QUESTIONS AND ANSWERS

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AUDELS NEW ELECTRIC LIBRARY

VOL. VII

FOR ENGINEERS, ELECTRICIANS
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MECHANICS AND STUDENTS

Presenting in simplest, concise form the fundamental principles, rules and applications of applied electricity.

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Design, construction, operation and maintenance of modern electrical machines and appliances.

Based on the best knowledge and experience of applied electricity.

by **FRANK D. GRAHAM, B.S., M.S., M.E., E.E.**

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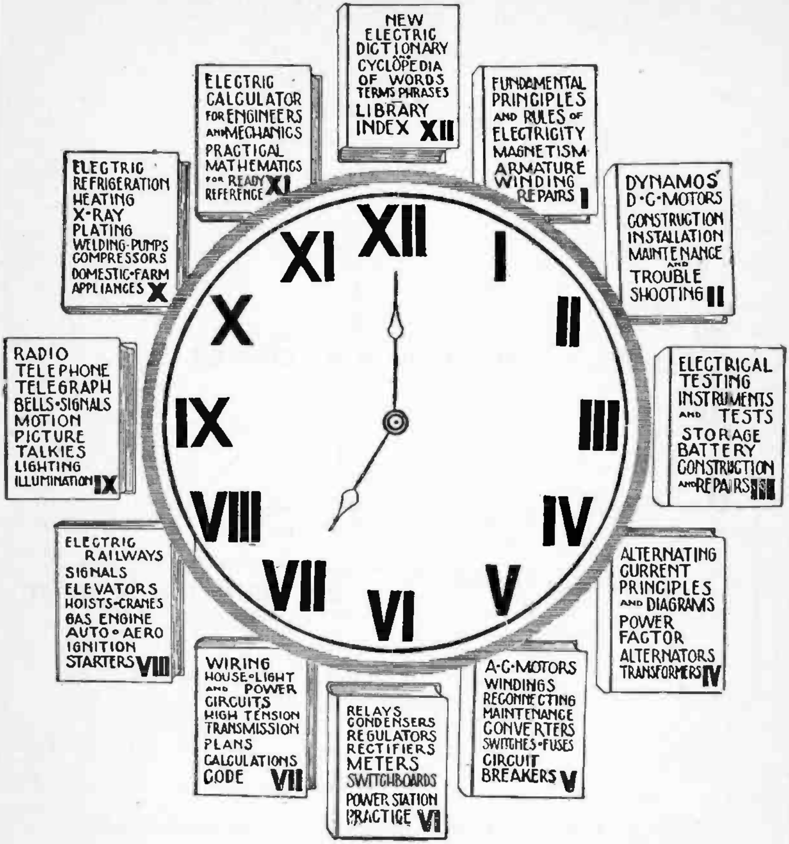

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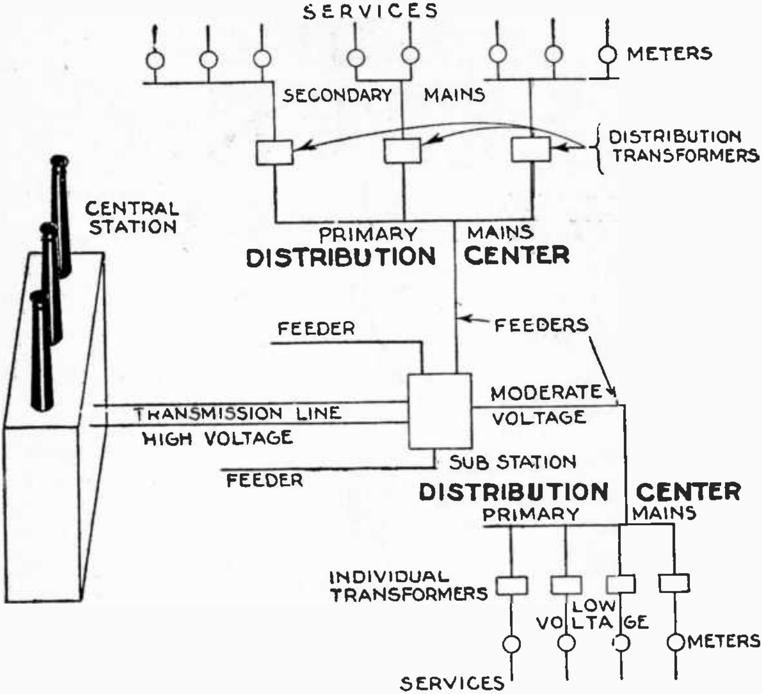

Typical Overhead Transmission and Distribution System Showing Central Station, Sub-Station, Distribution Centers, etc.

Foreword

This series is dedicated to Electrical Progress—to all who have helped and those who may in the coming years help to bring further under human control and service to humanity this mighty force of the Creator.

The Electrical Age has opened new problems to all connected with modern industry, making a thorough working knowledge of the fundamental principles of applied electricity necessary.

The author, following the popular appeal for practical knowledge, has prepared this progressive series for the electrical worker and student; for all who are seeking electrical knowledge as a life profession; and for those who find that there is a gap in their training and knowledge of Electricity.

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The author and publishers here gratefully acknowledge the hearty and generous help and co-operation of all those who have aided in developing this helpful series of Educators.

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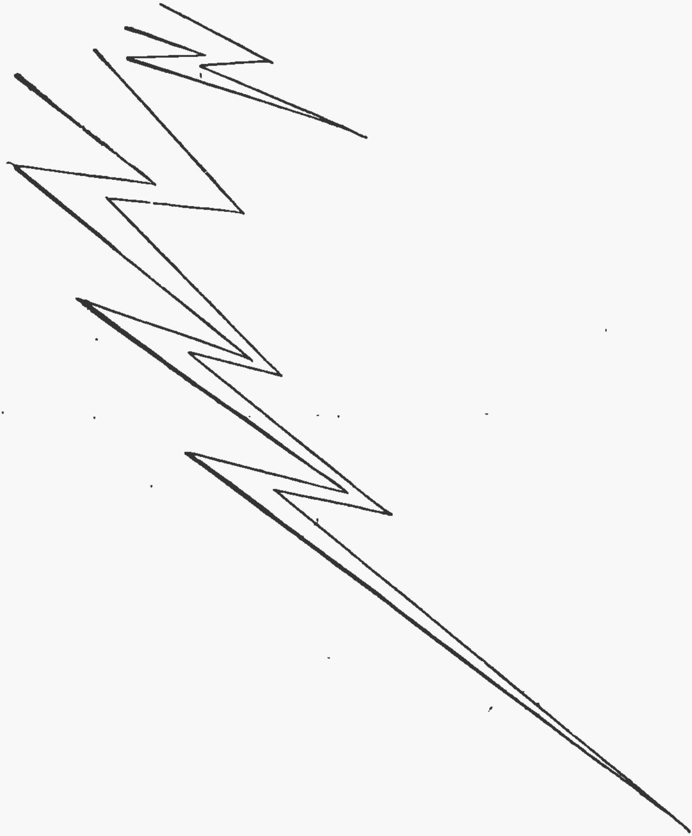
The Publishers.



How to Use This Book

Finder

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To quickly and easily find information on any subject, read over the general chapter headings as shown in the large type—this brings the reader's attention to the general classification of information in this book.

Each chapter is progressive, so that if the reader will use the outline following each general chapter heading, he will readily come to the information desired and the page on which to find it.

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"An hour with a book would have brought to your mind,
The secret that took the whole year to find;
The facts that you learned at enormous expense,
Were all on a library shelf to commence."

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CHAPTER 95

USEFUL MATHEMATICS

(for convenient reference)

MATHEMATICAL SIGNS

$+$ plus (addition)

$+$ positive

$-$ minus (subtraction)

$-$ negative

$\pm$ plus or minus

$\mp$ minus or plus

$=$ equals

$\times$ multiplied by

ab or $a \cdot b = a \times b$

$\div$ divided by

$/$ divided by

$\sqrt{\ }$ square root

$\sqrt[3]{\ }$ cube root

: is to, : : so is, : to (proportion)

2 : 4 : : 3 : 6, 2 is to 4 as 3 is to 6

: ratio; divided by

2 : 4, ratio of 2 to 4 $= 2/4$

$\therefore$ therefore

$>$ greater than

$<$ less than

$\square$ square

$\bigcirc$ round

$^\circ$ degrees, arc, or thermometer

$'$ minutes or feet

$''$ seconds or inches

$'$ $''$ $'''$ accents to distinguish letters as a', a'', a'''

a_1 a_2 a_3 a_b a_c read a sub 1, a sub b, etc

a^2, a^3, a squared, a cubed

a^n, a raised to the nth power

$a^{\frac{2}{3}} = \sqrt[3]{a^2}$ $a^{\frac{3}{2}} = \sqrt{a^3}$

$a^{-1} = \frac{1}{a}$, $a^{-2} = \frac{1}{a^2}$

$10^9 = 10$ to the 9th power $=$ 1,000,000,000

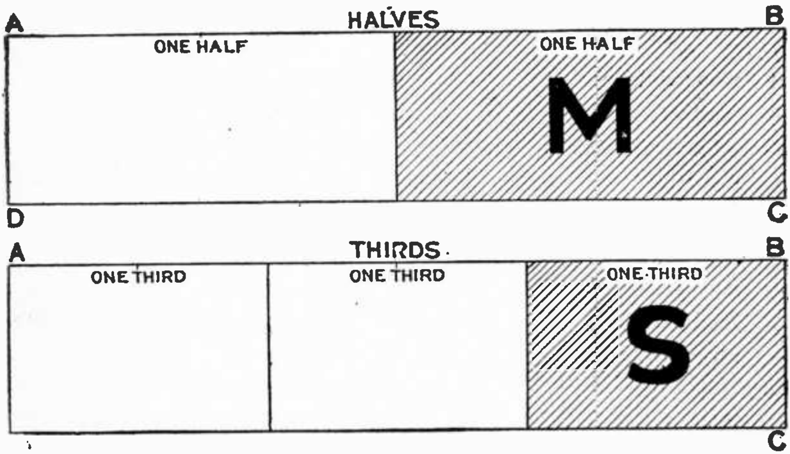
sin α = the sine of α

log = logarithm

$\log_e$ or hyp log = hyperbolic logarithm

() [] {} ——parentheses, brackets, braces, vinculum; denoting that the numbers enclosed are to be taken together; as, $(a+b)c=\overline{4+3}\times 5=35$

%	per cent	tan, tangent
△	angle	sec, secant
∟	right angle	versin, versed sine
⊥	perpendicular to	cot, cotangent
	sin, sine	cosec, cosecant
	cos, cosine	covers, co-versed sine



FIGS. 4,884 and 4,885.—Graphic representation of fractional parts. The figures show a rectangle ABCD, representing a unit divided into two equal parts or halves (fig. 4,884) and into three equal parts or thirds (fig. 4,885). Evidently the shaded section **M**, or one half is larger than the shaded section **S**, or one third.

Fractions.—By definition a fraction is *a quantity less than a unit.*

Fractions take their *name* and *value* from the *number* of parts into which the unit is divided. Thus, if the unit be divided into 2 equal parts, one of these parts is called *one-half.*

To reduce a common fraction to its lowest terms.—*Divide both terms by their greatest common divisor.* ***Example:*** $^{39}/_{52} = \frac{3}{4}$.

To change an improper fraction to a mixed number.—*Divide the numerator by the denominator;* the quotient is the whole number, and the remainder placed over the denominator is the fraction. ***Example:*** $^{39}/_{4} = 9\frac{3}{4}$.

To change a mixed number to an improper fraction.—*Multiply the whole number by the denominator of the fraction; to the product add the numerator; place the sum over the denominator.* ***Example:*** $1\frac{7}{8} = {}^{15}/_{8}$.

To express a whole number in the form of a fraction with a given denominator.—*Multiply the whole number by the given denominator, and place the product over that denominator.* ***Example:*** $13 = {}^{39}/_{3}$.

To reduce a compound to a simple fraction, also to multiply fractions.—*Multiply the numerators together for a new numerator and the denominators together for a new denominator.*

Examples: $\frac{2}{3}$ of $\frac{4}{3} = \frac{8}{9}$ also $\frac{2}{3} \times \frac{4}{3} = \frac{8}{9}$

To reduce a complex to a simple fraction.—*The numerator and denominator must each first be given the form of a simple fraction; then multiply the numerator of the upper fraction by the denominator of the lower for the new numerator, and the denominator of the upper by the numerator of the lower for the new denominator.*

Example: $\dfrac{\frac{7}{8}}{1\frac{3}{4}} = \dfrac{\frac{7}{8}}{\frac{7}{4}} = \dfrac{28}{56} = \dfrac{1}{2}$

To divide fractions.—*Reduce both to the form of simple fractions, invert the divisor, and proceed as in multiplication.*

Example: $\frac{3}{4} \div 1\frac{1}{4} = \frac{3}{4} \div \frac{5}{4} = \frac{3}{4} \times \frac{4}{5} = \frac{12}{20} = \frac{3}{5}$

Cancellation of fractions.—In compound or multiplied fractions, *divide any numerator and any denominator by any number which will divide them both without remainder, striking out the numbers thus divided and seting down the quotients in their stead.*

To reduce fractions to a common denominator.—Reduce each fraction to the form of a simple fraction; then multiply each numerator by all the denominators except its own for the new numerator, and all the denominators together for the common denominator:

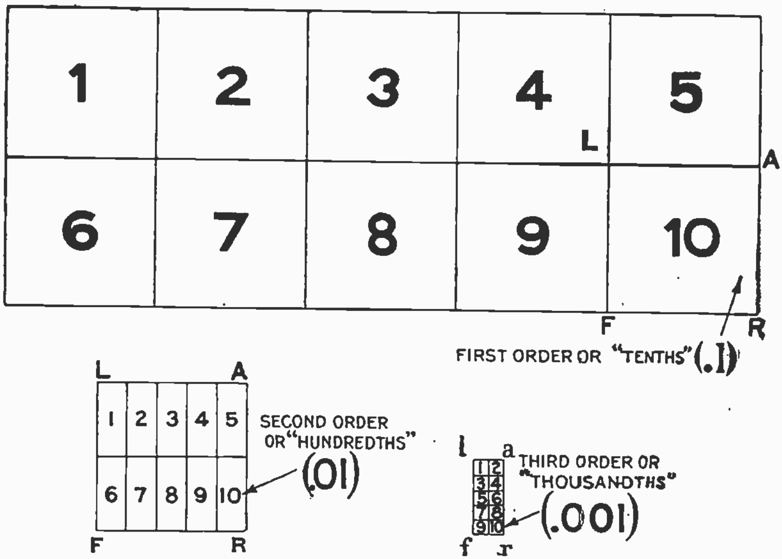
Example: $\frac{1}{2}, \frac{1}{3}, \frac{3}{7} = \frac{21}{42}, \frac{14}{42}, \frac{18}{42}$

To add fractions.—Reduce them to a common denominator, then add the numerators and place their sums over the common denominator:

Example: $\frac{1}{2} + \frac{1}{3} + \frac{3}{7} = \frac{21+14+18}{42} = \frac{53}{42} = 1^{11}/_{42}$

To subtract fractions.—Reduce them to a common denominator, subtract the numerators and place the difference over the common denominator:

$$\frac{1}{2} - \frac{3}{7} = \frac{7-6}{14} = \frac{1}{14}$$

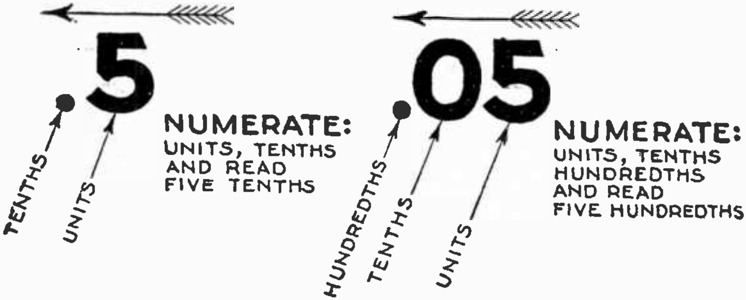


FIGS. 4,886 to 4,888.—Graphic representation of decimal fractions. Fig. 4,886, a unit divided into ten parts—1st order of "tenths;" fig. 4,887, one of the "tenths" as LARF, divided into ten parts—2nd order or "hundredths"; fig. 4,888, one of the "hundredths" as *larf*, divided into ten parts—3rd order or thousandths. Similarly the process of division may be continued indefinitely.

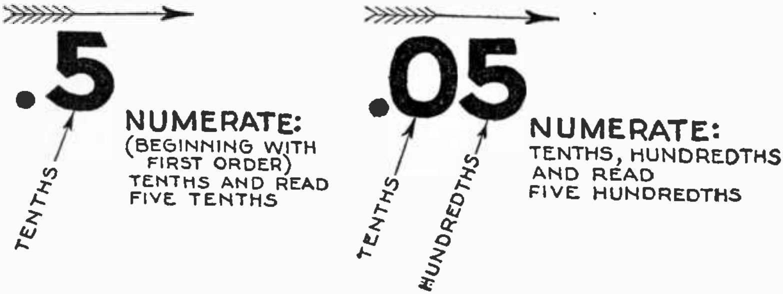
Decimal Fractions or Decimals.—The word decimal means *ten* and decimal fractions are usually called simply *decimals*.

In the formation of a decimal a single unit is divided into 10, 100, 1,000 (etc.) parts, as

fraction	decimal	called
$\frac{1}{10}$	.1	one-tenth
$\frac{1}{100}$	.01	one-hundredth



Figs. 4,889 and 4,890.—How to read decimals (*first method*). *Rule.—Numerate toward the decimal point (units, tenths, hundredths, etc.) numerating each order and the decimal point.*



Figs. 4,891 and 4,892.—How to read decimals (*second method*). *Rule.—Numerate from the decimal point, beginning with the first order "tenths."*

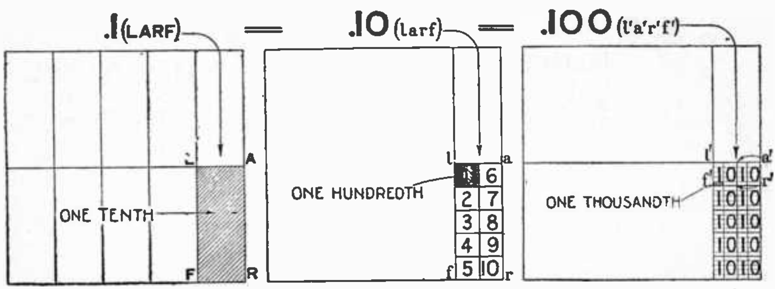
fraction	decimal	called
$\frac{1}{1000}$	.001	one thousandth

To avoid errors give special attention to the decimal point. Make it big enough to be seen without a microscope. The author objects to the questionable practice of placing a cipher on the left side of the decimal point.

To add decimals.—*Set down the figures so that the decimal points are one above the other, then proceed as in simple addition.*

Example:

```
 18.75
   .012
 18.762
```



FIGS. 4,893 to 4,895. Diagrams showing that *annexing ciphers after a decimal does not change its value.* In fig. 4,893, LARF, is equal to one-tenth (.1) of the large rectangle, and is equal to *larf* in fig. 4,894. If *larf*, be divided into 10 parts, each of these parts = one-hundredth (.01) of the large rectangle. Similarly if each of these parts, as *l'a'r'f'*, fig. 4,895, be again divided into 10 parts, each of the parts thus obtained = one-thousandth (.001) of the large rectangle. Hence .1 = .10 = .100.

To subtract decimals.—*Set down the figures so that the decimal points are one above the other, then proceed as in simple subtraction.*

Example:

```
 18.75
   .012
 18.738
```

To multiply decimals.—*Multiply as in multiplication of whole numbers, then point off as many decimal places as there are in multiplier and multiplicand taken together.*

Example: 1.5×.02=.030=.03.

To divide decimals.—*Divide as in whole numbers, and point off in the quotient as many decimal places as those in the dividend exceed those in the divisor.*

Ciphers must be added to the dividend to make its decimal places at least equal those in the divisor, and as many more as it is desired to have in the quotient.

Example: 1.5÷.25=6. .1÷0.3=.10000÷.3=.3333+.

To convert a common fraction into a decimal.—*Divide the numerator by the denominator, adding to the numerator as many ciphers prefixed by a decimal point as are necessary to give the number of decimal places desired in the result.*

Example: 1/3=1.0000÷3=.3333+.

Fractional Inch Decimal Equivalents

8ths	32ds	64ths	
1/8 = .125	1/32 = .03125	1/64 = .015625	33/64 = .515625
1/4 = .250	3/32 = .09375	3/64 = .046875	35/64 = .546875
3/8 = .375	5/32 = .15625	5/64 = .078125	37/64 = .578125
1/2 = .500	7/32 = .21875	7/64 = .109375	39/64 = .609375
5/8 = .625	9/32 = .28125	9/64 = .140625	41/64 = .640625
3/4 = .750	11/32 = .34375	11/64 = .171875	43/64 = .671875
7/8 = .875	13/32 = .40625	13/64 = .203125	45/64 = .703125
16ths	15/32 = .46875	15/64 = .234375	47/64 = .734375
	17/32 = .53125	17/64 = .265625	49/64 = .765625
1/16 = .0625	19/32 = .59375	19/64 = .296875	51/64 = .796875
3/16 = .1875	21/32 = .65625	21/64 = .328125	53/64 = .828125
5/16 = .3125	23/32 = .71875	23/64 = .359375	55/64 = .859375
7/16 = .4375	25/32 = .78125	25/64 = .390625	57/64 = .890625
9/16 = .5625	27/32 = .84375	27/64 = .421875	59/64 = .921875
11/16 = .6875	29/32 = .90625	29/64 = .453125	61/64 = .953125
13/16 = .8125	31/32 = .96875	31/64 = .484375	63/64 = .984375
15/16 = .9375			

To convert a decimal into a common fraction.—*Set down the decimal as a numerator, and place as the denominator* 1 *with as many ciphers annexed as there are decimal places in the numerator; erase the decimal point in the numerator and reduce the fraction thus formed to its lowest terms.*

Examples: $.25 = \frac{25}{100} = \frac{1}{4}$; $.3333 = \frac{3333}{10000} = \frac{1}{3}$, nearly.

Decimals of a Foot and Inches

Inch	0"	1"	2"	3"	4"	5"	6"	7"	8"	9"	10"	11"
0	.0	.0833	.1677	.2500	.3333	4167	.5000	.5833	.6667	.7500	.8333	.9167
1-16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1-8	.0104	.0937	.1771	2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
3-16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	9323
1-4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5-16	0260	1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3-8	0312	.1146	.1979	2812	.3646	.4479	.5312	.6146	.6979	7812	.8646	.9479
7-16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	,7865	.8698	9531
1-2	.0417	.1250	2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9-16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	8802	.9635
5-8	.0521	.1354	.2188	3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	9688
11-16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3-4	.0625	.1458	.2292	3125	.3958	.4792	.5625	.6458	.7292	8125.	.8958	.9792
13-16	.0677	.1510	.2344	.3177	4010	.4844	.5677	6510	.7344	.8177	.9010	.9844
7-8	.0729	.1562	.2396	.3229	4062	4896	5729	.6562	7396	.8229	.9062	.9896
15-16	.0781	.1615	2448	.3281	4115	.4948	.5781	6615	7448	.8281	9115	.9948

The Metric System.—This system is based upon *the decimal scale*, hence a thorough knowledge of decimals is necessary. The unit of the system is the meter and its value in inches should be remembered.

1 meter = 39.37079 ins.

Units of other denominations are named by prefixing to the word *meter* the Latin numerals for the lower denominations and Greek numerals for the higher denominations.

Thus one decimeter = $^1/_{10}$ of a meter; 1 millimeter = one-thousandth of a meter and one kilometer = one thousand meters.

Lower denomination	*Higher denomination*
Deci = $^1/_{10}$	Decka = 10
Centi = $^1/_{100}$	Hecto = 100
Milli = $^1/_{1000}$	Kilo = 1,000
	Myria = 10,000

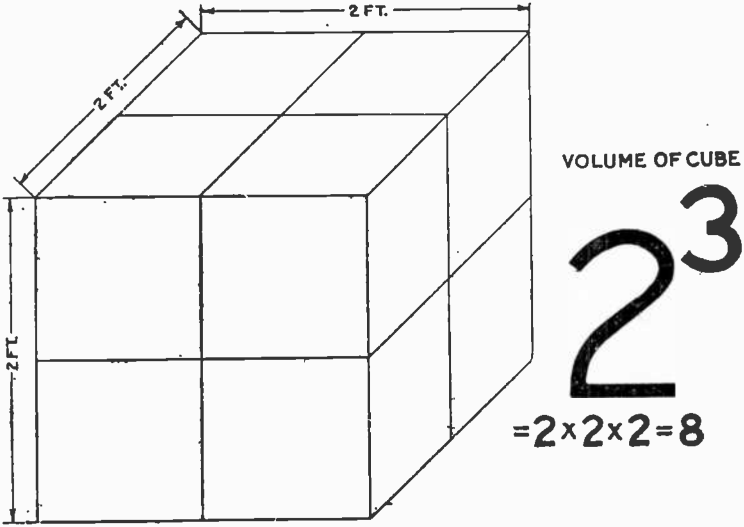


FIG. 4,896.—Two foot cube illustrating the cube of a number.

Symbol ☛ $\sqrt{}$

Roots of Numbers (Evolution).—The word *evolution* means *the operation of extracting a root.* The root here is a factor repeated to produce a power. Thus in the equation $2 \times 2 \times 2 = 8$, 2 is the root from which the power (8) is produced. This number is indicated by the symbol $\sqrt{\ }$ called the radical sign, which placed over a number means that the root of the number is to be extracted. Thus:

$\sqrt{4}$ means that the *square* root of 4 is tc be extracted.

The *index* of the root is a small figure placed over the radical sign which denotes what root is to be taken. Thus $\sqrt[3]{9}$ indicates the cube root of 9; $\sqrt[4]{16}$, the fourth root of 16. ***When there is no index the radical sign alone always means the square root.***

Example:—Extract the square root of 186,624.

```
      18'66'24)432
      16
    83)266
       249
  862) 1724
       1724
```

From right to left point off the given number into periods of two places each. Begin with the last period pointed off (18). Largest square in 18 is 4; put this down in the quotient and the square (16) under the 18. Write down remainder (2) and bring down next period (66). Multiply 4 (in quotient) by 2 for first number of next divisor and say 8 goes into 26, three times.

Place 3 after 4 in quotient and also after 8 in the divisor. Multiply the 83 by 3, placing product 249 under 266 and subtract obtaining remainder 17. Bring down last period 24 and proceed as before, obtaining 432 as the square root of 186,624.

Powers of Numbers (Involution).—The word *involution* means *the multiplication of a quantity by itself any number of times*, and a *power* as here applied is the product arising from this multiplication.

WEIGHTS AND MEASURES

U. S. SYSTEM

LENGTH

12 inches	=	1 foot	ft.
3 feet	=	1 yard	yd.
5½ yards or 16½ feet	=	1 rod	rd.
40 rods	=	1 furlong	fur.
8 furlongs	=	1 mile (statute)	mi.

Surveyor's Long Measure

25 links (l.)	=	1 rod	rd.
4 rods	=	1 chain	ch.
80 chains	=	1 mile (statute)	mi.
1.1527 statute miles	=	1 nautical mile	
3 nautical miles	=	1 league	

AREA

144 square inches	=	1 square foot	sq.ft.
9 square feet	=	1 square yard	sq.yd.
30¼ square yards	=	1 square rod	sq.rd.
40 square rods	=	1 rood	
4 roods	=	1 acre	A.
640 acres	=	1 square mile	sq. mi.

VOLUME or CAPACITY

1728 cubic inches	=	1 cubic foot	cu.ft.
27 cubic feet	=	1 cubic yard	cu.yd.
128 cubic feet	=	1 cord of wood	cd.
24¾ cubic feet	=	1 perch of stone	pch.

Liquid Measure

4 gills	=	1 pint	pt.
2 pints	=	1 quart	qt.
4 quarts	=	1 gallon (231 cubic inches)*	gal.
31½ gallons	=	1 barrel	bbl.
2 barrels	=	1 hogshead	hhd.

Apothecaries' Liquid Measure

60 minims	=	1 fluid dram	fʒ
8 fluid drams	=	1 fluid ounce	f℥
16 fluid ounces	=	1 pint	O
8 pints	=	1 gallon	cong.

Dry Measure

2 pints	=	1 quart	qt.
8 quarts	=	1 peck	pk.
4 pecks	=	1 bushel (2150.42 cubic inches)	bu.

MASS (Weight)

Troy

24 grains	=	1 pennyweight	pwt.
20 pennyweights	=	1 ounce	oz.
12 ounces	=	1 pound (5760 grains)	lb.

Apothecaries'

20 grains	=	1 scruple	sc. or ℈
3 scruples	=	1 dram	dr. or ʒ
8 drams	=	1 ounce	℥
12 ounces	=	1 pound (5760 grains)	lb. or ℔

Avoirdupois

16 ounces	=	1 pound (7000 grains)	lb.
100 pounds	=	1 hundredweight	cwt.
20 hundredweight	=	1 ton	T.

Long Ton

16 ounces	=	1 pound	lb.
28 pounds	=	1 quarter	qr.
4 quarters	=	1 hundredweight	cwt.
20 hundredweight or 2240 pounds	=	1 long ton	T.

Diamond

16 parts	=	1 carat grain
4 carat grains	=	1 carat

* British Imperial Gallon=277.274 Cu. ins

METRIC SYSTEM

Prefixes		*Meaning*	
Milli-	=	*one thousandth*	.001
Centi-	=	*one hundredth*	.01
Deci-	=	*one tenth*	.1
unit	=	*one*	1.
Deka-	=	*ten*	10.
Hecto-	=	*one hundred*	100.
Kilo-	=	*one thousand*	1000.

METER for Length GRAM for Mass
LITER for Capacity

LENGTH

10 millimeters mm.	=	1 centimeter	cm.
10 centimeters	=	decimeter	dm.
10 decimeters	=	1 meter	m.
10 meters	=	1 dekameter	dkm.
10 dekameters	=	1 hectometer	hm.
10 hectometers	=	1 kilometer	km.

AREA

100 sq. millimeters mm^2	=	1 sq. centimeter	cm^2
100 sq. centimeters	=	1 sq. decimeter	dm^2
100 sq. decimeters	=	1 sq. meter or centare	m^2
100 sq. meters or centares	=	1 are	a
100 ares	=	1 hectare	ha
100 hectares	=	1 sq. kilometer	km^2

VOLUME or CAPACITY

1000 cu. millimeters	=	1 cu. centimeter	cm^3
1000 cu. centimeters	=	1 cu. decimeter (1 liter)	dm^3
1000 cu. decimeters	=	1 cu. meter	m^3
1000 cu. meters	=	1 cu. dekameter	dkm^3
1000 cu. dekameters	=	1 cu. hectometer	hm^3
1000 cu. hectometer	=	1 cu. kilometer	km^3

(As the above table is too large and unwieldy for ordinary purposes, the following is commonly used:)

10 milliliters	=	1 centiliter	cl.
10 centiliters	=	1 deciliter	dl.
10 deciliters	=	1 liter (1 cu. decimeter)	l.
10 liters	=	1 dekaliter	dkl
10 dekaliters	=	1 hectoliter	hl.
10 hectoliters	=	1 kiloliter	kl.

MASS (Weight)

10 milligrams mg	=	1 centigram	cg.
10 centigrams	=	1 decigram	dg
10 decigrams	=	1 gram	g.
10 grams	=	1 dekagram	dkg
10 dekagrams	=	1 hectogram	hg
10 hectograms	=	1 kilogram	kg
1000 kilograms	=	1 metric ton	t

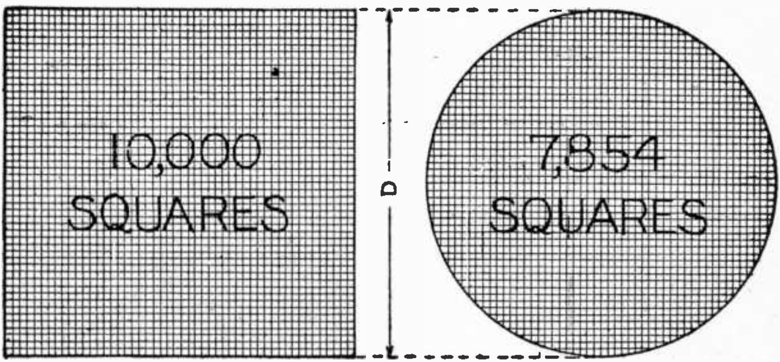
1 cubic centimeter of water at its greatest density (39.2° F = 4° C.) = 1 gram.
1 liter of water = 1 kilogram

International Carat=200 milligrams

Involution then is *the process of raising a number to a given power*. The "square" of a number is its second power; the "cube," its third power. Thus:

$$\text{square of } 2 = 2 \times 2 = 4$$
$$\text{cube of } 2 = 2 \times 2 \times 2 = 8$$

The power to which a number is raised is indicated by a small "superior" figure called an "exponent." Thus:

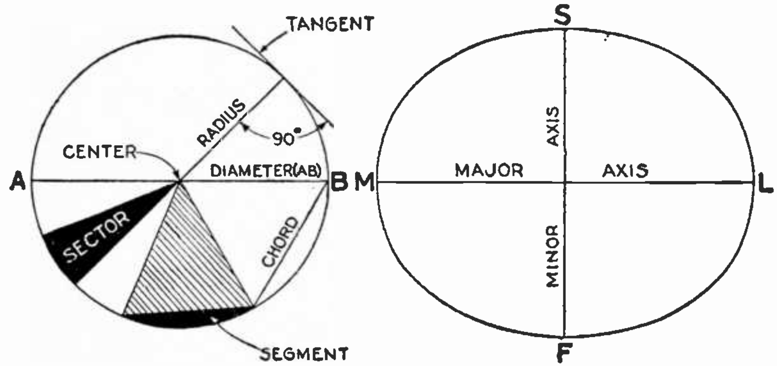


FIGS. 4,897 and 4,898.—Diagram illustrating why the decimal .7854 is used to find the area of a circle. If the square be divided into 10,000 parts or small squares, a circle having a diameter D, equal to a side of the large square will contain 7,854 small squares, hence, if the area of the large square be 1 sq. in., then the area of the circle will be 7854 ÷ 10,000 or .7854 sq. ins., that is, area of the circle = .7854 × D × D = .7854 × 1 × 1 = .7854 sq. ins

from which it is seen that the exponent indicates the number of times the number or "root" has been taken.

Circle.—By definition *a plane figure bounded by a uniformly curved line all points in which are at the same distance from a point within called the center.*

The ratio of the circumference to the diameter of a circle is represented by the Greek letter π (called Pi). $\pi = 3.1416$. An approximate fraction is $\frac{22}{7}$.



FIGS. 4,899 and 4,900.—Curved figures. Fig. 4,899, circle; fig. 4,900, ellipse. ***A circle*** is a plane figure bounded by a uniformly curved line, every point of which is equidistant from a point, within called the center. ***An ellipse*** is a curved figure enclosed by a curved line which is such that the sum of the distances between any point on the circumference and the two foci is invariable. ML, major axis; SF, minor axis.

To find the length of the circumference of a circle.

Rule.—*Multiply* 3.1416 *by the diameter.*

Example.—Circumference of a 3 in. circle $= 3 \times 3.1416 = 9.43$ ins.

To find the diameter of a circle.

Rule.—(1) *Multiply the circumference by* 7 *and divide by* 22; or (2) *Divide the circumference by* 3.1416.

Areas and Circumferences of Circles

Diameter	Circumference	Area	Diameter	Circumference	Area	Diameter	Circumference	Area
1/64	.049087	.00019	1. 15/16	6.08684	2.9483	4. 15/16	15.5116	19.147
1/32	.098175	.00077	2.	6.28319	3.1416	5.	15.7080	19.635
3/64	.147262	.00173	1/16	6.47953	3.3410	1/16	15.9043	20.129
1/16	.196350	.00307	1/8	6.67588	3.5466	1/8	16.1007	20.629
3/32	.294524	.00690	3/16	6.87223	3.7583	3/16	16.2970	21.135
1/8	.392699	.01227	1/4	7.06858	3.9761	1/4	16.4934	21.648
5/32	.490874	.01917	5/16	7.26493	4.2000	5/16	16.6897	22.166
3/16	.589049	.02761	3/8	7.46128	4.4301	3/8	16.8861	22.691
7/32	.687223	.03758	7/16	7.65763	4.6664	7/16	17.0824	23.221
1/4	.785398	.04909	1/2	7.85398	4.9087	1/2	17.2788	23.758
9/32	.883573	.06213	9/16	8.05033	5.1572	9/16	17.4751	24.301
5/16	.981748	.07670	5/8	8.24668	5.4119	5/8	17.6715	24.850
11/32	1.07992	.09281	11/16	8.44303	5.6727	11/16	17.8678	25.406
3/8	1.17810	.11045	3/4	8.63938	5.9396	3/4	18.0642	25.967
13/32	1.27627	.12962	13/16	8.83573	6.2126	13/16	18.2605	26.535
7/16	1.37445	.15033	7/8	9.03208	6.4918	7/8	18.4569	27.109
15/32	1.47262	.17257	15/16	9.22843	6.7771	15/16	18.6532	27.688
1/2	1.57080	.19635	3.	9.42478	7.0686	6.	18.8496	28.274
17/32	1.66897	.22166	1/16	9.62113	7.3662	1/8	19.2423	29.465
9/16	1.76715	.24850	1/8	9.81748	7.6699	1/4	19.6350	30.680
19/32	1.86532	.27688	3/16	10.0138	7.9798	3/8	20.0277	31.919
5/8	1.96350	.30680	1/4	10.2102	8.2958	1/2	20.4204	33.183
21/32	2.06167	.33824	5/16	10.4065	8.6179	5/8	20.8131	34.472
11/16	2.15984	.37122	3/8	10.6029	8.9462	3/4	21.2058	35.785
23/32	2.25802	.40574	7/16	10.7992	9.2806	7/8	21.5984	37.122
3/4	2.35619	.44179	1/2	10.9956	9.6211	7.	21.9911	38.485
25/32	2.45437	.47937	9/16	11.1919	9.9678	1/8	22.3838	39.871
13/16	2.55254	.51849	5/8	11.3883	10.321	1/4	22.7765	41.282
27/32	2.65072	.55914	11/16	11.5846	10.680	3/8	23.1692	42.718
7/8	2.74889	.60132	3/4	11.7810	11.045	1/2	23.5619	44.179
29/32	2.84707	.64504	13/16	11.9773	11.416	5/8	23.9546	45.664
15/16	2.94524	.69029	7/8	12.1737	11.793	3/4	24.3473	47.173
31/32	3.04342	.73708	15/16	12.3700	12.177	7/8	24.7400	48.707
1	3.14159	.78540	4.	12.5664	12.566	8.	25.1327	50.265
1/16	3.33794	.88664	1/16	12.7627	12.962	1/8	25.5254	51.849
1/8	3.53429	.99402	1/8	12.9591	13.364	1/4	25.9181	53.456
3/16	3.73064	1.1075	3/16	13.1554	13.772	3/8	26.3108	55.088
1/4	3.92699	1.2272	1/4	13.3518	14.186	1/2	26.7035	56.745
5/16	4.12334	1.3530	5/16	13.5481	14.607	5/8	27.0962	58.426
3/8	4.31969	1.4849	3/8	13.7445	15.033	3/4	27.4889	60.132
7/16	4.51604	1.6230	7/16	13.9408	15.466	7/8	27.8816	61.862
1/2	4.71239	1.7671	1/2	14.1372	15.904	9.	28.2743	63.617
9/16	4.90874	1.9175	9/16	14.3335	16.349	1/8	28.6670	65.397
5/8	5.10509	2.0739	5/8	14.5299	16.800	1/4	29.0597	67.201
11/16	5.30144	2.2365	11/16	14.7262	17.257	3/8	29.4524	69.029
3/4	5.49779	2.4053	3/4	14.9226	17.721	1/2	29.8451	70.882
13/16	5.69414	2.5802	13/16	15.1189	18.190	5/8	30.2378	72.760
7/8	5.89049	2.7612	7/8	15.3153	18.665	3/4	30.6305	74.662

.7854

OR

$\frac{1}{4}\pi$

The factor .7854 ($=\frac{1}{4}\pi$) is used to find the area of a circle etc. Thus to find the area of a circle:

Rule.—*Multiply the square of the diameter by* .7854.

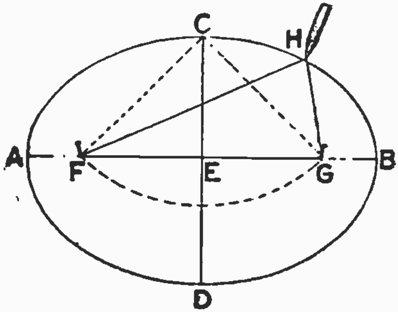


FIG. 4,901.—*To describe an ellipse when the axes are given.* Draw the major and minor axes AB and CD, at right angles, intersecting at E. On the center C, with AE, as radius, cut the axis AB, at F and G, the *foci*; insert pins through the axis at F and G, and loop a thread or cord upon them equal in length to the axis AB, so that when stretched it reaches the extremity C, of the *conjugate axis*, as shown in dotted lines. Place a pencil inside the cord, as at H, and guiding the pencil in this way keeping the cord equal in tension, carry the pencil round the pins FG, and so describe the ellipse.

Ellipse.—*By definition, a plane figure enclosed by a curved line*, as in fig. 4,900, which is such, that the sum of the distances between any point on the circumference and the two foci is invariable. The ellipse may also be defined as a conic section obtained by a plane cutting a cone obliquely to its axis.

To find the circumference (approximately) of an ellipse:

Rule.—*Multiply* 3.1416 *by* $\sqrt{\frac{D^2+d^2}{2}}$, D and d being the two axes.

To find the area of an ellipse:

Rules.—*Multiply the product of its semi-axes by* **3.1416**, *or multiply the product of its axes by* .7854.

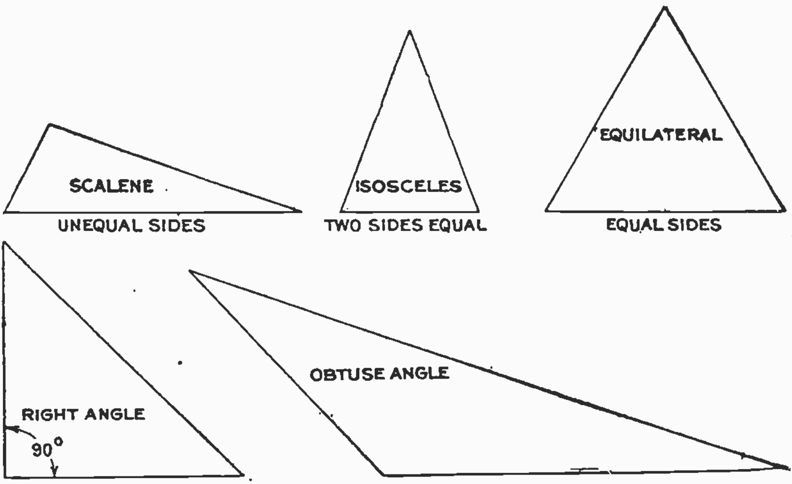
Circular Ring.—By definition, *a plane figure bounded by the circumference of two concentric circles.*

To find the area of a circular ring.

