
	Bottom.....				
Tantulum	Top........	1.84	800	.....	....
	Middle.....	1.91	1,075	0.056	0.26
	Bottom.....	2.00	1,350	0.128	0.41
Gem or Graphitized Filament	Top........	2.50	500	.....	....
	Middle.....	2.65	700	0.075	0.28
	Bottom.....	2.83	1,000	0.165	0.50
	Less Than 50 Watts				
Carbon	Top........	3.16	750	.....	....
	Middle.....	3.40	1,100	0.180	0.68
	Bottom.....	3.61	1,600	0.337	0.47
	50 Watts and Over.				
Carbon	Top........	2.97	650	.....	....
	Middle.....	3.18	925	0.136	0.30
	Bottom.....	3.39	1,425	0.273	0.54

TABLE XXXX

See pages 121-122. Wire tubes will take B. & S.

Shortest Length Obtainable	Longest Length Obtainable	External Diameter	Diameter of Hole	600 Volts or Less				600 to 3,500 Volts			
				Solid		Stranded		Solid		Stranded	
				S Braid	D Braid	S Braid	D Braid	S Braid	D Braid	S Braid	D Braid
½	24	36/64	20/64	10	14	12	..	..	..	..	..
½	24	44/64	24/64	8	10	8	14	14	..	14	..
1	24	52/64	32/64	3	5	4	6	6	8	8	10
1	24	60/64	40/64	0	1	2	3	2	3	2	4
1	24	1 3/16	48/64	000	00	00	1	00	0	0	0
1½	24	1 7/16	1	0000	0000	0000	0000	0000	000	0000	00
2½	24	1 13/16	1¼			450	000				
2½	24	2 3/16	1½			600	000				
2½	24	2 9/16	1¾			900	000				
2½	24	2 15/16	2			1,250	000				
2½	24	3 5/16	2¼			1,500	000				
2½	24	3 11/16	2½			2,000	000				

Three sizes in split tubes are obtainable. The inside diameters are 20/64, 24/64 and 32/64. Length is 3 inches.

TABLE XXXXI

Tables showing dimensions of porcelain insulators. See Fig. 7.

No.	Height	Over all Diam.	Diam. of Hole	Groove	Wire of Approximately Same Diam. as Groove
0	$2\frac{1}{4}$	3	$1\frac{1}{4}$	1	350,000
1	3	$2\frac{1}{8}$	$\frac{7}{16}$	$\frac{3}{4}$	0000
2	2	2	$\frac{1}{2}$	$\frac{1}{2}$	2
3	$1\frac{3}{4}$	2	$\frac{7}{16}$	$\frac{7}{16}$	4
3WG	$1\frac{3}{4}$	2	$\frac{7}{16}$	$\frac{3}{4}$	0000
$3\frac{1}{2}$	2	2	$\frac{7}{16}$	$\frac{7}{16}$	4
4	$1\frac{11}{16}$	$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	6
$4\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{7}{16}$	4
$5\frac{1}{2}$	$1\frac{9}{16}$	1	$\frac{1}{4}$	$\frac{5}{16}$	8
6	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	10
7	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{1}{4}$	$\frac{7}{16}$	4
8	$\frac{15}{16}$	1	$\frac{1}{4}$	$\frac{5}{16}$	8
9	$1\frac{1}{8}$	$\frac{5}{8}$	$\frac{3}{16}$	$\frac{3}{16}$	12
10	$1\frac{3}{4}$	$1\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	6
11	$\frac{11}{16}$	$1\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	2
12	$\frac{13}{16}$	$1\frac{3}{8}$	$\frac{5}{16}$	$\frac{9}{16}$	1
13	$\frac{3}{4}$	$\frac{15}{16}$	$\frac{1}{8}$	$\frac{5}{8}$	00
15	$1\frac{5}{16}$	$1\frac{3}{4}$	$\frac{7}{16}$	$\frac{1}{2}$	2
20	2	2	$\frac{3}{8}$	$\frac{5}{8}$	00
21	$2\frac{7}{8}$	2	$\frac{1}{2}$	$\frac{9}{16}$	1
22	$1\frac{5}{8}$	$2\frac{1}{8}$	1	$\frac{5}{16}$	350,000
23	$1\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{8}$	1	350,000
24	$1\frac{3}{4}$	$1\frac{7}{8}$	$\frac{7}{16}$	$\frac{5}{8}$	00
25	$1\frac{1}{2}$	$2\frac{1}{2}$	$\frac{11}{16}$	$1\frac{1}{16}$	400,000
26	2	$2\frac{1}{4}$	$\frac{5}{8}$	$\frac{9}{16}$	1
29	$2\frac{3}{8}$	$2\frac{1}{2}$	$\frac{1}{2}$	$1\frac{3}{8}$	450,000
36	$1\frac{3}{4}$	$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	0000
39	$1\frac{3}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$1\frac{3}{8}$	450,000

Split knobs are made only for wires from 14 to 8.

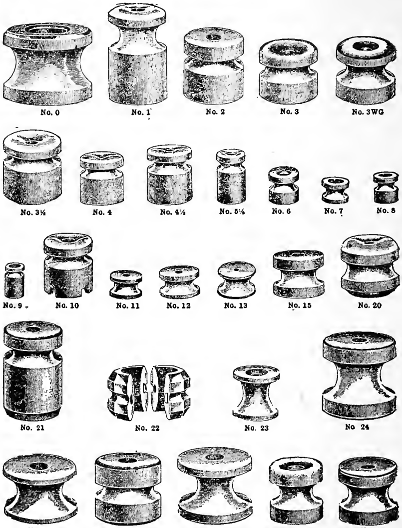


Figure 7.—Porcelain Insulators.

TABLE XXXXII

One Wire Cleats.

Height	Width	Length	Groove	Smallest Size of Wire to Fill Out Groove B. & S.
$1\frac{1}{4}$	$\frac{3}{4}$	2	$\frac{3}{8}$	8
$1\frac{13}{16}$	$\frac{3}{4}$	2	$\frac{3}{8}$	8
$1\frac{3}{4}$	1	$2\frac{1}{4}$	$\frac{1}{2}$	3
$2\frac{1}{8}$	1	$2\frac{1}{4}$	$\frac{1}{2}$	3
$1\frac{3}{4}$	$1\frac{1}{8}$	$2\frac{1}{2}$	$\frac{5}{8}$	1
$2\frac{1}{2}$	$1\frac{1}{8}$	$2\frac{1}{2}$	$\frac{5}{8}$	1
$2\frac{1}{4}$	$1\frac{3}{16}$	$2\frac{3}{4}$	$\frac{3}{4}$	000
$2\frac{1}{2}$	$1\frac{3}{16}$	$2\frac{3}{4}$	$\frac{3}{4}$	000
$2\frac{3}{8}$	$1\frac{5}{16}$	3	$\frac{15}{16}$	250,000
$2\frac{19}{32}$	$1\frac{5}{16}$	3	$\frac{15}{16}$	250,000
$3\frac{1}{4}$	$1\frac{3}{8}$	$3\frac{3}{8}$	$1\frac{1}{4}$	6,000,000
$3\frac{3}{8}$	$1\frac{7}{16}$	$3\frac{13}{16}$	$1\frac{3}{8}$	750,000
$3\frac{3}{4}$	$1\frac{5}{8}$	$4\frac{3}{4}$	2	2,000,000
4	2	5	$1\frac{7}{8}$	1,750,000
4	2	5	$1\frac{1}{2}$	1,000,000

Two Wire Cleats

$1\frac{1}{8}$	$\frac{5}{8}$	$3\frac{3}{8}$	$\frac{3}{16}$	14

Three Wire Cleats

$1\frac{1}{8}$	$\frac{5}{8}$	$3\frac{3}{8}$	$\frac{3}{16}$	14

* The wire sizes given are thought to be the smallest the cleats will grip well. Diameters of wires, however, vary considerable and some single braid wires may be too small for the cleats with which they are supposed to go. See tables giving diameters of insulated wires.

Insulating Materials.—The standard insulating materials are glass, porcelain, slate (without metal veins), marble, clay and certain compositions. The general requirement is that materials to be used for insulation shall be incombustible, shall not absorb moisture and shall not soften from heat. Wood and fiber are not approved, but are tolerated in some cases.

The dimensions and other data concerning insulators, cleats and tubes are given in Tables XXXX to XXXXII.

In buildings insulators must provide ½ inch separation between supports and wires and in damp places 1 inch is required.

Below are given sizes of bushings constructed according to the N. E. Code standard. Also the largest sizes of wire that can be used in them. The diameters of wires vary somewhat, and while it is believed that the wires given can be readily drawn through the bushings, it is advisable to use a larger bushing where it is necessary to draw wires through many of them, as in concealed knob and tube work.

Logarithms.—Logarithms are used for multiplication and division of large numbers, for raising numbers to any power or extracting roots. Every logarithm of the number 10 or greater than 10 consists of two parts—a whole number, which is known as the *characteristic*, and a decimal fraction known as the *mantissa*. The mantissa of all numbers consisting of the same digits is the same; thus in the table (which gives only the mantissa) we see that 0.8, 8, and 80 each have the same mantissa, viz., .903 09, and this mantissa would still be the same for 800 or 8000. The characteristics of these numbers, however, are not the same, but always 1 less than the number of integers or whole numbers; thus for 8 it would be 0, for 80 it would be 1, making the logarithm of 8=0.903 09 and that of 80=1.903 09. If the number of which the logarithm is to be taken is less than unity, the characteristic is 1 greater than the number of ciphers which follow the decimal point. The characteristics of various numbers are given below. The characteristic of a number does not change unless that number be increased or decreased by one decimal place.

1 000 000	= 6
100 000	= 5
10 000	= 4
1 000	= 3
100	= 2
10	= 1
1	= 0
0.1	= 1
0.01	= 2
0.001	= 3
0.0001	= 4

The characteristics of logarithms of numbers less than 1 are treated as minus quantities and usually designated by drawing a line above them.

The characteristics serve merely to determine the location of the decimal point. Whether they are added, subtracted or multiplied, if they are positive we must add to the number (found as hereafter described) ciphers enough so that the whole number will contain one more integer than the characteristic indicates. If the characteristic is minus, we must prefix one cipher less than the characteristic indicates.

How to Find the Logarithm of a Number.—Trace along first column at the left until the first two digits of the desired number are found; next follow along the same horizontal line until the third digit is found. At this place the mantissa required will be found. Put this down, prefixing it with a decimal point, and in front of it place a number equal to one less than the number of digits composing the original number. Example: find the logarithm of 676. Tracing down the left hand column, we come to the number 67 and in this horizontal line until we come to the third number, 6, we find 829 95. As 676 contains 3 digits our characteristic is 2 and we have 2.829 95, which is the logarithm of 676.

How to Find a Number Corresponding to a Certain Logarithm.—This is accomplished by the reverse process. Suppose we wish to find the number whose logarithm is 1.421 60; we first look for the mantissa part of it and find it in the horizontal line with 26 and under 4, giving us 264 as the required number; since the characteristic is 1 we locate our decimal point 2 places from the left and the actual number now is 26.4.

To Use Logarithms for Multiplication.—Find the logarithms of the two numbers; add them and find the number corresponding thereto. Example: What is the product of 36×88?

$$\begin{aligned} \log.\ 36 &= 1.556\ 30 \\ \log.\ 88 &= \underline{1.944\ 48} \\ & \ 3.500\ 78 \end{aligned}$$

The mantissa nearest equal to 500 78 is 499 69, which corresponds to 316. Since our characteristic is 3 we point off 4 from the left, giving us the number 3160.

To Divide by Logarithms.—Find the logarithms of the two numbers as before and subtract one from the other and find the number corresponding to the remainder.

To Raise a Number to Any Power.—Find the logarithm and multiply it by the index of the power. Example: What is the cube of 9?

Log $9 = .954\ 24$; this multiplied by $3 = 2.862\ 72$; looking to the table we find 862 73 as the nearest and this corresponds to 729, and as our characteristic is 2 we point off 3 from the left, which shows us that the desired number is 729.

To Extract Roots.—Find the logarithm of the number as before and divide by the index. Example: What is the cube root of 1331? The number 1331 is not tabulated, but the mantissa of 133 will be the same and it is 123 85 with a characteristic of 3, making it 3.123 85; this divided by 3 = 1.041 28, and the number corresponding to this is 11; since our characteristic is 1 we point off 2 from the left.

The method of dealing with quantities less than unity is explained by the following example: What is the product of 0.079 × 0.87? The log of 0.079 is 897 63 and as there is one cipher following the decimal point our characteristic is 2; the log of 0.87 is 939 52 and as there is no cipher after the decimal point the characteristic is 1. We now add the mantissae and the characteristics separately, and as the only characteristics are minus quantities, we subtract the positive characteristic found by adding the mantissae from the sum of the negative characteristics with the net result as given below:

$$
\begin{array}{ll}
\bar{2} & .897\ 63 \\
\bar{1} & .939\ 52 \\
\hline
\bar{3} & 1.837\ 15 \\
1 & \\
\hline
\multicolumn{2}{l}{\bar{2}.837\ 15}
\end{array}
$$

The nearest number in the tables to 837 15 is 836 96 and this we see corresponds to the number 688. As our characteristic is now 2 we prefix this number with one cipher, giving us 0.0688 as our product.

In case the mantissa is not tabulated and the nearest one to it is not considered accurate enough, the approximate value of the corresponding number can be found by taking the numbers corresponding to the nearest two mantissae and noting their difference. Multiply this difference by $\frac{a}{b}$ where a is the difference between the lowest mantissa and the one under con-

TABLE XXXXIII

Common Logarithms of Numbers

No.	0	1	2	3	4	5	6	7	8	9
0.		000 00	301 03	477 12	602 06	698 97	778 15	845 10	903 09	954 24
1.	000 00	041 39	079 18	113 94	146 13	176 09	204 12	230 45	255 27	278 75
2.	301 03	322 22	342 42	361 73	380 21	397 94	414 97	431 36	447 16	462 40
3.	477 12	491 36	505 15	518 51	531 48	544 07	556 30	568 20	579 78	591 06
4.	602 06	612 78	623 25	633 47	643 45	653 21	662 76	672 10	681 24	690 20
5.	698 07	707 57	716 00	724 28	732 39	740 36	748 19	755 87	763 43	770 85
6.	778 15	785 33	702 39	799 34	806 18	812 91	819 54	826 07	832 51	818 85
7.	845 10	851 26	857 33	863 32	869 23	875 06	880 81	886 49	892 09	807 63
8.	903 09	908 49	913 81	919 08	924 28	929 42	934 50	939 52	944 48	949 39
9.	952 24	959 04	963 79	968 48	973 13	977 72	982 27	986 77	991 23	995 64
10.	000 00	004 32	008 60	012 84	017 03	021 19	025 31	029 38	033 42	037 43
11.	041 39	045 32	049 22	053 08	056 90	060 70	064 46	068 19	071 88	075 55
12.	079 18	082 79	086 36	089 91	093 42	096 91	100 37	103 80	107 21	110 59
13.	113 94	117 27	120 57	123 85	127 10	130 33	133 54	136 72	139 88	143 01
14.	146 13	149 21	152 99	153 34	158 36	161 37	164 35	167 32	170 26	173 19
15.	176 09	178 97	181 84	184 69	187 52	190 33	193 12	195 90	198 66	201 40
16.	204 12	206 83	209 52	212 18	214 84	217 48	220 10	222 71	225 30	227 88
17.	230 45	232 99	235 52	238 04	240 54	243 03	245 51	247 97	250 42	252 85
18.	255 27	257 67	260 07	262 45	264 81	267 17	269 51	271 84	274 15	276 46
19.	278 75	281 03	283 30	285 55	287 80	290 03	292 25	294 46	296 66	298 85

TABLE XXXXIII—Continued

Common Logarithms of Numbers

No.	0	1	2	3	4	5	6	7	8	9
20.	301 03	303 19	305 35	307 49	309 63	311 75	313 86	315 97	318 06	320 14
21.	322 22	324 28	326 33	328 38	330 41	332 43	334 45	336 46	338 45	340 44
22.	342 42	344 39	346 35	348 30	350 24	352 18	354 10	356 02	357 93	359 83
23.	361 73	363 61	365 48	367 35	369 21	371 06	372 91	374 74	376 57	378 39
24.	380 21	382 01	383 81	385 60	387 39	389 16	390 93	392 69	394 45	396 19
25.	397 94	399 67	401 40	403 12	404 83	406 54	408 24	409 93	411 62	413 30
26.	414 97	416 64	418 30	419 95	421 60	423 24	424 88	426 51	428 13	429 75
27.	431 36	432 96	434 56	436 16	437 75	439 33	440 90	442 48	444 04	445 60
28.	447 16	448 70	450 24	451 78	453 31	454 84	456 36	457 88	459 39	460 89
29.	462 40	463 89	465 38	466 86	468 34	469 82	471 29	472 75	474 21	475 67
30.	477 12	478 56	480 00	481 44	482 87	484 30	485 72	487 13	488 55	489 95
31.	491 36	492 76	494 15	495 54	496 93	498 31	499 68	501 05	502 42	503 79
32.	505 15	506 50	507 85	509 20	510 54	511 88	513 21	514 54	515 87	517 19
33.	518 51	519 82	521 13	522 44	523 74	525 04	526 33	527 63	528 91	530 20
34.	531 48	532 75	534 02	535 29	536 55	537 81	539 07	540 33	541 57	542 82
35.	544 07	545 31	546 54	547 77	549 00	550 23	551 45	552 67	553 88	555 09
36.	556 30	557 51	558 71	559 91	561 10	562 29	563 48	564 67	565 85	567 03
37.	568 20	569 37	570 54	571 71	572 87	574 03	575 19	576 34	577 49	578 64
38.	579 78	580 92	582 06	583 20	584 33	585 46	586 59	587 71	588 83	589 95
39.	591 06	592 18	593 29	594 39	595 50	596 60	597 70	598 79	599 88	600 97

TABLE XXXXIII—Continued

Common Logarithms of Numbers

No.	0	1	2	3	4	5	6	7	8	9
40.	602 06	603 14	604 23	605 31	606 38	607 46	608 53	609 59	610 66	611 72
41.	612 78	613 84	614 90	615 95	617 00	618 05	619 09	620 14	621 18	622 21
42.	623 25	624 28	625 31	626 34	627 37	628 39	629 41	630 43	631 44	632 46
43.	633 47	634 48	635 48	636 49	637 49	638 49	639 49	640 48	641 47	642 46
44.	643 45	644 44	645 42	646 40	647 38	648 36	649 33	650 31	651 28	652 25
45.	653 21	654 18	655 14	656 10	657 06	658 01	658 96	659 92	660 87	661 81
46.	662 76	663 70	664 14	665 58	666 52	667 45	668 39	669 32	670 25	671 17
47.	672 10	673 02	673 94	674 86	675 78	676 69	677 61	678 52	679 43	680 34
48.	681 24	682 15	683 05	683 95	684 85	685 74	686 64	687 53	688 42	689 31
49.	690 20	691 08	691 97	692 85	693 73	694 61	695 48	696 36	697 23	698 10
50.	698 97	699 84	700 70	701 57	702 43	703 29	704 15	705 01	705 86	706 72
51.	707 57	708 42	709 27	710 12	710 46	711 81	712 65	713 49	714 33	715 17
52.	716 00	716 84	717 67	718 50	719 33	720 16	720 99	721 81	722 63	723 46
53.	724 28	725 09	725 91	726 73	727 54	728 35	729 16	729 97	730 78	731 59
54.	732 39	733 20	734 00	734 80	735 60	736 40	737 19	737 99	738 78	739 57
55.	740 36	741 15	741 94	742 73	743 51	744 29	745 07	745 86	746 63	747 41
56.	748 19	748 96	749 74	750 51	751 28	752 05	752 82	753 58	754 35	755 11
57.	755 87	756 64	757 40	758 15	758 91	759 67	760 42	761 18	761 93	762 68
58.	763 43	764 18	764 92	765 67	766 41	767 16	767 90	768 64	769 38	770 12
59.	770 85	771 59	772 32	773 05	773 79	774 52	775 25	775 97	776 70	777 43

TABLE XXXXIII—Continued

Common Logarithms of Numbers

No.	0	1	2	3	4	5	6	7	8	9
60.	778 15	778 87	779 60	780 32	781 04	781 76	782 47	783 19	783 90	784 62
61.	785 33	786 04	786 75	787 46	788 17	788 88	789 58	790 29	790 99	791 69
62.	792 39	793 09	793 79	794 49	795 18	795 88	796 57	797 27	797 96	798 65
63.	799 34	800 03	800 72	801 40	802 09	802 77	803 46	804 14	804 82	805 50
64.	806 18	806 86	807 54	808 21	808 89	809 56	810 23	810 90	811 58	812 24
65.	812 91	813 58	814 25	814 91	815 58	816 24	816 90	817 57	818 23	818 89
66.	819 54	820 20	820 86	821 51	822 17	822 82	823 47	824 13	824 78	825 43
67.	826 07	826 72	827 37	828 02	828 66	829 30	829 95	830 59	831 23	831 87
68.	832 51	833 15	833 78	834 42	835 06	835 69	836 32	836 96	837 59	838 22
69.	838 85	839 48	840 11	840 73	841 36	841 98	842 61	843 23	843 86	844 48
70.	845 09	845 71	846 33	846 95	847 57	848 18	848 80	849 41	850 03	850 64
71.	851 25	851 87	852 48	853 09	853 69	854 30	854 91	855 51	856 12	856 72
72.	857 33	857 93	858 53	859 13	859 73	860 33	860 93	861 53	862 13	862 72
73.	863 32	863 91	864 51	865 10	865 69	866 28	866 87	867 46	868 05	868 64
74.	869 23	869 81	870 40	870 98	871 57	872 15	872 73	873 32	873 90	874 48
75.	875 06	875 64	876 21	876 79	877 37	877 94	878 52	879 09	879 66	880 24
76.	880 81	881 38	881 95	882 52	883 09	883 66	884 22	884 79	885 36	885 92
77.	886 49	887 05	887 61	888 18	888 74	889 30	889 86	890 42	890 98	891 53
78.	892 09	842 65	893 20	893 76	894 31	894 87	895 42	895 97	896 52	897 07
79.	897 62	898 17	898 72	899 27	899 82	900 36	900 91	901 45	902 00	902 54

TABLE XXXXIII—Continued

Common Logarithms of Numbers

No.	0	1	2	3	4	5	6	7	8	9
80.	903 09	903 63	904 17	904 71	905 25	905 79	906 33	906 87	907 41	907 94
81.	908 48	909 02	909 55	910 09	910 62	911 15	911 69	912 22	912 75	913 28
82.	913 81	914 34	914 87	915 40	915 92	916 45	916 98	917 50	918 03	918 55
83.	919 07	919 60	920 12	920 64	921 16	921 68	922 21	922 72	923 24	923 76
84.	924 27	924 79	925 31	925 82	926 34	926 85	927 37	927 88	928 39	928 90
85.	929 41	929 93	930 44	930 95	931 46	931 96	932 47	932 98	933 48	933 99
86.	934 49	935 00	935 50	936 01	936 51	937 01	937 51	938 02	938 52	939 02
87.	939 51	940 01	940 51	941 01	941 51	942 00	942 50	943 00	943 49	943 98
88.	944 48	944 97	945 46	945 96	946 45	946 94	947 43	947 92	948 41	948 90
89.	949 39	949 87	950 36	950 85	951 33	951 82	952 30	952 79	953 27	953 76
90.	954 24	954 72	955 20	955 68	956 16	956 64	957 12	957 60	958 08	958 56
91.	959 04	959 51	959 99	960 47	960 94	961 42	961 89	962 36	962 84	963 31
92.	963 78	964 26	964 73	965 20	965 67	966 14	966 61	967 08	967 54	968 01
93.	968 48	968 95	969 41	969 88	970 34	970 81	971 27	971 74	972 20	972 66
94.	973 12	973 59	974 05	974 51	974 97	975 43	975 89	976 35	976 80	977 26
95.	977 72	978 18	978 63	979 09	979 54	980 00	980 45	980 91	981 36	981 81
96.	982 27	982 72	983 17	983 62	984 07	984 52	984 97	985 42	985 87	986 32
97.	986 77	987 21	987 66	988 11	988 55	989 00	989 45	989 89	990 33	990 78
98.	991 22	991 66	992 11	992 55	992 99	993 43	993 87	994 31	994 75	995 19
99.	995 63	996 07	996 51	996 94	997 38	997 82	998 25	998 69	999 13	999 56

sideration, and b the difference between the two mantissae; next add this number to the lower number. Example: Our mantissa is 2.851 60, and looking into our table, we find that it is not tabulated. The next lower is .851 26, which corresponds to the number 700; the next higher is 2.851 87, which corresponds to 710. Now, .851 60−.851 26 leaves us 34, and the difference between 851 26 and 851 87 is 61. We have now $\frac{34}{61}\times 10$, which equals 5.57, and this added to 700 gives us the approximate value of the number corresponding to the mantissa of 2.851 60, viz., 705.57.

Magnetic Blowout.—A strong magnetic field repels an arc and is often used to break it. It is made use of in lightning arresters, and at other places where the arc is troublesome.

TABLE XXXXIV

Melting Points of Various Substances in Degrees Centigrade and Fahrenheit

	C.	F.		C.	F.
Aluminum	659	1218	Mercury	—38.7	—37.7
Antimony	630	1166	Nickel	1452	2645
Bismuth	271	520	Paraffin	52	126
Brass	900	1652	Photo emulsion	32	90
Bronze	900	1652	Platinum	1755	3191
Carbon	3600	6512	Rubber	100	212
Chronium	510	950	Silenium	218	424
Cobalt	1490	3714	Silicon	1420	2588
German Silver	1100	2012	Silver	960	1760
Glass	1300	2372	Steel, Av.	1400	2552
Gold	1063	1945	Sulphur	110	230
Gutta Percha	100	212	Tantalum	2850	5162
Iridium	2300	4140	Tin	232	449
Iron	1520	2768	Tungsten	3000	5432
Lead	327	620	Vanadium	1730	3146
Manganese	1225	2237	Wax, Bees	62	143
Marble	2500	4532	Zinc	419	787

Bureau of Standards as authority for the majority.

Mains.—This term properly used applies only to the last set of wires feeding the final distribution point. Primary mains are those which feed the individual transformers. The wires leading from transformers are usually spoken of as secondary mains, although

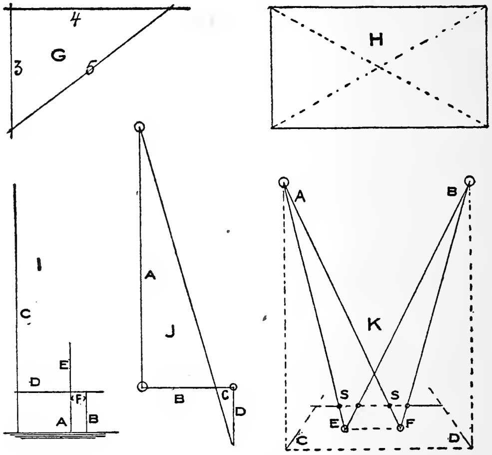


Figure 8.—Measurement of Heights and Distances.

there may be conditions in which they would be secondary feeders.

Measurement of Heights and Distances. The measurement of heights and distances requires first of all the use of right angles. Where no instruments or squares are available, a right angle can be laid out as in *G*, Figure 8, setting stakes or stretching lines so that the dimensions given, or multiples of them, obtain on the three sides.

A square or rectangle can be proved by stretching diagonals from the corners. When both diagonals are the same length we have a perfect rectangle. See *H,* Figure 8.

The height of a pole or other object can be found by the method shown in *I,* Figure 8. Set up two stakes, *A* and *B,* a known distance apart and of a height so that their tops form a straight line with top of pole. When this is done the length of pole *C* above *D* is to *E* as *D* is to *F,* hence $C=\frac{DE}{F}$. If the total length of $D+F$ is made equal to $27\frac{1}{2}$ feet and $F=2\frac{1}{2}$ feet, then $C=10\times E$. Add distance below line *D* to this to obtain total height of pole.

The distance between two points, one of which is accessible, can be found by means of the construction shown in *J,* Figure 8. Similarly to the foregoing, if *B* is made 10 times *C,* then *A* will be made 10 times *D.*

The distance between two inaccessible points may be measured by the methods shown in *K,* Figure 8. If two stakes, *C* and *D,* be set up with reference to *A* and *B,* so as to be at right angles to each other and with diagonals pointing to *A* and *B,* also forming the same angles, the distance between *C* and *D* will be equal to that between *A* and *B.*

Another method consists in setting up two stakes, *E* and *F,* and parallel to them drawing a line or laying a tape line upon the ground and setting up stakes as indicated at *S.* Measure distances between the various stakes and draw a plan of them to any convenient scale as indicated. Measure the distance between *A* and *B* on this plan. This method does not require that *E* and *F* be parallel or centered with reference to *A* and *B.*

Mensuration.—

Area of a triangle = base × ½ altitude.

Area of a parallelogram = base × altitude.

Area of a trapezoid = altitude × ½ the sum of parallel sides.

Area of trapezium: divide into two triangles and find area of the triangles and add together.

Area of circle = diameter^2 × 0.7854 = radius^2 × 3.1416.

Area of sector of circle = length of arc × ½ the radius.

Area of segment of circle = area of sector of equal radius − area of triangle, when the segment is less, and + area of triangle when the segment is greater than the semi-circle.

Area of circular ring = diameters of the two circles × difference of diameters × 0.7854.

Area of an ellipse = product of the two diameters × 0.7854.

Area of a parabola = base × ⅔ altitude.

Area of regular polygon = sum of its sides × perpendicular from its center to one of its sides ÷ 2.

REGULAR POLYGONS

No. of Sides		Area when dia. of inscribed circle =1	Area when side =1	Length of side when perpendicular =1	Perpendicular when side =1	Radius of circumscribed circle when side =1	Length of side when radius of circumscribed circle =1
3	Triangle	..1.299	0.433	3.464	0.289	0.577	1.732
4	Square	....1.000	1.000	2.000	0.500	0.707	1.414
5	Pentag.	...0.908	1.720	1.453	0.688	0.851	1.176
6	Hexag.	....0.866	2.598	1.155	0.866	1.000	1.000
7	Heptag.	...0.843	3.634	0.963	1.039	1.152	0.868
8	Octag.	....0.828	4.828	0.828	1.207	1.307	0.765
9	Nonag.	....0.819	6.182	0.728	1.374	1.462	0.684
10	Decag.	....0.812	7.694	0.650	1.539	1.618	0.618
11	Undecag.	..0.807	9.366	0.587	1.703	1.775	0.563
12	Dodecag.	..0.804	11.192	0.536	1.866	1.932	0.518

Surface of cylinder or prism = area of both ends + length × circumference.
Surface of sphere = diameter × circumference.
Convex surface of segment of sphere = height of segment × circumference of the sphere of which it is a part.
Surface of pyramid or cone = circumference of base × $\frac{1}{2}$ of the slant height + area of the base.
Surface of frustrum of cone or pyramid = sum of circumference at both ends × $\frac{1}{2}$ of slant height + area of both ends.
Contents of sphere = cube of diameter × 0.5236.
Contents of cylinder or prism = area of end × length.
Contents of segment of sphere = (height + three times the square of radius of base) × (height × 0.5236).
Contents of frustrum of cone or pyramid: Multiply areas of two ends together and extract square root. Add to this root the two areas × $\frac{1}{3}$ altitude.
Contents of a wedge = area of base × $\frac{1}{2}$ altitude.
Circumference of circle = diameter × 3.1416.
Circumference of circle = radius × 6.2832.
Circumference of circle = 3.5446 × square root of area of circle.
Circumference of circle × 0.159155 = radius.
Circumference of circle × 0.31831 = diameter.
Circumference of circle × 0.225 = side of inscribed square.
Circumference of circle × 0.282 = side of an equal square.
Half the circumference of circle × half its diameter = its area.
Square of circumference of circle × 0.7958 = area.
Diameter of circle × 0.86 = side of inscribed equilateral triangle.
Diameter of circle × 0.7071 = side of an inscribed square.
Diameter of circle × 0.8862 = side of an equal square.

Diameter = 1.1283 $\sqrt{}$ square root of area of circle.
Length of arc = number of degrees × 0.017453.
Degrees in arc whose length equals radius, 57.2958°.
Length of arc of 1° = radius × 0.017453.

Meter Capacity.—It is a general rule to install meters of about one-half the capacity of the connected load in residences; three-fourths this capacity in small stores, offices, etc., and full capacity for elevator motor service and similar installations where excessive starting currents are the rule. For more exact determinations, see *Demand Factors.*

The d. c. meter is essentially a shunt motor, and its direction of rotation is independent of the polarity, but if fed from the wrong side, it will run backwards. On a. c. circuits wattmeter readings will not check with volt and ammeter reading; the latter must be multiplied by the power factor. Current transformers are used in connection with large capacity a. c. meters.

Meter Location.—Meters must always be accessible, never in places that are locked or where meter readers would cause annoyance to occupants. The location selected must be free from moisture and vibration. Meters should not be placed on curb walls of streets on which cars operate nor on thin partitions. If meters are placed in cabinets, these should be fireproofed and no magnetic material should be brought close to the meter. Meters must be set level and leveling can be accomplished by placing a small weight upon disk, and shifting meter until disk remains at rest in any position. In order that meters may be properly set, meter boards must be provided. The necessary dimensions of such boards vary with the service to be rendered and are given on Figures 9 and 10. These are the requirements in force in the City of Chicago.

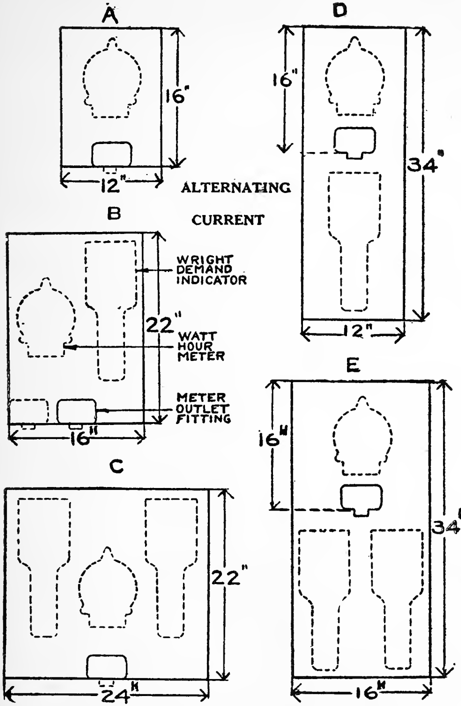


Figure 9.—Meter Fittings and Meter Boards.

Figure 9.—Showing Proper Location of Meter Fittings and Size of Meter Boards Required for Different Installations.

A. C. Residence or Apartment Lighting.

30 sockets or 1500 watts, or under, sketch *A*.

31 to 48 sockets or 1501 to 2640 watts, sketch *B* or *D*.

Above 48 sockets or 2640 watts, sketch *C* or *E*.

A. C. Business Lighting.
  24 sockets or 1320 watts, or under, sketch *A*.
  Above 24 sockets or 1320 watts, sketch *C* or *E*.

A. C. Power.
  5 H. P., and under, single-phase, sketch *A*.
  Above 5 H. P., and all three-phase, sketch *C*.

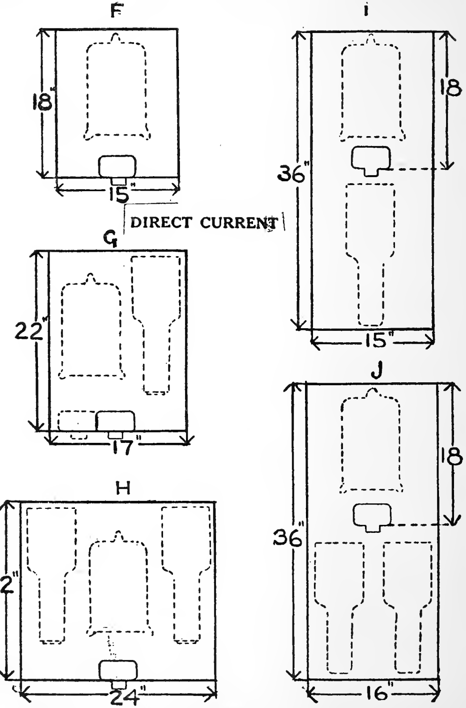


Figure 10.—Meter Fittings and Meter Boards.

Figure 10.—Showing Proper Location of Meter Fittings and Size of Meter Boards Required for Different Installations.

D. C. Residence or Apartment Lighting.
- 30 sockets or 1500 watts, or under, sketch *F*.
- 31 to 48 sockets or 1501-2640 watts, sketch *G* or *I*.
- Above 48 sockets or 2640 watts, sketch *H* or *J*.

D. C. Business Lighting.
- 24 sockets or 1320 watts, or under, sketch *F*.
- Above 24 sockets or 1320 watts, sketch *H* or *J*.

D. C. Power.
- 1500 watts, or under, sketch *F*.
- Above 1500 watts:
  - 2-wire, sketch *G* or *I*.
  - 3-wire, sketch *H* or *J*.

If the meter is located at service entrance, the measured energy will exceed the delivered energy by the percentage of loss occurring in the feed wires. If it is located at some distance from this point the service company will stand part or all of this loss.

The per cent loss per 100 feet run with different voltages, wires assumed to be loaded to full capacity, is given in Table XXXXV.

TABLE XXXXV

B. & S.	Amperes	110 v.	220 v.	440 v.	550 v.	1000 v.
14	15	4.80	2.40	1.20	0.96	0.53
12	20	5.80	2.90	1.45	1.16	0.64
10	25	4.50	2.25	1.13	0.90	0.50
8	35	4.00	2.00	1.00	0.80	0.44
6	50	3.60	1.80	0.90	0.72	0.40
5	55	3.10	1.55	0.77	0.62	0.34
4	70	3.10	1.55	0.77	0.62	0.34
3	80	2.90	1.45	0.73	0.58	0.32
2	90	2.60	1.30	0.65	0.52	0.29
1	100	2.20	1.10	0.55	0.44	0.24
0	125	2.20	1.10	0.55	0.44	0.24
00	150	2.10	1.05	0.53	0.42	0.23
000	175	1.90	0.95	0.47	0.38	0.21
0000	225	1.90	0.95	0.47	0.38	0.21
300 000	275	1.90	0.95	0.47	0.38	0.21

Reactances are not taken into consideration.

Meters, Maximum Demand.—The cost of supplying electrical energy is properly divided into two parts: One of these consists in charges to be made for meter reading, bookkeeping, and investment of capital; the other in the cost of energy consumed by the customer.

The capital investment depends largely upon the maximum demand of the customer and also upon the time at which this demand occurs. A given transformer, for instance, will serve perhaps twice as many families in which the ironing is done during the day, as it will where an iron is used at the same time with the lights. In order to obtain compensation for unnecessarily high demands for short times, maximum meters are installed, or a certain fixed charge per month is made against every customer whether current is used or not.

The maximum demand meter may be any arrangement which will indicate the highest amperage, or rate of power consumption, during any month or other convenient term. The method of computing bills where these meters are installed is somewhat confusing to one who does not make a business of it, and to show the influence of max. meters the following table is presented: This table shows the average rate per K.W. hour brought about by different maximum demands and total K.W. consumption per month.

TABLE XXXXVI

Max. Amp.	Total K.W. Hours							
	25	50	75	100	125	150	200	300
25	11.	11.	11.	10.1	9.3	8.7	7.7	6.4
20	11.	11.	10.4	9.3	8.6	8.0	7.0	6.0
15	11.	11.	9.3	8.4	7.9	6.9	6.2	5.5
10	11.	9.3	8.	7.	6.4	6.	5.5	5.
5	9.3	7.	6.	5.5	5.2	5.	4.7	4.4

This table is based on a charge of 11 cents per K. W. hour for the first thirty hours of the maximum used; 6 cents per K. W. hour for the next thirty hours of the maximum, and 4 cents per hour for the balance. The maximum load is found by multiplying the highest amperage during the month by the volts. If we have a maximum of 10 amperes our first charge will be $10 \times 110 \times 30 \times 0.11 = \$3.63$; the next will be $10 \times 110 \times 30 \times 0.06 = \$1.98$, and for the remaining K. W. hours we charge 4 cents, which equals $1.60, giving us

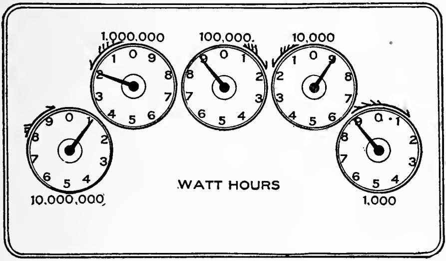


Figure 11.—Meter Dials.

a total of $7.21 for the 100 K. W. hours used, or approximately 7 cents per K. W. In the table the change in rates per K. W. is shown as affected by the proportion between the maximum demand and the total consumption.

Meter Reading.—This is a very simple matter when one has become accustomed to it, but is very confusing to those who have not had it to do. Most meters have five dials arranged somewhat on the order shown in Figure 11. These dials are all connected by gearing and serve merely as counters. The one at the right is driven by the meter mechanism proper, and through it the others are driven in turn. In the whole train each one revolves in a direction opposite to that of the one driving it, as indicated by arrows and also by the numbers used. The proportion of the gearing is such that while the pointer on the driving dial makes one complete revolution, the one on the next dial to the left makes only one-tenth of one revolution. From this it follows that any pointer, except the one at the extreme right, can be fully on any number only at the same time that the pointer to the right of it is on 0. This is the principal point to bear in mind in meter reading. In Figure 11 a complete revolution of any pointer indicates the use of the number of watt hours found at the top of that dial. Meter reading is best begun by noting the reading of the dials from right to left, although persons who have become accustomed to it find no trouble in reading from left to right. Let us begin reading our meter from right to left and note this rule: Put down the indication of the right-hand dial, and unless its pointer is fully on, or has just passed, 0, choose the lowest of the two numbers between which the pointer may be on the next dial, and continue in this manner, putting down each number to the left of the last. Following out this rule we have first 900, next 8, then another 8, after that 1, and for the fifth dial another 1, giving us a total of 1 188 900 watt hours. Striking out 3 figures at the right reduces this to K. W. hours. It must be borne in mind that some meters are arranged to read directly in K. W. hours and some require the use of multipliers to determine the actual watts registered.

Meter Testing.—In large cities meter fittings are usually provided for the connection of meters and the best of these are arranged to allow of easy connection for meter without interfering with the operation of meters. On all meters the disk is arranged to make a certain number of revolutions per K. W. and if this is known the load on the meter at any moment can be determined. The relation between the number of revolutions of the disk and the corresponding dial reading may be expressed by a multiplier which is known as the "constant" of the meter and is usually marked upon the disk or somewhere near it. The value of this constant in any particular instrument depends entirely upon the gearing between the disk and dial. Meter constants may be expressed in the following ways (1) number of watt hours indicated by one revolution of the disk; (2) the number of watt seconds indicated by one revolution of the disk; (3) the speed in R. P. M. at full load or rated load.

If K stands for the constant of the meter in either of the meanings given above and R for the number of revolutions made in S seconds, the load passing through the meter during any interval of time will be found by the following formulae:

$$1.\ \text{Watts} = \frac{KR \times 3600}{S}$$

$$2.\ \text{Watts} = \frac{KR}{S}$$

$$3.\ \text{Watts} = \frac{KR}{S}$$

The testing of meters is best done by connecting a standard meter in series with it, and comparing the readings. The test meter may be connected so as to measure the operating current in addition to the load of the one under test. In this case the meter under test will be found "slow" if it is arranged to measure that current; if the test meter is connected to avoid this current the other will be found "fast." Before making any test the meters should be allowed to be in circuit for about 15 minutes. A stop watch must be used if accurate results are required. On important installations it is advisable to test meters at least twice per year. In some cases two meters are installed in parallel; such meters are a constant check upon one another.

Motion Pictures.—*Photography.*—Cooper Hewitt lamps are used almost exclusively for this purpose, and about 50,000 c.p. are required to do good work. Lamps must be arranged adjustable to suit whim of producer.

Exhibition.—The exhibition of motion pictures may be carried on with one arc lamp, but it should have an adjustable rheostat or compensator. Many films are very dark, and require extra strong lighting. Good exhibitions require at least two machines and a corresponding number of arc lamps, one to be ready when the other runs out. Stereopticon lamps and spot lights must also often be provided for. It is customary to require at least a No. 6 wire for each motion picture arc, as they often draw as high as 50 amperes. There is considerable fire and life hazard connected with the exhibition of motion pictures, and each municipality usually has some rules governing the handling of films and apparatus, which should be consulted.

Motors.—*Alternating Current.*—There are four general types of alternating current motors; viz., induction, series, repulsion and synchronous motors.

Induction Motors.—The stationary part of this motor is termed the "stator," the moving part the "rotor." That part of the winding which receives current from the supply line is known as the "primary," the other as the "secondary." From a mechanical point of view this is the simplest and best of all motors, and it is also the most used type. Polyphase induction motors are self-starting, but single-phase motors require some special starting device. These motors are essentially constant speed motors, but their operation depends upon the "slip," which requires a slight reduction of speed with increasing load. This motor has a poor starting torque and often requires four or five times the running current to start it.

The rotor of the common induction motor is not provided with any winding, but for special purposes, such as printing presses, cranes, etc., wound rotors are often used. Resistances can be used with such motors and the speed also thus controlled. The speed will, however, be variable with the load and the motor will require watching. With a wound armature the torque is the same for all speeds. Auto-starters, or compensators, are used to start the larger motors, but the smaller ones may be connected directly to the circuit. A throw over switch fused on one side only, and so connected that the starting current need not pass through the fuses, is generally used for medium size motors, up to 5 H.P.

The synchronous speed of an induction motor can be found by the formula:

$$\text{R.P.M.} = \frac{60 \times \text{frequency}}{\text{number of pairs of poles}}$$

Below is a tabulation of all possible speeds of synchronism of 60 and 25 cycle motors with the numbers of poles given:

Number Poles	60 Cycles	25 Cycles
2	3600	1500
4	1800	750
6	1200	500
8	900	375
12	600	250
16	450	187½
24	300	125

Actual speeds, on account of "slip," are from 3 to 10 per cent lower.

Repulsion Motor.—The field winding of this motor is similar to that of a single-phase induction motor. There is no connection whatever between it and the armature, and the latter is always wound and provided with a commutator and short-circuiting brushes. The currents induced in the armature always tend to oppose those in the field, hence the name, repulsion motor. The speed of this motor is variable with the load and may be above synchronism, but the operation at this speed is not satisfactory. In some types the direction of rotation, speed, regulation, and stopping and starting may all be accomplished by simply shifting the brushes. Some single-phase motors are arranged to start as induction repulsion motors. When the motor is up to speed, the brushes are automatically thrown off, and the motor continues to run as a simple induction motor. The starting current of this type of motor is from two to three times the full load current and the starting torque is good.

Reversing Direction of Rotation.—The synchronous motor is not self-starting, and will run in whichever direction it is started. It is usually started by a small induction motor, and to reverse its direction of rotation the connections of the latter must be changed. Polyphase synchronous motors may be started by turning on the a. c. current while the d. c. fields are open. In such a case the direction of rotation can be changed by reversing two-phase wires in the same manner that induction motors are reversed. To reverse the direction of rotation of a two-phase motor, the two wires of one phase must be changed. If there are only three wires the connections must be changed so that the relative direction of current through one of the phases is reversed.

Three-phase induction motors are reversed by changing the connections of any two-phase wires. The direction of rotation of a single-phase induction motor is indeterminate unless it is provided with some special starting apparatus. Some may be started by hand and will run in whichever direction they are started; others require that the connections of the starting coils (not starting box) be reversed. The alternating current series motor may be reversed in the same manner as d. c. motors. The repulsion motor may be reversed by either shifting the brushes or reversing the field connections.

Series Motor.—This type of alternating current motor has about the same general characteristic as the direct current series motor. Except in small sizes it cannot be used without constant attendance. The field magnets are always laminated and the fields must be obtained with as few turns of winding as possible, as the self-induction increases as the square of the number of turns of wire. Series motors may be had for use either on alternating or direct current circuits.

The armature is relatively more powerful than the fields, and the field distortion is therefore greater than in direct current series motors. To regulate this, many of the motors are provided with extra coils, some of which are in series with the fields and armatures, and others arranged to receive current only by induction.

Synchronous Motors.—These motors may be either single of polyphase. They must run at an absolutely constant speed governed by that of the generator. This speed may be found by the formula

$$\text{R. P. M.} = \frac{60 \times \text{frequency}}{\text{number of pairs of poles}}$$

All synchronous motors require direct current for field excitation. They are not self-starting in the true sense of the word. and must be brought up to nearly the proper speed before current is finally turned on.

Synchronous motors are not much used, but where they are used they may be made to exert a beneficial effect upon the power factor of the line. They cannot be made to start under load, and if overloaded will come to a stop. "Hunting" or "phase swinging" is one of the chief troubles encountered with synchronous motors. The two chief objections to synchronous motors are: they require direct current for field excitation, and skilled attendance for starting.

Starting of a. c. Motors.—Most synchronous motors are started by small induction motors and gradually brought up to the speed of synchronism. A synchroscope is usually provided to determine when the proper moment to throw in switch has arrived.

Polyphase synchronous motors may be made self-starting by opening the field circuit and allowing the line currents to pass through the armature. The armature then creates its own fields, and begins to revolve on the principle of an induction motor. The speed gradually increases, and when it reaches about that of synchronism, the d. c. field circuit is closed. Where motors are started in this way, an ammeter should be in the circuit and the current observed. If the current grows less after the field circuit is closed, the motor is working properly; if otherwise, the switch must be opened again, and a new trial made. This method of starting should not be used unless it is known that the motor is arranged for it. Very high potentials may be induced and break down the insulation.

The starting current of induction motors thrown directly onto the line is from three to ten times the normal running current, and to keep it from becoming excessive, compensators or auto-transformers are usually inserted in the line wires. This provides low voltage for starting. There are usually either three or four taps in the connections of an auto-transformer. When only three are provided it is customary to arrange them to give 50, 65, and 80 per cent of the line voltage. Four taps are used only with the largest motors and in such a case the taps are arranged for about 40, 58, 70, and 80 per cent of the line voltage. Always make the connection for the lowest voltage at which the motor can be started. Modern starters are equipped with no-voltage and overload releases.

Three phase motors may be connected either in star or delta. If the latter is the permanent connection the switching arrangement may be such as to put the motor in star for starting, the switch being thrown over when the motor has attained some speed. In cases where the three transformers are near the motor the transformer connections may be switched in the same way, using the star connection to start the motor and throwing over to delta when it has gained some in speed.

Medium sized motors are often connected direct to the line without any means of reducing the voltage. In such cases a throw-over switch unfused on one side, but properly fused on the other, is provided. The switch is closed on the unfused side until the motor has attained its speed and is then thrown over to bring it under the protection of the fuses. With this arrangement the fuses at motor may be provided to fit the running current while those at the beginning of supply line must be large enough to stand the starting current which is often very excessive.

Speed Control.—The speed of a synchronous motor is unchangeable and governed entirely by the frequency and number of poles. The speed of an induction motor varies directly as the frequency, and if we have means of changing this, we may obtain any speed desired.

The same formula for speed which shows the above, also shows that the speed can be varied by varying the number of poles. This is sometimes accomplished by switching devices which combine poles so as to reduce their number by one-half. This method is not much used.

The speed can also be altered by changing the voltage applied to the motor. A fourth method of speed control consists in providing a wound armature in place of the ordinary squirrel cage armature and placing resistances in the armature windings. Sometimes these resistances are located inside of the armature spider, at other times the leads are brought out, and the resistances mounted outside of the machine. The loss in speed of an induction motor with increasing load is proportional to the resistance in the rotor circuit, and if carried too far will cause the motor to stop. A reduction in speed of from 15 to 20 per cent will cause the ordinary squirrel cage motor to stop, but with a wound rotor the variation may be much greater. The speed control of a. c. motors is never very satisfactory, but where it must be, the wound rotor method is the most practical.

Variable Speed Arrangements of Motors.—A well known method of obtaining various speeds is that known as the "tandem," "cascade" or concatenation method of coupling two motors together to obtain variable speed. The first motor is fed direct from the line through suitable starters and the currents in the second motor are produced in the wound rotor of the first. The rotor of the second motor is also wound and equipped with controlling resistances. Four speeds are obtainable. First, the natural speed of motor 1 running alone; second, that of motor 2 running alone; third, the speed of the two motors combined when both tend to revolve in the same direction, and fourth, the speed of the two motors combined when one tends to run in the opposite direction.

Connected in direct concatenation (both motors tending to run in the same direction) the speed can be found by the formula

$$\text{R. P. M.} = \frac{60 \times \text{frequency}}{\text{number of pairs of poles on both machines}}$$

When one of the rotors is connected to oppose the other the speed is

$$\text{R. P. M.} = \frac{60 \times \text{frequency}}{\text{difference in number of poles in the two machines}}$$

If the number of poles on the two machines is the same, they will run at half speed when connected in direct concatenation.

This method of control is not of much use with frequencies above 25 cycles on account of a low power factor. With this method a wound rotor is also always employed.

Motor Testing.—Motors may be tested to determine their capacity in H.P. or K.W.; their insulation resistance; their heating; speed regulation, and efficiency.

The H.P. capacity of a motor, other things being equal, depends entirely upon the current which the armature will stand, and this, assuming proper mechanical construction, depends entirely upon the heating. The heat generated is proportional to the square of the current, but the temperature of the wire is influenced considerably by the ventilation. The temperature also depends upon the length of time the current is used, and therefore the actual H.P. which any motor may develop depends very much upon whether it is to be used continuously or intermittently. Every motor thus has two ratings.

The continuous rating of a motor is at present usually taken as the output in H.P., or K.W. which it can deliver continuously, with a maximum rise in temperature above the surrounding air at 25° C. (77° F.) of not more than 40° C. (104° F.) on field and armature, and not more than 55° C. (131° F.) on commutator. The intermittent rating differs from this in that it allows a temperature rise of 65° C. on field and armature and 90° on the commutator to be attained in an hour's run. Motors designed to fulfill these requirements can be given a still higher overload rating to be used in connection with apparatus which is in operation for only a few minutes at a time. The test for heating is made by a thermometer placed upon the parts and covered with waste to shut out the cooling influence of the air. The places of highest temperature should be selected.

The H.P. output of a motor may be found by the well-known prony brake test. To make the test, adjust the screws until the motor speed is reduced sufficiently to allow the desired current through the armature. The H.P. of the motor can then be found by the formula:

$$\text{H.P.} = \frac{s \times l \times p}{33{,}000}$$

where s = speed of pulley; l = length of lever from center of pulley to scale attachment, and p = the pull on scales in pounds.

The H.P. delivered to the motor is equal to the product of volts and amperes, and dividing the H.P. developed by the motor by that delivered to it, will give us the efficiency. The prony brake test cannot well be continued long enough to test heating of motor, and some other form of load must be placed upon it. The speed regulation of a motor may be found by operating the motor at various loads from zero to maximum, and noting the changes in speed. In testing alternating current motors we must multiply the product of volts and amperes by the power factor, or use a wattmeter instead of volt and ammeters. The starting torque of a motor can be found in the same way as we found the H.P., but we must adjust the screws until the armature comes to a standstill.

Motor Troubles.—*If the fuses blow at starting*, contacts may be loose or dirty, or the fuses are of insufficient capacity. The motor may be overloaded or out of order in some way. The brushes may not be properly set. The rheostat may be manipulated too fast. It is usual to allow about 30 seconds to pass during the starting of the ordinary motor. The supply voltage may be higher than the motor is intended for, or the rheostat may be too large, and not introduce sufficient resistance. The motor may be improperly connected. The field circuit may be open. This would prevent the armature from generating the necessary counter e.m.f. There may be a short circuit in the armature, or in the fields. If a short circuit cuts out part of the field, it will indicate itself by undue heating and prevent the armature from picking up. If the frequency is too low, there will be an excessive current; if it is too high, there will be insufficient current.

If motor fails to start and the fuses do not blow, there may be a dead line; test for current.

In the case of a series motor there may be an open circuit in either armature or fields; this can be in the armature only if a shunt motor. Insufficient tension or poor contacts of brushes also often prevent the motor from starting. In an alternating current motor the frequency may be too high. One or more phases may be open.

Fields Running Hot.—The voltage at which machine operates may be higher than that for which it was intended. Fields may be in parallel where they were meant to be in series. A part of the field may be short circuited, or cut out by grounding. In such a case one of the fields will be cool while the other runs abnormally hot.

Heating of Armature.—This may be caused by an overload; the heating increases as the square of the current used. There may be a short-circuited armature coil; if so, it will speedily show itself by burning out. A strong odor of heated shellac will probably be the first indication. Poor ventilation is often the cause; many motors are meant to operate either open or enclosed, and the enclosed capacity is always much less than the open.

Shaft of Bearings Running Hot.—This may result from improper oiling, boxes too tight, shaft bent, belts too tight, rough bearings, or the armature may not be properly centered, and thus press too hard on one of the end collars.

Shocks Obtained from Machine.—These may be due to static electricity or to grounding of some live part of the motor or the frame. The troubles from static electricity can be overcome by grounding the frame or fitting the belting with arresters.

Sparking of Brushes.—This may be due to wrong position of the brushes. With increasing load, the brushes of motors must be shifted against the direction of rotation, and, vice versa, with generators the opposite rule holds. The best motors, however, require very little shifting of brushes. Rough commutator, ragged brushes, or dirty condition of either commutator or brushes are frequent cause of sparking. Insufficient tension is also a frequent cause of sparking. If the brush is too narrow it will leave one segment before making the proper connection with the next; if too wide, it will short circuit too many and thus cause sparking. Incorrect spacing of brushes will cause sparking. Compound wound motors, or those operating with light field, are subject to much sparking. To prevent this, inter-poles are often provided. Test direction of current in series winding by starting motor with shunt field open. An open circuit in an armature coil will cause severe sparking, which will occur only at a certain place on commutator.

Motors.—*Direct Current.*—There are three types of d. c. motors; viz., series, shunt, and compound.

The Series Motor.—Small series motors, such as fan motors, can be made to work successfully under any conditions. Large series motors with a variable load require constant attendance. Lightening the load will allow the motor to speed up inordinately and become dangerous. Such motors are very useful where heavy loads are to be started, as the torque is theoretically proportional to the square of the current as long as the fields are at a low point of saturation. And in all cases when the fields are not fully saturated, the torque increases faster than the current. The maximum torque exists at low speed and is independent of the voltage, depending entirely upon the current.

Shunt Motors.—The shunt motor is the most used of all direct current motors, and if properly constructed operates at a fairly uniform speed for all loads within its capacity. Once started it requires no attention. It is suitable for all classes of work, except such as street car service where the current is often suddenly interrupted and as suddenly thrown on again by accidents to the trolley. Its starting torque is not as good as that of the series motor, but it is fair. The field strength varies with the voltage, but as long as this is maintained it is independent of the voltage at armature terminals.

The Compound Motor.—This is a combination of shunt and series motor and has both windings. If the current in the compound winding is in the same direction as that in the shunt, the increased current strength necessary to handle a heavy load will strengthen the fields and slow the motor down. Such a motor is known as "cumulative" and has a very good starting torque. If the compound winding is in the opposite direction, an increased current will lighten the fields and cause the motor to speed up, but will give it a poor starting torque. The compound winding may be so adjusted that the motor will run at a very even speed for all loads within its capacity. A motor so connected is known as "differential." Owing to the fact that part of the field magnetization is destroyed by the series winding, the efficiency is somewhat low. Commutating or inter-poles are often inserted in d. c. motors. Such poles are provided to overcome the armature reaction and produce sparkless commutation. Motors so equipped can carry greater overloads. They are very useful where a good starting torque is required. Motors are further divided into open and enclosed types. The capacity of a totally enclosed motor is only about 60 per cent of that of the open motor. The capacity in H. P. depends upon whether the motor is to be used continuously or intermittently, and is governed by the heating limitation, the heat generated being proportional to I^2.

The current required by any motor can be found by the formula

$$\text{Current} = \frac{\text{H. P. delivered} \times 746}{\text{efficiency} \times \text{voltage}}$$

The efficiency of a motor can be found by dividing the input by the output. All motors are delivering their maximum power when the speed is such that the counter e. m. f. of the motor is one-half of that delivered at the terminals.

Reversing Direction of Rotation.—All d. c. motors may be reversed by changing the connections of either field or armature so that current passes through one of them in the opposite direction. If the current in both is reversed the direction of rotation will remain as before. Most multi-polar motors may be reversed by shifting the brushes sufficiently; this is equivalent to reversing armature leads.

Speed Control.—All d. c. motors tend to run at a speed which enables the armature to generate a counter e. m. f. equal to that of the supply. The speed can be varied by strengthening the field, which reduces it, or weakening the field to increase it. The commonest method of accomplishing speed control is by means of resistance cut into the armature circuit. This method, however, causes a speed variable with the load, the fall in pressure at the motor terminals being equal to *IR*. Adjusting the field strength to regulate the speed causes much sparking at the brushes. This can be obviated to a large extent by the use of commutating or inter-poles. The armature current passes around these and tends to keep the neutral point at a certain place, thus preventing sparking. Speed control is further effected by switching arrangements which enable one to connect several motors either in series or parallel; the parallel connection giving the higher speed and the series the lower. Such systems are used mostly in connection with d. c. street railway service.

Starting of d. c. Motors.—All d. c. motors, except the small ones which are wound with a high resistance in armature circuit, require some extra resistance to keep the current down until the armature has attained sufficient speed to generate the counter e. m. f. which finally limits the current. This resistance must never be in the field circuit of a shunt motor, but always in the armature circuit. In the differential motor, the series winding should be cut out of circuit until the motor is started, otherwise the excessive starting current will weaken the field too much. In the cumulative type of motor, the series field adds to the starting torque. A motor may be tested as to whether it is cumulative or differential by starting it with the shunt field open. If cumulative it will run in the same direction as with the shunt field closed. The starting resistances of shunt motors are usually wound with fine wire which will overheat and burn out if left in circuit too long. Not more than thirty seconds should be consumed in manipulating the handle. In some cases, however, special apparatus is provided which can carry the current indefinitely. If motor does not start at once, open switch and look for the cause of trouble.

Power Required to Operate Machinery.—When the H.P. needed to operate a given machine is not known it may in some cases be calculated from the formula:

$$\text{H.P.} = \frac{P \times 2\pi \times r \times n}{12 \times 33{,}000 \times e}$$

where P = pull in pounds which must be applied at periphery of pulley to move it; r = radius of pulley in inches; n = number of revolutions per minute; e = the efficiency of a direct current motor or the product of efficiency and power factor in an alternating current motor or circuit.

If the machinery to be started is equipped with heavy flywheels, or possesses considerable inertia of any kind, the size of the motor needed is governed by the starting requirements which depend largely upon the rate of acceleration demanded. In connection with other machinery, such as ventilating fans for instance, the power required increases faster than the speed and can be measured only when the device is operating at full speed. For such motors the above formula cannot be used and it is necessary to obtain data from manufacturers or other users.

TABLE XXXXVII

To find H. P. required, multiply pull in pounds at periphery of pulley by number found where the given speed and radius cross.

Radii of Pulley in Inches

R.P.M.	2	3	4	5	6	7	8	9	10	11	12
100.....	.0042	.0063	.0085	.0106	.0127	.0149	.0170	.0190	.0212	.0233	.0254
200.....	.0085	.0127	.0170	.0212	.0255	.0298	.0340	.0381	.0424	.0467	.0510
300.....	.0127	.0190	.0254	.0318	.0381	.0447	.0508	.0570	.0636	.0699	.0762
400.....	.0170	.0255	.0340	.0424	.0508	.0596	.0680	.0765	.0848	.0933	.1016
500.....	.0212	.0318	.0424	.0530	.0635	.0745	.0848	.0954	.1060	.1165	.1270
600.....	.0255	.0382	.0510	.0636	.0762	.0894	.1020	.1146	.1272	.1399	.1524
700.....	.0298	.0447	.0596	.0742	.0889	.1043	.1192	.1341	.1484	.1631	.1778
800.....	.0340	.0510	.0680	.0848	.1016	.1192	.1360	.1530	.1696	.1766	.2032
900.....	.0382	.0573	.0764	.0954	.1143	.1341	.1528	.1719	.1908	.2000	.2286
1000.....	.0424	.0636	.0848	.1060	.1270	.1490	.1696	.1908	.2120	.2332	.2540

In the table below the values of $\frac{2\pi \times r \times n}{12 \times 33{,}000 \times e}$ (e being assumed as of about .75) are given wherever the horizontal line pertaining to speed crosses with a vertical line pertaining to radius of pulley.

Care must be exercised in determining *P;* it must not be more than just enough to cause motion, and at best can be only an approximation. *P* may be determined by a spring balance, or by a weight and lever. If the latter is used and attached to rim of pulley, multiply weight by distance from center of pulley and divide by radius of pulley.

Group vs. Individual Drive.—The total H.P. capacity of motors for individual drive must be equal to the H.P. demands of all the machinery.

The H.P. capacity for group drive may be considerably less, because not all of the driven machinery is used at the same time. How much of saving there is in any given case depends upon circumstances. Very often the shafting necessary with group drive requires as much additional H.P. capacity as is saved by the other consideration above.

The total H.P. required for group drive can be found by the formula:

$$\text{H.P.} = \frac{(h.p. \times f) + s}{e}$$

where h.p. is the horsepower demanded by the total machinery if run all at the same time; f is the load factor; s the H.P. required to drive shafting, and e the efficiency of the motor. The large motors used for group drive are more efficient at full load than the smaller ones, but a group drive motor is seldom run at full load. If it is properly chosen it will be overloaded part of the time and inevitably be running with no other load than the shafting part of the time.

The nearer it can be kept running with full load the more efficient it will be. The total H. P. required for individual drive is equal to the sum of the H. P. of all the machines divided by the efficiency. The full load efficiency of the small motors is lower, but there is never any idle machinery or shafting to be moved, and if properly selected the motors may operate at full load efficiency most of the time. In most cases individual drive is the most economical where a permanent installation is considered, but the cost of installation is generally somewhat higher. In addition to the above advantages, which can be figured out in dollars and cents, the following considerations should be of interest and duly noted: With individual drive the fire and life hazard are somewhat increased, but the shafting and belting accidents are greatly decreased. In connection with low voltage (110 or 220) the life hazard is small, and the advantage is on the side of the individual drive. With high voltage group drive is probably safer. With individual drive the facilities for speed regulation are better and motor troubles cannot throw a whole shop out of order. There is no shafting to cause dirt and noise and interfere with illumination, and there is less vibration in the workroom. Individual drive, however, requires somewhat more care and attention.

Where we have the choice of motors of different efficiencies we can afford to expend for the motor of the better efficiency a sum of money upon which the annual interest charge will be equal to the saving in the cost of energy effected by the better motor. We must, however, select the rate of interest so as to cover all depreciation, and if we assume that the motor will be a dead loss at the end of the time it is to be used, we shall obtain the following rates of interest, using a 6 per cent basis:

Motor to be used 1 year only,	106	per cent
2 years,	56	"
3 years,	40	"
4 years,	32	"
5 years,	27	"
6 years,	24	"
7 years,	$21\frac{1}{2}$	"
8 years,	20	"
9 years,	$18\frac{3}{4}$	"

For longer periods of time the interest rate decreases slowly and the above will cover all ordinary cases.

According to the above principles we can determine the amount of money we may economically invest in order to substitute a motor of higher efficiency for another with lower efficiency by the formula,

$$C=\frac{\text{K. W.}\times r\times h\times d\times e}{\text{per cent interest}}$$

where C = capital to be invested; K. W. = the number of watts used; r = the rate per K. W. hour; h = the number of hours K. W. is used per day; d = the number of days per year; e = the difference in efficiency of the two motors; per cent interest = the rate of interest governed by the number of years motor is to remain in use as given above.

In the following table it is assumed that the motor will be used 300 days per year, and on this basis the numbers given represent the capital which could profitably be invested with K. W., r, and h equal to unity, and e and the rate of interest as given in the table. To use the table for determining how much can profitably be invested to substitute a more efficient motor in place of a poorer one, it is but necessary to find the product of K. W. $\times r\times h$, and with this multiply the number found where the horizontal line pertaining to the difference in efficiency in favor of the better motor

TABLE XXXXVIII

Number of Years Motor Is to Remain in Use

Efficiency	1 yr. 106	2 yrs. 56	3 yrs. 40	4 yrs. 32	5 yrs. 27	6 yrs. 24	7 yrs. 21½	8 yrs. 20	9 yrs. 18¾
1........	.0283	.0536	.0750	.0937	.1111	.1250	.1396	.1500	.1600
2........	.0566	.1172	.1500	.1874	.2222	.2500	.2792	.3000	.3200
3........	.0849	.1608	.2250	.2811	.3333	.3750	.4188	.4500	.4800
4........	.1132	.2144	.3000	.3748	.4444	.5000	.5584	.6000	.6400
5........	.1415	.2680	.3750	.4685	.5555	.6250	.6980	.7500	.8000
6........	.1698	.3216	.4500	.5622	.6666	.7500	.8376	.9000	.9600
7........	.1981	.3752	.5250	.6559	.7777	.8750	.9772	1.050	1.120
8........	.2264	.4288	.6000	.7496	.8888	1.000	1.127	1.200	1.280
9........	.2547	.4824	.6750	.8433	.9999	1.125	1.256	1.350	1.440
10........	.2830	.5360	.7500	.9370	1.111	1.250	1.396	1.500	1.600
12........	.3396	.6432	.9000	1.124	1.332	1.500	1.675	1.800	1.920
14........	.3962	.7504	1.050	1.312	1.554	1.750	1.954	2.100	2.220
16........	.4528	.8576	1.200	1.499	1.776	2.000	2.254	2.400	2.560
18........	.5094	.9648	1.350	1.686	1.998	2.250	2.512	2.700	2.880
20........	.5630	1.072	1.500	1.874	2.222	2.500	2.792	3.000	3.200

TABLE XXXXVIII—Continued

Efficiency	1 yr. 106	2 yrs. 56	3 yrs. 40	4 yrs. 32	5 yrs. 27	6 yrs. 24	7 yrs. 21½	8 yrs. 20	9 yrs. 18¾
22........	.6226	1.179	1.650	2.061	2.444	2.750	3.071	3.300	3.520
24........	.6792	1.286	1.800	2.248	2.664	3.000	3.350	3.600	3.840
26........	.7358	1.394	1.950	2.436	2.888	3.250	3.629	3.900	4.160
28........	.7924	1.501	2.100	2.624	3.108	3.500	3.908	4.200	4.480
30........	.8490	1.608	2.250	2.811	3.333	3.750	4.188	4.500	4.800
32........	.9056	1.715	2.400	2.998	3.552	4.000	4.467	4.800	5.120
34........	.9622	1.822	2.550	3.188	3.774	4.250	4.746	5.100	5.440
36........	1.018	1.929	2.700	3.372	3.996	4.500	5.025	5.400	5.760
38........	1.074	2.036	2.850	3.560	4.222	4.750	5.304	5.700	6.080
40........	1.132	2.144	3.000	3.748	4.444	5.000	5.584	6.000	6.400
42........	1.188	2.251	3.150	3.936	4.662	5.250	5.862	6.300	6.720
44........	1.245	2.358	3.300	4.122	4.888	5.500	6.142	6.600	7.040
46........	1.302	2.466	3.450	4.320	5.111	5.750	6.420	6.900	7.360
48........	1.358	2.572	3.600	4.496	5.328	6.000	6.700	7.200	7.680
50........	1.415	2.680	3.750	4.685	5.555	6.250	6.980	7.500	8.000

Rule: Find the difference in efficiency between motors under consideration; also the number of years motor is to be used. Select number found where lines pertaining to difference in efficiency and years of use cross and multiply this number by K. W. hours per day and rate per K. W. The result will give the number of dollars which may be invested to procure the motor of higher efficiency.

crosses with the rate of interest applicable to the problem. The result will be the sum in dollars and cents which can with profit be expended to procure the better motor.

Rule of Table.—Find the difference in efficiency between the motors considered and the number of years the motor is to be used. Select the number found in the longitudinal line where the corresponding efficiency (given in vertical column at the left) crosses with the proper rate of interest (given at top); multiply this number by the K. W. hours per day, and by the rate per K. W. The result will give the amount of money which may be invested to procure the motor of higher efficiency. If this sum will make up the difference in cost, the better motor should be provided.

Nails.—Use cut nails for driving into brickwork.

TABLE XXXXIX

Dimensions of Nails

		Common Nails			Finishing Nails		
Size	Length	Nearest B. & S.	Diam. in inches	Approx. number per lb.	Nearest B. & S.	Diam. in inches	Approx. number per lb.
2d	1	13	9/128	876	14	8/128	1351
3d	1¼	12	5/64	568	13	9/128	807
4d	1½	10	7/64	316	13	9/128	584
5d	1¾	10	7/64	271	13	9/128	500
6d	2	9	7/64	181	11	3/32	309
7d	2¼	9	7/64	161	11	3/32	238
8d	2½	8	17/128	106	10	7/64	189
9d	2¾	8	17/128	96	10	7/64	172
10d	3	7	19/128	69	9	7/64	121
12d	3¼	6	19/128	63	9	7/64	113
16d	3½	6	5/32	49	8	17/128	90
20d	4	4	25/128	31	8	17/128	62
30d	4½	4	27/128	24			
40d	5	3	29/128	18			
50d	5½	2	31/128	14			
60d	6	2	33/128	11			

National Electrical Code (*Abbreviated N.E.C*). —The N. E. C. contains the recommendations of the National Fire Protection Association in reference to electrical installations. It is revised every two years, and its recommendations are generally accepted as standard throughout the United States. Most municipalities pattern their regulations after this code, but introduce a few variations which local conditions seem to warrant. The National Board of Fire Underwriters issue "The List of Electrical Fittings." This contains a list of appliances which have been tested and are considered safe. Those engaged in electrical construction work are advised to keep in touch with the N. E. C., the List of Electrical Fittings, and local requirements.

Nernst Lamp.—This lamp is not as much used as formerly. It has a high intrinsic brilliancy; requires no reflectors; should be hung high. It requires considerable attention to keep in repair and cannot be used in theatres or similar places where quick changes are necessary.

Neutral Wire.—This term describes one of the three wires used in connection with the three-wire system. Normally this wire carries no current and is, therefore, often smaller than either of the outside wires. In case an outside fuse blows, it may, however, be called upon to carry the full load current. It is always fused higher than the outside wires, and often is not fused at all. Blowing of the neutral fuse may do much damage. Ordinarily this wire is also grounded.

In a star connected polyphase system, the point at which all of the wires connect is also spoken of as neutral. The fourth wire in a three-phase system may also be so termed.

Non-Inductive Load.—A non-inductive load is distinguished from an inductive load by the fact that the current is in phase with the voltage. Circuits supplying only incandescent lamps are very nearly non-inductive; arc lamps and motors make up a strongly inductive load.

Office Lighting.—Desk lights are very common, but they are also a nuisance. They cause constant annoyance, and increase the fire hazard.

Inverted lighting is very favorably received in many offices and deserves extended trials. The newer high efficiency lamps have done much to make it economical. Where all employes are constantly at their desks there can be no difference of opinion regarding the superiority of a good general illumination in every respect. Local illumination can appear advisable only in such places where most of the desks are occupied for a short time per day only.

Avoid large spreading chandeliers carrying many lamps. These often cause a multiplicity of shadows. If clusters are used, lamps should be close together. Do not run wires in any but the main walls or partitions; use three-fourths inch conduit so as to have plenty of capacity for changes which are always taking place. Arrange lighting to harmonize with windows, so that furniture placed correctly for daylight will also fit the artificial illumination.

Ohm.—The international ohm has been legalized in this country and is defined as the resistance which a column of mercury of a uniform cross section, at the temperature of melting ice, and 106.3 centimeters in length, and of a mass of 14.4521 grams, offers to an unvarying electric current.

Ohms Law.—$I=\frac{E}{R}$; $I \times R = E$; $R=\frac{E}{I}$

Ohmic Loss or Drop.—The loss in e. m. f. or drop in p. d. caused by the resistance as distinguished from that caused by reactance.

Overhead Construction.—The timbers most in use for poles are: Michigan cedar, Western cedar, chestnut, pine and cypress. Of these the cedars and chestnut are the most used. The cedars are easier to climb and the taper is greater so that the tops of cedar poles are smaller in proportion to the butts than chestnut poles. On account of the variable nature of the wood and the fact that they soon begin to rot at the ground line, which is the point of greatest strain, the strength of poles must be calculated with a large factor of safety. In the tables following the breaking strain of the wood has been taken as 7,000 pounds per square inch and a factor of safety of 10 has been used.

Poles are usually designated by their length in feet and diameter at top in inches; thus a pole 40 feet long and 8 inches in diameter at top is spoken of as a 40-8 pole. The standard or most used pole is 35 feet long and has a 7-inch top. In swampy places poles are often set in concrete.

Poles should be set with the sweep in the line so that the wires may be straight. Use no iron poles where lines must be worked on while alive. Set pole steps 32 inches apart and stagger them. In cities place poles on lot lines. Avoid placing poles near lamp posts, hydrants or catch basins. Give corner poles a slight rake outward. Use the heaviest poles for transformers. Special attention should be given to tamping at bottom and top of holes, and the earth should be piled up a little around pole to keep water from running in. Keep one side of pole free for climbing. Double arm all poles subject to unusual strains. The lowest cross arm should be at least 18 feet above ground and 22 feet above railway tracks. Allow at least 2 feet between cross arms; more if possible. Insulate guy wires. Make cross arms of uniform length.

Standard cross arms are rounded on top; $3\frac{1}{4}$ inches wide by $4\frac{1}{4}$ inches high; allow 24 inches between pole pins, and at least 12 inches between other pins; this distance varies with number of pins, length of span and voltage. Junction arms usually have a wider spacing between inside pins. The high tension wires should be carried on the top arms; secondary wires are usually run below them, and the lowest arms are left for signal wires if any are to be run on same line. There should be a space of about five feet between the signal and the lighting and power wires. The lowest voltage wires are usually run next to poles; circuit wires should be kept together, and neutral of three-wire system should be run in center. The fourth wire of a three-phase system is also carried next to pole.

Pole Line Calculations.—The first step in laying out a pole line must be to decide upon height of poles and maximum span lengths. The next step will be to calculate the strains to which poles may be subject. The main body of a pole line is subject only to wind pressure, and this can be determined by use of Table LII. End poles are subject to half of this wind pressure and strain from the wires as well. Poles from which taps are taken have the full wind pressure and strain of wires leading off. Corner poles must be considered as subject to 1.41 times the strain on end poles. The wire strains upon poles can be found by the use of Table LI. The strains upon poles having been determined, the proper diameter at ground line can be determined by Table LIII.

When the strains on a pole are found to be greater than a pole of desirable diameter can well bear, it must be reinforced by guying or bracing. The proper diameter of guy cables can be found from Tables LV to LVII. If the pole is light compared to the strain put upon it, it will be best to provide a guy cable to take care of the total strains.

TABLE L

It is common practice to string electric power wires in accordance with the following tabulation, which gives the sag in inches:

Length of span	Temperature in Fahrenheit 20°	30°	40°	50°	60°	70°	80°	90°
50....	8	8	9	9	10	11	11	12
60....	9	10	11	11	12	13	14	14
70....	10	11	12	13	14	15	16	17
80....	12	13	14	15	16	17	18	19
90....	14	14	16	17	18	19	20	21
100....	16	16	17	19	20	21	23	24
110....	18	18	19	21	22	24	25	26
120....	18	19	21	23	24	26	27	28
130....	20	22	24	26	28	30	32	33
140....	22	23	26	28	30	32	34	35
160....	24	26	28	30	32	34	36	38

With wires strung according to the above tabulation each wire at the lowest temperature given will cause a strain on poles as given below. To find total strain on pole multiply proper number in table below by number of wires. By allowing a greater sag the strain will be proportionately reduced.

TABLE LI

Bare Copper

Length of Span	B. & S. Gauge 14	12	10	8	6	5	4	3	2	1	0	00	000	0000
80	10	16	26	47	63	80	101	127	160	202	255	321	405	512
100	13	22	34	62	85	107	135	171	215	272	343	432	545	688
120	15	24	39	70	95	120	151	190	240	303	382	481	607	768
140	18	29	47	85	116	147	182	230	294	371	470	592	740	942
160	19	32	52	94	126	160	202	254	320	404	510	642	810	1024

Breaking Strains

B. & S. Gauge

	14	12	10	8	6	5	4	3	2	1	0	00	000	0000
Hard Drawn—	219	343	546	843	1300	1580	1900	2380	2970	3680	4530	5440	6530	8260
Annealed—	110	174	277	441	700	884	1050	1323	1670	2100	2650	3310	4270	5320

Insulation and sleet may easily treble the strains.

The Maximum wind pressure upon the pole alone will range from 125 to 250 lbs., according to length and diameter of pole.

The side strain on a straight pole line (125 ft. span) can be found by use of the table below. Multiply number of wires on pole by number found under size of wire and in proper horizontal line.

TABLE LII

Wind Pressure

B. & S.	14	12	10	8	6	5	4	3	2	1	0	00	000	0000
Bare wire..	8	11	13	19	22	26	29	32	36	40	45	50	55	60
Insulated ..	35	38	41	46	50	53	56	60	65	70	80	90	100	110

Sleet may easily treble these strains, but sleet seldom exists in stormy weather.

TABLE LIII

Table showing maximum strains (applied at top) to which poles of various heights above ground, and of various diameters at ground line, should be subject.

Dia. of pole at ground line in inches	Height of Poles Above Ground in Feet										
	20	25	30	35	40	45	50	55	60	65	70
8..	147	118	98	84	74	66	58	53	49	46	42
9..	209	168	138	120	105	93	83	76	70	65	60
10..	286	228	191	164	143	127	115	104	95	88	81
11..	381	304	254	218	191	169	152	138	127	117	109
12..	495	396	330	284	247	220	198	180	165	121	141
13..	624	500	416	356	312	278	250	226	208	192	178
14..	786	628	524	450	393	350	314	287	262	242	224
15..	960	768	640	548	480	427	384	349	320	296	274
16..	1176	940	784	672	588	524	470	428	392	362	336
17..	1407	1124	938	804	704	625	563	572	469	433	402
18..	1658	1328	1106	948	828	756	664	604	553	510	474
19..	1964	1572	1310	1120	982	872	786	716	655	604	562
20..	2288	1831	1526	1284	1144	916	915	832	763	704	652
21..	2665	2132	1764	1524	1333	1144	1066	968	885	820	762
22..	3048	2440	2032	1740	1524	1356	1209	1108	1016	938	870

Depth of Setting

Earth	5	5½	6	6	6½	6½	7	7½	8	8½	9
Rock	4	4½	5	5	5½	5½	6	6½	7	7	9½

When erected along a curved line it is best to set somewhat deeper.

TABLE LIV

The following table probably shows the average of poles used for general telegraph and telephone purposes:

Length	Butt Dia.	Top Dia.	Wt. App.	Length	Butt Dia.	Top Dia.	Wt. App.
25...	9 to 10	6 to 8	350	50...	9 to 15	6 to 8	1350
30...	9 to 11	6 to 8	450	55...	16 to 17	6 to 8	1700
35...	9 to 12	6 to 8	600	60...	16 to 18	6 to 8	2200
40...	9 to 13	6 to 8	850	65...	16 to 19	6 to 8	2500
45...	9 to 14	6 to 8	1100	70...	16 to 20	6 to 8	3000

Guys.—Guys should be fastened to pole at point of strain and when so fastened the strain upon the guy can be found by the formula

$$S = \frac{\sqrt{D^2 + H^2}}{D} \times P$$

where D = horizontal distance at ground of guy from pole; H = the height of guy, and P = the pull upon the pole.

TABLE LV

Table for Calculating Strength of Guys.—To find the proper size of wire or wire rope for guying, multiply total strain upon pole by number found at point where line pertaining to height of guy fastening on pole crosses with line pertaining to horizontal distance of guy at ground from pole. The product will equal the breaking strain of the proper cable or wire to be used. The table is calculated for a safety factor of 5.

Height of guy on pole	Horizontal distance in feet from pole to where the guy or its support leaves ground						
	5	10	15	20	30	40	50
10......	11	7.0	6.2	5.5	5.3	5.2	5.1
15......	16	9.0	7.0	6.2	5.6	5.3	5.2
20......	21	11	8.3	7.0	6.0	5.6	5.5
30......	31	16	11	9.0	7.0	6.3	5.8
40......	40	21	15	11	8.3	7.0	6.5
50......	50	26	18	14	9.5	8.0	7.0
60......	60	31	21	16	11	9.0	7.6
70......	70	36	24	18	13	10	8.5

TABLE LVI

Table Showing Breaking Strain of Cables and Wires.—Standard Steel Strand. American Steel and Wire Company. Seven steel galvanized wires twisted into a single strand. Galvanized or extra galvanized.

Dia. in inches	Approx. Weight per 1000 feet	Approx. Strength in pounds	Galvanized Steel Wire				
			A. S. & W. G.	Dia.	Breaking Strain	Nearest B. & S.	Dia.
$\frac{5}{8}$	800	14000	12	.106	510	10	.102
$\frac{9}{16}$	650	11000	10	.135	774	8	.128
$\frac{1}{2}$	510	8500	9	.148	942	7	.144
$\frac{7}{16}$	415	6500	8	.162	1170	6	.162
$\frac{3}{8}$	295	5000	6	.192	1770	5	.182
$\frac{5}{16}$	210	3800	5	.207	2079	4	.204
$\frac{1}{4}$	125	2300	4	.222	2433	3	.229
$\frac{7}{32}$	95	1800	The American Steel and Wire gauge is commonly used for iron wire.				
$\frac{3}{16}$	75	1400					
$\frac{5}{32}$	55	900					

TABLE LVII

When a pole or mast is held in place by several guys equally spaced the figures obtained by the above calculation may be divided by the following guy factors taken from publication of the American Steel and Wire Company:

No. guys	Min. value of guy factor	Corresponding line of action of force	Max. value of guy factor	Corresponding line of action of force
3	0.866	30° from 1 guy	1.000	Opposite 1 guy or half way between two
4	1.000	Opposite 1 guy	1.414	Half way between 2 guys
5	1.538	18° from 1 guy	1.618	Opposite 1 guy or half way between two
6	1.732	30° from 1 guy	2.000	Opposite 1 guy

Telephone Wires.—The tables below give the practice of the A. T. & T. Co. No. 12 hard drawn copper wires are strung according to the following table:

TABLE LVIII

Temp. in Degrees F.	Length of Span in Feet								
	75	100	115	130	150	175	200	250	300
	Sag in Inches								
— 30	1	2	2½	3½	4½	6	8	14	22
— 10	1½	2½	3	4	5	7	9	16	25½
+ 10	1½	3	3½	4½	6	8	10½	18½	29½
+ 30	2	3½	4	5½	7	9½	12	21	33
+ 60	2½	4½	5½	7	9	12	16	26½	42½
+ 80	3	5½	7	8½	11½	15	19	31	49
+100	4½	7	9	11	14	18	22½	36	55

The same sag is also allowed for iron wire.

Messenger Cables.—The standard messenger strands used are the following:

Size of Cable: No. 22 Gauge	Size of Cable: No. 19 Gauge	Strength of Strand
100 pair or smaller	50 pair or smaller	6000 lbs.
100 to 200 pair	55 to 100 pair	10000 lbs.
Larger than 200 pair	Larger than 100 pair	16000 lbs.

The above strands are about equivalent to $\frac{7}{16}$, $\frac{9}{16}$ and $\frac{5}{8}$ inch diameters of good quality steel and used for spans not exceeding 200 feet.

The sag allowed is the following:

Span in feet	Sag in inches for heavy cables	Sag in inches when not more than 50 pair No. 22 gauge wire will be used
80	16	10
90	20	12
100	22	16
110	26	18
120	30	20
130	34	22
140	40	26
150	44	30
175	62	42
200	82	58

Panel Boards.—The panel board is a small switchboard, but circuits supplying more than 660 watts are seldom fed through it. Those described in the following figures and tables are designed for 660-watt branch circuits. Main bars have a capacity of 6 amperes per branch circuit at 110 volts, but only 3 amperes if designed for 220 volts. The figures in the tables are those furnished by the Cuthbert Electric Mfg. Co. Wherever the depth of cabinet required is the same for all numbers of circuits, it has been given in the fourth column from the left. In other cases the special designations at each height will serve as a guide. Where no special mark is placed and no depth given, the required depth is $3\frac{1}{2}$ inches. When ordering boxes, see points to be noted under *Cabinets.*

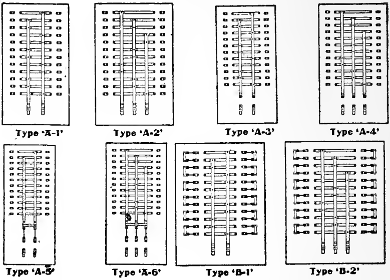


Figure 12.—Types of Panel Boards.

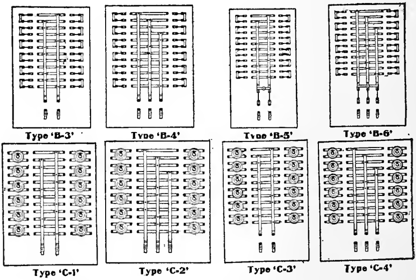


Figure 13.—Types of Panel Boards.

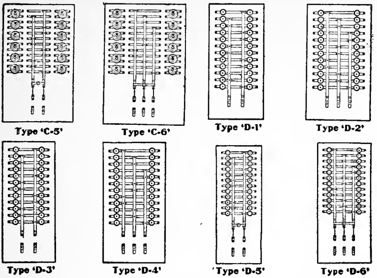


Figure 14.—Types of Panel Boards.

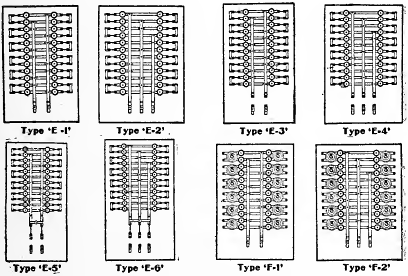


Figure 15.—Types of Panel Boards.

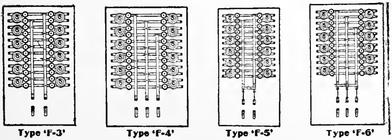


Figure 16.—Types of Panel Boards.

TABLE LIX

Dimensions of Panel Boards Cuthbert Electric Mfg. Co., Chicago

+4½ inches deep cabinet. △5½ inches deep. 3 wire 250 volts for 3 phase. See Figures 12 to 16.

				Number of Circuits													
Type	Volts	Wid.	Depth	4	6	8	10	12	14	16	18	20	22	24	26	28	30
'A-1'	125	10	3½	10	13	16	18	21	24	26	29	32	35	37	40	42	45
	250	10	3½	11	15	19	23	26	30	34	37	41	45	48	51	55	58
'A-2'	125	12	3½	10	12	15	18	21	23	26	28	31	33	36	39	41	43
	250	12	3½	12	16	20	25	29	33	37	41	45	49	53	57	61	65
'A-3'	125	10		12	16	19	24	27	29	32	34+	40+	42+	45+	47+	50+	52+
	250	10		14	17	21	26	30	33	37	40	47	50	54	57+	61+	64+
'A-4'	125	12		12	15	17	21	24	26	29	31	37	39	42	44	47+	49+
	250	12		14	18	22	28	32	36	40	44	51	55	59	63	67+	71+
'A-5'	125	10		15	21+	23+	29+	31+	35	38	40	44	47	49	52△	54△	57△
	250	10		16	20	23	30+	34+	37+	41+	44+	51+	55+	58+	63△	66△	70△
'A-6'	125	12		15	17	20	26+	28+	31+	33+	36+	41+	44+	46+	50+	52△	55△
	250	12		17	21	25	32+	36+	40+	44+	48+	55+	59+	63+	68+	72△	76△
'B-1'	125	14	4½	10	13	16	18	21	24	26	29	32	35	37	40	42	45
	250	16	5½	12	16	19	24	27	31	35	39	42	46	50	54	57	61
'B-2'	125	16	4½	10	12	15	18	21	23	26	28	31	33	36	39	41	43
	250	18	5½	13	17	22	27	32	36	41	45	50	54	59	63	68	72
'B-3'	125	14	4½	12	16	19	24	27	29	32	34	40	42	45	47	50	52
	250	16	5½	14	18	21	25	31	34	38	42	48	52	56	60	63	67
'B-4'	125	16	4½	12	15	17	21	24	26	29	31	37	39	42	44	47	49
	250	18	5½	15	19	24	30	35	39	44	48	56	60	65	69	74	78
'B-5'	125	14		15+	21+	23+	29+	31+	35△	38△	40△	44△	47△	49△	52△	54△	57△
	250	16	5½	17	20	24	31	35	39	42	46	53	56	60	65	69	73
'B-6'	125	16		15+	17+	20+	26+	28+	31+	33+	36+	41+	44+	46+	50+	52△	55△
	250	18	5½	18	22	26	35	39	44	48	53	60	65	69	75	79	84

TABLE LX

Dimensions of Panel Boards—Continued

Cuthbert Electric Mfg. Co., Chicago

+4½ inches. △5½ inches. 3 wire 250 volts for 3 phase. See Figures 12 to 16.

				Number of Circuits													
Type	Volts	Wid.	Depth	4	6	8	10	12	14	16	18	20	22	24	26	28	30
'C-1'	125	16	3½	10	13	16	18	21	24	26	29	32	35	37	40	42	45
	250	16	3½	11	15	19	23	26	30	34	37	41	45	48	51	55	58
'C-2'	125	18	3½	10	12	15	18	21	23	26	28	31	33	36	39	41	43
	250	18	3½	12	16	20	25	29	33	37	41	45	49	53	57	61	65
'C-3'	125	16		12	16	19	24	27	29	32	34+	40+	42+	45+	47+	50+	52+
	250	16		14	17	21	26	30	33	37	40	47	50	54	57+	61+	64+
'C-4'	125	18		12	15	17	21	24	26	29	31	37	39	42	44	47+	49+
	250	18		14	18	22	28	32	36	40	44	51	55	59	63	67+	71+
'C-5'	125	16		15	21+	23+	29+	31+	35△	38△	40△	44△	47△	49△	52+	54+	57+
	250	16		16	20	23	30+	34+	37+	41+	44+	51+	55+	58+	63+	66+	70+
'C-6'	125	18		15	17	20	26+	28+	31+	33+	36+	41+	44+	46+	50+	52△	55△
	250	18		17	21	25	32+	36+	40+	44+	48+	55+	59+	63+	68+	72△	76△
'D-1'	125	8	4½	11	15	18	21	24	27	30	34	38	41	44	47	51	54
	250	8	4½	11	15	19	23	26	30	34	37	40	45	48	51	55	58
'D-2'	125	10	4½	11	14	17	21	24	27	30	33	37	40	43	46	49	52
	250	10	4½	12	16	20	25	29	33	37	41	45	49	53	57	61	65
'D-3'	125	8	4½	13	18	21	27	30	33	36	40	45	47	52	55	58	61
	250	8	4½	14	17	21	26	30	33	37	40	47	50	54	57	61	64
'D-4'	125	10	4½	13	16	19	24	27	30	33	37	43	46	49	52	55	58
	250	10	4½	14	18	22	28	32	36	40	44	51	55	59	63	67	71
'D-5'	125	8		15+	22+	25+	31+	35+	39△	42△	45△	50△	53△	56△	59△	62△	66△
	250	8		16+	20+	23+	30+	34+	37+	41+	44+	51+	55+	58+	63△	66△	70△
'D-6'	125	10		15+	19+	22+	28+	31+	35+	38+	41+	47+	50+	53+	58+	61△	64△
	250	10		17+	21+	25+	32+	36+	40+	44+	48+	55+	59+	63+	68+	72△	76△

TABLE LXI

Dimensions of Panel Boards—Continued

Cuthbert Electric Mfg. Co.

+4½ inches. △5½ inches. 3 wire 250 volts for 3 phase. See Figures 12 to 16.

				Number of Circuits													
Type	Volts	Wid.	Depth	4	6	8	10	12	14	16	18	20	22	24	26	28	30
'E-1'	125	12	4½	11	15	18	21	24	27	30	34	38	41	44	47	51	54
	250	14	4½	12	16	19	24	27	31	35	39	42	46	50	54	57	61
'E-2'	125	14	4½	11	14	17	21	24	27	30	33	37	40	43	46	49	52
	250	16	4½	13	17	22	27	32	36	41	45	50	54	59	63	68	72
'E-3'	125	12	4½	13	18	21	27	30	33	36	40	45	47	52	55	58	61
	250	14	4½	14	18	21	25	31	34	38	42	48	52	56	60	63	67
'E-4'	125	14	4½	13	16	19	24	27	30	33	37	43	46	49	52	55	58
	250	16	4½	15	19	24	30	35	39	44	48	56	60	65	69	74	78
'E-5'	125	12		15+	22+	25+	31+	35+	39△	42△	45△	50△	53△	56△	59△	62△	66△
	250	14		17+	20+	24+	31+	35+	39+	42△	46+	53+	56+	60+	65△	69△	73△
'E-6'	125	14		15+	19+	22+	28+	31+	35+	38+	41+	47+	50+	53+	58+	61△	64△
	250	16		18+	22+	26+	35+	39+	44+	48+	53+	60+	65+	69+	75+	79△	84△
'F-1'	125	12	4½	11	15	18	21	24	27	30	34	38	41	44	47	51	54
	250	12	4½	11	15	19	23	26	30	34	37	41	45	48	51	55	58
'F-2'	125	14	4½	11	14	17	21	24	27	30	33	37	40	43	46	49	52
	250	14	4½	12	16	20	25	29	33	37	41	45	49	53	57	61	65
'F-3'	125	12	4½	13	18	21	27	30	33	36	40	45	47	52	55	58	61
	250	12	4½	14	17	21	26	30	33	37	40	47	50	54	57	61	64
'F-4'	125	14	4½	13	16	19	24	27	30	33	37	43	46	49	52	55	58
	250	14	4½	14	18	22	28	32	36	40	44	51	55	59	63	67	71
'F-5'	125	12		15+	22+	25+	31+	35+	39△	42△	45△	50△	53△	56△	59△	62△	66△
	250	12		16+	20+	23+	30+	34+	37+	41+	44+	51+	55+	58+	63△	66△	70△
	250	14		17+	21+	25+	32+	36+	35+	38+	41+	47+	50+	53+	58+	61△	64△
'F-6'	125	14		15+	19+	22+	28+	31+	40+	44+	48+	55+	59+	63+	68+	72△	76△

Plans.—Except in the case of large office buildings, hotels, street lighting, and other large undertakings, detailed plans cannot show much more than location of outlets and most of the information is gathered from specifications. In large installations it is customary to designate sizes of conduit as well as the wires. In making the installation according to such plans the work is often subdivided, separate plans being given to different workmen or groups of workmen. If each group is allowed to finish its particular installation a very reliable check on the labor performed by each man or group is obtained.

Small plans are usually drawn to a scale of $\frac{1}{4}$ inch per foot; for large plans the scale is often $\frac{1}{8}$ inch, or even less. Details are drawn to a larger scale and sometimes even full size.

Power.—This term expresses merely the rate of doing work. In order to obtain the quantity, it must be multiplied by time. Power is measured in watts and is usually expressed in watt hours, kilowatt hours, or horsepower hours, but any other length of time may be chosen.

Preservation of Wood.—This is effected by impregnating the timber with some sort of poison which destroys the fungi and deprives them of food. Creosote is the most used, and there are various patented substances of a similar nature. The more thoroughly dried the timber is at time of application, the more it will absorb. Ordinarily the preservative is applied with a brush, but it is also applied under pressure, the whole pole or tie being submerged in a tank full of the impregnating material, to which pressure can be applied.

Printing.—Printing presses are usually equipped with reversible and variable speed motors. For the larger sizes several motors are used. All of these are preferably fitted with remote control switches which enable the operator to govern the press from various points on and about it. Time is a very important consideration about large presses and the very best illumination should be supplied. On many presses from 10 to 20 lights are permanently installed so as to be ready at a moment's notice and obviate the necessity of using portable lamps. Such lights also assist in watching the mechanism while at work. Flexible conduit is serviceable, but it should be lead covered to guard against machine oil, which dissolves rubber.

Composing Rooms.—A good general illumination is advisable in composing rooms, but there must be local illumination with it in certain places. In some composing rooms the work is of such a nature that it is advisable to fit each stand with a foot or arm switch by which a compositor can turn the light on or off without using his hands.

Pumping.—One cubic foot of water weighs approximately 62.5 pounds and contains about 7.5 gallons. One gallon weighs 8.33 pounds and contains 231 cubic inches. If the head of a column of water is expressed in feet and the pressure at the foot of the column in pounds per square inch, then

$\text{Head} = 2.31 \times \text{pressure}$

$\text{Pressure} = \text{head} \div 2.31$, which equals $0.434 \times \text{head}$, and this is independent of size of column.

The H. P. required to deliver a certain quantity of water to a certain height is directly proportional to the product of the two if the so-called "friction head" is added to the actual height of lift. The friction head for various sizes of pipe and rate of flow through them is given in Table LXII. This friction head varies with the square of the velocity of the liquid, with the distance it flows, and with the conditions affecting its freedom of movement. Elbows, bends, burs, etc., increase it. The enormous losses in pressure which take place when a small pipe is used for the delivery of a large amount of water can be seen from the table. The efficiency of centrifugal pumps is sometimes as low as 35 per cent, and that of rotary and plunger pumps ranges from 60 to 80.