Rule.—*Take the difference between the areas of the two circles; or, subtract the square of the less radius from the square of the greater, and multiply their difference by* 3.1416 (that is, $4 \times \frac{1}{4}\pi$).

Triangle.—By definition, *a plane figure bounded by three lines called sides, and having consequently three angles, as in figs.* 4,902 to 4,906.

To find the area of a triangle:



FIGS. 4,902 to 4,906.—Various triangles. A triangle is a polygon having three sides and three angles. By altering the angles and sides a great variety of triangles may be obtained.

Rule.—*Multiply the base by half the altitude.*

Square.—By definition, *a four sided plane figure, whose sides are equal and whose angles are right angles, as in fig.* 4,907.

To find the area of a square:

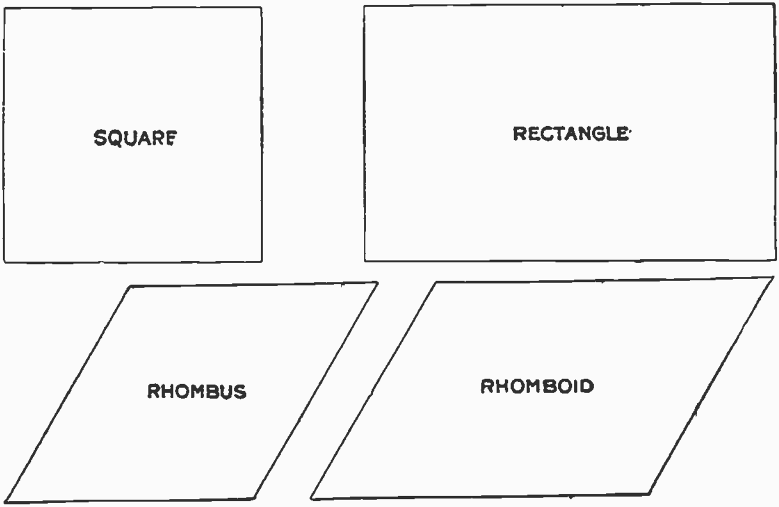
Rule.—*Multiply the base by the height.*

Rectangle.—By definition, *in geometry, a parallelogram, having its angles right angles, as in fig*. 4,908.

To find the area of a rectangle:

Rule.—*Multiply the base by the height.*

Parallelogram.—By definition, *a figure whose opposite sides are parallel*, as in fig. 4,910. The square and oblong are parallelograms, also the other four sided figures, whose angles are not right angles.



FIGS. 4,907 to 4,910.—*Various quadrilaterals.* *1.* Parallelograms. Opposite sides parallel.

To find the area of a parallelogram:

Rule.—*Multiply base by perpendicular height.*

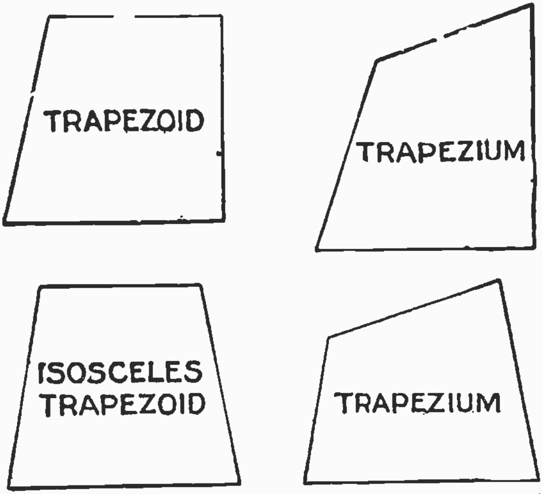
Trapezoid.—By definition, *a quadrilateral, two of whose sides are parallel and two are oblique*, as in fig. 4,911

To find the area of a trapezoid:

Rule.—*Multiply one half of the sum of the two parallel sides by the perpendicular distance between them.*

Trapezium.—By definition, *a quadrilateral having no two sides parallel*, as in fig. 4,914.

To find the area of a trapezium:



FIGS. 4,911 to 4,914.—*Various quadrilaterals.* 2. Trapezoids and trapeziums. A quadrilateral is called a trapezoid if two and only two sides be parallel; a trapezium, if no two sides be parallel; an isosceles trapezoid, if the legs be equal. Figs. 4,911 and 4,912 show right trapezoid and right trapezium respectively.

Rule.—*Draw a diagonal, dividing figure into triangles; measure diagonal and altitudes and find area of the triangles.*

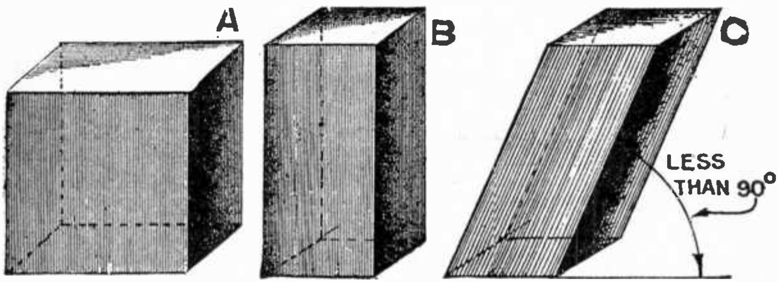
To find the area of any irregular polygon:

Rule.—*Draw diagonals dividing the figure into triangles and find the sum of the areas of these triangles.*

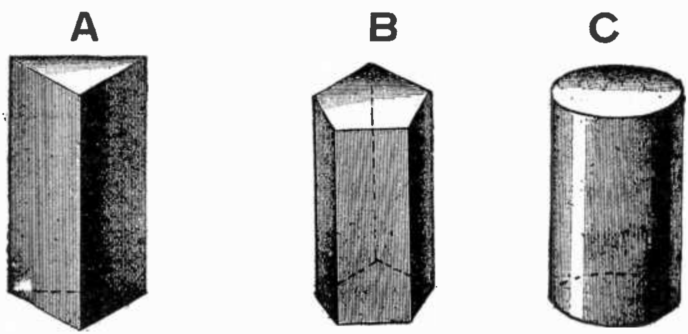
Rule.—When length of side only is given, *multiply the square of the sides by the figure for "area side = 1" opposite to the polygon in the table following.*

Table of Regular Polygons

Number of sides	3	4	5	6	7	8	9	10	11	12
Area when side = 1........	.433	1.	1.721	2.598	3.634	4.828	6.181	7.694	9.366	11.196



FIGS. 4,915 to 4,917.—*Various prisms 1.* A, cube or equilateral parallelopipedon; B, parallelopipedon; C, oblique parallelopipedon.

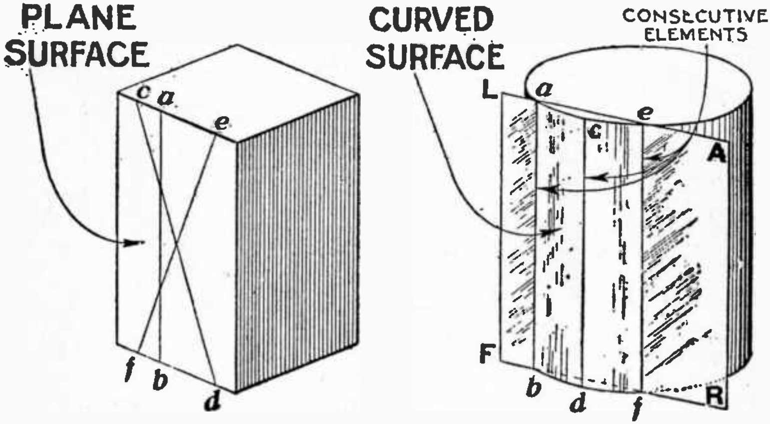


FIGS. 4,918 to 4,920.—*Various prisms 2.* A, triangular prism; B, pentagonal prism C, cylinder.

Cube.—By definition *a rectangular solid, measuring the same lineally in the three directions of length, breadth and thickness* (as in fig. 4,915).

Its volume is equal to the product of the lineal measurement of each dimension, hence the third power of a number is termed its cube, as it represents the product of three factors each equal to the stated number. This is written a^3 or *a* cubed, as it equals *aaa* or $a \times a \times a$.

To find the volume of a cube.



Figs. 4,921 and 4,922.—Plane and curved surfaces. Elements of a plane surface may be drawn in the surface in any direction as *ab*, *cd*, *ef*, as in fig. 4,921. In a curved surface no three *consecutive* elements lie in the same plane as in fig. 4,922.

Rule.—*Multiply the area of the base by the perpendicular*, or *multiply the length, breadth and height together*.

Parallelopipedon.—By definition, *a prism bounded by six parallelograms, the opposite ones being parallel and equal*, as in figs. 4,915 to 4,917.

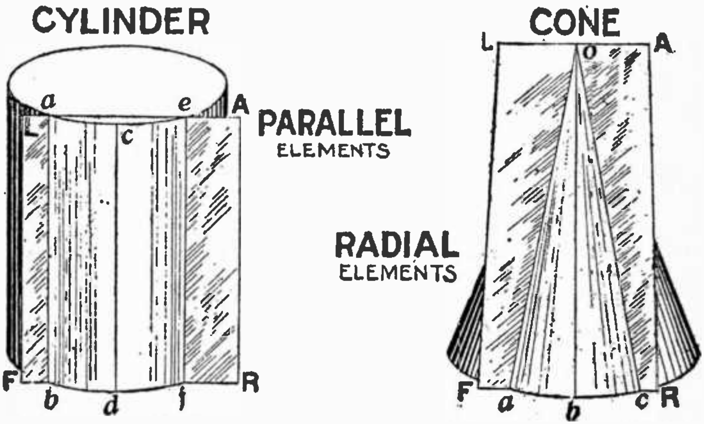
A cube is a parallelopipedon whose faces are all equal squares.

Cylinder.—*By definition, a circular body generated by the rotation of a straight line around an axis and parallel to same,* as in fig. 4,920.

To find the cylindrical surface of a cylinder:

Rule.—*Multiply* 3.1416 *by the diameter and by the length of the cylinder.*

To find the total surface of a cylinder:



Figs. 4,923 and 4,924.—Distinction between ***cylindrical*** and ***conical*** surfaces. Fig. 4,923, elements parallel; fig. 4,924, elements radial. Both surfaces being curved surfaces, no three consecutive elements lie in the same plane as indicated by plane LARF, passing through the first and third of the three consecutive elements *ab*, *cd*, and *ef*.

Rule.—*Add to the cylindrical surface twice the area of the base.*

To find the volume of a cylinder:

Rule.—*Multiply the area of the base by the length of the cylinder.*

Cone.—By definition, *a solid figure,* described by the rotation of a triangle upon one of its sides as axis, or one which tapers uniformly from a circular base to a point, as in fig. 4,924.

To find the slant area of a cone:

Rule.—*Multiply* 3.1416 *by diameter of base and by one-half the slant height.*

To find the volume of a cone:

Rule.—*Multiply the area of the base by the perpendicular height, and* $\frac{1}{3}$ *of the product will be the solidity.*

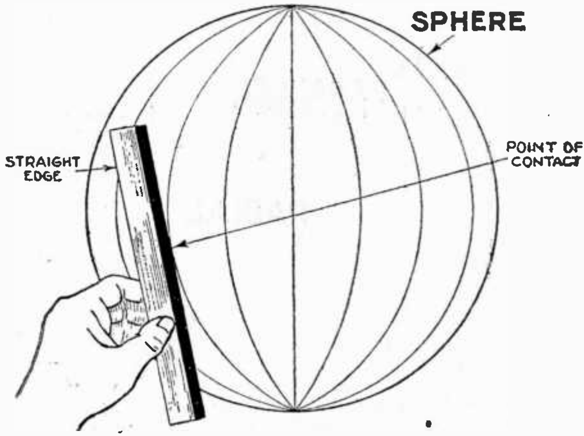


FIG. 4,925.—*Warped surface or surface in which a straight edge can be placed in contact only at a point.*

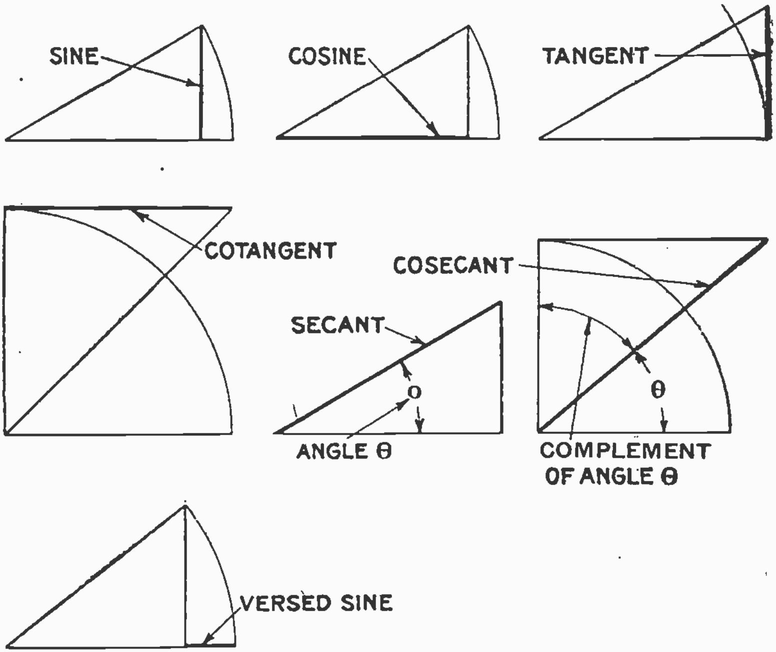
Sphere.—By definition, *a body whose surface has every point equally distant from a point within called its center*, as in fig. 4,925.

To find the volume of a sphere:

Rule.—*Multiply* .7854 *by the cube of the diameter and then take* $\frac{2}{3}$ *of the product.*

To find the volume of a segment of a sphere:

Rule.—*To three times the square of the radius of the segment's base, add the square of its height; then multiply this sum by the height and the product by* .5236.



Figs. 4,926 to 4,932.—The natural trigonometrical functions each shown separately for clearness. As elsewhere stated the cos., cot., and cosec., of an angle are respectively the sine, tan, and sec. of the complement of the angle.

Electrical Definitions

Joule.—The unit of work. It is the energy expended in one second by one ampere flowing against a resistance of one ohm.

Watt.—Unit of power. It is one ampere at a pressure of one volt and equals one joule per second.

***Henry* (*L*).**—Unit of induction. It is the induction in a circuit when the pressure induced is one volt while the inducing current varies one ampere per second.

***Frequency* (*f*).**—The frequency of an alternating current circuit is the number of cycles through which it passes per second.

OHM'S LAW

SYMBOLS	MEANING OF SYMBOLS
$I = \frac{E}{R}$	CURRENT = $\frac{\text{PRESSURE}}{\text{RESISTANCE}}$ THAT IS AMPERES = $\frac{\text{VOLTS}}{\text{OHMS}}$
$R = \frac{E}{I}$	RESISTANCE = $\frac{\text{PRESSURE}}{\text{CURRENT}}$ THAT IS OHMS = $\frac{\text{VOLTS}}{\text{AMPERES}}$
$E = IR$	PRESSURE = CURRENT X RESISTANCE THAT IS VOLTS = AMPERES X OHMS

***Reactance* (*X*).**—An apparent resistance of an alternating current circuit due to induction and capacity. It is expressed as $X = 2\pi fL - \frac{1}{2\pi fC}$

***Impedance* (*Z*).**—The apparent resistance of an alternating current circuit,

$$Z = \sqrt{R^2 + X^2} \text{ or } \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

Power Factor (*cos θ*).—The ratio of the power to the apparent power.

Direct Current Circuits:

$$I=\frac{E}{R},\ E=IR,\ R=\frac{E}{I} \qquad P=\text{watts loss}=I^2R$$

Alternating Current Circuits:

$$I=\frac{E}{Z}, \qquad E=IZ \qquad P=\text{watts loss}=I^2R$$

Single Phase: $P=EI\cos\theta$ $\quad I=\dfrac{P}{E\cos\theta}$

Two Phase: $P=2EI\cos\theta$ $\quad I=\dfrac{P}{2E\cos\theta}$

Three Phase: $P=\sqrt{3}\,EI\cos\theta$ $\quad I=\dfrac{P}{\sqrt{3}\,EI\cos\theta}$

Definitions of Mechanical Units

Speed or Velocity.—*Rate of change in position of a body with reference to some other body.*

Acceleration.—*Rate of change in speed.* It may be positive or negative. That is, the speed may be either increasing or decreasing.

Mass.—*The quantity of matter in a body.*

Force.—*That which changes or tends to change a body's state of rest or of motion.*

Force units are defined in two ways, as follows: 1, Unit force is the force exerted by gravity on unit mass, force $=\dfrac{\text{mass}}{g}\times$ acceleration. g = acceleration due to gravity. 2, Unit force is that force which will give unit acceleration to unit mass.

Work.—*Force exerted over a distance.*

$$\text{Work} = \text{force} \times \text{distance} = \text{power} \times \text{time}.$$

Energy.—*The capacity for doing work.* Units are the same as work.

Power.—*Rate at which work is performed.*

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

Mechanical Units

English System.

Speed or Velocity.

Feet per second.
Miles per hour.
Knots per hour (Marine).

Acceleration.

Feet per second per second.
Miles per hour per second.

Mass.

Pounds avoirdupois.
Pound troy.

Force 1.

Pound (force).
Poundal (very seldom used).

Force 2.

Pounds × feet per sec. per sec.
Poundal.

Work.

Foot-poundal.
Foot-pound.

Metric System.

Speed or Velocity.

Centimeters per second.
Kilometers per hour.

Acceleration.

Centimeters per second per second.
Kilometers per hour per second.

Mass.

Gram.

Force 1.

Gram.

Force 2.

Grams × cm. per sec. per sec.
Dyne.

Work.

Erg.
Joule.
Kilogrammeter.

Power.	*Power.*
Horse power.	Metric horse power 75 kilogram-meters per second.
	Watt (International unit) One joule per second.

Horse Power.—By definition, 33,000 *foot pounds of work per minute.*

To calculate horse power of an engine use the following formula:

$$^{*}h.p. = .000004d^{2}lnp$$

in which

h.p. = horse power

d. = diameter of piston in inches

l. = length of stroke in inches

n. = number of revolutions per minute

p. = mean effective pressure in lbs. per sq. in.

Example:—What is the horse power of a 5×6 engine running at 500 revolutions per minute and 50 lbs. mean effective pressure?

Substitute values in formula; disregard ciphers and decimal points and point off result by "sense of proportion" thus

$$h.p. = 4\times5^2\times6\times500\times50$$

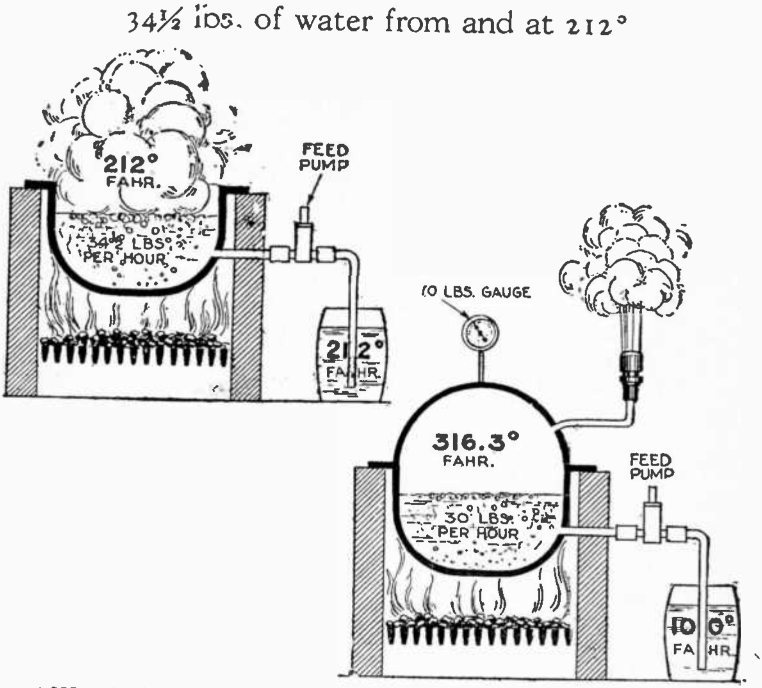
disregard first two factors because $4\times5^2=100$, then

$6\times500\times50=150{,}000$ or from sense of proportion 15 *h.p.*

Boiler Horse Power.—*The evaporation of* 30 *lbs. feed water per hour, from a feed temperature of* 100° F., *to steam of* 70 *lbs. gauge pressure.*

This is equivalent to 33.305 *b.t.u.* per hour, or the evaporation of

*NOTE.—***For full explanation*** of this time saving formula see volume No. 1 of the author's Engineers' and Mechanics' Guides.



FIGS. 4,933 and 4,934.—One boiler horse power illustrating the two units. The term *horse power* has two meanings in engineering: First, an absolute unit or measure of the rate of work, that is, of the work done in a certain definite period of time, by a source of energy, as a steam boiler, a waterfall, a current of air or water, or by a prime mover, as a steam engine, a waterwheel, or a wind-mill. The value of this unit, whenever it can be expressed in ft. lbs. of energy as in the case of steam engines, water wheels and waterfalls, is 33,000 ft. lbs. per min. In the case of boilers, where the work done, the conversion of water into steam, cannot be expressed in ft. lbs. of available energy, the usual value given to the term horse power is the evaporation of 30 lbs. of water at a temperature of 100° F. into steam at 70 lbs. pressure above the atmosphere.

Belts and Pulleys.—To calculate size of pulleys the following formulæ are used:

$$D = dr \div R \qquad R = dr \div D$$

$$d = DR \div r \qquad r = DR \div d$$

in which

D = diameter of driver pulley
d = " " driven "
R = revolutions per minute of driver pulley
r = " " " " driven "

Thermometer Scales.—The two principal scales in use are the Fahrenheit scale used in the U. S. and Great Britain, and the Centigrade scale used in France and Germany, and in scientific work everywhere.

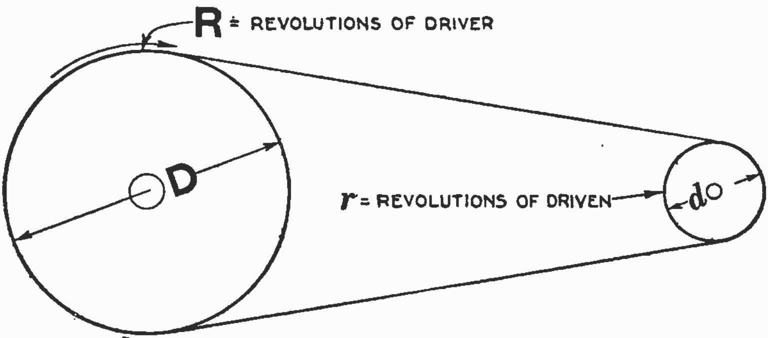


FIG. 4,935.—Single reduction belt device illustrating the symbols used in the accompanying formulæ.

Boiling point of water at sea level	= 100	degrees	Centigrade.
	212	"	Fahrenheit.
Freezing point of water	= 0	"	Centigrade.
	32	"	Fahrenheit.

Temperature conversion formulæ:

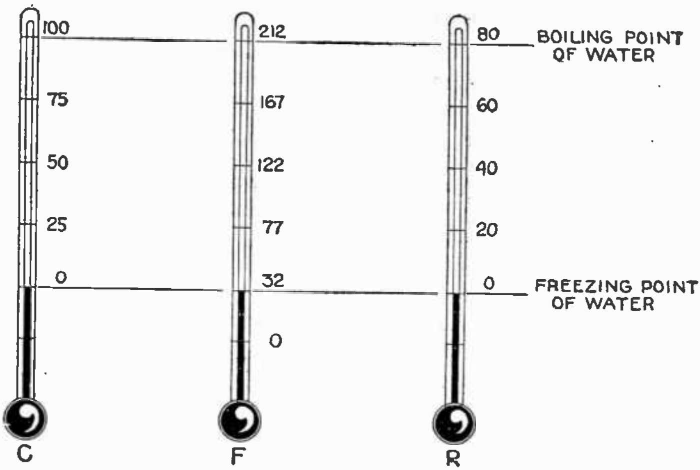
$$°C. \times 1.8 + 32 = °F.$$
$$°F. - 32 \div 1.8 = °C.$$

Air.—By definition, *a mechanical mixture of 23% of oxygen by weight; 76% nitrogen and 1% argon by weight.*

1 cu. ft. of pure air at 32° F., and at a barometric pressure of 29.92 inches of mercury (14.7 lbs. per sq. in.) weighs .080728 lb.

The volume of 1 lb. of air = 12.387 cu. ft.

Air expands 1/493 of its volume for each increase of 1° F., and the volume varies inversely as the pressure.



FIGS. 4,936 to 4,938—Comparative thermometer scales.

Air liquefies at −220° F. (its critical temperature) under a pressure of 573 lbs. per sq. in. and boils at −312° F.

Specific gravity of air at −312° F. = .94.

Latent heat of air = 123 to 144 *B.t.u.* per lb.

Liquid air occupies about 1/800 of the volume of the same weight of free air at normal temperatures.

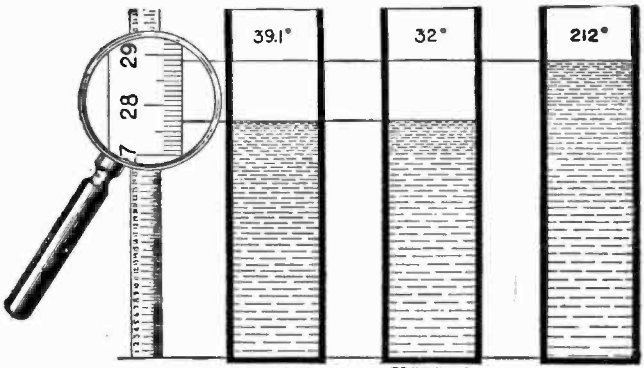
Barometer.—By definition, *an instrument for measuring the pressure of the atmosphere.*

Pressure of the atmosphere per square inch for various readings of the barometer.

Rule.—Barometer in inches of mercury × .49116 = *lbs. per sq. in.*

Barometer (ins. of mercury)	Pressure per sq. ins., lbs.	Barometer (ins. of mercury)	Pressure per sq. ins., lbs.
28.00	13.75	**29.921**	**14.696**
28.25	13.88	30.00	14.74
28.50	14.00	30.25	14.86
28.75	14.12	30.50	14.98
29.00	14.24	30.75	15.10
29.25	14.37	31.00	15.23
29.50	14.49		
29.75	14.61		

The above table is based on the standard atmosphere, which by definition = ***29.921*** ins. of mercury = ***14.696*** lbs. per sq. in. that is, 1 in. of mercury = 14.696 ÷ 29.921 = ***.49116*** lbs. per sq. in.



FIGS. 4,939 to 4,942.—The most remarkable characteristic of water: *expansion below and above its temperature or "point of maximum density"* 39.1° *Fahr.* Imagine one pound of water at 39.1° F. placed in a cylinder having a cross sectional area of 1 sq. in. as in fig. 4,940. The water having a volume of 27.68 cu. ins., will fill the cylinder to a height of 27.68 ins. If the liquid be cooled it will expand, and at say the *freezing point* 32° F., will rise in the tube to a height of 27.7 ins., as in fig. 4,941, before freezing. Again, if the liquid in fig. 4,940 be heated, it will also expand and rise in the tube, and at say the *boiling point* (for atmospheric pressure 212° F.), will occupy the tube to a height of 28.88 cu. ins., as in fig. 4,942.

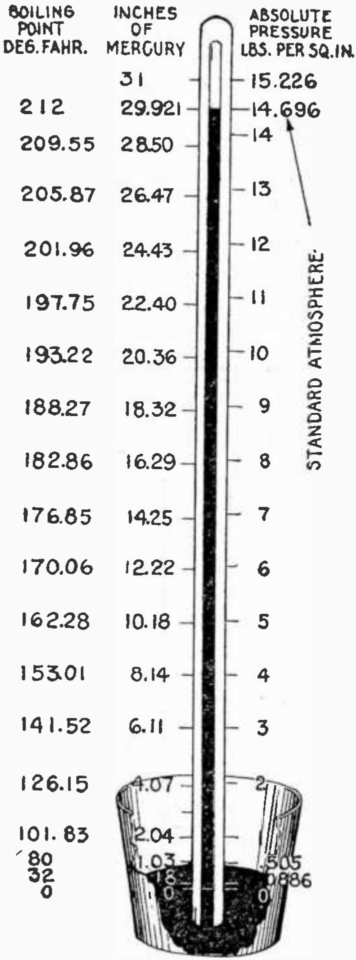


FIG. 4,943.—Mercurial barometer illustrating the relation between "*inches of mercury*" boiling point and absolute pressure in lbs. per sq. in.

Ice.—One cu. ft. of ice at 32° Fahr. weighs 57.5 lbs.; one lb. of ice at 32° F. has a volume of .0174 cu. ft. or 30.067 cu. ins.

The relative volume of ice to water at 32° F. is 1.0855, the expansion in passing into the solid state being 8.55%. Specific gravity of ice = .922, water at 62° F. being 1.

Water.—It consists of *a compound of hydrogen and oxygen in the proportion of 2 parts by weight of hydrogen to 16 parts by weight of oxygen.*

Water freezes at 32° and boils at 212° Fahr. at atmospheric pressure (14.7 lbs. per sq. in.). Maximum density 39.1° and expands as heat is added. Weight (at 62° Fahr.) 62.4 lbs. per cu. ft.; 8⅓ lbs. per U. S. gal. (231 cu. ins.). Pressure due to head = .433 lbs. per sq. in. per foot static head.

Steam.—*A colorless, expansive, invisible fluid; the vapor of water.*

It is classified as wet, saturated, super-heated.

Steam condenses when the temperature becomes less than the boiling point.

Latent heat at 212° (atmospheric pressure) 970.4 *B.t.u.*

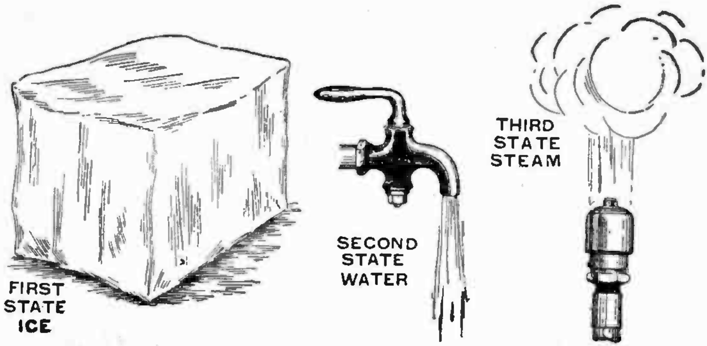


FIG. 4,944 to 4,946.—The three states: Solid, liquid and gas. The cake of ice represents a substance in the solid state. If the temperature of the surrounding air be above the freezing point (32° Fahr.) *the ice will gradually melt*, that is to say, ***change its state from solid to liquid,*** this process being known as ***fusion.*** If sufficient heat be transferred to the liquid, *it will boil*, that is to say, ***change its state from liquid to gas***, this process being known as ***vaporization.*** Very interesting phenomena take place during these changes. The author does not agree with the standard method of calculating the external latent heat, or external work of vaporization. See his ***Engineers and Mechanics Guide No. 1,*** page 31.

Physical Properties of Metals

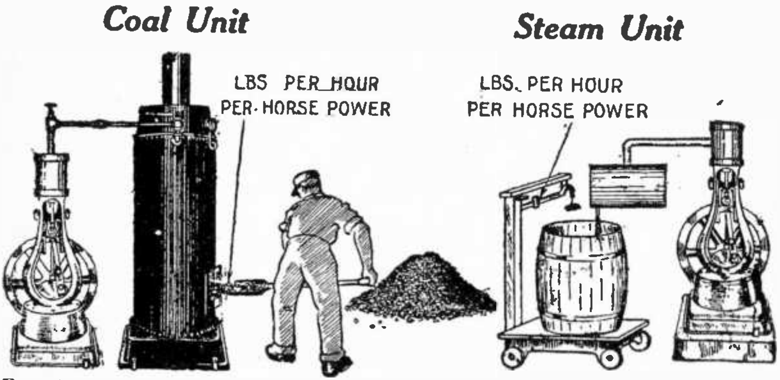
METALS	Weight per Cubic Inch in Pounds	Ultimate Tensile Strength. Pounds per sq. Inch	Melting Point in Cent. Degrees	Specific Heat	Coefficient of Linear Expansion Below 100° Cent.	Ohms Res. per Mil ft. 20° Cent.	Tempt. Coefficient. K. Cent. Degrees
Antimony	0.243	....	440	0.0508	0.00001129	230.2	0.00389
Aluminum, annealed	.096	15,000	625	.2185	.00002310	18.21	.00390
Bismuth	.354	6,400	266	.0298	.00001755	845.20	.00354
Brass, Cast	.303	18,000	1020	.0939	.00001720	45.00	......
Copper, Annealed	.319	30,000	1054	.0951	.00001596	10.35	.00388
Copper, Hard Drawn	.322	60,000	1200	.0951	....	10.7	.00388
German Silver Wire	.307	87,000	1093	.....	....	126.6	.000443
Gold, Annealed	.695	......	1046	.0324	.00001415	13.28	.00365
Iron, Cast	.260	16,500	1220	.1298	.00001001	380.	.00453
Iron, Wrought	.278	52,000	1620	.1138	.000011660	63.21	.0054
Lead	.411	3,300	325	.0314	.00002828	126.10	.00387
Manganese Steel	.282	......	1260	.....	....	245.	.00122
Mercury	.49	......	—39.4	.0333	.00006	577.6	.0007485
Nickel	.318	......	1620	.1150	.00001251	74.73	.0041
Platinum	.765	......	1800	.0324	.00000863	56.69	.0039
Phosphor Bronze	.321	64,700	......	.....	....	39.6	....
Silicon Bronze	.321	75,000	......	.....	....	12.9	....
Silver	.379	......	950	.0570	.00001943	10.48	.00377
Steel, High Carbon	.283	100,000	1410	.1175	.00001240	118.	.0050
Solder, Tin 1, Lead 1	.338	7,500	187	.....	....	111.	....
Tin	.265	4,500	230	.0562	.00002094	84.57	.00365
Zinc	.255	7,500	416	.0956	.00002532	36.60	.00365

Electrical Units

Ohm.—The unit of resistance, symbol R. The international standard ohm is represented by the resistance offered to an unvarying electric current by a column of mercury 106.3 centimeters long and 14.4521 grams mass at 0° C.

Megohm.—One million (1,000,000) ohms.

Ampere (I).—The unit of current. The international standard ampere is practically represented by the unvarying current which when passed



FIGS. 4,947 and 4,948.—Units for measuring performance of boilers and engines. The boiler or coal unit is stated in terms of *lbs. of coal burned per hour, per horse power*; the steam unit states *the lbs. (weight) of steam used by the engine per hour per horse power*.

through a solution of nitrate of silver in water, deposits silver at the rate of .001118 grams per second.

Volt (E).—The unit of electric pressure. It is the pressure which applied to one ohm, will produce a current of one ampere.

Coulomb (Q).—The unit of quantity. It is the quantity of electricity transferred by a current of one ampere in one second.

Farad (C).—The unit of capacity. It is the capacity of a conductor charged to a pressure of one volt by one coulomb.

Equivalents

Length

To convert	Multiply by	To convert	Multiply by
Inches to mils	1,000.	Mils to inches	.001
Inches to millimeters	25.4	Millimeters to inches	.03937
Inches to centimeters	2.54	Centimeters to inches	.3937
Inches to meters	.0254	Meters to inches	39.3701
Feet to centimeters	30.48	Centimeters to feet	.03281
Feet to meters	.3048	Meters to feet	3.2808
Yards to centimeters	91.44	Centimeters to yards	.01094
Yards to meters	.9144	Meters to yards	1.0936
Yards to kilometers	.0009144	Kilometers to yards	1,093.6
Miles to meters	1,609.34	Meters to miles	.0006214
Miles to kilometers	1.6093	Kilometers to miles	.6214

Area

To convert	Multiply by	To convert	Multiply by
Sq. ins. to sq. mils	1,000,000.	Sq. mils to sq. ins.	.000001
Sq. ins. to circular mils	1,273,240.	Circular mils to sq. ins.	.0000007854
Sq. mils to circular mils	1.2732	Circular mils to sq. mils	.7854
Circular mils to sq. millimeters	.0005066	Sq. millimeters to circular mils	1973.51
Sq. ins. to sq. millimeters	645.16	Sq. millimeters to sq. ins.	.00155
Sq. ins. to sq. centimeters	6.4516	Sq. centimeters to sq. ins.	.155
Sq. ft. to sq. meters	.0929	Sq. meters to sq. ft.	10.764
Sq. yds. to sq. meters	.8361	Sq. meters to sq. yds.	1.196

Equivalents—*Continued*

Volume

To convert	Multiply by	To convert	Multiply by
Cu. ins. to cu centimeters	16.3862	Cu. centimeters to cu. ins.	.06103
Cu. ins. to liters	.01639	Liters to cu. ins.	61.024
Cu. ft. to liters	28.317	Liters to cu. ft.	.03531
U. S. bushels to bushels (Eng.)	.9688	Bushels (Eng.) to U. S. bushels	1.032
Cu. ins. to U. S. bushels	.000465	U. S. bushels to cu. ins.	2,150.4
Cu. ft. to U. S. bushels.	.8035	U. S. bushels to cu. ft..	1.244
Liters to U. S. bushels..	.02838	U. S. bushels to liters..	35.24
U. S. gals. to Imperial (Eng.) gals.	.8336	Imp. (Eng. gals.) to U. S. gals.	1.1997
Cu. ins. to U. S. gals...	.00433	U. S. gals. to cu. ins...	230.98
Cu. ft. to U. S. gals....	7.482	U. S. gals. to cu. ft....	.1336
Liters to U. S. gals.....	.2642	U. S. gals. to liters.....	3.785

Weight

To convert	Multiply by	To convert	Multiply by
Grains to grams	.0648	Grams to grains	15.432
Ounces to grams	28.3495	Grams to ounces	.03527
Ounces to kilograms	.02835	Kilograms to ounces	35.274
Pounds to grams	453.59	Grams to pounds	.002205
Pounds to kilograms	.4536	Kilograms to pounds	2.2046
Tons (long) to tons (short)	.8929	Tons (short) to tons (long)	1.12
Tons (short) to kilograms	907.19	Kilograms to tons (short)	.001102
Tons (long) to kilograms	1,016.047	Kilograms to tons (long)	.0009842

Equivalents—*Continued*

Pressure

To convert	Multiply by	To convert	Multiply by
Lbs. per sq. in. to grams per sq. cm.	70.307	Gr. per sq. cm. to lbs. per sq. in.	.01422
Lbs. per sq. in to kg. per sq. cm.	.07031	Kg. per sq. cm. to lbs. per sq. in.	14.223
Lbs. per sq. ft. to kg. per sq. meter	4.883	Kg. per sq. meter to lbs. per sq. ft.	.2048
Lbs. per sq. in. to atmospheres	.06803	Atmospheres to lbs. per sq. in.	14.7
Lbs. per sq. in. to tons per sq. ft.	.06429	Tons per sq. ft. to lbs. per sq. in.	15.556
Tons per sq. ft. to atmospheres	1.058	Atmospheres to tons per sq. ft.	.945
Tons per sq. ft. to kg. per sq. cm.	1.0937	Kg. per sq. cm. to tons per sq. ft.	.9143
Ins. of mercury to atmospheres	.03342	Atmospheres to ins. of mercury	29.92

Water

To convert	Multiply by	To convert	Multiply by
Cu. ft. to lbs.	62.42	Lbs. to cu. ft.	.01602
Gals. (U. S.) to lbs.	8.34	Lbs. to U. S. gals.	.12
Gals. (Imperial) to lbs.	10.0	Lbs. to gals. (Imp.)	.10
Lbs. to liters	.4536	Liters to lbs.	2.2046
Head (in ft.) to lbs. per sq. in.	.4330	Lbs. per sq. in. to head in ft.	2.3093
Head (in ft.) to tons per sq. ft.	.02784	Tons per sq. ft. to head in ft.	35.92
Head (in meters) to lbs. per sq. in.	1.4207	Lbs. per sq. in. to head in meters.	.7039
Cu. ft. per min. to gals. (U. S.) per hr.	448.92	Gals. (U. S.) per hr. to cu. ft. per min.	.002227

Equivalents—*Continued*

Speed

To convert	Multiply by	To convert	Multiply by
Ft. per min. to meters per sec.	.00508	Meters per sec. to ft. per min.	196.848
Ft. per sec. to meters per min.	18.288	Meters per min. to ft. per sec.	.05468
Ft. per min. to miles per hr.	.01136	Miles per hr. to ft. per min.	88.00
Meters per min. to miles per hr.	.03728	Miles per hr. to meters per min.	26.822
Miles per hr. to kilometers per hr.	1.6093	Kilometers per hr. to miles per hr.	.6214
Miles per hr. to knots per hr.	.8674	Knots per hr. to miles per hr.	1.153

Energy

To convert	Multiply by	To convert	Multiply by
Ft. lbs. to joules	1.356	Joules to ft. lbs.	.7375
Ft. lbs. to *B.t.u.*	.001285	*B.t.u.* to ft. lbs.	778.0
Ft. lbs. to kilogram meters	.1383	Kg. meters to ft. lbs.	7.233
Joules to *B.t.u.*	.000947	*B.t.u.* to joules	1,055.0
Joules to gram-calories	.2388	Gram-calories to joules	4.186
Joules to kilogram meters	.10198	Kg. meters to joules	9.8117
B.t.u. to watt hours	.293	Watt hours to *B.t.u.*	3.4126
Joules to ergs	$10.^7$		

Equivalents—*Continued*

Power

To convert	Multiply by	To convert	Multiply by
Horse power to watts	*746.0	Watts to horse power	.001341
Ft. lbs. per sec. to watts	1.356	Watts to ft. lbs. per sec.	.7375
Ft. lbs. per sec, to *h.p.*	.001818	*h.p.* to ft. lbs. per sec.	550.0
Ft. lbs. per min. to watts	.0226	Watts to ft. lbs. per min.	44.25
Ft. lbs. per min. to *h.p.*	.0000303	*h.p.* to ft. lbs. per min.	33,000.0
Kilogram-meter per sec. to watts	9.807	Watts to kg. meters per sec.	.1020

*This value depends on gravitational force at different latitudes and is
746 at latitude of London
736 at latitude of Berlin
745.7 for latitude 45°.