Table LXII shows the resultant net efficiency of motors and pumps of various efficiencies working together.

From Table LXII we can take the number of cubic feet, pounds and gallons which one horsepower will lift to a height of one foot, the machinery having a net efficiency as given.

Rule for Determining Horsepower Needed.—Add to the actual head in feet the friction head as found in Table LXII and multiply this by the number of cu. ft., lbs. or gals., as the case may be. Next divide this sum by the number found in same table under the efficiency of the combination to be used; combined motor and pump efficiency.

Table showing number of cu. ft., lbs., or gals. which can be raised 1 foot per minute by 1 H.P. at efficiencies given.

TABLE LXII

Combined Motor and Pump Efficiency.

	64	60	56	52	48	46	43	40
Cu. Ft.	338	316	296	275	253	243	227	211
Lbs..	21,120	19,800	18,480	17,160	15,840	15,180	14,190	13,200
Gals..	2,535	2,370	2,220	2,062	1,897	1,822	1,702	1,582

Combined Motor and Pump Efficiency.

	38	36	34	32	30	28	26	24
Cu. Ft.	200	190	180	169	158	148	137	127
Lbs..	12,500	11,880	11,220	10,560	9,900	9,240	8,580	7,920
Gals.	1.500	1,425	1,350	1,267	1,185	1,110	1,027	952

TABLE LXII—Continued

Friction head per hundred feet of pipe of inside diameters given. Condensed from Westinghouse Electric & Mfg. Co. table.

			Inside Diameters of Pipes.						
Cu. Ft.	Lbs.	Gals.	¾″	1″	1¼″	1½″	2″	2½″	3″
0.6	37	5	7.59	1.93	0.71	0.27			
1.1	75	10	29.9	10.26	2.41	1.08			
1.6	112	15	66.01	16.05	5.47	2.23			
2.4	150	20	115.92	28.29	9.36	3.81			
3.0	187	25		43.70	14.72	5.02	1.18		
3.4	225	30		63.25	21.04	8.62	2.09		
4.2	263	35		85.10	28.52	11.61	2.76		
4.8	300	40		110.40	37.03	14.99	3.68	1.19	
5.2	338	45			46.46	18.74	4.60	1.49	
6.0	375	50			57.27	23.00	5.61	1.86	0.80
9.0	562	75			129.09	51.52	12.23	4.14	1.70
12.0	750	100				89.70	21.75	7.36	3.01
15.0	937	125					34.27	11.24	4.57
18.0	1,125	150					48.76	16.10	6.55
21.0	1,312	175					64.63	21.75	8.85
24.0	1,500	200					86.25	28.68	11.54
30.0	1,875	250						45.21	17.84
36.0	2,250	300						64.53	25.76
42.0	2,625	350							34.96
48.0	3,000	400							44.85
60.0	3,375	450							57.50
75.0	3,750	500							70.84

Table for determining combined efficiency of pump and motor.

Theoretical and practical suction limit.

TABLE LXII—Continued

Motor Efficiency	Pump Efficiency						Altitude	Theoretical	Practical
							Sea level	33.95	25
	75	65	50	45	40	35	1,320 ft. above	32.38	24
70	52	46	35	32	28	24	2,640 ft. above	30.79	23
75	56	48	38	34	30	26	3,960 ft. above	29.24	21
80	60	52	40	36	32	28	5,280 ft. above	27.76	20
85	64	56	43	38	34	30	10,560 ft. above	22.82	17

Reactive Coils.—This term describes coils introduced into a circuit to produce a certain reactance. They are also known as reactors. They are used to limit short-circuiting currents. Reactors are usually designed for a high temperature rise, and should be treated as sources of heat. When used in connection with lightning arresters they are often spoken of as "choke coils."

Rectifiers.—The mercury-arc rectifier is the one most used for arc lamp operation and is very common in motion picture theaters. Other types are the electrolytic and rotary. The mercury-arc type is also much used for storage battery work in connection with automobile charging. It is usually fed through autotransformers, but sometimes through constant current transformers, and then delivers a constant current. Most rectifiers are operated on single-phase circuits, but they can be arranged for two-phase and three-phase circuits and operate more advantageously. They may also be operated in parallel. Rectifiers designed for 40 to 50 amperes usually have glass tubes, but if larger capacities are required, the tubes are metallic. The power factor is ordinarily about 0.90. The drop in voltage is always about the same, hence the lower the voltage the lower the efficiency. The average efficiency is about 75 or 80 per cent. If the vacuum is good, shaking the tube will cause a metallic sound; if tube is dirty on inside, the vacuum is usually poor.

Reciprocals of Numbers.—The reciprocal of any number is equal to 1 divided by that number. The reciprocal gives by multiplication what the number would give by division, and vice versa. The principle involved is made use of in many formulae and is much used to facilitate calculations. The reciprocals have been given only for whole numbers and up to the number 100. The reciprocal of any number larger or smaller may, however, easily be found by adding a decimal point to the reciprocal for each number added to its integer or subtracting one for each integer taken from the whole number. The larger the number, the more decimal places the reciprocal will contain. The smaller the number, the greater will be its reciprocal.

Thus the reciprocal of	7.3	0.13698
	73	0.013698
	730	0.0013698
	7300	0.00013698
	0.73	1.3698
	0.073	13.698
	0.0073	136.98

To find the reciprocal of a number trace along until this number is found. Thus the reciprocal of 21.7 is 0.04608.

To find the number pertaining to any reciprocal find the reciprocal and take the number. Thus the whole number of which 0.2710 is the reciprocal is 36.9.

TABLE LXIII

Reciprocals of Numbers

0	0	1	2	3	4	5	6	7	8	9
0.....	.0	10.000	5.000	3.333	2.500	2.000	1.667	1.4286	1.250	1.111
1.....	1.000	.90909	.83333	.76923	.71429	.66667	.62500	.58823	.55555	.52631
2.....	.50000	.47619	.45456	.43478	.41666	.40000	.38461	.37037	.35714	.34483
3.....	.33333	.32258	.31250	.30303	.29412	.28571	.27778	.27027	.26316	.25641
4.....	.25000	.24390	.23809	.23256	.22727	.22222	.21739	.21276	.20833	.20408
5.....	.20000	.19608	.19231	.18868	.18518	.18182	.17857	.17544	.17214	.16949
6.....	.16667	.16393	.16129	.15873	.15625	.15384	.15151	.14925	.14706	.14493
7.....	.14285	.14084	.13889	.13699	.13513	.13333	.13158	.12987	.12820	.12658
8.....	.12500	.12345	.12195	.12048	.11904	.11764	.11628	.11494	.11364	.11236
9.....	.11111	.10989	.10869	.10753	.10638	.10526	.10417	.10309	.10204	.10101
10.....	.10000	.09901	.09804	.09709	.09615	.09524	.09434	.09346	.09259	.09174
11.....	.09090	.09009	.08929	.08849	.08772	.08696	.08621	.08547	.08475	.08403
12.....	.08333	.08264	.08196	.08130	.08064	.08000	.07937	.07874	.07812	.07752
13.....	.07692	.07633	.07576	.07519	.07463	.07407	.07353	.07299	.07246	.07194
14.....	.07143	.07092	.07042	.06993	.06944	.06896	.06849	.06803	.06757	.06711
15.....	.06667	.06622	.06579	.06536	.06493	.06452	.06410	.06369	.06329	.06289
16.....	.06250	.06211	.06173	.06135	.060976	.06060	.06024	.05988	.05952	.05917
17.....	.05882	.05848	.05814	.05780	.057471	.05714	.05682	.05650	.05618	.05587
18.....	.05556	.05525	.05494	.05464	.054348	.05404	.05376	.05348	.05319	.05291
19.....	.05263	.05236	.05208	.05181	.05154	.05128	.05102	.05076	.05050	.05025
20.....	.05000	.04975	.04950	.04926	.04902	.04878	.04854	.04831	.04808	.04785
21.....	.04762	.04739	.04717	.04695	.04673	.04651	.04630	.04608	.04587	.04566
22.....	.04545	.04525	.04504	.04484	.04464	.04444	.04425	.04405	.04386	.04367
23.....	.04348	.04329	.04310	.04292	.04273	.04255	.04237	.04219	.04202	.04184
24.....	.04167	.04149	.04132	.04115	.04098	.04081	.04065	.04049	.04932	.04016

TABLE LXIII—Continued

Reciprocals of Numbers

0	0	1	2	3	4	5	6	7	8	9
25.....	.04000	.03984	.03968	.03953	.03937	.03922	.03906	.03891	.03876	.03861
26.....	.03846	.03831	.03817	.03802	.03788	.03773	.03759	.03745	.03731	.03717
27.....	.03704	.03690	.03676	.03663	.03650	.03636	.03623	.03610	.03597	.03584
28.....	.03571	.03559	.03546	.03534	.03521	.03509	.03496	.03484	.03472	.03460
29.....	.03448	.03436	.03425	.03413	.03401	.03389	.03378	.03367	.03356	.03344
30.....	.03333	.03322	.03311	.03300	.03289	.03279	.03268	.03257	.03247	.03236
31.....	.03226	.03215	.03205	.03195	.03185	.03175	.03165	.03155	.03145	.03135
32.....	.03125	.03115	.03105	.03096	.03086	.03077	.03067	.03058	.03049	.03039
33.....	.03030	.03021	.03012	.03003	.02994	.02985	.02976	.02967	.02959	.02950
34.....	.02941	.02933	.02924	.02915	.02907	.02899	.02890	.02881	.02874	.02865
35.....	.02857	.02849	.02841	.02833	.02825	.02817	.02809	.02801	.02793	.02785
36.....	.02778	.02770	.02762	.02755	.02747	.02740	.02732	.02725	.02717	.02710
37.....	.02703	.02695	.02688	.02681	.02674	.02667	.02660	.02652	.02645	.02638
38.....	.02632	.02625	.02618	.02611	.02604	.02597	.02591	.02584	.02577	.02571
39.....	.02564	.02557	.02551	.02544	.02538	.02532	.02525	.02519	.02513	.02506
40.....	.02500	.02494	.02488	.02481	.02475	.02469	.02463	.02457	.02451	.02445
41.....	.02439	.02433	.02427	.02421	.02415	.02410	.02404	.02398	.02392	.02387
42.....	.02381	.02375	.02369	.02364	.02358	.02353	.02347	.02342	.02336	.02331
43.....	.02326	.02320	.02315	.02309	.02304	.02299	.02294	.02288	.02283	.02278
44.....	.02273	.02268	.02262	.02257	.02252	.02247	.02242	.02237	.02232	.02227
45.....	.02222	.02217	.02212	.02207	.02203	.02198	.02193	.02188	.02183	.02179
46.....	.02174	.02169	.02164	.02160	.02155	.02150	.02146	.02141	.02137	.02132
47.....	.02113	.02123	.02119	.02114	.02110	.02105	.02100	.02096	.02092	.02087
48.....	.02083	.02079	.02075	.02070	.02066	.02062	.02058	.02053	.02049	.02045
49.....	.02041	.02037	.02032	.02028	.02024	.02020	.02016	.02012	.02008	.02004

TABLE LXIII—Continued

Reciprocals of Numbers

0	0	1	2	3	4	5	6	7	8	9
50.....	.02000	.01996	.01992	.01988	.01984	.01980	.01976	.01972	.01968	.01965
51.....	.01961	.01956	.01953	.01949	.01945	.01942	.01938	.01934	.01930	.01927
52.....	.01923	.01919	.01916	.01912	.01908	.01905	.01901	.01897	.01894	.01890
53.....	.01887	.01883	.01880	.01876	.01873	.01869	.01866	.01862	.01859	.01855
54.....	.01852	.01848	.01845	.01842	.01838	.01835	.01832	.01828	.01825	.01821
55.....	.01818	.01815	.01812	.01808	.01805	.01802	.01798	.01795	.01792	.01789
56.....	.01786	.01782	.01779	.01777	.01773	.01770	.01767	.01764	.01761	.01757
57.....	.01754	.01751	.01748	.01745	.01742	.01739	.01736	.01733	.01730	.01727
58.....	.01724	.01721	.01718	.01715	.01712	.01709	.01706	.01704	.01700	.01698
59.....	.01695	.01692	.01689	.01686	.01683	.01681	.01678	.01675	.01672	.01669
60.....	.01667	.01664	.01661	.01658	.01656	.01653	.01650	.01647	.01645	.01642
61.....	.01639	.01637	.01634	.01631	.01628	.01626	.01623	.01621	.01618	.01615
62.....	.01613	.01610	.01607	.01605	.01603	.01600	.01597	.01595	.01592	.01590
63.....	.01587	.01585	.01582	.01580	.01577	.01575	.01572	.01570	.01567	.01565
64.....	.01562	.01560	.01558	.01565	.01553	.01550	.01548	.01546	.01543	.01541
65.....	.01538	.01536	.01534	.01531	.01529	.01527	.01524	.01522	.01520	.01517
66.....	.01515	.01513	.01511	.01508	.01506	.01504	.01501	.01499	.01497	.01495
67.....	.01492	.01490	.01488	.01485	.01484	.01481	.01479	.01477	.01475	.01473
68.....	.01471	.01468	.01466	.01464	.01462	.01460	.01458	.01456	.01453	.01451
69.....	.01449	.01447	.01445	.01443	.01441	.01439	.01437	.01435	.01433	.01431
70.....	.01429	.01426	.01424	.01422	.01420	.01418	.01416	.01414	.01412	.01410
71.....	.01408	.01406	.01404	.01402	.01400	.01399	.01397	.01395	.01393	.01391
72.....	.01389	.01387	.01385	.01383	.01381	.01379	.01377	.01375	.01374	.01372
73.....	.01370	.01368	.01366	.01364	.01362	.01360	.01359	.01357	.01355	.01353
74.....	.01351	.01349	.01347	.01346	.01344	.01342	.01340	.01339	.01337	.01335

TABLE LXIII—Continued
Reciprocals of Numbers

0	0	1	2	3	4	5	6	7	8	9
75.....	.01333	.01332	.01330	.01328	.01326	.01324	.01323	.01321	.01319	.01317
76.....	.01316	.01314	.01312	.01310	.01309	.01307	.01305	.01304	.01302	.01300
77.....	.01299	.01297	.01295	.01293	.01292	.01290	.01289	.01287	.01285	.01284
78.....	.01282	.01280	.01279	.01277	.01275	.01274	.01272	.01271	.01269	.01267
79.....	.01266	.01264	.01263	.01261	.01259	.01258	.01256	.01255	.01253	.01252
80.....	.01250	.01248	.01247	.01245	.01244	.01242	.01241	.01239	.01238	.01236
81.....	.01234	.01233	.01231	.01230	.01228	.01227	.01225	.01224	.01222	.01221
82.....	.01219	.01218	.01216	.01215	.01214	.01212	.01211	.01209	.01208	.01206
83.....	.01205	.01203	.01202	.01200	.01199	.01198	.01196	.01195	.01193	.01192
84.....	.01190	.01189	.01188	.01186	.01185	.01183	.01182	.01181	.01179	.01178
85.....	.01176	.01175	.01174	.01172	.01171	.01170	.01168	.01167	.01165	.01164
86.....	.01163	.01161	.01160	.01159	.01157	.01156	.01155	.01153	.01152	.01151
87.....	.01149	.01148	.01147	.01146	.01144	.01143	.01142	.01140	.01139	.01138
88.....	.01136	.01135	.01134	.01132	.01131	.01130	.01129	.01127	.01126	.01125
89.....	.01124	.01122	.01121	.01120	.01119	.01117	.01116	.01115	.01114	.01112
90.....	.01111	.01110	.01109	.01107	.01106	.01105	.01104	.01102	.01101	.01100
91.....	.01099	.01098	.01096	.01095	.01094	.01093	.01092	.01090	.01089	.01088
92.....	.01087	.01086	.01085	.01083	.01082	.01081	.01080	.01079	.01078	.01076
93.....	.01075	.01074	.01073	.01072	.01071	.01069	.01068	.01067	.01066	.01065
94.....	.01064	.01063	.01062	.01060	.01059	.01058	.01057	.01056	.01055	.01054
95.....	.01053	.01051	.01050	.01049	.01048	.01047	.01046	.01045	.01044	.01043
96.....	.01042	.01041	.01039	.01038	.01037	.01036	.01035	.01034	.01033	.01032
97.....	.01031	.01030	.01028	.01028	.01027	.01026	.01025	.01023	.01022	.01021
98.....	.01020	.01019	.01018	.01017	.01016	.01015	.01014	.01013	.01012	.01011
99.....	.01010	.01009	.01008	.01007	.01006	.01005	.01004	.01003	.01002	.01001
100.....	.01000	.00999	.00998	.00997	.00996	.00995	.00994	.00993	.00992	.00991

Reflectors.—Perfect prismatic glass makes the very best reflector. The following table gives approximately the percentage of light reflected by various materials:

TABLE LXIV

	Per Cent Light Reflected
Well polished silver	92
Silvered mirror	70 to 90
Highly polished brass	70 to 85
Mirror backed with amalgam	70
Well polished copper	60 to 70
Well polished steel	60
Burnished copper	40 to 50
Chrome yellow paper	60
Orange paper	50
Yellow paper or painted wall	40
Pink paper	35
Blue wall paper	25
Emerald green paper	18
Dark brown paper	13
Vermilion paper	12
Bluish green paper	12
Cobalt blue paper	12
Deep chocolate colored paper	4
Black cloth	1.2
Black velvet	0.4

Refrigeration.—Refrigeration by machinery is much more reliable, effective and cleanly than that produced by the use of ice. Electric power compares favorably with steam power in large installations, but more especially so in the smaller plants. Its main advantages are: lower first cost, less space required; less attendance and operation; can be made automatic. For direct current, compound-wound motors are preferable, and where variable speed is desired, the speed control should be by means of field regulation. For alternating current, the squirrel cage type of armature may be used, but if speed control is desired, a wound armature should be provided. The latter is much preferable for automatic control. The horse-power required for refrigeration can be determined by means of the curves in Figure 17, due to Westinghouse Electric & Mfg. Co. The upper curve is for compressors of 50 H.P. and smaller; the lower curve

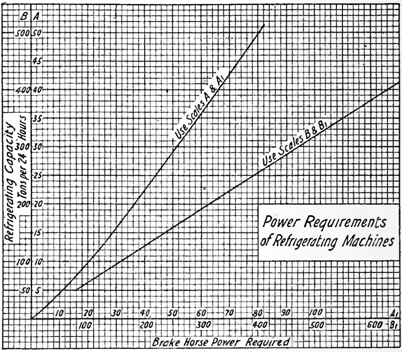


Figure 17.

for larger machines. For example: a 30-ton compressor requires a 52 H.P. motor; a 300-ton compressor requires a 470 H.P. motor. When the ice-making capacity of compressor is given, the motor H.P. required will in general be about double the figure given in the curve.

Refrigerators.—All refrigerators are at times very damp. As long as they are kept cold, ice forms, and as soon as they are empty the ice melts and all parts become wet. No very bright illumination is required, and in many of them workmen are required to get along with lanterns. Weatherproof construction is preferable to conduit in all places except where heavy coatings of ice form on the wires. This frost is scraped off from time to time, and open wires are likely to be torn loose. Porcelain sockets break easily and should not be used. Circuits should not enter or leave too close to entrances; the meeting of the cold and warm air at such places cause the deposit of much moisture. Lamps are usually placed only in runways, and in large refrigerators the circuits are apt to be long. In some of the large refrigerators watchmen are regularly making rounds; in such places three-way switches at doors are useful. Keep cut-outs and switches outside of damp rooms and avoid the use of the common fiber-lined brass shell socket.

Residence Wiring.—As a general rule a total wattage capacity of about $\frac{1}{2}$ watt per sq. ft. should be provided for the whole building, including cellar and attic. If these latter are not to be illuminated, 1 watt per sq. ft. will be ample for the balance of house. The best place for service switch and meters is in the basement. Select a location easily accessible to meter readers. If not too much economy is necessary, let two circuits enter each room that contains more than one outlet. Place all switches at doors where room is most likely to be entered, and if there are two entrances two-way switches will be a great convenience. In some elaborate residences circuits are sometimes so arranged that lights in all rooms may be thrown on by a master switch, even if turned off in rooms. This is useful as burglar protection and also in case of fires. A measure of protection against intruders can be obtained by placing lights above doors so that an intruder must show himself in the light before he can enter a room. The bright light will prevent him from seeing what is inside the door.

Attics.—No part of residence requires light more than the attic. The use of matches is exceedingly dangerous in such places. Run wires where they will not be molested.

Bathroom.—A center light in a bathroom is an abomination. Place a light at each side of shaving mirror if practicable, but locate them so that person in tub cannot reach socket. An outlet for heater will be a great convenience. If possible place or shade lamps so they will not cast shadows of persons on window. Place a switch at door. If expense is no object, inverted lighting will be very useful.

Basement.—The wiring of the basement depends upon the use to which it may be put. Two or three-way switches, one at each entrance, will be very convenient. Plenty of light will be an inducement for servants to keep basement cleaner than the average. Provisions should be made for motors to operate ice cream freezers, washing machines, mangels, or vacuum cleaning motors. It is much preferable to place the motor for this purpose in the basement rather than to bother with portable machines. Fan motor outlets will assist in drying clothes. If part of basement is used as laundry and likely to be damp, use weatherproof construction and avoid placing sockets where one standing on wet floor will be likely to touch them. Provide outlet for flatiron.

Bedrooms.—A center fixture should never be installed in a bedroom unless it is intended also as a sort of living room. Lights should be arranged to suit the various positions in which a bed can advantageously be placed, and so that one can use the light for reading in bed or make easy connections for heating pads. Special outlets along baseboard for flatiron heaters, sewing machine motors, etc., will be found very useful. One light on each side of dresser mirror is a great convenience. Avoid placing lights so that they will cast shadows of occupants on windows. For protection against burglars, a switch by which lights in other rooms may be turned on is very effectual. See "Modern Wiring Diagrams and Descriptions" for circuits. Such a switch might be placed in each bedroom. Inverted lighting is very useful if only one light can be installed and if ceilings are light enough.

Cellars.—A cellar is usually damp, and weatherproof construction should be used. Keep switch outside at door.

Closets.—The use of matches in closets is very dangerous and will be entirely eliminated by good illumination. Place a light at ceiling and control by switch if closet is small. In large closets a pendant light may be advisable, but there is usually too much chance of clothing coming in contact with it and the cord.

Dining Rooms.—Beam lighting is used to some extent in dining rooms. Special illumination of buffet and china closet is also often practiced. Small lamps are used for the latter and should be located to show off cut glass, etc., to the best advantage. It is well to study the effect of such lights carefully before finally locating them. To show off silverware, fine table linen, etc., to the best advantage it is advisable to concentrate a strong light upon the table and leave balance of room somewhat dark. Side outlets for fan motors, and floor sockets for chafing dishes, are very useful. The low hanging fixtures often seen in dining rooms should not be recommended. They will soon become obnoxious.

Halls.—Halls ordinarily require only a perfunctory illumination unless a showy appearance is desired. These lights are often combined with stair lights and fitted with two or three-way switches. Place switch for hall light close to the door.

Ice Boxes or Chambers.—A light placed opposite door will be very useful.

Kitchen.—If kitchen walls are of light color, a center light will give good illumination. With dark colored walls a light should be placed over sink and near range, but a little to one side, so as to avoid the cooking fumes as much as possible. A small motor to drive steam out will be of great use. Ozonators to destroy odors will also be much appreciated. As ironing is often done in the kitchen, an outlet for irons should always be provided. If electric cooking is indulged in this must be provided for.

Laundry.—There should be a light directly over wash tubs and another arranged to be directly over ironing board. If clothes are dried in laundry a fan or ventilating motor will be of great service. Provisions should be made for washing machine motors, mangels and flatiron. Locate sockets so persons will not be likely to touch them while standing on wet floor.

Lavatory.—One light controlled by door-switch is very useful here.

Library.—Inverted lighting of sufficient c.p. to allow the reading of titles of books in cases is the best means of illumination here. In addition to this there should be outlets for reading lamps and brackets conveniently located on walls to give a brighter light for those that need it. A direct light with strong reflector under inverted light is useful for reading purposes.

Nursery.—The lighting of the nursery should be ample, but precautions should be taken to guard against the possibility of outlets being short circuited by children. Avoid placing sockets within easy reach. Electric toys should be confined to battery current, or a low-voltage transformer, to which children have no access, might be used. The lighting voltage is too dangerous for them. Control all lights by switches and keep them high.

Pantry.—Provide bright illumination to show up dust and dirt and induce cleanliness.

Parlor.—The illumination of the parlor is usually effected by means of quite elaborate chandeliers. Outlets for piano and reading lamps should be provided. The center light does not illuminate pictures very well, and for this reason inverted lighting is often useful. Really good pictures, however, deserve special illumination.

Porch.—A light should be arranged close to main entrance and so located as to reveal features of persons applying for admission without making the party inside of house visible. The light should be controlled by a switch inside and should be out of reach from the outside. If porch is to be enclosed, other outlets for lamps or fan motors will be useful, but they should be arranged at ceiling so as to avoid moisture. Use no fiber lined sockets outside.

Resuscitation from Electric Shock.—Rules recommended by commission on resuscitation from electric shock, representing The American Medical Association, The National Electric Light Association, The American Institute of Electrical Engineers. Issued and copyrighted by National Electric Light Association. Reprinted by permission.

Follow these instructions even if victim appears dead.

I. Immediately Break the Circuit.—With a single quick motion, free the victim from the current. Use any *dry non-conductor* (clothing, rope, board) to move either the victim or the wire. Beware of using metal or any moist material. While freeing the victim from the live conductor have every effort also made to shut off the current quickly.

II. Instantly Attend to the Victim's Breathing.—(1) As soon as the victim is clear of the conductor, rapidly feel with your finger in his mouth and throat and remove any foreign body (tobacco, false teeth, etc.). Then *begin artificial respiration at once.* Do not stop to loosen the victim's clothing now; *every moment of delay is serious.* Proceed as follows:

a. Lay the subject on his belly, with arms extended as straightforward as possible and with face to one side, so that nose and mouth are free for breathing.

Figure 18. Inspiration—Pressure Off.

See Figure 18. Let an assistant draw forward the subject's tongue.

b. Kneel straddling the subject's thighs and facing his head; rest the palms of your hands on the loins (on the muscles of the small of the back), with fingers spread over the lowest ribs, as in Figure 18.

c. With arms held straight, swing forward slowly so that the weight of your body is gradually, but *not violently,* brought to bear upon the subject. See Figure 19. This act should take from two to three seconds.

Immediately swing backward so as to remove the pressure, thus returning to the position shown in Figure 18.

d. Repeat deliberately twelve to fifteen times a minute the swinging forward and back—a complete respiration in four or five seconds.

e. As soon as this artificial respiration has been started, and while it is being continued, an assistant

Figure 19. Expiration—Pressure On.

should loosen any tight clothing about the subject's neck, chest or waist.

(2) Continue the artificial respiration (if necessary, at least an hour), *without interruption,* until natural breathing is restored, or until a physician arrives. If natural breathing stops after being restored, use artificial respiration again.

(3) *Do not give any liquid by mouth until the subject is fully conscious.*

(4) Give the subject fresh air, but keep him warm.

III. Send for Nearest Doctor as Soon as Accident Is Discovered.

Ropes.—

TABLE LXV

Standard Iron Hoisting Rope, 6 Strands—19 Wires to the Strand—1 Hemp Rope. American Steel & Wire Co.

Diameter in Inches	Circumference in Inches	Approximate Weight Per Ft. in Pounds	Approximate Strength in Tons of 2,000 Lbs.	Proper Working Load in Tons	Diameter of Drum or Sheave Advised in Feet
$2\frac{3}{4}$	$8\frac{5}{8}$	11.95	111.0	22.2	17
$2\frac{1}{2}$	$7\frac{7}{8}$	9.85	92.0	18.4	15
$2\frac{1}{4}$	$7\frac{1}{8}$	8.00	72.0	14.4	14
2	$6\frac{1}{4}$	6.30	55.0	11.0	12
$1\frac{7}{8}$	$5\frac{3}{4}$	5.55	50.0	10.0	12
$1\frac{3}{4}$	$5\frac{1}{2}$	4.85	44.0	8.8	11
$1\frac{5}{8}$	5	4.15	38.0	7.6	10
$1\frac{1}{2}$	$4\frac{3}{4}$	3.55	33.0	6.6	9
$1\frac{3}{8}$	$4\frac{1}{4}$	3.00	28.0	5.6	8.5
$1\frac{1}{4}$	4	2.45	22.8	4.56	7.5
$1\frac{1}{8}$	$3\frac{1}{2}$	2.00	18.6	3.72	7.0
1	3	1.58	14.5	2.90	6.0
$\frac{7}{8}$	$2\frac{3}{4}$	1.20	11.8	2.36	5.5
$\frac{3}{4}$	$2\frac{1}{4}$	0.89	8.5	1.70	4.5
$\frac{5}{8}$	2	0.62	6.0	1.20	4.0
$\frac{9}{16}$	$1\frac{3}{4}$	0.50	4.7	0.94	3.5
$\frac{1}{2}$	$1\frac{1}{2}$	0.39	3.9	0.78	3.0
$\frac{7}{16}$	$1\frac{1}{4}$	0.30	2.9	0.58	2.75
$\frac{3}{8}$	$1\frac{1}{8}$	0.22	2.4	0.48	2.25
$\frac{5}{16}$	1	0.15	1.5	0.30	2.00
$\frac{1}{4}$	$\frac{3}{4}$	0.10	1.1	0.22	1.50

For better grades of rope smaller sheaves are advised.

Manila Rope.

Diameter	Circumference	Ultimate Strength	Pounds Per Foot	Diameter	Circumference	Ultimate Strength	Pounds Per Foot
$\frac{1}{2}$	$1\frac{1}{2}$	2,000	0.09	$1\frac{3}{8}$	$4\frac{1}{8}$	13,500	0.65
$\frac{5}{8}$	2	3,250	0.14	$1\frac{1}{2}$	$4\frac{1}{2}$	15,000	0.77
$\frac{3}{4}$	$2\frac{1}{4}$	4,000	0.20	$1\frac{5}{8}$	$4\frac{7}{8}$	18,200	0.90
$\frac{7}{8}$	$2\frac{5}{8}$	6,000	0.27	$1\frac{3}{4}$	$5\frac{1}{4}$	21,700	1.05
1	3	7,000	0.35	2	6	25,000	1.40
$1\frac{1}{8}$	$3\frac{3}{8}$	9,300	0.45	$2\frac{1}{4}$	$6\frac{3}{4}$	32,000	1.75
$1\frac{1}{4}$	$3\frac{3}{4}$	10,000	0.55	$2\frac{1}{2}$	$7\frac{1}{2}$	40,000	2.15

Splicing of Manila Rope.—The successive operations for making a common or English splice in a $1\frac{3}{4}$-inch 4-strand rope is as follows:

1. Tie a piece of twine, 9 and 10, *A*, Figure 20, around the rope to be spliced, about six feet from each end. Then unlay the strands of each end back to the twine.

2. Put the ropes together and twist each corresponding pair of strands loosely, to keep them from being tangled, as shown at *A*.

3. The twine 10 is now cut, and the strand 8 unlaid and strand 7 carefully laid in its place for a distance of four and a half feet from the junction.

4. The strand 6 is next unlaid about one and a half feet and strand 5 laid in its place.

5. The ends of the cores are now cut off so they just meet.

6. Unlay strand 1 four and a half feet, laying strand 2 in its place.

7. Unlay strand 3 one and a half feet, laying in strand 4.

8. Cut all the strands off to a length of about twenty inches, for convenience in manipulation. The rope now assumes the form shown in *B*, with the meeting point of the strands three feet apart.

Each pair of strands is now successively subjected to the following operations:

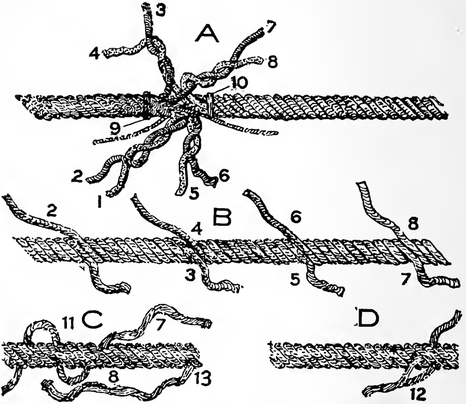


Figure 20.—Method of Splicing Ropes.

9. From the point of meeting of the strands 8 and 7 unlay each one three turns; split both the strand 8 and the strand 7 in halves, as far back as they are now unlaid, and the end of each half strand "whipped" with a small piece of twine.

10. The half of the strand 7 is now laid in three turns, and the half of 8 also laid in three turns. The half strands now meet and are tied in a simple

knot 11, *C*, making the rope at this point its original size.

11. The rope is now opened with a marlinspike, and the half strand of 7 worked around the half

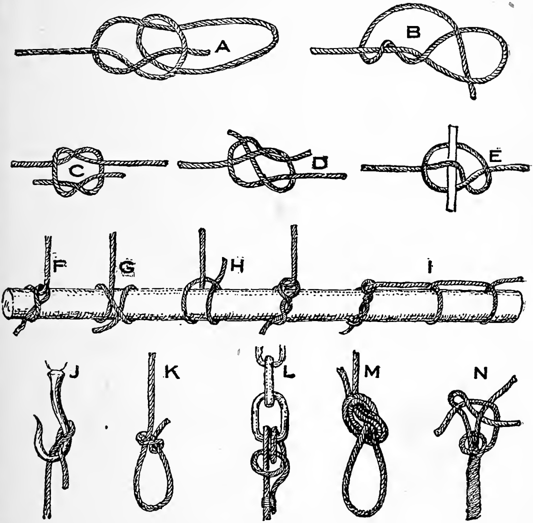


Figure 21.—Methods of Tieing Knots.

strand of 8 by passing the end of the half strand through the rope, as shown, drawn taut, and again worked around this half strand until it reaches the half strand 13 that was not laid in. This half strand 13 is now split, and the half strand 7 drawn through the opening thus made, and then tucked under the two adjacent strands, as shown in *D*.

12. The other half of the strand 8 is now wound around the other half strand 7 in the same way. After each pair of strands has been treated in this manner, the ends are cut off at 12, leaving them about four inches long. After a few days' wear they will draw into the body of the rope or wear off, so that the locality of the splice can scarcely be detected.

Figure 21 shows specimens of knots frequently used.

A, Bowline; *B,* Stevedore knot; *C,* Reef knot; *D.* Weavers knot; *E,* Boat knot; *F,* Half hitch; *G,* Timber hitch; *H,* Clove hitch; *I,* Timber and half hitch; *J,* Blackwall hitch; *K,* Common noose; *L,* Fishermen's bend; *M,* Common knot; *N,* Turks head.

Saloons.—In small saloons not much illumination is required. Where there is any pretense of importance, however, there is always some back-bar lighting, and this may often furnish the whole illumination. Special outlets for cash registers and hot water heaters should be provided. Nearly every saloon sooner or later provides a beer pump. In pretentious saloons a very elaborate illumination is often striven for. In case wine rooms, or other private places fitted with glass partitions, are to be illuminated the lights should be so placed that they will not cast shadows of occupants on glass.

Schools.—In large cities schools are often classed as assembly halls and special rules for wiring are made. There should be emergency lighting. A stereopticon outlet is a common requirement.

Screws.—Formulae for wood screws. N = number; D = diameter.

$$D = (N \times 0.01325) + 0.056$$

$$N = \frac{D - 0.056}{0.01325}$$

TABLE LXVI

Dimensions of Iron Screws (Approximate).

Trade Number	Diameter in Fractions	Nearest B. & S. Gauge	Greatest Length Obtainable
0	7/128	15	3/8
1	9/128	14	1/2
2	5/64	12	7/8
3	3/32	11	1 1/2
4	7/64	9	1 1/2
5	4/32	8	2 1/2
6	17/128	7	3
7	19/128	7	3
8	5/32	6	4
9	11/64	5	4
10	12/64	5	4
11	13/64	4	4
12	27/128	4	6
13	29/128	3	6
14	15/64	3	6
15	1/4	2	6
16	17/64	2	6
17	9/32	1	6
18	19/64	1	6

Service Entrance.—The service wires should be protected by fuses as close as possible to where they enter the building. There should be a service switch, and it and the fuses should be accessible.

Shelving.—To illuminate shelving properly is a troublesome matter. Portable lamps are essential, but these introduce an appreciable fire hazard. It is best to suspend lamps from ceiling by reinforced cord, and fit each lamp with a substantial guard. It is usually necessary to have good light close to the floor, but this can be had by keeping lamps about 6½ feet above floor. If shelves are deep and contain dark-colored materials carrying indistinct numbers, attachments to these cords will often be necessary. Where lights are not constantly in use, three-way ceiling switches will be very useful and economical. Provide each group of lamps commonly used together with its own switch.

Show Windows.—In the best form of show-window lighting the lamps are always entirely hidden. Very brilliant effects are often striven for and the gas-filled mazda lamp is in great favor. Where there is bright illumination on the street in front, even greater illumination is required within. The object is, not only to make things visible, but to attract attention, and for this purpose the very brightest and whitest light is necessary. Most show windows are lighted from the top by reflectors, but in some cases an illumination from the bottom up must also be provided. In some cases the object is to show the lights and call attention to the fact that they are there. For this purpose small lamps, well frosted, are preferable. If they are too bright they will blind people to the objects in window. In some cases 32 c. p. lamps have been thickly studded over the whole ceiling of window. Time switches are much used for show-window lighting and enable one to keep his windows illuminated for advertising purposes after the store is closed. Fan motor outlets are very useful for winter to keep windows clear of frost. Place no wires near glass where water is liable to run down.

Signs, Electric.—Signs should be wired with the two sides independent so as to enable flasher to be used. Small lamps of low intrinsic brilliancy are preferable. Letters should be glossy white and kept clean. The following table gives dimensions and numbers of sockets of stock letters made by the Federal Electric Co. of Chicago, which may serve as a general guide to present practice.

TABLE LXVII

	10 Inch Letters		14 Inch Letters		16 Inch Letters 4 Lamp High		16 Inch Letters 5 Lamp High		24 Inch Letters	
	Sockets	Width	Sockets	Width	Sockets	Width	Sockets	Width	Sockets	Width
A	8	10	8	12½	8	15½	10	15½	11	21
B	10	10	10	12½	11	15½	13	15½	13	21
C	7	10	7	12½	7	15½	8	15½	8	21
D	8	10	8	12½	9	15½	11	15½	11	21
E	9	10	9	12½	9	15½	10	15½	13	21
F	7	10	7	12½	7	15½	8	15½	10	21
G	8	10	8	12½	8	15½	9	15½	11	21
H	9	10	9	12½	9	15½	11	15½	12	21
I	4	5½	4	6	4	8	5	8	5	9
J	6	10	6	12½	6	15½	7	15½	7	21
K	8	10	8	12½	9	15½	11	15½	11	21
L	6	10	6	12½	6	15½	7	15½	8	21
M	13	12½	13	15½	13	19½	15	19½	17	25
N	10	10	10	15½	10	15½	13	15½	13	21
O	8	10	8	15½	9	15½	10	15½	10	21
P	8	10	8	15½	8	15½	10	15½	10	21
Q	9	10	10	15½	9	15½	10	15½	11	21
R	10	10	10	15½	10	15½	12	15½	12	21
S	8	10	8	15½	8	15½	10	15½	10	21
T	6	10	6	15½	6	15½	7	15½	8	21
U	8	10	8	15½	9	15½	10	15½	10	21
V	7	10	7	15½	7	15½	9	15½	9	21
W	12	12½	12	15½	13	19½	15	19½	15	25
X	8	10	8	15½	9	15½	9	15½	9	21
Y	6	10	6	15½	6	15½	7	15½	8	21
Z	8	10	8	15½	8	15½	9	15½	11	21
&	8	10	8	15½	9	15½	9	15½	10	21
1	4	10	4	15½	4	15½			5	21
2	9	10	8	15½	8	15½			11	21
3	9	10	7	15½	7	15½			9	21
4	7	10	7	15½	7	15½			11	21
5	10	10	10	15½	10	15½			12	21
6	9	10	8	15½	9	15½			11	21
7	6	10	6	15½	6	15½			8	21
8	11	10	11	15½	8	15½			10	21
9	9	10	8	15½	9	15½			11	21
$	8	10	8	15½	8	15½			8	21
				15½		15½				

The supporting cable is usually attached to the electric sign somewhat back of its outer end, and it may be assumed that the cable carries about 60 per cent of the weight of sign. With this assumption and using a safety factor of 5, the strength of the cables necessary to support it can be found by the formula:

$$S = 5 \times .60 \times W \frac{\sqrt{H^2 + D^2}}{H}$$

where W = weight of sign; H = height of attachment to wall above sign, and D = the distance from attachment on sign to a point vertically under sign support.

Table LXVIII is calculated according to this formula (omitting W), and to find the proper cable to support a given sign it is but necessary to multiply number found at intersection of line pertaining to height of support and that pertaining to distance of sign attachment from wall, by the weight of sign. The result will give the breaking strain of the necessary cable.

TABLE LXVIII

Supports for Weight of Sign.

Distance from Wall to Attachment on Sign in Feet	Height of Cable Fastening Above Sign in Feet										
	3	4	5	6	8	10	12	14	16	18	20
4	5	4	4	3.6	3.4	3.2	3.0	3	3	3	3
5	6	5	4.2	3.7	3.5	3.3	3.2	3	3	3	3
6	7	5.4	5.0	4.2	3.8	3.5	3.4	3.2	3	3	3
7	8	6.0	5.1	4.7	4.0	3.7	3.5	3.4	3.3	3	3
8	8.6	6.8	5.7	5.0	4.2	4.0	3.6	3.5	3.4	3.3	3
10	10.5	8.1	6.9	6.0	5.0	4.4	3.9	3.8	3.6	3.4	3.3
12	12.4	9.4	7.8	6.7	5.4	4.6	4.3	4.0	3.7	3.5	3.4
14	14.6	11.1	9.0	7.8	6.0	5.2	4.8	4.1	4.0	3.9	3.7

SIDE GUYS FOR SIGNS

The wind pressure on the ordinary sign must be calculated on the basis of 20 lbs. per square foot and requires much better supports to withstand it than are necessary to support the weight of sign, although they are never so provided.

The table below has been calculated according to the same general formula as the one above. To find the proper size of cable for side guys, multiply the number of square feet in sign by number found where lines pertaining to the two fastenings of side guys cross.

TABLE LXIX

Distance of Attachment on Sign from Wall	Distance of Guy Attachment on Wall from Sign in Feet.									
	3	4	5	6	7	8	10	12	14	16
2	17	17	16	15	15	14	14	14	14	14
3	21	18	18	17	16	15	14	14	14	14
4	24	20	18	17	16	16	15	15	14	14
5	27	22	20	19	18	17	16	16	15	14
6	31	25	22	20	19	18	17	16	15	15
7	34	28	24	22	20	19	18	17	16	15
8	38	32	27	24	21	19	18	17	17	16
9	44	35	29	26	22	21	19	18	18	17
10	48	38	32	28	24	23	20	19	18	17
12	57	45	37	33	27	25	22	21	19	18

For signs hung at corners the distance of guy attachment on wall must be taken as the point at right angles to sign where the guy would strike wall if it were at right angles to sign.

TABLE LXX

Table showing approximate strength in pounds of Standard Steel Strand—American Steel & Wire Co.

Diameter in Inches	Approximate Strength	Diameter in Inches	Approximate Strength
$\frac{1}{2}$	8,500 lbs.	$\frac{7}{32}$	1,800 lbs.
$\frac{7}{16}$	6,500 lbs.	$\frac{3}{16}$	1,400 lbs.
$\frac{3}{8}$	5,000 lbs.	$\frac{5}{32}$	900 lbs.
$\frac{5}{16}$	3,800 lbs.	$\frac{1}{8}$	500 lbs.
$\frac{1}{4}$	2,300 lbs.	$\frac{3}{32}$	400 lbs.

Cable Supports for Signs Over Streets.—Signs of this kind are usually supported from steel cables swung across street, or other open place, from the tops of buildings or suitable poles. The table below gives the stresses caused by various loads per foot evenly distributed, and also for loads suspended from center. The arrangement of sign is usually such that neither case exactly applies, so that an approximate mean of the two must be taken. The calculations are for a 100-foot span and a sag of 4 feet.

TABLE LXXI

Diameter of Cable	Wt. per Foot	Approximate Strength	Stress Caused by Cable Alone	Distributed Load Pounds	Distributed Load Stress	Load in Center Pounds	Load in Center Stress
$1\frac{3}{4}$	4.85	84,000	1,500	50	17,140	2,500	15,625
$1\frac{1}{2}$	3.55	60,000	1,109	30	10,484	1,500	9,375
$1\frac{1}{4}$	2.45	46,000	766	20	7,015	1,000	6,250
1	1.58	28,000	493	15	5,181	750	4,687
$\frac{7}{8}$	1.20	22,200	375	12	4,125	600	3,750
$\frac{3}{4}$	0.89	15,600	278	9	3,090	500	3,125

The above figures represent the maximum loads which should be suspended by such cables unless a greater sag is allowed, and do not take wind pressure into consideration. See "Side Guys."

The above figures are based on the following formulae used by American Steel and Wire Co.:

$S_1 = \frac{Wl^2}{8d}$ giving stress for evenly distributed load, and

$S_2 = \frac{Wl}{4d}$ for stress due to load in center.

S = stress on cable
W = weight per foot of cable and load if evenly distributed, or load in center
l = length of span
d = sag in feet.

To find total stress those due to cable and load must be added.

Slide Rule.—Figure 22 is an illustration of the ordinary slide rule. The numbers on the top, or *A*, scale, may be read naturally as 1, 2, 3, 4, etc., ending with the last figure 1 at the right, which would then be called 100, or these values may be considered increased or decreased to any extent by adding or prefixing the necessary number of ciphers. Thus if the 2 is called 20 or 200 the 3 would be called 30 or 300, etc. The same also holds true of the upper half of the slide, or *B* scale. The divisions between the main figures are of various dimensions, but serve only

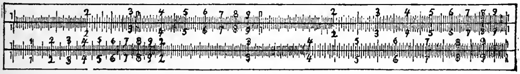


Figure 22.—The Slide Rule.

to designate fractional values of the figures. The principle of operation can easiest be made clear by examples.

Multiplication.—Set the 1 on upper half of slide under one of the factors on scale *A*. Find the other factor on the slide and directly above it you have the product. Multiply 4 by 2. Setting the slide as directed we find 8. This same setting might be used to multiply 40 by 20, or 4000 by 2 or 200. We have but to note as we go along by how much we increased the value of either of the factors, and add the corresponding number of ciphers. Different settings could also be used for the same problem. Considerable practice is necessary before one can become really proficient in these calculations.

Division.—In division the above process is reversed. Place the divisor on the slide under the dividend on scale A and the 1 on slide will be directly below the quotient.

Multiplication and Division Combined.—

$$\text{Example: } \frac{7\times3\times4}{6}$$

Set 1 on slide under 7, note product above 3; next set 1 on slide under this product and note product above 4. Now move slide back until 6 is under last product and find answer above 1.

Proportion.—By setting any number on B against any convenient number on A it can be seen that all other coinciding numbers are in the same proportion to each other. Hence any problem in direct proportion can be solved by simply setting the first term on B against the second on A; this being done, we shall find the last term directly above the third on B. Example: If 7 bushels of wheat cost $13.00, how much will 23 bushels cost? Answer, $42.71. In direct proportion all factors are either increasing or decreasing. If they are mixed it is termed Inverse Proportion. In order to solve a problem in inverse proportion we invert the slide, but continue to read A and B together. Example: If 9 men can do a piece of work in 17 days, how many days will 13 men require? Inverting the slide and setting the 9 on the left under 17 and bringing the runner over the 13 at the right at about the center of the scale, we find 11.8 as the answer.

Squaring Numbers and Extracting Square Roots.—When the slide is set even on all sides, the numbers in the scales A and B are the squares of those in C and D. Hence also those in the last named scales are the square roots of the upper. They must, however, be taken with the proper number of ciphers. The square of 2, for instance, is 4, that of 20 is 400 and that of 200 equals 40,000. In extracting square roots, if the number of digits is odd, 4, 400, etc., the root will be found directly under the number on left hand side of scale. If the number of digits is even, it will be found on right hand side, viz., square root of 40 equals 6.41.

Extracting Cube Root.—Set the runner on the number, the root of which is to be found, and shift the slide until the same number found under this number is also found under the index of the slide on the lower part *D*. According to location of runner either the right or left hand index must be used. Practice raising number to the third power; reversing this process will show method of extracting roots.

Sockets.—Nearly all lamps used in this country are fitted with the well-known Edison base. A few old installations equipped with the T. H. base still remain, but are usually equipped with adjusters to permit the use of Edison base lamps.

The standard sockets as recognized by the N. E. C. are given below:

Classification.—Sockets to be classed according to diameters of lamp bases, as Candelabra, Medium and Mogul. Base to be known respectively as ½ inch, 1 inch and 1½ inch nominal sizes, with ratings as specified in the following table:

		Ratings					
		Key			Keyless		
Class	Nominal Diam.	Watts	Volts	Max. Amp. at any Voltage	Watts	Volts	Max. Amp. at any Voltage
Candelabra	½ in.	75	125	¾	75	125	1
Medium	1 "	250	250	2½	660	250	6
		(a) 660	250	6	660	600	
Mogul	1½ in.				1,500	250	
		(b)			1,500	600	

(a) This rating may be given only to sockets having a switch mechanism which produces both a quick "make" and a quick "break" action.

(b) Ratings to be assigned later, pending further discussion with manufacturers.

Miniature sockets and receptacles having screw shells smaller than the candelabra size may be used for decorative lighting systems, Christmas tree lighting outfits, and similar purposes.

Double-ended Sockets.—Each lamp holder to be rated as specified above, the device being marked with a single marking applying to each end.

In addition to these there is the Edi-Swan base, which is $\frac{5}{8}$ inch diameter, and has bayonet-type connections and is sometimes used on automobiles and other places where there is much jarring. The Edison miniature base is $\frac{3}{8}$ inch in diameter and is used only for low voltages. Some very small lamps are made without bases, the wires connecting direct to lamp terminals. The mogul socket is used for series incandescent lighting and often fitted with automatic cut-out. It is also used for gas-filled lamps of 300 watts or over. Fiber lined or brass shell sockets should not be used in damp places, or where corrosive vapors exist. Key sockets should also be avoided in damp places, or where inflammable gases may exist.

Sparking Distances.—Very high-test voltages are often measured by their sparking distance. The following table gives the sparking distances between sharp points corresponding to different alternating current voltages, when the ratio between maximum and mean effective voltages is equal to 1.41, or the square root of two. The values given were derived from a long series of careful and accurate tests.

TABLE LXXII

(Copyright, 1906, by Standard Underground Cable Co.)

Volts	Spark Distance A. or B.	Volts	Spark —Distance— A.	B.	Volts	Spark —Distance— A.	B.
1,000	0.028	18,000	0.945	0.945	35,000	1.840	1.895
2,000	0.098	19,000	0.995	0.995	36,000	1.900	1.958
3,000	0.159	20,000	1.042	1.042	37,000	1.945	2.020
4,000	0.216	21,000	1.092	1.097	38,000	2.012	2.085
5,000	0.270	22,000	1.143	1.150	39,000	2.062	2.153
6,000	0.324	23,000	1.195	1.206	40,000	2.127	2.220
7,000	0.378	24,000	1.247	1.260	41,000	2.190	2.290
8,000	0.432	25,000	1.300	1.314	42,000	2.247	2.360
9,000	0.487	26,000	1.353	1.373	43,000	2.308	2.434
10,000	0.540	27,000	1.405	1.427	44,000	2.370	2.506
11,000	0.595	28,000	1.460	1.485	45,000	2.432	2.580
12,000	0.644	29,000	1.512	1.540	46,000	2.495	2.660
13,000	0.695	30,000	1.566	1.600	47,000	2.560	
14,000	0,746	31,000	1.620	1.655	48,000	2.625	
15,000	0.797	32,000	1.675	1.712	49,000	2.692	
16,000	0.845	33,000	1.728	1.772	50,000	2.760	
17,000	0.897	34,000	1.785	1.833			

SPARKING DISTANCES IN INCHES.

Column *A* gives spark distances with 10 inch concave metal shields, the plane of whose edges was 1 inch back of the needle points. Column *B* gives the spark distances without shields.

Sharp needles are essential for uniform spark distances, as points measuring from 0.001 inch to 0.002 inch gave in many instances spark distances that were from 20 to 45 per cent greater than those obtained with sharp points. See also table of A. I. E. E. in Standardization Recommendations.

Specific Gravity (Solids).—The specific gravity of a substance is defined as the ratio of the weight of that substance to the weight of an equal volume of water or air. Water is used as the standard of liquids and solids. Air at the temperature 0°, C. (32° F.) and 766 mm. mercury pressure for gases. By multiplying the specific gravity of any substance by the weight of an equal volume of water we find the weight of that volume of the material. The weight of a cubic foot of water is approximately 62.5 lbs. The weight of a gallon is approximately 8.33 lbs. To find the specific gravity of a body heavier than water approximately by experiment, weigh it in air and then weigh it in pure water. Divide the weight in air by the loss of weight (buoyancy) in water and the quotient will give the specific gravity. If the body is lighter than water load it down with a substance heavy enough to sink it. Then weigh the two submerged together. Also weigh both separately in air and the heavy body in water. Subtract the buoyancy of the heavy body from the buoyancy of the two bodies together. The remainder will be the buoyancy of the lighter body by which its weight in air is to be divided as before.

Specifications.—In many cases preliminary specifications, setting forth what the purchaser desires, are made out. Unless these are quite broad many dealers or manufacturers may not be able to comply with them and for this reason often submit specifications of their own, and thus the final specifications which form the basis of contracts must be somewhat modified.

In general, specifications may be divided into two parts: one part which deals with machinery and materials, and another which deals with the installation work and results to be obtained. If certain materials are specified, and at the same time requirements as to certain results are made, there is always a chance for disputes as to who is responsible in case the installation does not fulfill requirements. Unless the work is to be carried on under the supervision of a consulting engineer, it is best to give the contractor free choice of materials and hold him entirely responsible for the final result.

All specifications should be based upon the standards of the engineering societies governing the particular kind of work. The A. I. E. E. have standardization rules which govern everything electrical, but these do not largely concern themselves with safety rules. In this regard the National Electrical Code should be adopted as the standard and all material and workmanship should be specified to conform with its requirements. This is a reliable guide in every respect except that of economy and efficiency and suitability of systems, etc. It deals only with safety and reliability.

It is best always to have some sort of a plan showing location of cut-out centers, switches, lights and motors, or any other parts about which there may afterwards be disputes. If there are no plans the location of cut-outs and other conspicuous elements should be mentioned in the specifications. They should also mention how much conduit, open or molding work is to be used. Every item mentioned should form a clause and these should be numbered for reference.

Where accurate calculations are to be made, all circuits and runs of wire should be measured and the specifications thoroughly read and considered. The estimator should take plenty of time to understand every phase of his job. As a reminder of the many items so easily overlooked, he should have prepared an estimate sheet on the order of that following which is furnished by courtesy of the National Electrical Contractors' Association. Large apartments, hotels, etc., usually have many floors and rooms which are exact duplicates, and very careful measurements of one floor or room will answer for the whole building or that part of it which is typical.

Table LXXIII shows approximate quantities of material used for rough wiring in average flats.

TABLE SHOWING APPROXIMATE QUANTITY OF ROUGH MATERIAL PER OUTLET IN AVERAGE FLATS.

	Ft. Single Wire.	Ft. Twin Wire.	Ft. Loom.	Ft. Moulding.	No. Insulators.	No. Tubes.	Ft. Conduit.	No. Elbows.	No. Outlet Boxes.	No. Lock Nuts and Bushings.	No. Couplings, Extra.	Lb. Nails.	Oz. Brads.	Rolls Tape, Each Kind.
All Center Lights. No Switches, Conduit	....	16	....	....	....	....	15	1	1	4	1	....	....	....
All Center Lights. No " K and Tube, Loop	32	....	3½	....	8	16	....	....	....	....	....	⅛	....	....
All Center Lights. No " K and Tube, Taps	28	....	2	....	7	14	....	....	....	....	....	⅛	....	....
All Center Lights. No " Moulding	28	....	....	13	....	2	....	....	....	....	....	⅛	½	....
All Center Lights. Switches, Conduit	....	15	....	....	....	....	14	1	1	4	1	....	....	....
All Center Lights. Switches, K and Tube, Loop	30	....	3½	....	7	14	....	....	....	....	....	⅛	....	....
All Center Lights. Switches, K and Tube, Taps	24	....	2	....	6	12	....	....	....	....	....	⅛	....	....
All Center Lights. Switches, Moulding	24	....	....	12	....	2	....	....	....	....	....	⅛	½	....
All Brackets. No Switches, Conduit	....	22	....	....	....	....	21	1	1	4	1	....	....	....
All Brackets. No " K and Tube, Loop	44	....	3½	....	11	22	....	....	....	....	....	⅛	....	....
All Brackets. No " K and Tube, Taps	35	....	2	....	9	18	....	....	....	....	....	⅛	....	....
All Brackets. No " Moulding	35	....	....	17	..	2	....	....	....	....	..	⅛	½	....

In using this table, count all switches except those located in cutout boxes or on fixtures as outlets.

Ceilings are assumed to be 10 feet high; switches 4 feet from floor and brackets 6 feet. All runs have been figured at right angles, so that a small saving can be made with diagonal runs.

National Electrical Contractors' Association Universal Estimate Sheet.

	Bid Goes to.................	
	Address	
No. Lights........	Architect or Engineer.......	
No. Switches......	Address Arch. or Engr.......	
No. Circuits......		
No. Base Plugs....	Name of Job or Building.....	Estimate No...
No. Telephones....	Location of Job of Building..	Sheet No......
No. Motors........		
H. P. Motors......	See Mr.....Telephone No....	Date..... 19..
No. Fixtures......	Bid Must Be In by......M..	
K. W. Generator..		
Switchboard	Salesman	Job No........

Material Estimated by   Labor Estimated by   Priced by   Approved by

Conduit, Rigid	Knife Switches	Screws
Conduit Elbows	Door Switches	Nails
Conduit Bushings	Pendant Switches	Toggle Bolts
Conduit Straps	Rubber Covered Wire	Annunciators
Conduit Hangers	Lead Covered Wire	Annunciator Wire
Lock Nuts	Fixture Wire	Annunciator Cable
Conduit Flexible	Special Wire	Elevator Cable
Conduit Fittings	Lamp Cord	Bells
Conduit, Non-Metallic	Reinforced Cord	Buzzers
Ceiling Boxes	Packing House Cord	Push Buttons
Bracket Boxes	Show Window Cord	Silk Cord
Switch Boxes	Molding Wood	Door Openers
Floor Boxes	Molding Metal	Burglar Alarm
Box Covers	Molding Fitting	Batteries
Fixture Hangers	Fixtures	Bell Ringers
Cutout Cabinets	Clusters	Telephones
Panelboards	Key Sockets	Telephone Cable
Metering Panels	Keyless Sockets	Speaking Tube
Meter Loops	Wall Sockets	Whistles
Cutout Boxes	Rosettes	Letter Boxes
Asbestos	Socket Bushings	Tape
Cut Out Blocks	Cord Adjusters	Solder
Fuse Plugs	Shades	Compound
Enclosed Fuses	Shadeholders	Acid
Flush Switches	Adapters	Oil
D. P. Flush Switches	Attachment Plugs	Car Fare
3 Way Flush Switch	Lamps, Incandescent	Cartage
4 Way Flush Switch	Lamp Guards	Bond
Snap Switches	Arc Lamp	Drafting
D. P. Snap Switches	Cleats	Inspection
3 Way Snap Switch	Knobs	Incidentals
4 Way Snap Switch	Tubes	

Bid Sent to Following:

Total
Material
Labor
Overhead Expenses   Per cent
Profit   Per cent
Bid

Figures 23, 24 and 25 will assist in illustrating the most economical manner of running wires for branch circuits. In Figure 23 the heavy black lines denote the mains, and at their terminals the cut-outs are located. It is never economical to push mains any farther than is necessary to enable one branch circuit to reach the far end of the space to be covered. In the arrangement shown in Figure 23 the greatest possible economy would be effected if a cut-out were

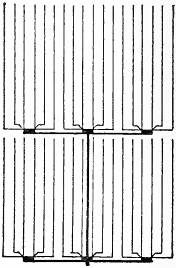


Figure 23.—Comparison of Materials.

provided for each circuit, but for various reasons this is not advisable. The next best arrangement is to provide a number of cut-out centers as shown in the figure, locating each cut-out in the center of the group it is to supply.

In case a given number of lights are to be fed with wires running at right angles, the most economical arrangement can be found by running a straight line through the space covered at such point as to leave an equal number of lights on each side of it, as in Figure 24.

If the lights are to be fed by diagonal runs, the shortest runs can be quickly found by bearing in mind that from the cut-out center, or from any outlet, this point in connection with any two other outlets forms a triangle and it is merely necessary to avoid using the longest side of this triangle. The position

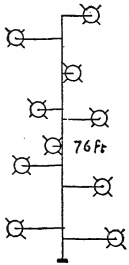


Figure 24.

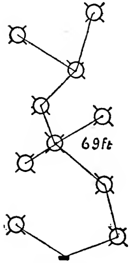


Figure 25.

of lamps shown in Figures 24 and 25 is identical, but Figure 25 requires about 10 per cent less material than Figure 24. The relative economy of running mains or branch circuits can be determined by Table LXXIV, which gives the equivalent in mains of various sizes and branch circuits of 660 watt capacity.

TABLE LXXIV

Showing Mains and Their Equivalent in No. 14 Branch Circuits.

2 Wire Mains	2 Wire Branches	3 Wire Mains	3 Wire Branches
2 ft. No. 14=	4 ft. No. 14	3 ft. No. 14=	10 ft. No. 14
2 ft. No. 12=	6 ft. No. 14	3 ft. No. 12=	12 ft. No. 14
2 ft. No. 10=	8 ft. No. 14	3 ft. No. 10=	16 ft. No. 14
2 ft. No. 8=	10 ft. No. 14	3 ft. No. 8=	22 ft. No. 14
2 ft. No. 6=	16 ft. No. 14	3 ft. No. 6=	32 ft. No. 14
2 ft. No. 5=	18 ft. No. 14	3 ft. No. 5=	36 ft. No. 14
2 ft. No. 4=	22 ft. No. 14	3 ft. No. 4=	44 ft. No. 14
2 ft. No. 3=	26 ft. No. 14	3 ft. No. 3=	52 ft. No. 14
2 ft. No. 2=	30 ft. No. 14	3 ft. No. 2=	60 ft. No. 14
2 ft. No. 1=	32 ft. No. 14	3 ft. No. 1=	64 ft. No. 14
2 ft. No. 0=	40 ft. No. 14	3 ft. No. 0=	80 ft. No. 14
2 ft. No. 00=	50 ft. No. 14	3 ft. No. 00=	100 ft. No. 14
2 ft. No. 000=	58 ft. No. 14	3 ft. No. 000=	116 ft. No. 14
2 ft. No. 0000=	74 ft. No. 14	3 ft. No. 0000=	148 ft. No. 14

Street Lighting.—In villages and suburbs, the street lighting is often of a perfunctory nature. It consists often merely of an incandescent or arc lamp placed at each street intersection. Such lights should be over center of streets. In parks, the object of the illumination must be not merely the road or path, but fields and lagoons as well. At band-stands and similar places, arc lamps are preferable, but where the lights must be brought down under trees they are not very serviceable. Along curved driveways place lights on the outer curve; this will enable drivers to see farther, but will require more material.

In business streets a very brilliant illumination is often desired. Tungsten lamps, installed on posts, are the most common illuminants at present where a permanent installation is contemplated. For temporary effects festoons are much used. The systems upon which such lights are operated will usually be governed by that which is already in use. The following points should be noted in connection with street lighting: Large units are most economical in first cost, but waste much of their light outside of the street. At street intersections this waste is not so great. Large units should always be hung high. A bright illumination, except on business streets, is not necessary, but the light should be white. For series incandescent lighting special lamps are always used. The thicker the filament the less will the flickering effect of low frequencies affect them. For overhead work wires smaller than No. 6 are seldom used. No incandescent lamp should ever be used outside without a reflector to prevent light being wasted on the upper air. Time switches are often serviceable on street lighting. Those who undertake to install a system of street lighting should prepare themselves for an unlimited amount of annoyance from residents who imagine their trees will be ruined or who quarrel about the location of poles and lamps.

Switches.—The standard height of switches in offices and residences is 4 ft. 6 in. above finished floor. If switches of the push button type are used the white button should be uppermost. Switches should contain sufficient metal to prevent a temperature rise of over 28° C. (50° F.). There should be a contact surface of about 1 sq. in. for every 75 amperes. To obtain this contact surface large capacity switches are made up of a number of blades in parallel. This arrangement also allows better radiation. The following table shows the capacity of single blades of dimensions given, the clip being assumed as of some width.

TABLE LXXV

Width, in.	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8
Amperes	8	15	30	58	85	115	150	180	215	280	330	395

These widths will not determine capacity of switch unless the temperature rise is within the limits. Below are given the dimensions and spacings of knife switches as required by the N. E. C. Over all dimensions of standard knife switches as made by the George Cutter Company are given on pages 226 and 230.

Spacings and Dimensions.—Spacings and dimensions must be at least as great as those given in the following tables:

TABLE LXXVI

Not over 125 volts d. c. and a. c.
For switchboards and panel boards:

	Width and Thickness: Blades	Width and Thickness: Clips and Hinges	Minimum separation of nearest metal parts of opposite polarity	Minimum break distance
30 amp.	$\frac{1}{2}$x$\frac{5}{64}$ in.	$\frac{1}{2}$x$\frac{3}{64}$ in.	1 in.	$\frac{3}{4}$ in.
60 amp.			$1\frac{1}{4}$ in.	1 in.

TABLE LXXVII

Not over 125 volts d. c. and a. c.
For individual switches:

	Inch	Inch	Inch	Inch
30 amp.	$\frac{1}{2}$x$\frac{5}{64}$	$\frac{1}{2}$x$\frac{3}{64}$	$1\frac{1}{4}$	1
60 & 100 amp.			$1\frac{1}{2}$	$1\frac{1}{4}$
200 amp.			$2\frac{1}{4}$	2
400 & 600 amp.			$2\frac{3}{4}$	$2\frac{1}{2}$
800 & 1000 amp.			3	$2\frac{3}{4}$

A 300-ampere switch with the spacings of the 200-ampere switch above may be used on switchboards.

TABLE LXXVIII

250 volts only d. c. and a. c.
For all switches:

	Inch	Inch	Inch	Inch
30 amp...............	$\frac{1}{2}$x$\frac{5}{64}$	$\frac{1}{2}$x$\frac{3}{64}$	$1\frac{3}{4}$	$1\frac{1}{2}$

TABLE LXXIX

Not over 250 volts d. c. nor over 500 volts a. c.
For all switches:

	Inch	Inch	Inch	Inch
30 amp........	$\frac{5}{8}$x$\frac{1}{8}$	$\frac{5}{8}$x$\frac{1}{16}$	$2\frac{1}{4}$	2
60 & 100 amp........			$2\frac{1}{4}$	2
200 amp........			$2\frac{1}{2}$	$2\frac{1}{4}$
400 & 600 amp........			$2\frac{3}{4}$	$2\frac{1}{2}$
800 & 1000 amp........			3	$2\frac{3}{4}$

A 300-ampere switch with the spacings of the 200-ampere switch above may be used on switchboards.

Cut-out terminals on switches for over 250 volts must be designed and spaced for 600-volt fuses.

TABLE LXXX

Not over 600 volts d. c. and a. c.
For all switches:

	Inch	Inch	Inch	Inch
30 amp..............	$\frac{5}{8}$x$\frac{1}{8}$	$\frac{5}{8}$x$\frac{1}{16}$	4	$3\frac{1}{2}$
60 amp..............			4	$3\frac{1}{2}$
100 amp..............			$4\frac{1}{2}$	4

Auxiliary contacts of either a readily renewable or a quick-break type or the equivalent are recommended for d. c. switches, designed for over 250 volts, and must be provided on d. c. switches designed for use in breaking currents greater than 100 amperes at a voltage of over 250.

For 3-wire direct current and 3-wire single phase systems the separation and break distances for plain 3-pole knife switches must not be less than those required in the above table for switches designed for the voltage between neutral and outside wires.

TABLE LXXXI

CUTTER KNIFE SWITCHES

See Figure 26

Dimensions, in Inches, for Paragon Switches

Cap. Amps.	A		B				C	D		E	F	G	H	J
	250V. D.C. 500V. A.C.	600V. D.C. or A.C.	125V. D.C. or A.C.	250V. D.C. or A.C.	500V. A.C.	600V. D.C. or A.C.		250 V.D.C. 500V. A.C.	600V. D.C. or A.C.			Diam. of Stud	Diam. of Screw	Diam. of Screw
†30....	5	7	1 3/4	2 1/4	..	4 1/2	1 3/8	2	4	1 3/8	3 1/8	1/4	11/64	11/64
60....	6 1/2	8 1/2	2 1/8	2 7/8	3 1/2	5 1/8	1 15/16	2 5/8	4 5/8	1 5/8	3 1/4	5/16	11/64	11/64
100....	7 3/8	9 1/4	2 1/4	3	3 1/2	5 1/4	2 3/8	3	4 7/8	2	4	1/2	7/32	7/32
200....	10	12 3/4	3 1/4	3 1/2	3 3/4	6	3 1/2	3 3/4	6 1/4	2 7/8	4	5/8	7/32	7/32
*300....	10 3/4	13 1/4	3 1/2	3 3/4	..	6 1/4	4 3/8	4	6 1/2	3 3/8	4	5/8	1/4	1/4
400....	12	14 1/4	4 1/2	4 1/2	4 1/2	7	4 15/16	4 3/4	7	4 3/16	4 1/2	3/4	1/4	1/4
600....	13	15 1/4	4 3/4	4 3/4	5	7 1/4	6 1/4	5 1/4	7 1/2	5 1/8	4 7/8	1	3/8	3/8
800....	12	16 3/8	5	5	5 3/4	8	6 1/2	4 3/4	7 3/4	4 3/16	5 3/8	1 1/8	3/8	3/8
1000....	13 3/4	17 1/8	5 1/4	5 1/4	6 1/4	8 1/4	7	5	8 1/4	5 1/8	5 1/2	1 1/4	3/8	3/8
1500....	14	18	6 1/4	6 1/4	..	8 1/2	..	5 1/2	8 1/4	5 1/8	6 1/8	1 1/2	1/2	..
2000....	15	18	7 1/4	7 1/4	..	9 1/4	..	6	8 1/4	6	6 3/4	1 3/4	1/2	..

TABLE LXXXI—Continued

Cap. Amps.	K: 250 V. D.C. 500 V. A.C.	K: 600 V. D.C. or A.C.	L: 250 V. D.C. or A.C.	L: 600 V. D.C. or A.C.	M: 250 V. D.C. or A.C.	M: 600 V. D.C. or A.C.	N	O: 250 V. D.C. or A.C.	O: 500 V. A.C.	O: 600 V. D.C. or A.C.	P	R	U
†30.........	$2\frac{7}{8}$	$4\frac{7}{8}$	3	6	$1\frac{1}{2}$	$4\frac{1}{2}$	$\frac{5}{8}$	5	..	10	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$
60.........	$3\frac{11}{16}$	$5\frac{11}{16}$	$4\frac{3}{16}$	$6\frac{11}{16}$	$2\frac{3}{8}$	$4\frac{7}{8}$	$\frac{3}{4}$	$6\frac{13}{16}$	$9\frac{5}{16}$	$11\frac{5}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{5}{8}$
100.........	$4\frac{3}{8}$	$6\frac{1}{4}$	$7\frac{3}{8}$	$9\frac{3}{8}$	$4\frac{7}{8}$	$6\frac{7}{8}$	$1\frac{1}{8}$	$10\frac{3}{8}$	$12\frac{3}{8}$	$14\frac{1}{4}$	1	1	$\frac{3}{4}$
200.........	$5\frac{11}{16}$	$8\frac{3}{16}$	$9\frac{1}{8}$	$11\frac{5}{8}$	$5\frac{3}{4}$	$8\frac{1}{4}$	$1\frac{5}{8}$	$12\frac{7}{8}$	$15\frac{3}{8}$	$17\frac{7}{8}$	$1\frac{7}{16}$	$1\frac{1}{4}$	1
*300.........	$6\frac{1}{4}$	$8\frac{3}{4}$	..	..	..	..	..	..	..	..	$1\frac{5}{8}$	..	$1\frac{1}{4}$
400.........	$7\frac{3}{8}$	$9\frac{5}{8}$	$11\frac{5}{8}$	$14\frac{5}{8}$	$6\frac{3}{4}$	$9\frac{3}{4}$	$2\frac{3}{8}$	$16\frac{3}{8}$	$19\frac{3}{8}$	$21\frac{5}{8}$	$1\frac{7}{8}$	$1\frac{3}{4}$	$1\frac{1}{2}$
600.........	$8\frac{3}{8}$	$10\frac{5}{8}$	14	17	$8\frac{1}{8}$	$11\frac{1}{8}$	3	$19\frac{1}{4}$	$22\frac{1}{4}$	$24\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{3}{4}$
800.........	$8\frac{1}{8}$	$11\frac{1}{8}$	$15\frac{3}{16}$	$18\frac{3}{16}$	$8\frac{15}{16}$	$11\frac{5}{16}$	3	$19\frac{15}{16}$	$22\frac{15}{16}$	$25\frac{15}{16}$	$2\frac{3}{8}$	$2\frac{1}{4}$	2
1000.........	$8\frac{3}{4}$	12	17	20	$9\frac{3}{4}$	$12\frac{3}{4}$	$3\frac{5}{8}$	22	25	$28\frac{1}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{4}$
1500.........	$9\frac{5}{8}$	..	..	..	..	..	..	..	..	..	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{1}{2}$
2000.........	$10\frac{7}{8}$	..	..	..	..	..	..	..	..	..	$3\frac{1}{8}$	$3\frac{1}{2}$	$3\frac{1}{2}$

†30-ampere switches for use on 500 volts A. C. will take dimensions of 60-ampere switches, except for fuse spacings.

*300-ampere switches, unfused.

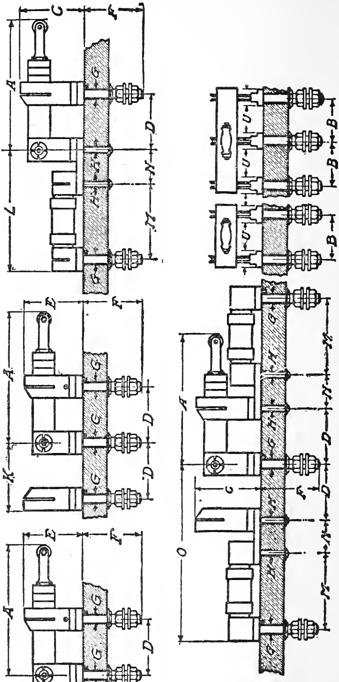


Figure 26.—Cutter Knife Switches Paragon Type.

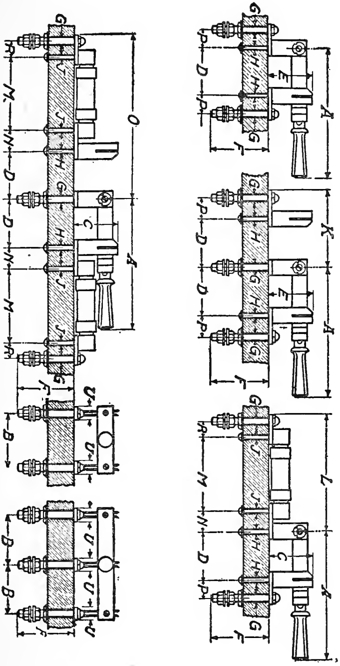


Figure 27.—Cutter Knife Switches Type FF.

TABLE LXXXII

CUTTER KNIFE SWITCHES

See Figure 27

Dimensions, Inches, for Type FF Switches

Cap. Amps.	A					B			C	D		E	F
	Spade Handle		Straight Handle										
	250 V. D.C. 500 V. A.C.	600 V. D.C. or A.C.	250 V. D.C. 500 V. A.C.	500 V. D.C. or A.C.	125 V. D.C. or A.C.	250 V. D.C. or A.C.	500 V. A.C.	600 V. D.C. or A.C.		250 V. D.C. 500 V. A.C.	600 V. D.C. or A.C.		
†30	4 13/16	6 13/16	5 1/4	7 1/4	1 3/4	2 1/4	..	4 1/2	1 9/16	2 1/8	4 1/8	1 9/16	3 1/8
60	6 1/2	8 1/2	6 3/4	8 3/4	2 1/8	2 7/8	3 1/2	5 1/8	2 1/8	2 7/8	4 7/8	2 1/8	3 1/4
100	7 7/8	9 7/8	7 7/8	9 7/8	2 1/4	3	3 1/2	5 1/4	2 3/4	3 1/8	5 1/8	2 3/4	4
200	9 1/4	11 5/8	9 3/4	12 1/8	3 1/4	3 1/2	3 3/4	6	3 15/16	3 7/8	6 1/4	3 15/16	4
*300	10 1/8	13 1/8	10 5/8	12 7/8	3 1/2	3 3/4	..	6 1/4	4 7/16	4 1/4	6 1/2	4 7/16	4 1/2
400	11 5/16	14 13/16	12	14 1/2	4 1/2	4 1/2	4 1/2	7	5 1/8	4 3/4	7 1/4	5 1/8	4 3/4
600	12 9/16	15 1/16	13 1/2	16	4 3/4	4 3/4	5	7 1/4	5 15/16	5 1/4	7 3/4	15 15/16	4 7/8
800	12 3/16	14 15/16	13 5/8	16 3/8	5	5	5 3/4	8	5 3/8	5	7 3/4	5 3/8	5 3/8
1000	13 11/16	16 7/16	14 1/2	17 1/4	5 1/4	5 1/4	6 1/4	8 1/4	6	5 1/2	8 1/4	6	5 1/2
1500	14 3/16	16 11/16	15 1/2	18	6 1/4	6 1/4	..	8 1/2	6 1/8	5 3/4	8 1/4	6 1/8	6 1/8
2000	14 3/16	16 11/16	15 1/2	18	7 1/4	7 1/4	..	9 1/4	6 1/8	5 3/4	8 1/4	6 1/8	6 3/4
3000	17 7/16	19 11/16	17 5/8	19 7/8	7 3/4	7 3/4	..	9 3/4	8	7	9 1/4	8	8
4000	17 7/16	19 11/16	17 5/8	19 7/8	8 3/4	8 3/4	..	10 3/4	8 1/4	7	9 1/4	8 1/4	9

TABLE LXXXII—Continued

Cap. Amp.	G Diam. of Stud	H Diam. of Screw	K 250V. D. C. 500V. A. C.	K 600V. D. C. or A. C.	L 250V. D. C. or A. C.	L 600V. D. C. or A. C.	M 250V. D. C. or A. C.	M 600V. D. C. or A. C.	N	O 250V. D. C. or A. C.	O 500V. A. C.	O 600V. D. C. or A. C.	U
†30....	1/4	11/64	2 3/8	4 3/8	2 1/2	5 1/2	1 1/2	4 1/2	3/4	4 5/8	..	9 5/8	1/2
60....	5/16	11/64	3 1/4	5 1/4	3 11/16	6 3/16	2 3/8	4 7/8	1	6 9/16	9 1/16	11 1/16	5/8
100....	1/2	7/32	3 5/8	5 5/8	6 5/8	8 5/8	4 7/8	6 7/8	1 5/16	9 3/4	11 3/4	13 3/4	3/4
200....	5/8	7/32	4 5/8	7	8 1/4	10 3/4	5 3/4	8 1/4	1 7/8	12 1/8	14 5/8	17	1
*300....	3/4	1/4	5 1/8	7 3/8	..	..	..	..	..	..	..	..	1 1/4
400....	7/8	1/4	5 3/4	8 1/4	10 1/8	13 1/8	6 3/4	9 3/4	2 1/2	14 7/8	17 7/8	20 3/8	1 1/2
600....	1	3/8	6 1/2	9	12 3/16	15 3/16	8 1/8	11 1/8	3	17 7/16	20 7/16	22 13/16	1 3/4
800....	1 1/8	3/8	6	8 3/4	13 9/32	16 9/32	8 15/16	11 15/16	3 1/8	18 9/32	21 9/32	24 1/32	2
1000....	1 1/4	3/8	6 3/4	9 1/2	14 3/4	17 3/4	9 3/4	12 3/4	3 5/8	20 1/4	23 1/4	26	2 1/4
1500....	1 1/2	..	7	9 1/2	..	..	..	..	..	..	..	..	2 1/2
2000....	1 3/4	..	7	9 1/2	..	..	..	..	..	..	..	..	3 1/4
3000....	2	..	8 3/4	11	..	..	..	..	..	..	..	..	3 1/2
4000....	2 1/2	..	8 3/4	11	..	..	..	..	..	..	..	..	4 1/2

†30-ampere switches for use on 500 volts A. C. will take dimensions of 60-ampere switches, except for fuse spacings.

*300-ampere switches, unfused.

Switchboards.—The best material for mounting switches and bus-bars is marble. Slate may be used, but metal veins may cause trouble. A liberal allowance of space should be allowed back of board, and its panels should be kept well above the floor. Where more than one machine is connected it is customary to operate them in parallel on d. c. For dimensions of bus-bars, switches and fuses, see those headings. It is customary to provide the following instruments, etc., for good switchboards: One main three pole switch for each generator, where there are several operated in parallel. One ammeter for each generator, or an ammeter arranged for connection to each machine. A voltmeter which may be connected to any machine, and also be used as a ground detector. One field rheostat for each machine. Sufficient pilot lights to illuminate board properly. In some cases also a wattmeter measuring the total current.

Alternating current boards are also often equipped for parallel running, but not always. In some cases the board is divided and fitted with throw over switches so that either generator may supply everything connected, or only a part of it, as desired.

The following equipment is commonly used: Main switch for each generator. Synchronizing lamps, or synchroscope. Frequency indicator. Power factor indicator. Voltmeter to be used as with d. c. machines. An ammeter for each phase, and also for each generator. Exciter equipment. Wattmeters. To these must of course be added the necessary fuses and switches. The N. E. C., however, does not require fuses on a. c. generator or their exciters. If practicable, light and power circuits should be kept separate.

Symbols.—The following are the symbols recommended by the American Institute of Electrical Engineers.

The following notation is recommended:

Name of quantity	Symbol	Unit
Voltage, e.m.f., potential difference	E, e,	volt
Current	I, i,	ampere
Resistance	R, r,	ohm
Reactance	X, x,	ohm
Impedance	Z, z,	ohm
Admittance	Y, y,	mho
Conductance	G, g,	mho
Susceptance	B, b,	mho
Power	P, p,	watt
Capacity	C, c,	farad
Inductance	L,	henry
Magnetic flux	Φ	maxwell
Magnetic density	B	gauss
Magnetic force	H	gilbert per cm.
Length	L, l,	cm. or inch
Mass	M, m,	gm. or lb.
Time	T, t,	second or hour

Em, Im and *Bm* should be used for maximum cyclic values, *e, i* and *p* for instantaneous values, *E* and *I* for r.m.s. values, and *P* for the average value or effective power. These distinctions are not necessary in dealing with continuous current circuits. Vector quantities are preferably represented by bold face capitals.

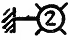
Testing.—It is assumed that the reader of this work is familiar with the general principles employed in testing, and therefore no attempt will be made to explain methods of using the various instruments. The list given in the following pages is intended as a reminder of the various instruments available for different purposes. Those about to undertake testing work with which they are not entirely familiar are advised to consult this list, and select those instruments needed. Consult Standardization Rules of A. I. E. E. and N. E. C. and make tests in conformity with their standards.

STANDARD SYMBOLS FOR WIRING PLANS

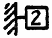
As adopted and recommended by the National Electrical Contractors Association of the United States.


Ceiling Outlet; electric only. Numeral in center indicates number of standard 16 c. p. incandescent lamps.


Ceiling Outlet; combination. 4-2 indicates 4-16 c. p. standard incandescent lamps and 2 gas burners.

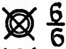

Bracket Outlet; electric only. Numeral in center indicates number of standard 16 c. p. incandescent lamps.


Bracket Outlet; combination. 4-2 indicates 4-16 c. p. standard incandescent lamps and 2 gas burners.


Wall or Baseboard Receptacle Outlet. Numeral in center indicates number of standard 16 c. p. incandescent lamps.


Floor Outlet. Numeral in center indicates number of standard 16 c. p. incandescent lamps.


Outlet for Outdoor Standard or Pedestal; electric only. Numeral indicates number of stand. 16 c. p. incan. lamps.


Outlet for Outdoor Standard or Pedestal; combination. 6-6 indicates 6-16 c. p. stand. incan. lamps; 6 gas burners.


Drop Cord Outlet.


One Light Outlet, for lamp receptacle.


Arc Lamp Outlet,


Special Outlet, for lighting heating and power current, as described in specifications.


Ceiling Fan Outlet.

S^1 S. P. Switch Outlet.

S^2 D. P. Switch Outlet.

S^3 3-Way Switch Outlet.

S^4 4-Way Switch Outlet.

Show as many symbols as there are switches. Or in case of a very large group of switches, indicate number of switches by a Roman numeral, thus: SI XII; meaning 12 single pole switches.

Describe type of switch in specifications, that is,

Flush or surface push button or snap.

STANDARD SYMBOLS FOR WIRING PLANS

As adopted and recommended by the NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION OF THE UNITED STATES.

S^D Automatic Door Switch Outlet.

S^E Electrolier Switch Outlet.

 Meter Outlet.

 Distribution Panel.

 Junction or Pull Box.

 Motor Outlet; numeral in center indicates horse power.

 Motor Control Outlet.

 Transformer.

 Main or feeder run concealed under floor.

 Main or feeder run concealed under floor above.

 Main or feeder run exposed.

 Branch circuit run concealed under floor.

 Branch circuit run concealed under floor above.

 Branch circuit run exposed.

 Pole line.

 Riser.

SUGGESTIONS IN CONNECTION WITH STANDARD SYMBOLS FOR WIRING PLANS.

Indicate on plan, or describe in specifications, the height of all outlets located on side walls.

It is important that ample space be allowed for the installation of mains, feeders, branches and distribution panels.

It is desirable that a key to the symbols used accompany all plans.

If mains, feeders, branches and distribution panels are shown on the plans, it is desirable that they be designated by letters or numbers.

STANDARD SYMBOLS FOR WIRING PLANS

As adopted and recommended by the NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION OF THE UNITED STATES.

 Telephone Outlet; private service.

 Telephone Outlet; public service.

 Bell Outlet

 Buzzer Outlet.

 Push Button Outlet; numeral indicates number of pushes.

 Annunciator; numeral indicates number of points.

 Speaking Tube.

 Watchman Clock Outlet.

 Watchman Station Outlet.

 Master Time Clock Outlet.

 Secondary Time Clock Outlet

 Door Opener.

 Special Outlet; for signal systems, as described in specifications

 Battery Outlet.

 Circuit for clock, telephone, bell or other service, run under floor, concealed. Kind of service wanted ascertained by symbol to which line connects.

 Circuit for clock, telephone, bell or other service, run under floor above concealed. Kind of service wanted ascertained by symbol to which line connects.

NOTE—If other than standard 16 c. p. incandescent lamps are desired, specifications should describe capacity of lamp to be used.

TABLE LXXXIII

Terminals.—George Cutter Co.

Square Type, Cast.

(See Figure 28.)

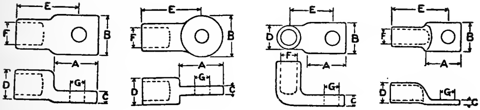


Figure 28.— Terminals.

Amps.	Wire Size	A	B	C	D	E	F	G
		Standard Dimensions, Inches						
30	8	1/2	1/2	1/8	5/16	3/4	3/16	3/16
50	5	5/8	5/8	1/8	3/8	1	7/32	3/16
75	3	5/8	5/8	3/16	1/2	1 1/8	9/32	9/32
100	1	13/16	3/4	3/16	17/32	1 1/4	11/32	9/32
150	00	15/16	7/8	3/16	5/8	1 3/8	7/16	13/32
175	000	1	15/16	1/4	11/16	1 1/2	1/2	13/32
200	0000	1 1/16	1	1/4	13/16	1 5/8	19/32	13/32
250	300000	1 3/32	1	5/16	15/16	1 3/4	11/16	13/32
300	350000	1 3/8	1 1/4	3/8	1	2	3/4	13/32
350	400000	1 1/2	1 1/2	7/16	1 1/16	2 1/4	3/16	13/32
400	500000	1 5/8	1 1/2	1/2	1 1/4	2 3/8	15/16	13/32
500	750000	1 3/4	1 3/4	9/16	1 3/8	2 3/4	1 1/16	17/32
600	1000000	2	1 3/4	9/16	1 9/16	3	1 3/16	17/32
700	1250000	2 1/4	2	5/8	1 3/4	3 1/8	1 5/16	17/32
800	1500000	2 1/2	2	5/8	2	3 1/4	1 1/2	17/32
1000	2000000	2 5/8	2 1/4	3/4	2 1/4	3 3/8	1 3/4	21/32

Round Type, Cast.

Amps.	Wire Size	A	B	C	D	E	F	G
30	8	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{5}{16}$	$\frac{3}{4}$	$\frac{3}{16}$	$\frac{3}{16}$
50	5	$\frac{13}{16}$	$\frac{3}{4}$	$\frac{3}{16}$	$\frac{3}{8}$	$1\frac{1}{8}$	$\frac{7}{32}$	$\frac{3}{16}$
75	3	$\frac{15}{16}$	$\frac{7}{8}$	$\frac{3}{16}$	$\frac{1}{2}$	$1\frac{1}{4}$	$\frac{9}{32}$	$\frac{9}{32}$
100	1	$1\frac{1}{16}$	1	$\frac{7}{32}$	$\frac{1}{2}$	$1\frac{3}{8}$	$\frac{11}{32}$	$\frac{9}{32}$
150	00	$1\frac{1}{16}$	1	$\frac{1}{4}$	$\frac{5}{8}$	$1\frac{1}{2}$	$\frac{7}{16}$	$\frac{13}{32}$
175	000	$1\frac{3}{16}$	$1\frac{1}{8}$	$\frac{1}{4}$	$\frac{11}{16}$	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{13}{32}$
200	0000	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{1}{4}$	$\frac{13}{16}$	$1\frac{3}{4}$	$\frac{19}{32}$	$\frac{13}{32}$
250	300000	$1\frac{5}{16}$	$1\frac{1}{4}$	$\frac{5}{16}$	$\frac{15}{16}$	$1\frac{7}{8}$	$\frac{11}{16}$	$\frac{13}{32}$
300	350000	$1\frac{1}{2}$	$1\frac{3}{8}$	$\frac{5}{16}$	1	2	$\frac{3}{4}$	$\frac{13}{32}$
350	400000	$1\frac{5}{8}$	$1\frac{1}{2}$	$\frac{5}{16}$	$1\frac{1}{8}$	$2\frac{1}{8}$	$\frac{13}{16}$	$\frac{13}{32}$
400	500000	$1\frac{3}{4}$	$1\frac{5}{8}$	$\frac{7}{16}$	$1\frac{1}{4}$	$2\frac{3}{8}$	$\frac{15}{16}$	$\frac{13}{32}$
500	750000	$2\frac{1}{8}$	$1\frac{15}{16}$	$\frac{1}{2}$	$1\frac{3}{8}$	3	$1\frac{1}{16}$	$\frac{17}{32}$
600	1000000	$2\frac{3}{8}$	$2\frac{1}{4}$	$\frac{5}{8}$	$1\frac{5}{8}$	$3\frac{3}{8}$	$1\frac{3}{16}$	$\frac{17}{32}$
700	1250000	$2\frac{5}{8}$	$2\frac{1}{2}$	$\frac{3}{4}$	$1\frac{3}{4}$	$3\frac{7}{8}$	$1\frac{5}{16}$	$\frac{17}{32}$
800	1500000	$2\frac{5}{8}$	$2\frac{1}{4}$	$\frac{3}{4}$	2	$3\frac{7}{8}$	$1\frac{1}{2}$	$\frac{17}{32}$
1000	2000000	$2\frac{3}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$2\frac{1}{4}$	4	$1\frac{3}{4}$	$\frac{21}{32}$

Right Angle Type, Cast.

30	8	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{5}{16}$	$\frac{9}{16}$	$\frac{3}{16}$	$\frac{3}{16}$
50	5	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{7}{32}$	$\frac{3}{16}$
100	1	$\frac{13}{16}$	$\frac{3}{4}$	$\frac{3}{16}$	$\frac{1}{2}$	1	$\frac{11}{32}$	$\frac{9}{32}$
150	00	1	$\frac{7}{8}$	$\frac{5}{16}$	$\frac{5}{8}$	$1\frac{1}{8}$	$\frac{7}{16}$	$\frac{11}{32}$
200	0000	$1\frac{1}{8}$	1	$\frac{3}{8}$	$\frac{13}{16}$	$1\frac{3}{8}$	$\frac{19}{32}$	$\frac{13}{32}$
300	350000	$1\frac{1}{4}$	$1\frac{1}{4}$	$\frac{3}{8}$	1	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{13}{32}$
400	500000	$1\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{3}{4}$	$\frac{15}{16}$	$\frac{13}{32}$
600	1000000	2	$1\frac{3}{4}$	$\frac{7}{16}$	$1\frac{5}{8}$	2	$1\frac{3}{16}$	$\frac{17}{32}$

Wrought Type.

25- 50	6	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{3}{32}$	$\frac{5}{16}$	$\frac{7}{8}$	$\frac{3}{16}$	$\frac{3}{16}$
75-100	3	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
150	0	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{1}{8}$	$\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{11}{32}$
200	000	$1\frac{1}{16}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{8}$
300	300000	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{4}$	2	$\frac{5}{8}$	$\frac{13}{32}$

Ammeter.—In choosing an ammeter one must consider whether it is for a. c., d. c. milli-amperes, full current, or shunt. Special instruments are made for each of these conditions; they are also made recording.

Bond Tester.—This is an instrument made especially for testing the conductivity of rail bonds and rails.

Cable Testing Set.—Usually an instrument capable of locating faults in cables without cutting into the cable.

Capacity Testing Sets.—A portable insulating and capacity testing set is made by the Leeds and Northrup Co. Other cable testing sets can also be used for this purpose.

Current Transformers.—These instruments are used with a. c. circuits where large currents are to be measured; also with wattmeters.

Dynamometer.—This is a special form of galvanometer which may be used for very accurate measurements of either voltage, current or watts. It can also be used for testing capacity and inductance and other tests for which volt or ammeters may be used. It is used mostly for a. c. work.

Electrolytic Conductivity Apparatus.—The internal resistance of batteries can be measured by means of the Wheatstone Bridge, but slight errors are possible. To avoid these errors special apparatus has been constructed.

Electrometer.—This is an instrument the operation of which is based on electric charges; used in laboratories for measuring difference of potentials.

Frequency Meter.—Such instruments are used to determine the frequency of a. c. circuits. They may also be used as speed indicators.

Fault Finder.—This is a name given to certain special forms of testing instruments containing a battery and resistances and arranged to facilitate testing.

Galvanometer.—The galvanometer is a very delicate testing instrument and exists in a variety of forms. It is more delicate than the telephone receiver for d. c., and where there is much noise, but for fluctuating currents the latter is more serviceable.

Gauges.—Wire gauges are used for measuring the diameters of wires, sheet metal, etc. See description under this heading.

Ground Detectors.—Voltmeters and lamps are used for this purpose, as well as special electrostatic instruments.

Hydrometer.—This instrument is frequently required in testing battery solutions.

Illuminometer.—Illuminometers are of various kinds. Some of them are very simple and somewhat crude; others are good photometers, a little more simple and portable than the latter; usually calibrated in foot candles.

Induction Standards.—Self and mutual induction standards are used in connection with the Wheatstone Bridge for comparing inductances.

Iron Loss Watt and Voltmeters.—This is a special instrument made by the Westinghouse Co. for measuring the iron losses in transformers.

Keys.—For high potential or precision work specially constructed keys or switches are employed.

Lamp and Scale.—For reflecting galvanometers a special lamp and scale are often required.

Megger.—This is a trade name for a special testing set gotten out for general purposes.

Meter Testing Sets.—These are special plugs and connections to facilitate the testing of wattmeters.

Micrometer.—This instrument answers the same purpose as the wire gauge, but is much more accurate and can be used for very accurate measurements.

Multipliers.—These are resistances intended to be placed in series with voltmeters and which enable the voltmeters to be used for the measurement of higher voltages.

Ohm-meters.—This is a simplified form of Wheatstone Bridge and is used for the same purposes; measuring resistances, detecting faults, etc.

Oscillograph.—This is an instrument used for recording accurately the variation in the wave form of an alternating current or e. m. f.

Permeability Meter.—The permeability meter is used for testing samples of iron as to their magnetic reluctance, or permeability.

Phase Rotation Indicator.—This is an instrument used in determining direction of rotating field, or in connecting motors, etc.

Photometer.—This device is used to measure intensity or degrees of illumination. Some photometers are cumbersome laboratory instruments; others are portable.

Polarity Indicator.—This is an instrument used to determine the polarity of electric currents; also made to determine the polarity of magnets.

Potential Transformer.—This is a piece of apparatus used mostly for reducing the voltage by a fixed ratio so as to bring it within the range of instruments.

Power Factor Meter.—This piece of apparatus indicates the phase relation between the current and e. m. f. of the circuit, or generator, to which it is connected.

Pyrometer.—The pyrometer is used for measuring heat. Some pyrometers depend upon electrical principles for their action. They are sometimes used to determine the temperature of field coils.

Resistances.—Separately mounted resistances are sometimes used in connection with the Wheatstone Bridge and other instruments to enlarge their scope.

Rotating Standard.—This is a wattmeter in which a pointer moves rapidly, its movement being in proportion to the power consumed in the circuit at the time. It is especially designed to facilitate comparison of meters with it.

Sechometer.—This is an instrument used to measure coefficients of self-induction.

Shunts.—These are used in connection with ammeters and so chosen that only a predetermined portion of the total current shall pass through the meter.

Slide Wire Bridge.—This is a modification of the Wheatstone Bridge.

Standardizing Set.—This is usually an arrangement of instruments of high grade which may be used to calibrate or standardize other instruments.

Synchroscope.—This device indicates the phase difference between two currents or e. m. f.'s to which it is connected.

Tachometer.—This is a speed indicator, usually arranged to be held against end of shaft. When fitted also with a stop watch, it is known as a tachoscope.

Telefault.—This is a special type of testing instrument manufactured by Matthews & Bro., which enables certain tests to be made without cutting into the wires; can also be used for locating underground pipes.

Telephone Receiver.—The receiver is very sensitive to fluctuations in current strength and is much used for testing. With d. c. it gives only one click when current is switched on or off. Where there is much noise it is somewhat handicapped.

Thermometers.—These are used in testing machinery and wires. Specially constructed instruments are mostly used.

Voltameter.—An instrument measuring current strength by the amount of electrolyte decomposed.

Volt-ammeter.—An instrument capable of measuring both current and voltage.

Voltmeters.—They are used for measuring p. d. Not all are suitable for a. c. and d. c.; some are electrostatic, some read in milli-volts and are recording.

Wattmeters.—These are used for measuring power. Not all of them are suitable for d. c. and a. c.

Wheatstone Bridge.—This is the best known of all electrical testing instruments. With it more tests can be made than with any other device. It is, however, cumbersome and more difficult to handle than many of the other instruments.

Thawing Water Pipes.—Special stepdown transformers are generally used for a. c. and must have at least 200 amperes capacity for the smaller pipes and should have much more for larger ones. Storage batteries have also been used.

Theatres.—A full treatise on this subject is given in "Motion Picture Operation, Stage Electrics and Illusions."

Arc Pockets.—These should be wired with no smaller than No. 6; switched at the board, and open at the bottom to prevent accumulation of dirt. Large theatres can well use pocket capacity for twenty arc lamps. The pockets should be arranged off stage, as close to the scenery as practicable. Each pocket usually contains four circuits.

Auditorium.—Some auditoriums are thickly studded with lamps, the purpose being to produce decorative effects. In such cases frosted lamps are advisable. The actual illumination may be brought about by arc lamps, or large chandeliers. Unless decorative effects are striven for, one 50-watt lamp will furnish enough illumination for twenty seats. From two to ten fan motors should be provided for, according to size of theatre. It is impossible to arrange a system of direct lighting in connection with which some of the lights will not be in the range of vision of part of the audience at least. If the expense is not prohibitive cove, or indirect lighting, would be very serviceable. Cove lighting is very useful to show off decorations about proscenium arch.

Balcony.—In the balcony or gallery, provision for several arc lamps should be made. These should also be controllable from the main board. The ceilings in balconies are usually low, and lights must be kept well back to avoid range of vision of spectators. Use inverted lighting or small c.p. lamps kept well up at ceiling. Provide for fan motors.

Blinding Lights.—This is a row of lights sometimes placed about proscenium arch, the purpose being to blind the audience for a few moments to permit a quick change of scenery. Lamps of high intrinsic brilliancy should be used. If decorations are of a light color, or emergency lights must be kept burning, the plan is not very successful. Never frost lamps used for this purpose.