Miscellaneous Factors

To convert	Multiply by
Resistance at 20° C. to resistance at 60° F.	.9827
Resistance at 60° F. to resistance at 20° C.	1.0176
Ohms per kilometer to ohms per 1000 feet	.3048
Ohms per 1000 feet to ohms per kilometer	3.2808
Pounds per 1000 feet to kilograms per kilometer	1.488
Kilograms per kilometer to pounds per 1000 feet	.6719

TEST QUESTIONS

1. *Write down the various mathematical signs and explain their meaning.*
2. *What is a fraction?*
3. *Explain how to add, subtract, multiply and divide fractions.*
4. *What is a decimal fraction?*
5. *Explain fully how to figure with decimals.*
6. *How is a decimal converted into a common fraction?*
7. *What is the metric system?*
8. *Extract the square root of* 186,624.
9. *What is the square of* 23?
10. *Why is the decimal* .7854 *used to find the area of a circle?*
11. *What is the value of* $\frac{1}{4}\pi$?
12. *Give rules for finding the area of an ellipse and other figures.*
13. *What is the difference between a rectangle and a parallelogram?*
14. *Name the various quadrilaterals.*
15. *What is a parallelopipedon?*
16. *What is a trapezium?*
17. *What is the difference between a plane surface and a curved surface?*
18. *Give rule for finding the area of any irregular polygon.*
19. *What is the difference between a cylinder and a cone?*

20. *What kind of a surface has a sphere?*
21. *Give rule for finding volume of a sphere.*
22. *Define the natural trigonometrical functions.*
23. *Define the various electrical units.*
24. *What is the equation for reactance?*
25. *Give an expression for impedance.*
26. *Solve the Ohm's law formula for E, I and R.*
27. *Give the definitions of various mechanical units.*
28. *Give two ways of defining force units.*
29. *What is the difference between work and power?*
30. *Give the various mechanical units expressed in the metric system.*
31. *Give the simplest formula for horse power of a steam engine.*
32. *Define two units of boiler horse power.*
33. *What is understood by the expression "from and at 212° Fahr."?*
34. *Name the various thermometers.*
35. *Explain how to convert Fahr. degrees to Cent. degrees.*
36. *What is air?*
37. *What does a barometer measure and how?*
38. *Give the rule for converting barometer readings into lbs. per sq. in.*
39. *What is the standard atmosphere?*
40. *What is the most remarkable characteristic of water?*

41. *What are the three states of matter?*

42. *Describe an experiment illustrating the British thermal unit.*

CHAPTER 96

Distribution Systems

There are several methods of wiring for distribution which are commonly used with either direct current or alternating current. They may be classified as:

1. Series;
2. Parallel;
3. Series-parallel;
4. Parallel-series.

In the series systems the current is constant, but the voltage varies. In the parallel systems, the voltage is constant, but the current varies.

Series System.—A series system affords the simplest arrangement of lamps, motors, or other devices supplied with electric energy. The connections of such a system are shown in fig. 4,949.

Example:—Each open arc lamp requires about 50 volts. In the system shown in fig. 4,949, the pressure measured across the brushes of the dynamo is assumed to be 1,000 volts. As this current flows through the circuit 45 volts will be actually lost in each lamp, and as the drop on the line wire is usually about 10 per cent. of the total voltage, there will be a drop of 5 volts on the conductor between any two lamps. In the circuit shown, there are twenty lamps, therefore, the difference in pressure between either terminal of the dynamo and middle point A of the circuit will be 10 lamps×50 volts=500 volts. Likewise, the difference in pressure between any two points on the circuit will be equal to 50 volts multiplied by the number of lamps included between them.

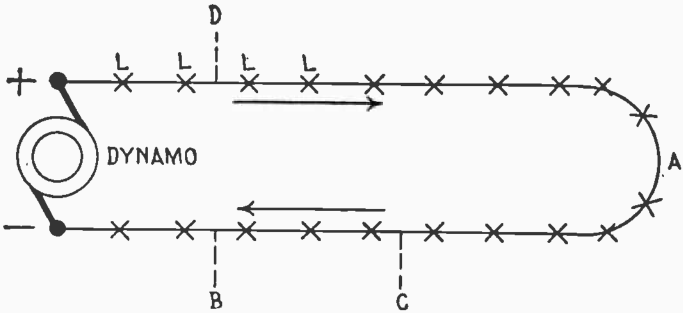


FIG. 4,949.—Series system of distribution. This is a constant current system, so called because the current remains practically constant. It is used chiefly for series lighting. The current from the terminal of the dynamo passes through the lamps, L, L, L, L, one after the other and finally returns to the terminal. The current in the circuit remains constant, but the voltage falls throughout the circuit in direct proportion to the resistance, and the difference in pressure between any two points in the circuit is equal to the current in amperes multiplied by the resistance in ohms included between them.

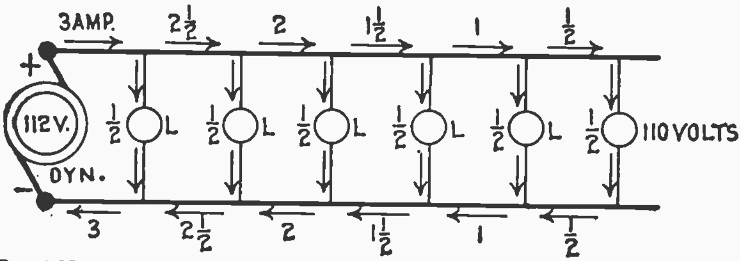


FIG. 4,950.—Parallel system of distribution. This is a constant voltage system and is used principally for incandescent lighting and electric motor circuits. The general principle of the parallel system is shown in the diagram. With six lamps on the circuit, each requiring one-half ampere of current, at 110 volts, the dynamo will have to supply a current of 3 amperes at a pressure of 112 volts, and this current will flow through the circuit and distribute itself as shown on account of the lesser resistance of the wire relatively to that of the lamps. At the first lamp, the 3 amperes will divide, ½ ampere flowing through the lamp and the remaining 2½ amperes passing on to the next lamp and so on through the entire circuit.

NOTE.—***Danger in Series Lighting.***—If in fig. 4,949, the line be grounded at B, owing to defective insulation, the pressure of the circuit at that point will be zero, and therefore, a man standing on the ground could touch that point without receiving a shock, but if he should touch the line at the point C, he will receive a slight shock of 150 volts, as there are three lamps between the point C, and the ground connection B. Therefore, the danger of touching the circuit increases directly with the resistance between the point touched and the ground connection, so that if a man touch the circuit at the point D, he will receive a dangerous shock of $16 \times 50 = 800$ volts.

Parallel System.—Parallel or multiple systems are usually more complicated than series systems, but since the voltage can be maintained nearly constant by various methods, practically all incandescent lamps, electric motors and other current consuming devices are supplied by parallel systems.

The general principle of the parallel system is shown in fig. 4,950. In the figure, the reduction of pressure from 112 volts across the brushes to 110 volts at the last lamp is due to the resistance of the conducting wires.

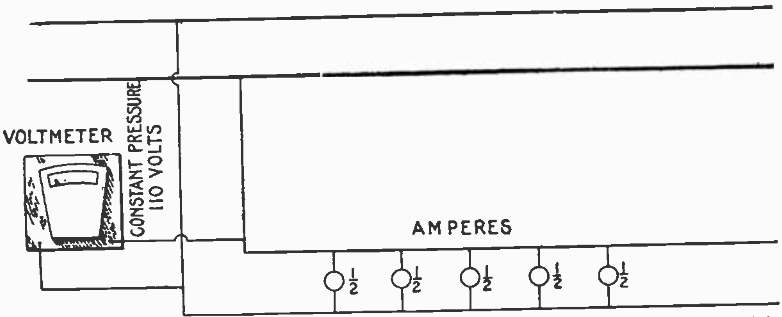


FIG. 4,951.—Diagram of ***parallel circuit***. *It is a constant pressure circuit* and is very widely used for lighting and power. If each lamp take say ½ ampere, the current flowing in the circuit will vary with the number of lamps in operation; in the above circuit with all lamps on, the current is ½ ×5 = 2½ amperes.

There are three effects due to the drop in pressure:

1. All the lamps or motors in the circuit receive a lower voltage than that at the dynamo.

2. Some lamps or motors may receive a lower voltage than the others.

3. The voltage at some lamps or motors may vary when the others are turned on or off.

The first is the least harmful and may be counteracted by running the dynamo at a little higher voltage; but the second and third are very objectionable and difficult to overcome. They are counteracted successfully in practice, however, by various methods of regulation, the use of *boosters*, and the operation of dynamos in parallel.

A disadvantage of the parallel system as compared with the series system is the greater cost of copper—larger wires must be used. The usual arrangement of a parallel lighting system consists of wires known as a *feeder*, run out from the station, and connected to these are other wire conductors known as a *main* to which in turn the lamps or other devices are connected as shown in fig. 4,952.

The feeders may be connected at the same end of the main,

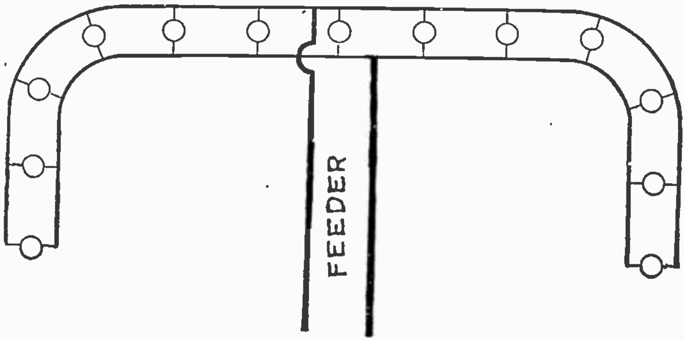


FIG. 4,952.—Arrangement of feeder and mains in parallel system. *By locating* the feeder at the electrical center, less copper is required for the mains. The cut does not show the fuses which in practice are placed at the junction of feeder and main.

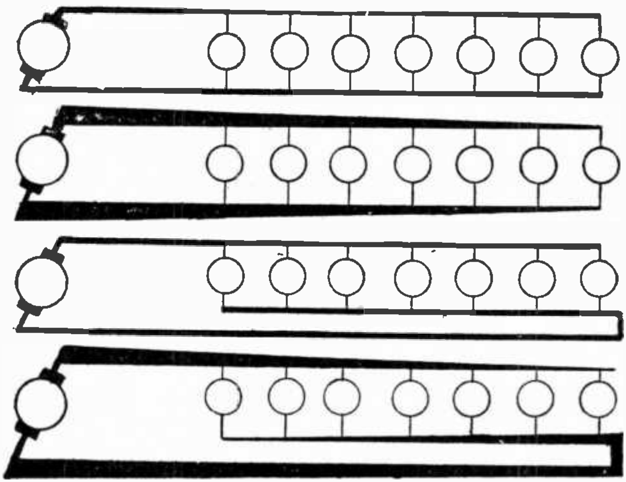
known as *parallel feeding*, or they may be connected at the opposite end of the main. called *anti-parallel feeding*.

The main may be of uniform cross section throughout, or it may change in size so as to keep the current density approximately constant. The above condition gives rise to four possible combinations:

1. Cylindrical conductors parallel feeding, fig. 4,953;
2. Tapering conductors, parallel feeding, fig. 4,954;
3. Cylindrical conductors, anti-parallel feeding, fig. 4,955;
4. Tapering conductors. anti-parallel feeding, fig. 4,956.

Series Parallel System.—This is *a combination of the series and parallel systems*, and is arranged as indicated in fig. 4,957. *Several lamps are arranged in parallel to form a group, and a number of such sets are connected in series*, as shown.

It is not necessary for the groups to be identical, provided they are all adapted to take the same current in amperes, which should be kept constant, and provided the lamps of each set agree in voltage.



FIGS. 4,953 to 4,956.—Various parallel systems. Fig. 4,953, cylindrical conductors parallel feeding; fig. 4,954, tapering conductors parallel feeding; fig. 4,955, cylindrical conductors anti-parallel feeding; fig. 4,956, tapering conductors anti-parallel feeding. In an anti-parallel system, the current is fed to the lamps from opposite ends of the system.

Example:—On the ordinary 10 ampere arc circuit, one group might consist of 5 lamps, each requiring 2 amperes at 50 volts; the next might be composed of 10 lamps, each taking 1 ampere at 100 volts, and so on.

Parallel-Series System.—In this method of connection, *one or more groups of lamps are connected in series and the groups in parallel as shown in fig*. 4,958.

A series-parallel system is used when it is desired to operate

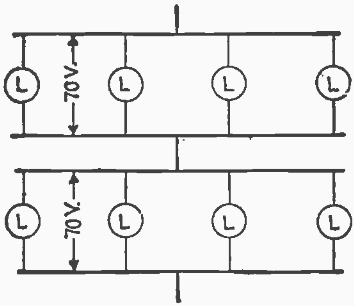


FIG. 4,957.—Series-parallel system of distribution. *It consists of* groups of parallel connected receptive devices, the groups being arranged in the circuit in series.

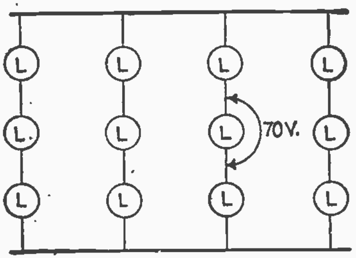


FIG. 4,958.—Parallel-series system of distributon. *It consists of* groups of series connected receptive devices, the groups being arranged in the circuit in parallel.

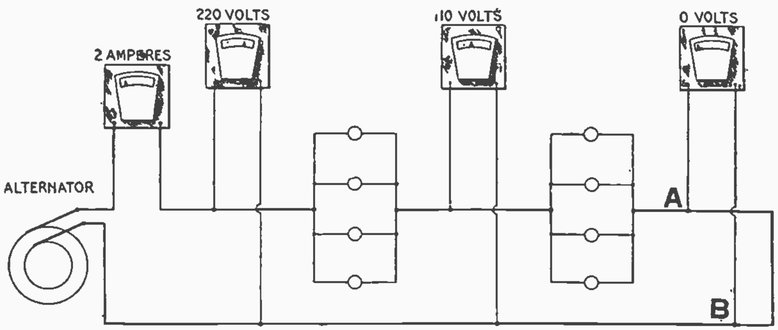
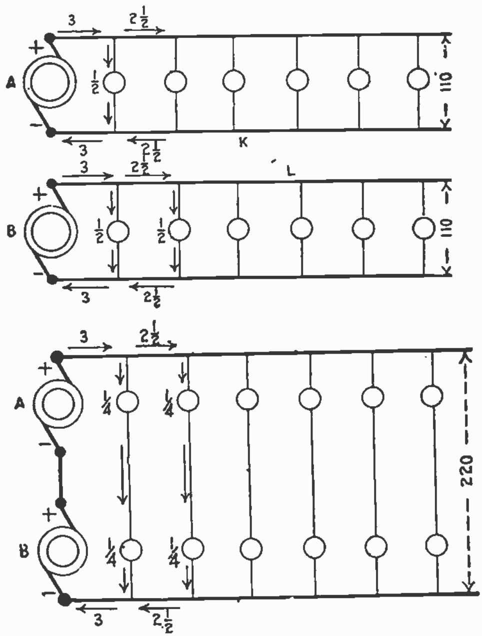


FIG. 4,959.—Diagram of *parallel series circuit, showing fall of pressure between units. This system is very rarely used;* it has the disadvantage that if a lamp filament break, the resistance of the circuit is altered and the strength of the current changed. The volt meter shows the fall of pressure along the line. *It should be noted* that, although the meter across AB, is shown as registering zero pressure, there is, strictly speaking, a slight pressure across AB, in amount, being that required to overcome the resistance of the conductor between A and B a number of lamps or motors on a line where voltage is several times that required to operate a single lamp or motor.

The parallel-series system is employed chiefly in the lighting circuit on electric traction lines; here, usually five 110 volt lamps are connected to the source of supply which has a pressure of 550 volts.

Edison Three Wire System.—The object of this system is to



FIGS. 4,960 to 4,962.—Evolution of the three wire system. In Figs. 4,960 and 4,961 two dynamos supply two independent circuits. These may be connected in series as in fig. 4,962, thus operating the two circuits as shown with two wires instead of four. To balance the system in case of unequal loading, a third or *neutral wire* is used as shown in fig. 4,962.

effect a saving in copper. In figs. 4,960, and 4,961, two dynamos A and B, supply two independent incandescent lighting circuits, each circuit receiving 3 amperes of current at a pressure of 110 volts. It is evident that the dynamos could be connected with each other in series, and the lamps connected in series with two each, as shown, thus making the two wires K and L, of the two independent circuits unnecessary, as the pressure will be increased to 220 volts while the current will remain at 3 amperes, and each lamp will require ¼ ampere.

The amount of copper saved will be 100 per cent., but this arrangement is open to the objection, that when one of the lamps is turned off, or burned out, its companion will also go out. This difficulty is avoided in the three

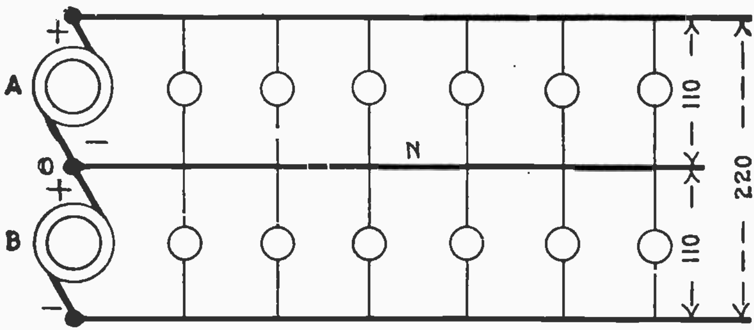


FIG. 4,963.—Balanced three wire system. The middle conductor, known as the *neutral wire*, keeps the system balanced in case of unequal loading, that is, a current will flow through it, to or from the dynamos, according to the preponderance of lamps on the one side or the other. These current conditions are shown in fig. 4,964.

wire system by running a third wire N, from the junction O, between the two dynamos, as shown in fig. 4,963, thus providing a supply or return conductor to any one of the lamps, and permitting any number of lamps to be disconnected without affecting those which remain.

If the system be exactly balanced, no current will flow through the wire N, because the pressure *toward* the − terminal of the dynamo A, will be equal to the pressure *from* the + terminal of dynamo B, thus neutralizing the pressure in the wire. For this reason the middle wire of a three wire system is called the *neutral wire*, and is usually indicated by the symbol O, or ± the latter meaning that it is positive to the first wire and negative to the second.

If the system be unbalanced, a current will flow through the neutral wire, to or from the dynamos, according to the preponderance of lamps in the upper or lower sets.

When the number in the lower set is the greater, the current in the neutral wire will flow *from* the dynamos as shown in fig. 4,964, and *toward* the dynamos under the reverse condition.

Modifications of the Three Wire System

Three Wire Storage Battery System, in which a storage battery is connected between the two outside wires, and the pressure of the neutral wire varied to balance the system by shifting the point at which it is connected to the battery.

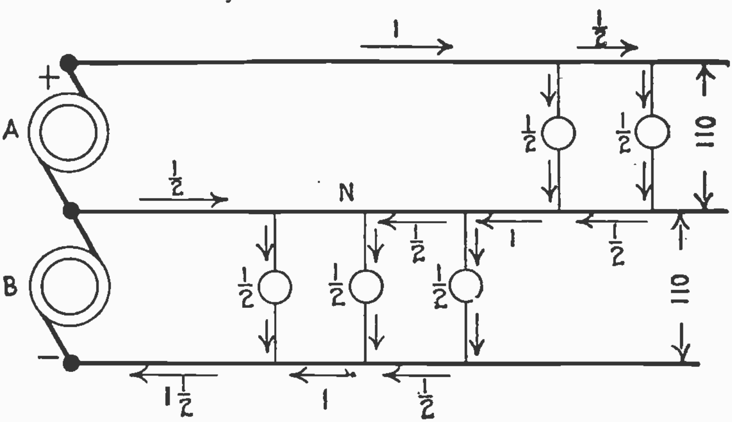


Fig. 4,964.—Three wire double dynamo system having two separate windings on the same core and separate commutators A and B as shown.

Three Wire Double Dynamo System, in which a double dynamo having two armature windings upon the same core, connected to two

NOTE.—*Copper Economy in Three Wire Systems.*—Theoretically, the size of the neutral wire has to be only sufficient to carry the largest current that will pass through it. A large margin of safety, however, is allowed in practice so that its cross section ranges from about one-third that of the outside line, in large central station systems, to the same as that of each outside line in small isolated systems. If the neutral wire be made one-half the size of the outside conductor, as is usually the case in feeders, the amount of copper required is $^{5}/_{16}$ of that necessary for the two wire system. For mains it is customary to make all three conductors the same size increasing the amount of copper to $3/8$ of that required for the two wire system.

separate commutators, is used in the same manner as two separate dynamos connected in series.

Three Wire Bridge System, in which a resistance is connected across the two outside wires, and the neutral wire is brought to a point on the resistance through a movable switch. The pressures on the two sides of

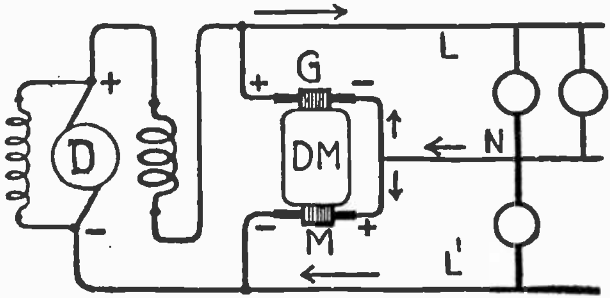


FIG. 4,965.—Diagram showing dynamotor connections when used as an equalizer in the three wire system. DM dynamotor; G, dynamo side; M, motor side. *In operation,* when both sides of the system are balanced, there will be no current in the neutral lead N, and a small current will pass through the two armature windings of the dynamotor in series, both armatures acting as motors. If the load on one side of the system become larger than the load on the other side, there will be a greater drop in the leads connected to the overloaded side and consequently a lower voltage will exist over the larger load than exists over the smaller load. The armature winding of the dynamotor connected to the higher voltage will act as a dynamo, whose pressure will tend to raise the voltage of the more heavily loaded side.

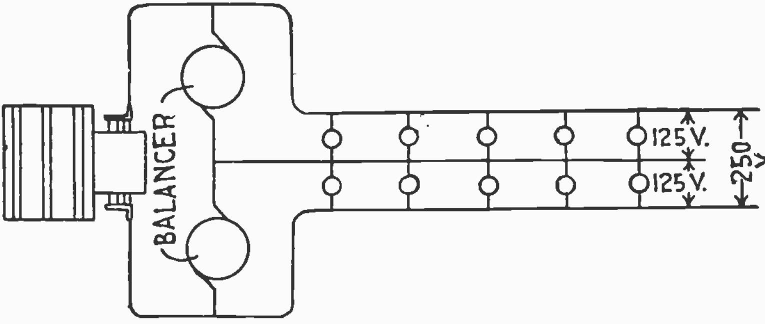


FIG. 4,966.—Diagram showing connections of balancing set in three wire one dynamo system. The set consists of a motor and dynamo connected, and its operation is practically the same as a dynamotor.

the circuit are equalized by adjusting the arm of the switch for any change of load.

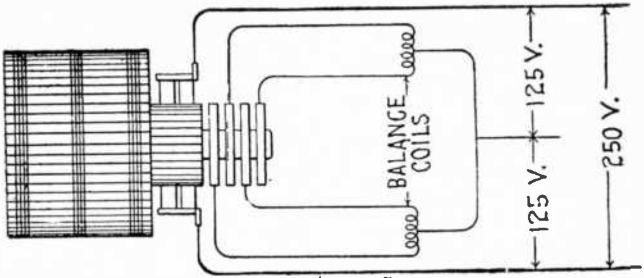


FIG. 4,967.—Diagram showing connections of balancing coil system. The dynamo used in this system is provided with both commutator and collector rings. *In operation,* on balanced load, the coils take a small alternating exciting current from the collector rings as any transformer does when connected to an alternating current line with its secondary open. When an unbalanced load comes on, the current in the neutral divides, half going to each coil. This enters the coil at the middle point and half flows each way through the coil and the slip rings into the armature winding. The unbalanced current is thus fed back directly into the dynamo armature continuously.

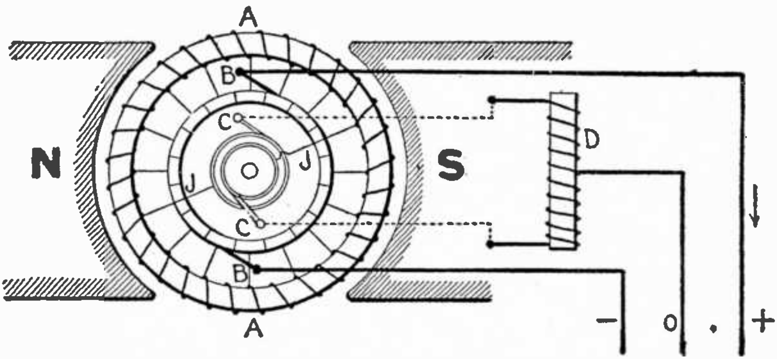


FIG. 4,968.—Dobrowolsky three wire system with self-induction coil. *In operation* when the two sides of the system are unbalanced in load, the difference in current carried in one direction or the other by the neutral wire passes freely through the coil D, since the current is steady, or varies slowly, and is therefore unimpeded by the self-induction. It is evident that the ohmic resistance of D, should be as low and its self-induction as high as possible, in order that the loss of energy and the difference in voltage on the two sides of the system shall be as small as possible under all conditions. *The parts are:* AA, armature winding; BB, commutator brushes; CC, slip ring brushes; JJ, connections of slip rings to winding; D, coil; O, neutral conductor.

Three Wire Three Brush Dynamo System, in which the neutral wire is connected to a third brush on the dynamo.

Dobrowolsky Three Wire System, in which a self-induction coil is connected to two diametrically opposite points of the armature of an ordinary dynamo. The principle of this system is illustrated in fig. 4,968.

Three Wire Auxiliary Dynamo System, in which the neutral wire is connected to an auxiliary dynamo which supplies a pressure one-half

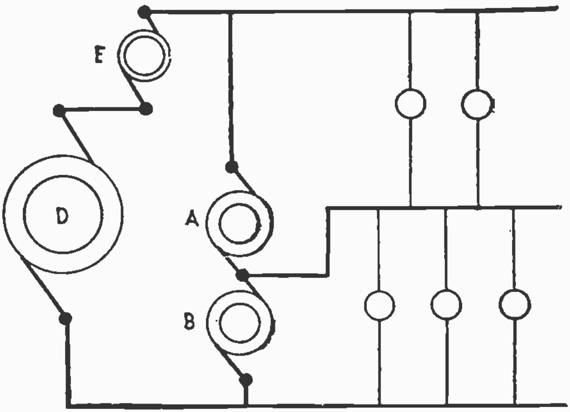


FIG. 4,969.—Three wire compensator system. A and B, are the compensators or equalizers. They consist of auxiliary dynamos coupled together and connected to the system as shown. D, is the main dynamo, and E, a booster. Each compensator generates one-half as much pressure as the main dynamo D, and serves to equalize the pressure and the load, the compensator on the lightly loaded side operating as a motor and driving the other as a dynamo. When the system is exactly balanced, both compensators run as motors under no load, therefore, consume very little energy

as great as that of the main dynamo. The auxiliary dynamo is usually belt driven by the main dynamo, and acts as a dynamo when the load is greater on the negative side of the circuit, and as a motor when the excess of load is on the positive side.

Three Wire Compensator System, in which two auxiliary dynamos A and B called *compensators* or *equalizers*, are coupled together and connected to the system as shown in fig. 4,969.

Booster System.—When a number of feeders run out from a station, the longest and those carrying the heaviest loads will have so much drop on the line that the pressure at distant points is too low. It is therefore necessary to raise the pressure to compensate for the drop and this is done by inserting a booster in the circuit.

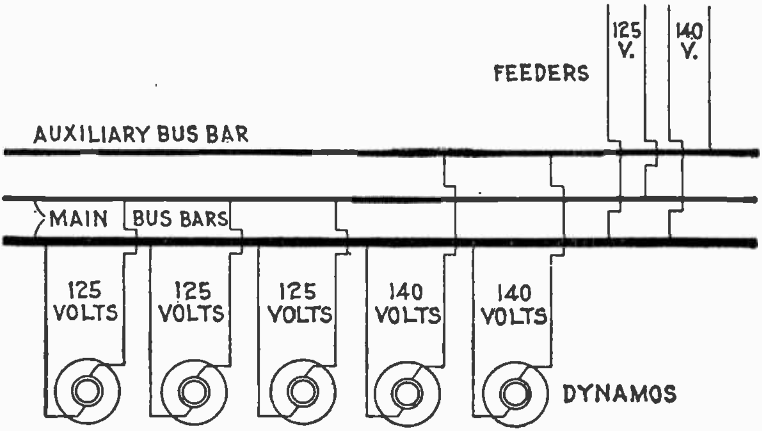


FIG. 4,970.—Diagram showing use of auxiliary bus bar. In order to avoid the necessity for boosters, some stations have an extra bus bar, which is kept at a higher pressure than the main bus, and to this are connected the feeders that have an extra large drop.

NOTE.—*Extension of the Three Wire Principle.*—In order to attain still greater economy in copper, the principles of the three wire system may be extended to include four, five, six, and seven wire systems. The comparative weights of copper required by such systems are as follows:

Two	wire system		1.000
Three	" "	all wires of equal size	.370
Three	" "	neutral wire one-half size	.313
Four	" "	all wires of equal size	.222
Five	" "	" " " " "	.156
Seven	" "	" " " " "	.096

*NOTE.—*A booster* may be defined as, *a dynamo inserted in a circuit at a point where it is necessary to change the voltage.* A booster is generally driven by a motor, the two armatures being directly coupled, although boosters are sometimes driven from the engine or line shaft.

It would not be economical to raise the voltage on all the lines by supplying current from the main dynamo at higher pressure, hence the voltage is raised only on the lines which need it by means of the booster working in series with the main dynamo.

Auxiliary Bus Bar System.—In this arrangement *an extra bus bar which is kept at higher pressure than the main bar is used in place of a booster* as shown in fig. 4,970.

One or more dynamos maintain the pressure between the auxiliary bar and the common negative bar. The feeders which need boosting are connected to the common negative bar and the auxiliary bar as shown.

TEST QUESTIONS

1. *Name four general systems of distribution.*
2. *What is the principal use for the series system?*
3. *Draw diagrams illustrating series and parallel systems.*
4. *What is the danger incurred in series lighting?*
5. *What are the names given to the parallel system?*
6. *Name three effects due to the drop in voltage.*
7. *Name a disadvantage of the parallel system as compared with the series system.*
8. *Draw a diagram showing one arrangement of feeder and mains in the parallel system.*
9. *What is the difference between parallel feeding and anti-parallel feeding?*
10. *What is understood by tapering conductors?*
11. *Define the series parallel system.*
12. *Draw diagrams of various parallel systems.*
13. *What is the difference between a series parallel system and a parallel series system?*
14. *Draw a diagram of series parallel system and parallel series system.*
15. *What is the principal use of the series parallel system?*
16. *Describe the Edison three wire system and draw diagram showing evolution of this system.*
17. *How much copper is saved with the three wire system?*
18. *Name an objection to the three wire system, especially on auto lighting systems.*
19. *Name some modifications of the three wire system.*

20. *Draw diagrams illustrating the modification of the three wire system.*
21. *What is a booster system?*
22. *How is the three wire system extended to give greater economy?*
23. *Describe the auxiliary bus bar system.*

CHAPTER 97

Effects of the Alternating Current

In the case of alternating current, because of its peculiar behavior, there are several effects which must be considered in making wiring calculations, which do not enter into the problem with direct current.

*Accordingly, in determining the size of wires, allowance must be made for

1. Self-induction;
2. Mutual-induction;
3. Power factor;
4. Skin effect;
5. Corona effect;
6. Foucault or eddy currents;
7. Frequency;
8. Resistance;
9. Dielectric hysteresis.

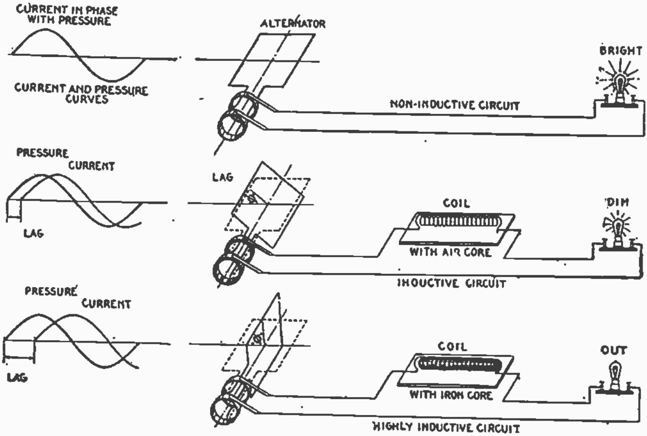
Induction.—The effect of induction, whether self-induction or mutual induction, is to set up a back pressure or *spurious*

*NOTE.—Most of these items have already been explained at such length, that only a brief summary of facts need be added, to point out their connection and importance in alternating current wiring.

resistance, which must be considered, as it sometimes materially affects the calculation of circuits even in interior wiring.

Self-induction is the effect produced by the action of the electric current upon itself during variations in strength.

Besides variations in current strength, other conditions govern the amount of self-induction in a circuit, such as the shape of the circuit, and the character of the surrounding medium.



FIGS. 4,971 to 4,976.—The effect of self-induction. In a non-inductive circuit, as in fig. 4,972, the whole of the virtual pressure is available to cause current to flow through the lamp filament, hence it will glow with maximum brilliancy. If an inductive coil be inserted in the circuit as in fig. 4,974, the reverse pressure due to self-induction will oppose the virtual pressure, hence the effective pressure (which is the difference between the virtual and reverse pressures), will be reduced and the current flow through the lamp diminished, thus reducing the brilliancy of the illumination. The effect may be intensified to such a degree by interposing an iron core in the coil as in fig. 4,976, as to extinguish the lamp.

If the circuit be straight, there will be little self-induction, but if coiled, the effect will become pronounced. If the surrounding medium be air, the self-induction is small, but if it be iron, the self-induction is considerable.

In wiring, when iron conduits are used, *the wires of each circuit should not be installed in separate conduits*, because such an arrangement would cause excessive self-induction.

The importance of this may be seen from the experience of one contractor, who installed feeders and mains in separate iron pipes. When the current was turned on, it was found that the self-induction was so great as to reduce the pressure to such an extent that the lamps, instead of giving full candle power, were barely red. This necessitated the removal of the feeders and mains and re-installing them, so that those of the same circuit were in the same pipe.

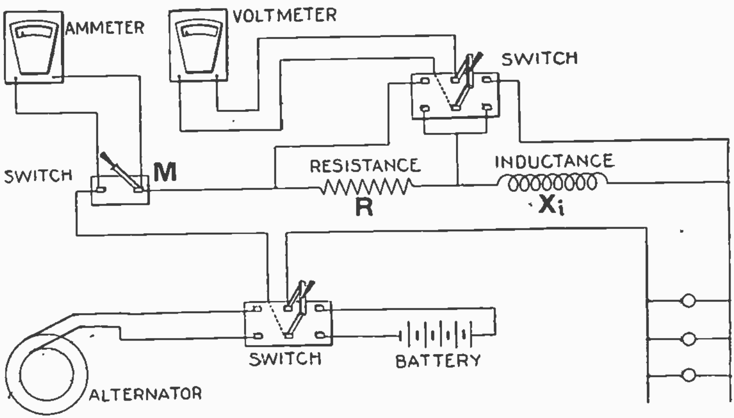


FIG. 4,977.—Measurement of self-induction when the frequency is known. The apparatus required consists of a high resistance or electrostatic *a.c.* volt meter, *d.c.* ammeter, and a non-inductive resistance. Connect the inductive resistance to be measured as shown, and close switch M, short circuiting the ammeter. Connect alternator in circuit and measure drop across R, and across X_i. Disconnect alternator and connect battery in circuit, then open switch M, and vary the continuous current until the drop across R, is the same as with the alternating current, both measurements being made with the same volt meter, read ammeter, and measure drop across X_i. Call the drop across X_i, with alternating current E, and with direct current E_i, and the reading of the ammeter J. Then $L = \sqrt{E^2 + E_i^2} \div 2\pi f I$. If the resistance X_i be known, and the ammeter be suitable for use with alternating current, the switch and R, may be dispensed with. Then $L = \sqrt{E^2 - X_i^2 I_i^2} \div 2\pi f I$, where I is the value of the alternating current. The resistance of the volt meter should be high enough to render its current negligible as compared with that through X_i.

Mutual Induction is the effect of one alternating current circuit upon another. It is due to the magnetic field surrounding a conductor cutting adjacent conductors and inducing back pressures therein.

This effect as a rule in ordinary installations is negligible.

Transpositions.—The effect of mutual induction between two circuits is proportional to the inter-linkage of the magnetic fluxes of the two lines. This in turn depends upon the proximity of the lines and upon the general relative arrangement of the conductors.

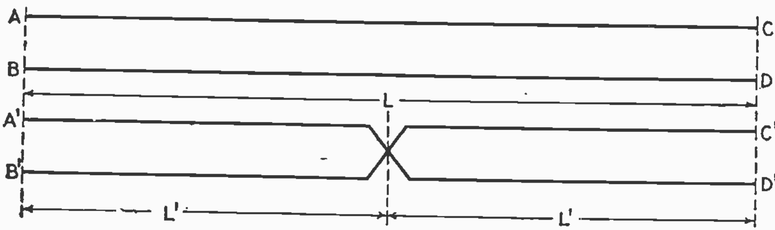


FIG. 4,978.—Transposition diagram for two parallel lines consisting of two wires each.

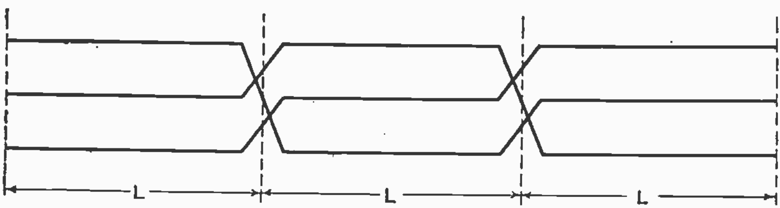


FIG. 4,979.—Transposition diagram for three phase, three wire line, transposing at the vertices of an equilateral triangle. The line is originally balanced and becomes unbalanced in transposing, a procedure which should be resorted to only to prevent *mutual induction*.

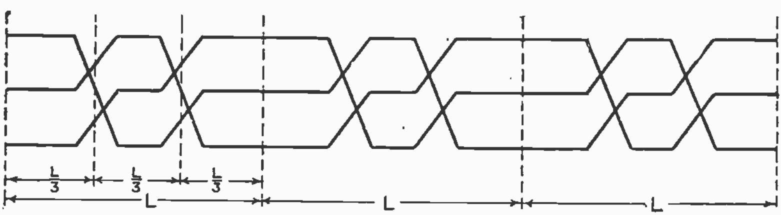


FIG. 4,980.—Transposition diagram of three phase, three wire line, with center arranged in a straight line.

The inductive effect of one line upon another is equal to the algebraic sum of the fluxes due to the different conductors of the first line, considered separately, which link the secondary line.

INDUCTANCE PER MILE OF THREE PHASE CIRCUIT

Size B. & S.	Diam. in inch.	Distance *d* in inches.	Self inductance L henrys.	Size B. & S.	Diam. in inch.	Distance *d* in inches.	Self inductance L henrys.
0000	.46	12	.00234	4	.204	12	.00280
		18	.00256			18	.00300
		24	.00270			24	.00315
		48	.00312			48	.00358
000	.41	12	.00241	5	.182	12	.00286
		18	.00262			18	.00307
		24	.00277			24	.00323
		48	.00318			48	.00356
00	.365	12	.00248	6	.162	12	.00291
		18	.00269			18	.00313
		24	.00285			24	.00329
		48	.00330			48	.00369
0	.325	12	.00254	7	.144	12	.00298
		18	.00276			18	.00310
		24	.00293			24	.00336
		48	.00331			48	.00377
1	.289	12	.00260	8	.128	12	.00303
		18	.00281			18	.00325
		24	.00308			24	.00341
		48	.00338			48	.00384
2	.258	12	.00267	9	.114	12	.00310
		18	.00288			18	.00332
		24	.00304			24	.00348
		48	.00314			48	.00389
3	.229	12	.00274	10	.102	12	.00318
		18	.00294			18	.00340
		24	.00310			24	.00355
		48	.00351			48	.00396

INDUCTANCE IN MILLIHENRIES

PER 1000 FEET OF CONDUCTOR

SOLID CONDUCTORS

Size B. & S. Gauge	Resistance at 20°C. Ohms per 1000 ft.	Distance between centres (inches)									
		6	9	12	18	24	30	36	42	60	72
10	1.0259	.3052	.3299	.3473	.3720	.3895	.4031	.4141	.4236	.4452	.4563
8	.6452	.2911	.3158	.3332	.3579	.3754	.3890	.4000	.4095	.4311	.4422
6	.4058	.2770	.3017	.3191	.3438	.3613	.3749	.3859	.3954	.4170	.4281
4	.2552	.2629	.2876	.3050	.3297	.3472	.3608	.3718	.3813	.4029	.4140
2	.1605	.2488	.2735	.2909	.3156	.3331	.3467	.3577	.3672	.3888	.3999
1	.1272	.2418	.2665	.2839	.3086	.3261	.3397	.3507	.3602	.3818	.3929
1/0	.1009	.2347	.2594	.2768	.3015	.3190	.3326	.3436	.3531	.3747	.3858
2/0	.08003	.2276	.2523	.2697	.2944	.3119	.3255	.3365	.3460	.3676	.3787
3/0	.06347	.2206	.2453	.2627	.2874	.2949	.3185	.3295	.3390	.3606	.3717
4/0	.05033	.2135	.2382	.2556	.2803	.2978	.3114	.3224	.3319	.3535	.3646

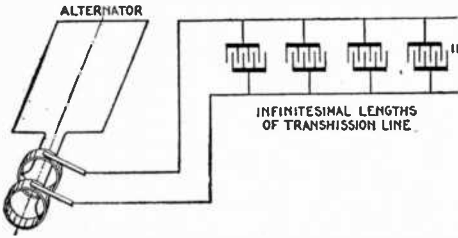
STRANDED CONDUCTORS

Size Circular Mils	Resistance at 20°C. Ohms per 1000 ft.	Distance between centres (inches)									
		6	9	12	18	24	30	36	42	60	72
4 B.&S.	.2598	.2604	.2851	.3025	.3272	.3447	.3583	.3693	.3788	.4004	.4115
2 "	.1633	.2464	.2711	.2885	.3132	.3307	.3443	.3553	.3648	.3864	.3975
1 "	.1294	.2381	2688	.2812	.3059	.3234	.3370	.3480	.3575	.3791	.3902
1/0 "	.1027	.2318	.2565	.2739	.2986	.3161	.3297	.3407	.3502	.3718	.3829
2/0 "	.08164	.2248	.2495	.2669	.2916	.3091	.3227	.3337	.3432	.3648	.3759
3/0 "	.06470	.2178	.2425	.2599	.2846	.3021	.3157	.3267	.3362	.3578	.3689
4/0 "	.05125	.2106	.2353	.2527	.2774	.2949	.3085	.3195	.3290	.3506	.3617
250,000	.04344	.2057	.2304	.2478	.2725	.2900	.2036	.3146	.3241	.3457	.3568
300,000	.03625	.2001	.2248	.2422	.2669	.2844	.2980	.3090	.3185	.3401	.3512
350,000	.03102	.1954	.2201	.2375	.2622	.2797	.2933	.3043	.3138	.3354	.3465
400,000	.02722	.1914	.2161	.2335	.2582	.2757	.2893	.3003	.3098	.3314	.3425
450,000	.02413	.1877	.2124	.2298	.2545	.2720	.2856	.2966	.3061	.3277	.3388
500,000	.02177	.1847	.2094	.2268	.2515	.2690	.2826	.2936	.3031	.3247	.3358

Resistances above are for Hard-drawn Copper having a conductivity of 97.3 per cent. of the International Annealed Copper Standard. These resistances do not allow for Skin Effect.