Borders.—From one to six borders, according to size and pretensions of house, are installed. Feed borders to center. Leave cables long enough so borders may be lowered to within five feet of stage floor. Use slow-burning wire and arrange for color circuits. Borders should be suspended by wire rope and insulated. Lamps are placed from six to twelve inch centers. The proportion of white and colored lamps is: two white, one red and one blue. Some borders are provided with a special circuit providing just light enough for rehearsals.

Bridges.—This is a name given to small galleries usually located at each side of proscenium and opening on stage side. Arc lamps are often operated from these bridges and arc pockets should be provided. This is also a good place from which to connect stage chandeliers.

Bunch Lights.—These lights are mostly fed out of stage pockets. The bunch circuits should be switched at the board, and some of them at least should be grouped with color circuits. Plugs used for incandescent circuits on stage should not be interchangeable with arc lamp plugs.

Canopies.—Most theatres are equipped with canopies in front of house. These are often studded with lights. Arrange for low-wattage lamps and have them frosted. Arrange lamps to be out of weather. Sometimes provision is made for lamps in glass signs; 1320 watts will be allowed per circuit with these lights if they are properly wired for.

Chandeliers.—Large chandeliers are often used in theatres. These should be hung so they may either be raised or lowered for renewal of lamps.

Curtain.—In large cities all theatres are fitted with heavy asbestos and steel curtains. These usually require motors to operate them. In some cities hydraulic operation is required. In some cases the drop curtain is also operated by motor.

Damper.—All good theatres are provided with stage dampers which can be instantly opened in case of a fire on the stage. It is customary to hold the damper closed by an electromagnet, and to place a switch on each side of stage, said switch when opened releasing the magnet and allowing the damper to open.

Dressing Rooms.—Arrange dressing room illumination without cords if possible. Provide circuit for flatiron. Cover each lamp with a strong locked guard. Arrange lights so that each side of face is illuminated by at least one lamp. Door switches are useful in dressing rooms.

Emergency Lighting.—Every theatre should have an emergency lighting system capable of furnishing sufficient light for the audience to leave the house in case the main system fails. The emergency system should be entirely independent of the other lighting and in no way connected with it. It is customary to provide capacity for about one 25-watt lamp for each 400 square feet of auditorium space. To this emergency system may also be connected a sufficient number of exit lights to indicate doors and fire escapes. Allow no key sockets, fan motors, or other devices on emergency lighting circuits.

Fire Alarm.—Provisions for fire alarm should be made. It is customary to connect the stage with the box office through a signal circuit that can be used for various purposes.

Fire Pump.—This is provided to insure good pressure in case of fire. It must be wired for in the most substantial and reliable manner.

Fly Floor.—This is that part of the gallery above stage, from which stage hands operate the curtains. A few lights only are needed, but they should be located convenient for men lounging between acts.

Footlights.—These form the most important and effective part of the permanently located stage lights. They must be very carefully located so as to illuminate the lower part of stage without obstructing the view of the audience. Lights are generally studded as thickly as possible, and about half of them arranged for white and the other half divided into two colors.

Galleries.—On these pockets for arc lamps, etc., are usually provided.

Grid.—This is the name given to that part of the rigging loft to which sheaves, etc., operating curtains and drops, are attached. Provide one light for each 400 square feet.

Lobby.—The lobby is usually very brilliantly illuminated, but the lights must be controlled by switches so that most of them may be turned out when the audience is inside. Provide side outlets for picture illumination, etc.; also for portable signs.

Orchestra Lights.—The largest theatres have about 100 outlets for orchestra lights. Less than twenty should not be considered in any first-class house. Place fuses on switchboard and arrange control so that one of the musicians can control lights in dark scenes.

Program Board.—This is an arrangement of lights by which the next number on the program can be given the audience. A special outlet at each side of stage should be provided for it. Run large conduit, as many wires must be accommodated.

Proscenium Side Lights.—These lights are arranged at each side of proscenium opening on stage side. Sometimes they are wired for three colors.

Retiring Rooms.—These are usually wired in imitation of homes, cozy corner effects, table lamps, etc. Illuminate pictures on walls.

Stage Switchboard.—The stage switchboard is usually located on right hand side of stage, facing the audience, and it is preferable to elevate it above stage level. The wiring of a good board should be divided into four parts, each independent of the others. All of the house lights should be controlled by one main switch; the footlights and all of the upper part of stage lighting by another, and the stage pockets by a third. In addition to this there should be a division to which lights that remain in use all of the time are connected. The stage lighting is again divided into three color groups, the white lights being equal numerically to all of the colored lights.

A list of the circuits which should be independent of all others and make up group four is given in the following:

Dusting circuit.	Fan motor circuit.
Ventilating motor circuit.	Curtain motor.
Orchestra lights.	Dressing room circuits.
Program lights.	Electric signs
Fly floor lights.	Rigging loft lights.
Pilot lights.	

Fig. 29 shows a well-laid-out switchboard. All of the lights in the auditorium are controlled by switches shown in the upper right hand corner, and all of these are under control of the main switch. House lights are usually operated as a unit.

The stage pockets are controlled by the bank of switches shown at F. Lights burning off of stage pockets are generally controlled by special operators or by actors, so that switches need not be so very convenient to switchboard operator. He must, however, have them under his control. In the arrangement shown in Figure 29 the white lights predominate in the ratio of two to one, and are laid out in two groups, *A* and *B*. Both groups are controlled by the switch *C*. The switches *A* and *B* do not control the lights at all if the smaller throw-over switches at the right are thrown downward. A diagram of these switches is given in Figure 30, where the switches *B* and *C* are indicated. The object of the switches *A* and *B* is to help in quickly increasing or decreasing the illumination on the stage. If in the beginning of a certain scene, for instance, only a small quantity of light is wanted, the low illumination may be obtained by throwing the proper switches down; the additional illumination which will be wanted a few minutes later may be prepared for by setting the other switches needed to the upward position and at the proper

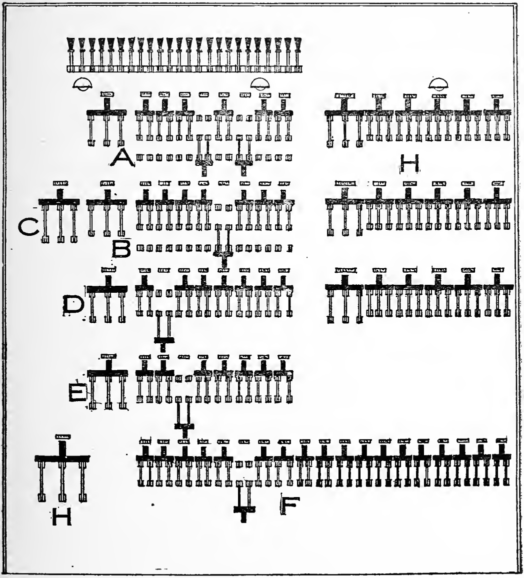


Figure 29.—Stage Switchboard.

moment closing switch *B*. In the same way, by a reversal of the process, the illumination may be instantly reduced. This feature is very valuable in many stage settings. To throw off all of the white lights the switch C must be opened. The switches D and E are main switches controlling the colored lamps. All lamps of one color should be connected to one or the other of these switches.

From these three groups of switches circuits extend into all borders, proscenium side lights and footlights, so that the color scheme may be carried out in any or all of them.

The handles of all switches in the same row should be of the same height. Switches should be extra heavy. Dimmer handles should be located directly above switches controlling them.

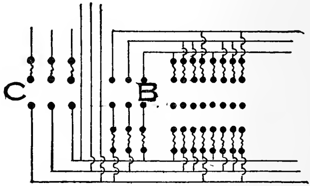


Figure 30.

The fuses or switches controlling lights not usually manipulated by switchboard operator are generally worked into the vacant spaces between the groups mentioned above.

All branch circuits are preferably located behind the board. This will allow of trouble being instantly rectified.

Transformers.—The transformer capacity which must be provided ranges from .20 to .80 percent of the connected load.

The full load efficiency of transformers varies from about 0.95 to 0.985. The smaller transformers are less efficient than the larger, cost more per K. W., and give poorer regulation. Their installation is, however, much more economical in regard to wire.

Transformers are properly rated in kilo-volt-amperes (K.V.A.). They cannot accurately be rated in K. W. (although this term is often used), because the wattage depends upon the power factor, which is governed mainly by the load and line to which the transformer is connected. The efficiency of a transformer can be found by dividing the output by the input.

The polarity is generally such that the current is entering the primary side at the same time it is leaving the secondary side corresponding to it. Oil cooled transformers are the most reliable, but should not be used where overflowing oil could do harm.

The principal losses are the core or iron losses and the copper losses. The iron losses are the most important in transformers which are idle but connected the greater part of the time. Iron losses are continuous while the transformer is connected, whether it is delivering power or not. The copper losses take place only at time current is being used. The drop in voltage caused by them is proportional to the current, while the power loss is proportional to the square of the current. The iron losses are not of much importance at time of full load, but at this time the copper losses are the most disturbing.

The core losses can be ascertained by measuring the current delivered to the primary side while the secondaries are open and noting the percentage of this to the full load current.

The copper loss can be found by applying voltage enough to the primary wires to cause the full load current to flow in the secondary, which must be short-circuited. This power must be measured by a watt meter and the percentage to the total power noted.

Test all transformers for insulation before connecting.

All transformers should have their secondaries grounded, preferably at some neutral point. Shells of transformers should also be grounded.

Tables for Determining the Most Economical Number and Location of Transformers.—In a territory which has but few customers, and these somewhat scattered, each transformer constitutes a system by itself and is not connected to any other transformer. As the number of customers increases it becomes necessary either to extend the lines from one transformer or provide additional transformers and transfer part of the load to them. If the number of customers keeps on increasing, the mains from the various transformers soon meet, and may then be connected together, although, if transformers are far apart, there is no great advantage in this. Under these circumstances we have a number of transformers feeding a common line extending along a street. Finally, if the customers still increase, or the load becomes greater, lines must be run on cross streets and these are connected to the others and we have a network of wires. In all three stages of the evolution of a secondary system of distribution, the determination of the most economical arrangement of conductors and transformers is an important one. To keep the cost of wiring down to a minimum we must install a large number of small transformers. Small transformers are, however, more expensive in proportion to their capacity than large ones; and full load, as well as all-day efficiency, is also much lower.

The most economical arrangement from the point of view of first cost of installment is that with which the investment for wires plus the investment for transformers is a minimum. There are three different conditions under which it may be necessary to determine the most advantageous location of transformers: The first is that where a secondary system exists at the terminus of a primary extension. Since the secondary wires usually carry about ten times as much current as the primary, it is generally economical to extend the primary line to the center of the secondary system. If, for instance, the secondary system consists of a straight run, by doing this we may use a wire with four times the impedance that would be required if the transformer were at one end, or with a given wire, we may distribute four times the current for the same drop in voltage.

These observations also hold good in case a number of transformers are to feed a continuous main. If we double the number of transformers, we quadruple the capacity of our wires or divide the drop by 4, provided, of course, they are evenly spaced throughout.

When the secondary system finally reaches the network stage and, if we assume wires leading out from each transformer in four directions with an equal load in each, we should be able to do with wire of sixteen times the impedance of the first-considered case. There, is however, no great advantage in using such small wires, and at this stage large transformers are indicated. The whole network of wires is also interconnected so that current from any one transformer tends to distribute toward any part in which an area of low potential develops.

In order to facilitate calculations concerning secondary lines the following tables have been prepared. By their use, if we assume even distribution of current, and even distance between distributing points, the drop at any part can be easily determined. In the lower table, LXXXVI, we have given the impedances for one ampere of 100 feet of line at 60 cycles and of various sizes of wire and at various separations. In the upper table, LXXXIV, are given multipliers with which to multiply these impedances. It is assumed that the secondary line extends over a certain number of poles, and that at each of these poles a certain number of amperes are taken off. In order to use this table we select the horizontal line pertaining to the number of poles covered by the line, and in it select the number found where the vertical line pertaining to the pole at which we wish to determine the drop, crosses it. Multiplying this number by the current assumed to be taken off at each pole and by the impedance of the wire, we obtain the drop in voltage at this pole.

Example: We have a line extending over six poles (100 feet apart) and wish to find the drop at the third pole. We find the number 15 where the two lines cross; our wire is No. 1 and the separation 36 inches while the current at each pole is 5 amperes; we have then for our drop $15 \times 0.036 \times 5 = 2.7$ volts.

In case we wish to determine the smallest wire that can be used under similar circumstances or conditions, we use the formula

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

in which Z is the impedance of the wire to be used, V the volts to be lost, I the current and K a number selected from the table as explained above.

Values of $\frac{V}{I K}$ have been calculated for all of the figures given in Table LXXXIV, and in order to find the smallest wire to deliver any amperage considered over any number of poles given, and at the desired loss, it is but necessary to follow the horizontal line pertaining to the proper constant K until it crosses the vertical line pertaining to the amperes to be transmitted, and at this place we find the impedance of the wire, which will give us the drop of 2.7 volts. By referring the impedance to the table of impedances we can then select the proper size of wire. These tables enable us to make trial calculations very rapidly, and we can thus easily determine the most economical arrangement of conductors and transformers.

Example: Suppose we have twelve poles spaced 100 feet apart, and at each pole 5 amperes are to be used, while the drop must nowhere be greater than 2.2 volts. Is it cheaper to feed this line with one large transformer or with two small ones? Placing the large transformer at about the center, we have six poles on one side and five on the other. In table LXXXIV for the sixth pole we find the constant 21, and in table LXXXV, where the line pertaining to this constant crosses with that pertaining to 5 amperes, we find the impedance 0.021. Looking up table LXXXVI for a corresponding impedance under 12-inch separation, we find 0.022 as the nearest, and that a 0000 wire is needed to come that near to our purpose. On the other side of the transformer we have only five poles, and the constant for this is 15, which in the same way we find requires an impedance of 0.029 or a No. 0 wire. Making the calculations for two transformers, and for a continuous main, we may use the constant for the third pole, which is 6. Looking this up as before, we find an impedance of 0.07, which indicates a No. 5 wire continuous main for us. In order to find which is the cheapest we must now balance 1,100 feet of No. 5 wire and two 30-ampere transformers against 600 feet of 0000 wire plus 500 feet of No. 0, plus one 60-ampere transformer.

Tables for calculating the most economical arrangement of transformers and conductors.

TABLE LXXXIV

Number of poles covered by line	Transformer pole not counted. 1st Pole	2nd	3rd	4th	5th	6th
1	1					
2	2	3				
3	3	5	6			
4	4	7	9	10		
5	5	9	12	14	15	
6	6	11	15	18	20	21

TABLE LXXXV

Showing Values of $\frac{V}{IK}$

Constants K	Amperes 1	2	3	4	5	6	7	8	9	10	12	15
1	2.20	1.10	.733	.550	.440	.367	.314	.275	.244	.220	.183	.147
2	1.10	.550	.366	.275	.220	.183	.157	.138	.122	.110	.091	.073
3	.733	.366	.244	.183	.147	.122	.104	.092	.081	.073	.061	.049
4	.550	.275	.183	.137	.110	.092	.078	.069	.061	.055	.046	.037
5	.440	.220	.146	.110	.088	.073	.063	.055	.049	.044	.037	.029
6	.366	.183	.122	.092	.073	.061	.052	.046	.041	.037	.030	.024
7	.314	.157	.105	.079	.063	.052	.045	.039	.035	.031	.026	.021
9	.244	.122	.081	.061	.049	.041	.035	.031	.027	.024	.020	.016
11	.200	.100	.067	.050	.040	.033	.029	.025	.022	.020	.017	.013
12	.183	.092	.061	.046	.037	.031	.026	.023	.020	.018	.015	.012
14	.157	.078	.052	.039	.032	.026	.022	.020	.018	.016	.013	.010
15	.147	.074	.049	.037	.029	.024	.021	.018	.016	.015	.012	.010
18	.123	.061	.041	.031	.025	.021	.018	.016	.014	.012	.010	.009
20	.110	.055	.037	.028	.022	.017	.016	.014	.012	.011	.009	.007
21	.105	.052	.035	.027	.021	.017	.015	.013	.012	.010	.009	.007

TABLE LXXXVI

Showing Impedance Per Run of 100 Feet; 60 Cycles.

B. & S.	Separation in Inches. ½	6	12	24	36	B. & S.	Separation in Inches. ½	6	12	24	36
8	.126	.127	.128	.128	.128	1	.026	.031	.033	.035	.036
6	.081	.082	.083	.083	.084	0	.021	.027	.029	.031	.033
5	.066	.068	.069	.070	.071	00	.017	.023	.026	.028	.030
4	.051	.054	.055	.056	.057	000	.014	.021	.024	.026	.028
3	.041	.044	.046	.047	.048	0000	.011	.019	.022	.025	.027
2	.032	.038	.040	.041							

An inspection of table LXXXVII will show that large transformers have a much higher all-day efficiency than small ones; for instance, by placing one 4-K.W. transformer in place of four of 1 K.W.'s, we raise the efficiency (assuming the full load to be used three hours per day) from .84 to .91. In addition to this we also gain some in capacity, for the greater the number of customers connected to a transformer the greater will be the diversity factor. If we have a large number of small residences connected to one transformer, we need provide only about one-fourth the capacity of the connected load, whereas if we have one transformer for each customer we should be called upon for nearly the whole connected capacity. This gain in capacity comes in to such a marked extent only as long as we are dealing with transformers which are about fully loaded by one customer. As soon as the number of customers on any transformer reaches about twenty, they can be served with a transformer capacity which a larger number will not materially improve. A transformer capacity of one-fourth of the connected load will be sufficient for residence or flat lighting, but for stores, churches, and theatres a special study should be made as to what the maximum load of each is, and whether they are likely to occur at the same time.

The use of larger transformers effects a saving in cost of transformers and in operating expenses, but entails a greater outlay for conductors, and to find which is the more economical we must balance the increased cost against the saving, and the most economical arrangement will be that in connection with which the value of the energy lost equals the interest on the investment of capital that must be made to save it. This must be found by trial calculations, and the various tables given will facilitate the calculations. It will, however, seldom be necessary to make such calculations, for in the first place the regulation of incandescent lamps limits us to a drop of about 2 volts, which alone requires the use of comparatively large wires; in the second place very low efficiency comes in only where the transformers are idle a large part of the time. This condition, even with low efficiency, causes only a nominal loss of power.

TABLE LXXXVII

Table Showing All Day Efficiency of Various Commercial Sizes of Transformers Used for Various Hours Per Day.

Equivalent Full Load Hours Per Day.

K.W.	1	2	3	6	9	12	18	24
1	.66	.78	.84	.89	.92	.93	.94	.96
1½	.70	.81	.86	.90	.93	.94	.96	.96
2	.72	.84	.88	.93	.94	.95	.96	.96
3	.77	.86	.90	.94	.95	.96	.96	.97
4	.79	.87	.91	.94	.95	.96	.96	.97
5	.81	.88	.92	.95	.95	.96	.96	.97
7½	.82	.90	.92	.95	.96	.97	.97	.97
10	.83	.90	.93	.96	.96	.97	.97	.97
15	.85	.91	.93	.96	.97	.97	.97	.98
20	.86	.91	.94	.96	.97	.97	.97	.98
25	.87	.92	.94	.96	.97	.97	.97	.98
30	.87	.93	.95	.96	.97	.97	.97	.98
40	.88	.93	.95	.96	.97	.97	.97	.98
50	.89	.94	.96	.97	.98	.98	.98	.98

Trolley Lines.—Trolley wires range in size from 0 to 0000; No. 0 is seldom used and 00 and 0000 are the most used.

Standard voltages d-c. are 600 and 1,200; a-c., 3,300, 6,600, and 11,000. A trolley system usually consists of feeders, trolley, and track return. The track return is often reinforced with negative feeders, and negative boosters are also used. (See also *Electrolysis.*)

The height of trolleys ranges from about 15 to 22 feet above the street; 22 feet is about the minimum allowed above tracks.

Trolley sections range from a few hundred yards to several miles in length; heavy traffic zones are usually fitted with short sections. Poles range from 30 to 40 feet in length, and wooden poles usually have 7-inch tops. The rake of poles varies from 4 to 12 inches, according to nature of soil.

There are various ways of trolley wire connections.

The trolley may be run alone; it may be reinforced by feeders, trolley and feeders being in parallel, or

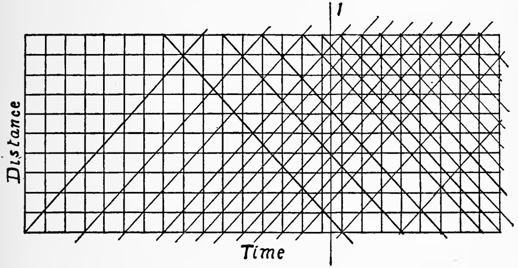


Figure 31.—Train Sheet.

it may be cut in sections, each section being fed by its own feeder. Alternating current systems do not usually have any secondary feeders. The drop allowed in d-c. systems ranges from 10 to 25 per cent; for a-c. systems it is 5 to 10 per cent.

The current used at any point can be approximately determined by use of the "train sheet" illustrated in Figure 31. The height of the figure represents the length of the road or of any part of it to be considered. The width of it may represent the length of time during which the load is to be determined.

For each car, or train, entering a section of trolley, draw a line beginning with the time the car enters the section at the bottom and to meet the time point at the top at which it leaves that section. Draw lines beginning at the top of the figure in the same manner for all cars moving in the opposite direction. These lines will then cross, and to find the load on this section at any desired time, it is only necessary to draw an ordinate such as 1 at that point and count the number of car lines this crosses. This will give the number of cars fed over this section of trolley at that time, and the maximum current used can be easily determined.

TABLE LXXXIX

Table Showing Drop in Voltage Per 100 Amperes for Distance Given.

	Feet				Miles				
B. & S.	1,000	2,000	3,000	4,000	1	2	3	4	5
0	11.9	23.8	35.7	47.6	62.8	125.6	188.4	251	314
00	9.44	18.9	28.3	37.8	49.8	99.6	149.	199	249
000	7.48	15.0	22.4	29.9	39.5	79.0	118.	158	198
0000	5.94	11.9	17.8	23.8	31.4	62.8	71.4	126	157
C. M.				D. C. Only.					
500000	2.513	5.0	7.5	10.5	13.26	26.5	39.8	53.0	66.3
1000000	1.256	2.51	3.7	5.0	6.63	13.3	19.9	26.6	33.2
2000000	0.628	1.26	1.88	2.51	3.31	6.6	10.0	13.2	16.6
3000000	0.419	0.84	1.26	1.67	2.21	4.4	6.6	8.8	11.0
4000000	0.315	0.63	0.95	1.26	1.65	3.3	5.0	6.6	8.3
5000000	0.251	0.50	0.75	1.00	1.33	2.65	4.0	5.3	6.6

TABLE LXXXX

Table Showing P.D. on Return for Distances Above.

Wt. of Rails Per Yard. 2 Rails Used.									
40	1.23	2.46	3.69	4.92	6.5	13.0	19.5	26.0	32.5
45	1.09	2.18	3.27	4.36	5.8	11.6	17.4	23.2	29.0
50	0.98	1.96	2.94	3.92	5.2	10.4	15.6	20.8	26.0
60	0.81	1.62	2.43	3.24	4.3	8.6	12.9	17.2	21.5
70	0.70	1.40	2.10	2.80	3.7	7.4	11.1	14.8	18.5
80	0.61	1.22	1.83	2.44	3.2	6.4	9.6	12.8	16.0
90	0.55	1.10	1.65	2:20	2.9	5.8	8.7	11.6	14.5
100	0.49	0.98	1.47	1.96	2.6	5.2	7.8	10.4	13.0
110	0.45	0.90	1.35	1.80	2.4	4.8	7.2	9.6	12.0

The copper loss calculations are based on resistivity of hard drawn copper at 65° C 149° F.

Rails are supposed to be standard and of specific resistance of 10 times that of copper.

The losses in return circuit will be less than indicated because part of current returns through piping and earth.

The combined drop in conductors and rails in parallel is

equal to $\dfrac{1}{\frac{1}{d}+\frac{1}{d^1}+\frac{1}{d^2}}$ where d, d^1, d^2, etc., represent the drop in the different conductors.

The impedance of the rails at 25 cycles is said to be from 6 to 7 times as high as the ohmic resistance.

Impedance of trolley=1.5 times ohmic resistance.

Tables LXXXIX and LXXXX have been especially prepared to facilitate calculations concerning drop in trolley circuits. Every trolley circuit consists of three elements: trolley proper, its feeders and the track return, and in order to effect distribution economically, it is necessary to consider all of these separately.

The upper part of table LXXXIX gives the drop in voltage caused by the trolley proper, and the lower part that caused by feeders, either overhead to reinforce trolley or underground to help out track rails, and table LXXXX the drop caused by the iron rails. The calculations have not been carried out for a-c. because the circuits used for this method of transmission differ materially from d-c. systems. In a-c. systems the ground return may be considered as made up of a number of comparatively short sections, the current returning not to the central station but to its transformer. This is also true of the trolley. With energy distributed at 25 cycles, the drop caused by the rails will be about 6.5 times as great as for d-c. and that in the trolley about 1.5 times. The drop caused by trolley and feeders, when they are in parallel, is equal to the reciprocal of the sum of the reciprocals of their lines. This is also the case with track rails and their reinforcement.

As far as these are used in series the various losses must be added.

The use of the tables can perhaps be best made clear by an example.

Example: The train sheet shows that 1,200 amperes will be required on a certain section of trolley one mile long and fed in the center by a feeder two miles long. The loss at far end of trolley must not exceed 15 per cent of the voltage, which is 600. The rails weigh 100 lbs. per yard, and the difference in potential between any two points must not exceed 5 volts. What size of feeder and reinforcement of track rails will be necessary?

Table LXXXIX shows that a 0000 trolley wire will cause a drop of 31.4 volts in one mile per 100 amperes. Our trolley is fed in the center and must be considered one-half mile long; each half carries half of the current, viz., 600 amperes; therefore, the drop caused by a 0000 trolley will be six times the drop in half a mile, or, according to our table, 94.2 volts. This alone is more than 15 per cent of our voltage, 600, hence we must divide our trolley into shorter sections. Making two sections out of the same length, or feeding it in two places, will give us a loss equal to 300 amperes for one-fourth mile, or just one-fourth of what we had before, viz., 23.6 volts lost in trolley.

We have next to deal with the size of feeder, and are allowed a loss of slightly over 60 volts in it. The loss in feeders two miles long is given in table LXXXX, and we may use any feeder the loss of which, multiplied by 12, does not exceed 67 volts.

12 times 6.6 equals 79.2, and is the loss caused by a 2,000,000-cm. cable. This we must not use, but the next larger one will give us a loss of only 52.8, and this, added to the trolley loss, makes a total of 76.4 volts. If it is desired to lose the full 90 volts a smaller trolley wire may now be considered.

The loss in one mile of 100-lb. track is 2.6 volts per 100 amperes, which makes 31.2 for 1200; a 5,000,000-cm. cable causes a drop of twelve times 1.33, or 15.96 volts. The drop caused by both in parallel will be the reciprocal of the sum of the reciprocals. By the table of reciprocals we find the reciprocal of 31.2 is, roughly, 0.032051, and that of 15.96 is 0.062500. Adding these, we have 0.094, approximately. The number corresponding to this from the same table is 10.6, which is more than two times too high. Let us now consider the use of two 5,000,000 cables. The drop in the cables will be just half of what it was before, or about 8. The reciprocal of 8 is 0.01250; this added to 0.032 gives us 0.157, and the number corresponding to it is about 6.4. This is still above what we require, but it must be borne in mind that not all of the current returns over the rails and negative feeders, hence, this will give us about the right p.d. The loss in trolley lines, track, and feeders can be lessened very much by increasing the number of substations from which they are fed, and the most economical arrangement can be determined by the same calculations laid out for locating transformers.

Underground Construction.—Underground conductors are usually lead encased and as the lead is not very strong it is best to run the conductors in some form of conduit which protects them and facilitates removal in case of trouble. These conduits usually consist of some kind of clay, concrete or fiber, and their heat conductivity is generally not as good as that of moist earth. Conduits arranged as shown in Figure 32 carry away more heat than those shown at Figure 33, but if there are many of them they also require more trench area.

All conduits should be arranged to drain, and at suitable intervals should be provided with splicing chambers. If space between them is to be filled with concrete they must be anchored to prevent floating.

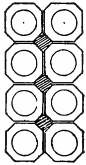


Figure 32.

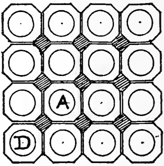


Figure 33.

Underground Ducts.

The following tables and information is taken from Handbook No. 17 of the Standard Underground Cable Co. (Copyright by Standard Underground Cable Co., 1906).

Recommended Current Carrying Capacities for Cables, and Watts Lost per Foot, for each of four equally loaded single conductor paper insulated lead covered cables, installed in adjacent ducts in the usual type of conduit system where the initial temperature does not exceed 70° F. (21.1° C.), the maximum safe temperature for continuous operation being taken as 150° F. (65.5° C.).

TABLE LXXXXI

Size B. & S.	Safe Current in Amp.	Watts Lost Per Ft. at 150° F.	Size B. & S. or C. M.	Safe Current in Amp.	Watts Lost Per Ft. at 150° F.	Size Circular Mils.	Safe Current in Amp.	Watts Lost Per Ft. at 150° F.
14	18	0.97	2	125	2.77	900000	650	5.71
13	21	1.03	7	146	3.00	1000000	695	5.86
12	24	1.09	0	168	3.23	1100000	740	6.01
11	29	1.15	00	195	3.46	1200000	780	6.13
10	33	1.25	000	225	3.69	1300000	820	6.25
9	38	1.39	0000	260	3.92	1400000	857	6.37
8	45	1.53	300000	323	4.22	1500000	895	6.49
7	53	1.67	400000	390	4.61	1600000	933	6.61
6	64	1.85	500000	450	4.91	1700000	970	6.73
5	76	2.08	600000	505	5.16	1800000	1010	6.85
4	91	2.31	700000	558	5.36	1900000	1045	6.97
3	108	2.54	800000	607	5.56	2000000	1085	7.09

Assuming that unity (1.00) represents the carrying capacity of single-conductor cables, the capacity of multi-conductor cables would be given by the following:

2 Cond., flat or round form, 0.87; concentric form, 0.79.

3 Cond., triplex form, 0.75; concentric form, 0.60.

The following experiment on duplex concentric cable of 525,000 c. m. indicates clearly the danger in subjecting this type of cable to heavy overloads of even short duration. The cable was first heated up by a current of 440 amperes for five hours. An overload of 50 per cent was then applied, the results in degrees Fahrenheit above the surrounding air being as follows:

Time from start	0 min.	15 min.	30 min.	45 min.	60 min.	90 min.
Inner condr...	70°	84°	98°	111°	123°	142°
Outer condr...	55°	65°	76°	85°	94°	108°
Lead cover...	31°	35°	40°	45°	49°	57°

As it is the final temperature reached which really affects the carrying capacity, the initial temperature of surrounding media must be taken into account. If, for instance, the conduit system parallels steam or hot water mains, the temperature of 150 F., which we have assumed in the table to be the maximum for safe continuous work on cables, will be reached with lower values of current than would otherwise be the case; and as 70 is the actual temperature we have assumed to exist in the surrounding medium prior to loading the cables, any increase over 70 must be compensated for by reducing the current.

For rough calculations it will be safe to use the following multipliers to reduce the current carrying capacity given in table LXXXXI to the proper value for the corresponding initial temperatures.

Initial temp. F.	70°	80°	90°	100°	110°	120°	130°	140°	150°
Multipliers ...	1.00	0.93	0.86	0.78	0.70	0.60	0.48	0.34	0.00

When a number of loaded cables are operating in close proximity to one another, the heat from one radiates, or is carried by conduction, to each of the others, and all are raised in temperature beyond what would have resulted had only a single cable been in operation. And if the cables occupy adjacent ducts in a conduit system of approximately square cross-section laid in the usual way, the centrally located cable or the one just above the center in large installations (*A* in Figure 32) will reach the highest temperature. This is equivalent to saying that its current carrying capacity is reduced and while this reduction does not amount to more than 12 per cent (as compared with the cable most favorably located, *D*, Figure 32) in the duct arrangement given it may easily assume much greater proportions where a large number of cables are massed together.

Assuming that not more than twelve cables, arranged as shown in Figure 32, can be used, the average carrying capacity may be taken as the criterion for proper size of conductor, and for cables of a given type and size the carrying capacities of all cables, even though placed in adjacent ducts, will be represented by the following figures, taking unity as the average carrying capacity of four cables. (See Table LXXXXI.)

Number of cables	2	4	6	8	10	12
Multiplier	1.16	1.00	0.88	0.79	0.71	0.63

Recommended Power Carrying Capacity in Kilowatts of Delivered Energy.—The tables below are based on the carrying capacities of cables as given in Table LXXXXI. A power factor of unity was used in the calculations and hence the values found in the lower table are correct for direct current. For alternating current the kilowatts given must be multiplied by the power factor of the delivered load.

Units.—Synopsis of units and symbols in general use.

Unit	Name	Symbol	Defining Equation: Direct Current	Defining Equation: Alternating Current
Electromotive force	Volt	E, e	IR	IZ
Current	Ampere	I, i	$E \div R$	$E \div Z$
Resistance	Ohm	R, r	$E \div I$	$\sqrt{Z^2 - X^2}$
Power	Watt	P	EI	$EI \times$ p. f.
Impedance	Ohm	Z, z		$\sqrt{R^2 + X^2}$
Reactance	Ohm	X, x		$\sqrt{Z^2 - R^2}$
Inductance	Henry	L, l	$\Phi \div I$	
Capacity	Farad	C, c	$Q \div E$	$Q \div E$
Quantity	Coulomb	Q, q	$I \times$ time	$I \times$ time
Admittance	Mho	Y, y		$I - Z = \sqrt{G^2 + B^2}$
Conductance	Mho	G, g	$I \div R$	$R \div Z^2 = \sqrt{Y^2 - B}$
Susceptance	Mho	B, b		$X - Z^2 = \sqrt{Y^2 - G^2}$

TABLE LXXXXII

Three Conductor, Three-Phase Cables.

Size in B. & S.	Volts. 1100	2200	3300	4000	6000	11000	13200	22000
	Kilo-Watts.							
6	92	183	275	333	549	915	1098	1831
5	109	217	326	395	652	1087	1304	2174
4	130	260	390	473	781	1301	1562	2603
3	154	309	463	562	927	1544	1854	3089
2	179	358	536	650	1073	1788	2145	3575
1	209	418	626	759	1253	2088	2506	4176
0	240	481	721	874	1442	2402	2884	4805
00	279	558	836	1014	1674	2788	3347	5577
000	322	644	965	1172	1931	3217	3862	6435
0000	372	744	1115	1352	2231	3717	4462	7435
250000	413	827	1240	1503	2480	4132	4960	8264

Single Conductor Cables, A. C. or D. C.

	Volts. 125	250	500	1100	2200	3300	6600	11000
	Kilo-Watts.							
6	8.0	16.0	32	70	141	211	422	704
5	9.5	19.0	38	84	167	251	502	836
4	11.4	22.8	45	100	200	300	601	1001
3	13.5	27.0	54	119	238	356	713	1188
2	15.6	31.2	62	138	275	413	825	1375
1	18.3	36.5	73	161	321	482	964	1606
0	21.0	42.0	84	185	370	554	1109	1848
00	24.4	48.8	97	215	429	644	1287	2145
000	28.1	56.3	113	248	495	743	1485	2475
0000	32.5	65.0	130	286	572	858	1716	2860
300000	40.4	80.8	162	355	711	1066	2132	3553
400000	48.8	97.5	195	429	858	1287	2574	4290
500000	56.3	112.5	225	495	990	1485	2970	4950
600000	63.1	126.3	253	556	1111	1667	3333	5555
700000	69.8	139.5	279	614	1228	1841	3683	6138
800000	75.9	151.8	304	668	1335	2003	4006	6677
900000	81.3	162.5	325	715	1430	2145	4290	7150
1000000	86.9	173.8	348	764	1529	2294	4587	7645
1100000	92.5	185.0	370	814	1628	2442	4884	8140
1200000	97.5	195.0	390	858	1716	2574	5148	8580
1400000	107.1	214.3	429	943	1885	2828	5656	9427
1500000	111.9	223.8	448	985	1969	2954	5907	9845
1600000	116.6	233.3	467	1026	2053	3079	6158	10263
1700000	121.3	242.5	485	1067	2134	3201	6402	10670
1800000	126.3	252.5	505	1111	2222	3333	6666	11110
2000000	135.6	271.3	543	1194	2387	3581	7161	11935

Ventilation.—Ventilation for the purpose of providing a certain quantity of fresh air to occupants of rooms or shops requires the apparatus to be in use continuously while the rooms are occupied, regardless of temperature. Where it is provided mainly to carry off surplus heat, it is used only in warm weather. The capacity in such cases must be sufficient to take care of the hottest weather.

The quantity of air moved by any fan varies directly as the speed, but the power required to run the fan varies as the cube of the speed. The net result is that the cost of moving different volumes of air by any given fan varies about as the square of the speed at which the fan must operate to move it. This is the theoretical relation, but this is somewhat disturbed by the difference in efficiency of large and small motors operating at various speeds. Owing to the above facts it is often a difficult task to decide whether it is more profitable to install a small, cheap fan and run it at a high rate of speed, or to provide a more expensive one and operate it at a lower cost per unit of air moved. Which is the more profitable in the long run depends upon the number of hours per year the fan is to be used at its various speeds. In any case the most economical ventilator will be the one in connection with which the cost of energy saved per year will equal the interest charge upon the investment of capital necessary to provide it in place of the cheapest fan which can do the work. The following tables are taken from publications of the American Blower Co. and give all the necessary data for comparison of various fans. In order to find the most economical fan select the smallest fan capable of moving the requisite amount of air and note the K.W. necessary to run it (divide H.P. given by 1.3). Next select some larger fan and note the K.W. necessary to move the same volume of air with this fan and subtract it from the first. The next step is to find the value of the annual saving, by multiplying the number of hours per year this power is used by the rate per K. W. Having found this, if we divide it by the rate of interest applicable, we shall obtain the sum of money which we can afford to spend to substitute this fan in place of the smallest one we were considering. The rate of interest by which we must divide is determined by the number of years the installation is to remain in use and is as follows:

One year, 1.06 per cent; 2 years, .57; 3 years, .40; 4 years, .32; 5 years, .27; 6 years, .24; 7 years, .21½; 8 years, .20; and 9 years, .18¾.

We have now the following formula by which we can determine the amount of capital which can with profit be invested in a larger fan:

$$C = \frac{\text{K. W.} - k.\,w. \times h \times r}{\%}$$

where C = capital to be invested; K. W. − $k.\,w.$ = the saving in energy per hour, and h and r = the number of hours per year and rate per K. W. hour of energy.

In case the fan is used intermittently at various speeds the calculations should be made accordingly, since the power required at high speeds is much greater than at low speeds. The capacity of a fan used only to provide a sufficient quantity of fresh air is best determined by allowing from 30 to 50 cubic feet of air per minute for each adult, and from 20 to 35 for each child. In special places such as hospitals this quantity is often doubled. The maximum quantities given will secure ample ventilation for all ordinary persons. In public places such as toilet rooms, waiting rooms, etc., it is customary to require from three to six changes of air per hour.

TABLE LXXXXIII

"Ventura" Disc Ventilating Fans.

General Capacity Table.—American Blower Co.

Capacities, Speeds and Horse Powers with Unobstructed Inlet and Discharge.

No. of Fan		Velocity of Air in Feet per Minute. 600	900	1200	1500	1800	2100
3	Cu. Ft. Per Min..	950	1420	1895	2370	2840	3320
	Pres. Ins. W. G..	.0225	.055	.09	.1406	.2025	.2755
	R. P. M.........	625	980	1255	1565	1880	2190
	H. P.	.0097	.036	.079	.153	.265	.42
4	C. F. M.........	1620	2430	3240	4050	4860	5670
	Pres. ins........	.0225	.055	.09	.1406	.2025	.2755
	R. P. M.........	470	735	945	1175	1410	1645
	H. P............	.0168	.062	.13	.262	.455	.72
5	C. F. M.........	2500	3750	5000	6250	7500	8750
	Press. Ins.......	.0225	.055	.09	.1406	.2025	.2755
	R. P. M.........	375	585	755	938	1125	1310
	H. P............	.026	.095	.207	.405	.701	1.10
6	C. F. M.........	3560	5350	7125	8900	10700	12500
	Press. Ins.......	.0225	.055	.09	.1406	.2025	.2755
	R. P. M.........	315	492	632	786	945	1100
	H. P............	.037	.136	.295	.575	1.00	1.59
7	C. F. M.........	4800	7200	9600	12000	14400	16800
	Press. Ins.......	.0225	.055	.09	.1406	.2025	.2755
	R. P. M.........	268	419	537	669	803	936
	H. P............	.05	.182	.398	.776	1.345	2.13
8	C. F. M.........	6250	9375	12500	15600	18750	21850
	Press. Ins........	.0225	.055	.09	.1406	.2025	.2755
	R. P. M.........	234	366	470	584	702	817
	H. P............	.065	.237	.516	1.01	1.75	2.77
9	C. F. M..........	7875	11800	15700	19650	23600	27500
	Press. Ins........	.0225	.055	.09	.1406	.2025	.2755
	R. P. M.........	209	326	419	521	626	730
	H. P............	.082	.30	.65	1.27	2.20	3.48

TABLE LXXXXIV

Capacities, Speeds and Horse Powers with Resistance of Average Piping System.

No. of Fan		Velocity of Air in Feet per Minute. 600	900	1200	1500	1800	2100
	Cu. Ft. Per Min..	950	1420	1895	2370	2840	3320
3	Press. Ins. W. G..	.06	.15	.24	.37	.53	.73
	R. P. M.........	716	1075	1435	1790	2150	2510
	H. P............	.022	.085	.18	.34	.59	.93
	C. F. M.........	1620	2430	3240	4050	4860	5670
4	Press. Ins........	.06	.15	.24	.37	.53	.73
	R. P. M.........	540	808	1075	1345	1615	1885
	H. P............	.037	.14	.30	.58	1.00	1.59
	C. F. M.........	2500	3750	5000	6250	7500	8750
5	Press. Ins.......	.06	.15	.24	.37	.53	.73
	R. P. M.........	430	644	860	1075	1288	1500
	H. P............	.057	.21	.46	.90	1.54	2.45
	C. F. M.........	3560	5350	7125	8900	10700	12500
6	Press. Ins.......	.06	.15	.24	.37	.53	.73
	R. P. M.........	361	540	720	900	1080	1260
	H. P............	.082	.30	.65	1.27	2.20	3.50
	C. F. M.........	4800	7200	9600	12000	14400	16800
7	Press. Ins.......	.06	.15	.24	.37	.53	.73
	R. P. M.........	307	460	614	767	920	1075
	H. P............	.11	.40	.88	1.71	2.96	4.69
	C. F. M.........	6250	9375	12500	15600	18750	21850
8	Press. Ins.......	.06	.15	.24	.37	.53	.73
	R. P. M.........	268	402	535	670	803	940
	H. P............	.143	.53	1.14	2.23	3.85	6.10
	C. F. M..........	7875	11800	15700	19650	23600	27500
9	Press. Ins.......	.06	.15	.24	.37	.53	.73
	R. P. M.........	239	358	477	597	716	835
	H. P............	.18	.67	1.43	2.80	4.84	7.68

Pressures noted are static pressures.

Where it is desired to reduce temperature or remove steam, etc., we must proceed to find the necessary capacity in another way. If we remove all of the heated air in a room and replace it with air from the outside in the same length of time required to heat it, we shall reduce the temperature by one-half the difference between that of the air in the room and the air brought in. From this fact we can deduce the following method for determining the amount of air which must be taken out of a room in order to lower its temperature by any desired amount. Before the room has attained its full temperature place one or more thermometers at representative locations and note the temperature rise for any convenient length of time, but be sure that you are observing the maximum or general temperature rise which is to be ventilated for. By providing ventilator capacity to exhaust all of the air in the room one or more times in the same length of time in which the rise took place we shall reduce it according to the following tabulation which shows the number of degrees F. which the room temperature will be above the outside temperature with the number of changes taking place as given at the left in column 0. The column 0 is correct only when the room is so tightly closed that there is no natural ventilation. Under the other columns, headed by 1, 2, 3, 4, and 5, are given the number of times the air must be changed to limit the temperature rise in room to the increases above the outside air as given in right hand section of table. Thus, if the increase in temperature allowed over the outside air is 30 degrees and the air is naturally changing three times we must change it twelve times to limit the rise to 5 degrees.

TABLE LXXXXV

Number of natural changes of air assumed.						Increase in degrees F. above outside air.							
5	4	3	2	1	0	5	10	15	20	25	30	35	40
10	8	6	4	2	1	$2\frac{1}{2}$	5	$7\frac{1}{2}$	10	$12\frac{1}{2}$	15	$17\frac{1}{2}$	20
15	12	9	6	3	2	$1\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{3}{4}$	5	$6\frac{1}{8}$	$7\frac{1}{2}$	$8\frac{3}{4}$	10
20	16	12	8	4	3	$\frac{5}{6}$	$1\frac{2}{3}$	$2\frac{1}{2}$	$3\frac{1}{3}$	$4\frac{1}{6}$	5	$5\frac{5}{6}$	$6\frac{2}{3}$
25	20	15	10	5	4	$\frac{5}{8}$	$1\frac{1}{4}$	$1\frac{7}{8}$	$2\frac{1}{2}$	$3\frac{1}{8}$	$3\frac{3}{4}$	$4\frac{3}{8}$	5

Rule.—Determine difference in temperature between outer and inner air which is to be ventilated for, and trace down column headed by this temperature until the allowable temperature of inner over outer air is reached. Next estimate number of natural changes taking place during the time of previous test and in section of table at left headed by this number trace down to same horizontal line in which the permissible temperature was found. At this point the necessary number of changes in air will be found. These changes must take place in the same length of time in which the temperature rise took place.

If there is a temperature rise accompanied by natural ventilation the reductions in temperature given in Table LXXXXV, column 0, can be obtained only by doubling the number of changes taking place during the time that the rise in temperature was going on.

Suppose, for instance, that a certain temperature rise takes place in an hour while during the same time the air is naturally changing ten times. The starting of the ventilator, if of sufficient capacity, immediately ends all natural ventilation because every former outlet for air now becomes an inlet and all air passes through the fan. The number of changes which were naturally taking place now count for nothing and to reduce the temperature by one-half we must provide ten more changes per hour, *i.e.*, change the air by means of the fan twenty times to obtain the effect of one change as given in column 0. Thus to find the number of changes necessary to obtain the effects given in the table in column 0 we must use the formula $c=(a\times b)+a$, where c=the number of changes that must be made; a=the number of natural changes taking place, and b=the figure in column 0 which corresponds to the desired rise above the outside air at the difference in temperature.

Example.—The increase in temperature in a certain room is 10 degrees above that of the outside air and is to be limited to $2\frac{1}{2}$ degrees; the dimensions of the room are $100\times 20\times 12$, while the natural change of air is assumed to be about three times per hour. What must be the capacity of the ventilating fan? Tracing down in Table LXXXXV under 10 degrees to where $2\frac{1}{2}$ is found, and then in the horizontal line to the left, to column pertaining to three changes of air per hour, we find the number 9, which signifies that we must have capacity to change the air nine times per hour, and since the room contains 24,000 cubic feet we must select a fan which can move 3,600 cubic feet per minute.

Practical Hints.—Place ventilators at end of room opposite to where most of the air enters or so that all disagreeable air is nearest to the fan. Protect fan against wind blowing into it. Avoid noise by selecting large fans to operate at low speeds. Air in motion does not feel as warm as stationary air. It is best to provide a separate fan for kitchen ranges, etc., and attach it directly to hoods placed over such apparatus.

In wide or square rooms provide several ventilators so as to secure a more uniform movement of air over the whole space. If fan capacity is small compared to size of room and cooling is the only consideration it is best to blow air into the room. An exhaust fan which does not change the air oftener than it is naturally changing has little effect. Even in well constructed places the air is supposed to change itself once per hour at least.

Voltage Regulation.—In a network of wiring the regulation is always fairly good because a heavy demand at any point immediately causes current from all sides to rush in. The drop at feeder ends can be easily compensated for if they are all of the same length. If they are not of the same length they should be divided into groups of the same length and each group separately regulated. For d. c. work individual feeder regulators waste too much energy to be considered except with very short lines.

In long lines a booster is often installed. To determine whether it is profitable to install a booster we must compare its cost and the losses due to its operation, with the cost of increasing the size of conductors proportionately and the losses incident to the improved lines. Obviously this depends upon the length of the line, and the drop which may be allowed. Determine investment for booster, interest and depreciation and cost of operation and losses. This amount can be saved by the installation of proper feeders, and if we can obtain the larger feeders by an investment of capital upon which the above sum will be the proper interest it will not be profitable to install the booster.

For a. c. work individual feeder regulators are much used, and as they waste comparatively little energy, they may be used in each feeder and all feeders connected to a common line. Such regulators may be arranged either to boost or choke. For low tension work, either a. c. or d. c., pressure wires are often run from the end of feeder back to switchboard to indicate the pressure at feeder end. The same object is also attainable by line drop compensators, or if the size and length of line be known the drop at the far end or any other point may be calculated from the number of amperes.

The following table (LXXXXVI) is provided to assist in making the necessary calculations for the setting of a. c. line drop compensators, and also to determine the drop in voltage occurring at any part of the line so that the voltage at the station may be raised correspondingly.

To find the drop in voltage we may use the formula $IZ \times d$; in which I is the current in amperes; Z the impedance as given in the table for various sizes of wire and separation, and d the number of 1,000 feet of line.

For line compensators it is necessary to find the percentage of the reactive, and ohmic drop. The same formula may be used substituting X or R for Z and dividing the result by the transmission voltage. This will give the percentage according to which the two sections of the compensator must be set. See detail instructions sent out with compensators. The values of Z, R and X are for 1,000 feet of wire. A single phase installation can be served by a single compensator, but then the drop will be double that given, or for 2,000 feet instead of 1,000 feet of wire. The same may be said of a two phase installation which is served by two compensators, but in two phase three wire, or in three phase systems, a compensator must be installed in each wire, and a four wire three phase system requires four, so that in connection with these systems the value given in the table need not be doubled.

TABLE LXXXXVI

Table Showing Resistance, Reactance and Impedance of 1,000 Feet of Wire of Sizes Given and at Various Separations.

		Separation of Wires in Inches.											
		12		24		36		48		60		72	
B. & S.	R	X	Z	X	Z	X	Z	X	Z	X	Z	X	Z
8	.627	.126	.640	.142	.640	.151	.640	.157	.640	.163	.640	.167	.640
6	.397	.120	.415	.136	.415	.145	.420	.152	.420	.157	.420	.161	.420
5	.314	.118	.345	.134	.350	.143	.355	.150	.357	.155	.360	.159	.362
4	.250	.115	.275	.131	.280	.140	.285	.147	.290	.152	.292	.156	.294
3	.198	.112	.230	.128	.235	.137	.240	.144	.245	.150	.248	.153	.251
2	.157	.110	.190	.126	.200	.135	.205	.141	.212	.147	.215	.151	.217
1	.126	.107	.165	.123	.175	.132	.180	.139	.187	.144	.191	.148	.194
0	.100	.104	.145	.120	.155	.129	.165	.136	.169	.141	.173	.145	.176
00	.079	.102	.130	.118	.140	.127	.150	.133	.156	.139	.159	.143	.162
000	.063	.099	.120	.115	.130	.124	.140	.131	.145	.136	.149	.140	.153
0000	.050	.096	.110	.112	.125	.122	.135	.128	.138	.133	.140	.137	.146

Weights of Materials in Pounds *(Approximate)*.—
Aluminum, cu. ft., 167; cu. in., 0.095. For wires, see tables.
Antimony, cu. ft., 418; cu. in., 0.242.
Asphaltum, cu. ft., 84; gal., 11.2.

Bismuth, cu. ft., 612; cu. in., 0.354.
Brass, cu. ft., 522; cu. in., 0.302.
Brick, cu. ft., 119; per thousand, 4500.
Bronze, cu. ft., 537; cu. in., 0.311.

Cement, loose, cu. ft., 88; bu., 95.
Charcoal; cu. ft., 25; bu., 27.
Coal, anthracite, piled loose, cu. ft., 52; bu., 56.
" bituminous, piled loose, cu. ft., 50; bu., 54.
Coke, piled loose, cu. ft., 27; bu., 29.

Concrete, cu. ft., 150; cu. yd., 4050.
Copper, cu. ft., 555; cu. in., 0.321. For wires, see tables.
Cork, cu. ft., 15.6.
Crushed Stone, cu. yd., 2700.

Earth, cu. ft., 109; cu. yd., 2943.

Glass, cu. ft., 165.
Gold, cu. ft., 1225; cu. in., 0.709.
Gravel, cu. ft., 119; cu. yd., 3213.

Ice, cu. ft., 56; cu. yd., 1512.
Iridium, cu. ft., 1400; cu. in., 0.81.
Iron, cu. ft., 490; cu. in., 0.225. For wires, see tables.

Lead, cu. ft., 709; cu. in., 0.41.
Limestone, cu. ft., 165; cu. yd., loose, 2700.
Loam, cu. ft., 78; cu. yd., 2106.

Mercury, cu. ft., 850; cu. in., 0.492.

Nickel, cu. ft., 540; cu. in., 0.312.

Oils, olive, gal., 7.6.
" cottonseed, gal., 8.0.
" linseed, gal., 7.8.
" turpentine, gal., 7.2.
" lard, gal., 7.9.
" whale, gal., 7.8.
" gasoline, gal., 5.7.
" petroleum, gal., 7.3.
" mineral lubricating, gal., 7.8.

Paper, cu. ft., 56.
Paraffine, cu. ft., 56; gal., 7.41.
Pitch, cu. ft., 67; gal., 8.9.

Platinum, cu. ft., 1340; cu. in., 0.718.
Porcelain, cu. ft., 150; cu. in., 0.087.

Salt, cu. ft., 60; gal., 8.04.
Sand, cu. ft., 105; cu. yd., 2835.
Silver, cu. ft., 653; cu. in., 0.377.
Slate, cu. ft., 184; cu. in., 0.109.
Sulphur, cu. ft., 125.

Tantalum, cu. ft., 1040; cu. in., 0.60.
Tar, cu. ft., 62.5; gal., 8.33.
Tin, cu. ft., 455; cu. in., 0.263.
Tungsten, cu. ft., 1175; cu. in., 0.68.

Water, plain, cu. ft., 62.5; gal., 8.33.
" sea, cu. ft., 79; gal., 10.3.

Wood,	ash,	cu. ft.,	46;	per 1000 ft.,	3850.
"	butternut,	"	28;	"	2330.
"	cedar,	"	38;	"	3165.
"	chestnut,	"	39;	"	3250.
"	cypress,	"	35;	"	2915.
"	elm,	"	36;	"	3000.
"	fir,	"	35;	"	2915.
"	hemlock,	"	27;	"	2250.
"	hickory,	"	55;	"	4600.
"	lignum vitae,	"	81;	"	6750.
"	mahogany	"	36;	"	3000.
"	maple,	"	50;	"	4560.
"	oak,	"	47;	"	3915.
"	pine, white,	"	25;	"	2275.
"	pine, yellow,	"	45;	"	3750.
"	poplar,	"	24;	"	2200.
"	redwood,	"	30;	"	2740.
"	spruce,	"	28;	"	2330.
"	walnut,	"	41;	"	3400.

Zinc, cu. ft., 420; cu. in., 0.243.

Contents of Barrels or Round Containers = average diameter squared × height × 0.7854.

If measurements are taken in inches

$$D^2 \times H \times 0.000454 = \text{cu. ft.}$$
$$D^2 \times H \times 0.0034 = \text{gal.}$$
$$D^2 \times H \times 0.000425 = \text{bu.}$$

If cubic contents are known in feet, multiply by 7.58 to obtain gallons, and by 0.936 to obtain bushels. To obtain cubic yards divide by 27.

Welding.—From 30 to 60 H.P. per square inch area of weld to be made are used. This is the power required to be delivered to welder. The greater the capacity the shorter will be the time required to make a weld. In some cases only a few seconds are required.

Wire Calculations.—This division contains the following tables:

A table of carrying capacities of copper and aluminum wires.

A table showing carrying capacities of different combinations of wires.

Table for determining the total wattage of groups of lamps or other devices usually rated in watts.

Tables for calculating the amperage per H.P. of motors at various efficiencies and power factors.

Tables showing maximum H.P. allowed on wires according to N.E.C. rules and carrying capacities.

Tables for determining proper size of wire for a certain loss in voltage; copper and aluminum wires, direct current, and 60 and 25 cycles.

Tables to facilitate determining the most economical conductors.

Various tables showing physical properties of copper, aluminum, copper clad, german silver and steel wires.

Tables showing outside diameters of wires and cables.

TABLE LXXXXVIII

Table of Allowable Carrying Capacity of Wires.

B. & S. Gauge	Rubber Insulation		Other Insulations		Circular Mils
	Copper	Aluminum	Copper	Aluminum	
18	3	2	5	4	1624
16	6	5	10	8	2583
14	15	12	20	17	4107
12	20	17	25	21	6530
10	25	21	30	25	10380
8	35	29	50	42	16510
6	50	42	70	59	26250
5	55	46	80	67	33100
4	70	59	90	76	41740
3	80	67	100	84	52630
2	90	76	125	105	66370
1	100	84	150	126	83690
0	125	105	200	168	105500
00	150	126	225	189	133100
000	175	147	275	231	167800
0000	225	189	325	273	211600
Circular Mils					
200000	200	168	300	252	
300000	275	231	400	336	
400000	325	273	500	420	
500000	400	336	600	504	
600000	450	378	680	571	
700000	500	420	760	639	
800000	550	462	840	705	
900000	600	504	920	773	
1000000	650	546	1000	840	
1100000	690	580	1080	901	
1200000	730	613	1150	966	
1300000	770	646	1220	1024	
1400000	810	680	1290	1083	
1500000	850	714	1360	1142	
1600000	890	748	1430	1201	
1700000	930	781	1490	1251	
1800000	970	815	1550	1301	
1900000	1010	848	1610	1352	
2000000	1050	882	1670	1402	

Carrying Capacities of Different Combinations of Wires.—Owing to the relatively different radiating surface of wires of different sizes the carrying capacity per circular mil is not the same for all wires, and where wires of different gauge number are to be connected in parallel this must be taken into account. In the following table this is done and the carrying capacity of smaller wires at the current density allowed for the larger wires is given wherever the horizontal and vertical lines pertaining to any two wires cross. The number found at this place indicates the amperage the smaller wire will have with the larger wire fully loaded. The figures are based on the carrying capacities given by the National Electrical Code. To find the proper wire to reinforce another which has been overloaded: Select the horizontal line pertaining to the larger wire and follow along this line until a number about equal to the necessary additional amperes is found. At the head of the vertical column in which this number is found will be found the gauge number of the proper wire to be used.

TABLE LXXXXIX

Table Showing Combined Carrying Capacity of Different Wires—Rubber Insulation

Amps.	B.&S.	14	12	10	8	6	5	4	3	2	1	0	00	000	0000
15	14	15													
20	12	12	20												
25	10	10	15	25											
35	8	8	13	22	35										
50	6	7	12	20	31	50									
55	5	7	11	17	27	44	55								
70	4	7	11	18	28	45	55	70							
80	3	6	10	16	25	39	50	64	80						
90	2	5	9	14	22	35	45	56	71	90					
100	1	5	8	12	19	31	39	49	63	80	100				
125	0	5	7	12	19	31	39	49	62	77	98	125			
150	00	4	7	11	18	30	37	47	59	74	94	118	150		
175	000	4	6	10	17	27	34	43	54	69	87	108	138	175	
225	0000	4	7	11	17	28	35	44	56	76	89	112	141	178	225
275	300000		6	9	15	24	30	38	48	61	77	96	122	154	194
325	400000		5	8	13	21	26	33	43	54	68	85	109	137	172
400	500000		5	8	13	21	26	33	42	53	67	84	106	134	169

Other Insulations

Amps.	B&S.	14	12	10	8	6	5	4	3	2	1	0	00	000	0000
20	14	20													
25	12	15	25												
30	10	11	19	30											
50	8	12	19	31	50										
70	6	10	17	27	44	70									
80	5	10	16	25	40	64	80								
90	4	10	16	25	40	64	80	90							
100	3	7	12	19	31	50	63	80	100						
125	2	7	12	19	31	50	63	78	99	125					
150	1	7	11	18	29	47	59	74	94	118	150				
200	0	7	12	19	31	49	62	79	99	125	157	200			
225	00	7	11	17	28	44	56	70	89	112	141	178	225		
275	000	6	10	17	27	43	54	68	86	109	137	173	218	275	
325	0000	6	10	16	25	40	51	64	81	102	128	162	204	258	325
400	300000	5	8	14	22	35	44	55	70	88	112	140	177	223	282
500	400000	5	8	13	20	33	41	52	66	83	104	132	166	209	264
600	500000	5	8	12	20	31	40	50	63	80	100	127	160	202	255

TABLE C

Table for determining total wattage required for incandescent lamps or other devices usually rated in watts.

To find total wattage add all numbers found where lines pertaining to number of lamps and wattage of same cross.

Number of	Watts								
lamps	1000	750	500	250	150	100	60	40	25
2	2000	1500	1000	500	300	200	120	80	50
3	3000	2250	1500	750	450	300	180	120	75
4	4000	3000	2000	1000	600	400	240	160	100
5	5000	3750	2500	1250	750	500	300	200	125
6	6000	4500	3000	1500	900	600	360	240	150
7	7000	5250	3500	1750	1050	700	420	280	175
8	8000	6000	4000	2000	1200	800	480	320	200
9	9000	6750	4500	2250	2700	900	540	360	225
10	10000	7500	5000	2500	1500	1000	600	400	250
15	15000	11250	7500	3750	2250	1500	900	600	375
20	20000	15000	10000	5000	3000	2000	1200	800	500
25	25000	18750	12500	6250	3750	2500	1500	1000	625
30	30000	22500	15000	7500	4500	3000	1800	1200	750
35	35000	26250	17500	8750	5250	3500	2100	1400	875
40	40000	30000	20000	10000	6000	4000	2400	1600	1000
45	45000	33750	22500	11250	6750	4500	2700	1800	1125
50	50000	37500	25000	12500	7500	5000	3000	2000	1250
55	55000	41250	27500	13750	8250	5500	3300	2200	1375
60	60000	45000	30000	15000	9000	6000	3600	2400	1500
65	65000	48750	32500	16250	9750	6500	3900	2600	1625
70	70000	52500	35000	17500	10500	7000	4200	2800	1750
75	75000	56250	37500	18750	11250	7500	4500	3000	1875
80	80000	60000	40000	20000	12000	8000	4800	3200	2000
85	85000	63750	42500	21250	12750	8500	5100	3400	2125
90	90000	67500	45000	22500	13500	9000	5400	3600	2025
100	100000	75000	50000	25000	15000	10000	6000	4000	2500
110	110000	82500	55000	27500	16500	11000	6600	4400	2750
120	120000	90000	60000	30000	18000	12000	7200	4800	3000
130	130000	92500	65000	32500	19500	13000	7800	5200	3250
140	140000	105000	70000	35000	21000	14000	8400	5600	3500
150	150000	112500	75000	37500	22500	15000	9000	6000	3750

TABLE CI

Table showing wattage capacity of different wires.

	—110 Volts—		—220 Volts—		—440 Volts—	
	Rubber Ins.	Other Ins.	Rubber Ins.	Other Ins.	Rubber Ins.	Other Ins.
14	1650	2200	3300	4400	6600	8800
12	2200	2750	4400	5500	8800	11000
10	2750	3300	5500	6600	11000	13200
8	3850	5500	7700	11000	15400	22000
6	5500	7700	11000	15400	22000	30800
5	6050	8800	12100	17600	24200	35200
4	7700	9900	15400	19800	30800	39600
3	8800	11000	17600	22000	35200	44000
2	9900	13750	19800	27500	39600	55000
1	11000	16500	22000	33000	44000	66000
0	13750	22000	27500	44000	55000	88000
00	16500	24750	33000	49500	66000	99000
000	19250	30250	38500	60500	77000	121000
0000	24750	35750	49500	71500	99000	143000
200000	22000	33000	44000	66000	88000	132000
300000	30250	44000	60500	88000	121000	176000
400000	35750	55000	71500	110000	143000	220000
500000	44000	66000	88000	132000	176000	264000

If system is balanced use columns 220 volts for 3-wire 110-volt systems and column 440 volts for 3-wire 220 volt systems or for such voltages direct.

Tables for calculating amperage of motors with various efficiencies, power factors systems and voltages.

RULE FOR FINDING AMPERES

In top part of table select numbers found where lines pertaining to efficiency and power factors cross and find same number in middle table. In same line under proper system will be found the number of amperes required for 1 H.P. at 110 volts. In bottom table select divisor pertaining to higher voltages, divide amperes by this and multiply by number of H.P. The result will give the total number of amperes required. The efficiency of small motors is always much less than that of larger motors.

TABLE CII

Power Factors	Efficiency .95	.90	.87½	.85	.82½	.80	.75	.70	.65	.60	.55
.95	.90	.86	.83	.81	.78	.76	.71	.67	.62	.57	.53
.90	.86	.81	.79	.77	.74	.72	.68	.63	.59	.54	.50
.85	.81	.77	.74	.72	.70	.68	.64	.60	.55	.51	.47
.80	.76	.72	.70	.68	.66	.64	.60	.56	.52	.48	.44
.75	.71	.68	.66	.64	.62	.60	.56	.53	.49	.45	.41
.70	.67	.63	.61	.59	.58	.56	.53	.49	.46	.42	.39

Amperes for 1 H. P. at 110 Volts

	Direct current or s. phase	Two phase	Three phase		Direct current or s. phase	Two phase	Three phase
.39	17.4	12.5	10.0	.66	10.3	7.3	5.9
.41	16.5	11.9	9.6	.67	10.1	7.2	5.9
.42	16.1	11.6	9.3	.68	9.9	7.1	5.8
.44	15.4	11.1	8.9	.70	9.7	7.0	5.6
.45	15.1	10.8	8.7	.71	9.6	6.9	5.5
.46	14.7	10.5	8.6	.72	9.5	6.8	5.4
.47	14.4	10.3	8.4	.74	9.2	6.6	5.3
.48	14.1	10.2	8.2	.76	8.9	6.4	5.1
.49	13.8	9.9	8.0	.77	8.8	6.3	5.1
.50	13.6	9.7	7.8	.78	8.7	6.2	5.0
.51	13.3	9.5	7.6	.79	8.6	6.1	5.0
.52	13.0	9.4	7.5	.81	8.4	6.0	4.8
.53	12.8	9.2	7.4	.83	8.2	5.9	4.7
.54	12.6	9.0	7.3	.84	8.1	5.8	4.6
.55	12.4	8.8	7.1	.85	8.0	5.7	4.6
.56	12.1	8.7	7.0	.86	7.9	5.7	4.5
.57	11.9	8.5	6.8	.90	7.5	5.4	4.3
.58	11.7	8.4	6.7	.92	7.4	5.3	4.3
.59	11.5	8.3	6.6	.93	7.3	5.2	4.2
.60	11.3	8.1	6.5	.94	7.2	5.2	4.2
.61	11.1	8.0	6.4	.95	7.1	5.1	4.1
.62	10.9	7.8	6.3	.96	7.0	5.1	4.1
.63	10.7	7.7	6.2	.97	7.0	5.0	4.0
.64	10.6	7.6	6.1	.98	6.9	4.9	4.0

Voltages

	110	220	440	550	650	1100	2080	2200
Divisor	1	2	4	5	5.9	11	18.9	20

DIRECT CURRENT MOTORS

TABLE CIII

Direct Current Motors

Table Showing Maximum H. P. Allowed on Wires According to N. E. Code Rules and Carrying Capacities. Assumed Efficiency of Motors, .90.

Carrying Capacities			110 Volts				220 Volts				550 Volts				650 Volts			
			Mains		Branches		Mains		Branches		Mains		Branches		Mains		Branches	
R.I.	O.I.	B. & S.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.
15	20	14	2.0	2.7	1.6	2.1	4.0	5.4	3.2	4.2	10.0	13.5	8.0	10.5	11.8	15.9	9.4	12.4
20	25	12	2.7	3.3	2.1	2.7	5.4	6.6	4.2	5.4	13.5	16.5	10.5	13.5	15.9	19.5	12.4	15.9
25	30	10	3.3	4.0	2.7	3.2	6.6	8.0	5.4	6.4	16.5	20.0	13.5	16.0	19.5	23.6	15.7	18.9
35	50	8	4.7	6.7	3.7	5.4	9.4	13.4	7.4	10.8	23.5	33.5	18.5	27.0	27.8	39.5	21.8	31.8
50	70	6	6.6	9.3	5.3	7.7	13.2	18.6	10.6	15.4	33.0	46.5	26.5	38.5	38.9	54.9	31.3	45.4
55	80	5	7.3	10.7	5.8	8.5	14.6	21.4	11.6	17.0	36.5	53.5	29.0	42.5	43.1	63.1	34.2	50.1
70	90	4	9.3	12.0	7.4	9.6	18.6	24.0	14.8	19.2	46.5	60.0	37.0	48.0	54.9	70.8	43.7	56.6
80	100	3	10.7	13.3	8.5	10.6	21.4	26.6	17.0	21.2	53.5	66.5	42.5	53.0	63.1	78.5	50.1	62.5
90	125	2	12.0	16.7	9.6	13.3	24.0	33.4	19.2	26.6	60.0	83.5	48.0	66.5	70.8	98.5	56.7	78.5
100	150	1	13.3	20.0	10.6	16.0	26.6	40.0	21.2	32.0	66.5	100.	53.0	80.0	78.5	118.0	62.5	94.4
125	200	0	16.7	26.7	13.3	21.2	33.4	53.4	26.6	42.4	83.5	133.5	66.5	106.0	98.5	157.5	78.5	125.1
150	225	00	20.0	30.0	16.0	23.9	40.0	60.0	32.0	47.8	100.0	150.0	80.0	119.5	118.0	177.0	94.4	141.0
175	275	000	23.3	36.7	18.6	29.3	46.6	73.4	37.2	58.6	116.5	183.5	93.0	146.5	137.5	216.5	109.7	172.9
225	325	0000	30.0	43.3	24.0	34.6	60.0	86.6	48.0	69.2	150.0	216.5	120.0	173.0	177.0	255.5	141.6	204.1
200	300	200000	26.6	40.0	21.3	32.0	53.2	80.0	42.6	64.0	133.0	200.0	106.5	160.0	156.9	236.0	125.7	188.8

To find smallest wire permissible for a given motor load, find H. P. under proper voltage and insulation of wire; in same horizontal line under B. & S. will be found the gauge number of the wire to be used.

DIRECT CURRENT MOTORS

TABLE CIV

Direct Current Motors

Carrying Capacities		Cir. Mils.	110 Volts				220 Volts				550 Volts				650 Volts			
			Mains		Branches		Mains		Branches		Mains		Branches		Mains		Branches	
R.I.	O.I.		R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.
275	400	300000	36.6	53.3	29.2	42.5	73	106	58	85	183	266	146	212	216	314	172	251
325	500	400000	43.3	66.6	34.4	53.2	86	133	68	106	216	333	172	266	255	393	203	314
400	600	500000	53.3	80.0	42.5	63.8	106	160	85	128	266	400	212	319	314	472	251	376
450	680	600000	60.0	90.6	47.9	72.3	120	181	96	145	300	453	239	361	354	534	283	427
500	760	700000	66.6	102.3	53.2	80.8	133	202	106	162	333	506	266	404	393	598	314	477
550	840	800000	73.3	112.0	58.5	89.4	147	224	117	179	366	560	292	497	432	661	345	527
600	920	900000	80.0	122.6	63.8	97.9	160	245	128	196	400	613	319	489	472	723	376	528
650	1000	1000000	86.6	133.3	69.1	106.4	173	266	138	213	433	666	345	532	511	786	408	628
690	1080	1100000	92.0	144.0	73.4	115.0	184	288	147	230	460	720	367	575	543	850	433	678
730	1150	1200000	97.3	153.3	77.7	122.3	195	306	155	245	486	766	388	611	574	904	458	721
770	1220	1300000	102.6	162.6	81.9	129.7	205	325	164	259	513	813	409	648	605	959	483	765
810	1290	1400000	108.0	172.0	86.2	137.2	216	344	172	274	540	860	431	686	637	1015	509	809
850	1360	1500000	113.3	181.3	90.4	145.0	226	362	181	290	566	906	452	725	668	1070	533	855
890	1430	1600000	118.6	190.6	94.7	152.1	237	381	189	304	593	953	473	760	700	1124	559	897
930	1490	1700000	124.0	199.0	99.0	158.5	248	398	198	317	620	995	495	792	732	1174	584	935
970	1550	1800000	129.3	206.6	103.2	165.0	258	413	206	330	646	1033	516	825	763	1219	609	973
1010	1610	1900000	134.6	214.6	107.4	171.2	269	429	215	342	673	1073	537	856	794	1266	634	1010
1050	1670	2000000	140.0	222.6	111.7	177.6	280	445	223	355	700	1113	558	888	826	1313	659	1048

To find the smallest wire permissible for a given motor load, find H. P. under proper voltage and insulation of wire; in same horizontal line under B. & S. will be found the gauge number of the wire to be used.

SINGLE PHASE MOTORS

TABLE CV

Single Phase Motors

Table Showing Maximum H. P. Allowed on Wires, According to N. E. Code Rules, and Carrying Capacities. Assumed Efficiency, .90; Power Factor, .85.

Carrying Capacities			110 Volts				220 Volts				440 Volts				550 Volts			
			Mains		Branches		Mains		Branches		Mains		Branches		Mains		Branches	
R.I.	O.I.	B. & S.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.
15	20	14	1.7	2.2	1.37	1.8	3.4	4.4	2.7	3.6	6.8	8.8	5.4	7.2	8.5	11.0	6.8	9.0
20	25	12	2.2	2.8	1.8	2.3	4.4	5.6	3.6	4.6	8.8	11.2	7.2	9.2	11.0	14.0	9.0	11.5
25	30	10	2.8	3.4	2.3	2.7	5.6	6.8	4.6	5.4	11.2	13.6	9.2	10.8	14.0	17.0	11.5	13.5
35	50	8	3.9	5.6	3.2	4.6	7.9	11.2	6.4	9.2	15.8	22.4	12.8	18.4	19.8	28.0	16.0	23.0
50	70	6	5.6	7.9	4.5	6.4	11.3	15.8	9.0	12.8	22.6	31.6	18.0	25.6	28.2	39.5	22.5	32.0
55	80	5	6.2	9.0	5.0	7.3	12.4	18.0	10.0	14.6	24.8	36.0	20.0	29.2	31.0	45.0	25.0	36.5
70	90	4	7.9	10.1	6.4	8.2	15.8	20.2	12.8	16.4	31.6	40.4	25.6	32.8	39.5	50.5	32.0	41.0
80	100	3	9.0	11.3	7.3	9.1	18.0	22.6	14.6	18.2	36.0	45.2	29.2	36.4	45.0	56.5	36.5	45.5
90	125	2	10.1	14.1	8.2	11.4	20.2	28.2	16.4	22.8	40.4	56.4	32.8	45.6	50.5	70.5	41.0	57.0
100	150	1	11.3	17.0	9.1	13.7	22.6	34.0	18.2	27.4	45.2	68.0	36.4	54.8	56.5	85.0	45.5	68.5
125	200	0	14.1	22.5	11.4	18.2	28.2	45.0	22.8	36.4	56.4	90.0	45.6	72.8	70.5	112.5	57.0	91.0
150	225	00	16.9	25.4	13.6	20.5	33.8	50.8	27.2	41.0	67.6	101.6	54.4	82.0	84.5	127.0	68.0	102.5
175	275	000	19.7	31.0	15.9	25.0	39.4	62.0	31.8	50.0	78.8	124.0	63.6	100.0	98.5	155.0	79.5	125.0
225	325	0000	25.4	36.6	20.4	29.5	50.8	73.2	40.8	59.0	101.6	146.4	81.6	118.0	127.0	183.0	102.0	147.5
200	300	20000	22.5	33.8	18.2	27.3	45.0	67.6	36.4	54.6	90.0	133.2	72.8	109.2	112.5	169.0	91.0	136.5
275	400	300000	31.0	45.1	25.0	36.3	62.0	90.2	50.0	72.6	124.0	180.4	100.0	145.2	155.0	225.5	125.0	181.5
325	500	400000	36.6	56.4	29.5	45.4	73.2	112.8	59.0	90.8	146.4	225.6	118.0	181.6	183.0	282.0	147.5	227.0
400	600	500000	45.1	67.7	36.4	54.5	90.2	134.4	72.8	109.0	180.4	270.8	145.6	218.0	225.5	338.5	182.0	272.5

To find smallest wire permissible for a given motor load, find H. P. under proper voltage and insulation of wire; in same horizontal line under B. & S. will be found the gauge number of the wire to be used.

TWO PHASE MOTORS

TABLE CVI

Two Phase Motors

Table Showing Maximum H. P. Allowed on Wires, According to N. E. Code Rules, and Carrying Capacities. Assumed Efficiency, .90; Power Factor, .85.

Carrying Capacities			110 Volts				220 Volts				440 Volts				550 Volts			
			Mains		Branches		Mains		Branches		Mains		Branches		Mains		Branches	
R.I.	O.I.	B. & S.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.
15	20	14	3.4	4.4	2.7	3.6	6.8	8.8	5.4	7.2	13.6	17.6	10.8	14.4	17.0	22.0	13.6	18.0
20	25	12	4.4	5.6	3.6	4.6	8.8	11.2	7.2	9.2	17.6	22.4	14.4	18.4	22.0	28.0	18.0	23.0
25	30	10	5.6	6.8	4.6	5.4	11.2	13.6	9.2	10.8	22.4	27.2	18.4	21.6	28.0	34.0	23.0	27.0
35	50	8	7.8	11.2	6.4	9.2	15.8	22.4	12.8	18.4	31.6	44.8	25.6	36.8	39.6	56.0	32.0	46.0
50	70	6	11.2	15.8	9.0	12.8	22.6	31.6	18.0	25.6	45.2	63.2	36.0	51.2	56.4	79.0	45.0	64.0
55	30	5	12.4	18.0	10.0	14.6	24.8	36.0	20.0	29.2	49.6	72.0	40.0	58.4	62.0	90.0	50.0	73.0
70	90	4	15.8	20.2	12.8	16.4	31.6	40.4	25.6	32.8	63.2	80.8	51.2	65.6	79.0	101.0	64.0	82.0
80	100	3	18.0	22.6	14.6	18.2	36.0	45.2	29.2	36.4	72.0	90.4	58.4	72.8	90.0	113.0	73.0	91.0
90	125	2	20.2	28.2	16.4	22.8	40.4	56.4	32.8	45.6	80.8	112.8	65.6	91.2	101.0	141.0	82.0	114.0
100	150	1	22.6	34.0	18.2	27.4	45.2	68.0	36.4	54.8	90.4	136.0	72.8	109.6	113.0	170.0	91.0	137.0
125	200	0	28.2	45.0	22.8	36.4	56.4	90.0	45.6	72.8	112.8	180.0	91.2	145.6	141.0	225.0	114.0	182.0
150	225	00	33.8	50.8	27.2	41.0	67.6	101.6	54.4	82.0	135.2	203.2	108.8	164.0	169.0	254.0	136.0	205.0
175	275	000	39.4	62.0	31.8	50.0	78.8	124.0	63.6	100.0	157.6	248.0	127.2	200.0	197.0	310.	159.0	250.0
225	325	0000	50.8	73.2	40.8	59.0	101.6	146.4	81.6	118.0	203.2	292.8	163.2	236.0	254.0	366.	204.0	295.0
200	300	200000	45.0	67.6	36.4	54.6	90.0	135.2	72.8	109.2	180.0	266.4	145.6	218.4	225.0	338.	182.0	273.0
275	400	300000	62.0	90.2	50.0	72.6	124.0	180.4	100.0	145.2	248.0	360.8	200.0	290.4	310.0	451.	250.0	363.0
325	500	400000	73.2	112.8	59.0	90.8	146.4	225.6	118.0	181.6	292.8	451.2	236.0	363.2	366.0	564.0	295.0	454.0
400	600	500000	90.2	135.4	72.8	109.0	180.4	268.8	145.6	218.0	360.8	541.6	291.2	436.0	451.0	677.0	364.0	545.0

To find smallest wire permissible for a given motor load, find H. P. under proper voltage and insulation of wire; in same horizontal line under B. & S. will be found the gauge number of the wire to be used

THREE PHASE MOTORS

TABLE CVII

Three Phase Motors

Table Showing Maximum H. P. Allowed on Wires, According to N. E. Code Rules, and Carrying Capacities. Assumed Efficiency, .90; Power Factor, .85.

Carrying Capacities			110 Volts				220 Volts				440 Volts				550 Volts			
			Mains		Branches		Mains		Branches		Mains		Branches		Mains		Branches	
R.I.	O.I.	B. & S.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.
15	20	14	2.9	3.9	2.34	3.1	5.8	7.8	4.6	6.2	11.6	15.6	9.2	12.4	14.5	19.5	11.5	15.5
20	25	12	3.9	4.9	3.1	3.9	7.8	9.8	6.2	7.8	15.6	19.6	12.4	15.6	19.5	24.5	15.5	19.5
25	30	10	4.9	5.9	3.9	4.7	9.8	11.8	7.8	9.4	19.6	23.6	15.6	18.8	24.5	29.5	19.5	23.5
35	50	8	6.9	9.8	5.5	7.8	13.8	19.6	11.0	15.6	27.6	39.2	22.0	31.2	34.5	49.0	27.5	39.0
50	70	6	9.8	13.7	7.8	10.9	19.6	27.4	15.6	21.8	39.2	54.8	31.2	43.6	49.0	68.5	39.0	54.5
55	80	5	10.8	15.7	8.6	12.5	21.6	31.4	17.2	25.0	43.2	62.8	34.4	50.0	54.0	78.5	43.0	62.5
70	90	4	13.7	17.6	10.9	14.1	27.4	35.2	21.8	28.2	54.8	70.4	43.6	56.4	68.5	88.0	54.5	70.5
80	100	3	15.7	19.6	12.5	15.6	31.4	39.2	25.0	31.2	62.8	78.4	50.0	62.4	78.5	98.0	62.5	78.0
90	125	2	17.6	24.5	14.1	19.5	35.2	49.0	28.2	39.0	70.4	98.0	56.4	78.0	88.0	122.5	70.5	97.5
100	150	1	19.6	29.4	15.6	23.4	39.2	58.8	31.2	46.8	78.4	117.6	62.4	93.6	98.0	147.0	78.0	117.0
125	200	0	24.5	39.2	19.5	31.2	49.0	78.4	39.0	62.4	98.0	156.8	78.0	124.8	122.5	196.0	97.5	156.0
150	225	00	29.4	44.1	23.4	35.1	58.8	88.2	46.8	70.2	117.6	176.4	93.6	140.4	147.0	220.5	117.0	176.0
175	275	000	34.3	53.9	27.3	42.9	68.6	107.8	54.6	85.8	137.2	215.6	109.2	171.6	171.5	269.5	136.5	214.5
225	325	0000	44.1	63.7	35.1	50.8	88.2	127.4	70.2	101.6	176.4	254.8	140.4	203.2	220.5	318.5	175.5	254.0
200	300	200000	39.2	58.8	31.2	46.9	78.4	117.6	62.4	93.8	156.8	235.2	124.8	187.6	196.0	294.0	156.0	234.5

To find smallest wire permissible for a given motor load, find H. P. under proper voltage and insulation of wire; in same horizontal line under B. & S. will be found the gauge number of the wire to be used.

THREE PHASE MOTORS

TABLE CVIII

Three Phase Motors

Carrying Capacities		Cir. Mils.	110 Volts				220 Volts				440 Volts				550 Volts			
			Mains		Branches		Mains		Branches		Mains		Branches		Mains		Branches	
R.I	O.I.		R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.	R.I.	O.I.
275	400	300000	54	78	43	62	108	156	86	125	216	312	172	248	270	390	215	310
325	500	400000	64	98	51	78	128	196	102	156	256	392	204	312	320	490	255	390
400	600	500000	78	117	62	94	156	234	124	188	312	468	248	376	390	585	310	470
450	680	600000	88	133	70	106	176	266	140	212	352	532	280	424	440	665	350	530
500	760	700000	98	149	78	119	196	298	156	238	392	596	312	476	490	745	390	595
550	840	800000	108	164	86	131	216	328	172	262	432	656	344	524	540	820	430	655
600	920	900000	117	180	94	143	234	360	188	286	468	720	376	572	585	900	470	715
650	1000	1000000	127	196	102	156	254	392	204	312	508	784	408	624	635	980	510	780
690	1080	1100000	135	211	108	169	270	422	216	338	540	844	432	676	675	1055	540	845
730	1150	1200000	143	225	114	179	286	450	228	358	572	900	456	716	715	1125	570	895

To find the smallest wire permissible for a given motor load, find H. P. under proper voltage and insulation of wire; in same horizontal line under B. & S. will be found the gauge number of the wire to be used.

Tables for Calculating Drop in Voltage.—The drop in voltage in a direct current circuit is always equal to IR, while in an alternating current circuit it is equal to IZ. These formulae are, however, not well suited for use when the problem is to find the proper wire to be used where the loss is determined upon.

That portion of the following tables devoted to direct currents consists simply of one column of figures in which are given the conductances of the various wires. That part of the tables used for alternating current circuits gives the admittances of the various wires under different circumstances. The losses in voltage which form the basis of the following tables have been calculated from the formula:

$$\sqrt{[(E \times p.f.) + (IR)]^2 + [(E \times r.f.) + (IX)]^2} = E^1$$

where E stands for voltage to be delivered at end of line; $p.f.$ for power factor of load; I for current in amperes; R for ohmic resistance of line; $r.f.$ for reactive factor; X for reactive volts in line, and E^1 for the e. m. f. necessary at the starting point to deliver E at the end of line. The ohmic resistance and the reactive volts can be taken from Tables CIX and CX and the power factor (cosine of angle of lag) and reactive factor (sine of angle of lag) from Table CXI. To obtain the loss in volts it is necessary to subtract E from E^1. Referring to Figure 34, which illustrates the common method of figuring drop in voltage for alternating current circuits, the losses for which the tables are calculated are equal to the difference between the lines A and B.

Having thus briefly outlined how the line losses, used as the basis of the following tables have been derived, we may now proceed to explain the tables and the method of their use.

Since, according to a transposition of Ohms law, $\frac{E}{I}=R$ it follows that $\frac{I}{E}=\frac{1}{R}$. In other words $\frac{1}{R}$ or $\frac{1}{Z}$ give us the conductance or admittance which in connection with the current I will consume the voltage E. The numerical value of conductance or admittance in any line equals the number of amperes which can be transmitted over that line at a loss of one volt. This conductance for direct currents and admittance for alternating currents has been tabulated in the following pages. Hence, if we divide the current to be trans-

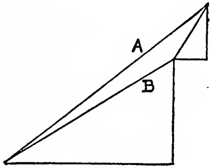


Figure 34.

mitted by the volts we wish to lose we shall obtain the value of the conductance or admittance which is necessary to cause this loss. The basis of the table is a line of 100 feet in length, which represents 200 feet of wire of a two-wire line. In order to find a wire which shall give us any desired loss, we need then merely to find what that loss is to be per 100 feet of line, and divide the amperes to be transmitted by this loss; then trace down the column describing the conditions (direct current or separation of wires) until we come to a number which about equals the one previously found. In connection with three-phase systems, if great accuracy is required, it will be necessary to divide the volts to be lost by 0.86 before proceeding with the rest.

In order to facilitate the calculations, the tables, CXII to CXIII, have been added. Table CXII gives the average value of amperes per H. P. with various voltages, and table CXIII shows the value in actual volts per hundred feet run of 1 per cent loss with the distances and voltages given. If the loss to be allowed over any distance and with any of the voltages given is stated in per cent, we need merely to multiply the number found where distance and voltage cross by the number of per cent to find the number of volts to be lost per 100 feet.

Example: We have 50 H.P., three-phase, 60 cycles, at 1000 volts, to transmit a distance of 2200 feet, with 24-inch separation, at a loss of 5 per cent. What size of wire must be used? Fifty H.P. three phase at 1000 volts equals 35 amperes. (See Table CXII.) For a voltage of 1000 and a distance of 2200 feet the number with which we must divide our current for one per cent is .451. (See Table CXIII.)

This multiplied by the percentage of loss, 5 = 2.255, and this, in turn, divided by 0.86, gives us 2.62, with which we divide our amperes, 35, and obtain 13.3 as the admittance required. Tracing downward in table CXIV under the proper separation, 24 inches, we find the number 14.2 as the nearest, and this indicates a No. 5 wire. The same plan is used for direct current, and the conductances are given in column D. C. If larger wires are indicated, the conductances of the larger wire are in proportion to the circular mils for direct current.

TABLE CIX

Table Showing Reactance and Resistance Volts, 1 Ampere, 100 Feet Run (200 Ft. Wire).

60 Cycles

Copper Wire		Reactance Volts									Resistance Volts
	Resistance	Separation of Wires in Inches									Aluminum
B. & S.	Volts	½	3	6	12	24	36	48	60	72	Wire
14	0.511	.0138	0.0220	0.0252	0.0282	0.0315	0.0334	0.0347	0.0358	0.0366	0.814
12	0.323	.0127	0.0209	0.0241	0.0273	0.0305	0.0323	0.0336	0.0347	0.0355	0.512
10	0.2036	.0116	0.0198	0.0230	0.0262	0.0243	0.0313	0.0326	0.0337	0.0345	0.322
8	0.1308	.0106	0.0188	0.0220	0.0251	0.0283	0.0302	0.0315	0.0325	0.0334	0.202
6	0.082	.0095	0.0177	0.0209	0.0241	0.0273	0.0291	0.0304	0.0315	0.0323	0.1274
5	0.0652	.0090	0.0171	0.0204	0.0236	0.0267	0.0285	0.0298	0.0308	0.0316	0.1010
4	0.0518	.0085	0.0167	0.0199	0.0231	0.0262	0.0280	0.0293	0.0303	0.0312	0.0801
3	0.041	.0079	0.0162	0.0194	0.0226	0.0257	0.0275	0.0288	0.0298	0.0307	0.0635
2	0.0324	.0074	0.0156	0.0188	0.0220	0.0251	0.0269	0.0283	0.0293	0.0301	0.0504
1	0.0258	.0068	0.0151	0.0182	0.0214	0.0246	0.0264	0.0278	0.0288	0.0296	0.0399
0	0.0204	.0063	0.0146	0.0177	0.0209	0.0240	0.0259	0.0272	0.0282	0.0291	0.0317
00	0.0162	.0057	0.0140	0.0172	0.0204	0.0235	0.0254	0.0267	0.0277	0.0285	0.0251
000	0.0128	.0052	0.0135	0.0167	0.0199	0.0230	0.0248	0.0262	0.0272	0.0280	0.0199
0000	0.0102	.0046	0.0129	0.0161	0.0193	0.0225	0.0243	0.0257	0.0267	0.0275	0.0158
250000	0.0086		0.0125	0.0157	0.0189	0.0221	0.0239	0.0253	0.0263	0.0271	0.0138
300000	0.0072		0.0121	0.0153	0.0185	0.0217	0.0235	0.0249	0.0259	0.0267	0.0115
350000	0.00616		0.0118	0.0149	0.0181	0.0213	0.0232	0.0245	0.0255	0.0264	0.0098
400000	0.00540		0.0113	0.0144	0.0176	0.0208	0.0228	0.0241	0.0251	0.0260	0.0086
500000	0.00432		0.0109	0.0141	0.0173	0.0205	0.0224	0.0237	0.0247	0.0255	0.0069
600000	0.00360		0.0106	0.0137	0.0169	0.0201	0.0219	0.0233	0.0244	0.0251	0.0057
700000	0.00308		0.0103	0.0134	0.0166	0.0198	0.0215	0.0230	0.0240	0.0247	0.0049
750000	0.00288		0.0100	0.0132	0.0164	0.0196	0.0214	0.0228	0.0238	0.0246	0.0046
800000	0.00270		0.0098	0.0130	0.0162	0.0193	0.0212	0.0225	0.0236	0.0244	0.0043
900000	0.00240		0.0096	0.0127	0.0159	0.0190	0.0209	0.0222	0.0233	0.0241	0.0038
1000000	0.00216		0.0094	0.0126	0.0157	0.0189	0.0208	0.0221	0.0231	0.0239	0.0035

TABLE CX

Table Showing Reactance and Resistance Volts, 1 Ampere, 100 Feet Run (200 Ft. Wire).

25 Cycles

Copper Wire B. & S.	Copper Wire Resistance Volts	Reactance Volts, Separation in Inches: ½	3	6	12	24	36	48	60	72	Resistance Volts Aluminum Wire
14	0.511	0.0057	0.0091	0.0105	0.0117	0.0131	0.0139	0.0145	0.0149	0.0152	0.814
12	0.323	0.0053	0.0087	0.0100	0.0114	0.0127	0.0135	0.0140	0.0145	0.0148	0.512
10	0.2036	0.0048	0.0083	0.0097	0.0110	0.0122	0.0130	0.0136	0.0140	0.0144	0.322
8	0.1308	0.0044	0.0078	0.0092	0.0105	0.0118	0.0126	0.0131	0.0135	0.0139	0.202
6	0.082	0.0039	0.0074	0.0087	0.0100	0.0114	0.0121	0.0127	0.0131	0.0135	0.1274
5	0.0652	0.0037	0.0071	0.0085	0.0098	0.0111	0.0119	0.0124	0.0129	0.0132	0.1010
4	0.0518	0.0036	0.0069	0.0083	0.0096	0.0109	0.0117	0.0122	0.0126	0.0130	0.0801
3	0.041	0.0033	0.0067	0.0081	0.0094	0.0107	0.0115	0.0120	0.0124	0.0128	0.0635
2	0.0324	0.0031	0.0065	0.0078	0.0092	0.0105	0.0112	0.0118	0.0122	0.0125	0.0504
1	0.0258	0.0027	0.0063	0.0076	0.0089	0.0103	0.0110	0.0116	0.0120	0.0123	0.0399
0	0.0204	0.0026	0.0061	0.0074	0.0087	0.0100	0.0108	0.0113	0.0118	0.0121	0.0317
00	0.0162	0.0024	0.0059	0.0072	0.0085	0.0098	0.0106	0.0111	0.0115	0.0119	0.0251
000	0.0128	0.0022	0.0056	0.0070	0.0083	0.0096	0.0103	0.0109	0.0113	0.0117	0.0199
0000	0.0102	0.0019	0.0054	0.0067	0.0080	0.0094	0.0101	0.0107	0.0117	0.0115	0.0158
250000	0.0086		0.0052	0.0065	0.0078	0.0092	0.0099	0.0106	0.0109	0.0113	0.0138
300000	0.0072		0.0050	0.0064	0.0077	0.0090	0.0098	0.0104	0.0107	0.0111	0.0115
350000	0.00616		0.0049	0.0062	0.0075	0.0088	0.0097	0.0102	0.0106	0.0110	0.0098
400000	0.00540		0.0048	0.0060	0.0073	0.0087	0.0095	0.0100	0.0105	0.0109	0.0086
500000	0.00432		0.0046	0.0059	0.0072	0.0086	0.0093	0.0099	0.0103	0.0106	0.0069
600000	0.00360		0.0044	0.0057	0.0070	0.0084	0.0091	0.0098	0.0102	0.0105	0.0057
700000	0.00308		0.0043	0.0056	0.0069	0.0083	0.0090	0.0096	0.0100	0.0103	0.0049
750000	0.00288		0.0042	0.0055	0.0068	0.0082	0.0089	0.0095	0.0099	0.0102	0.0046
800000	0.00270		0.0041	0.0054	0.0067	0.0080	0.0088	0.0094	0.0098	0.0101	0.0043
900000	0.00240		0.0040	0.0053	0.0066	0.0079	0.0087	0.0093	0.0097	0.0100	0.0038
1000000	0.00216		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE CXI

Power and Reactive Factors for Different Angles of Lag or Lead

Degres Lag or Lead	Power Factors Cosine ϕ	Reactive Factors Sine ϕ	Degres Lag or Lead	Power Factors Cosine ϕ	Reactive Factors Sine ϕ	Degres Lag or Lead	Power Factors Cosine ϕ	Reactive Factors Sine ϕ
1	.999	.017	31	.857	.515	61	.485	.875
2	.999	.035	32	.848	.530	62	.469	.883
3	.998	.052	33	.839	.545	63	.454	.891
4	.997	.070	34	.829	.559	64	.438	.899
5	.996	.087	35	.819	.574	65	.423	.906
6	.994	.105	36	.809	.588	66	.407	.914
7	.992	.122	37	.798	.602	67	.391	.921
8	.990	.139	38	.788	.616	68	.375	.927
9	.988	.156	39	.777	.629	69	.358	.934
10	.985	.174	40	.766	.643	70	.342	.940
11	.982	.191	41	.755	.656	71	.326	.946
12	.978	.208	42	.743	.669	72	.309	.951
13	.974	.225	43	.731	.682	73	.292	.956
14	.970	.242	44	.719	.695	74	.276	.961
15	.966	.259	45	.707	.707	75	.259	.966
16	.961	.276	46	.695	.719	76	.242	.970
17	.956	.292	47	.682	.731	77	.225	.974
18	.951	.309	48	.669	.743	78	.208	.978
19	.946	.326	49	.656	.755	79	.191	.982
20	.940	.342	50	.643	.767	80	.174	.985
21	.934	.358	51	.629	.777	81	.156	.988
22	.927	.375	52	.616	.788	82	.139	.990
23	.920	.391	53	.602	.799	83	.122	.992
24	.914	.407	54	.588	.809	84	.105	.994
25	.906	.423	55	.574	.819	85	.087	.996
26	.899	.438	56	.560	.829	86	.070	.997
27	.891	.454	57	.545	.839	87	.052	.998
28	.883	.470	58	.530	.848	88	.035	.999
29	.875	.485	59	.515	.857	89	.017	.999
30	.866	.500	60	.500	.866			

TABLE CXII

Table Showing Average Amperage Per H. P. or K. W. with Various Systems and Voltages of Transmission

	Direct Current		Single Phase		Two Phase 4 Wire		Two Phase 3 Wire		Three Phase	
Volts	H.P.	K.W.	H.P.	K.W.	H.P.	K.W.	H.P.	K.W.	H.P.	K.W.
110	8	10.7	11.0	14.7	5.5	7.4	7.7	10.3	6.4	8.5
220	4	5.4	5.5	7.4	2.8	3.7	3.8	5.2	3.2	4.2
440	2	2.7	2.8	3.7	1.4	1.9	1.9	2.6	1.6	2.1
650	1.3	1.8	1.8	2.5	1.0	1.3	1.3	1.7	1.1	1.4
1000	0.9	1.2	1.2	1.6	0.6	0.8	0.9	1.2	0.7	0.9

TABLE CXIII

Table Showing Divisors of Current for Use in Connection With Tables

Distance in Feet

Volts	100	200	300	400	500	600	700	800	900	1000	1100	1200	1320
110	1.1	.55	.367	.275	.220	.183	.157	.138	.122	.110	.100	.092	.083
220	2.2	1.10	.734	.550	.440	.366	.314	.276	.244	.220	.200	.184	.166
440	4.4	2.20	1.47	1.100	.880	.732	.628	.552	.488	.440	.400	.368	.332
650	6.5	3.25	2.17	1.63	1.30	1.08	.938	.813	.722	.650	.591	.542	.492
1000	10.0	5.00	3.34	2.50	2.00	1.67	1.43	1.25	1.11	1.000	.910	.833	.758

Distance in Feet

Volts	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2640
110	.079	.073	.069	.065	.061	.058	.055	.053	.050	.047	.046	.044	.041
220	.157	.146	.138	.130	.122	.116	.110	.106	.100	.094	.092	.088	.082
440	.314	.292	.276	.260	.244	.232	.220	.212	.200	.188	.184	.176	.164
650	.464	.433	.406	.382	.361	.342	.325	.309	.295	.283	.271	.260	.246
1000	.714	.667	.625	.588	.556	.527	.500	.476	.451	.435	.417	.400	.379

TABLE CXIV

The table below is designed to assist in selecting the proper wire for any desirable loss in connection with direct current and alternating current at 60 cycles.

Rule: Determine number of amperes to be transmitted and divide by number of volts to be lost per 100 feet of line (200 feet wire). Next trace down column under proper separation until a number equal to this or larger is found. In the same horizontal line and at the left under B. & S. will be found the gauge number of the wire to be used.

For three-phase systems, if great accuracy is required, divide volts to be lost by 0.86 before proceeding with the rest. Select no wire unless its carrying capacity is equal to the amperage required.