The effect of mutual induction is to induce surges in the line where a difference of frequency exists between the two currents, and to induce high electrostatic charges in lines carrying little or no current, such as telephone lines.

This effect may be nullified by separating the lines and by transposing the wires of one of the lines so that the effect produced in one section is opposed by that in another. Of two



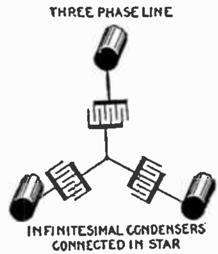


Fig. 4,981.—Capacity effect in single phase transmission line. The effect is the same as would be produced by shunting across the line at each point an infinitesimal condenser having a capacity equal to that of an infinitesimal length of circuit. For the purpose of calculating the charging current, a very simple and sufficiently accurate method is to determine the current taken by a condenser having a capacity equal to that of the entire line when charged to the pressure on the line at the generating end.

Fig. 4,982.—Capacity effect in a three phase transmission line. It is the same as would be produced by shunting the line at each point by three infinitesimal condensers connected in star with the neutral point grounded, the capacity of each condenser being twice that of a condenser of infinitesimal length formed by any two of the wires. The effect of capacity on the regulation and efficiency of the line can be determined with sufficient accuracy in most cases by considering the line shunted at each end by three condensers connected in star, the capacity of each condenser being equal to that formed by any two wires of the line. An approximate value for the charging current per wire is the current required to charge a condenser, equal in capacity to that of any two of the wires, to the pressure at the generating end of the line between any one wire and the neutral point.

parallel lines consisting of two wires each, one may be transposed to neutralize the mutual inductance.

Fig. 4,978 shows this method. The length L′, should be an even factor of L, so that to every section of the line transposed there corresponds an opposing section.

The self-inductance of lines is readily calculated from the following formula:

$L = .000558 \left\{2.303 \log (2\ A \div d) + .25\right\}$ per mile of circuit where

L = inductance of a loop of a three phase circuit in henrys.

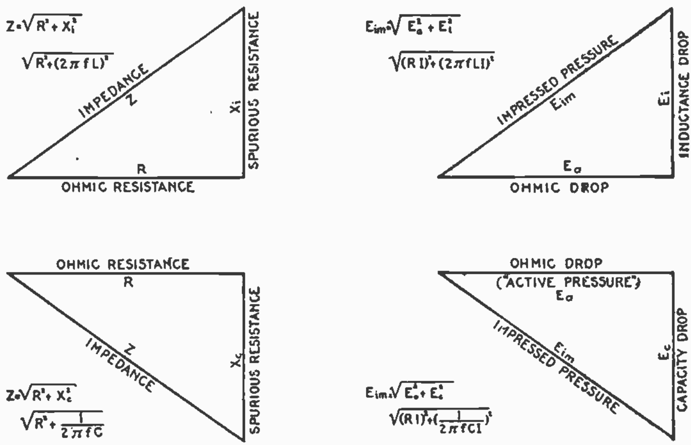
NOTE.—The inductance of a complete single phase circuit $= L \times 2 \div \sqrt{3}$.

CAPACITY IN MICRO-FARADS PER MILE OF CIRCUIT FOR THREE PHASE SYSTEM

Size B. & S.	Diam. in inch.	Distance A in inches.	Capacity C in micro-farads	Size B. & S.	Diam. in inch.	Distance A in inches.	Capacity C in micro-farads
0000	.46	12	.0226	4	.204	12	.01874
		18	.0204			18	.01726
		24	.01922			24	.01636
		48	.01474			48	.01452
000	.41	12	.0218	5	.182	12	.01830
		18	.01992			18	.01690
		24	.01876			24	.01602
		48	.01638			48	.01426
00	.365	12	.0124	6	.162	12	.01788
		18	.01946			18	.01654
		24	.01832			24	.01560
		48	.01604			48	.0140
0	.325	12	.02078	7	.144	12	.01746
		18	.01898			18	.01618
		24	.01642			24	.01538
		48	.01570			48	.01374
1	289	12	.02022	8	.128	12	.01708
		18	.01952			18	.01586
		24	.01748			24	.01508
		48	.0154			48	.01350
2	.258	12	.01972	9	.114	12	.01660
		18	.01818			18	.01552
		24	.01710			24	.01478
		48	.01510			48	.01326
3	.229	12	.01938	10	.102	12	.01636
		18	.01766			18	.01522
		24	.01672			24	.01452
		48	.01480			48	.01304

A = distance between wires;
d = diameter of wire.

Capacity.—In any given system of electrical conductors, a pressure difference between two of them corresponds to the presence of a quantity of electricity in each. With the same



FIGS. 4,983 to 4,986.—Triangles for obtaining graphically, impedance, impressed pressure, etc., in alternating current circuits. For a full explanation of this method the reader is referred to Vol. 4, Chapter 48, on Alternating Current Diagrams. A thorough study of this chapter is recommended.

charges, the difference of pressure may be varied by varying the geometrical arrangement and magnitudes and also by introducing various dielectrics. The constant connecting the charge and the resulting pressure is called the capacity of the system.

All circuits have a certain capacity because each conductor acts like the plate of a condenser, and the insulating medium acts as the dielectric. The capacity depends upon the insulation.

For a given grade of insulation, the capacity is proportional to the surface of the conductors, and inversely to the distance between them.

INDUCTIVE REACTANCE IN OHMS

PER 1000 FEET OF CONDUCTOR

SOLID CONDUCTORS **FREQUENCY 60 CYCLES PER SECOND**

Size B.&S. Gauge	Distance between centres (inches)									
	6	9	12	18	24	30	36	42	60	72
10	.11505	.12438	.13093	.14025	.14685	.15198	.15612	.15970	.16785	.17203
8	.10973	.11906	.12561	.13493	.14153	.14666	.15080	.15438	.16253	.16671
6	.10441	.11374	.12029	.12961	.13621	.14134	.14548	.14906	.15721	.16139
4	.09909	.10842	.11497	.12429	.13089	.13602	.14016	.14374	.15189	.15607
2	.09377	.10310	.10965	.11897	.12557	13070	.13484	.13842	.14657	.15075
1	.09111	.10044	.10699	.11631	.12291	.12804	.13218	.13576	.14391	.14809
1/0	.08845	.09778	.10433	.11365	.12025	.12538	.12952	.13310	.14125	.14543
2/0	.08579	.09512	.10167	.11099	.11759	.12272	.12686	.13044	.13859	.14277
3/0	.08313	.09246	.09901	.10833	.11493	.12006	.12420	.12778	.13593	.14011
4/0	.08047	.08980	.09635	.10571	.11227	.11740	.12154	.12512	.13327	.13745

STRANDED CONDUCTORS **FREQUENCY 60 CYCLES PER SECOND**

Size Circular Mils	Distance between centres (inches)									
	6	9	12	18	24	30	36	42	60	72
4 B.&S.	.0982	.1076	.1141	.1234	.1300	.1351	.1393	.1429	.1511	.1553
2 "	.0929	.1023	.1088	.1181	.1247	.1298	.1340	.1376	.1458	.1500
1 "	.0901	.0995	.1060	.1153	.1219	.1270	.1312	.1348	.1430	.1472
1/0 "	.0874	.0968	.1033	.1126	.1192	.1243	.1285	.1321	.1403	.1445
2/0 "	.0847	.0941	.1006	.1099	.1165	.1216	.1258	.1294	.1376	.1418
3/0 "	.0821	.0915	.0980	.1073	.1139	.1190	.1232	.1268	.1350	.1392
4/0 "	.0794	.0888	.0953	.1046	.1112	.1163	.1205	.1241	.1323	.1365
250,000	.0775	.0869	.0934	.1027	.1093	.1144	.1186	.1222	.1304	.1346
300,000	.0754	.0848	.0913	.1006	.1072	.1123	.1165	.1201	.1283	.1325
350,000	.0736	.0830	.0895	.0988	.1054	.1105	.1147	.1183	.1265	.1307
400,000	.0721	.0815	.0880	.0973	.1039	.1090	.1132	.1168	.1250	.1292
450,000	.0707	.0801	.0866	.0959	.1025	.1076	.1118	.1154	.1236	.1278
500,000	.0696	.0790	.0855	.0948	.1014	.1065	.1107	.1143	.1225	.1267

INDUCTIVE REACTANCE IN OHMS

PER 1000 FEET OF CONDUCTOR

SOLID CONDUCTORS **FREQUENCY 25 CYCLES PER SECOND**

Size B.&S. Gauge	Distance between centres (inches)									
	6	9	12	18	24	30	36	42	60	72
10	.04796	.05185	.05458	.05846	.06121	.06335	.06507	.06657	.06996	.07170
8	.04574	.04963	.05236	.05624	.05899	.06113	.06285	.06435	.06774	.06948
6	.04352	.04741	.05014	.05402	.05677	.05891	.06063	.06213	.06552	.06726
4	.04130	.04519	.04792	.05180	.05455	.05669	.05841	.05991	.06330	.06504
2	.03908	.04297	.04570	.04958	.05233	.05447	.05619	.05769	.06108	.06282
1	.03797	.04186	.04459	.04847	.05122	.05336	.05508	.05658	.05997	.06171
1/0	.03686	.04075	.04348	.04736	.05011	.05225	.05397	.05547	.05886	.06060
2/0	.03575	.03964	.04237	.04625	.04900	.05114	.05286	.05436	.05775	.05949
3/0	.03464	.03853	.04126	.04514	.04789	.05003	.05175	.05325	.05664	.05837
4/0	.03353	.03742	.04015	.04403	.04678	.04892	.05064	.05214	.05553	.05728

STRANDED CONDUCTORS **FREQUENCY 25 CYCLES PER SECOND**

Size Circular Mils	Distance between centres (inches)									
	6	9	12	18	24	30	36	42	60	72
4 B.&S.	.0409	.0448	.0476	.0514	.0542	.0563	.0580	.0595	.0629	.0647
2 "	.0387	.0426	.0454	.0492	.0520	.0541	.0558	.0573	.0607	.0625
1 "	.0375	.0414	.0442	.0480	.0508	.0529	.0546	.0561	.0595	.0613
1/0 "	.0364	.0403	.0431	.0469	.0497	.0518	.0535	.0550	.0584	.0602
2/0 "	.0353	.0392	.0420	.0458	.0486	.0507	.0524	.0539	.0573	.0591
3/0 "	.0342	.0381	.0409	.0447	.0475	.0496	.0513	.0528	.0562	.0580
4/0 "	.0331	.0370	.0398	.0436	.0464	.0485	.0502	.0517	.0551	.0569
250,000	.0323	.0362	.0390	.0428	.0456	.0477	.0494	.0509	.0543	.0561
300,000	.0314	.0353	.0381	.0419	.0447	.0468	.0485	.0500	.0534	.0552
350,000	.0307	.0346	.0374	.0412	.0440	.0461	.0478	.0493	.0527	.0545
400,000	.0301	.0340	.0368	.0406	.0434	.0455	.0472	.0487	.0521	.0539
450,000	.0295	.0334	.0362	.0400	.0428	.0449	.0466	.0481	.0515	.0533
500,000	.0290	.0329	.0357	.0395	.0423	.0444	.0461	.0476	.0510	.0528

A three phase three wire transmission line spaced at the corners of an equilateral triangle as regards capacity acts precisely as though the neutral line were situated at the center of the triangle.

The capacity of circuits is readily calculated by applying the following formulæ:

$$C = \frac{38.83\ sc\ 10^{-8}}{\log (D \div d)}$$ per mile, insulated cable with lead sheath;

$$C = \frac{38.83 \times 10^{-8}}{\log (4h \div d)}$$ per mile, single conductor with earth return;

$$C = \frac{19.42 \times 10^{-8}}{\log (2A \div d)}$$ per mile of parallel conductors forming metallic circuit;

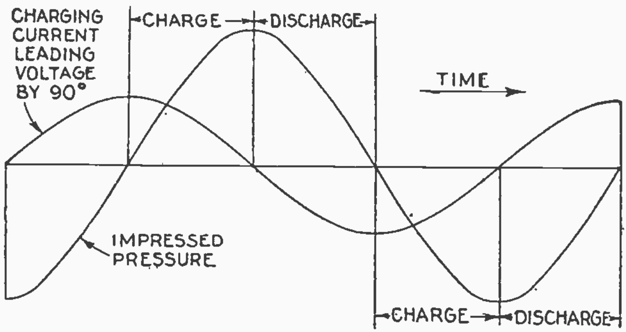


FIG. 4,987.—Curves showing charging current in line containing capacity. If an alternating voltage be impressed upon the terminals of a circuit containing capacitance, the charging current will vary directly with the impressed voltage. There is current to the condenser during rising and from the condenser during decreasing voltage. Thus the condenser is charged and then discharged in the opposite direction during the next alternation, making two complete charges and discharges for each cycle of impressed voltage. As long as the voltage at the terminals is changing, the condenser will continue to receive or give out current.

in which

C = Capacity in micro-farads; for a metallic circuit, C = capacity between wires
sc = Specific inductive capacity of insulating naterial; = 1 for arc, and 2.25 to 3.7 for rubber;
D = Inside diameter of lead sheath;
d = Diameter of conductor;
h = Distance of conductors above ground;
A = Distance between wires.

Frequency.—The number of cycles per second, or the frequency, has a direct effect upon the inductance reactance in an alternating current circuit, as is plainly seen from the formula

$$X_i = 2\pi f L$$

In the case of a transmission line alone; the lower frequencies are the more desirable, in that they tend to reduce the inductance drop and charging current.

The inductance drop is proportional to the frequency.

The natural period of a line, with distributed inductance and capacity, is approximately given by

$$P = \frac{7{,}900}{\sqrt{LC}}$$

where L, is the total inductance in milli-henrys, and C, the total capacity in micro-farads. Accordingly some lower odd harmonic of the impressed frequency may be present which corresponds with the natural period of the line. When this obtains, oscillations of dangerous magnitude may occur. Such coincidences are less likely with the lower harmonics than with the higher.

This is due to the fact that the inductance of the center strands is greater than that of the outer strands. In consequence of this effect the resistance of the conductor to an alternating current is greater than its resistance to a continuous current. This increase in resistance is nearly proportional to the area of conductor and the frequency.

To reduce the skin effect, large cables are often constructed with a core of hemp or other insulating material.

Skin Effect.—In a conductor carrying alternating current, *the current tends to flow near the circumference rather than through the center of the conductor. This is called skin effect.*

The following table shows the diameters of hemp cores used to reduce the skin effect on large stranded conductors for a frequency of 60 cycles per second.

Hemp Core Table

(According to American Electrical Works)

Size of Conductor Circular Mils	Diam. of Hemp Core (ins.)	Number of Wires in strand	Diameter of each wire (ins.)	Diameter of strand (ins.)
500,000	.20	45	.1055	.833
600,000	.25	45	.116	.946
700,000	.30	51	.117	1.002
750,000	.32	51	.1212	1.047
800,000	.35	54	.1216	1.080
900,000	.40	100	.0948	1.158
1,000,000	.43	104	.098	1.214
1,250,000	.55	116	.103	1.478
1,500,000	.66	124	.109	1.532
1,750,000	.80	136	.113	1.704
2,000,000	.90	144	.117	1.836

The current carrying capacity of these cables is rather greater than that of ordinary stranded cables due to the increased radiating surface.

Skin effect may be neglected at frequencies of 60 or less with conductors having a diameter not greater than 0000 B. & S. gauge.

It becomes more pronounced at higher frequencies, because the *self-induced voltage is proportional to the frequency as well as to the total flux linked.*

NOTE.—*A current* induced in a conductor builds up from the surface, and an appreciable period of time is required for the current to penetrate to the interior portions of the conductor. If the frequency be high, the central portion of large conductors may contribute nothing to the conducting powers of the conductor. This is equivalent to increasing the resistance of the conductor, or in effect the conductor will have a spurious resistance which will be greater than its real resistance. The effect is much greater in iron than in copper, owing to the high magnetic permeability of iron. It also increases directly with the frequency of alternations. With the two standard frequencies now being used, 25 and 60, the skin effect in copper does not become appreciable until a diameter of conductor of about three quarters of an inch has been reached. In distribution systems which conduct heavy currents of high frequency, the conductor wires may be built up into cables about a hemp core, thus offering a greater amount of surface by placing the copper where it will do the greatest service without increasing its weight.

Approximate values of the effective resistance of straight copper conductors at 68° F. can be obtained by multiplying the actual ohmic resistance by factors given in the following table.

Factors to Obtain Effective Resistance from Ohmic Resistance

Diameter Bare Copper Conductor Inches	Approximate Area in Circular Mils	Frequency 25	Frequency 60	Frequency 130	Diameter Bare Copper Conductor Inches	Approximate Area in Circular Mils	Frequency 25	Frequency 60	Frequency 130
2.00	4,000,000	1.265	1.826	2.560	1.000	1,000,000	1.020	1.111	1.397
1.75	3,062,500	1.170	1.622	2.272	.75	563,500	1.007	1.040	1.156
1.50	2,500,000	1.098	1.420	1.983	.50	250,000	1.002	1.008	1.039
1.25	1,562,500	1.053	1.239	1.694	46	211,600	1.001	1.006	1.027
1.125	1,265,625	1.035	1.168	1.545					

To calculate skin effect, *its area in circular mils multiplied by the frequency gives the ratio of the wire's ohmic resistance to its combined resistance.*

That is to say, the factor thus obtained multiplied by the resistance of the wire to direct current, will give its combined resistance or resistance to alternating current.

The following table gives these ratio factors for large conductors.

RATIO FACTOR FOR COMBINED RESISTANCE

Circular mils × frequency	Factor	Circular mils × frequency	Factor
10,000,000	1.000	80,000,000	1.158
20,000,000	1.008	90,000,000	1.195
30,000,000	1.025	100,000,000	1.230
40,000,000	1.045	125,000,000	1.332
50,000,000	1.070	150,000,000	1.443
60,000,000	1.096	175,000,000	1.530
70,000,000	1.126	200,000,000	1.622

Foucault or Eddy Currents.—These may be induced in the conductor itself, or in the lead sheathing or in the steel armor wires *by the rapidly changing alternating magnetic flux.*

Foucault currents are produced at the expense of energy supplied the conductor, and they are dissipated in the form of heat. This loss would be much greater in single conductor cables carrying alternating current than in two conductor or three conductor cables, in which the outer resultant magnetic field should be very small.

Placing a single conductor alternating current cable in an iron conduit would very greatly increase the energy loss, and for that reason it is seldom done. This loss will be greater in solid conductors than in stranded conductors of equal section, and it will increase with thickness of lead sheath and with the diameter of the armor wires.

Corona Effect.—When two wires, having a great difference of pressure are placed near each other, a certain phenomenon occurs, called the *corona effect.*

If the spacing or distance between the wires be small and the difference of pressure in the wires very great, a continuous passage of energy takes place through the dielectric or atmosphere. The amount of this energy may be an appreciable percentage of the power transmitted. Therefore in laying out high pressure transmission lines, this effect must be considered in the spacing of the wires.

The corona effect manifests itself as a bluish luminous envelope at night and is audible as a hissing sound.

The critical voltage is that voltage at which the corona effect loss takes place. The critical voltage depends upon the radius of the wires, the spacing and the atmospheric conditions.*

The critical voltage increases with both the diameter of the wires, and the spacing.

*NOTE.—*Fog, sleet, rain and snow storms* lower the critical voltage. The effect of snow is greater than other weather conditions. Increase in temperature or decrease in barometric pressure lowers the voltage at which visual corona starts.

The losses due to corona effect increase very rapidly with increasing pressure beyond the critical voltage.

Spacing of Wires.—Wires should be so spaced as *to lessen the tendency to leakage and to prevent the wires swinging together or against towers.*

The spacing should be only sufficient for safety, since increased spacing increases the self-induction of the line, and while it lessens the capacity, it does so only in a slight degree.

The following spacing is in accordance with average practice.

Spacing for Various Voltages

Volts	Spacing	Volts	Spacing	Volts	Spacing
5,000	28 ins.	45,000	60 ins.	90,000	96 ins.
15,000	40 ins.	60,000	60 ins.	105,000	108 ins.
30,000	48 ins.	75,000	84 ins	120,000	120 ins.

Dielectric Hysteresis.—This loss in the insulating material is *somewhat similar to the magnetic hysteresis loss in iron.*

A dielectric is *a poorly conducting material used for insulating conductors, through which voltage establishes a molecular strain or an electrostatic field of flux.*

The total dielectric loss is due to the sum of a direct I^2R, leakage of current through the dielectric and to the dielectric hysteresis loss, which is thought to be a function of the insulation resistance, varying inversely.

The hysteresis loss in the dielectric of a cable is constant and independent of load.

It increases with voltage, with the length of cable and with frequency.

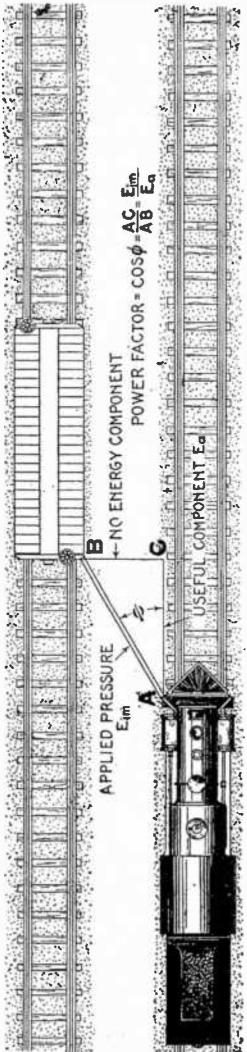


FIG. 4,988—Mechanical analogy of power factor, as exemplified by a locomotive "poling" a car off a siding. The car and locomotive are shown moving in parallel, and the pole AB, inclined at an angle φ. Now, if the length AB, be taken to represent the pressure exerted on the pole by the locomotive, then the imaginary lines AC and BC, drawn respectively parallel and at right angles to the direction of motion will represent respectively the useful and no energy (wattless) components; that is to say, if the pressure AB, be applied to the car at an angle φ, only part of it, AC, is useful in propelling the car, the other component, BC, being wasted in tending to push the car off the track at right angles to the rails, being resisted by the flanges of the outer wheels.

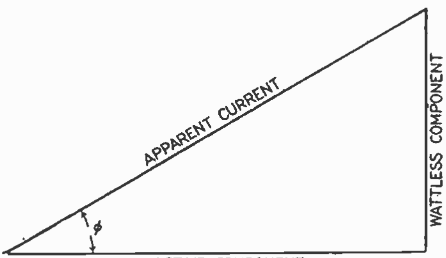
It may be lessened by increasing the thickness of the dielectric, by using a dielectric of low specific inductive capacity and by working at low voltage and low frequency. The loss is thought to be negligible in direct current systems and in low voltage alternating current distribution systems.

While the amount of heat developed under ordinary service conditions by any one of the last three mentioned causes would probably be small, yet the aggregate amount tends to increase the temperature of the conductor, which increases its resistance, reduces its carrying capacity and shortens the life of the insulation.

Power Factor. — When the current falls out of step with the pressure, as on inductive loads, the power factor becomes less than unity, and the effect is to increase the current required for a given load. Accordingly, this must be considered in calculating the size of the wires. As has been explained, the current flowing in an alternating current circuit, as measured by an ammeter, can be resolved into two components, representing respectively the active component and the wattless component or idle current, as shown in fig. 4,989.*

With inductive loads, the heating of the wires depends on the apparent current as represented by the hypothenuse of the triangle in fig. 4,989.

The Three Circuits.—The transmission of alternating current power involves three separate circuits, one of which is



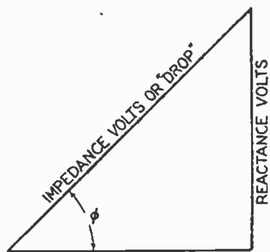


Fig. 4,989.—Diagram showing that the apparent current is more than the active current the excess depending upon the angle of phase difference.

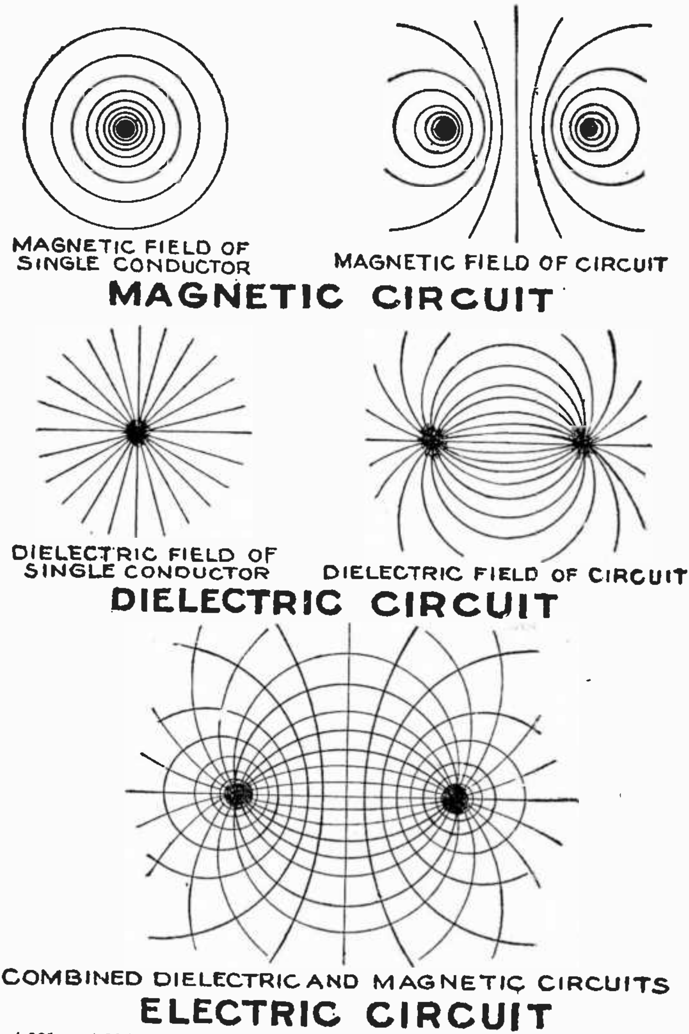
Fig. 4,990.—Diagram showing components of impedance volts. Compare this diagram with figs. 4,983 and 4,986, and note that the term "reactance" is the difference between the inductance drop and the capacity drop if the circuit contain capacity, for instance, if inductance drop be 10 volts and capacity drop be 7 volts then reactance = 10 − 7 = 3 volts.

composed of the wires forming the transmission line, while the others lie in the medium surrounding the wires. The constants of these circuits are interdependent; although any one may vary greatly from the others in magnitude.†

†NOTE.—For a further description of these circuits see "*Alternating Currents*" by Prof. Carl E. Magnusson.

NOTE.—***Besides power factor,*** the efficiency of the motor, and the heavy starting current should be considered in wire calculations. The product of the efficiency of the motor multiplied by the power factor gives the *apparent efficiency*, which governs the size of the wires, apparatus, etc., necessary to feed the motors. Allowance should be made for the heavy starting current required for some motors to avoid undue drop.

*NOTE.—***Power factor*** has been explained so thoroughly in earlier chapters that it is unnecessary to go into the subject further here.



Figs. 4,991 to 4,995.—The three circuits.

There is first the electric circuit through the conductors. Then since all magnetic and dielectric lines of force are closed upon themselves forming complete circuits there is a magnetic and a dielectric circuit. The magnetic circuit consists of magnetic lines of force encircling the current carrying conductors and the dielectric circuit, the dielectric lines of force terminating in the current carrying conductors. These circuits are shown in figs. 4,991 to 4,995.

The accompanying table gives a comparison of the three circuits·

The Three Circuits

The electric circuit	The magnetic circuit	The dielectric circuit
Current I Voltage $E = RI$ Electric power	Magnetic flux ϕ Magnetomotive force $F = ni$ Magnetic energy	Dielectric flux ψ Electromotive force $E = Q/C$ Dielectric energy
Resistivity Resistance $R = W/I^2$	Reluctivity Reluctance R Inductance $L = \phi/i$	Elastivity $1/K$ Elastance S Capacitance $C = \psi/E$
	Reactance $x = wL - 1/wC$	
Impedance $z = \sqrt{r^2 + x^2}$		
Conductivity γ Conductance $g = W/E^2$, $g = r/z^2$	Permeability $\mu = B/H$ Permeance $M = \phi/4\pi F$	Permittivity K Permittance (Capacitance) C
	Susceptance $b = x/z^2$	
Admittance $y = 1/z = g \pm jb = \sqrt{g^2 + b^2}$		

NOTE.—*Twisting or spiraling* of the strands of a stranded conductor *causes an increase of resistance to alternating current* as compared with an unspiraled conductor but tests have also shown that the increase due to spirality effect is negligible within the limits of frequency and conductor sizes used in overhead transmission circuits.

NOTE.—*Spiraling* of the strands of a cable and spiraling of the conductors of a three conductor cable *tend to increase the inductance.* It is difficult to calculate the effect of spiraling for the various cases, but it may be considered negligible for high tension aerial transmission circuits using non-magnetic conductors.

NOTE.—*Corona*, manifesting its presence visually by an electrostatic glow or luminous discharges, and audibly by a hissing sound, was clearly observed and studied in connection with electrostatic machines. It did not become a serious factor to be considered in connection with the design of commercial electrical apparatus until the increasing generator and transmission voltage emphasized its importance.

NOTE.—*Although it is usual* to think of corona effect only in connection with high voltage transmission lines, it has received not a little thought of late by the designers of high voltage alternators and motors, notably large, high voltage turbo alternators. By effectively insulating the portion of the conductor embedded in the iron of the armatures of alternating current machines, particularly with mica, punctures to ground due to corona effect are not likely to occur. However, at the ends of the armature coils (where it is difficult to employ mica for insulating) where air is partially depended upon as an insulating medium between coils and ground, corona may appear. The presence of these corona stresses results in disintegrating and weakening some kinds of insulating materials, causing them to break down after a period of service. This deterioration of insulation may be due to local heating, mechanical vibration or chemical formations in the overstressed air, such as ozone, nitric acid, etc.

NOTE.—*Higher voltages* are being chosen as an economic means for reducing loss in transmission. These higher voltages may result in corona loss far in excess of the saving in transmission loss due to the adoption of the higher voltages. It is, therefore, pertinent that particular consideration be given to the limitation of corona loss when the choice of conductors is made. This consideration will sometimes make it desirable to take advantage of the higher critical voltage limits of aluminum conductors (with steel reinforced centers) of an equivalent resistance, due to their greater diameter; or it may be desirable to obtain the necessary larger diameter by the use of copper conductors having some form of insulating centers or, for still larger diameters, of aluminum conductors having such centers, in order to avoid skin effect The use of copper conductors having hemp centers has in some instances given mechanical trouble.

NOTE.—*The critical voltage* at which corona becomes manifest, is not constant for a given line, but is somewhat dependent upon atmospheric conditions. Assuming a line employing conductors just within the critical voltage limitations for the conditions to be met, the corona loss in such a line would be almost negligible during fair weather, but during stormy weather (particularly during snow storms) this corona loss would be many times what it is during fair weather. On the other hand, since the storm will usually not appear over the whole length of lines at the same time and since storms occur only at intervals, it may often be economical to allow this loss to reach fairly high values during storms. Fog, sleet, rain and snow storms lower the critical voltage and increase the losses.

NOTE.—*The critical voltage* increases with both the diameter of conductors and their distance apart. This sometimes makes it desirable to use aluminum conductors.

NOTE.—*The losses due to corona increase very rapidly with increase in voltage after the critical voltage has been reached.*

NOTE.—*A long transmission line* having considerable capacitance may deliver *a higher voltage than appears at the alternator end of the line due to capacitance effect.*

TEST QUESTIONS

1. *Name nine items for which allowance must be made in determining the size of wires for* a.c. *circuits.*
2. *What is the effect of induction?*
3. *What is the difference between self induction and mutual induction?*
4. *When iron conduits are used, how should the wires of each circuit be installed?*
5. *What is done to counteract the effects of mutual induction?*
6. *Draw diagrams of transpositions for single, two and three phase circuits.*
7. *Describe the effect of mutual induction on various circuits.*
8. *Define capacity.*
9. *Draw diagrams illustrating capacity effect in single phase and three phase circuits.*
10. *Explain the graphic method of obtaining impedance, impressed pressure, etc., in* a.c. *circuits.*
11. *Do all circuits have capacity?*
12. *Define frequency.*
13. *What is skin effect?*
14. *What is done to reduce skin effect?*
15. *How does a current induced in a conductor build up?*
16. *Is skin effect more pronounced for low frequency or for high frequency?*
17. *Explain how to calculate skin effect.*
18. *What are Foucault or eddy currents?*
19. *How are Foucault currents produced?*

20. *What is understood by corona effect?*
21. *How should the wires be spaced to lessen the tendency to leakage?*
22. *What is dielectric hysteresis?*
23. *Give a mechanical analogy of power factor.*

CHAPTER 98

Alternating Current Systems

A classification of the various alternating current systems, to be comprehensive, should be made according to several points of view. as follows:

1. With respect to the arrangement of the circuit, as

   a. Series;
   b. Parallel;
   c. Series parallel;
   d. Parallel series.

2. With respect to transformation, as

   a. Non-transformer;
   b. Transformer.

3. With respect to the mode of transmitting the energy, as

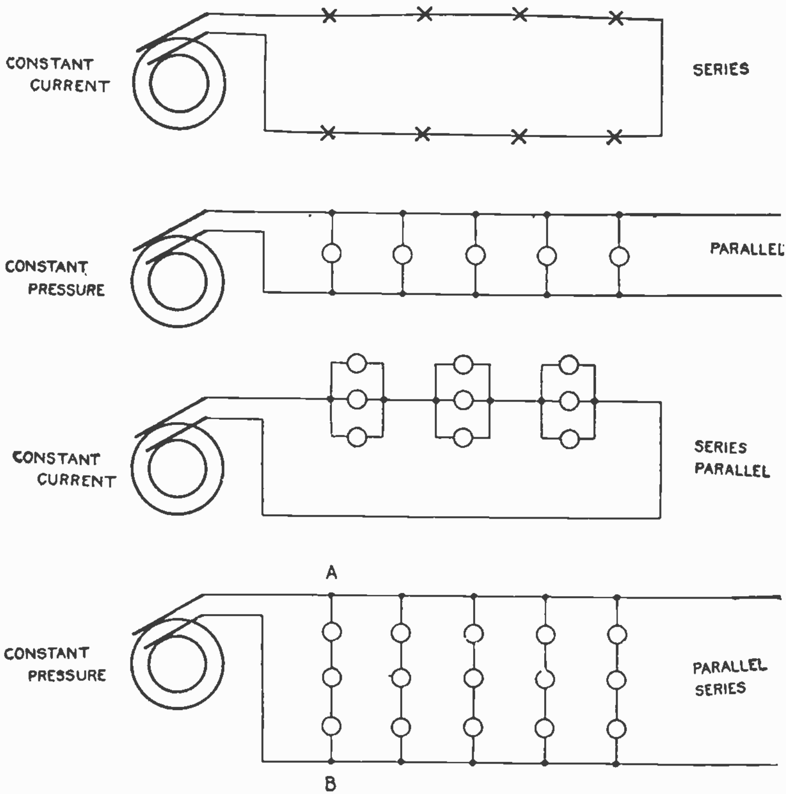
   a. Constant pressure;
   b. Constant current.

4. With respect to the kind of current, as

   a. Single phase {two wire; three wire;
   b. Monocyclic
   c. Two phase {three wire; four wire; five wire;

d. Three phase { three wire; four wire; six wire; star connection; delta connection; star delta connection; delta star connection;

e. Multi-phase { of more than three phases;



Figs. 4,996 to 4,999.—Various forms of circuit. These well-known forms of circuit are used in both alternating and direct current systems.

5. With respect to transmission and distribution, as

   a. Frequency changing;
   b. Phase changing;
   c. Converter;
   d. Rectifier.

Transformer Systems.—Nearly all alternating current systems are transformer systems, since the chief feature of alternating current is the ease with which it may be transformed

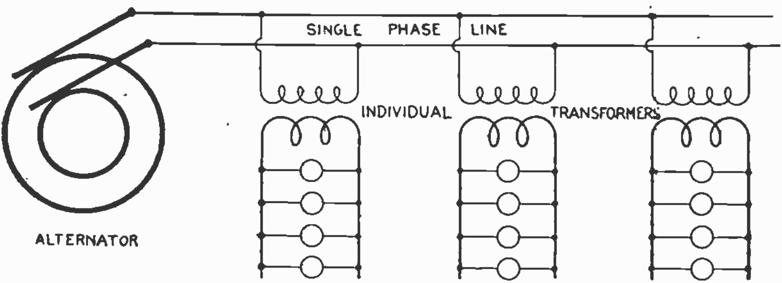


FIG. 5,000.—Diagram of transformer system with individual transformers. The efficiency is low, but such a method of distribution is necessary in sparsely settled or rural districts.

from one pressure to another. Accordingly, considerable economy in copper may be effected by transmitting the current at high pressure, especially if the distance be great, and by means of step down transformers; reducing the voltage at points where the current is used or distributed.

There are numerous transformer systems and they may be classed broadly as those employing

1. Step down transformers.
2. Step up and step down transformers.

With respect to the step down transformers, there are two arrangements:

1. Individual transformers;
2. One transformer for several customers.

Individual transformers, that is, a separate transformer for each customer is necessary in rural districts where the intervening distances are great as shown in fig. 5,000.

An objection to this method is that it requires the use of small transformers which are necessarily less efficient and more expensive per kilowatt than large transformers. The transformer must be built to carry, within its overload capacity, all the lamps installed by the customer, since all may be used occasionally.

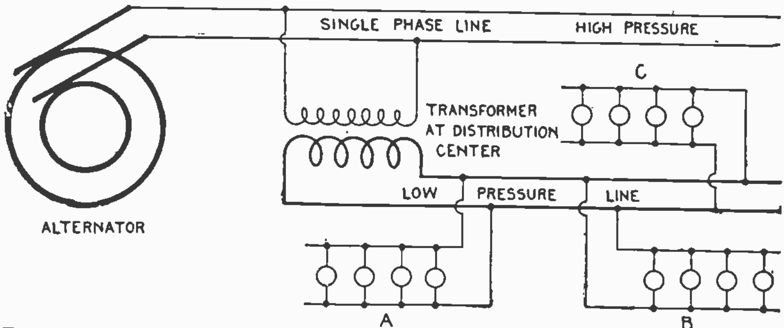


FIG. 5,001.—Diagram of transformer system with one transformer located at a distribution center and supplying several customers as A, B, and C. Such arrangement is considerably more efficient than that shown in fig. 5,000, as explained in the accompanying text.

The efficiency may be improved by placing one large transformer at a distribution center, to supply several customers, as in fig. 5,001, if the several customers be located close together.

For long distance transmission it is customary to use step up and step down transformers as in fig. 5,002 to effect, as must

NOTE.—*Economy with one large transformer for several customers.*—Less transformer capacity is required because with several customers supplied from one transformer it is extremely improbable that all the customers will burn all their lamps at the same time. It is therefore unnecessary to install a transformer capable of operating the full load, as is necessary with individual transformers. Moreover, one large transformer is more efficient than a multiplicity of small transformers, because the core loss is less.

be evident, a saving in copper. This saving is partly offset by the cost of the transformers as well as by transformer losses and the higher insulation requirements.

Single Phase Systems.—There are various arrangements for transmission and distribution classed as single phase systems.

Thus, single phase current may be conveyed to the various receiving units by the well known circuit arrangements known as series, parallel,

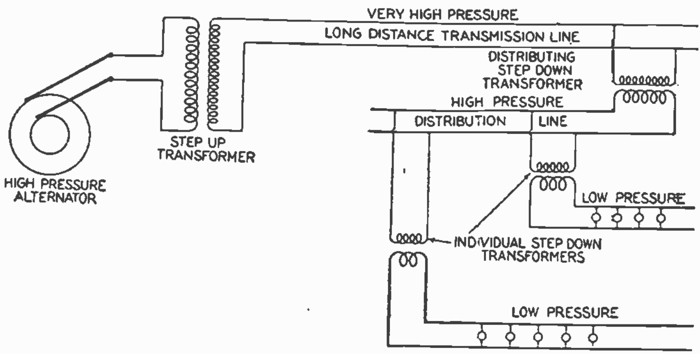


Fig. 5,002.—Diagram illustrating the use of *step up* and *step down* transformers on long distance transmission lines. The saving in copper is considerable by employing extra high voltages on lines of moderate or great length as indicated by the relative sizes of wire.

series parallel, parallel series, connections previously described and illustrated in figs. 4,996 to 4,999.

Again single phase current may be transmitted by two wires and distributed by three wires. This is done in several ways, the simplest being shown in fig. 5,003.

This method of treating the neutral wire is only permissible where there is very little unbalancing, that is, where the load is kept practically the same on both sides of the neutral.

With the three wire distribution the pressure at the alternator can be doubled, which means, for a given number of lamps, that the current is reduced to half, the permissible drop may be doubled, the resistance of the wires quadrupled, and their cost reduced nearly 75 per cent.

To allow for unbalancing in the three wire circuit A, fig. 5,003, an auto-transformer, sometimes called "balance coil," should be used as at B. This is a very desirable method of balancing when the ratio of transformation is not too large.

The system shown in fig. 5,003 is suitable for short distance transmission, as for instance, in the case of an isolated plant because of the low pressure at which the current is generated.

The standard voltages of low pressure alternators are 400, 480, and 600 volts.

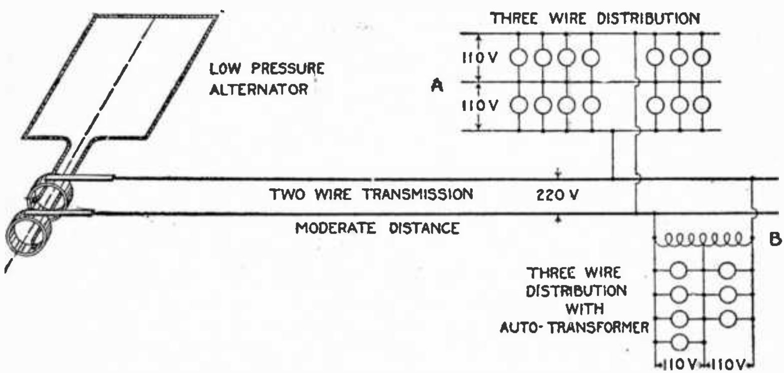


FIG. 5,003.—Diagram illustrating single phase two wire transmission and three wire distribution. The simplified three wire arrangement at A, is not permissible except in cases of very little *unbalancing*. Where the difference between loads on each side of the neutral may be great, some form of balancing as an auto-transformer or equivalent should be used, as at B.

Selection of Alternators.—In practice, alternators are wound for one, two or three phases. Three phase machines are more commonly supplied and in many cases it will pay to install them in preference to single phase, even if they be operated single phase temporarily.

For a given output, three phase machines are smaller than single phase and the single phase load can usually be approximately balanced between the three phases. Moreover, if a three phase machine be installed, polyphase current will be available in case it may be necessary to operate polyphase motors at some future time.

Standard three phase alternators will carry about 70 per cent. of their rated kilowatt output when operated single phase, with the same temperature rise.

A three phase alternator may be operated single phase by connecting the single phase circuit to any two of the three phase terminal leads. Objectionable features of a single phase

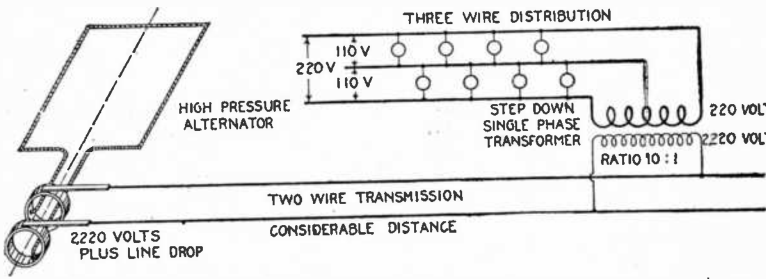


Fig. 5,004.—Diagram showing arrangement of *single phase system* for two wire transmission and three wire distribution, *where the transmission distance is considerable.* In order *to reduce the cost* of the transmission line, *the current must be transmitted at high pressure*; this necessitates the use of a step down transformer at the distributing center as shown in the illustration.

alternator are that it has an unbalanced armature reaction which is the cause of considerable flux variation in the field pole tips and in fact throughout the field structure.

In order to minimize eddy currents, such alternators must accordingly be built with thinner laminations and frequently poorer mechanical construction, resulting in increased cost of the machine. The large armature reaction results in a much poorer regulation than that obtained with three phase alternators, and an increased amount of field copper is required, also larger exciting units. These items augment the cost so that the single phase machine is considerably more expensive than the three phase, of the same output and heating.

The difficulties appear to increase with a *decrease* in frequency.

The adoption of any lower frequency than 25 cycles may result in serious difficulties in construction for a complete line of machines, especially those of the two or four pole turbine driven type where the field flux is very large per pole.

Long Distance Transmission.—Electric current may be transmitted a long distance economically by the use of

1. High pressure alternator, or
2. Low pressure alternator with step up transformer.

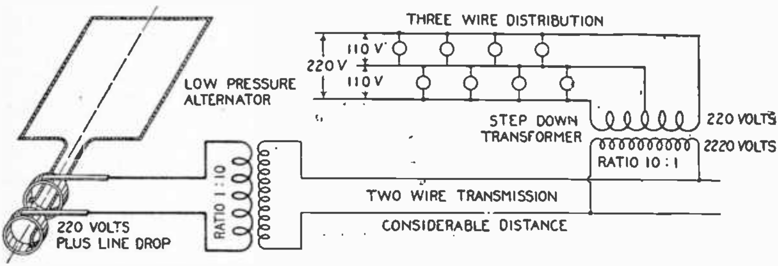


FIG. 5,005.—Diagram illustrating how electricity can be economically transmitted a considerable distance with low pressure alternator already in use.

These two methods are shown in figs. 5,004 and 5,005. In either case a step down transformer is placed at each distribution center to reduce the pressure to the proper voltage to suit the service requirements, as shown in the diagrams.

The system used in fig. 5,005 can be made more efficient than that in fig. 5,004 by using a high pressure alternator in order to considerably increase the transmission voltage.

Thus, a 2,200 volt alternator and 1:10 step up transformer would give a line pressure of 22,000 volts, which at the distribution end could be reduced, to 220 volts for the three wire circuit, using a 100:1 step down transformer.

Objections to these single phase systems are that they do not permit of the use of synchronous converters, self-starting synchronous motors, or induction motor starting under load. They are poorly adapted to general power distribution, hence are open to grave objections of a commercial nature where there exists any possibility of selling power or in any way utilizing them for general converter and motor work.

However, single phase systems are suitable for railway operation.*

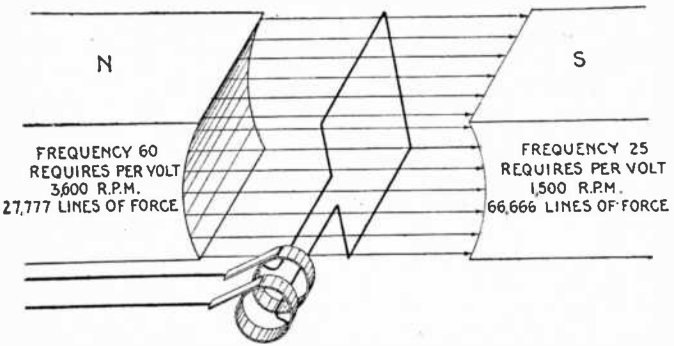


FIG. 5,006.—Elementary alternator developing one volt at frequencies of 60 and 25, showing the effect of reducing the frequency. Since for the same number of poles, the *r.p.m.* have to be decreased to decrease the frequency, increased flux is required to develop the same voltage. Hence in construction, low frequency machines require *larger magnets, increased number of turns in series on the armature coils, larger exciting units* as compared with machines built for higher frequency.

Two Phase Systems.—A two phase circuit *is equivalent to two single phase circuits.* Either four or three wires may be employed in transmitting two phase current, and even in the latter instance the conditions are practically the same as for single phase transmission, excepting the unequal current distribution in the three wires.

*NOTE.—*There are advantages of* simplicity in the entire generating, primary, and secondary distribution systems for single phase roads. These advantages are so great that they justify considerable expense, looked at from the railway point of view only, the single phase system throughout may be considered as offering the greatest advantage.

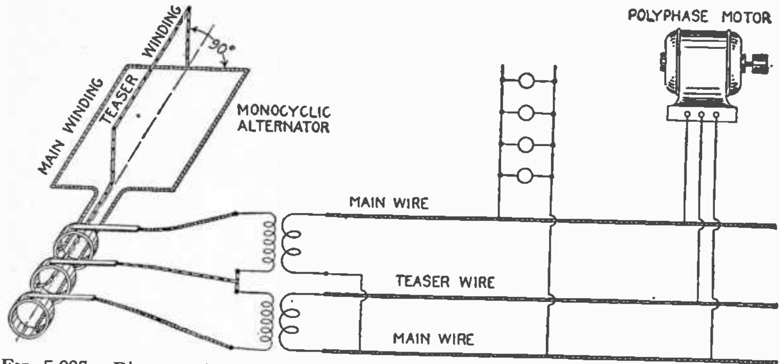


FIG. 5,007.—Diagram of monocyclic system, showing lighting and power circuits. ***In construction,*** there is a *main* single phase winding an auxiliary or *teaser* winding connected to the central point of the main winding in quadrature. The teaser coil generates a voltage equal to about 25 per cent. of that of the main coil so that the pressure between the terminals of the main coil and the free end of the teaser is the resultant of the pressure of the two coils. By various transformer connections it is possible to obtain a practically correct three phase relationship so that polyphase motors may be employed.

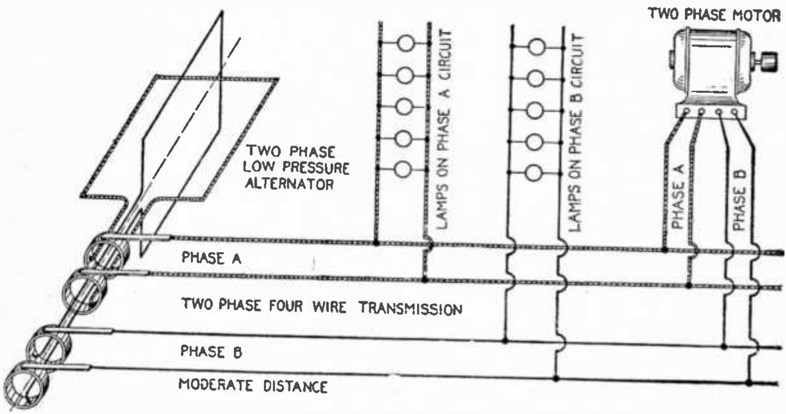


FIG. 5,008.—Diagram of two phase four wire system. ***It is desirable*** for supplying current for lighting and power. The arrangement here shown should be used only for lines of short or moderate length, because of the low voltage. Motors should be connected to a circuit separate from the lighting circuit to avoid drop on the latter while starting a motor.

A four wire two phase system is shown in fig. 5,008 and three wire in fig. 5,009. The system shown in fig. 5,008 is adapted to supplying current for lighting and power at moderate or short distances.

Either 110 or 220 volts are ordinarily used which is suitable for incandescent lighting and for constant pressure arc lamps, the lamps being connected singly or two in pairs.

On a two phase three wire system the load on the two phases must be

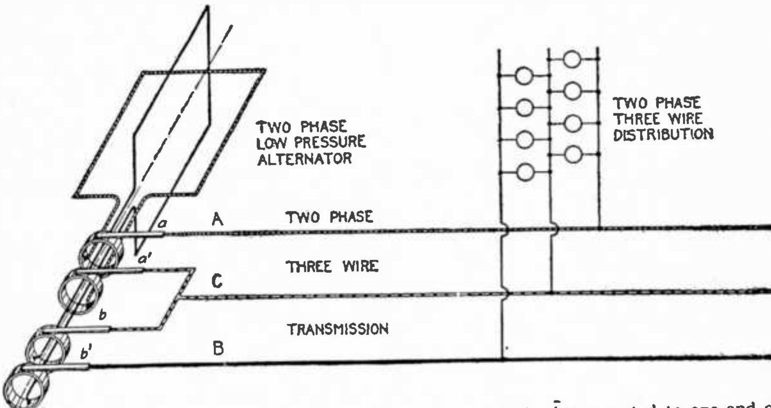


FIG. 5,009.—Diagram of two phase three wire system. A wire is connected to one end of each phase winding as at A and B, and a third wire C, to the other end of both phases as shown. One end of each phase winding is connected by the brushes *a* and *b'*, to one of the circuit wires, that is to A and B, respectively. The other end of each phase winding is connected by a lead across brushes *a'* and *b*, to which the third wire C, is joined. The current and pressure conditions of this system are represented diagrammatically in fig. 5,010. The letters correspond to those in this figure, with which it should be compared. *This system* is desirable for supplying current of minimum pressure to apparatus in the vicinity of transformers. It is more frequently used in connection with motors operating from the secondaries of the transformers.

carefully balanced, and the power factor should be kept high to keep the voltage on the phases nearly the same at the receiving ends.

Fig. 5,012 shows another two phase system in which the current is transmitted on a four wire circuit and distributed on a three wire circuit.

NOTE.—*In changing from four to three wires* it is just as well to connect the two outside wires A and B, together (fig. 5,009), as it is to connect *a'* and *b*. It makes no difference which two secondary wires are joined together, so long as the other wires of each transformer are connected to the outside wires of the secondary system.

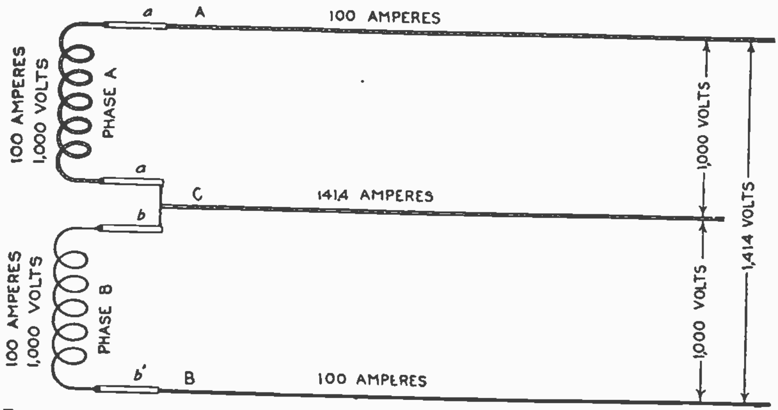


FIG. 5,010.—Diagram illustrating two phase three wire transmission. The third wire C, is attached to the connector between one end of phase A, and phase B, windings. As shown in the figure each coil is carrying 100 amperes at 1,000 volts pressure. Since the phase difference between the two coils is 90°, the voltage between A and B, is $\sqrt{2}=1.414$ times that between either A or B and the common return wire C. The current in C, is $\sqrt{2}=1.414$ times that in either outside wire A or B, as indicated.

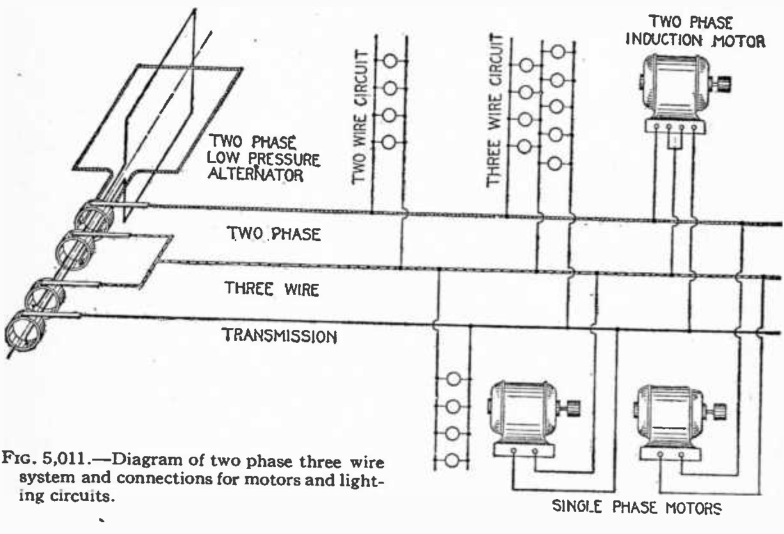


FIG. 5,011.—Diagram of two phase three wire system and connections for motors and lighting circuits.

The transmission part of this system is evidently equivalent to two independent single phase circuits.

Since, in the two phase three wire system, it is desirable for supplying current of minimum pressure to apparatus in the vicinity of transformers. It is more frequently used in connection with motors operating from the secondaries of the transformers.

Three Phase Systems.—There are various ways of arranging the circuit for three phase current giving numerous three phase systems.

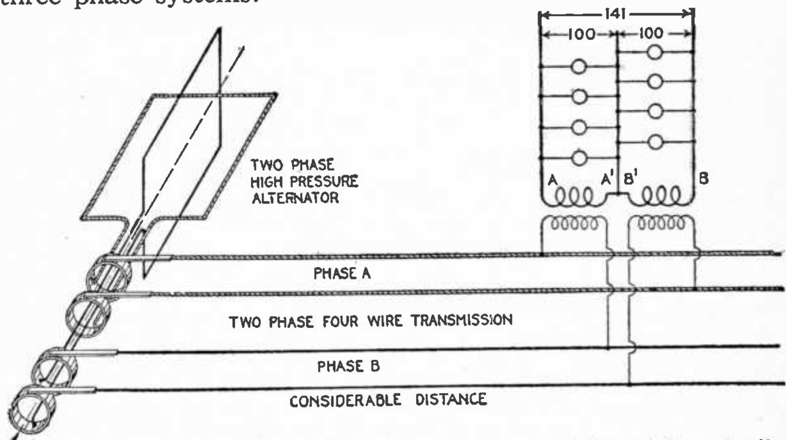


FIG. 5,012.—Diagram of two phase system with four wire transmission and three wire distribution. In the three wire circuits the relative pressures between conductors are as indicated; that is, the pressure between the two outer wires A and B, is 141 volts, when the pressure between each outer wire and the central is 100 volts.

1. With respect to the number of wires used they may be classified as

a. Six wire;
b. Four wire;
c. Three wire.

NOTE.—***Inductive loads*** on the two phase three wire system cause an unbalancing of both sides of the system even though the energy load be equally divided. The self-induction pressure in one side of the system is in phase with the virtual pressure in the other side, thus distorting the current distribution in both circuits.

2. With respect to the connections, as

a. Star;
b. Delta;
c. Star delta;
d. Delta star.

The six wire system is shown in fig. 5,018. It is equivalent to three independent single phase circuits. Such an arrangement would only be used in very rare instances.

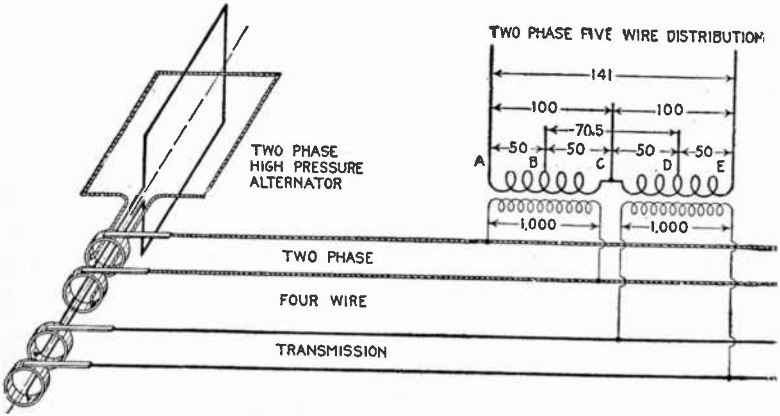
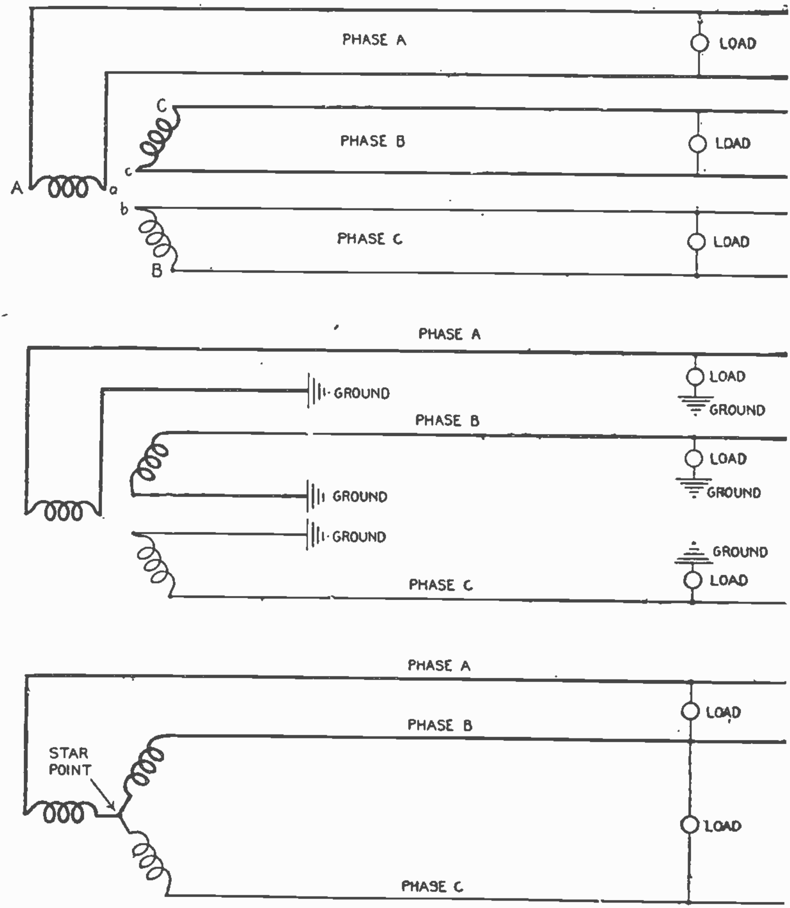


FIG. 5,013.—Two phase four wire transmission and five wire distribution system. The relative pressures between the various conductors are indicated in the diagram. *As shown*, the secondaries of the transformers are joined in series and leads brought out from the middle point of each secondary winding and at the connection of the two windings, giving five wires. With 1,000 volts in the primary windings and a step down ratio of 10:1, the pressure between A and C and C and E, will be 100 volts and between the points and the connections B or D, at the middle of the secondary coils, 50 volts. The pressure across the two outer wires A and E, is, as in the three wire system, $\sqrt{2}$ or 1.41 times that from either outer wire to the middle wire C, that is 141 volts. The pressure across the two wires connected to the middle of the coils, that is, across B and D, is $50 \times \sqrt{2} = 70.5$ volts.

Three Phase Star Connected Systems.—These are systems with star connections employing three wires or four wires as shown in figs. 5,019 to 5,022.

Assuming 100 amperes and 1,000 volts in each phase winding, the



FIGS. 5,014 to 5,016.—Evolution of the three phase three wire system. Fig. 5,014 is a conventional diagram of the three phase six wire system shown in fig. 5,018. A wire is connected to both ends of each phase winding, giving six conductors, or three independent two wire circuits. In place of the wires running from A, B and C, they may be removed and each circuit provided with a *ground* return as shown in fig. 5,015. The sum of the three currents being zero, or nearly zero, according to the degree of unbalancing, the ground return may be eliminated and the ends A, B and C, of the three phase winding connected, as in fig. 5,016, giving the so-called *star point*.

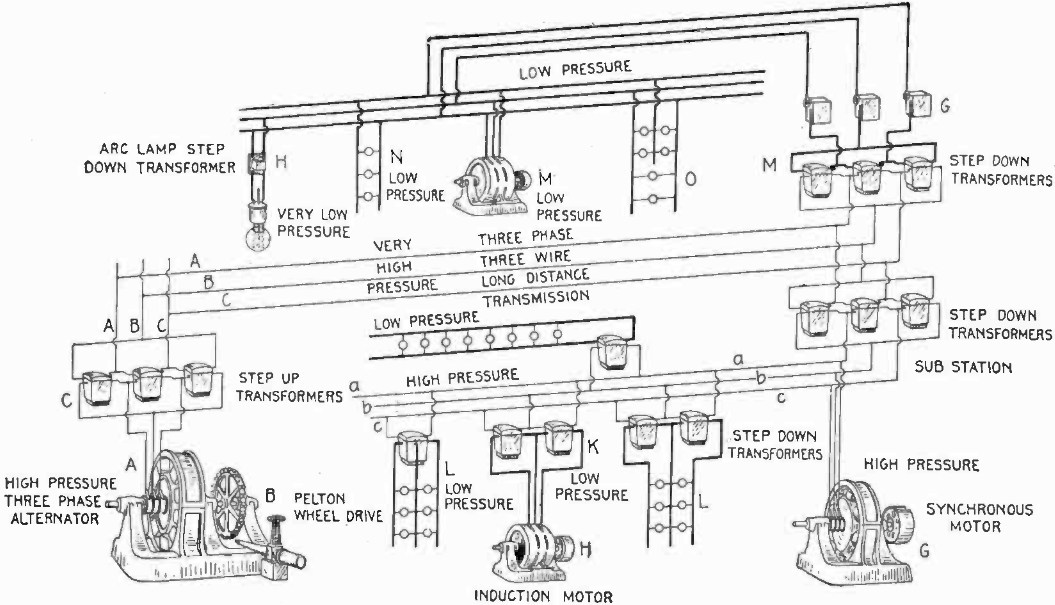


FIG. 5,017.—Line connections of three phase three wire long distance transmission, and distribution system. The three phase alternator A, is driven by the water wheel B, and furnishes current at say 2,200 volts plus sufficient pressure to compensate for line drop. With 1:10 step up transformer C, this would give a transmission pressure of 22,000 volts plus line drop. *It is* ***this transformation*** *that secures the* ***copper economy*** *of the system.* At the distribution end are the step down transformers; one set reducing the voltage down to 2,200 volts, and supplying current direct to the synchronous motor, and through another set of other step down transformers, as L and K, to lighting and power circuits at 220 volts. Another set of step down transformers M, reduce the pressure directly to 120 volts for power and lighting, the pressure being regulated by the regulators G. Arc lamps with individual transformers further reducing the pressure to 50 volts are connected to this circuit as shown.

pressure between any two conductors is equal to the pressure in one winding multiplied by $\sqrt{3}$, that is, 1,000×1.732=1,732 volts.

The current in each conductor is equal to the current in the winding, or 100 amperes.

Three Phase Delta Connected System.—This arrangement employs three wires as shown in figs. 5,023 and 5,024. The current and pressure relations are shown in fig. 5,024.

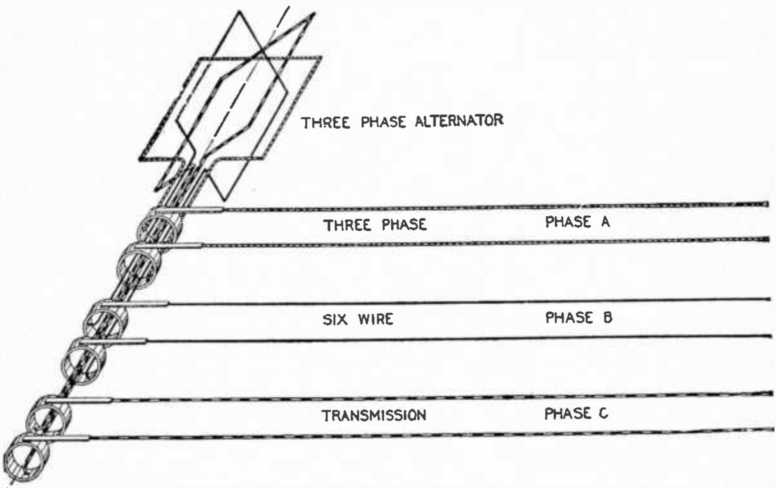


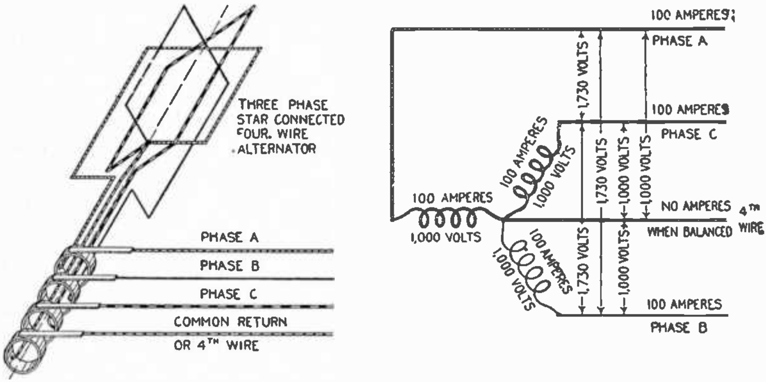
FIG. 5,018.—Three phase six wire system. It is equivalent to three independent single phase circuits and would be used only in very rare cases.

Assuming 100 amperes and 1,000 volts in each phase winding, the pressure between any two conductors is the same as the pressure in the winding, and the current in any conductor is equal to the current in the winding multiplied by $\sqrt{3}$, that is, 100×1.732=173.2 amperes, that is, disregarding the fraction, 173 amperes.

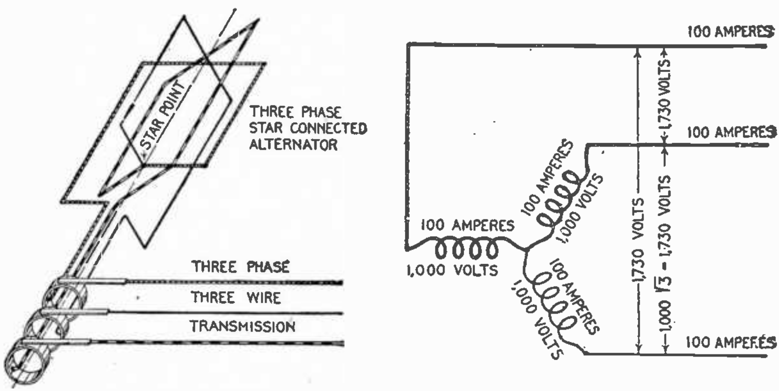
Comparison of Star and Delta Connections.—The power output of each is the same, but the star connection gives a higher line voltage, hence smaller conductors may be used.

When it is remembered that the cost of copper conductors is inversely as the square of the voltage, the advantage of the **Y** connected system can be seen at once.

Assuming that three transformers are used for a three phase system of given voltage, each transformer, star connected, would be wound for $1 \div \sqrt{3} = 58\%$ of the given voltage, and for full current.



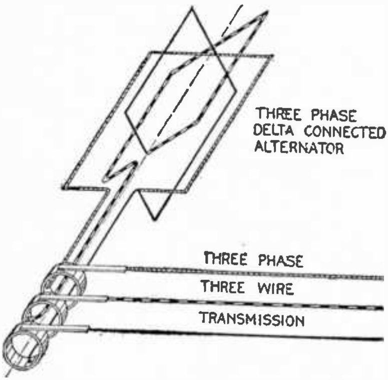
FIGS. 5,019 and 5,020.—Three phase *four wire star connected* alternator and conventional diagram showing pressure and current relations.

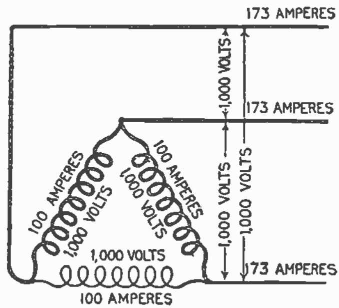


FIGS. 5,021 and 5,022.—Three phase *star connected* alternator, and conventional diagram showing pressure relations.

For delta connection, the winding of each transformer is for 58% of the current. Accordingly the turns required for star connection are only 58% of those required for delta connection.

An objection to the star connection for three phase work is that it requires the use of three transformers, and if anything happen to one, the entire set is disabled.





FIGS. 5,023 and 5,024.—Three phase *delta connected* alternator and conventional diagram showing pressure and current relations.

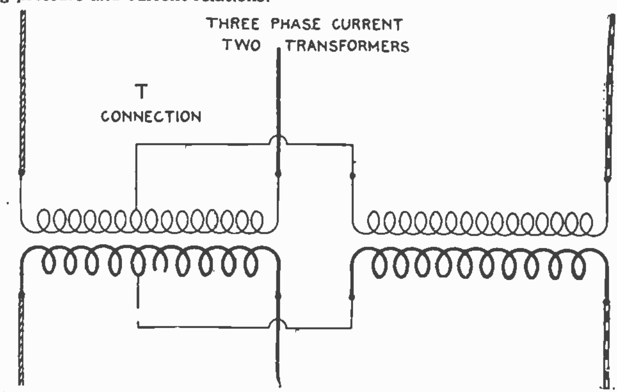


FIG. 5,025.—*T* connection of transformers in which three phase current is transformed with two transformers. The connections are clearly shown in the illustration.

With the delta connection one transformer may be cut out and the other two operated at full capacity, that is, at 86.6% the capacity of the three.

Change of Frequency.—There are numerous instances where it is desirable to change from one frequency to another, as for instance to join two systems of different frequency which may

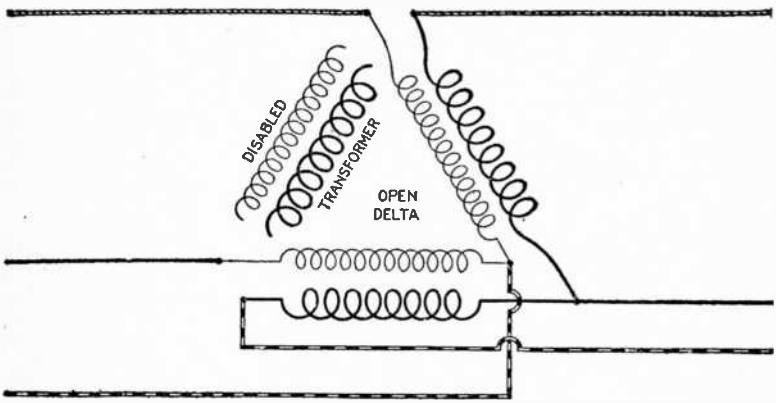


FIG. 5,026.—Open delta connection or method of connecting two transformers in delta for three phase transformation. It is used when one of the three single phase delta connected transformers becomes disabled.

supply the same or adjacent territory, or, in the case of a low frequency installation, in order to operate incandescent lights satisfactorily it would be desirable to increase the frequency for such circuits.

This is done by motor generator sets, the motor taking its current from the low frequency circuit.

Synchronous motors are generally used for such service as the frequency is not disturbed by load changes; it also makes it possible to use the set in the reverse order, that is, taking power from the high frequency mains and delivering energy at low frequency.

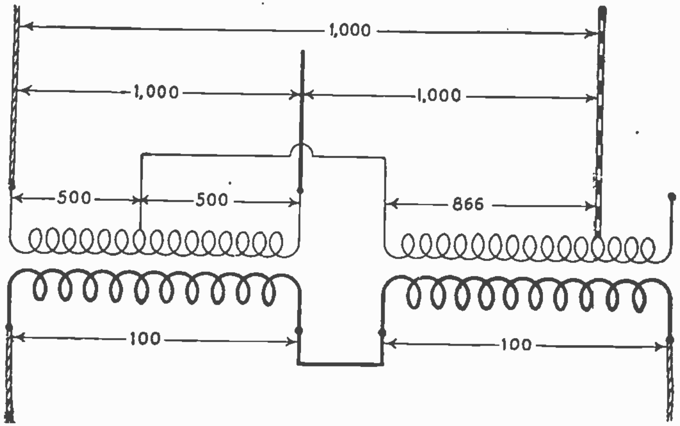


FIG. 5,027.—Three phase to one phase transformation with two transformers. The diagram shows the necessary connections and the relative pressures obtained.

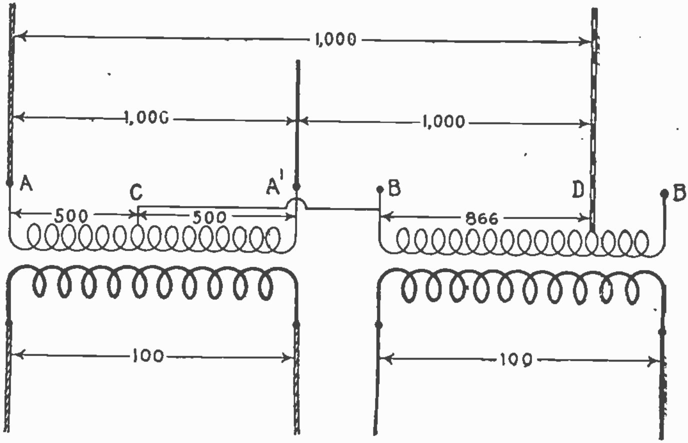


FIG. 5,028.—The Scott connection for transforming from three phase to two phase. In this method one of the primary wires B, of the .866 ratio transformer is connected to the middle of the other primary as at C, the ends of which are connected to two of the three phase wires. The other phase wire is connected at D, the point giving the .866 ratio. The secondary wires are connected as shown. It is customary to employ standard transformers having the ratios 10:1, and 9:1. The transformer having the 10:1 ratio is called the *main* transformer, and the other with the 8.66:1 ratio, the *teaser* transformer.

Transformation of Phases.—This is frequently desirable, for instance in the case of a converter, it is less expensive and more efficient to use one built for six phases than for either two or three phases.

The numerous conditions met with necessitate various phase transformations, as

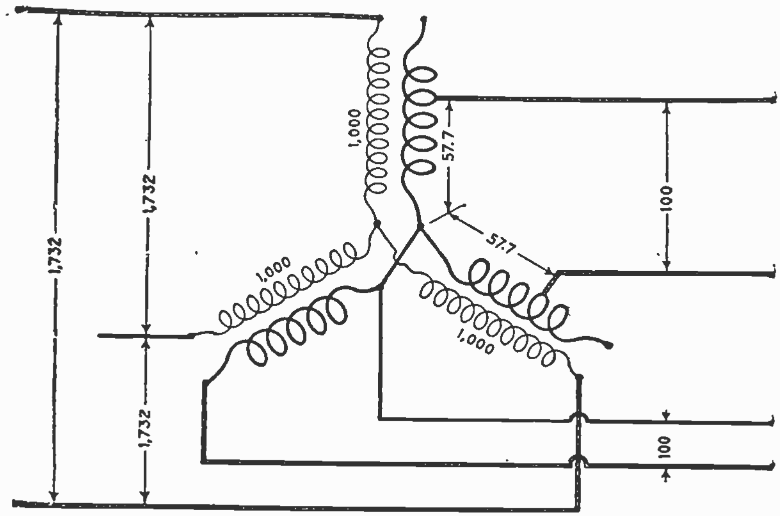


FIG. 5,029.—Three phase to two phase transformation with three star connected transformers. Two of the secondary windings are tapped at points corresponding to 57.7% of full voltage; these two windings are connected in series to form one secondary phase of voltage equal to that obtained by the other full secondary winding.

1. Three phase to one phase;
2. Three phase to two phase;
3. Two phase to six phase;
4. Three phase to six phase.

These transformations are accomplished by the numerous arrangements and combinations of the transformers.

These various transformations are shown in the accompanying illustrations.

Relative Weights of Copper Required by Polyphase Systems.—A comparison between the weights of copper required by the different alternating current systems is rendered quite difficult

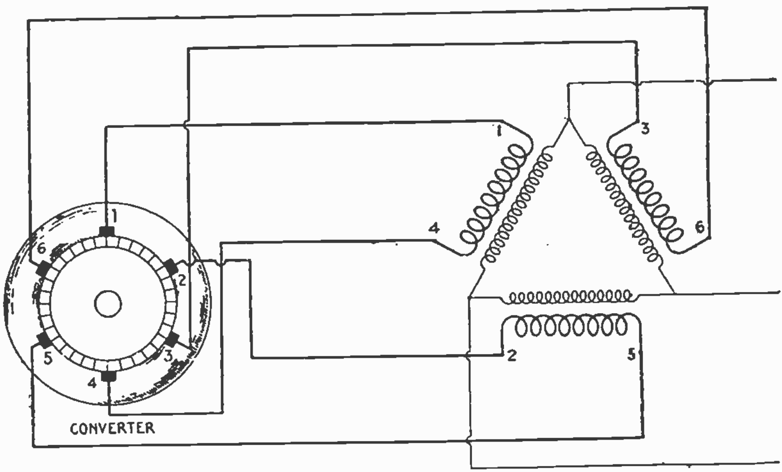
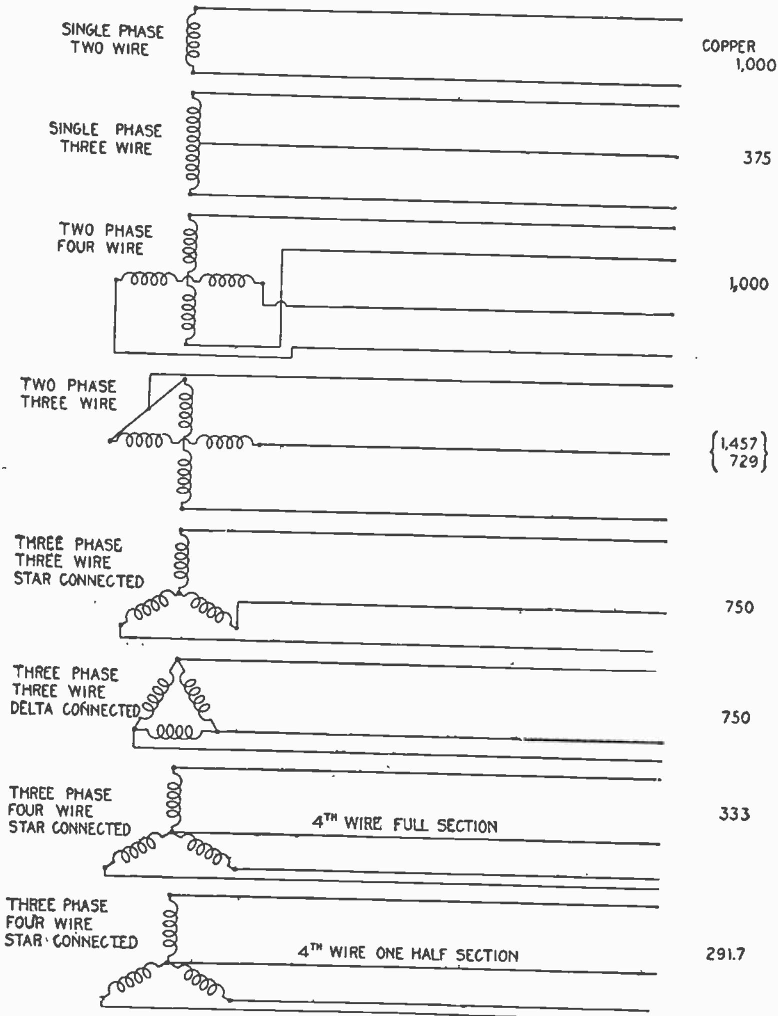


FIG. 5,030.—Diagram of ***diametrical connection**, three phase to six phase. It is obtained by bringing both ends of each secondary winding to opposite points on the rotary converter winding,* utilizing the converter winding to give the six phases. This transformation of phases may also be obtained with transformers having two secondary windings.

by the fact that the voltage ordinarily measured is not the maximum voltage, and as the insulation has to withstand the strain of the maximum voltage, the relative value of copper obtained by calculation depends upon the basis of comparison adopted.

As a general rule, the highest voltage practicable is used for long distance transmission, and a lower voltage for local distribution. Furthermore, some polyphase systems give a multiplicity of voltages, and the



FIGS. 5,031 to 5,038.—Circuit diagrams showing relative copper economy of various alternating current systems question arises as to which of these voltages shall be considered the transmission voltage.

If the transmission voltage be taken to represent that of the distribution circuit, and the polyphase system has as many independent circuits as there are phases, the system would represent a group of several single phase systems, and there would be no saving of copper.

Under these conditions, if the voltage at the distant end be taken as the transmission voltage, and the copper required by a single phase two wire system as shown in fig. 5,039, be taken as the basis of comparison, the relative weights of copper required by the various polyphase systems are given in figs. 5,031 to 5,038.