Copper Wire Carrying Capacities			Direct Current and 60 Cycle Alternating Power Factor 85%									
				Separation in Inches								
R. I.	O. I.	B. & S.	D. C.	½	3	6	12	24	36	48	60	72
15	20	14	1.95	1.96	1.95	1.98	1.98	1.98	1.98	1.98	1.98	1.98
20	25	12	3.09	3.10	3.15	3.14	3.13	3.13	3.12	3.12	3.11	3.11
25	30	10	4.91	4.99	4.98	4.96	4.94	4.93	4.92	4.91	4.90	4.89
35	50	8	7.64	7.44	7.37	7.32	7.28	7.24	7.22	7.20	7.19	7.17
50	70	6	12.2	12.3	12.00	11.9	11.8	11.6	11.5	11.5	11.4	11.4
55	80	5	15.3	15.5	15.0	14.8	14.5	14.2	14.1	14.0	13.9	13.8
70	90	4	19.3	19.3	18.4	18.1	17.6	17.2	16.9	16.7	16.6	16.5
80	100	3	24.4	24.3	22.8	22.2	21.4	20.7	20.2	19.9	19.7	19.5
90	125	2	30.9	30.6	27.9	26.8	25.6	24.4	23.9	23.6	22.2	22.7
100	150	1	38.7	38.0	33.4	31.7	29.8	28.1	27.2	26.7	26.0	25.7
125	200	0	49.0	47.1	39.9	37.1	34.4	32.1	30.6	29.8	29.0	28.5
150	225	00	61.7	58.6	46.9	42.4	38.9	35.6	33.8	32.7	31.8	31.2
175	275	000	78.1	72.6	54.3	48.2	42.9	39.1	36.7	35.1	34.2	33.3
225	325	0000	98.0	96.9	61.6	53.4	46.8	41.6	39.0	37.2	36.0	35.0
240	350	250000	116.3	....	67.0	57.1	49.5	44.2	43.0	38.6	37.2	36.4
275	400	300000	138.9	....	72.9	60.9	51.9	45.1	42.0	39.9	38.4	37.3
300	450	350000	162.3	....	77.3	64.1	54.1	46.6	43.1	40.9	39.4	38.1
325	500	400000	185.2	....	82.5	67.4	56.3	48.2	44.2	41.6	40.2	38.9
400	600	500000	231.5	....	88.3	70.3	58.1	49.4	45.3	42.8	41.1	40.0

TABLE CXV

The table below is designed to assist in selecting the proper wire for any desirable loss in connection with direct current and alternating current at 60 cycles.

Rule: Determine number of amperes to be transmitted and divide by number of volts to be lost per 100 feet of line (200 feet wire). Next trace down column under proper separation until a number equal to this or larger is found. In the same horizontal line and at the left under B. & S. will be found the gauge number of the wire to be used.

For three-phase systems, if great accuracy is required, divide volts to be lost by 0.86 before proceeding with the rest. Select no wire unless its carrying capacity is equal to the amperage required.

Copper Wire Carrying Capacities			Direct Current and 25 Cycle Alternating Power Factor 85%									
				Separation in Inches								
R. I.	O. I.	B. & S.	D. C.	½	3	6	12	24	36	48	60	72
15	20	14	1.95	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98	1.98
20	25	12	3.09	3.31	3.31	3.31	3.31	3.31	3.31	3.30	3.30	3.30
25	30	10	4.91	5.03	5.02	5.01	5.01	5.01	5.00	5.00	5.00	4.99
35	50	8	7.64	7.83	7.81	7.79	7.78	7.76	7.74	7.73	7.72	7.71
50	70	6	12.2	12.5	12.4	12.3	12.3	12.3	12.2	12.2	12.2	12.2
55	80	5	15.3	15.7	15.5	15.4	15.4	15.3	15.3	15.3	15.2	15.2
70	90	4	19.3	19.7	19.5	19.3	19.2	19.1	19.0	18.9	18.8	18.8
80	100	3	24.3	24.5	24.3	24.1	23.8	23.7	23.6	23.5	23.4	23.4
90	125	2	30.9	31.5	30.8	30.4	30.0	29.5	29.3	29.0	29.1	29.1
100	150	1	38.7	39.7	38.1	37.6	36.9	36.1	35.7	35.4	35.2	35.1
125	200	0	49.0	49.8	47.5	46.3	45.1	44.1	43.2	42.9	42.4	42.2
150	225	00	61.7	62.7	58.1	56.6	54.7	53.0	51.7	50.8	50.4	50.0
175	275	000	78.1	78.8	71.7	68.6	65.5	62.7	60.6	59.5	58.9	58.1
225	325	0000	98.0	98.2	86.9	82.1	84.2	72.3	70.1	68.2	66.9	65.6
240	350	250000	116.3	....	104.3	95.8	89.8	82.5	79.5	76.2	74.7	73.1
275	400	300000	138.9	....	114.1	104.5	95.8	87.8	83.6	80.4	79.2	77.2
300	450	350000	162.3	....	127.1	114.9	104.5	94.9	89.0	85.9	83.8	81.5
325	500	400000	185.2	....	138.8	125.5	112.3	100.0	94.3	90.6	87.4	84.9
400	600	500000	231.5	....	159.5	130.9	122.4	107.9	101.7	96.4	93.4	91.1

TABLE CXVI

The table below is designed to assist in selecting the proper wire for any desirable loss in connection with direct current and alternating current at 60 cycles.

Rule: Determine number of amperes to be transmitted and divide by number of volts to be lost per 100 feet of line (200 feet wire). Next trace down column under proper separation until a number equal to this or larger is found. In the same horizontal line and at the left under B. & S. will be found the gauge number of the wire to be used.

For three-phase systems, if great accuracy is required, divide volts to be lost by 0.86 before proceeding with the rest. Select no wire unless its carrying capacity is equal to the amperage required.

Aluminum Wire			Direct Current and 60 Cycle Alternating.									Power Factor 0.85
Carrying Capacities				Separation in Inches								
R. I.	O. I.	B. & S.	D. C.	½	3	6	12	24	36	48	60	72
12	17	14	1.23	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
17	21	12	1.95	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93
21	25	10	3.11	3.14	3.13	3.13	3.13	3.12	3.12	3.12	3.12	3.12
29	42	8	4.95	5.00	4.99	4.98	4.97	4.96	4.95	4.94	4.93	4.93
42	59	6	7.85	7.95	7.72	7.82	7.78	7.73	7.70	7.68	7.66	7.64
46	67	5	9.90	10.2	9.87	9.78	9.71	9.63	9.56	9.53	9.50	9.47
59	76	4	12.40	12.6	12.3	12.2	12.1	11.9	11.8	11.7	11.6	11.5
67	84	3	15.70	15.8	15.4	15.1	14.8	14.6	14.4	14.3	14.3	14.2
76	105	2	19.80	19.9	19.0	18.6	18.1	17.7	17.4	17.3	17.2	17.1
84	126	1	25.10	25.1	23.5	22.9	22.1	21.4	20.9	20.5	20.3	20.1
105	168	0	31.50	31.3	28.7	27.6	26.4	25.1	24.4	24.0	23.5	23.3
126	189	00	39.80	39.5	34.8	32.7	30.8	29.2	28.1	27.4	26.9	26.5
147	231	000	50.20	49.1	41.7	38.6	35.6	33.1	31.7	30.6	30.0	29.4
189	273	0000	63.30	61.1	49.0	44.4	40.4	36.7	34.9	33.6	32.6	31.9
202	294	250000	72.40	....	53.8	48.2	43.1	38.9	36.5	35.3	34.2	33.4
231	336	300000	86.90	....	60.3	52.9	46.5	41.4	38.9	37.2	36.0	35.1
252	378	350000	102.00	....	65.8	56.8	49.5	43.5	40.5	38.7	37.4	36.3
273	420	400000	116.30	....	71.1	60.6	52.1	45.4	41.9	40.0	38.6	37.4
336	504	500000	144.90	....	78.9	65.0	54.9	47.4	43.9	41.5	40.0	38.8

TABLE CXVII

The table below is designed to assist in selecting the proper wire for any desirable loss in connection with direct current and alternating current at 60 cycles.

Rule: Determine number of amperes to be transmitted and divide by number of volts to be lost per 100 feet of line (200 feet wire). Next trace down column under proper separation until a number equal to this or larger is found. In the same horizontal line and at the left under B. & S. will be found the gauge number of the wire to be used.

For three-phase systems, if great accuracy is required, divide volts to be lost by 0.86 before proceeding with the rest. Select no wire unless its carrying capacity is equal to the amperage required.

Aluminum Wire Carrying Capacities			Direct Current and 25 Cycle Alternating, Separation in Inches									
R. I.	O. I.	B. & S.	D. C.	½	3	6	12	24	36	48	60	72
12	17	14	1.23	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
17	21	12	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
21	25	10	3.11	3.16	3.16	3.16	3.15	3.15	3.15	3.15	3.15	3.15
29	42	8	4.95	5.01	5.00	4.99	4.98	4.97	4.96	4.96	4.96	4.96
42	59	6	7.85	8.00	7.98	7.97	7.96	7.95	7.94	7.93	7.92	7.92
46	67	5	9.90	10.11	10.1	10.07	10.05	10.03	10.02	10.01	10.0	9.9
59	76	4	12.40	12.7	12.6	12.6	12.5	12.5	12.5	12.4	12.4	12.4
67	84	3	15.70	15.9	15.8	15.8	15.7	15.7	15.6	15.6	15.5	15.4
76	105	2	19.80	21.2	20.9	20.6	20.5	20.4	20.3	20.2	20.2	20.2
84	126	1	25.10	25.6	25.2	24.9	24.6	24.4	24.3	24.2	24.1	24.0
105	168	0	31.50	32.1	31.4	31.1	30.7	30.3	29.9	29.8	29.7	29.6
126	189	00	39.80	40.5	38.9	38.6	37.7	37.2	36.8	36.4	36.2	36.1
147	231	000	50.20	51.0	48.8	47.7	46.5	45.3	44.6	44.1	43.7	43.4
189	273	0000	63.30	64.3	60.3	58.4	56.5	54.3	53.3	52.4	51.8	51.6
202	294	250000	72.40	....	69.9	67.4	64.5	61.5	60.1	58.7	57.9	57.3
231	336	300000	86.90	....	79.9	75.9	72.3	68.4	66.4	64.7	63.6	62.7
252	378	350000	102.0	....	91.1	86.1	81.1	76.1	72.8	71.1	69.7	68.5
273	420	400000	116.3	....	101.7	95.2	88.7	82.2	78.5	76.5	74.6	72.8
336	504	500000	144.9	....	120.5	110.7	101.1	91.7	87.7	84.2	82.2	80.6

Economy of Conductors.—Any system of electrical conductors may be designed with reference to any of the following conditions:

1. The conductors may be designed for minimum first cost, regardless of waste or quality of service.

2. The conductors may be designed for the best possible service regardless of cost.

3. The conductors may be designed for a minimum cost of generating plant.

4. The conductors may be designed for maximum general economy of operation and installation; i. e., to yield the most profitable results in the long run.

5. The conductors may be designed for a minimum first cost of generating plant and conductors.

The first problem is solved by selecting the smallest wire allowed, either by heating limitations, or mechanical considerations.

The second problem is solved by selecting very large wires, thus reducing the loss to any desired minimum.

The third condition is fulfilled by selecting such large wires that the generator will not be called upon to deliver much waste power.

The fourth problem has heretofore required some very extensive and elaborate calculations, but with the tables following, these have been reduced to a minimum and can be made in a few moments. This is, moreover, a subject which has been very much neglected, especially in connection with short runs such as are used inside of buildings, or to connect one building with another. The general practice has been to figure on a loss of from 2 to 5 per cent, or to disregard all question of economy and work from the standpoint of minimum first cost entirely.

It must be understood that a certain loss in electrical transmission is unavoidable, and that the nearer we approach to an efficiency of 100 per cent the more copper proportionately will be required to reduce the remaining loss. For instance, if we have a certain wire causing a loss of 10 per cent, by adding another wire just like it we reduce our loss to 5 per cent; by adding two more similar wires we reduce the loss only $2\frac{1}{2}$ per cent more, and by adding four more wires of the same size we gain only $1\frac{1}{4}$ per cent more. In other words, the original wire was capable of transmitting 90 per cent of our energy; two wires 95 per cent, four wires $97\frac{1}{2}$ per cent, and eight wires $98\frac{3}{4}$ per cent. That under such circumstances it is easy to spend more in trying to save the energy than it is worth, is evident. It has been shown by Sir Wm. Thompson and others that the most economical loss is that at which the annual value of the energy lost equals the interest charge on the cost of line construction necessary to save it. In making calculations on this subject we need have nothing to do with the total length of line, or even the total cost of the line; we need be concerned only with the difference in cost between installing any convenient length of the smallest wire permissible, and that of substituting a larger wire. In some cases this may cause no other expense except that of the larger wire, in other cases it may be necessary to reconstruct the whole line in order to make room for larger wires.

The basis of the following tables is found in the proposition and formula below:

$$\left(\frac{R}{1000\times c}-\frac{r}{1000\times c}\right)\times I^{2}\times p\times h=$$

the maximum capital which may economically be invested to substitute a larger wire in place of the smallest permissible wire where:

R equals the resistance of the smallest wire considered,

r the resistance of the larger wire to be considered,

c the interest rate applicable (governed by the number of years line is to remain in use),

I the current to be transmitted,

p the rate per K. W. and

h the number of hours I is used per year.

In connection with this formula we need not consider the whole length of line, but may take any convenient portion of it; therefore, in these tables a run of 100 feet (200 feet of wire) is taken as the basis of all calculations.

The rate of interest applicable in this formula is the following: If line is to be in use only one year it must pay a dividend of 106 per cent; two years, 56; three years, 40; four years, 32; five years, 27; six years, 24; seven years, $21\frac{1}{2}$; eight years, about 20, and nine years, $18\frac{3}{4}$ per year.

In table CXVIII the values have been calculated for all of the wire sizes given, I^2 can be easily calculated and p and h can be found, for many values thereof, in table CXIX. The figures in table CXVIII have all been carried out to seven decimal points in order to simplify the comparison of small wires with the larger ones, and also to obtain greater accuracy. In most cases, however, when comparing small wires, it will not be necessary to use the full figures, and one or more figures at the right may be dropped.

In using the tables it will be best to first find the quantity $(I^2 \times p \times h)$, as this is fixed in any given problem. Next determine the smallest wire permissible, either on account of safety rules, mechanical considerations, or perhaps because it is already installed. Note the number given in horizontal line in which the B & S gauge number is found and under the column pertaining to the number of years line is to remain in service; from this number subtract the corresponding number pertaining to some larger wire and with the remainder multiply the quantity I p h previously determined. This will give us the sum in dollars which may economically be invested to substitute the larger wire in place of the smaller. Bear in mind that this is only for a length of run of 100 feet. Example: We wish to find whether it will be profitable to substitute a No. 6 wire in place of a No. 14 carrying a load of 15 amperes, the rate per K.W. being 3 cents, the current to be used 1000 hours per year, and the line assumed to remain in use five years, at the end of which time it will be worthless. Three cents times 1000 hours gives us \$30.00; this multiplied by 225 (I^2) gives us 6750. We now subtract .0002944 (No. 6) from .0018229 (No. 14), which leaves us (omitting the last three decimals) .0016; multiplying 6750 by this, we have 10.8, which is the number of dollars we may spend to install a No. 6 instead of a No. 14 wire. The difference in cost between a No. 14 and a No. 6 is from about ten to twelve dollars, not figuring the cost of supports.

The foregoing calculations are assumed to be made from the standpoint of an engineer who connects onto an established system and who is responsible only for the actual loss in watts occurring on his part of the line. Sometimes, however, a line must be laid out from the central station, and the point then is not only the wattage loss, but also the loss in generator capacity. In this connection the length of the line is the principal consideration, and it becomes a question whether it is cheaper to provide a certain excess capacity in the generator and allow this to be lost in a small transmission line, or to provide a heavier line and use the generator pressure more economically. In lines of this character boosters are usually resorted to to regulate the pressure.

The standard central station system usually soon evolves into an interconnected system of wires in which no accurate calculations on loss can be made.

TABLE CXVIII

To find the maximum amount of capital which may be economically invested to substitute a larger conductor for the smallest one permissible for a run of 100 feet, select smallest wire permissible and note number given in column headed by number of years line is assumed to remain in use. From this number subtract that of a larger wire in same vertical column and with the remainder multiply square of current times cost of 1 K. W. for number of hours line is assumed to be used per year.

B. & S.	1 year	2 years	3 years	4 years	5 years	6 years	7 years	8 years	9 years
14	.0004800	.0009786	.0012710	.0015887	.0018829	.0021184	.0023646	.0025676	.0027187
12	.0003013	.0005703	.0007985	.0009982	.0011829	.0013309	.0015786	.0016131	.0017080
10	.0001902	.0003600	.0005040	.0006300	.0007466	.0008400	.0009376	.0010181	.0010780
8	.0001183	.0002239	.0003135	.0003918	.0004644	.0005225	.0005832	.0006333	.0006706
6	.0000750	.0001419	.0001887	.0002480	.0002944	.0003313	.0003697	.0004015	.0004251
5	.0000595	.0001126	.0001577	.0001971	.0002336	.0002628	.0002933	.0003185	.0003372
4	.0000472	.0000893	.0001250	.0001562	.0001852	.0002083	.0002325	.0002525	.0002674
3	.0000373	.0000707	.0000990	.0001238	.0001466	.0001650	.0001842	.0002000	.0002117
2	.0000296	.0000561	.0000785	.0000981	.0001162	.0001334	.0001460	.0001585	.0001679
1	.0000237	.0000450	.0000630	.0000787	.0000933	.0001050	.0001172	.0001272	.0001347
0	.0000188	.0000357	.0000500	.0000625	.0000741	.0000833	.0000930	.0001010	.0001069
00	.0000149	.0000282	.0000395	.0000494	.0000580	.0000658	.0000734	.0000798	.0000845
000	.0000119	.0000225	.0000315	.0000396	.0000466	.0000525	.0000586	.0000636	.0000673
0000	.0000094	.0000179	.0000250	.0000312	.0000370	.0000417	.0000465	.0000505	.0000534
300000	.0000067	.0000126	.0000177	.0000222	.0000263	.0000296	.0000330	.0000358	.0000379
400000	.0000050	.0000094	.0000132	.0000165	.0000196	.0000221	.0000246	.0000267	.0000283
500000	.0000039	.0000075	.0000105	.0000132	.0000155	.0000175	.0000195	.0000212	.0000224
600000	.0000033	.0000063	.0000088	.0000110	.0000128	.0000146	.0000163	.0000176	.0000187
700000	.0000028	.0000053	.0000075	.0000093	.0000110	.0000125	.0000139	.0000151	.0000160
800000	.0000025	.0000047	.0000066	.0000081	.0000095	.0000108	.0000121	.0000131	.0000139
900000	.0000022	.0000042	.0000060	.0000075	.0000090	.0000100	.0000111	.0000121	.0000128
1000000	.0000020	.0000038	.0000052	.0000066	.0000077	.0000087	.0000097	.0000106	.0000112

TABLE CXIX

Economy of Conductors

Table shows products of various rates per K.W. **multiplied by number of hours used per year.**

Rates per K.W.

Hours used per year	½	1	1½	2	2½	3	4	5	6	7	8	10
100	.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0	10.0
200	1.	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0	16.0	20.0
300	1.5	3.0	4.5	6.0	7.5	9.0	12.0	15.0	18.0	21.0	24.0	30.0
400	2.0	4.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	32.0	40.0
500	2.5	5.0	7.5	10.0	12.5	15.0	20.0	25.0	30.0	35.0	40.0	50.0
600	3.0	6.0	9.0	12.0	15.0	18.0	24.0	30.0	36.0	42.0	48.0	60.0
700	3.5	7.0	10.5	14.0	17.5	21.0	28.0	35.0	42.0	49.0	56.0	70.0
800	4.0	8.0	12.0	16.0	20.0	24.0	32.0	40.0	48.0	56.0	64.0	80.0
900	4.5	9.0	13.5	18.0	22.5	27.0	36.0	45.0	54.0	63.0	72.0	90.0
1000	5.0	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0	70.0	80.0	100.0
1500	7.5	15.0	22.5	30.0	37.5	45.0	60.0	75.0	90.0	105.0	120.0	150.0
2000	10.0	20.0	30.0	40.0	50.0	60.0	80.0	100.0	120.0	140.0	160.0	200.0
3000	15.0	30.0	45.0	60.0	75.0	90.0	120.0	150.0	180.0	210.0	240.0	300.0

TABLE CXX

Copper Wire Table

Bureau of Standards, Washington, D. C.

Working Table, International Standard Annealed Copper American Wire Gauge (B. & S.)

Gauge No.	Diam. in Mils	Cross Section Circular Mils	Cross Section Square Inches	Ohms per 1000 Feet 25° C (=77° F)	Ohms per 1000 Feet 65° C (=149° F)	Pounds per 1000 Feet
0000	460.	212 000.	0.166	0.0500	0.0577	641.
000	410.	168 000.	.132	.0630	.0727	508.
00	365.	133 000.	.105	.0795	.0917	403.
0	325.	106 000.	.0829	.100	.116	319.
1	289.	83 700.	.0657	.126	.146	253.
2	258.	66 400.	.0521	.159	.184	201.
3	229.	52 600.	.0413	.201	.232	159.
4	204.	41 700.	.0328	.253	.292	126.
5	182.	33 100.	.0260	.319	.369	100.
6	162.	26 300.	.0206	.403	.465	79.5
7	144.	20 800.	.0164	.508	.586	63.0
8	128.	16 500.	.0130	.641	.739	50.0
9	114.	13 100.	.0103	.808	.932	39.6
10	102.	10 400.	.008 15	1.02	1.18	31.4
11	91.	8230.	.006 47	1.28	1.48	24.9
12	81.	6530.	.005 13	1.62	1.87	19.8
13	72.	5180.	.004 07	2.04	2.36	15.7
14	64.	4110.	.003 23	2.58	2.97	12.4
15	57.	3260.	.002 56	3.25	3.75	9.86
16	51.	2580.	.002 03	4.09	4.73	7.82
17	45.	2050.	.001 61	5.16	5.96	6.20
18	40.	1620.	.001 28	6.51	7.51	4.92
19	36.	1290.	.001 01	8.21	9.48	3.90
20	32.	1020.	.000 802	10.4	11.9	3.09
21	28.5	810.	.000 636	13.1	15.1	2.45

TABLE CXX—Continued

Gauge No.	Diam. in Mils	Cross Section Circular Mils	Cross Section Square Inches	Ohms per 1000 Feet 25° C (=77° F)	Ohms per 1000 Feet 65° C (=149° F)	Pounds per 1000 Feet
22	25.3	642.	.000 505	16.5	19.0	1.94
23	22.6	509.	.000 400	20.8	24.0	1.54
24	20.1	404.	.000 317	26.2	30.2	1.22
25	17.9	320.	.000 252	33.0	38.1	0.970
26	15.9	254.	.000 200	41.6	48.0	.769
27	14.2	202.	.000 158	52.5	60.6	.610
28	12.6	160.	.000 126	66.2	76.4	.484
29	11.3	127.	.000 099 5	83.4	96.3	.384
30	10.0	101.	.000 078 9	105.	121.	.304
31	8.9	79.7	.000 062 6	133.	153.	.241
32	8.0	63.2	.000 049 6	167.	193.	.191
33	7.1	50.1	.000 039 4	211.	243.	.152
34	6.3	39.8	.000 031 2	266.	307.	.120
35	5.6	31.5	.000 024 8	335.	387.	.0954
36	5.0	25.0	.000 019 6	423.	488.	.0757
37	4.5	19.8	.000 015 6	533.	616.	.0600
38	4.0	15.7	.000 012 3	673.	776.	.0476
39	3.5	12.5	.000 009 8	848.	979.	.0377
40	3.1	9.9	.000 007 8	1070.	1230.	.0299

Note. 1.—The table is based on the international standard of resistance for copper, which takes the fundamental mass resistivity = 0.15328 ohm (meter, gram) at 20° C, the corresponding temperature coefficient = 0.00393 at 20° C, and the density = 8.89 grams per cc at 20° C. The temperature coefficient is proportional to the conductivity, whence the change of mass resistivity per degree C is a constant, 0.000597 ohm (meter, gram).

Note 2.—The values given in the table are only for annealed copper of the standard resistivity. The user of the table must apply the proper correction for copper of any other resistivity. Hard-drawn copper may be taken as about 2.7 per cent higher resistivity than annealed copper.

Note 3.—Ohms per mile, or pounds per mile, may be obtained by multiplying the respective values above by 5.28.

Note 4.—For complete tables and other data see Circular No. 31 of the Bureau of Standards.

Bureau of Standards, Washington, D. C., 1914

TABLE CXXI

Bare Concentric-Lay Cables of Standard Annealed Copper

Bureau of Standards, Washington, D. C.

Size of Cable Circular Mils	Size of Cable A.W.G. No.	Ohms per 1000 Feet 25° C (=77° F)	Ohms per 1000 Feet 65° C (=149° F)	Pounds per 1000 ft.	Standard Concentric Stranding Number of Wires	Standard Concentric Stranding Diam. of Wires, in Mils	Standard Concentric Stranding Outside Diam., in Mils	Flexible Concentric Stranding Number of Wires	Flexible Concentric Stranding Diam. of Wires, in Mils	Flexible Concentric Stranding Outside Diam., in Mils
2 000 000		0.005 39	0.006 22	6180.	127	125.5	1631.	169	108.8	1632.
1 900 000		.005 68	.006 55	5870.	127	122.3	1590.	169	106.0	1590.
1 800 000		.005 99	.006 92	5560.	127	119.1	1548.	169	103.2	1548.
1 700 000		.006 34	.007 32	5250.	127	115.7	1504.	169	100.3	1504.
1 600 000		.006 74	.007 78	4940.	127	112.2	1459.	169	97.3	1460.
1 500 000		.007 19	.008 30	4630.	91	128.4	1412.	127	108.7	1413.
1 400 000		.007 70	.008 89	4320.	91	124.0	1364.	127	105.0	1365.
1 300 000		.008 30	.009 58	4010.	91	119.5	1315.	127	101.2	1315.
1 200 000		.008 99	.0104	3710.	91	114.8	1263.	127	97.2	1264.
1 100 000		.009 81	.0114	3400.	91	109.9	1209.	127	93.1	1210.
1 000 000		.0108	.0124	3090.	61	128.0	1152.	91	104.8	1153.
950 000		.0114	.0131	2930.	61	124.8	1123.	91	102.2	1124.
900 000		.0120	.0138	2780.	61	121.5	1093.	91	99.4	1094.
850 000		.0127	.0146	2620.	61	118.0	1062.	91	96.6	1063.

TABLE CXXI—Continued

Size of Cable: Circular Mils	Size of Cable: A.W.G. No.	Ohms per 1000 Feet: 25° C (=77° F)	Ohms per 1000 Feet: 65° C (=149° F)	Pounds per 1000 ft.	Standard Concentric Stranding: Number of Wires	Standard Concentric Stranding: Diam. of Wires, in Mils	Standard Concentric Stranding: Outside Diam., in Mils	Flexible Concentric Stranding: Number of Wires	Flexible Concentric Stranding: Diam. of Wires, in Mils	Flexible Concentric Stranding: Outside Diam., in Mils
800 000		.0135	.0156	2470.	61	114.5	1031.	91	93.8	1031.
750 000		.0144	.0166	2320.	61	110.9	998.	91	90.8	999.
700 000		.0154	.0178	2160.	61	107.1	964.	91	87.7	965.
650 000		.0166	.0192	2010.	61	103.2	929.	91	84.5	930.
600 000		.0196	.0207	1185.	61	99.2	893.	91	81.2	893.
550 000		.0196	.0226	1700.	61	95.0	855.	91	77.7	855.
500 000		.0216	.0249	1540.	37	116.2	814.	61	90.5	815.
450 000		.0240	.0277	1390.	37	110.3	772.	61	85.9	773.
400 000		.0270	.0311	1240.	37	104.0	728.	61	81.0	729.
350 000		.0308	.0356	1080.	37	97.3	681.	61	75.7	682.
300 000		.0360	.0415	926.	37	90.0	630.	61	70.1	631.
250 000		.0431	.0498	772.	37	82.2	575.	61	64.0	576.
212 000	0000	.0509	.0587	653.	19	105.5	528.	37	75.6	533.
168 000	000	.0652	.0741	518.	19	94.0	470.	37	67.3	471.
133 000	00	.0811	.0936	411.	19	83.7	418.	37	60.0	420.
106 000	0	.102	.117	326.	19	74.5	373.	37	53.4	374.
83 700	1	.129	.149	258.	19	66.4	332.	37	47.6	333.
66 400	2	.162	.187	205.	7	97.4	292.	19	59.1	296.
52 600	3	.205	.237	163.	7	86.7	260.	19	52.6	263.

TABLE CXXI—Continued

Size of Cable		Ohms per 1000 Feet		Pounds per 1000 ft.	Standard Concentric Stranding			Flexible Concentric Stranding		
Circular Mils	A.W.G. No.	25° C (=77° F)	65° C (=149° F)		Number of Wires	Diam. of Wires, in Mils	Outside Diam., in Mils	Number of Wires	Diam. of Wires, in Mils	Outside Diam., in Mils
41 700	4	.259	.299	129.	7	77.2	232.	19	46.9	234.
33 100	5	.326	.376	102.	7	68.8	206.	19	41.7	209.
26 300	6	.410	.473	81.0	7	61.2	184.	19	37.2	186.
20 800	7	.519	.599	64.3	7	54.5	164.	19	33.1	166.
16 500	8	.654	.755	51.0	7	48.6	146.	19	29.5	147.

Note 1.—The fundamental resistivity used in calculating the table is the International Annealed Copper Standard, viz., 0.15328 ohm (meter, gram) at 20° C (increased by 2 per cent as explained in Note 2 and on P. —). The temperature coefficient is given in Table —. The density is 8.89 grams per cubic centimeter.

Note 2.—This table is in accord with standards adopted by the Standards Committee of the American Institute of Electrical Engineers, both in respect to the "Number of wires" and in respect to the correction for increase of resistance and mass due to the twist of the wires. The values given for "Ohms per 1000 feet" and "Pounds per 1000 feet" are 2 per cent greater than for a solid rod of cross section equal to the total cross section of the wires of the cable. This increment of 2 per cent means that the values are correct for cables having a lay of 1 in 15.7. For any other lay, equal to 1 in n, resistance or mass may be calculated by increasing the above tabulated values by

$$\left(\frac{493.}{n^2} - 2.\right)\%.$$

TABLE CXXII

Aluminum Company of America

Stranded Aluminum Wire

Diameter and Properties

Conductivity at 62 in the Matthiessen Standard Scale

		DIAMETERS		WEIGHT IN POUNDS			
				BARE		Triple Braid Insulated	Resistance in Ohms. at 70° F
Number B. & S. Gauge	Circular Mils.	Decimal Parts of an Inch.	Nearest 32nd of an Inch.	Per 1000 Feet.	Per Mile.	Per 1000 Feet.	per 1000 Ft.
....	1000000	1.152	$1\frac{5}{32}$	920.	4858.	1406.	.016726
....	950000	1.125	$1\frac{1}{8}$	874.	4617.	1337.	.017606
....	900000	1.092	$1\frac{3}{32}$	828.	4374.	1268.	.018585
....	850000	1.062	$1\frac{1}{16}$	782.	4131.	1199.	.019679
....	800000	1.035	$1\frac{1}{32}$	736.	3888.	1129.	.020907
....	750000	.996	1	690.	3645.	1060.	.022301
....	700000	963	$\frac{31}{32}$	644.	3402.	990.	.023894
....	650000	.928	$\frac{15}{16}$	598.	3159.	921.	.025734
....	600000	.891	$\frac{29}{32}$	552.	2916.	852.	.027878
....	550000	.854	$\frac{27}{32}$	506.	2673.	782.	.030411
....	500000	.814	$\frac{13}{16}$	460.	2430.	713.	.033450
....	450000	.772	$\frac{25}{32}$	414.	2187.	644.	.037170
....	400000	.725	$\frac{23}{32}$	368.	1944.	575.	.041818
....	350000	.679	$\frac{11}{16}$	322.	1701.	506.	.047789
....	300000	.621	$\frac{5}{8}$	276.	1458.	436.	.055755
....	250000	.567	$\frac{9}{16}$	230.	12.15	366.	.066905
0000	211600	.522	$\frac{17}{32}$	195.	1028.	313.	.079045
000	167805	.464	$\frac{15}{32}$	155.	816.	253.	.099675
00	133079	.414	$\frac{13}{32}$	123.	647.	204.	.12569
0	105534	.368	$\frac{3}{8}$	97.	513.	165.	.15849
1	83694	.328	$\frac{11}{32}$	77.	407.	135.	.19984
2	66373	.291	$\frac{9}{32}$	61.	323.	112.	.25200
3	52634	.261	$\frac{1}{4}$	48.5	256.	93.5	.31779
4	41742	.231	$\frac{7}{32}$	38.5	203.	76.5	.40069
5	33102	.206	$\frac{7}{32}$	30.2	161.	56.0	.50530
6	26250	.180	$\frac{3}{16}$	24.1	128.	47.0	.63720

TABLE CXXIII

Aluminum Company of America

Weight of Aluminum, Wrought Iron, Steel, Copper and Brass Wire.

Diameters determined by American (Brown & Sharpe) Gauge.

Water at 62° Fahrenheit, 62.355 lbs. per cubic foot.

Drawn	Wrought Iron	is	2.8724	times	heavier	than	Drawn	Aluminum.
"	Steel	"	2.9322	"	"	"	"	"
"	Copper	"	3.3321	"	"	"	"	"
"	Brass	"	3.1900	"	"	"	"	"

No. of Gauge	Size of each No. Inch	Ft. per lb. Aluminum Feet	Weight of Wire per 1000 Lineal Feet: Aluminum Lbs.	Wro't Iron Lbs.	Steel Lbs.	Copper Lbs.	Brass Lbs.
0000	.46000	5.185	192.86	553.97	565.50	642.68	615.21
000	.40964	6.539	152.94	439.33	448.45	509.32	487.92
00	.36480	8.246	121.28	348.40	355.65	404.20	386.94
0	.32486	10.396	96.18	276.30	282.02	320.50	306.83
1	.28930	13.108	76.29	219.11	223.68	254.20	243.35
2	.25763	16.529	60.50	173.78	177.38	201.60	192.98
3	.22942	20.846	47.97	137.80	140.67	159.86	153.02
4	.20431	26.281	38.05	109.28	111.57	126.78	121.37
5	.18194	33.146	30.17	86.68	88.46	100.54	96.26
6	.16202	41.789	23.93	68.73	70.15	79.72	76.32
7	.14428	52.687	18.98	54.43	55.56	63.23	60.53
8	.12849	66.445	15.05	43.23	44.12	50.14	48.00
9	.11443	83.822	11.93	34.28	34.99	39.77	38.07
10	.10189	105.68	9.462	27.18	27.74	31.53	30.18
11	.090742	133.24	7.505	21.56	22.01	25.01	23.94
12	.080808	168.01	5.952	17.10	17.46	19.83	18.99
13	.071961	211.86	4.720	13.56	13.84	15.73	15.06
14	.064084	267.17	3.743	10.75	10.98	12.47	11.94

TABLE CXXIII—Continued

No. of Gauge	Size of each No. Inch	Ft. per lb. Aluminum Feet	Weight of Wire per 1000 Lineal Feet: Aluminum Lbs.	Wro't Iron Lbs.	Steel Lbs.	Copper Lbs.	Brass Lbs.
15	.057068	336.93	2.968	8.526	8.704	9.890	9.468
16	.050820	424.81	2.354	6.761	6.903	7.843	7.508
17	.045257	535.62	1.867	5.362	5.474	6.220	5.955
18	.040303	675.67	1.480	4.252	4.342	4.933	4.723
19	.035890	851.79	1.174	3.372	3.443	3.912	3.755
20	.031961	1074.11	.9310	2.672	2.730	3.102	2.970
21	.028462	1356.	.7382	2.121	2.165	2.460	2.355
22	.025347	1707.94	.5855	1.682	1.717	1.951	1.868
23	.022571	2153.78	.4643	1.333	1.361	.547	1.481
24	.020100	2715.91	.3682	1.058	1.080	1.227	1.175
25	.017900	3424.66	.2920	.8388	.8563	.9731	.9316
26	.015940	4317.78	.2316	.6652	.6791	.7716	.7387
27	.014195	5446.63	.1836	.5276	.5385	.6120	.5858
28	.012641	6868.13	.1456	.4183	.4270	.4853	.4645
29	.011257	8657.5	.1155	.3317	.3386	.3849	.3683
30	.010025	10917.0	.0916	.2631	.2686	.3052	.2922
31	.008928	13762.8	.0727	.2087	.2130	.2421	.2318
32	.007950	17361.1	.0576	.1655	.1693	.1919	.1837
33	.007080	21886.7	.0457	.1312	.1340	.1522	.1457
34	.006304	27622.	.0362	.1040	.1062	.1207	.1155
35	.005614	34807.3	.0287	.0825	.0842	.0957	.0916
36	.005000	43878.9	.0228	.0655	.0668	.0759	.0727
37	.004453	55245.	.0181	.0519	.0530	.0602	.0577
38	.003965	69783.7	.0143	.0413	.0420	.0478	.0457
39	.003531	88028.2	.0114	.0326	.0333	.0379	.0363
40	.003144	110980.	.0090	.0259	.0264	.0300	.0287
Specific gravity Wire...			2.680	7.698	7.858	8.930	8.549
Wt., per cu. ft., Wire..			167.111	480.000	490.000	556.830	533.073

TABLE CXXIV

Circular of the Bureau of Standards

Hard-Drawn Aluminum Wire at 20° C (or, 68° F)

Bureau of Standards, Washington, D. C.

American Wire Gauge (B. & S.)

Gauge No.	Diameter in Mils	Cross Section		Ohms per 1000 Feet	Pounds per 1000 Feet	Pounds per Ohm	Feet per Ohm
		Circular Mils	Square Inches				
0000	460.	212 000.	0.166	0.0804	195.	2420.	12 400.
000	410.	168 000.	.132	.101	154.	1520.	9860.
00	365.	133 000.	.105	.128	122.	957.	7820.
0	325.	106 000.	.0829	.161	97.0	602.	6200.
1	289.	83 700.	.0657	.203	76.9	379.	4920.
2	258.	66 400.	.0521	.256	61.0	238.	3900.
3	229.	52 600.	.0413	.323	48.4	150.	3090.
4	204.	41 700.	.0328	.408	38.4	94.2	2450.
5	182.	33 100.	.0260	.514	30.4	59.2	1950.

TABLE CXXIV—Continued

Gauge No.	Diameter in Mils	Cross Section Circular Mils	Cross Section Square Inches	Ohms per 1000 Feet	Pounds per 1000 Feet	Pounds per Ohm	Feet per Ohm
6	162.	26 300.	.0206	.648	24.1	37.2	1540.
7	144.	20 800.	.0164	.817	19.1	23.4	1220.
8	128.	16 500.	.0130	1.03	15.2	14.7	970.
9	114.	13 100.	.0103	1.30	12.0	9.26	770.
10	102.	10 400.	.008 15	1.64	9.55	5.83	610.
11	91.	8230.	.006 47	2.07	7.57	3.66	484.
12	81.	6530.	.005 13	2.61	6.00	2.30	384.
13	72.	5180.	.004 07	3.29	4.76	1.45	304.
14	64.	4110.	.003 23	4.14	3.78	0.911	241.
15	57.	3260.	.002 56	5.22	2.99	.573	191.
16	51.	2580.	.002 03	6.59	2.37	.360	152.
17	45.	2050.	.001 61	8.31	1.88	.227	120.
18	40.	1620.	.001 28	10.5	1.49	.143	95.5
19	36.	1290.	.001 01	13.2	1.18	.0897	75.7
20	32.	1020.	.000 802	16.7	0.939	.0564	60.0
21	28.5	810.	.000 636	21.0	.745	.0355	47.6
22	25.3	642.	.000 505	26.5	.591	.0223	37.8
23	22.6	509.	.000 400	33.4	.468	.0140	29.9

TABLE CXXIV—Continued

Gauge No.	Diameter in Mils	Cross Section Circular Mils	Cross Section Square Inches	Ohms per 1000 Feet	Pounds per 1000 Feet	Pounds per Ohm	Feet per Ohm
24	20.1	404.	.000 317	42.1	.371	.008 82	23.7
25	17.9	320.	.000 252	53.1	.295	.005 55	18.8
26	15.9	254.	.000 200	67.0	.234	.003 49	14.9
27	14.2	202.	.000 158	84.4	.185	.002 19	11.8
28	12.6	160.	.000 126	106.	.147	.001 38	9.39
29	11.3	127.	.000 099 5	134.	.117	.000 868	7.45
30	10.0	101.	.000 078 9	169.	.0924	.000 546	5.91
31	8.9	79.7	.000 062 6	213.	.0733	.000 343	4.68
32	8.0	63.2	.000 049 6	269.	.0581	.000 216	3.72
33	7.1	50.1	.000 039 4	339.	.0461	.000 136	2.95
34	6.3	39.8	.000 031 2	428.	.0365	.000 085 4	2.34
35	5.6	31.5	.000 024 8	540.	.0290	.000 053 7	1.85
36	5.0	25.0	.000 019 6	681.	.0230	.000 033 8	1.47
37	4.5	19.8	.000 015 6	858.	.0182	.000 021 2	1.17
38	4.0	15.7	.000 012 3	1080.	.0145	.000 013 4	0.924
39	3.5	12.5	.000 009 79	1360.	.0115	.000 008 40	.733
40	3.1	9.9	.000 007 77	1720.	.0091	.000 005 28	.581

Copper Clad Steel Wire

Copper Clad Wire is made by welding molten copper to a steel billet. This copper clad billet is then hot-rolled to a ⅜-inch rod and cold-drawn into wire under a process similar to that of copper and other wire.

It is absolutely rustproof, possesses greater strength than copper, and is less expensive.

Comparative Characteristics of Copper and Copper Clad

Size B. & S.	Weight, Lbs. Per Mile: Copper Clad	Weight, Lbs. Per Mile: Copper	Approximate Elastic Limit: Copper Clad	Approximate Elastic Limit: Copper	Approximate Breaking Weight, Lbs.: Copper Clad	Approximate Breaking Weight, Lbs.: Copper	Av. Resistance Int. Ohms per Mile at 75° Fahr. Copper Clad 30% Grade: Max. 27%	30% Grade: Av. 30%	40% Grade: Max. 35%	40% Grade: Av. 40%	Copper
0000	3140	3378	5000	2770	10000	8310	1	.90	.77	.67	.27
000	2490	2678	4150	2190	8300	6580	1.26	1.13	.97	.85	.34
00	1975	2124	3420	1740	6850	5226	1.59	1.43	1.23	1.07	.43
0	1570	1685	2850	1520	5700	4558	2	1.80	1.54	1.35	.54
1	1240	1336	2400	1250	4800	3746	2.55	2.30	1.97	1.72	.69
2	985	1059	2000	1040	4000	3127	3.19	2.87	2.46	2.15	.86
3	780	840.1	1600	830	3200	2480	4.04	3.63	3.11	2.72	1.09
4	620	666.3	1300	650	2600	1967	5.07	4.57	3.91	3.43	1.37
5	491	528.2	1100	520	2200	1559	6.40	5.77	4.94	4.33	1.73
6	390	419	900	410	1800	1237	8.07	7.26	6.23	5.45	2.18
7	309	332.4	720	330	1450	980	10.22	9.20	7.88	6.90	2.76
8	245	263.6	600	260	1200	778	12.92	11.63	9.97	8.73	3.49
9	194	208.9	480	210	975	617	16.26	14.63	12.54	10.97	4.39
10	154	165.8	400	160	800	489	20.33	18.30	15.68	13.72	5.49
11	122	131.3	325	130	650	388	25.55	23	19.71	17.25	6.90
12	97	104.2	250	100	510	307	32.22	29	24.85	21.75	8.70
13	77	82.7	200	80	410	244	40.78	36.70	31.45	27.57	11.01
14	61	65.5	165	60	320	193	51.63	46.47	39.83	34.85	13.94

It will be noted that, owing to the difference in specific gravities, there is a saving of about 7 per cent in copper clad over copper wire of the same size and length.

We have given above, under each grade, two columns of resistances, the first giving the maximum allowable resistance of any coil, and the second the average resistance of the material furnished in that grade. **For practical purposes and line calculations, the average resistance is the figure that should be used.**

TABLE CXXVI

Comparative Weights of Copper Clad and Copper Weatherproof Wire.

Size B. & S.	Double Braid Per 1000 Feet Copper Clad	Double Braid Per 1000 Feet Copper	Double Braid Per Mile Copper Clad	Double Braid Per Mile Copper	Triple Braid Per 100 Feet Copper Clad	Triple Braid Per 100 Feet Copper	Triple Braid Per Mile Copper Clad	Triple Braid Per Mile Copper
0000	678	723	3578	3817	722	767	3811	4050
000	551	587	2909	3098	593	629	3131	3320
00	439	467	2317	2467	473	502	2500	2650
0	354	377	1870	1989	385	407	2031	2150
1	276	294	1458	1553	298	316	1575	1670
2	225	239	1189	1264	245	260	1295	1370
3	174	185	918	977	188	199	991	1050
4	142	151	748	795	155	164	818	865
5	115	122	608	646	127	135	673	710
6	94.5	100	499	529	106	112	560	590
8	62.5	66	330	349	71.25	75	376	395
9	50.75	54	268	283	58.75	62	310	325
10	43.5	46	229	241	50.75	53	268	280
12	28.5	30	151	158	33.75	35	178	185
14	19.5	20	102	107	24.00	25	127	130

An allowable variation of 3 per cent on either side is understood.

TABLE CXXVII

18% German Silver Resistance Wire.

No. B. & S. Gauge	Diam. Ins.	Area C. M.	Resistance per 1000 Ft. at 75° F.	Weight Lbs. per 1000 Ft. Bare	Ohms Per Lb
0	.325	105,625	1.95	302	.00645
1	.289	83,521	2.53	239	.01025
2	.258	66,564	3.22	190	.0163
3	.229	52,441	4.14	150	.0259
4	.204	41,616	5.18	119	.0412
5	.182	33,124	6.55	95	.0656
6	.162	26,244	8.28	72	.1042
7	.144	20,736	10.47	59	.1657
8	.128	16,384	13.22	47	.2635
9	.114	12,996	16.68	37.6	.4189
10	.102	10,404	20.8	29.2	.6663
11	.091	8,281	26.2	23.7	1.059
12	.081	6,561	33.2	18.8	1.684
13	.072	5,184	42	14.8	2.619
14	.064	4,096	53	11.7	4,258
15	.057	3,249	67	9.3	6.773
16	.051	2,601	84	7.45	10.768
17	.045	2,025	107	5.73	17.121
18	.040	1,600	136	4.57	27.216
19	.036	1,296	168	3.7	43.281
20	.032	1,024	222	2.93	68.838
21	.0285	812.3	270	2.32	109.45
22	.0253	640.1	340	1.83	174.03
23	.0226	510.8	425	1.46	276.78
24	.0201	404.0	540	1.15	439.95
25	.0179	320.4	680	.91	699.72
26	.0159	252.8	864	.72	1,112.4
27	.0142	201.6	1,076	.58	1,768.8
28	.0126	158.8	1,370	.46	2,811.9
29	.0113	127.7	1,700	.365	4,473
30	.010	100.0	2,180	.286	7,011
31	.0089	79.2	2,750	.266	11,306
32	.008	64.0	3,400	.183	17,980
33	.0071	50.4	4,300	.144	28,581
34	.0063	39.7	5,480	.113	45,465
35	.0056	31.4	6,920	.090	72,261
36	.005	25.0	8,700	.071	114,933
37	.0045	20.2	11,000	.058	182,742
38	.004	16.0	13,850	.046	291,270
39	.0035	12.2	17,550	.035	462,000
40	.003	9.0	22,200	.026	887,250

The composition commonly known as German Silver is that containing 18% of nickel. Its resistance varies somewhat in different lots, and according to temper, and is approximately 21 times that of copper.

30% German Silver Wire has a resistance approximately 28 times that of copper.

TABLE CXXVIII

Properties of Galvanized Telephone and Telegraph Wires.

Based on Standard Specifications.

American Steel and Wire Co.

Size B.W.G.	Diam. in Mils	Area in Circular Mils	Approximate wt. in lbs.		Approximate breaking strain in lbs.			Res. per mile (Latent Ohms) at 68° F., 20° C.		
			Per 1000 feet	Per mile	Ex. B.B.	B.B.	Steel	Ex. B.B.	B.B.	Steel
0	340	115600	313	1655	4138	4634	4965	2.84	3.38	3.93
1	300	90000	244	1289	3223	3609	3867	3.65	4.34	5.04
2	284	80656	218	1155	2888	3234	3465	4.07	4.85	5.63
3	259	67081	182	960	2400	2688	2880	4.90	5.83	6.77
4	238	56644	153	811	2028	2271	2433	5.80	6.91	8.01
5	220	48400	131	693	1732	1940	2079	6.78	8.08	9.38
6	203	41209	112	590	1475	1652	1770	7.97	9.49	11.02
7	180	32400	87	463	1158	1296	1389	10.15	12.10	14.04
8	165	27225	74	390	975	1092	1170	12.05	14.36	16.71
9	148	21904	60	314	785	879	942	14.97	17.84	20.70
10	134	17956	49	258	645	722	774	18.22	21.71	25.29
11	120	14400	39	206	515	577	618	22.82	27.19	31.55
12	109	11881	32	170	425	476	510	27.65	32.94	38.23
13	95	9025	25	129	310	347	372	37.90	45.16	52.41
14	83	6889	19	99	247	277	297	47.48	56.56	65.66
15	72	5184	14	74	185	207	222	63.52	75.68	87.84
16	65	4225	11	61	152	171	183	77.05	91.80	106.55

TABLE CXXIX

Approximate Outside Dimensions of Wires and Cables

The table below is for the use of those who wish to estimate carrying capacities of conductors without cutting into insulation or shutting down a plant. The figures given are thought to be an average for voltage up to 600. Weatherproof dimensions are for minimum thickness allowed by N. E. C.