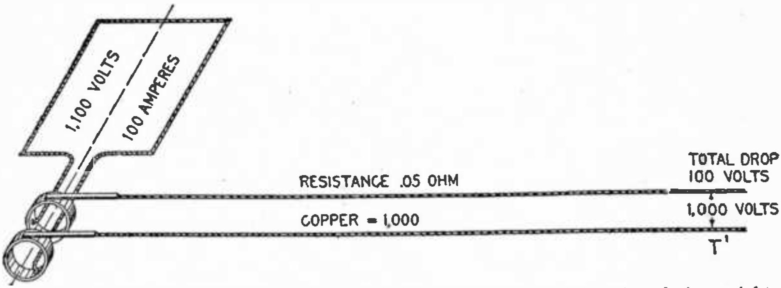
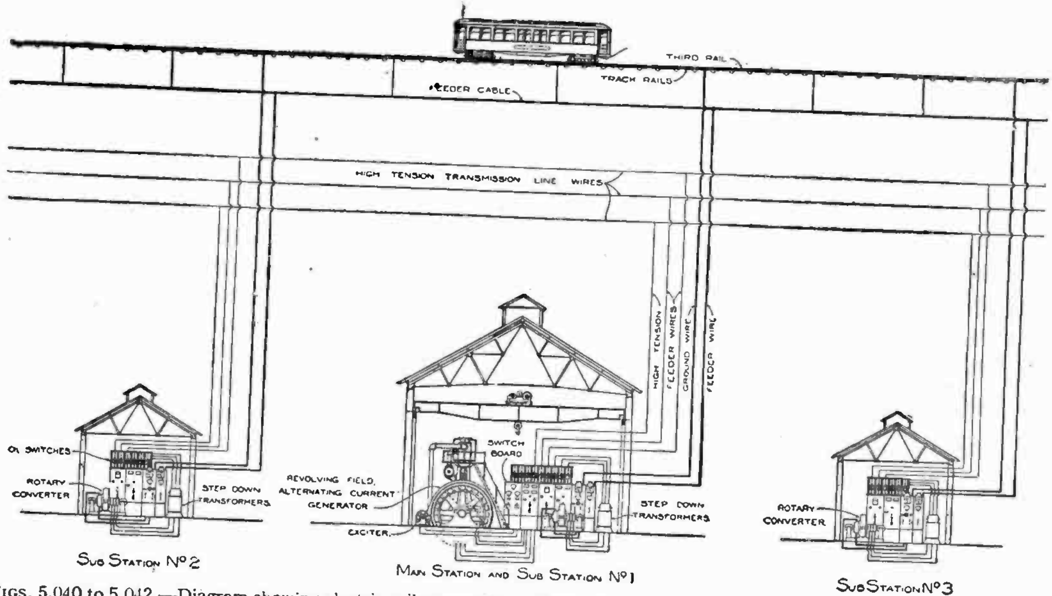


FIG. 5,039.—Single phase line, used as basis of comparison in obtaining the relative weights of copper required by polyphase systems, as indicated in figs. 5,031 to 5,038. If the total drop on the line be 100 volts, the generated voltage must be 1,100 volts, and the resistance of each line must be 50 ÷ 1,000 = .05 ohms. Calculated on this basis, a two phase four wire system is equivalent to two single phase systems and gives no economy of copper in power transmission over the ordinary single phase two wire system. This is the case also with any of the other two phase systems, except the two phase three wire system.

In the two phase three wire system two of the four wires of the four wire two phase system are replaced by one of full cross section.

The amount of copper required, when compared with the single phase system, will differ considerably according as the comparison is based on the highest voltage permissible for any given distribution, or on the minimum voltage for low pressure service.

If E, be the greatest voltage that can be used on account of the insulation strain, or for any other reason, the pressure between the other conductors of the two phase three wire system must be reduced to $E \div \sqrt{2}$.



FIGS. 5,040 to 5,042.—Diagram showing electric railway system. Three phase current is generated at the main station where it passes to ***step up*** transformers to increase the pressure a suitable amount for economical transmission. At various points along the railway line are *sub-stations*, where the three phase current is reduced in pressure to 500 or 600 volts by ***step down*** transformers, and converted into direct current by rotary converters. The relatively low pressure direct current is then conveyed by "feeders" to the rails, thus resulting in a considerable saving in copper.

The weight of copper required under this condition is 145.7% that of the single phase copper.

On the basis of minimum voltage, the relative amount of copper required is 72.9% that of the single phase system.

Figs. 5,037 and 5,038 are two examples of three phase four wire systems. The relative amount of copper required as compared with the single phase system depends on the cross section of the fourth wire. The arrangement shown in fig. 5,038, where the fourth wire is only half size, is used only for secondary distribution systems.

Choice of Voltage.—The most economical voltage for a transmission line depends on the length of the line and the cost of apparatus.

For instance, alternators, transformers, insulation and circuit control and lightning protection devices become expensive when manufactured for very high pressures. Hence if a very high pressure be used, it would involve that the transmission distance be great enough so that the extra cost of the high pressure apparatus would be offset by the saving in copper effected by using the high pressure.

No fixed rule can be established for proper voltage based on the length, but the following table will serve as a guide:

Usual Transmission Voltages

Length of line in miles	Voltage
1	500 to 1,000
1 to 2	1,000 to 2,300
2 to 3	2,300 to 6,600
3 to 10	6,600 to 13,200
10 to 15	13,200 to 22,000
15 to 20	22,000 to 44,000
20 to 40	44,000 to 66,000
40 o 60	66,000 to 88,000
60 to 100	88,000 to 110,000

Mixed Current Systems.—It is often desirable to transmit electrical energy *in the form of alternating current, and distribute it as direct current or vice versa.*

Such systems may be classed as mixed current systems. The usual conversion is from alternating current to direct current because of the

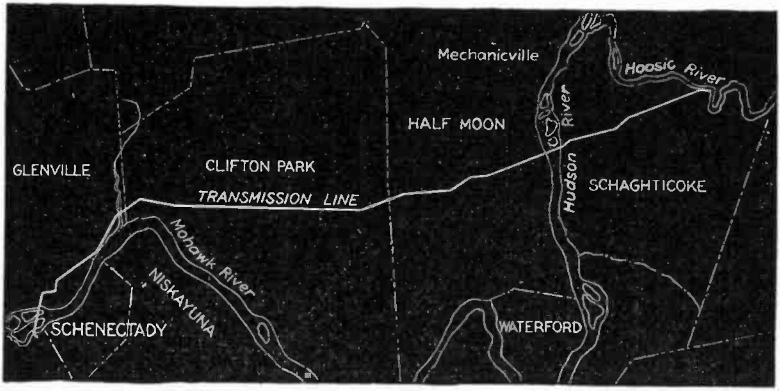


FIG. 5,043.—Course of the Schaghticoke-Schenectady transmission line of the Schenectady Power Co. This transmission line carries practically the entire output of the Schaghticoke power house to Schenectady, N. Y., a distance of approximately 21 miles. The line consists of two separate three phase, 40 cycle, 32,000 volt circuits, each of 6,000 *kw*. normal capacity. These circuits start from opposite ends of the power house, and, after crossing the Hoosic River, are transferred by means of two terminal towers, to a single line of transmission towers. The two circuits are carried on these on opposite ends of the cross arms, the three phases being superimposed. The power house ends of the line are held by six short quadrangular steel lattice work anchor poles with their bases firmly embedded in concrete, the cables being dead ended by General Electric disc strain insulators. This equipment has lightning arrester horn gaps and heavy line outlet insulators mounted on the roof of the power house. While each circuit carries only 6,000 *kw*. under normal conditions, either is capable of carrying the entire output of the station; in this case, however, the line losses are necessarily augmented. This feature prevents any interruption of the service from the failure of one of the circuits. There are altogether 197 transmission towers, comprising several distinct types.

saving in copper secured by the use of alternating current in transmission, especially in the case of long distance lines. Such conversion involves the use of a rotary converter, motor generator set, or rectifier, according to the conditions of service.

TEST QUESTIONS

1. *Give a classification of the various* a.c. *systems*
2. *What is nearly always used in* a.c. *systems?*
3. *Give two arrangements for step-down transformers.*
4. *Give examples for the use of individual transformers and one transformer for several customers.*
5. *Explain the various arrangements of single phase systems.*
6. *Give some points on the selection of alternators.*
7. *Can a three phase alternator be operated single phase?*
8. *How are alternators built to minimize eddy currents?*
9. *Name two systems for long distance transmission.*
10. *What are the objections to single phase systems?*
11. *Can three wires be employed on a two phase system?*
12. *Draw a diagram of a two phase two wire system.*
13. *Give the various wire arrangements on three phase systems.*
14. *Draw a diagram of a three phase star connected system.*
15. *Describe the three phase delta connected system.*
16. *Give comparison of star and delta connections.*
17. *What is an objection to the star connection for three phase work?*
18. *What can be done with the delta connection?*
19. *Give example illustrating change of frequency.*
20. *Name the usual transformation of phases.*

21. *How are phase transformations accomplished?*
22. *Give the relative weights of copper required by polyphase systems.*
23. *On what does the choice of voltage depend?*

CHAPTER 99

D.C. Wiring Calculations

All wires *will heat when a current of electricity passes through them.*

The greater the current or the smaller the wire, the greater will be the heating effect.

Large wires are heated comparatively more than small wires because the latter have a relatively greater radiating surface. Hence the necessity for calculating the proper size of wire to carry the load.

The temperature of a wire *increases approximately as the square of the current strength and inversely as the cube of the diameter of the wire.*

The elevation in temperature of a wire carrying a current represents so much lost energy.

From these considerations it must be clear that it is important not to overload conductors in order to secure efficient working, and to avoid risk of fire on inside installations.

Safe Carrying Capacity of Wire.—The Board of Underwriters specifies that the carrying capacity of a conductor is safe when the wire will conduct a certain current without becoming painfully hot.

In the following table of carrying capacities, prepared by the Underwriters, a wire is assumed to have a safe carrying capacity

*Safe Carrying Capacities of Wires

(Maximum amperes allowed by the Underwriters.)

Brown and Sharpe Gauge	Circular mils	Rubber insulation — Amperes	Other insulations — Amperes
18	1,624	3	5
16	2,583	6	10
14	4,107	15	20
12	6,530	20	25
10	10,380	25	30
8	16,510	35	50
6	26,250	50	70
5	33,100	55	80
4	41,740	70	90
3	52,630	80	100
2	66,370	90	125
1	83,690	100	150
0	105,500	125	200
00	133,100	150	225
000	167,800	175	275
0000	200,000	200	300
	211,600	225	325
	300,000	275	400
	400,000	325	500
	500,000	400	600
	600,000	450	680
	700,000	500	760
	800,000	550	840
	900,000	600	920
	1,000,000	650	1,000
	1,100,000	690	1,080
	1,200,000	730	1,150
	1,300,000	770	1,220
	1,400,000	810	1,290
	1,500,000	850	1,360
	1,600,000	890	1,430
	1,700,000	930	1,490
	1,800,000	970	1,550
	1,900,000	1,010	1,610
	2,000,000	1,050	1,670

when its temperature is not increased by the given current over 30° Fahr. above that of the surrounding air.

The lower limit is specified for rubber covered wires to prevent gradual deterioration of the high insulation by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the table on page 3,014.

The carrying capacity of Nos. 16 and 18 B. & S. gauge wire is given,

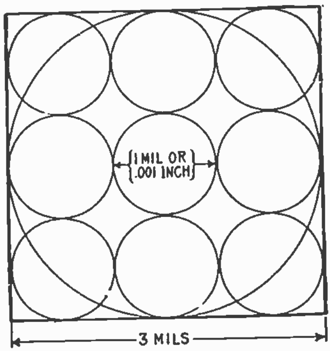


FIG. 5,044.—Diagram illustrating circular mils. The circular mil is used as a unit of cross sectional area in measuring wires. It is equal to the area of a circle .001 in. diameter; its value is .0000007854 square inch. In the figure the sum of the areas of the nine small circles equals the area of the large circle. This is evident from the following: Take the diameter of the small circles as unity, then the diameter of the large circle is three. Hence, the sum of the area of the small circles $\times (\frac{1}{4}\ \pi \times 1^2) \times 9 = .7854 \times 9 = 7.0686$; area of the large circle $= \frac{1}{4}\ \pi\ \times 3^2 = .7854 \times 9 = 7.0686$. Therefore since the area of the large circle equals the sum of the areas of the small circles, the area of a wire in circular mils is equal to *the square of its diameter expressed in mils*.

but no smaller than No. 14 is to be used, except as allowed under rules for fixture wiring.—*Underwriters' Rules.*

Circular Mils.—The unit of measurement in measuring the cross sectional area of wires is the *circular mil;* it is the area of a circle one mil (.001 in.) in diameter.

The area of a wire in circular mils is equal to the square of the diameter in mils.

*NOTE.—In the Chapter on Power Wiring Calculations, page 3,058, values are given for varnished cambric insulation.

Thus a wire 2 mils in diameter (.002 in.) has a cross sectional area of 2×2=4 circular mils. Accordingly to obtain the area of a wire in circular mils, *measure its diameter with a micrometer which reads directly in mils or thousandths of an inch, and square the reading.*

The circular mil (abbreviated *c.m.*) applies to all *round* conductors, and has a value of .7854 times that of the square mil, that is, 1 circular mil = .7854 square mil. If the diameter be expressed as a fraction of an inch, as for instance ⅓ in., the circular mil area may be found as follows: Reduce the fraction ⅓ to the decimal of an inch, multiply the result by 1,000 to express the diameter in mils, and square the diameter so expressed, thus: ⅓ = 1÷3 = .333. .333×1,000 = 333 mils; 333×333 = 110,889 circular mils.

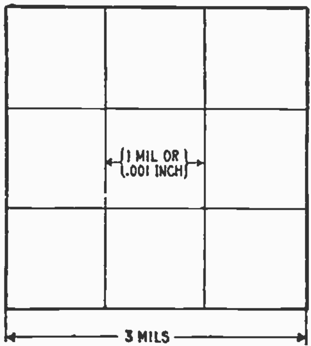


Fig. 5,045.—Diagram illustrating square mils. A square mil is a unit of area employed in measuring the areas of cross sections of square or rectangular conductors. It is equal to .000001 square inch. One square mil equals 1.2732 circular mils. The figure shows an area of nine square mils; this is equal to 9×1.2732 = 11.4588 circular mils.

The diameter of any wire may be found when its circular mil area is known by extracting the square root of the circular mil area.

Square Mils.—For measuring conductors of square or rectangular cross section, such as bus bars, copper ribbon, etc., the square mil is used. A square mil is the area of a square whose sides are one mil (.001 in. long) and is equal to .001×.001 = .000001 square inch.

Example.—A copper ribbon for a field coil measures ⅝ inch by ⅛ inch. What is its area in square mils? What is its area in circular mils?

$\frac{5}{8}$ = .625 in., or 625 mils; $\frac{1}{8}$ = .125 in., or 125 mils

Area in square mils = 625×125 = 78,125.

$$\text{Area in circular mils} = \left\{ \begin{matrix} 78{,}125 \div .7854 \\ \text{or } 78.125 \times 1.2732 \end{matrix} \right\} = 99{,}469$$

Mil Foot.—This unit is used as a basis for computing the resistance of any given wire. A mil foot means *a volume one mil in diameter and one foot long.*

The resistance of a wire of commercially pure copper one mil in diameter and one foot long is taken as a standard in calculating the resistance of wires, and has been found to be equal to 10.79 *ohms at* 75° *Fahr.*

The calculation is made according to the following rule.

The resistance of a copper wire is equal to its length in feet, multiplied by the resistance of one mil foot (10.79 *ohms*) *and divided by the number of circular mils, or the square of its diameter.*

Expressed as a formula:

$$\text{resistance in ohms} = \frac{\text{length of wire in ft.} \times 10.79}{\text{circular mils}} \quad \ldots\ldots (1)$$

Example—What is the resistance of a copper wire 1,500 feet long, and having a transverse area of 10,381 circular mils?

Substituting these values in formula (1)

$$\text{resistance} = \frac{1{,}500 \times 10.79}{10{,}381} = 1.559 \text{ ohms.}$$

The transverse area of a copper wire is found by multiplying the resistance of a mil foot (10.79) *by its length in feet and dividing the result by its resistance in ohms.*

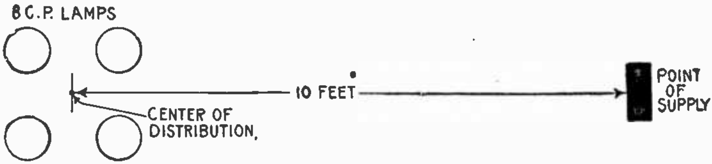
This is obtained directly from the formula (1) by solving the equation for circular mils, thus:

$$\text{circular mils} = \frac{\text{length of wire in ft.} \times 10.79}{\text{resistance in ohms}} \quad \ldots\ldots\ldots\ldots \text{(2)}$$

Example.—What is the circular mil area of a wire 1,500 feet long and having a resistance of 1.559 ohms?

Substituting the values in equation (2)

$$\text{circular mils} = \frac{1{,}500 \times 10.79}{1.559} = 10{,}381.$$



FIGS. 5,046 and 5,047.—Diagrams illustrating the meaning of the term lamp foot, and how to apply it in calculating a circuit. As defined, *one 16 candle power lamp at a distance of one foot from the fuse block or point of supply is called a lamp foot*; this is equivalent to one 8 candle power lamp at a distance of 2 feet, or one 32 candle power lamp one-half foot from the fuse block. In fig. 5,047, there are four 8 candle power lamps, and the distance to center of distribution is 10 feet. The circuit then contains $4 \div 2 \times 10 = 20$ lamp feet.

Lamp Foot.—This unit facilitates laying out wiring and calculating the drop. A lamp foot is defined as *one* 16 *candle power lamp at a distance of one foot from the point of supply.* Accordingly the number of lamp feet in any circuit is equal to the number of 16 candle power lamps (or equivalent in other sizes) in the circuit multiplied by the distance in feet from the fuse block to the center of distribution.

When no point is specified the feet are always measured from the supply point to the center of distribution. When other than 16 c.p.

lamps are in the circuit they must be reduced to 16 c.p. lamps. Thus two 8 c.p. lamps would be counted one 16 c.p. lamp, one 32 c.p. lamp would be counted two 16 c.p. lamps, etc.

Ampere Foot.—From the foregoing explanation of *lamp foot*, the significance of *ampere foot* is easily understood—the two terms are in fact self-defining.

An ampere foot may be defined as *the product of one ampere multiplied by one foot*.

The unit ampere foot is used in figuring motor circuits or currents designed to carry a mixed load.

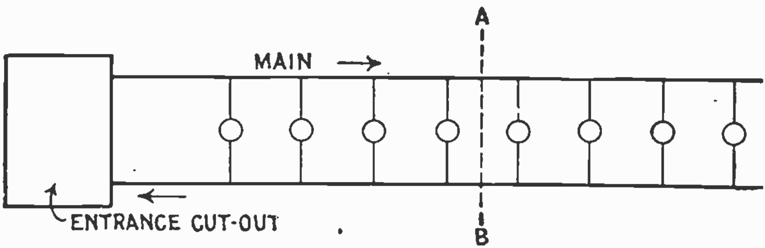


FIG. 5,048.—The center of distribution of a circuit coincides with the geometrical center of the group of lamps when the lamps are of uniform size and spaced equal distances apart. The center of distribution is here indicated by the dotted line A B.

The ampere feet of a main are found by *multiplying the maximum load in amperes by the distance from the fuse block to the electrical center of the load*.

Thus if the center of distribution be 50 feet from the fuse block and the maximum load be 9 amperes, the number of ampere feet is equal to $9 \times 50 = 450$

Electrical Center of Distribution.—The electrical center of a circuit depends upon the distances between the lamps and the fuse block; also the relative sizes of the lamps.

It may be defined as *the sum of the lamp feet for each section divided by the number of* 16 *candle power lamps in the circuit.*

If the lamps be of uniform capacity, and placed at equal distances apart, the center of distribution will coincide with the geometrical center of the group of lamps. However, if the lamps vary in size, and be irregularly spaced, the electrical center will not coincide with the geometrical center unless the lamps be symmetrically arranged so as to compensate for the difference in sizes and spacing.

In such cases, as shown in fig. 5,049, the electrical center can be determined by adding together the lamp feet of the several sections A,B,C,

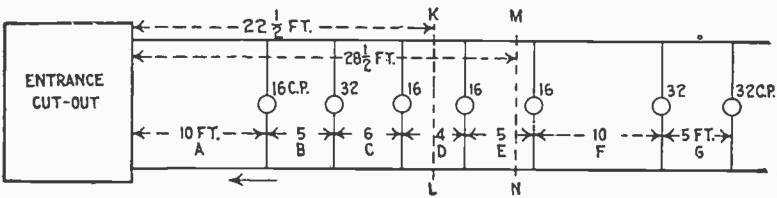


FIG. 5,049.—Diagram of an irregular circuit illustrating method of finding the center of distribution. Rule: *Divide the sum of the lamp feet for each section by the number of 16 candle power lamps or equivalent in the circuit*; the quotient gives the distance in feet from the fuse block to the center of distribution.

etc., of the main and dividing the result by the 16 c.p. units. Thus the lamp feet of

Section	A = 10	lamps	× 10	feet	=	100
"	B = 9	"	× 5	"	=	45
"	C = 7	"	× 6	"	=	42
"	D = 6	"	× 4	"	=	24
"	E = 5	"	× 5	"	=	25
"	F = 4	"	× 10	"	=	40
"	G = 2	"	× 5	"	=	10

which added together gives a total of............286 lamp feet. This when divided by the ten 16 c.p. units comprising four 16 c.p. lamps and three 32 c.p. lamps, gives a little over 28½ feet as the distance from the fuse block to the center of distribution, the position of which is shown by the line M N, in fig. 5,049, while that of the geometrical center is shown by the line K L.

When the center of distribution is at a considerable distance from the supply circuit, and it becomes advisable to divide the wiring into two distinct elements—a feeder and one or more mains, the junction of the feeder and the mains should be located at the electrical center of the mains whenever possible. When this is done, it is obvious that the wire size of only one-half the main needs to be calculated, as both halves of the main are identical.

Wire Calculations.—The problem of calculating the size of wire will be presented here in as simple a form as possible, with explanation of the various steps so that any one can understand how the formula is derived.

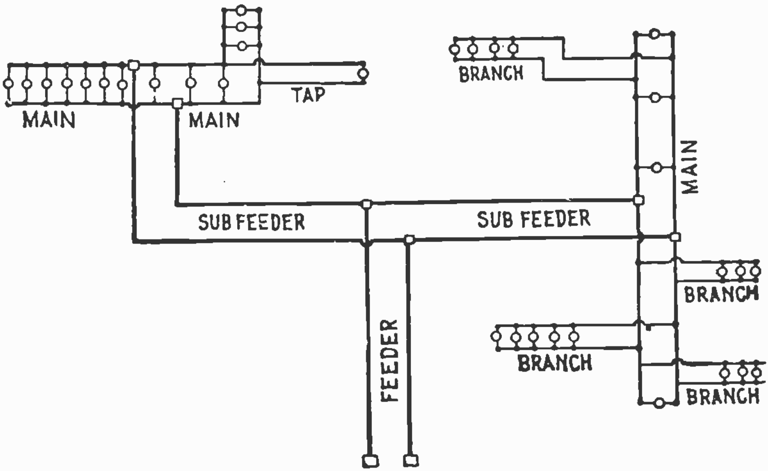
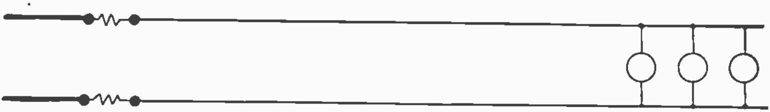


FIG. 5,050.—Circuit diagram illustrating names of the various parts. A circuit may consist of the following parts as defined in the accompanying text: 1, feeder; 2, sub-feeders; 3, mains; 4, branches; 5, taps. It is well to clearly distinguish between these divisions because the terms are constantly used in wiring.

In determining the size of wire, there are four known factors which enter into the calculation, viz.:

1. Length of circuit in feet;
2. Maximum current in amperes;
3. Drop or volts lost in the circuit, *in % of the impressed voltage;*



FIGS. 5,051 and 5,052.—Simplest forms of circuit, consisting of a main with one or more lamps at the end. The smallest size wire allowed (No. 14 B. & S. gauge) will generally be found amply large for such circuits. Note carefully the difference between a main and a branch by comparison with fig. 5,050. A main begins from a fuse block, while a branch is an offset from a main without any fuse block.

Lamp Table for Rubber Covered Wires

Showing the maximum number of 16 candle power 110 to 240 volt lamps in parallel that may be carried by the various sizes of wire without violating the Underwriters' rules.

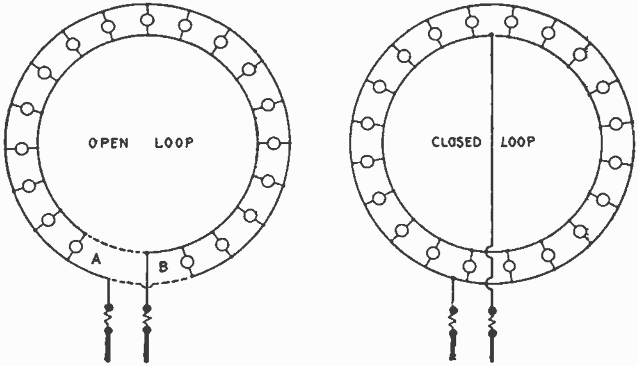
Wire size B. & S. gauge.	Amperes.	3.1-watt lamps		3.5-watt lamps.		4-watt lamps.		
		At 110 volts.	220 V.	At 110 volts.	220 V.	220 V.	230 V.	240 V.
0000	210	462	924	412	825	722	754	787
000	177	389	778	347	695	608	636	663
00	150	330	660	294	589	515	539	562
0	127	279	558	249	499	436	456	476
1	107	235	470	210	420	367	384	401
2	90	197	396	176	353	309	323	337
3	76	167	334	149	298	261	273	285
4	65	143	286	127	255	223	233	243
5	54	118	237	106	212	185	194	202
6	46	101	202	90	180	158	165	172
8	33	72	145	64	129	113	118	123
10	24	52	105	47	94	82	86	90
12	17	37	74	33	66	58	61	63
14	12	26	52	23½	47	41	43	45
16*	6	13	5*	11.	..	20	21	22

*This size can be used only in the shape of flexible cord.

4. Heating effect of the current.

The calculation is based on the *mil foot*, which as previously explained, is a foot of copper wire one mil in diameter and whose resistance is equal to 10.79 ohms at 75° Fahr.

The first step is to find an expression for the resistance of the wire which may be later substituted in Ohm's law formula.



FIGS. 5,053 and 5,054—Wrong and right methods of loop wiring. ***In general,*** when a large percentage of loss is allowed with lamps at short distances, the size of wire, calculated simply in accordance with the resistance rules, will be found too small to carry the current safely. This fact is often overlooked, and even though wires may have been correctly calculated for a uniform percentage of loss, they will become painfully hot simply because the table of carrying capacity was not consulted. The cross connection of mains wherever possible, for the purpose of equalizing the pressure, will also often reduce the heating effect of the current. An example of this is shown in the above figures. A circle of lights was wired as in fig. 5,053, and after the current had been turned on, the wires of the circle became hot, and there was quite a perceptible difference of candle power between the lights near A and those near B. Investigation disclosed the fact that the loop, contrary to instructions, had been left open. A few inches of wire as shown in dotted lines remedied the fault. A better arrangement, however, is shown in fig. 5,054.

Accordingly, the resistance of any conductor is equal to *its length in feet multiplied by its resistance per mil foot and the product divided by its area in circular mils*, thus:

$$\text{resistance in ohms} = \frac{\text{length in feet} \times \text{resistance per mil foot}}{\text{circular mils}}$$

or $$\text{ohms} = \frac{\text{feet} \times 10.8}{\text{circular mils}} \qquad (1)$$

(calling the resistance per mil foot 10.8 instead of 10.79 to facilitate calculation).

Now, according to Ohm's law,

$$\text{volts} = \text{amperes} \times \text{ohms} \qquad (2)$$

Lamp Table for Weather Proof Wires

Showing the maximum number of 16 candle power 120 to 240 volt lamps in parallel that may be carried by various sizes of weather proof wire without violating the Underwriters' rules.

Wire size B. & S. gauge.	Amperes.	3.1-watt lamps.		3.5-watt lamps.		4-watt lamps.		
		110 V.	220 V.	110 V.	220 V.	220 V.	230 V.	240 V.
0000	312	686	1372	612	1225	1072	1121	1170
000	262	576	1152	514	1029	900	941	982
00	220	484	968	432	864	756	790	825
0	185	407	814	363	726	636	665	693
1	156	343	686	306	612	536	560	585
2	131	288	576	257	514	450	470	491
3	110	242	484	216	432	378	395	412
4	92	202	404	180	361	316	330	345
5	77	169	338	151	302	264	276	288
6	65	143	286	127	255	223	233	243
8	46	101	202	90	180	158	165	172
10	32	70	140	62	125	110	115	120
12	23	50	101	45	90	79	82	86
14	16	35	70	31	62	55	57	60

hence, substituting in (2) the value for the resistance in ohms, as obtained in (1):

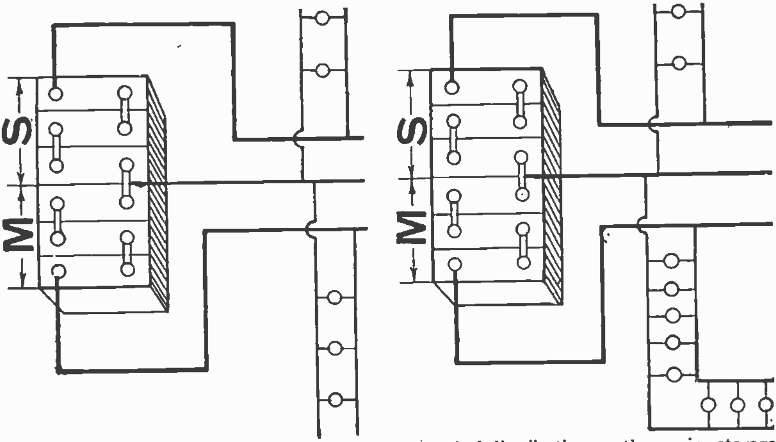
$$\text{volts} = \text{amperes} \times \frac{\text{feet} \times 10.8}{\text{circular mils}}$$

or using the usual symbols

$$E = I \times \frac{\text{feet} \times 10.8}{\text{circular mils}} \qquad (3)$$

Now, since the length of the circuit is given as the "run" or distance one way, that is, one half the total length of wire in the circuit, formula (3) must be multiplied by 2 to get the total drop, that is:

$$E = I \times \frac{\text{feet} \times 10.8 \times 2}{\text{circular mils}} = \frac{I \times \text{feet} \times 21.6}{\text{circular mils}} \qquad (4)$$



FIGS. 5,055 and 5,056.—Symmetrical and unsymmetrical distribution on three wire storage battery system, showing disadvantage of the arrangement for unequal loading. When each leg of the three wire system has the same load, as in fig. 5,055, each half of the battery as M and S, will discharge at the same rate. However, if a greater load be on one leg than the other as in fig. 5,056, the half M, of the battery will discharge at a higher rate than the half S.

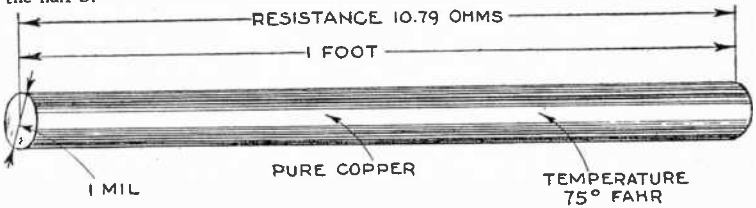


FIG. 5,057.—The mil foot pictured. This unit is used as a basis for computing the resistance of any given wire, as fully described on page 3,017.

Solving the last equation for the unknown quantity, the following equation is obtained for size of wire:

$$\text{circular mils} = \frac{\text{amperes} \times \text{ft.} \times 21.6}{\text{“drop”}} \quad \ldots\ldots\ldots(5)$$

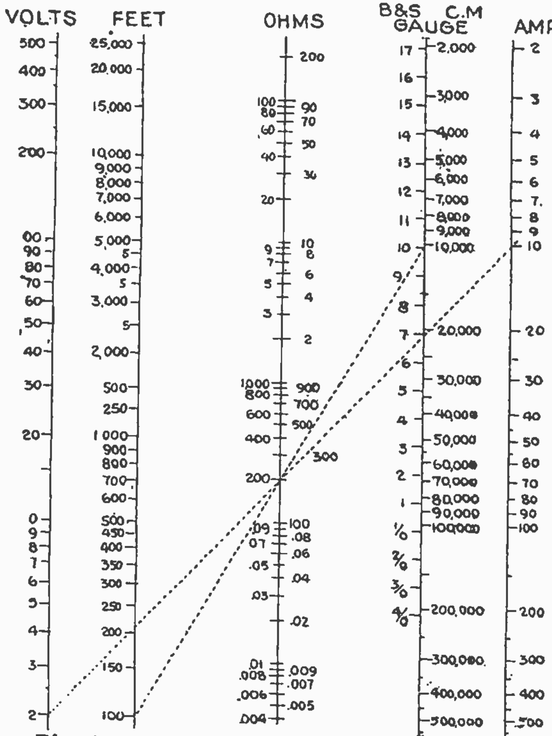


FIG. 5,058.— Chart for Calculating Wiring Circuits

For direct current, or for alternating current circuits of ordinary length and high power-factor, such as for incandescent lamps.

EXAMPLE—To find the size of wire to carry 10 amperes a distance of 100 feet with a 2 volt drop of potential.

SOLUTION—First—Place a straight edge on 2 volts on volts scale and 10 amperes on amperes scale. Read at point of intersection on ohms scale—which reading is 0.2 ohms.

Second—Place straight edge on 0.2 on ohms scale and 100 feet on feet scale and read at point of intersection on B. & S., C. M. Gauge—which reading is No. 10—the size of wire desired.

After the wire size has been calculated it is necessary to determine whether this wire will safely carry the current. Safe carrying capacities of wires, as given in the "National Electrical Code" of the National Board of Fire Underwriters, will be found in the tables on pages 12 to 22.

From this table we find that 10 amperes is permissible for No. 10 wire with any type of insulation.

Example:—What size wire should be used on a 250 volt circuit to transmit a current of 200 amperes a distance of 350 feet to a center of distribution with a loss of three per cent. under full load?

The volts lost or drop is equal to $250\times.03=7.5$ volts.

Substituting the given value in formula (5)

$$\text{circular mils}=\frac{350\times200\times21.6}{7.5}=201,600.$$

Diameter $=\sqrt{201,600}=449$ mils or .449 in.

From the table (on page 3,014 or on page 3,079) the nearest (*larger*) size of wire is 0000 B. & S. gauge.*

Properties of Copper Wire

Giving weights, length and resistances of wires of Matthiessen's Standard Conductivity for both B. & S. G. (Brown & Sharpe Gauge) and B. W. G. (Birmingham Wire Gauge) from Transactions October 1903, of the American Institute of Electrical Engineers.

Gauges. To the nearest fourth significent digit.				Weight. Lbs. per 1,000 feet.	Length.	Resistance.
		Diameter.	Area.		Feet per lb.	Ohms per 1,000 feet.
B. & S.	B. W. G.	Inches.	Circular mils			@ 68° F.
0000		0.460	211,600	640.5	1.561	.04893
	0000	0.454	206,100	623.9	1.603	.05023
	000	0.425	180,600	546.8	1 829	.05732
000		0.4096	167,800	508.0	1.969	.06170
	00	0.380	144,400	437.1	2.288	.07170
00		0.3648	133,100	402.8	2,482	.07780
	0	0.340	115,600	349.9	2.858	.08957
0		0.3249	105,500	319.5	3.130	.09811
	1	0.3000	90,000	272.4	3.671	.1150
1		0.2893	83,690	253.3	3.947	.1237
	2	0.2840	80,660	244.1	4.096	.1284
	3	0.2590	67,080	203.1	4.925	.1543
2		0.2576	66,370	200.9	4.977	.1560
	4	0.2380	56,640	171.5	5,832	.1828
3		0.2294	52,630	159.3	6.276	.1967
	5	0.2200	48,400	146.5	6.826	.2139
4		0.2043	41,740	126 4	7.914	.2480
	6	0 2030	41,210	124.7	8.017	.2513

*CAUTION.—The size thus obtained should be compared with the table of carrying capacity of wires as given on page 3,014 to see if the wires would have to carry more than the allowable current.

Properties of Copper Wire

(Continued)

Gauges. To the nearest fourth significant digit.				Weight. Lbs. per 1,000 feet.	Length.	Resistance.
		Diameter.	Area.		Feet per lb.	Ohms per 1,000 feet.
B. & S.	B. W. G.	Inches.	Circular mils			@ 68° F.
5		0.1819	33,100	100.2	9.980	.3128
	7	0.1800	32,400	98.08	10.20	.3196
	8	0.1650	27,230	82.41	12.13	.3803
6		0.1620	26,250	79.46	12.58	.3944
	9	0.1480	21,900	66.30	15.08	.4727
7		0.1443	20,820	63.02	15.87	.4973
	10	0.1340	17,960	54.35	18.40	.5766
8		0.1285	16,510	49.98	20.01	.6271
	11	0.1200	14,400	43.59	22.94	.7190
9		0.1144	13,090	39.63	25.23	.7908
	12	0.1090	11,880	35.96	27.81	.8715
10		0.1019	10,380	31.43	31.82	.9972
	13	0.0950	9,025	27.32	36.60	1.147
11		0.09074	8,234	24.93	40.12	1.257
	14	0.08300	6,889	20.85	47.95	1.503
12		0.08081	6,530	19.77	50.59	1.586
	15	0.07200	5,184	15.69	63.73	1.997
13		0.07196	5,178	15.68	63.79	1.999
	16	0.06500	4,225	12.79	78.19	2.451
14		0.06408	4,107	12.43	80.44	2.521
	17	0.0580	3,364	10.18	98.23	3.078
15		0.05707	3,257	9.858	101.4	3.179
16		0.05082	2,583	7.818	127.9	4.009
	18	0.04900	2,401	7.268	137.6	4.312
17		0.045260	2,048	6.200	161.3	5.055
	19	0.042000	1,764	5.340	187.3	5.870
18		0.040300	1,624	4.917	203.4	6.374
19		0.035890	1,288	3.899	256.5	8.038
	20	0.035000	1,225	3.708	269.7	8.452
	21	0.032000	1,024	3.100	322.6	10.11
20		0.031960	1,022	3.092	323.4	10.14
21		0.028460	810.1	2.452	407.8	12.78
	22	0.028000	784.0	2.373	421.4	13.21
22		0.025350	642.4	1.945	514.2	16.12
	23	0.025000	625.0	1.892	528.6	16.57

Properties of Copper Wire

(Concluded)

Gauges.	To the nearest fourth significent digit.			Weight. Lbs. per 1,000 feet.	Length.	Resistance.
		Diameter.	Area.		Feet per lb.	Ohms per 1,000 feet.
B. & S.	B. W. G.	Inches.	Circular mils			@ 68° F.
23		0.022570	509.5	1.542	648.4	20.32
	24	0.022000	484.0	1.465	682.6	21.39
24		0.020100	404.0	1.223	817.6	25.63
	25	0.020000	400.0	1.211	825.9	25.88
	26	0.018000	324.0	.9808	1,020	31.96
25		0.017900	320.4	.9699	1,031	32.31
	27	0.016000	256.0	.7749	1,290	40.45
26		0.015940	254.1	.7692	1,300	40.75
27		0.014200	201.5	.6100	1,639	51.38
	28	0.014000	196.0	.5933	1,685	52.83
	29	0.013000	169.0	.5116	1,955	61.27
28		0.012640	159.8	.4837	2,067	64.79
	30	0.012000	144.0	.4359	2,294	71.90
29		0.011260	126.7	.3836	2,607	81.70
30		0.010030	100.5	.3042	3,287	103.0
	31	0.010000	100.0	.3027	3,304	103.5
	32	0.009000	81.0	.2452	4,078	127.8
31		0.008928	79.70	.2413	4,145	129.9
	33	0.008000	64.0	.1937	5,162	161.8
32		0.007950	63.21	.1913	5,227	163.8
33		0.007080	50.13	.1517	6,591	206.6
	34	0.007000	49.0	.1483	6,742	211.3
34		0.006305	39.75	.1203	8,311	260.5
35		0.005615	31.52	.09543	10,480	328.4
36	35	0.005000	25.0	.07568	13,210	414.2
37		0.004453	19.83	.06001	16,660	522.2
	36	0.004000	16.	.04843	20,650	647.1
38		0.003965	15.72	.04759	21,010	658.5
39		0.003531	12.47	.03774	26,500	830.4
40		0.003145	9.888	.02993	33,410	1047.

NOTE.—It should be noted that the Underwriters prohibit the use of wire smaller than No. 14 B. & S. gauge, except as allowed for fixture work and pendant cord.

If the calculated size of wire be larger than any in the table, the required area is obtained by using two or more smaller wires in parallel, whose combined area is equal to the required area.

To facilitate finding the equivalent sizes the accompanying table of wire equivalents has been prepared.

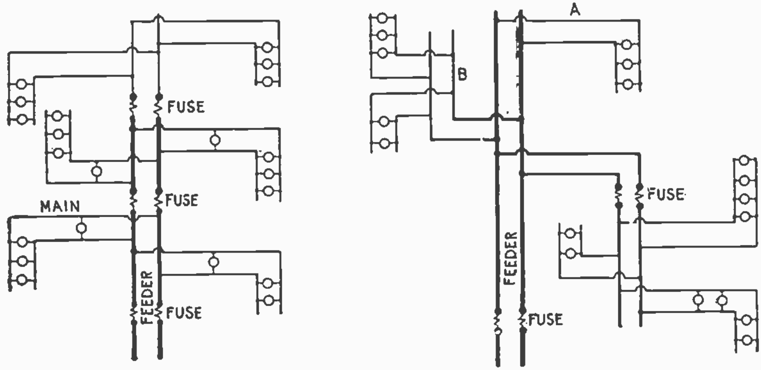
Table of Wire Equivalents

GAUGE B. & S.	NUMBER OF WIRES 2	4	8	16	32	64	128	256	512	1024	2048	4096	8192	16394
0000	0	3	6	9	12	15	18	21	24	27	30	33	36	39
000	1	4	7	10	13	16	19	22	25	28	31	34	37	40
00	2	5	8	11	14	17	20	23	26	29	32	35	38	0+6
0	3	6	9	12	15	18	21	24	27	30	33	36	39	1+7
1	4	7	10	13	16	19	22	25	28	31	34	37	40	2+8
2	5	8	11	14	17	20	23	26	29	32	35	38	3+9	4+6
3	6	9	12	15	18	21	24	27	30	33	36	39	4+10	5+7
4	7	10	13	16	19	22	25	28	31	34	37	40	5+11	6+8
5	8	11	14	17	20	23	26	29	32	35	38	6+12	7+9	
6	9	12	15	18	21	24	27	30	33	36	39	7+13	8+10	
7	10	13	16	19	22	25	28	31	34	37	40	8+14	9+11	
8	11	14	17	20	23	26	29	32	35	38	9+15	10+12		
9	12	15	18	21	24	27	30	33	36	39	10+16	11+13		
10	13	16	19	22	25	28	31	34	37	40	11+17	12+14		
11	14	17	20	23	26	29	32	35	38	12+18	13+15			
12	15	18	21	24	27	30	33	36	39	13+19	14+16			
13	16	19	22	25	28	31	34	37	40	14+20	15+17			
14	17	20	23	26	29	32	35	38	15+21	16+18				
15	18	21	24	27	30	33	36	39	16+22	17+19				
16	19	22	25	28	31	34	37	40	17+23	18+20				
17	20	23	26	29	32	35	38	18+24	19+21					
18	21	24	27	30	33	36	39	19+25	20+22					
19	22	25	28	31	34	37	40	20+26	21+23					
20	23	26	29	32	35	38	21+27	22+24						
21	24	27	30	33	36	39	22+28	23+25						
22	25	28	31	34	37	40	23+29	24+26						
23	26	29	32	35	38	24+30	25+27							
24	27	30	33	36	39	25+31	26+28							
25	28	31	34	37	40	26+32	27+29							
26	29	32	35	38	27+33	28+30								
27	30	33	36	39	28+34	29+31								
28	31	34	37	40	29+35	30+32								
29	32	35	38	30+36	31+33									
30	33	36	39	31+37	32+34									
31	34	37	40	32+38	33+35									
32	35	38	33+39	34+36										
33	36	39	34+40	35+37										
34	37	40	36+38											
35	38	37+39												
36	39	38+40												
37	40													

Figuring in Watts Instead of Amperes.—*The power required to operate most electrical appliances is marked in* ***watts.***

For instance, the standard incandescent lamp is rated as equivalent to the light given by 16 candles, and may consume, according to type and make, from 50 to 56 watts, or from 3.1 to 3.5 watts per candle power. Therefore, a 660 watt circuit will carry thirteen 16 candle power 49.6 watt lamps, or eleven 56 watt lamps.