	Rubber Covered			Weatherproof			Lead Covered		
Circular Mils.	Diameter	Circumference	Wt. per 1000 Ft.	Diameter	Circumference	Wt. per 1000 Ft.	Diameter	Circumference	Wt. per 1000 Ft.
2000000	2 1/8	6 43/64	7200	1 56/64	5 57/64	7008	2 8/64	6 43/64	11300
1750000	2 1/32	6 25/64	6300	1 49/64	5 35/64	6190	2 2/64	6 25/64	10225
1500000	1 7/8	5 57/64	5550	1 42/64	5 13/64	5375	1 60/64	6 6/64	9100
1250000	1 3/4	5 32/64	4700	1 35/64	4 55/64	4500	1 50/64	5 38/64	7950
1000000	1 34/64	4 52/64	3900	1 26/64	4 27/64	3675	1 39/64	5 4/64	6280
950000	1 31/64	4 46/64	3750				1 35/64	4 55/64	6050
900000	1 29/64	4 36/64	3575	1 20/64	4 8/64	3330	1 33/64	4 49/64	5800
850000	1 27/64	4 30/64	3400				1 33/64	4 46/64	5580
800000	1 25/64	4 23/64	3250	1 16/64	3 59/64	3000	1 30/64	4 40/64	5350
750000	1 23/64	4 17/64	3000	1 14/64	3 53/64	2800	1 28/64	4 33/64	5110
700000	1 20/64	4 8/64	2850	1 12/64	3 47/64	2650	1 26/64	4 28/64	4880
650000	1 18/64	4 1/64	2835				1 24/64	4 20/64	4640
600000	1 15/64	3 56/64	2575	1 7/64	3 35/64	2250	1 23/64	4 17/64	4385
550000	1 12/64	3 47/64	2325				1 22/64	4 14/64	4150
500000	1 8/64	3 34/64	2130	1 5/64	3 25/64	1900	1 13/64	3 50/64	3480
450000	1 5/64	3 25/64	1925	61/64	2 63/64	1700	1 12/64	3 47/64	3225
400000	1 2/64	3 18/64	1735	59/64	2 57/64	1550	1 10/64	3 41/64	3000
350000	63/64	3 6/64	1525	56/64	2 48/64	1350	1 5/64	3 25/64	2750
300000	60/64	2 56/64	1360	52/64	2 35/64	1175	1 1/64	3 12/64	2480
250000	57/64	2 51/64	1185	49/64	2 28/64	985	61/64	3	2230
225000	55/64	2 45/64	975						

TABLE CXXX

Approximate Outside Diameter of Wires and Cables Rubber Covered, 0 to 600 Volts

B. & S.	Solid S.B.	Solid D.B.	Stranded S.B.	Stranded D.B.	Wt. per 1000 feet	Duplex Solid	Duplex Stranded
0000	44/64	47/64	49/64	52/64	850	48/64 × 91/64	52/64 × 99/64
000	40/64	43/64	45/64	48/64	700	44/64 × 82/64	48/64 × 92/64
00	37/64	40/64	41/64	44/64	575	41/64 × 77/64	44/64 × 83/64
0	34/64	37/64	38/64	41/64	475	38/64 × 71/64	41/64 × 78/64
1	32/64	35/64	35/64	38/64	375	35/64 × 66/64	38/64 × 72/64
2	28/64	31/64	30/64	33/64	300	31/64 × 58/64	34/64 × 63/64
3	26/64	29/64	28/64	31/64	260	29/64 × 54/64	31/64 × 58/64
4	24/64	27/64	26/64	29/64	215	28/64 × 51/64	30/64 × 54/64
5	23/64	26/64	25/64	27/64	185	26/64 × 48/64	27/64 × 50/64
6	21/64	24/64	23/64	26/64	150	25/64 × 45/64	26/64 × 48/64
8	17/64	20/64	18/64	21/64	100	21/64 × 31/64	22/64 × 39/64
10	15/64	18/64	16/64	19/64	75	19/64 × 33/64	20/64 × 35/64
12	14/64	17/64	15/64	18/64	60	17/64 × 31/64	18/64 × 32/64
14	13/64	16/64	14/64	17/64	45	16/64 × 28/64	17/64 × 29/64
16	10/64	13/64			30	13/64 × 22/64	
18	9/64	12/64			20	12/64 × 21/64	

600 to 3500 Volts

B. & S.	Solid S.B.	Solid D.B.	Stranded S.B.	Stranded D.B.	Wt. per 1000 feet	Duplex Solid	Duplex Stranded
0000	46/64	49/64	51/64	54/64	850	50/64 × 94/64	54/64 × 104/64
000	43/64	46/64	47/64	50/64	700	46/64 × 88/64	50/64 × 96/64
00	39/64	42/64	43/64	46/64	575	43/64 × 81/64	46/64 × 89/64
0	37/64	40/64	40/64	43/64	475	40/64 × 76/64	43/64 × 82/64
1	34/64	37/64	37/64	40/64	375	38/64 × 70/64	40/64 × 77/64
2	32/64	35/64			300	36/64 × 66/64	37/64 × 71/64
3	30/64	33/64	34/64	37/64	260	33/64 × 62/64	35/64 × 67/64
4	28/64	31/64	30/64	33/64	215	32/64 × 59/64	33/64 × 63/64
5	27/64	30/64	32/64	35/64	185	30/64 × 56/64	32/64 × 59/64
6	26/64	29/64	27/64	30/64	150	29/64 × 54/64	30/64 × 56/64
8	23/64	26/64	24/64	27/64	100	27/64 × 49/64	28/64 × 52/64
10	22/64	25/64	22/64	24/64	75	25/64 × 45/64	26/64 × 48/64
12	20/64	23/64	21/64	24/64	60	24/64 × 43/64	24/64 × 44/64
14	19/64	22/64	20/64	23/64	45	23/64 × 41/64	23/64 × 41/64

Weights given are thought to be average weights; duplex wires weigh nearly double the amounts given.

TABLE CXXXI

Approximate Weight and Diameters of Rubber Covered Lead Encased Cables

Single Conductor 0 to 600 Volts Duplex Conductor

B. & S.	Diameter	Wt. per 1000 ft.	Diameter	Wt. per 1000 ft.
0000	54/64	1600	54/64 × 104/64	2900
000	51/64	1400	50/64 × 96/64	2600
00	49/64	1250	47/64 × 90/64	2300
0	45/64	1100	44/64 × 78/64	2000
1	38/64	900	39/64 × 68/64	1700
2	34/64	750	38/64 × 62/64	1400
4	29/64	500	32/64 × 56/64	1100
6	26/64	400	28/64 × 50/64	800
8	22/64	300	22/64 × 40/64	600
10	21/64	275	21/64 × 38/64	500
12	18/64	175	19/64 × 34/64	350
14	16/64	150	18/64 × 32/64	300

TABLE CXXXII

8ths.	16ths.	32nds.	64ths.	Mils.	8ths.	16ths.	32nds.	64ths.	Mils.
			1	15.6				33	515.6
		1	2	31.2			17	34	531.2
			3	46.9				35	546.8
	1	2	4	62.5		9	18	36	562.5
			5	78.1				37	578.1
		3	6	93.7			19	38	593.7
			7	109.3				39	609.3
1	2	4	8	125.	5	10	20	40	625.
			9	140.6				41	640.6
		5	10	156.2			21	42	656.2
			11	171.8				43	671.8
	3	6	12	187.5		11	22	44	687.5
			13	203.1				45	703.1
		7	14	218.7			23	46	718.7
			15	234.3				47	734.3
2	4	8	16	250.	6	12	24	48	750.
			17	265.6				49	765.6
		9	18	281.2			25	50	781.2
			19	296.8				51	796.8
	5	10	20	312.5		13	26	52	812.5
			21	328.1				53	828.1
		11	22	343.7			27	54	843.7
			23	359.3				55	859.3
3	6	12	24	375.	7	14	28	56	875.
			25	390.6				57	890.6
		13	26	406.2			29	58	906.2
			27	421.8				59	921.8
	7	14	28	437.5		15	30	60	937.5
			29	453.1				61	953.1
		15	30	468.7			31	62	968.7
			31	484.3				63	984.3
4	8	16	32	500.	8	16	32	64	1000.

CARRYING CAPACITIES OF WIRES FOR SHORT PERIODS AND INTERMITTENT LOADS.

The following tables of carrying capacities were prepared by the use of formulae deduced by the authors from heating curves of a large number of conductors experimentally determined in the laboratories of the Commonwealth Edison Co. of Chicago. The tests were made at the suggestion of the Department of Gas and Electricity of the City of Chicago and in some of these tests the engineers of the above company were assisted by engineers of the city department. A full description of these tests was given in the Electrical World during 1918.

The data used in compiling the figures given were obtainable only in the form of "curves." It is well known that such curves are to a large extent an interpolation of values, and it is therefore quite unlikely that many of the values given would produce exactly the temperature assigned to them if subject to a test. A study of the curves showed that in a general way the temperature rise in any given conductor was proportional to the square of the current used, but there were also some exceptions, due probably to errors of observation and interpolation as well as to a variety of causes.

In order to eliminate these errors as much as possible, and at the same time provide a simple means of interpolation to determine the carrying capacity of such wires as were not tested, the amperage necessary to bring each size of wire to a certain temperature was first computed. After this had been done, the circular mils of the conductor were divided by the amperage found, thus giving the circular mils per ampere.

The circular mils per ampere of all the conductors tested were then plotted vertically, while the copper contents were laid out horizontally, and the whole combined in the form of a curve in the well known way. The final carrying capacity was then determined by dividing the circular mils in the conductor by the circular mils per ampere indicated by the curve. It is believed that, in this manner, fairly accurate average values have been obtained.

The current which will cause a given temperature rise in a conductor can be found by the following formula:

$$I = xi\sqrt{\frac{T}{t}}$$

in which T is the desired temperature; t the temperature attained in the conductor by the current i and I is the current to be found. This formula does not take into account the fact that the resistance of the conductor increases with the temperature, as this is considered negligible for all practical purposes. The values of t and i are given in the tables for rubber covered wires. Those conductors, in connection with which no temperature rises are given, were not tested, but the current values given were obtained by interpolation as before explained.

The tables applying to conduits also give the dimensions of the conduits used in the tests. Under the heading, "N. E. Code," we give the amperage allowed by the code. Under the heading, "Calculated Carrying Capacities," we give those calculated as described above. These values must not be used in conflict with the official figures given by the code, as they are not yet sanctioned thereby. The amperages given under, "Short Time in Minutes," are those which it is believed the various conductors can safely carry for the length of time given, provided no appreciable heating has been caused before this load is applied.

Four tables are given. Two of them are calculated for a temperature rise of 72 degrees Fahrenheit, and the other for 36 degrees Fahrenheit. They are also arranged for open and concealed wires, the latter in conduit. The three wires run in conduit were all carrying the same current and the heating effect there obtained will be exceeded only in cases where the four wires of a two-phase system are run in the same pipe. With the ordinary three-wire lighting system, the heating will be considerably less.

The temperature of rubber covered wire should not exceed 120 degrees F. but that covered with other insulations may rise to 150 degrees, and asbestos covered wires may be carried to higher temperatures than this.

The following tables are intended to assist in the selection of the smallest conductor that may be used to carry an intermittent load. The ultimate temperature rise of a conductor subject to an intermittent load depends upon the ratio between the "on" and "off" time of the current. Unless the current is off long enough to allow the loss of the heat accumulated during the "on" time, the temperature will rise.

At low temperatures the dissipation of heat proceeds slowly, but at higher temperatures it is much more rapid. For this reason, the relative time in which a given quantity of heat can be dissipated varies greatly with the temperature permitted.

A separate table is provided for each size of wire considered; in conduit as well as for open wiring. Each table is divided into two parts. In the left hand portion of the tables is given the time in seconds required for the currents given at the top, under the heading, "Heating Load; Amperes," to raise the temperature of the wire 5 degrees F. within the range of temperature given under the heading, "Temperature Range," in conduit or open wires as the case may be.

Thus, referring to the table for No. 14 wire in conduit, we see that a current of 25 amperes will produce a rise of 5 degrees, between the range of 47 and 52, in 220 seconds, but also that it will require 1,350 seconds to effect a temperature rise from 67 to 72 in the same conductor by the same current. In this connection we need not pay any attention to the lower temperatures, as we are interested only as the critical temperatures are approached.

If an intermittent load is continued long enough, there will be a steady rise in temperature until the point is reached at which the dissipation of heat equals the supply. Therefore, if we allow sufficient cooling time, we can keep the temperature within bounds.

In the right hand portion of the tables we give the time in seconds required to dissipate the heat generated during the time given in the same horizontal lines.

Thus, again referring to the table for No. 14 wire, we see that with a temperature range of 22-27 degrees, the heat produced in 110 seconds requires 300 seconds to cool off, while if we allow the temperature to go to 57-62, that generated in 400 seconds will be lost in 40 seconds. Cooling times are given with zero load as well as with continued loads of the amperages given.

The temperature of rubber covered wire should not be allowed to rise above 120 degrees Fahrenheit, and that of "Other Insulations" should not go above 150 degrees F. Asbestos covered wires, however, may be allowed to run much hotter. In order to facilitate the selection of the proper conductor there is provided a column "Limiting Outer Temperature." A separate column is provided for rubber covered and other insulation covered wires. The figures there given indicate that, in locations where the temperature of the air does not rise above the values given, the temperature of the conductor may be allowed to rise to the value of the highest figure given in the same horizontal line under the heading "Temperature Range," either in conduit or open wires.

The simplest method of using the tables consists of first determining the limiting outer temperature. Next find the peak number of amperes and the length of time in seconds during which this amperage is used. Then proceed to find the minimum amperage and the length of time during which it is in use. Make notes of these values and always estimate them with a view to obtaining the hardest operating conditions likely to occur. Now proceed to find the smallest wire under which the amperage in question is given and, selecting the horizontal line in which the limiting temperature is found, see whether the ratio of the on and off times corresponding to the temperature given is the same as that in the problem.

Example: We have a peak load of 80 amperes which lasts for 60 seconds and is then reduced to 25 amperes for 200 seconds; this being the estimated regular cycle of operation of the circuit. Wires are in conduit. The smallest wire under which an amperage of 80 or more is found is a No. 8. Here we find, in the horizontal line pertaining to 83 degrees F., that 105 amperes will cause a temperature rise of 5 degrees in 21 seconds and that this heat, even with only 17½ amperes in continued use, requires 285 seconds for its dissipation. This will not do, and we proceed to the next size of wire. Here we find, in the corresponding horizontal line, that 80 amperes will require 100 seconds to raise the temperature of the wire 5 degrees, and that this heat will be lost in 300 seconds, even with 25 amperes in continued use. Furthermore, as the cooling time is three times as long in this case, while in our problem it was three and one-third times as long, the wire thus found will not heat quite as much as indicated and will therefore be safe to use.

Table CXXXII

Wires in Conduit

Table of Carrying Capacities; three conductors in conduit, each carrying same current.

20° C.; 36° F. temperature rise above surrounding air.

Use this table for rubber covered wires in conduit where temperature of air does not exceed 85° F., and for other insulations at temperatures from 85° F. to 125° F.

B. & S. gauge.	Size conduit	N. E. CODE		Calculated Carrying Capacities 36° F. rise				
		Carrying capacity amperes	Temp. rise in deg. F	Indefinite time amperes	Short time in minutes			
					30	15	10	5
14	½″	15	27.0	17	19	22	24	30
12	¾″	20	31.0	22	24	26	29	35
10	¾″	25	27.9	27	30	35	40	45
8	1 ″	35	29.9	36	43	50	60	65
6	1 ″	50	33.1	52	60	73	80	105
5	...	55	...	56	69	88	100	125
4	1¼″	70	40.7	64	77	97	110	140
3	1¼″	80	34.9	82	93	113	135	165
2	1½″	90	34.7	90	106	130	155	195
1	1½″	100	39.1	96	126	154	180	225
0	2 ″	125	41.2	110	147	182	210	275
2/0	2 ″	150	41.8	130	179	220	260	340
3/0	2 ″	175	39.4	150	213	270	320	420
200000	...	200	...	175	247	310	355	480
4/0	2½″	225	57.6	180	256	325	395	515
250000	...	240	...	205	297	375	455	585
300000	3 ″	275	45.2	238	345	435	535	690
350000	...	300	...	265	395	500	605	790
400000	3 ″	325	42.1	290	440	555	690	850
500000	3 ″	400	48.1	345	529	660	800	1090
600000	...	450	...	390	610	750	915	1225
700000	...	500	...	430	680	830	1025	1400
750000	4 ″	525	44.8	450	710	870	1080	1450
800000	...	550	...	465	745	905	1120	1525
900000	...	600	...	495	810	975	1210	1665
1000000	4½″	650	55.2	525	870	1040	1295	1800

TABLE CXXXIII
WIRES IN CONDUIT

Table of Carrying Capacities; three conductors in conduit, each carrying same current.

40° C.; 72° F. temperature rise above surrounding air.

Use this table for "Other insulations" in conduit where temperature does not exceed 80° F., and for rubber covered wire where temperature of air does not exceed 50° F.

B. & S. gauge.	Size conduit	N. E. CODE		Calculated Carrying Capacities 72° F. rise				
		Carrying capacity amperes	Temp rise in deg. F	Indefinite time amperes	Short time in minutes			
					30	15	10	5
14	½″	15	27.0	24	26	31	34	42
12	¾″	20	31.0	30	33	37	41	50
10	¾″	25	27.9	38	43	50	55	65
8	1 ″	35	29.9	50	60	70	85	95
6	1 ″	50	33.1	70	86	105	115	150
5	...	55	...	80	95	125	140	180
4	1¼″	70	40.7	90	110	140	155	200
3	1¼″	80	34.9	110	130	150	190	235
2	1½″	90	34.7	125	150	175	220	275
1	1½″	100	39.1	135	175	215	250	315
0	2 ″	125	41.2	140	205	255	290	385
2/0	2 ″	150	41.8	185	245	310	360	440
3/0	2 ″	175	39.4	215	300	380	430	565
200000	...	200	...	240	350	430	520	675
4/0	2½″	225	57.6	250	360	455	550	720
250000	...	240	...	280	420	525	640	820
300000	3 ″	275	45.2	335	485	610	750	965
350000	...	300	...	375	560	700	845	1105
400000	3 ″	325	42.1	415	630	775	965	1190
500000	3 ″	400	48.1	480	750	925	1130	1520
600000	...	450	...	545	860	1050	1280	1700
700000	...	500	...	600	950	1160	1435	1960
750000	4 ″	525	44.8	630	1020	1220	1510	2030
800000	...	550	...	660	1050	1260	1560	2135
900000	...	600	...	700	1140	1365	1690	2330
1000000	4½″	650	55.2	740	1215	1460	1840	2520

Table CXXXIV

Open Wires

Table of Carrying Capacities; open wires.

20° C.; 36° F. temperature rise above surrounding **air.**

Use this table for rubber covered wires where temperature does not exceed 85° F., and for "Other insulations" where temperature is between 85° F. and 125° F.

B & S. gauge	N. E. CODE		Calculated Carrying Capacities 36° F. rise				
	Carrying capacity amperes	Est. temp. rise deg. F.	Indefinite time amperes	Short time in minutes			
				30	15	10	5
14	20	21.6	25	25	29	33	37
12	25	19.1	31	31	39	42	47
10	30	18.0	41	41	47	53	60
8	50	27.9	52	52	60	66	75
6	70	29.5	67	67	80	87	95
5	80	...	80	80	90	100	112
4	90	32.0	90	90	105	120	137
3	100	26.1	100	100	125	145	168
2	125	30.6	120	120	150	175	210
1	150	32.4	140	145	180	220	265
0	200	40.0	160	165	215	260	330
2/0	225	41.2	186	210	250	310	380
3/0	275	45.7	215	250	300	380	465
200000	300	...	240	290	345	440	535
4/0	325	56.0	250	300	360	450	560
250000	350	...	285	335	410	520	660
300000	400	38.0	325	400	475	620	765
350000	450	...	360	450	545	700	895
400000	500	47.0	400	500	600	790	1020
500000	600	51.4	480	600	730	950	1220
600000	680	...	560	690	860	1110	1565
700000	760	...	625	775	970	1260	1785
750000	800	57.0	650	800	1025	1340	1910
800000	840	...	680	850	1090	1400	2040
900000	920	...	730	930	1190	1550	2300
1000000	1000	54.0	775	1000	1285	1665	2500

Table CXXXV
Open Wires

Table of Carrying Capacities; open wires.

40° C.; 72° F. temperature rise above surrounding air.

Use this table for "Other insulations" where temperature does not exceed 80° F., and for rubber covered wires where temperature does not exceed 50° F.

	N. E. CODE		Calculated Carrying Capacities 72° F. rise				
B & S. gauge	Carrying capacity amperes	Est. temp. rise deg. F.	Indefinite time amperes	short time in minutes			
				30	15	10	5
14	20	21.6	34	34	40	46	52
12	25	19.1	43	43	54	59	65
10	30	18.0	57	57	67	74	83
8	50	27.9	72	72	84	92	103
6	70	29.5	94	94	109	122	134
5	80	...	110	110	127	141	157
4	90	32.0	125	125	145	165	190
3	100	26.1	145	145	175	202	234
2	125	30.6	168	170	205	245	295
1	150	32.4	195	205	250	309	372
0	200	40.0	225	235	300	360	460
2/0	225	41.2	260	290	350	430	530
3/0	275	45.7	300	345	410	520	645
200000	300	...	335	400	480	610	750
4/0	325	56.0	350	410	500	630	785
250000	350	...	400	470	575	730	925
300000	400	38.0	450	550	660	860	1070
350000	450	...	500	630	760	980	1250
400000	500	47.0	560	700	840	1100	1425
500000	600	51.4	670	840	1025	1330	1785
600000	680	...	780	965	1200	1550	2190
700000	760	...	870	1080	1370	1760	2500
750000	800	57.0	910	1110	1435	1860	2675
800000	840	...	950	1190	1525	1960	2855
900000	920	...	1020	1300	1665	2150	3215
1000000	1000	54.0	1085	1400	1800	2330	3500

Table CXXXVI

Wires in Conduit

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 14 Wires in ½″ Conduit Heating load; amperes				Cooling Load; Amperes	
			15	20	25	45	7½	0
123	93	22-27	2280	250	110	15	300	180
118	88	27-32		300	120	15	210	130
113	83	32-37		450	160	15	195	100
108	78	37-42		660	180	15	125	80
103	73	42-47		1560	210	15	95	70
98	68	47-52			220	15	80	60
93	63	52-57			350	15	60	60
88	58	57-62			400	15	40	40
83	53	62-67			540	15	40	40
78	48	67-72			1350	15	40	40

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 12 Wires in ¾″ Conduit Heating load; amperes				Cooling Load; Amperes	
			20	25	35	60	10	0
123	93	22-27	840	200	50	13	230	200
118	88	27-32		270	50	13	200	150
113	83	32-37		500	60	13	170	100
108	78	37-42		660	80	13	120	100
103	73	42-47		2000	100	13	100	100
98	68	47-52			100	13	100	90
93	63	52-57			120	13	80	80
88	58	57-62			200	13	50	50
83	53	62-67			200	13	50	50
78	48	67-72			220	13	50	50

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 10 Wires in ¾″ Conduit Heating load; amperes				Cooling Load; Amperes	
			25	35	50	75	12½	0
123	93	22-27	1380	210	60	21	360	270
118	88	27-32		210	60	21	250	225
113	83	32-37		270	65	21	200	150
108	78	37-42		300	70	21	150	130
103	73	42-47		540	75	21	90	115
98	68	47-52		1440	80	21	90	85
93	63	52-57			90	21	90	75
88	58	57-62			120	21	90	75
83	53	62-57			140	21	90	75
83	53	62-67			140	21	90	75
78	48	67-72			160	21	90	75

TABLE CXXXVII

WIRES IN CONDUIT

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 8 Wires in Conduit Heating load; amperes 35	50	70	105	Cooling Load; Amperes 17½	0
123	93	22-27	1380	210	60	21	510	420
118	88	27-32		240	60	21	345	290
113	83	32-37		270	70	21	285	210
108	78	37-42		350	80	21	240	160
103	73	42-47		540	90	21	180	120
98	68	47-52		900	100	21	120	100
93	63	52-57		1360	105	21	100	100
88	58	57-62			110	21	90	90
83	53	62-67			115	21	90	90
78	48	67-72			120	21	90	90

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 6 Wires in Conduit Heating load; amperes 50	70	80	100	150	Cooling Load; Amperes 25	0
123	93	22-27	1000	120	100	45	19	600	330
118	88	27-32	1920	180	100	50	19	420	240
113	83	32-37		200	100	60	19	300	225
108	78	37-42		220	120	80	19	220	200
103	73	42-47		300	140	80	19	180	120
98	68	47-52		360	160	90	19	120	100
93	63	52-57		450	180	90	19	100	100
88	58	57-62		630	220	90	19	100	100
83	53	62-67		840	240	90	19	100	100
78	48	67-72		1260	260	90	19	100	100

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 4 Wires in Conduit Heating load; amperes 70	80	90	100	140	210	Cooling Load; Amperes 35	0
123	93	22-27	600	360	240	135	50	22	720	300
118	88	27-32	900	450	270	150	50	22	480	270
113	83	32-37	1260	510	300	160	60	22	480	210
108	78	37-42	2400	630	390	200	70	22	320	150
103	73	42-47		1080	480	240	70	22	220	120
98	68	47-52			600	360	70	22	180	110
93	63	52-57			950	450	75	22	150	90
88	58	57-62			1800	510	75	22	130	80
83	53	62-67				570	75	22	130	60
78	48	67-72				780	80	22	130	60

Table CXXXVIII
Wires in Conduit

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 3 Wires in 1¼" Conduit Heating load; amperes 80	90	100	160	240	Cooling Load; Amperes 40	0
123	93	22-27	780	480	240	60	28	600	420
118	88	27-32	1500	645	300	60	28	400	300
113	83	32-37		900	400	70	28	330	175
108	78	37-42		1300	570	72	28	300	100
103	73	42-47			780	74	28	250	100
98	68	47-52				76	28	240	100
93	63	52-57				80	28	200	75
88	58	57-62				85	28	150	75
83	53	62-67				85	28	150	75
78	48	67-72				85	28	150	75

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 2 Wires in 1½" Conduit Heating load; amperes 90	125	180	270	Cooling Load; Amperes 45	0
123	93	22-27	840	240	65	25	660	480
118	88	27-32	1560	260	70	25	450	350
113	83	32-37		320	75	25	345	240
108	78	37-42		360	85	25	270	200
103	73	42-47		570	95	25	165	150
98	68	47-52		720	95	25	155	110
93	63	52-57		1000	95	25	155	110
88	58	57-62		1900	95	25	155	110
83	53	62-67			100	25	155	110
78	48	67-72			100	25	155	100

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 1 Wires in 1½" Conduit Heating load; amperes 100	125	150	200	300	Cooling Load; Amperes 50	0
123	93	22-27	840	310	170	90	29	750	480
118	88	27-32	1020	330	180	90	29	580	360
113	83	32-37	1560	420	200	100	29	420	300
108	78	37-42		600	220	100	29	360	270
103	73	42-47		810	240	110	29	270	195
98	68	47-52		1000	270	110	29	220	165
93	63	52-57		1560	390	125	29	180	135
88	58	57-62			450	135	29	150	135
83	53	62-67			480	135	29	150	135
78	48	67-72			720	140	29	150	135

Table CXXXIX

Wires in Conduit

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 0 Wires in Conduit Heating load; amperes 125	175	250	375	Cooling Load; Amperes 62½	0
123	93	22-27	550	190	85	32	840	525
118	88	27-32	800	210	85	32	600	390
113	83	32-37	1140	230	85	32	480	300
108	78	37-42	2000	250	85	32	420	225
103	73	42-47		300	85	32	350	200
98	68	47-52		400	95	32	300	190
93	63	52-57		480	115	32	270	180
88	58	57-62		540	135	32	190	140
83	53	62-67		700	135	32	190	140
78	48	67-72		1140	135	32	190	140

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 00 Wires in Conduit Heating load; amperes 150	225	300	450	Cooling Load; Amperes 75	0
123	93	22-27	700	180	60	31	900	500
118	88	27-32	960	190	60	31	720	360
113	83	32-37	1680	210	60	31	570	330
108	78	37-42	4000	220	90	31	435	315
103	73	42-47		230	90	31	360	240
98	68	47-52		250	90	31	250	210
93	63	52-57		265	105	31	195	160
88	58	57-62		285	105	31	160	130
83	53	62-67		315	105	31	160	130
78	48	67-72		400	105	31	160	130

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 000 Wires in Conduit Heating load; amperes 175	262½	350	525	Cooling Load; Amperes 87½	0
123	93	22-27	1100	200	100	38	960	540
118	88	27-32	1470	210	100	38	660	480
113	83	32-37	2300	220	100	38	560	450
108	78	37-42		240	110	38	500	350
103	73	42-47		270	110	38	480	310
98	68	47-52		300	110	38	360	270
93	63	52-57		360	120	38	315	180
88	58	57-62		420	135	38	210	120
83	53	62-67		480	135	38	180	120
78	48	67-72		660	135	38	180	120

Table CXL

Wires in Conduit

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 200,000 C. M. Cables estimated Heating load; amperes						Cooling Load; Amperes	
			212	265	318	380	424	636	106	0
123	93	22-27	420	180	135	100	72	29	2040	660
118	88	27-32	495	220	135	100	72	29	1320	540
113	83	32-37	600	240	140	100	72	29	780	450
108	78	37-42	780	250	140	100	72	29	570	300
103	73	42-47	1200	270	150	100	72	29	450	300
98	68	47-52	1980	300	150	100	72	29	390	240
93	63	52-57	3300	340	165	100	72	29	270	180
88	58	57-62		380	165	100	72	29	170	150
83	53	62-67		400	240	100	72	29	170	150
78	48	67-72		480	240	100	72	29	170	150

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 400 Cables in 2½ " Conduit Heating load; amperes						Cooling Load; Amperes	
			225	281	337	393	450	675	112½	0
123		22-27	420	180	135	100	72	29	2040	660
118		27-32	495	220	135	100	72	29	1320	540
113		32-37	600	240	140	100	72	29	780	450
108		37-42	780	250	140	100	72	29	570	300
103		42-47	1200	270	150	100	72	29	450	300
98		47-52	1980	300	150	100	72	29	390	240
93		52-57	3300	340	165	100	72	29	270	180
88		57-62		380	165	100	72	29	170	150
83		62-67		400	240	100	72	29	170	150
78		67-72		480	240	100	72	29	170	150

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 250,000 C. M. Cables estimated Heating load; amperes						Cooling Load; Amperes	
			250	312	375	437	500	750	125	0
123	93	22-27	420	180	135	100	72	29	2040	660
118	88	27-32	495	220	135	100	72	29	1320	540
113	83	32-37	600	240	140	100	72	29	780	450
108	78	37-42	780	250	140	100	72	29	570	360
103	73	42-47	1200	270	150	100	72	29	450	300
98	68	47-52	1980	300	150	100	72	29	390	240
93	63	52-57	3300	340	165	100	72	29	270	180
88	58	57-62		380	165	100	72	29	170	150
83	53	62-67		400	240	100	72	29	170	150
78	48	67-72		480	240	100	72	29	170	150

Table CXLI

Wires in Conduit

Limiting Outer Temp. Other Ins.	Rubber Ins.	Temperature Range in Conduit F.	3 No. 300,000 C. M. Cables in 3″ Conduit Heating load; amperes					Cooling Load; Amperes	
			275	343	412	550	825	137	0
123	93	22-27	720	360	120	100	33	1140	480
118	88	27-32	840	370	150	100	33	690	400
113	83	32-37	1320	400	160	100	33	600	360
108	78	37-42	1980	420	170	100	33	480	260
103	73	42-47		450	180	100	33	360	240
98	68	47-52		540	190	100	33	300	220
93	63	52-57		810	250	100	33	280	180
88	58	57-62		1080	300	100	33	210	150
83	53	62-67		2040	350	100	33	210	150
78	48	67-72			400	100	33	210	150

Limiting Outer Temp. Other Ins.	Rubber Ins.	Temperature Range in Conduit F.	3 No. 350,000 C. M. Cables in Conduit, estimated Heating load; amperes					Cooling Load; Amperes	
			300	375	450	600	900	150	0
123	93	22-27	840	370	165	105	40	1070	600
118	88	27-32	1000	400	185	105	40	780	485
113	83	32-37	3000	455	200	105	40	660	435
108	78	37-42		480	210	105	40	600	370
103	73	42-47		540	225	105	40	480	320
98	68	47-52		630	240	105	40	400	260
93	63	52-57		825	315	105	40	315	210
88	58	57-62		1080	350	105	40	300	200
83	53	62-67		1900	415	105	40	250	175
78	48	67-72			470	105	40	220	165

Limiting Outer Temp. Other Ins.	Rubber Ins.	Temperature Range in Conduit F.	3 No. 400,000 C. M. Cables in 3″ Conduit Heating load; amperes					Cooling Load; Amperes	
			325	406	487	650	975	162½	0
123	93	22-27	960	390	210	110	46	990	720
118	88	27-32	1170	430	225	110	46	870	570
113	83	32-37	1800	510	235	110	46	720	510
108	78	37-42	4000	540	250	110	46	615	480
103	73	42-47		630	265	110	46	600	400
98	68	47-52		720	290	110	46	510	300
93	63	52-57		840	330	110	46	480	270
88	58	57-62		1080	400	110	46	330	250
83	53	62-67		1740	480	110	46	300	200
78	48	67-72		4000	540	110	46	240	180

Table CXLII

Wires in Conduit

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 500,000 C. M. Cables in 3″ Conduit Heating load; amperes 400	500	600	700	800	1200	Cooling Load; Amperes 200	0
123	93	22-27	1050	360	250	165	122	42	3500	1080
118	88	27-32	1140	400	270	165	122	42	1620	950
113	83	32-37	1440	430	300	175	122	42	1200	720
108	78	37-42	1860	480	330	175	122	42	900	540
103	73	42-47	2700	560	360	195	122	42	870	450
98	68	47-52		650	390	195	122	42	600	360
93	63	52-57		750	420	210	122	42	500	300
88	58	57-62		870	450	210	122	42	440	240
83	53	62-67		960	465	225	122	42	280	160
78	48	67-72		1260	480	225	122	42	200	110

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 600,000 C. M. Cables in Conduit, estimated Heating load; amperes 450	562	675	785	900	1350	Cooling Load; Amperes 230	0
123	93	22-27	1000	420	240	160	122	42	2280	900
118	88	27-32	1110	450	250	160	122	42	1500	720
113	83	32-37	1440	480	260	160	122	42	1150	600
108	78	37-42	2340	580	270	160	122	42	900	500
103	73	42-47	3500	660	290	160	122	42	750	480
98	68	47-52		720	320	160	122	42	660	420
93	63	52-57		780	360	160	122	42	600	390
88	58	57-62		1020	410	160	122	42	510	360
83	53	62-67		1500	420	160	122	42	420	300
78	48	67-72			430	160	122	42	270	250

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 700,000 C. M. Cables in Conduit, estimated Heating load; amperes 505	630	757	880	1010	1515	Cooling Load; Amperes 253	0
123	93	22-27	1000	420	240	160	130	45	2280	900
118	88	27-32	1110	450	250	160	130	45	1500	720
113	83	32-37	1440	480	260	160	130	45	1150	600
108	78	37-42	2340	600	270	160	130	45	900	500
103	73	42-47	3500	660	300	160	130	45	750	480
98	68	47-52		720	340	160	130	45	660	420
93	63	52-57		780	380	160	130	45	600	390
88	58	57-62		1020	420	160	130	45	510	360
83	53	62-67		1500	460	160	130	45	420	300
78	48	67-72			500	160	130	45	270	250

TABLE CXLIII

WIRES IN CONDUIT

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 750,000 C. M. Cables in 4″ Conduit Heating load; amperes 525	656	787	1050	1575	Cooling Load; Amperes 262½	0
123	93	22-27	900	420	230	150	54	2280	900
118	88	27-32	1110	450	240	150	54	1500	720
113	83	32-37	1440	480	250	150	54	1150	600
108	78	37-42	2340	570	270	150	54	900	500
103	73	42-47	3500	660	300	150	54	750	460
98	68	47-52		720	340	150	54	660	420
93	63	52-57		780	370	150	54	600	390
88	58	57-62		1020	410	150	54	510	360
83	53	62-67		1500	450	150	54	420	300
78	48	67-72			500	150	54	270	250

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 800,000 C. M. Cables in Conduit, estimated Heating load; amperes 550	688	825	1100	1650	Cooling Load; Amperes 275	0
123	93	22-27	900	420	230	150	54	2280	900
118	88	27-32	1110	450	240	150	54	1500	720
113	83	32-37	1440	480	250	150	54	1150	600
108	78	37-42	2340	570	270	150	54	900	500
103	73	42-47	3500	660	300	150	54	750	460
98	68	47-52		720	340	150	54	660	420
93	63	52-57		780	370	150	54	600	390
88	58	57-62		1020	410	150	54	510	360
83	53	62-67		1500	450	150	54	420	300
78	48	67-72			500	150	54	270	250

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 900,000 C. M. Cables in Conduit, estimated Heating load; amperes 600	750	900	1200	1800	Cooling Load; Amperes 300	
123	93	22-27	920	420	250	100	50	2500	930
118	88	27-32	1020	465	260	100	50	1560	780
113	83	32-37	1200	480	270	100	50	1320	720
108	78	37-42	1350	500	280	100	50	1050	660
103	73	42-47	2250	530	290	100	50	870	600
98	68	47-52		550	300	100	50	780	540
93	63	52-57		600	330	100	50	670	485
88	58	57-62		690	345	100	50	600	450
83	53	62-67		960	370	100	50	400	360
78	48	67-72		1400	450	100	50	330	300

Table CXLIV

Wires in Conduit

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	3 No. 1,000,000 C. M. Cables in 4½" Conduit Heating load; amperes 650	812	975	1300	1950	Cooling Load; Amperes 325	0
123	93	22-27	930	420	250	100	50	2500	930
118	88	27-32	1020	465	260	100	50	1560	780
113	83	32-37	1200	480	270	100	50	1320	720
108	78	37-42	1350	500	280	100	50	1050	660
103	73	42-47	2250	530	290	100	50	870	600
98	68	47-52		550	300	100	50	780	540
93	63	52-57		600	330	100	50	670	485
88	58	57-62		690	345	100	50	600	450
83	53	62-67		960	385	100	50	400	360
78	48	67-72		1400	450	100	50	330	300

Table CXLV

Open Wires

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 14 D. B. R. C. Wire in Air Heating load; amperes 15	20	25	45	Cooling Load; Amperes 0
123	93	22-27			120	21	21
118	88	27-32			390	21	21
113	83	32-37				21	21
108	78	37-42				21	21
103	73	42-47				21	21
98	68	47-52				21	21
93	63	52-57				21	21
88	58	57-62				21	21
83	53	62-67				21	21
78	48	67-72				21	

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 12 D. B. R. C. Wire in Air Heating load; amperes 20	25	35	60	Cooling Load; Amperes 0
123	93	22-27			120	21	24
118	88	27-32			150	21	24
113	83	32-37			660	21	24
108	78	37-42				21	24
103	73	42-47				21	24
98	68	47-52				21	24
93	63	52-57				21	24
88	58	57-62				21	24
83	53	62-67				21	24
78	48	67-72				21	24

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F	No. 10 D. B. R. C. Wire in Air Heating load; amperes 25	35	50	75	Cooling Load; Amperes 0
123	93	22-27		1020	80	32	21
118	88	27-32			90	32	21
113	83	32-37			180	32	21
108	78	37-42			300	32	21
103	73	42-47				32	21
98	68	47-52				32	21
93	63	52-57				32	21
88	58	57-62				32	21
83	53	62-67				32	21
78	48	67-72				32	21

Table CXLVI

Open Wires

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range F.	No. 8 D. B. R. C. Wire in Air Heating load; amperes 35	50	70	105	Cooling Load; Amperes 0
123	93	22-27		960	60	23	40
118	88	27-32			70	23	40
113	83	32-37			85	23	40
108	78	37-42			100	23	40
103	73	42-47			180	23	40
98	68	47-52			1350	23	40
93	63	52-57				23	40
88	58	57-62				23	40
83	53	62-67				23	40
78	48	67-72				23	40

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range F.	No. 6 D. B. R. C. Wire in Air Heating load; amperes 50	70	80	100	Cooling Load; Amperes 0
123	93	22-27		420	150	21	80
118	88	27-32			240	21	70
113	83	32-37			650	21	60
108	78	37-42				21	50
103	73	42-47				21	40
98	68	47-52				21	30
93	63	52-57				21	30
88	58	57-62				21	30
83	53	62-67				21	30
78	48	67-72				21	30

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range F.	No. 4 D. B. R. C. Wire in Air Heating load; amperes 70	80	90	100	140	210	Cooling Load; Amperes 0
123	93	22-27			420	200	60	17	85
118	88	27-32			2000	250	60	17	80
113	83	32-37				600	60	17	75
108	78	37-42					70	17	70
103	73	42-47					80	17	60
98	68	47-52					90	17	50
93	63	52-57					120	17	40
88	58	57-62					160	17	40
83	53	62-67					240	17	40
78	48	67-72					500	17	40

Table CXLVII

Open Wires

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 3 D. B. R. C. Wire in Air, Heating load; amperes					Cooling Load; Amperes
			80	90	100	160	240	0
123	93	22-27			1800	70	27	90
118	88	27-32				75	27	80
113	83	32-37				80	27	70
108	78	37-42				85	27	60
103	73	42-47				95	27	50
98	68	47-52				120	27	40
93	63	52-57				180	27	40
88	58	57-62				300	27	40
83	53	62-67				2000	27	40
78	48	67-72					27	40

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 2 D. B. R. C. Wire in Air, Heating load; amperes				Cooling Load; Amperes	
			90	125	180	270	45	0
123	93	22-27		780	90	32	130	100
118	88	27-32			95	32	90	80
113	83	32-37			100	32	80	60
108	78	37-42			120	32	60	40
103	73	42-47			200	32	52	40
98	68	47-52			330	32	52	40
93	63	52-57			540	32	52	40
88	58	57-62				32	52	40
83	53	62-67				32	52	40
78	48	67-72				32	52	40

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 1 D. B. R. C. Wire in Air, Heating load; amperes					Cooling Load; Amperes	
			100	125	150	200	300	50	0
123	93	22-27			540	120	41	150	100
118	88	27-32			1300	150	41	100	70
113	83	32-37				200	41	60	60
108	78	37-42				250	41	60	60
103	73	42-47				350	41	60	60
98	68	47-52				500	41	60	60
93	63	52-57				800	41	60	60
88	58	57-62					41	60	60
83	53	62-67					41	60	60
78	48	67-72					41	60	60

Table CXLVIII

Open Wires

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 0 D. B. R. C. Cable in Air Heating load; amperes 125	175	250	375	Cooling Load; Amperes 62½	0
123	93	22-27		2000	100	29	190	72
118	88	27-32			105	29	150	72
113	83	32-37			110	29	110	72
108	78	37-42			115	29	100	72
103	73	42-47			120	29	90	72
98	68	47-52			180	29	80	72
93	63	52-57			300	29	72	60
88	58	57-62			500	29	72	60
83	53	62-67			2000	29	72	60
78	48	67-72				29	72	60

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 00 D. B. R. C. Cable in Air Heating load; amperes 150	225	450	675	Cooling Load; Amperes 75	0
123	93	22-27		375	100	38	250	160
118	88	27-32		500	100	38	210	140
113	83	32-37		750	100	38	190	120
108	78	37-42		1620	120	38	120	110
103	73	42-47			140	38	70	80
98	68	47-52			160	38	60	60
93	63	52-57			180	38	60	60
88	58	57-62			200	38	60	60
83	53	62-67			230	38	60	60
78	48	67-72			260	38	60	60

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 000 D. B. R. C. Cable in Air Heating load; amperes 175	262½	350	525	Cooling Load; Amperes 87½	0
123	93	22-27		390	85	38	120	250
118	88	27-32		465	85	38	120	165
113	83	32-37		690	85	38	120	130
108	78	37-42		2000	100	38	100	120
103	73	42-47			125	38	90	110
98	68	47-52			195	38	80	90
93	63	52-57			300	38	80	80
88	58	57-62			405	38	70	70
83	53	62-67			600	38	70	70
78	48	67-72			930	38	70	70

Table CXLIX

Open Wires

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 200,000 C. M. Wire in Air — Heating load; amperes 210	315	420	630	Cooling Load; Amperes 0
123	93	22-27		195	75	29	240
118	88	27-32		195	75	29	200
113	83	32-37		195	75	29	135
108	78	37-42		195	75	29	100
103	73	42-47		240	90	29	80
98	68	47-52		300	105	29	80
93	63	52-57		400	130	29	80
88	58	57-62		540	170	29	80
83	53	62-67		1200	200	29	80
78	48	67-72			250	29	80

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 0000 C. M. Cable in Air — Heating load; amperes 225	337	450	675	Cooling Load: Amperes 0
123	93	22-27	2000	195	75	29	240
118	88	27-32		195	75	29	200
113	83	32-37		195	75	29	135
108	78	37-42		195	75	29	100
103	73	42-47		240	90	29	80
98	68	47-52		300	105	29	80
93	63	52-57		400	130	29	80
88	58	57-62		540	170	29	80
83	53	62-67		1200	200	29	80
78	48	67-72			250	29	80

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 250,000 C. M. Cable in Air — Heating load; amperes 250	375	500	750	Cooling Load; Amperes 0
123	93	22-27		200	100	35	150
118	88	27-32		200	100	35	125
113	83	32-37		220	100	35	110
108	78	37-42		250	100	35	90
103	73	42-47		300	120	35	80
98	68	47-52		400	135	35	70
93	63	52-57		500	160	35	60
88	58	57-62		800	200	35	60
83	53	62-67		1500	300	35	60
78	48	67-72			400	35	60

Table CL

Open Wires

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	No. 300,000 C. M. Cable in Air Heating load; amperes					Cooling Load; Amperes	
			275	343	412	550	825	137	0
123	93	22-27		1020	285	125	42	240	240
118	88	27-32		4000	480	135	42	210	210
113	83	32-37			750	150	42	150	150
108	78	37-42			2300	160	42	120	120
103	73	42-47				180	42	100	100
98	68	47-52				250	42	90	90
93	63	52-57				275	42	80	80
88	58	57-62				330	42	80	80
83	53	62-67				375	42	80	80
78	48	67-72				600	42	80	80

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	No. 350,000 C. M. Cable in Air Heating load; amperes					Cooling Load; Amperes	
			300	375	450	600	900	150	0
123	93	22-27		960	300	110	46	360	200
118	88	27-32		3000	450	120	46	240	150
113	83	32-37			720	130	46	180	80
108	78	37-42			1200	165	46	150	80
103	73	42-47				185	46	80	80
98	68	47-52				240	46	80	80
93	63	52-57				290	46	80	80
88	58	57-62				340	46	80	80
83	53	62-67				420	46	80	80
78	48	67-72				500	46	80	80

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	No. 400,000 C. M. Cable in Air Heating load; amperes					Cooling Load; Amperes	
			325	406	487	650	975	162	0
123	93	22-27		960	300	110	46	360	200
118	88	27-32		3000	450	120	46	240	150
113	83	32-37			720	130	46	180	80
108	78	37-42			1200	165	46	150	80
103	73	42-47				185	46	80	80
98	68	47-52				240	46	80	80
93	63	52-57				290	46	80	80
88	58	57-62				340	46	80	80
83	53	62-67				420	46	80	80
78	48	67-72				500	46	80	80

Table CLI
Open Wires

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	No. 500,000 C. M. Cable in Air Heating load; amperes 400	500	600	700	800	1200	Cooling Load; Amperes	0
123	93	22-27		690	345	190	180	50	480	400
118	88	27-32		1110	480	200	180	50	300	300
113	83	32-37		4000	750	240	180	50	200	250
108	78	37-42			900	270	180	50	125	200
103	73	42-47			1500	300	180	50	84	150
98	68	47-52				360	180	50	84	84
93	63	52-57				540	180	50	84	84
88	58	57-62				750	180	50	84	84
83	53	62-67					180	50	84	84
78	48	67-72					180	50	84	84

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	No. 600,000 C. M. Cable in Air Heating load; amperes 450	560	675	786	900	1350	Cooling Load; Amperes 225	
123	93	22-27		700	360	200	185	52	480	400
118	88	27-32		1200	500	210	185	52	300	300
113	83	32-37			775	250	185	52	200	250
108	78	37-42			950	280	185	52	125	200
103	73	42-47			1600	310	185	52	84	150
98	68	47-52				370	185	52	84	84
93	63	52-57				550	185	52	84	84
88	58	57-62				775	185	52	84	84
83	53	62-67					185	52	84	84
78	48	67-72					185	52	84	84

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	No. 700,000 C. M. Cables in Air Heating load; amperes 500	625	750	1000	1500	Cooling Load; Amperes 262	0
123	93	22-27		660	270	150	53	660	400
118	88	27-32		840	300	160	53	450	300
113	83	32-37		1410	375	170	53	400	250
108	78	37-42			500	180	53	270	220
103	73	42-47			625	195	53	220	200
98	68	47-52			775	210	53	200	200
93	63	52-57			1200	240	53	150	150
88	58	57-62				260	53	150	150
83	53	62-67				280	53	150	150
78	48	67-72				300	53	150	150

Table CLII

Open Wires

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 750,000 C. M. Cable in Air Heating load; amperes 525	656	787	1050	1575	Cooling Load; Amperes 262	0
123	93	22-27		660	270	150	54	660	400
118	88	27-32		840	300	160	54	450	300
113	83	32-37		1410	375	170	54	400	250
108	78	37-42			500	180	54	270	220
103	73	42-47			625	195	54	220	200
98	68	47-52			775	210	54	200	200
93	63	52-57			1200	240	54	150	150
88	58	57-62				260	54	150	150
83	53	62-67				280	54	150	150
78	48	67-72				300	54	150	150

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 800,000 C. M. Cable in Air Heating load; amperes 550	687	825	1100	1650	Cooling Load; Amperes 275	0
123	93	22-27		660	270	150	56	660	400
118	88	27-32		840	300	160	56	450	300
113	83	32-37		1410	375	170	56	400	250
108	78	37-42			500	180	56	270	220
103	73	42-47			625	195	56	220	200
98	68	47-52			775	210	56	200	200
93	63	52-57			1200	240	56	150	150
88	58	57-62				260	56	150	150
83	53	62-67				280	56	150	150
78	48	67-72				300	56	150	150

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range of Wire F.	No. 900,000 C. M. Cable in Air Heating load; amperes 600	750	900	1200	1800	Cooling Load; Amperes 300	0
123	93	22-27		720	330	120	58	660	480
118	88	27-32		1035	400	130	58	500	320
113	83	32-37		2400	525	140	58	420	275
108	78	37-42			630	150	58	300	200
103	73	42-47			800	160	58	250	175
98	68	47-52			1100	170	58	200	175
93	63	52-57				180	58	175	175
88	58	57-62				200	58	175	175
83	53	62-67				220	58	175	175
78	48	67-72				250	58	175	175

TABLE CLIII

OPEN WIRES

Limiting Outer Temp. Other Ins.	Limiting Outer Temp. Rubber Ins.	Temperature Range in Conduit F.	No. 1,000,000 C. M. Cable in Air Heating load; amperes 650	812	975	1300	1950	Cooling Load; Amperes 325	0
123	93	22-27		720	330	120	58	660	480
118	88	27-32		1035	400	130	58	500	320
113	83	32-37		2400	525	140	58	420	275
108	78	37-42			630	150	58	300	200
103	73	42-47			800	160	58	250	175
98	68	47-52			1100	170	58	200	175
93	63	52-57				180	58	175	175
88	58	57-62				200	58	175	175
83	53	62-67				220	58	175	175
78	48	67-72				250	58	175	175

INDEX TO TABLES