The proper size of wire for a 660 watt circuit will depend upon the voltage for which the lamps are made. For example: a 16 candle power lamp which consumes 56 watts on 110 volt circuit will take, 56÷110=.5



FIGS. 5,059 and 5,060.—The "tree" and "modified tree" systems of wiring. The tree system consists of a feeder reducing in size and supplying mains for each floor, the general arrangement resembling the trunk and branches of a tree. Since fuses must be inserted on each floor where the size of the feeder is reduced, the system requires a large number of joints, and in the event of a fuse blowing it could not be quickly located. The tree system is not to be recommended, as it results in considerable drop, and at full load the lamps nearest the point of supply will either burn too brightly or those more remote will not give the rated candle power. In the modified tree system, fig. 5,060, the size of the feeder is not reduced. With this arrangement the losses are considerably reduced owing to the much smaller losses on the feeder between those centers farthest away from the point of supply.

or ½ ampere of current, while the same lamp, if made for 220 volts, will take only 55÷220=.25 or ¼ ampere. Therefore, eleven 16 candle power 56 watt lamps will require a current of 5½ amperes at 110 volts, or 2¾ amperes at 220 volts.

According to the laws of resistance, the resistance of a round wire is inversely proportional to the square of the diameter, and if the circuit be taken at 100 feet, and the allowable percentage of drop at 1 volt, then

Wiring Table for Light and Power Circuits

VOLTS		PERCENTAGE OF LOSS																
2000		1.7	1.5	1.4	1.2	1.1	1.0	0.75	0.5	0.45	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05
1000		3.4	2.9	2.7	2.4	2.2	2.0	1.5	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
500		6.5	5.7	5.2	4.8	4.3	3.9	2.9	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2
220		13.7	12.0	11.0	10.3	9.3	8.3	6.5	4.4	3.9	3.5	3.1	2.7	2.2	1.8	1.4	0.9	0.45
110		—	—	20.0	18.5	17.0	15.4	12.0	8.4	7.6	6.8	6.0	5.2	4.4	3.5	2.7	1.8	0.9
52		—	—	—	—	—	—	22.4	16.1	14.7	13.3	11.8	10.3	8.8	7.1	5.5	3.7	1.9
		ACTUAL VOLTS LOST																
*Carrying Capacity Amperes.	Size B. & S.	35	30	27.5	25	22.5	20	15	10	9	8	7	6	5	4	3	2	1
300	0000	345800	296400	271700	247000	222300	197600	148200	98800	88920	79040	69160	59280	49400	39520	29640	19760	9880
245	000	274400	235200	215600	196000	176400	156800	117600	78400	70560	62720	54880	47040	39200	31360	23520	15680	7840
215	00	217525	186450	170912	155375	139837	124300	93225	62150	55935	49720	43505	37290	31075	24860	18645	12430	6215
190	0	172550	147900	135575	123250	110925	98600	73950	49300	44370	39440	34510	29580	24650	19720	14790	9860	4930
160	1	136850	117300	107525	97750	87975	78200	58650	39100	35190	31280	27370	23460	19550	15640	11730	7820	3910
135	2	108500	93000	85250	77500	69750	62000	46500	31000	27900	24800	21700	18600	15500	12400	9300	6200	3100
115	3	86100	73800	67650	61500	55350	49200	36900	24600	22140	19680	17220	14760	12300	9840	7380	4920	2460
100	4	68250	58500	53625	48750	43875	39000	29250	19500	17550	15600	13650	11700	9750	7800	5850	3900	1950
90	5	54250	46500	42625	38750	34875	31000	23250	15500	13950	12400	10850	9300	7750	6200	4650	3100	1550
80	6	43050	36900	33825	30750	27675	24600	18450	12300	11070	9840	8610	7380	6150	4920	3690	2460	1230
60	8	26985	23130	21202	19275	17347	15420	11565	7710	6939	6168	5397	4626	3855	3084	2313	1542	771
40	10	16975	14550	13337	12125	10912	9700	7275	4850	4365	3880	3395	2910	2425	1940	1455	970	485
30	12	10675	9150	8388	7625	6862	6100	4575	3050	2745	2440	2135	1830	1525	1220	915	610	305
22	14	6720	5760	5280	4800	4320	3840	2880	1920	1728	1536	1344	1152	960	768	576	384	192
15	16	4235	3630	3328	3025	2723	2420	1815	1210	1089	968	847	726	605	484	363	242	121

according to formula, (5) on page 3,026, the wire required for a circuit carrying eleven 16 candle power 56 watt 110 volt lamps, will have a cross sectional area of,

$$\frac{5.5\times100\times21.6}{1}=11{,}880 \text{ circular mils}$$

while the same number of lamps on a 220 volt circuit will require wire having a cross sectional area of,

$$\frac{2.75\times100\times21.6}{1}=5{,}940 \text{ circular mils.}$$

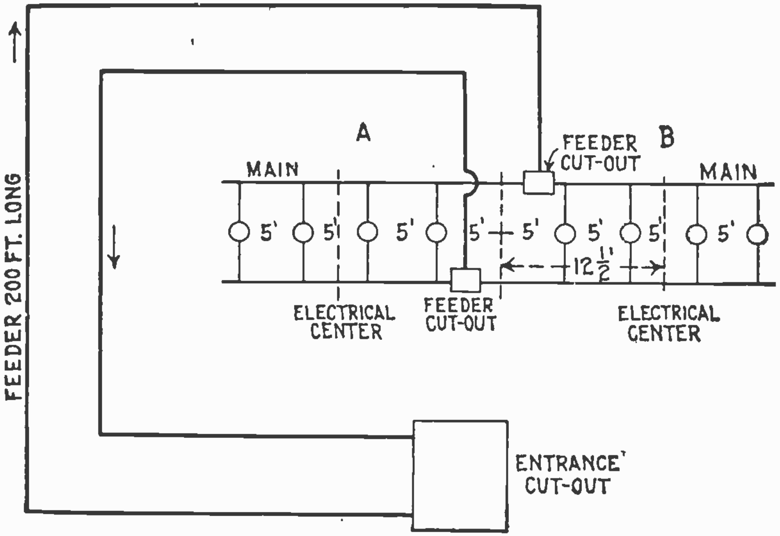


FIG. 5,061.—Wiring for lights requiring unusually long feeders.

In order to conform to the Underwriters' requirements, No. 8, B. & S. gauge wire must be used for the circuit carrying the 110 volt lamps, while No. 12, B. & S. wire, would be sufficient for the 220 volt circuit.

In the case shown in fig. 5,061, the branch circuits A and B, are identical, each supplying four 16 candle power lamps requiring 3.5 watts per candle power at 110 volts or carrying a load of 4×16×3.5=224 watts, =224÷110=2 *amperes*.

The distance from the feeder junction or cut out to the electrical center of each branch circuit is 12.5 *feet*. The compact area of distribution permits the reduction of the loss of volts to 1 per cent. or 110×.01=1.1 volts "drop." Then substituting in formula (5) on page 3,026 the values for *amperes*, *feet* and *drop* as obtained above

$$\frac{2\times25\times21.6}{1.1}=981 \text{ circular mils,}$$

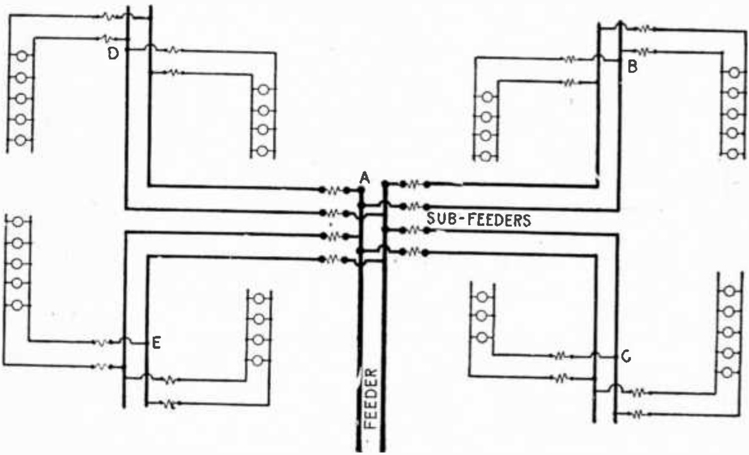


FIG. 5,062.—Distribution with sub-feeders (multi-center distribution). The feeder connects at a central point, A, with several sub-feeders which run to distributing centers, as at B, C, D, and E. With this arrangement, compound wound dynamos may be so designed that the pressure at A will remain nearly uniform for all loads. If, for instance, the wiring be proportioned for 2% drop, the dynamos may be over compounded to that extent, and the even illumination will compensate for the extra cost in the installation.

or a value far below that of even No. 18 wire, B. & S. gauge (see table on page 3,014), but the smallest wire allowed by the Underwriters for the mains A and B, is No. 14, B. & S. gauge.

NOTE.—*Size of the Neutral Wire.*—In three wire circuits, the size of the neutral wire will depend to a great extent upon operating conditions. In the case of installations which occasionally have to be worked as two wire systems, the cross section of the neutral wire should be equal to the combined cross section of the two outer wires. For interior wiring which must pass inspection, the neutral wire must always be twice the size of one of the outside wires.

In calculating the size of wire for the feeders the total load must be considered. This is equal to eight 16 candle power lamps, requiring 3.5 watts per candle power at 110 volts $=8\times16\times3.5=448$ watts $=4$ amperes.

The distance from the entrance cut out to the feeder cut out is 200 feet. The drop should not be greater than 1.5 per cent. or $110\times1.5=$ 1.6 volts. Then,

$$\frac{4\times200\times21.6}{1.6}=10{,}800 \text{ circular mils}$$

a value which indicates that No. 8 wire, B. & S. gauge, must be used for the feeders in order to keep the drop within the limit of predetermined value.

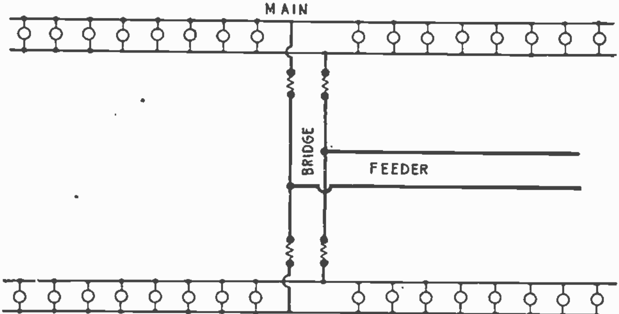


FIG. 5,063.—Diagram showing "bridge wiring." This method is used in the case of two parallel mains where one feeder is ample for both. The feeder is run to a central point as shown and connected to the two mains by a so called "bridge." The arrangement clearly gives good distribution and effects a saving in copper and labor, for if the bridge were omitted two feeders would be necessary.

Table for Taps, Bridges or Other Wires at Negligible Drop

Wire Nos.	0	1	2	3	4	5	6	7	8	10	12	14	16	18
Lamp Feet 52 v.	300	260	200	160	130	100	80	65	50	38	24	15	9	6
Lamp Feet 110 v.	1,280	1,085	860	680	560	435	345	280	220	160	100	60	40	25

NOTE.—In using this table, it is only necessary to calculate the lamp feet of the tap and take the size of wire corresponding to the nearest greater number of lamp feet in the table. The lamp feet specified by this table should not be exceeded by more than 10 per cent. Thus, if a tap measure 108 lamp feet, in 110 volt lamps, No. 12 wire would be used, but if it measure 115 lamp feet, it would be advisable to use No. 10 wire.

Calculations for Three Wire Circuit.—In all cases of interior conduit work, and in most cases of inside open work, the main feeders from a three wire source of supply are installed on the three wire plan, and the sub-feeders and distributing mains, on the two wire plan, except where the application of the method necessitates the use of unwieldy sizes.

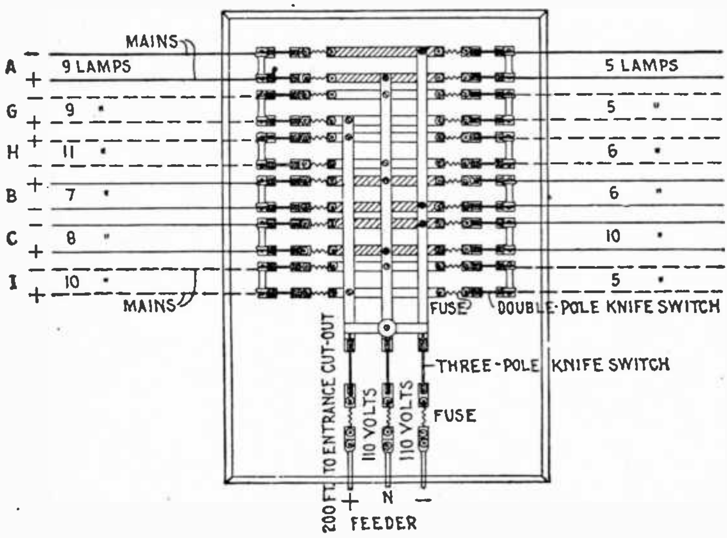


FIG. 5,064.—Three wire circuit panel board with connections for 12 mains. The wires shown in solid lines as A, B, C, etc., are connected between the neutral wire and the negative wire of the feeder, and those shown by dotted lines, as G, H, I, etc., are connected between the neutral wire and the positive wire of the feeder.

In laying out sub-feeders and mains, the total load, under normal operating conditions, should be divided as nearly as possible into two equal parts, and one part connected on each side of the neutral part of the entrance cut out, or the neutral bus bar of the switch board or panel board in an isolated plant, thus making the load on each side of the neutral wire of the feeder as near equal as possible.

Fig. 5,064 shows a three wire panel board with connection for 12 mains;

those shown in solid lines as A,B,C, etc., being connected between the neutral wire and the negative wire of the feeder, and those shown by dotted lines as G, H, I, etc., being connected between the neutral wire and the positive wire of the feeder. The total load consists of ninety-one 16 candle power lamps, which are so distributed that the positive wire of the feeder carries the current for 46 lamps, and the negative wire, 45 lamps, the neutral wire carrying the difference or current for 1 lamp.

The proper size of wire for the mains may be calculated as already explained, but in calculating the outer wires of the three wire feeder, the neutral wire should be disregarded and the outer wires connected as a *two wire circuit carrying the total load of* 91 *lamps at the over all pressure of* 220 *volts*.

Example.—Ninety-one 16 candle power lamps consuming 3.1 watts per candle power at a pressure of 110 volts, will require a current of

$$\frac{16\times3.1\times91}{110}=41 \text{ amperes.}$$

The distance from the entrance cut out to the main or feeder switch is 200 feet, then for a 2 per cent. drop, or a loss of $110\times.02=2.2$ volts, the cross sectional area of the wire will be

$$\frac{41 \text{ amperes}\times200 \text{ feet}\times21.6}{2.2 \text{ volts}}=80{,}509 \text{ circular mils.}$$

The joint resistance of the lamps on a three wire system, however, would be four times greater than on a two wire system; consequently the resistance of the outer wires of the feeder in this case will be four times greater for the same percentage of loss, and the cross sectional area of each of the outer wires will be, $80{,}509\div4=20{,}127$ circular mils. According to the Underwriters' rules, this value compels the use of No. 6 B. & S. gauge wire.

If the *lamp* voltage, 110 volts, be used, the two wire formula (5) given on page 3,026 must be modified to

$$\text{circular mils}=\frac{\text{amperes}\times\text{feet}\times21.6}{\text{drop}\times4}$$

but if an *over all* voltage (that. is, the voltage between the outer wires), of 220 volts be used, the two wire formula does not require any modification.

The proper size of wire may also be calculated by means of the formula

$$\frac{\text{drop}}{2 \times \text{distance} \times \text{amperes}} = \text{resistance per foot} \quad \ldots\ldots\ldots\ldots (1)$$

Example.—If in calculating a three wire feeder, the over all voltage be 220 volts, the drop = 4.4 volts, twice the distance = 400 feet, and the current = 20.5 amperes, then,

$$\frac{4.4 \text{ volts}}{400 \text{ feet} \times 20.5 \text{ amperes}} = .0005366 \text{ ohms per foot.}$$

In the table of the properties of copper wire which gives the resistance of various sizes of wire, it will be noted that at all of the given temperatures No. 8 wire has a resistance greater than the value just calculated, therefore, No. 6 B. & S. gauge wire should be used for the outer wires of the feeder. In the table the resistance is given per 1,000 feet, hence it is only necessary to move the decimal point to obtain the resistance per foot. This table is shown on pages 3,027 to 3,029.

If the calculation be based on the lamp voltage, 110 volts, the formula (1) must be modified to

$$\frac{\text{drop} \times 4}{2 \times \text{distance} \times \text{amperes}} = \text{resistance} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In this case, drop = 2.2 volts, 2 × distance = 400 feet, and current = 41 amperes, then,

$$\frac{2.2 \text{ volts} \times 4}{400 \text{ feet} \times 41 \text{ amp.}} = \frac{8.8}{16,400} = .005366 \text{ ohms.}$$

Size of the Neutral Wire.—In three wire circuits, the size of the neutral wire will depend to a great extent upon operating conditions. In the case of installations which occasionally have to be worked as two wire systems, the cross section of the neutral wire should be equal to the combined cross section of the two outer wires.

For interior wiring which must pass inspection, the neutral wire must always be twice the size of one of the outside wires. However, for general distribution, if it be reasonably sure that the system will always be worked three wire and that the drop in the two outer wires does not exceed 1½ per cent., the cross section of the neutral wire may be made smaller than that of one of the outer wires. In such a case the size of the neutral wire may be calculated for a maximum unbalancing of 25 per cent., when the current in one of the outer wires is 75 per cent. of the current in the other outer wire.

For instance, suppose that in a balanced system, the total load on each of the outer wires of a feeder be 211 amperes, and that on account of certain operating conditions, this load has to be divided unequally so as to put 242 amperes on one of the outer wires, and 181 amperes on the other outer wire. In this case the neutral wire will carry 61 amperes, or 25 per cent. of the current carried by the heavier outer wire.

If the drop in the outer wires exceed 1½ per cent., the cross section of the neutral wire will have to be equal to or larger than that of each of the outer wires, otherwise the drop in the neutral wire will exceed ½ volt with an unbalancing of 25 per cent.

Figuring in Watt Feet.—By definition a *watt foot* is *the product of one watt multiplied by one foot*; it is a convenient unit for quick calculation with the aid of tables.

30 Volts

Rule.—To find the size of wire to carry a given number of watts a given distance, on 30 volt circuits, *multiply the distance in feet by the total number of watts to be carried (thus obtaining the watt feet), and use the size of wire in the table specified for the nearest number of watt feet.*

Table of Watt Feet for 30 Volts

Between	0	and	18,870	watt ft.	use	No.	12	wire
"	18,870	"	29,000	"	"	"	10	"
"	29,000	"	46,545	"	"	"	8	"
"	46,545	"	73,018	"	"	"	6	"
"	73,018	"	116,363	"	"	"	4	"
"	116,363	"	186,180	"	"	"	2	"
"	186,180	"	232,727	"	"	"	1	"
"	232,727	"	290,000	"	"	"	0	"
"	290,000	"	372,362	"	"	"	00	"

Example.—Ten 20 watt lamps are to be installed in a barn 200 ft. distant. What size wire is required for a 30 volt circuit?

Load = 10×20×200 = 40,000 watt ft. Nearest size wire from table is No. 8.

110 Volts

Rule.—*In using the table just given for* 110 *volts multiply either the watts or the distance by* 3⅔, because for a given load the current is reduced 110÷30 = 3⅔ times as compared with 30 volts.

TEST QUESTIONS

1. *What happens when a current of electricity passes through a wire?*
2. *How does the temperature of the wire increase with respect to the current?*
3. *How is the safe carrying capacity of wire determined?*
4. *What is a circular mil?*
5. *Define mil foot and lamp foot, also ampere foot.*
6. *Explain the electrical center of distribution, and how it is calculated.*
7. *Name four known factors which enter into the calculation of wire sizes.*
8. *Explain fully the method of calculating wire sizes.*
9. *What is the meaning of the factor* **10.8,** *also* **21.6** *in the equations?*
10. *Draw diagrams showing symmetrical and un-symmetrical distribution.*
11. *What precaution should be taken in checking calculated wire sizes?*
12. *What may be done if the calculated size of wire be larger than in the table?*
13. *Describe the method of figuring in watts.*
14. *Upon what does the proper size of wire for a* 660 *watt circuit depend?*
15. *What is the difference between the "tree" and "modified tree" system of wiring?*
16. *Draw a diagram illustrating distribution with sub-feeders (multi-center distribution).*
17. *Upon what does the size of the neutral wire depend?*

18. *Draw diagram illustrating the bridge system of wiring.*
19. *What portion of an interior wiring system is usually made three wire?*
20. *Draw a diagram of a three wire circuit panel board with connections for 12 mains.*
21. *Describe the method of calculating wire sizes for three wire system.*
22. *How is the size of the neutral wire calculated?*
23. *Explain the method of figuring in watt feet.*

CHAPTER 100

A. C. Wire Calculations

In the calculation of alternating current circuits, the two chief factors which make the computation different from that for direct current circuits, are:

1. *Induction* and
2. *Power factor.*

The first depends upon the frequency, and physical condition of the circuit, and the second upon the character of the load.

Induction may be neglected in cases where the wires of a circuit are not spaced over an inch apart, or in conduit work, where both wires are in the same conduit. Induction must be considered on exposed circuits with wires separated several inches, especially with large wires.

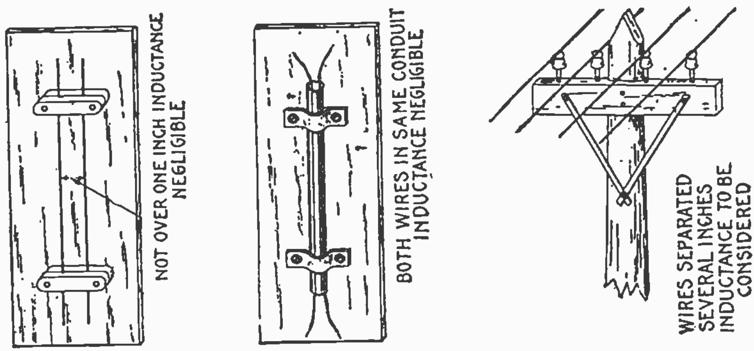
The size of wire for any alternating circuit may be determined by slightly modifying the formula used in direct current work, which as derived on page 3,026, is:

$$\text{circular mils} = \frac{\text{amperes} \times \text{feet} \times 21.6}{\text{drop}} \qquad (1)$$

The quantity 21.6 is twice the resistance (10.8) of a foot of copper wire one mil in diameter (*mil foot*). This resistance (10.8) is multiplied by 2, giving the quantity 21.6, because the length of a circuit, or feet in the formula, is given as the "run" or distance one way, that is, one-half the total length of wire in the circuit, must be multiplied by 2 to get the total drop, viz.:

$$\text{circular mils} = \frac{\text{amperes} \times \text{feet} \times 10.8 \times 2}{\text{drop}} = \frac{\text{amperes} \times \text{feet} \times 21.6}{\text{drop}}$$

It is however, sometimes convenient to make the calculation in terms of watts. Formula (1) may be modified for such calculation.



FIGS. 5,065 to 5,067.—Example of wiring showing where inductance is negligible, and when it must be considered in wire calculation.

In modifying the formula, the "drop" should be expressed in percentage instead of actual volts lost, that is, instead of the difference in pressure between the beginning and the end of the circuit.

In any circuit the loss in percentage, or

$$\%\ \text{loss} = \frac{\text{drop}}{\text{impressed pressure}} \times 100$$

from which

$$\text{drop} = \frac{\%\ \text{loss} \times \text{impressed pressure}}{100} \quad \ldots\ldots (2)$$

Substituting equation (2) in equation (1)

$$\text{circular mils} = \frac{\text{amperes} \times \text{feet} \times 21.6}{\dfrac{\%\ \text{loss} \times \text{imp. pressure}}{100}}$$

$$= \frac{\text{amperes} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{imp. pressure}} \quad \ldots\ldots (3)$$

Equation (3) is modified for calculation in terms of watts as follows: The power in watts is equal to the *applied voltage* multiplied by the current, that is to say, the power is equal to the *volts at the consumer's end of the circuit multiplied by the current*, or simply

$$\text{watts} = \text{volts} \times \text{amperes}$$

from which

$$\text{amperes} = \frac{\text{watts}}{\text{volts}} \quad \ldots\ldots (4)$$

Substituting this value for the current in equation (3) and remembering that the pressure taken is the volts at the consumer's end of the line

$$\text{circular mils} = \frac{\dfrac{\text{watts}}{\text{volts}} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{volts}}$$

$$= \frac{\text{watts} \times \text{feet} \times 2{,}160}{\%\ \text{loss} \times \text{volts}^2} \quad \ldots\ldots (5)$$

This formula (5) applies to a direct current two wire circuit. and to adapt it to any alternating current circuit it is only necessary to use the letter M, instead of the number 2,160, thus

$$\text{circular mils} = \frac{\text{watts} \times \text{feet} \times M}{\% \text{ loss} \times \text{volts}^2} \quad ..(6)$$

in which M, is a coefficient which has various values according to the kind of circuit and value of the power factor. These values are given in the following table:

Values of M.

SYSTEM	POWER FACTOR									
	1.00	.98	.95	90	85	80	.75	.70	.65	.60
Single phase	2,160	2,249	2,400	2,660	3,000	3,380	3,840	4,400	5,112	6,000
Two phase (4 wire)	1,080	1,125	1,200	1,330	1,500	1,690	1,920	2,200	2,556	3,000
Three phase (3 wire)	1,080	1,125	1,200	1,330	1,500	1,690	1,920	2,200	2,556	3,000

It must be evident that when 2,160 is taken as the value of M, formula (6) applies to a two wire direct current circuit and also to a single phase alternating current circuit when the power factor is unity.

In the table the value of M, for any particular power factor is found by dividing 2,160 by the square of that power factor for single phase and twice the square of the power factor for two phase and three phase.

Since the two phase system is virtually two single phase systems, the four wires of the two phase system are half the size of the two wires of the single phase system, and accordingly, the weight is the same for either system, when the load, voltage and power factor are the same in each case.

***Values of T.**

System	Power Factor				
	1.00	.98	90	.80	.70
Single phase..........	1.00	.98	.90	.80	.70
Two phase, 4 wire.....	2.00	1.96	1.80	1.60	1.40
Three phase, 3 wires...	1.73	1.70	1.55	1.38	1.21

Although there is no saving in copper in using two phases, the two phase system has the advantage over the one phase system in that it is more desirable on power circuits, because two phase motors are self-starting.

That is to say, the rotating magnetic field that can be produced by a two phase current, permits an induction motor to start without being equipped with any special phase splitting devices which are necessary on single phase motors, because the oscillating field produced by a single phase current does not produce any torque on a squirrel cage armature at rest.

*NOTE.—*This table* is for finding the value of the current in line, using the formula, I = W ÷ (E × T), in which I = current in line; E = voltage between main conductors at receiving or consumers' end; W = watts. For instance, what is the current in a two phase line transmitting 1,000 watts at 550 volts, power factor .80? I = 1,000 ÷ (550 × 1.60) = 1.13.

The following is a comparison between the single, two and three phase systems as to size and weight of wires:—

Each wire of the three phase system is half the size of one of the wires of the single phase system, hence the weight of copper required for the three phase system is 75% of that required for the single phase system.

Since in the two phase system half of the load is carried by each phase, each wire of the three phase system is the same size as one of the wires of the two phase system, hence, the copper required by the three phase system is 75% of that required by the two phase system.

Example.—What size wires must be used on a single phase circuit 2,000 feet in length to supply 30 *kw*. at 220 volts with loss of 4%, the power factor being .9?

The formula for circular mils is

$$\text{circular mils} = \frac{\text{watts} \times \text{feet} \times M}{\% \text{ loss} \times \text{volts}^2} \quad \cdots\cdots (1)$$

Substituting the given values and the proper value of M, from the table in (1)

$$\text{circular mils} = \frac{30{,}000 \times 2{,}000 \times 2{,}660}{4 \times 220^2} = 82{,}438$$

Referring to the table of the properties of copper wire, (pages 3,027 to 3,029) the nearest *larger* size wire is No. 1 B. & S. gauge having an area of 83,690 circular mils.

Drop.—In order to determine the drop or volts lost in the line, the following formula may be used:

$$\textbf{drop} = \frac{\% \text{ loss} \times \text{volts}}{100} \times S \quad \cdots\cdots (1)$$

in which the % loss is a percentage of the applied power, that is, the power delivered to the consumer and not a percentage of the power at the alternator. "Volts" is the pressure at the consumer's end of the circuit.

Value of "S" for 60 Cycles

Size of wire B. & S. gauge	Area in circular mils.	.98 power factor — Spacing of conductors 1″	3″	6″	12″	24″	.90 power factor — Spacing of conductors 1″	3″	6″	12″	24″	.80 power factor — Spacing of conductors 1″	3″	6″	12″	24″	.70 power factor — Spacing of conductors 1″	3″	6″	12″	24″
500,000	500,000	1.21	1.45	1.61	1.77	1.92	1.32	1.80	2.11	2.44	2.75	1.27	1.89	2.25	2.64	3.03	1.14	1.72	2.12	2.53	2.92
300,000	300,000	1.15	1.29	1.38	1.48	1.57	1.19	1.47	1.66	1.84	2.02	1.11	1.46	1.68	1.90	2.12	1.00	1.33	1.56	1.78	2.01
0,000	211,600	1.12	1.22	1.28	1.34	1.41	1.13	1.33	1.45	1.58	1.63	1.03	1.27	1.43	1.58	1.75	1.00	1.14	1.29	1.45	1.69
000	167,800	1.09	1.18	1.22	1.28	1.29	1.08	1.23	1.33	1.44	1.53	1.00	1.16	1.28	1.41	.153	1.00	1.02	1.15	1.28	1.50
00	133,100	1.07	1.14	1.18	1.21	1.25	1.03	1.16	1.24	1.32	1.40	1.00	1.07	1.17	1.27	1.36	1.00	1.00	1.03	1.13	1.21
0	105,500	1.05	1.10	1.14	1.17	1.20	1.00	1.09	1.16	1.22	1.28	1.00	1.00	1.07	1.15	1.22	1.00	1.00	1.00	1.01	1.09
1	83,690	1.04	1.08	1.10	1.13	1.15	1.00	1.05	1.09	1.14	1.19	1.00	1.00	1.00	1.05	1.11	1.00	1.00	1.00	1.00	1.00
2	66,370	1.02	1.05	1.08	1.10	1.12	1.00	1.00	1.04	1.08	1.12	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.00	1.00
3	52,630	1.02	1.04	1.06	1.07	1.09	1.00	1.00	1.00	1.03	1.06	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4 5	41,740 33,100	1.00	1.02	1.03	1.04	1.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6 7	26,250 20,820	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8 9 10	16,510 13,090 10,380	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The coefficient S, has various values as given in the accompanying tables. As will be seen from the table, the value of S, to be used depends upon the size of wire, spacing, power factor and frequency.

These values are accurate enough for all practical purposes, and may be used for distances of 20 miles or less and for voltages up to 25,000.

The capacity effect on very long high voltage lines, makes this method of determining the drop somewhat inaccurate beyond the limits above mentioned.

Example.—A circuit supplying current at 440 volts, 60 frequency, with 5% loss and .8 power factor is composed of No. 2 B. & S. gauge wires spaced one foot apart. What is the drop in the line?

Value of "S" for 25 Cycles

Size of wire B. & S. gauge	Area in circular mils.	.98 power factor					.90 power factor					.80 power factor					.70 power factor				
		Spacing of conductors					Spacing of conductors					Spacing of conductors					Spacing of conductors				
		1"	2"	6"	12"	24"	1"	3"	6"	12"	24"	1"	3"	6"	12"	24"	1"	3"	6"	12"	24"
500,000	500,000	1.01	1.17	1.23	1.29	1.36	1.02	1.22	1.35	1.43	1.61	1.00	1.15	1.30	1.47	1.62	1.00	1.00	1.16	1.33	1.49
300,000	300 000	1.04	1.10	1.13	1.18	1.21	1.00	1.08	1.16	1.25	1.31	1.00	1.00	1.09	1.16	1.25	1.00	1.00	1.00	1.02	1.12
0,000	211,600	1.03	1.07	1.09	1.11	1.14	1.00	1.02	1.07	1.13	1.15	1.00	1.00	1.00	1.03	1.10	1.00	1.00	1.00	1.00	1.00
000	167,800	1.00	1.05	1.06	1.09	1.10	1.00	1.00	1.02	1.07	1.11	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.00	1.00
00	133,100	1.00	1.03	1.05	1.06	1.08	1.00	1.00	1.00	1.02	1.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0	105,500	1.00	1.01	1.02	1.03	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1 2 3	83,690 66,370 52,630	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4 5 6	41,740 33,100 26,250	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7 8 9 10	20,820 16,510 13,090 10,380	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

According to the formula

$$\text{drop} = \frac{\%\ \text{loss} \times \text{volts}}{100} \times S$$

Substituting the given values, and value of S, as obtained from the table for frequency 60

$$\text{drop} = \frac{5 \times 440}{100} \times 1 = 22 \text{ volts}$$

Current.—As has been stated, the effect of power factor less than unity, is *to increase the current*; hence, in inductive circuit calculations, the first step is to determine the current flowing in a circuit. This is done as follows:

$$\text{current} = \frac{\text{apparent load}}{\text{volts}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

and

$$\text{apparent load} = \frac{\text{watts}}{\text{power factor}} \quad \text{. . . . .} \quad (2)$$

Stranded Copper Conductors

Capacity of Conductor, C. M.	Number of Wires in the Strand									
	7	19	37	(7x7) 49	61	91	127	(19x7) 133	169	217
	Diameter of Each Wire in the Strand in Decimal Parts of an Inch									
2,000,000	.5345	.3243	.2325	.2020	.1810	.1482	.1255	.1226	.1088	.0960
1,750,000	.5000	.3034	.2175	.1889	.1694	.1386	.1174	.1147	.1018	.0898
1,500,000	.4629	.2810	.2013	.1750	.1568	.1284	.1087	.1062	.0942	.0831
1,250,000	.4226	.2565	.1838	.1597	.1431	.1172	.0992	.0969	.0862	.0759
1,000,000	.3780	.2294	.1644	.1429	.1280	.1048	.0887	.0867	.0760	.0679
950,000	.3684	.2236	.1602	.1392	.1248	.1021	.0864	.0845	.0750	.0662
900,000	.3586	.2176	.1559	.1355	.1215	.0994	.0841	.0822	.0730	.0644
850,000	.3484	.2115	.1516	.1317	.1181	.0966	.0818	.0799	.0709	.0626
800,000	.3380	.2052	.1470	.1278	.1145	.0937	.0794	.0776	.0688	.0607
750,000	.3273	.1986	.1424	.1237	.1109	.0908	.0768	.0751	.0666	.0588
700,000	.3163	.1919	.1375	.1195	.1071	.0877	.0742	.0726	.0644	.0568
650,000	.3047	.1850	.1325	.1152	.1032	.0845	.0716	.0699	.0620	.0547
600,000	.2928	.1776	.1273	.1107	.0992	.0812	.0687	.0672	.0596	.0526
550,000	.2803	.1701	.1219	.1049	.0950	.0777	.0658	.0643	.0570	.0503
500,000	.2672	.1622	.1162	.1010	.0905	.0741	.0627	.0613	.0544	.0480
450,000	.2535	.1539	.1103	.0958	.0859	.0703	.0595	.0581	.0516	.0455
400,000	.2391	.1451	.1040	.0904	.0810	.0663	.0561	.0548	.0487	.0429
350,000	.2236	.1357	.0973	.0845	.0757	.0620	.0526	.0513	.0455	.0401
300,000	.2070	.1257	.0901	.0783	.0701	.0573	.0486	.0475	.0421	.0372
250,000	.1890	.1147	.0822	.0714	.0640	0524	.0444	.0435	.0384	.0340
Size Am. Wire Gauge (B. & S.)										
0000	.1736	.1055	.0756	.0657	.0589	.0482	.0408	.0399	.0354	.0312
000	.1548	.0940	.0673	.0586	.0525	.0429	.0363	.0355	.0315	.0278
00	.1378	.0836	.0599	.0521	.0467	.0382	.0323	.0316	.0281	.0248
0	.1228	.0746	.0534	.0464	.0416	.0340	.0288	.0282	.0250	.0221
1	.1093	.0663	.0475	.0413	.0370	.0303	.0252	.0251	.0222	.0196
2	.0973	.0592	.0423	.0369	.0329	.0269	.0228	.0224	.0199	.0175
3	.0867	.0526	.0377	.0327	.0294	.0240	.0203	.0199	.0176	.0156
4	.0772	.0468	.0335	.0290	.0261	.0214	.0179	.0177	.0157	.0139
5	.0687	.0417	.0299	.0259	.0233	.0190	.0161	.0158	.0140	.0121
6	.0612	.0372	.0266	.0231	.0207	.0169	.0143	.0141	.0125	.0110
8	.0485	.0293	.0211	.0184	.0164	.0135	.0114	.0111	.0098	.0087
10	.0385	.0233	.0168	.0145	.0129	.0106	.0090	.0088	.0078	.0069
12	.0305	.0185	.0133	.0116	.0104	.0085	.0072	.0070	.0062	.0055
14	.0242	.0147	.0105	.0091	.0082	0069	.0057	.0056	.0049	.0043

CIRCULAR MIL.—A unit of area employed in measuring the cross-section of wires, equal, approximately, to 0.7854 square mils; the area of a circle one mil. in diameter.

EXAMPLE: The circular millage measurement of 4/0 American Wire Gauge (B. & S.) is the square of the diameter in mils.—*i.e.*, .460 x .460 = 211,600 *cm.*

SQUARE MIL.—A unit of area employed in measuring the areas of cross-section of wires, equal to .000001 square inch; a unit of area equal to 1.2732 circular mils.

Substituting (2) in (1)

$$\text{current} = \frac{\frac{\text{watts}}{\text{power factor}}}{\text{volts}} = \frac{\text{watts}}{\text{power factor} \times \text{volts}} \quad \ldots\ldots\ldots (3)$$

Figuring with Watts.—The table given on page 3,047 is for finding the value of the current in the line using the formula.

$$I = W \div (E \times T)$$

in which I = current in line; E, voltage between main conductors at receiving or consumers' end; W = watts.

Example.—What is the current in a two phase line transmitting 1,000 watts at 550 volts, power factor .8? Substituting, I = 1,000 ÷ (550 × 1.6) = 1.13 amperes.

There is no saving in copper using two phases, but it is desirable on power circuits because two phase motors are self-starting. For equal working conditions, each wire of the three phase system is half the size of one of the wires of the single phase system, hence the weight of copper required for the three phase system is 75% of that required for the single phase system. Since in the two phase system half of the load is carried by each phase, each wire of the three phase system is the same size as one of the wires of the two phase system, hence, the copper required by the three phase system is 75% of that required by the two phase system.

Example.—What size wire must be used on a single phase circuit 2,000 feet in length to supply 30 *kw*. at 220 volts with loss of 4%, the power factor being .9?

The formula for circular mils is

$$\text{circular mils} = \frac{\text{watts} \times \text{feet} \times M}{\%\ \text{loss} \times \text{volts}^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Substituting the given values and the proper value of M from the table, in (1)

$$\text{circular mils} = \frac{30{,}000 \times 2{,}000 \times 2{,}660}{4 \times 220^2} = 82{,}438$$

Referring to the table of the properties of copper wire, the nearest *larger* size wire is No. 1 B. & S. gauge having an area of 83,690 circular mils.

Additional Wiring Formulæ.—For most practical purposes the following formulæ can be used to determine the size of copper conductors, current per wire, and weight of copper per circuit for any system of electrical distribution.

$$\text{Area of wire in circular mils} = \frac{D \times W}{P \times E^2} K.$$

$$\text{Current in main wire} = \frac{W}{E} T. \quad P = \frac{D \times W}{cm \times E^2} K$$

$$\text{Weight of copper} = \frac{D^2 \times W \times K \times A}{P \times E^2 \times 1{,}000{,}000} \text{ pounds.}$$

In these equations the symbols used denote the following quantities:

W = total watts delivered

D = distance of transmission, one way in feet

E = voltage between main wires at the receiving or consumers' end of circuit

P = loss in line in per cent. of power delivered, *i.e.* of W, this being a whole number. K, T and A, are constants given in the following table:

Wiring Formulæ Constants

System	Values of A	Values of K					Values of T				
		Per Cent. Power Factor					Per Cent. Power Factor				
		100	95	90	85	80	100	95	90	85	80
1-phase, & D C	6.04	2160	2400	2660	3000	3380	1.00	1.05	1.11	1.17	1.25
2-phase-4 wire.	12.08	1080	1200	1330	1500	1690	.50	.53	.55	.59	.66
3-phase-3 wire.	9.06	1080	1200	1330	1500	1690	.58	.61	.64	.68	.72

These constants depend upon the system of distribution as well as the conditions of the circuit. For direct current K = 2,160, T = 1 and A = 6.04. For any particular power factor the value of K, is obtained by dividing 2,160, the value for continuous current, by the square of the power factor for single phase and by twice the square of the power factor for three wire three phase, or four wire two phase. In direct current Edison three wire systems, the neutral should be made of one-third the section obtained by the formula for either of the outside mains. In both direct and alternating current systems, the neutral wire for secondary mains (*i.e.* service connections) and house wiring, should be taken as large as the other wire.

The three wires of a three phase circuit and the four wires of a two phase circuit, should all be of the same size, and each wire should be of the cross section as obtained by the proper application of the first formula.

Physical Properties of Copper, Aluminum, Iron and Steel Wire

Physical Properties	Copper		Aluminum 99 Per Cent. Pure	Iron (Ex. B. B.)	Steel (Siemens Martin)
	Annealed	Hard Drawn			
Conductivity, Matthiessen's Standard	99 to 102	96 to 99	61 to 63	16.8	8.7
Ohms per mil-foot at 68° F. = 20°C. (K)	10.36	10.57	16.7	62.9	119.7
Ohms per mile at 68° F. = 20° C.	54,600 / cir. mils	55,700 / cir. mils	88,200 / cir. mils	332,000 / cir. mils	632,000 / cir. mils
Pounds per mile-ohm at 68° F. = 20° C.	875	896	424.0	4700	8900
Temperature co-efficient per degrees F. Mean values	.00233	.00233	.0022	.0028	....
Temperature co-efficient per degrees C. Mean values	.0042	.0042	.0040	.0050	....
Specific gravity. Mean values	8.89	8.94	2.68	7.77	7.85
Pounds per 1,000 feet per circular mil	.003027	.003049	.000909	002652	002671
Weight, in pounds per cubic inch	.320	.322	.0967	.282	.283
Specific heat. Mean values	.093	.093	.214	.113	.117
Melting point in degrees F. Mean values	2012	2012	1157	2975	2480
Melting point in degrees C. Mean values	1100	1100	625	1635	1360
Mean co-efficient of linear expansion. Degrees F.	.00000950	.00000950	.00001285	.00000673	.00000662
Mean co-efficient of linear expansion. Degrees C.	.0000171	.0000171	.0000231	.000120	.000118
Solid Wire, Pounds per square inch — Tensile strength	30,000 to 42,000	45,000 to 68,000	20,000 to 35,000	50,000 to 55,000	100,000 to 120,000
Solid Wire, Pounds per square inch — Elastic limit	6,000 to 16,000	25,000 to 45,000	14,000	25,000 to 30,000	50,000 to 72,000
Solid Wire, Pounds per square inch — Modulus of elasticity	7,000,000 to 17,000,000	13,000,000 to 18,000,000	10,500,000 to 11,500,000	22,000,000 to 27,000,000	22,000,000 to 27,000,000
Concentric Strand, Pounds per square inch — Tensile strength	29,000 to 37,000	43,000 to 65,000	25,800	....	98,000 to 118,000
Concentric Strand, Pounds per square inch — Elastic limit	5,800 to 14,800	23,000 to 42,000	13,800	....	45,000 to 55,000
Concentric Strand, Pounds per square inch — Modulus of elasticity	5,000,000 to 12,000,000	12,000,000 to 14,000,000	Approx. 10,000,000	....	16,000,000 to 22,000,000

The following assumed values of power factors for circuits may be used in any calculation when their exact values are not known:

Incandescent lighting and synchronous motors, 95 per cent.
Lighting and induction motors, 85 per cent.
Induction motors alone, 80 per cent.

TEST QUESTIONS

1. *What are the two chief factors to be considered in the calculation of* a.c. *circuits?*
2. *Upon what does induction depend?*
3. *In what cases may induction be neglected?*
4. *Describe in full the method of calculating the size of wire for any* a.c. *circuit.*
5. *Is it sometimes convenient to make the calculation in terms of watts?*
6. *In modifying the* d.c. *formula, how should drop be expressed?*
7. *How is equation modified for calculation in terms of watts?*
8. *How are the wire sizes for three phase systems determined?*
9. *Give a formula for drop.*
10. *What is the effect of power factor less than unity?*
11. *Is there any saving in copper by using the two phase system?*
12. *What is the advantage of using the two phase instead of one phase system?*

13. *Give additional wiring formulae for*: 1, *area of wire in circular mils*; 2, *current in main wire*; 3, *weight of copper*.
14. *Upon what do these formulae depend?*

CHAPTER 101

Power Wiring Calculations

Wire Calculations for D.C. Motors.—The proper size of wire for a motor may be readily determined by means of the following formula:

$$\text{circular mils} = \frac{\text{H.P.} \times 746 \times L \times 21.6}{E \times D \times K}$$

in which

H.P. = horse power of motor;

746 = watts per H.P.;

L = length of motor circuit from fuse block to motor;

21.6 = ohms per foot run in circuit where wires are one mil in diameter;

E = voltage at the motor;

D = drop in percentage of the voltage at the motor

K = efficiency of the motor expressed as a decimal.

The average values for K, are about as follows: 1 H.P., .75; 3 H.P., .80; 5 H.P., .80; 10 H.P. and over, 90 per cent.

Example.—What is the proper size of wire for a 10 *h.p.*, 220 volt motor with 2% drop on 200 ft. circuit?

Substituting the given values in the above formula:

$$\text{circular mils} = \frac{10 \times 746 \times 200 \times 21.6}{220 \times 4.4 \times .9} = 36{,}991$$

The nearest larger value to this result, in the table of carrying capacities of copper wire (page 3,058), is 41.740, corresponding to No. 4 wire, B. & S. gauge.

Allowable Carrying Capacities of Wires

(According to the National Electrical Code)

Gage No.	Diameter of Solid Wires in Mils	Area in Circular Mils	Column A Rubber Insulation Amperes	Column B Varnished Cambric Insulation, Amperes	Column C Other Insulation Amperes
18	40.3	1,624	3		5
16	50.8	2,583	6		10
14	64.1	4,107	15	18	20
12	80.8	6,530	20	25	25
10	101.9	10,380	25	30	30
8	128.5	16,510	35	40	50
6	162.0	26,250	50	60	70
5	181.9	33,100	55	65	80
4	204.3	41,740	70	85	90
3	229.4	52,630	80	95	100
2	257.6	66,370	90	110	125
1	289.3	83,690	100	120	150
0	325.	105,500	125	150	200
00	364.8	133,100	150	180	225
000	409.6	167,800	175	210	275
		200,000	200	240	300
0000	460.	211,600	225	270	325
		250,000	250	300	350
		300,000	275	330	400
		350,000	300	360	450
		400,000	325	390	500
		500,000	400	480	600
		600,000	450	540	680
		700,000	500	600	760
		800,000	550	660	840
		900,000	600	720	920
		1,000,000	650	780	1,000
		1,100,000	690	830	1,080
		1,200,000	730	880	1,150
		1,300,000	770	920	1,220
		1,400,000	810	970	1,290
		1,500,000	850	1,020	1,360
		1,600,000	890	1,070	1,430
		1,700,000	930	1,120	1,490
		1,800,000	970	1,160	1,550
		1,900,000	1,010	1,210	1,610
		2,000,000	1,050	1,260	1,670

1 Mil = 0.001 inch.

Standardized Stranding

(According to the National Electrical Code)

Strands			Cable		Allowable Carrying Capacities in Amperes		
No. of Strands	Mils Dia.	Gage No.	Area in Cir. Mils	Outside Dia. over Copper	Column A Rubber Insulation	Column B Varnished Cambric Insulation	Column C Other Insulation
7/	25	22	4,490	.075	15	18	20
7/	32	20	7,150	.096	20	25	25
7/	40	18	11,370	.120	25	30	35
7/	51	16	18,080	.153	35	40	50
7/	64	14	28,740	.192	50	60	70
7/	81	12	45,710	.253	70	85	90
7/	91	11	58,000	.273	80	95	110
7/	102	10	72,680	.306	90	110	130
19/	64	14	78,030	.320	100	120	150
19/	72	13	98,380	.360	125	150	175
19/	81	12	124,900	.405	150	180	210
19/	91	11	157,300	.455	175	210	250
19/	107	*	217,500	.540	225	270	325
19/	114	9	248,700	.570	250	300	350
37/	91	11	306,400	.637	275	330	400
37/	97	*	347,500	.679	300	360	450
37/	102	10	381,200	.714	325	390	500
37/	116	*	484,300	.798	400	480	600
61/	102	10	633,300	.918	475	565	700
61/	107	*	698,000	.963	500	600	750
61/	114	9	798,300	1.030	550	660	825
61/	121	*	893,100	1.090	600	720	900
61/	128	8	1,007,000	1.150	650	780	1000
91/	114	9	1,191,000	1.250	725	870	1125
91/	128	8	1,502,000	1.410	850	1020	1350
127/	114	9	1,660,000	1.480	900	1100	1460
127/	128	8	2,097,000	1.660	1100	1300	1700

*These individual strands are odd sizes not listed in the American Wire Tables.

Amperes and Wire Sizes for D.C. Motors

Horse-power.	Amperes at Full Load.			Size of Wire.								
				Rubber Insulation			Varnished Cloth Insulation.			Other Insulation.		
	115 Volts.	230 Volts.	550 Volts.	115 Volts.	230 Volts.	550 Volts.	115 Volts.	230 Volts.	550 Volts.	115 Volts.	230 Volts.	550 Volts.
0.5	5	2.5	1.1	14	14	14	14	14	14	14	14	14
1	8.8	4.4	1.8	14	14	14	14	14	14	14	14	14
2	16	8	3.4	12	14	14	12	14	14	14	14	14
3	24	12	5	8	14	14	10	14	14	10	14	14
5	40	20	8.4	6	10	14	6	12	14	8	12	14
7.5	58	29	12.1	3	6	14	4	8	14	5	8	14
10	76	38	15.9	1	6	12	2	6	12	3	8	14
15	112	56	23.4	00	4	8	0	4	8	1	6	10
20	146	73	30.5	0,000	1	6	000	2	8	0	3	8
25	182	91	38.1	0,000	0	6	0,000	0	6	00	2	8
30	216	108	45.2	300,000	00	4	0,000	0	6	000	1	6
35	252	126	52.6	400,000	000	4	300,000	00	4	0,000	0	6
40	288	144	60.2	500,000	0,000	3	400,000	000	4	300,000	0	5
50	356	178	74.4	600,000	0,000	1	500,000	0,000	2	350,000	00	3
60	428	214	89.5	800,000	350,000	0	600,000	0,000	2	500,000	000	2
75	532	266	111	1,100,000	450,000	00	750,000	300,000	0	600,000	250,000	1
100	710	355	148	1,700,000	600,000	0,000	1,200,000	500,000	00	900,000	350,000	0
125	886	443	185	Two 850,000	850,000	300,000	1,700,000	600,000	0,000	1,200,000	500,000	00
150	1076	538	224	Two 1,100,000	1,100,000	400,000	Two 900,000	900,000	250,000	1,600,000	700,000	0,000

Based on 40-degree motors and 25 per cent overload. For 50-degree motors the fusing would be for about 15 per cent overload.

Note that varnished cloth wires smaller than No. 6 may be used only by special permission.

In all cases the size of the wire thus found should be compared with that allowed by the Underwriters for full load current of motor, plus 25 per cent. of that current, and if the size calculated happen to be smaller than the allowable size, it should be increased to the latter, otherwise it will not pass inspection.

To determine the current required for a motor, as for instance, the 10 H.P. motor under consideration, *multiply the horse power by 746, and divide the product by the voltage of the motor multiplied by its efficiency as follows:* $(10 \times 746) \div (220 \times .90) = 37.6$ amperes.

Table of Amperes per Motor

H. P.	Per Cent. Eff.	Watts Input.	50 Volts.	100 Volts.	220 Volts.	500 Volts.
¾	70	800	16	7	4	2
1½	70	1600	32	15	7	3
3	75	2980	60	27	14	6
5	80	4660	93	42	21	9
7½	85	6580	132	60	30	13
10	85	8780	176	80	40	18
15	85	13200	264	120	60	26
20	85	17600	352	160	80	35
25	85	21900	438	199	100	44
30	90	24900	498	226	113	50
40	90	33200	664	301	151	66
50	90	41400	828	376	188	83
60	90	49700	994	452	226	99
70	90	58000	1160	527	264	116
80	90	66300	1330	603	302	133
90	90	74600	1490	678	339	149
100	90	82900	1660	755	377	166
120	90	99500	1990	905	453	199
150	90	124000	2480	1130	564	248

Table of Amperes per Dynamo

K. W.	125 Vs.	250 Vs.	500 Vs.	Appx. H. P.	K. W.	125 Vs.	250 Vs.	500 Vs.	Appx. H. P.
1.	8	4	2	1.3	30.	240	120	60	40.
2.	16	8	4	2.7	37.5	300	150	75	50.
3.	24	12	6	4.0	40.	320	160	80	53.
5.	40	20	10	6.7	50.	400	200	100	67.
7.5	60	30	15	10.	60.	480	240	120	80.
10.	80	40	20	13.	75.	600	300	150	100.
12.5	100	50	25	17.	100.	800	400	200	134.
15.	120	60	30	20.	125.	1000	500	250	167.
20.	160	80	40	27.	150.	1200	600	300	201.
25.	200	100	50	34.	200.	1600	800	400	268.

Wire Calculations for A.C. Motors.—If the efficiency and power factor of an *a.c.* motor at a given horse power load be known, the current in amperes per phase which will be required to drive the motor at rated voltage is given by the formula:

$$\text{amperes} = \frac{\text{horse power} \times 746}{\text{K} \times \text{volts} \times \text{efficiency} \times \text{power factor}}$$

in which

K = 1 for single phase;
= 2 for two phase, four wire system;
= $\sqrt{3}$ for three phase, three wire system.

Example.—A 50 horse power, 440 volt motor has a full load efficiency of .9 and power factor of .8. How much current is required: 1, for single phase motor; 2, for three phase, three wire motor?

1. *For single phase motor.*

Substituting in the formula and taking K = 1

$$\text{amperes} = \frac{50 \times 746}{1 \times 440 \times .9 \times .8} = 117.6$$

2. *For three phase, three wire motor.*

Substituting in the formula and taking $K = \sqrt{3} = 1.73$

$$\text{amperes} = \frac{50 \times 746}{1.73 \times 440 \times .9 \times .8} = 68.07$$

Example.—A 50 horse power single phase 440 volt motor, having a full load efficiency of .92 and power factor of .8, is to be operated at a distance of 1,000 feet from the alternator. The wires are to be spaced 6 inches apart and the frequency is 60, and % of loss 5. Determine: **A**, *electrical horse power*; **B**, *watts*; **C**, *apparent load*; **D**, *current*; **E**, *size of wires*; **F**, *drop*; **G**, *voltage at the alternator*.

A. *Electrical horse power*

$$\text{E.H.P.} = \frac{\text{brake horse power}}{\text{efficiency}} \times \frac{50}{.92} = 54.3$$

or,

$$54.3 \times 746 = 40{,}508 \text{ watts}$$

B. *Watts*

$$\text{watts} = \text{E.H.P.} \times 746 = 54.3 \times 746 = 40{,}508$$

C. *Apparent load*

$$\text{apparent load or } kva = \frac{\text{actual load or watts}}{\text{power factor}} = \frac{40{,}508}{.8} = 50{,}635$$

D. *Current*

$$\text{current} = \frac{\text{apparent load or } kva}{\text{volts}} = \frac{50{,}635}{440} = 115 \text{ amperes}$$

E. *Size of wires*

$$\text{cir. mils} = \frac{\text{watts} \times \text{feet} \times \text{M}}{\% \text{ loss} \times \text{volts}^2} = \frac{40{,}508 \times 1{,}000 \times 3{,}380}{5 \times 440^2} = 141{,}443$$

From table page 3,027, nearest size *larger* wire is No. 000 B. & S. gauge.

F. *Drop*

$$\text{drop} = \frac{\% \text{ loss} \times \text{volts}}{100} \times \text{S} = \frac{5 \times 440}{100} \times 1.17 = 25.74 \text{ volts}$$

NOTE.—Values of S are given on page 3,049.

G. *Voltage at alternator*

$$\text{alternator pressure} = \text{volts at motor} + \text{drop} = 440 + 25.74 = 465.7 \text{ volts}$$

The following table gives minimum size wire for *d.c.* motor wiring when wires are concealed or partly concealed, also good practice for open wires.

Minimum Wire Sizes for D.C. Motors

(Western Electric Co.)

H.P.	Size wire B. & S. Gauge 30 volts	110 volts	220 volts	H.P.	Size wire B. & S. Gauge 30 volts	110 volts	220 volts
1/16	14	..	.	3	.	10	14
¼	14	..	..	4	..	8	12
½	10	14	14	5	..	6	10
1	8	14	14	7½	..	4	8
2	..	12	14	10	..	3	6

This table shows only safe size of wire to avoid overheating. If motor be over 30 ft. from dynamo, larger wire must be used. Find amperes in the table which follows and select size of wire by using the table of watt ft., page 3,040, dividing the watt ft., by the proper factor for voltages other than 30.

Approximate Amperes Taken at 30 Volts

Motors Horsepower	Motors Amperes	Mazda Lamps Watts	Mazda Lamps Amperes
1/16	2½	10	.3
⅛	5	20	.7
¼	9	40	1.3
½	16	75	2.5
1	30	..	...

	Amperes		Amperes
6 in. 4 blade fan motors	.80	Coffee percolator	14.0
12 in., 6 blade fan motors	1.00	Water heater	15.6
Flatiron	16.4	Soldering iron	10.0
Toaster	15.0	Cleaner	4.0
Disc heater	15.0	Washing machine	8.0
Water heater	9.4	Sewing machine	.66

Example.—What size wire is required for a 1 *h.p.* 220 volt motor located 200 feet from the dynamo?

From the table of approximate amperes at 30 volts, a 1 *h.p.* motor would require 30 amperes. Load at 30 volts $=30\times30\times200=180{,}000$ watt feet, and for $220=180{,}000\times30\div220=24{,}545$ watt feet. Size wire for table of watt feet, page 3,040, for 30 volts is No. 10.

Data Relating to Standard Annealed & Cleaned Bare Copper Cable Stranded

Approximate Values

Circular Mils.	Number of Wires in Strand	Diameter Each Wire, Inches	Diameter of Strand, Inches	Weight per 1,000 Foot Strand, Pounds	Weight per Mile, Pounds	Area Strand Square, Inches	Resistance per 1,000 Feet at 68° F. or 20° C.
2,000,000	91	.1482	1.6302	6164.	32546.	1.56874	.00530
1,750,000	91	.1386	1.5257	5394.	28480.	1.36494	.00607
1,500,000	91	.1284	1.4124	4623.	24409.	1.17831	.00707
1,250,000	91	.1172	1.2892	3853.	20344.	.98170	.00852
1,000,000	61	.1280	1.1520	3081.	16268.	.78494	.01060
950,000	61	.1248	1.1232	2927.	15455.	.74618	.01115
900,000	61	.1215	1.0935	2773.	14641.	.70724	.01179
850,000	61	.1181	1.0629	2619.	13828.	.66852	.01247
800,000	61	.1145	1.0305	2465.	13015.	.62810	.01325
750,000	61	.1109	.9981	2311.	12202.	.58922	.01413
700,000	61	.1071	.9639	2157.	11389.	.54954	.01514
650,000	61	.1032	.9288	2003.	10576.	.51020	.01630
600,000	61	.0992	.8928	1849.	9763.	.47146	.01767
550,000	37	.1219	.8533	1694.	8944.	.43181	.01925
500,000	37	.1162	.8134	1540.	8131.	.39237	.02116
450,000	37	.1103	.7721	1386.	7318.	.35234	.02349
400,000	37	.1040	.7280	1232.	6505.	.31431	.02648
350,000	37	.0973	.6811	1078.	5692.	.27512	.03026
300,000	19	.1257	.6285	923.	4873.	.23591	.03531
250,000	19	.1147	.5738	769.	4060.	.19635	.04233
211,600	19	.1055	.5275	647.1	3416.7	.16609	.04997
167,772	19	.094	.4700	513.2	2709.7	.13187	.06293
133,079	7	.1378	.4134	405.9	2143.2	.10429	.07935
105,625	7	.1228	.3684	321.7	1698.6	.08303	.10007
83,694	7	.1093	.3279	255.2	1347.5	.06559	.12617
66,358	7	.0973	.2919	202.4	1068.7	.05205	15725
52,624	7	.0867	.2601	160.5	847.4	.04132	19827
41,738	7	.0772	.2316	127.3	672.1	.03276	25000
26,244	7	.0612	.1836	80.0	422.4	.02059	39767
16,512	7	.0485	.1458	50.3	265.6	.01298	.62686
10,384	7	.0385	.1155	31.6	166.8	.00815	1.00848
6,528	7	.0305	.0915	19.9	105.1	.00511	1.59716
4,108	7	.0242	.0726	12.5	66.0	.00322	2.54192

Construction of Stranded Copper Conductors

To ascertain the diameter of the wires in a cable of any given capacity, divide the circular mils. capacity of the cable by the number of wires in the strand and extract the square root of the quotient. The result thus obtained gives the diameter in mils. of the wires composing the strand.

To ascertain the diameter of a concentric strand of 7, 19, 37, 61, 91, 127 or 169 wires:

7 wire strand, diameter equals 3 times diameter wires composing strand
19 wire strand, diameter equals 5 times diameter wires composing strand
37 wire strand, diameter equals 7 times diameter wires composing strand
61 wire strand, diameter equals 9 times diameter wires composing strand
91 wire strand, diameter equals 11 times diameter wires composing strand
127 wire strand, diameter equals 13 times diameter wires composing strand
169 wire strand, diameter equals 15 times diameter wires composing strand

The diameter of a 49-wire conductor, rope lay (7x7), equals 9 times the diameter of the individual wires, and the diameter of a conductor of 133 wires (7x19) equals 15 times the diameter of the individual wires.

To ascertain in circular mils. the capacity of a cable of which the number and diameter of the component wires are given, square the diameter (in mils.) of the individual wires and multiply the product by the number of wires in the strand.

All rules and data here given are based upon strands in which all of the individual wires are of the same size. The use of two or more different sizes of wire in the same strand complicates the subject to such an extent as to prevent giving specific instruction or rules.

Calculation Tables for D.C. and A.C. Machines

To Find	Direct Current	ALTERNATING CURRENT		
		Single-Phase	Two-Phase* Four-Wire	Three-Phase
Amperes when Horse-power is Known	$\frac{H.P.\times 746}{E\times \%\,Eff.}$	$\frac{H.P.\times 746}{E\times \%\,Eff.\times P.F.}$	$\frac{H.P.\times 746}{2\times E\times \%\,Eff.\times P.F.}$	$\frac{H.P.\times 746}{1.73\times E\times \%\,Eff.\times P.F.}$
Amperes when Kilowatts is Known	$\frac{K.W.\times 1000}{E}$	$\frac{K.W.\times 1000}{E\times P.F.}$	$\frac{K.W.\times 1000}{2\times E\times P.F.}$	$\frac{K.W.\times 1000}{1.73\times E\times P.F.}$
Amperes when K.V.A. is Known		$\frac{K.V.A.\times 1000}{E}$	$\frac{K.V.A.\times 1000}{2\times E}$	$\frac{K.V.A.\times 1000}{1.73\times E}$
Kilowatts	$\frac{I\times E}{1000}$	$\frac{I\times E\times P.F.}{1000}$	$\frac{I\times E\times 2\times P.F.}{1000}$	$\frac{I\times E\times 1.73\times P.F.}{1000}$
K. V. A.		$\frac{I\times E}{1000}$	$\frac{I\times E\times 2}{1000}$	$\frac{I\times E\times 1.73}{1000}$
Horse-power (Output)	$\frac{I\times E\times \%\,Eff.}{746}$	$\frac{I\times E\times \%\,Eff.\times P.F.}{746}$	$\frac{I\times E\times 2\times \%\,Eff.\times P.F.}{746}$	$\frac{I\times E\times 1.73\times \%\,Eff.\times P.F.}{746}$

I = Amperes; E = Volts; % Eff. = per cent Efficiency; P. F. = Power Factor.
K.W. = Kilowatts; K. V. A. = Kilo-Volt-Amperes; H. P. = Horse-power.
* For three-wire, two-phase circuits the current in the common conductor is 1.41 times that in either of the other two conductors.

Ratings in Watts.—A motor is rated by the power it delivers, not by the power it takes. The figures given are the approximate watts at full load.

Approximate Watts

(Western Electric Co.)

1/16 H.P. motor	75
1/8 H.P. motor	150
1/6 H.P. motor	210
1/4 H.P. motor	270
Sewing machine	20
Vacuum cleaner, 1/12 H.P	120
Vacuum cleaner, 1/6 H.P	230
Washing machine, 1/6 H.P	230
Dish washer, 1/7 H.P	200
6 in. fan	23
9 in. fan, non-oscillating	25
Electric iron	500
Toaster	440
Disc heater (various sizes)	450 to 600

Underwriters' Requirements for Wire Sizes.—As before stated in *all cases the size of the wire thus found should be compared with that allowed by the Underwriters for full load current of motor, plus 25 per cent. of that current*, and if the size calculated happen to be smaller than the allowable size, it should be increased to the latter, otherwise it will not pass inspection.

Code.

808. Motors and Motor Circuits

a. Motors used for continuous duty. Except as otherwise provided in this section, the following tables shall govern the minimum allowable size of the conductors of any individual motor circuit from the main or feeder to the motor, and the maximum allowable rating or setting of the circuit and motor automatic overload protective devices to be used in each ungrounded conductor of any individual motor circuit. These tables are based upon a conductor current-carrying capacity and a rating or setting of motor-running protective device of 125% of the motor full-load current rating, with branch-circuit fuse protection according to the following percentages of the motor full-load current.

Type of Motor	Per Cent. Motor Full-Load Current
Single-phase, repulsion or split-phase starting	300
Squirrel-cage, full-voltage starting	300
Squirrel-cage, reduced-voltage starting (not more than 30 amperes)	250
High-reactance squirrel-cage (not more than 30 amperes)	250
Squirrel-cage, reduced-voltage starting (more than 30 amperes)	200
High-reactance squirrel-cage (more than 30 amperes)	200
Slip-ring A.C. and D.C	150

Code.—Continued.

(1) For motors having larger full-load current ratings than those given in these tables, calculations for the sizes of conductors and rating or setting of protective devices shall be made on the same basis as the foregoing.

(2) The maximum setting of circuit-breakers for such use shall not be in excess of that specified in sub-paragraph 5 of this section.

(3) Although it is desirable to keep the branch-circuit protection at as low a rating as is possible, cutout bases for such branch-circuit fuses shall not be of a smaller size than that required to accommodate the branch fuses specified in the following tables for any value of motor full load current.

(4) The rating of a combination cutout and switch used as a motor-controller shall be such that the cutout will accommodate the size of fuse specified in the table for motor-running protection. The rating of a combination cutout and switch at a service supplying motors or at a tap for a motor branch-circuit shall be such that the cutout will accommodate fuses rated not less than is specified in the table for motor branch-circuit fuses.

(5) Where thermal cutouts or thermal relays are used for time-limit automatic overload protection and the values given in Column 6 of Table 1 following do not correspond to standard sizes or ratings, the next higher standard rating or size of thermal cutout or relay may be used. For long runs it may be necessary, in order to avoid excessive voltage drops, to use conductors of sizes larger than the minimum sizes given in the following tables:

TABLE 1.

For Selecting Wire and Fuse Sizes for Motor Branch-Circuits.

Full-load current rating of motor Amperes	Minimum allowable size of copper wire, Am. gauge or cir. mils.			For Running Protection of Motors		Maximum Allowable Rating of Branch Circuit Fuses (See table following the first paragraph of this section)			
	Rubber	Varnished Cambric	Slow Burning	Max. Rating of N.E.C. fuses Amperes	Max. Setting of time-limit protective device Amperes	Squirrel-cage, full-voltage starting. Single-phase repulsion or split-phase. Amperes	Squirrel-cage, reduced-voltage starting. High-reactance squirrel-cage*** (up to 30 a.). Amperes	Squirrel-cage, reduced-voltage starting. High-reactance squirrel-cage*** (above 30 a.) Amperes	Slip-Ring A.C. and D.C. Amperes
1	2	3	4	5	6	7	8	9	10
1**	14	14	14	2*	1.25*	15	15	—	15
2**	14	14	14	3*	2.50*	15	15	—	15
3**	14	14	14	4*	3.75*	15	15	—	15
4**	14	14	14	6*	5.0 *	15	15	—	15
5**	14	14	14	8*	6.25*	15	15	—	15
6**	14	14	14	8*	7.50*	20	15	—	15
7	14	14	14	10*	8.75*	25	20	—	15
8	14	14	14	10*	10.0 *	25	20	—	15
9	14	14	14	12*	11.25*	30	25	—	15
10	14	14	14	15*	12.50*	30	25	—	15
11	14	14	14	15*	13.75*	35	30	—	20
12	14	14	14	15*	15.00*	40	30	—	20
13	12	14	14	20*	16.25*	40	35	—	20
14	12	14	14	20*	17.50*	45	35	—	25
15	12	13	14	20*	18.75*	45	40	—	25
16	12	12	14	20*	20.00*	50	40	—	25
17	10	12	12	25*	21.25*	60	45	—	30
18	10	12	12	25*	22.50*	60	45	—	30
19	10	12	12	25*	23.75*	60	50	—	30
20	10	12	12	25*	25.0 *	60	50	—	30

Code.—*Continued.*

TABLE 1 (continued).

For Selecting Wire and Fuse Sizes for Motor Branch-Circuits.

Full-load current rating of motor Amperes 1	Minimum allowable size of copper wire, Am. gauge or cir. mils. Rubber 2	Varnished Cambric 3	Slow Burning 4	For Running Protection of Motors: Max. Rating of N.E.C. fuses Amperes 5	Max. Setting of time-limit protective device Amperes 6	Maximum Allowable Rating of Branch Circuit Fuses (See table following the first paragraph of this section): Squirrel-cage, full-voltage starting. Single-phase repulsion or split-phase. Amperes 7	Squirrel-cage, reduced-voltage starting. High-reactance squirrel-cage*** (up to 30 a.) Amperes 8	Squirrel-cage, reduced-voltage starting. High-reactance squirrel-cage*** (above 30 a.) Amperes 9	Slip-Ring A.C. and D.C. Amperes 10
22	8	10	10	30	27.50	70	60	—	35
24	8	10	10	30	30.00	80	60	—	40
26	8	8	8	35	32.50	80	70	—	40
28	8	8	8	35	35.00	90	70	—	45
30	6	8	8	40	37.50	90	80	—	45
32	6	8	8	40	40.00	100	—	70	50
34	6	6	8	45	42.50	110	—	70	60
36	6	6	8	45	45.00	110	—	80	60
38	6	6	8	50	47.50	125	—	80	60
40	6	6	8	50	50.00	125	—	80	60
42	5	6	6	50	52.50	125	—	90	70
44	5	6	6	60	55.0	125	—	90	70
46	4	6	6	60	57.50	150	—	100	70
48	4	6	6	60	60.0	150	—	100	80
50	4	5	6	60	62.50	150	—	100	80
52	4	5	6	70	65.0	175	—	110	80
54	4	4	6	70	67.50	175	—	110	90
56	4	4	6	70	70.00	175	—	120	90
58	3	4	5	70	72.50	175	—	120	90
60	3	4	5	80	75.00	200	—	120	90
62	3	4	5	80	77.50	200	—	125	100
64	3	4	5	80	80.00	200	—	150	100
66	2	4	4	80	82.50	200	—	150	100
68	2	4	4	90	85.00	225	—	150	110
70	2	3	4	90	87.50	225	—	150	110
72	2	3	4	90	90.00	225	—	150	110
74	1	3	3	90	92.50	225	—	150	125
76	1	3	3	100	95.00	250	—	175	125
78	1	2	3	100	97.50	250	—	125	125
80	1	2	3	100	100.00	250	—	175	125
82	0	2	2	110	102.50	250	—	175	125
84	0	2	2	110	105.00	250	—	175	150
86	0	2	2	110	107.50	300	—	175	150
88	0	2	2	110	110.00	300	—	200	150
90	0	1	0	110	112.50	300	—	200	150
92	0	1	2	125	115.00	300	—	200	150
94	0	1	2	125	117.50	300	—	200	150
96	0	1	2	125	120.00	300	—	200	150
98	0	0	2	125	122.50	300	—	200	150
100	0	0	2	125	125.00	300	—	200	150
105	00	0	1	150	131.5	350	—	225	175
110	00	0	1	150	137.5	350	—	225	175
115	00	0	1	150	144.0	350	—	250	175
120	00	0	1	150	150.0	400	—	250	200
125	000	00	0	175	156.5	400	—	250	200
130	000	00	0	175	162.5	400	—	300	200
135	000	00	0	175	169.0	450	—	300	225
140	000	00	0	175	175.0	450	—	300	225
145	200,000	000	0	200	181.5	450	—	300	225
150	200,000	000	0	200	187.5	450	—	300	225
155	200,000	000	0	200	194.0	500	—	350	250
160	200,000	000	0	200	200.0	500	—	350	250
165	0000	000	00	225	206.	500	—	350	250
170	0000	200,000	00	225	213.	500	—	350	300
175	0000	200,000	00	225	219.	600	—	350	300
180	0000	200,000	00	225	225.	600	—	400	300
185	250,000	200,000	000	250	231.	600	—	400	300
190	250,000	200,000	000	250	238.	600	—	400	300
195	250,000	0000	000	250	244.	600	—	400	300
200	250,000	0000	000	250	250.	600	—	400	300
210	300,000	0000	000	250	263.	—	—	450	350
220	300,000	250,000	000	300	275.	—	—	450	350

Code.—*Continued.*

TABLE 1 (continued)

For Selecting Wire and Fuse Sizes for Motor Branch-Circuits.

Full load current rating of motor Amperes 1	Minimum allowable size of copper wire, Am. gauge or cir. mils. Rubber 2	Varnished Cambric 3	Slow Burning 4	For Running Protection of Motors: Max. Rating of N.E.C. fuses Amperes 5	Max. Setting of time limit protective device Amperes 6	Maximum Allowable Rating of Branch Circuit Fuses (See table following the first paragraph of this section): Squirrel cage, full voltage starting. Single phase repulsion or split phase. Amperes 7	Squirrel cage, reduced voltage starting. High reactance squirrel cage*** (up to 30 a.). Amperes 8	Squirrel cage, reduced voltage starting. High reactance squirrel cage*** (above 30 a.) Amperes 9	Slip Ring A.C. and D.C. Amperes 10
230	350,000	250,000	200,000	300	288.	—	—	500	350
240	350,000	250,000	200,000	300	300.	—	—	500	400
250	400,000	300,000	0000	300	313.	—	—	500	400
260	400,000	300,000	0000	350	325.	—	—	600	400
270	500,000	350,000	250,000	350	338.	—	—	600	450
280	500,000	350,000	250,000	350	350.	—	—	600	450
290	500,000	350,000	300,000	350	363.	—	—	600	450
300	500,000	400,000	300,000	400	375.	—	—	600	450
320	500,000	500,000	300,000	400	400.	—	—	—	500
340	600,000	500,000	350,000	450	425.	—	—	—	600
360	600,000	500,000	350,000	450	450.	—	—	—	600
380	700,000	500,000	400,000	500	475.	—	—	—	600
400	700,000	600,000	400,000	500	500.	—	—	—	600
420	800,000	600,000	500,000	600	525.	—	—	—	—
440	800,000	700,000	500,000	600	550.	—	—	—	—
460	900,000	700,000	500,000	600	575.	—	—	—	—
480	900,000	700,000	500,000	600	600.	—	—	—	—
500	1,000,000	800,000	600,000	—	625.	—	—	—	—
520	1,000,000	800,000	600,000	—	650.	—	—	—	—
540	1,100,000	900,000	600,000	—	675.	—	—	—	—
560	1,200,000	900,000	700,000	—	700.	—	—	—	—
580	1,200,000	1,000,000	700,000	—	725.	—	—	—	—
600	1,300,000	1,000,000	700,000	—	750.	—	—	—	—
625	1,400,000	1,000,000	800,000	—	782.	—	—	—	—

FULL-LOAD MOTOR CURRENTS.

TABLE 2.

Two-Phase A.C. Motors (4-wire).†*

HP	Squirrel-Cage Induction-Type Amperes 110V	220V	440V	550V	2200V	Wound-Rotor and High-Reactance Squirrel-Cage Type Amperes 110V	220V	440V	550V	2200V
½*	4.3	2.2	1.1	.9	—	—	—	—	—	—
¾*	4.7	2.4	1.2	1.0	—	—	—	—	—	—
1	5.7	2.9	1.4	1.2	—	6.8	3.4	1.7	1.3	—
1½*	7.7	4.0	2	1.6	—	—	—	—	—	—
2*	10.4	5	3	2.0	—	12.5	6.2	3.1	2.5	—
3	—	8	4	3.0	—	17.3	8.7	4.3	3.4	—
5	—	13	7	6	—	—	13	6.5	5.2	—
7½	—	19	9	7	—	—	22	11	9	—
10	—	24	12	10	—	—	24	12	10	—
15	—	33	16	13	—	—	39	20	16	—
20	—	45	23	19	—	—	49	25	20	—
25	—	55	28	22	6	—	58	29	23	7
30	—	67	34	27	7	—	71	36	20	8
40	—	88	44	35	9	—	92	46	37	10
50	—	108	54	43	11	—	110	55	44	12
60	—	129	65	52	13	—	130	65	52	14
75	—	156	78	62	16	—	163	82	66	17
100	—	212	106	85	22	—	213	106	85	22
125	—	268	134	108	27	—	269	135	108	27
150	—	311	155	124	31	—	315	157	125	32
200	—	415	208	166	43	—	430	215	173	45

Code.—Contiuned.

TABLE 3

Single-Phase A.C. Motors.

Amperes

HP	110V	220V	440V
1/6*	3.34	1.67	—
¼*	4.8	2.4	—
½*	7	3.5	—
¾*	9.4	4.7	—
1*	11	5.5	—
1½*	15.2	7.6	—
2*	20	10	—
3	28	14	—
5	46	23	—
7½	68	34	17
10	86	43	21.5

†Values of current in common wire of 2-phase 3-wire system will be 1.41 times values given.
‡These values of full-load currents are average for all speeds and frequencies.
*For the running protection of motors of 2 H. P. and less see sub-paragraph 1 below
**For the fusing of small motors under the protection of a single set of fuses see sub-paragraph 2 below
***High reactance squirrel-cage motors are those designed to limit the starting current by means of deep-slot-secondaries or double-wound secondaries.

TABLE 4.

Three-Phase A.C. Motors.

	Squirrel-Cage Induction-Type Amperes					Wound-Rotor and High-Reactance Squirrel-Cage Type Amperes				
HP	110V	220V	440V	550V	2200V	110V	220V	440V	550V	2200V
½*	5	2.5	1.3	1	—	—	—	—	—	—
¾*	5.4	2.8	1.4	1.1	—	—	—	—	—	—
1*	6.6	3.3	1.7	1.3	—	7.8	3.9	2	1.6	—
1½*	9.4	4.7	2.4	2.0	—	—	—	—	—	—
2*	12	6	3	2.4	—	14.4	7.2	3.6	2.9	—
3	—	9	4.5	4	—	20.0	10	5	4	—
5	—	15	7.5	6	—	—	15	7.5	6	—
7½	—	22	11	9	—	—	25	13	10	—
10	—	27	14	11	—	—	28	14	11	—
15	—	38	19	15	—	—	45	23	18	—
20	—	52	26	21	—	—	56	28	22	—
25	—	64	32	26	7	—	67	34	27	7.5
30	—	77	39	31	8	—	82	41	33	9
40	—	101	51	40	10	—	106	53	42	11
50	—	125	63	50	13	—	128	64	51	14
60	—	149	75	60	15	—	150	75	60	16
75	—	180	90	72	19	—	188	94	75	19
100	—	246	123	98	25	—	246	123	99	25
125	—	310	155	124	32	—	310	155	124	31
150	—	360	180	144	36	—	364	182	145	37
200	—	480	240	195	49	—	490	245	196	52

Code.—Continued.

TABLE 5.
Direct-Current Motors.
Amperes

HP	115V	230V	550V
½*	4.5	2.3	—
¾*	6.5	3.3	1.4
1*	8.4	4.2	1.7
1½*	12.5	6.3	2.6
2*	16.1	8.3	3.4
3	23.0	12.3	5.0
5	40	19.8	8.2
7½	58	28.7	12.0
10	75	38	16.0
15	112	56	23.0
20	140	74	30
25	185	92	38
30	220	110	45
40	294	146	61
50	364	180	75
60	436	215	90
75	540	268	111
100	—	357	146
125	—	443	184
150	—	—	220
200	—	—	295

Article 19. Lightning Arresters

1901. In Stations

a. A lightning arrester shall be connected to each overhead wire entering a station.

b. Lightning arresters shall be located in readily accessible places, away from combustible materials and as near as practicable to the point where the wires enter the station.

c. Lightning arresters shall be well isolated from other equipment and, if of the oil-filled type, shall be placed in a fireproof room or compartment.

d. Lightning arresters shall be grounded as provided in Article 9 of this code.

e. All choke coils, or other attachments inherent to the lightning-protection equipment, shall have an insulation from the ground or other conductors at least equal to the insulation required at the points of the circuit in the station.

f. Kinks, coils and sharp bends in the wires between arresters and outdoor lines shall be avoided as far as practicable.

TEST QUESTIONS

1. *Give formula for calculating wire size for a* d.c. *motor.*
2. *How should the calculated wire size be checked in all cases?*
3. *How is the current required for a motor determined?*
4. *Explain in full the method of calculating wire size for an* a.c. *motor.*
5. *A* 50 h.p., 440 *volt motor has a full load efficiency of* .9 *and power factor of* .8. *How much current is required*: 1, *for single phase motor*; 2, *for three phase, three wire motor?*
6. *A* 50 h.p. *single phase* 440 *volt motor, having a full load efficiency of* .92 *and power factor of* .8, *is to be operated at a distance of* 1,000 *feet from the alternator. The wires are to be spaced* 6 *ins. apart and the frequency is* 60, *and* % *of loss* 5. *Determine*: 1, *electrical horse power*; 2, *watts*; 3, *apparent load*; 4, *current*; 5, *size of wires*; 6, *drop*; 7, *voltage at the alternator.*
7. *How is a motor usually rated?*
8. *Give the Underwriter's requirements for wire sizes.*

CHAPTER 102

Wire Gauges

For the purpose of measuring the size of wires a wire gauge is used.

The sizes of wires were for many years indicated in commercial practice almost entirely by gauge numbers. This practice was accompanied by considerable confusion because numerous gauges were in use. Wire gauges are in use now less than formerly, the specification of diameter directly being preferred in many cases and, furthermore, the confusion is diminishing because practice is eliminating most of the gauges and is assigning well defined fields to the remaining ones.

The American wire gauge (*A.w.g.* or B. & S.) was devised by J. R. Brown, one of the founders of the Brown and Sharpe Manufacturing Co., in 1857. It speedily superseded the Birmingham wire gauge in this country, which was then in general use. It is perhaps more generally known by the name "Brown & Sharpe Gauge" and that name should be used to avoid confusion.

In their catalogues they regularly refer to the gauge as the "American Standard Wire Gauge." The word "Standard" is probably not a good one to retain in the name of this gauge, since it is not the standard gauge for all metals in the United States; and further, since it is not a legalized gauge, as are the British standard wire gauge and the United States standard sheet metal gauge. The abbreviation for the name of this gauge has usually been written "*A.w.g.*"; it is better to abbreviate its real name: B. & S.

The American wire gauge is now used for more metals than any other in this country, and is practically the only gauge used for copper wire, and in general for wire used in electrical work.

It is the only wire gauge now in use whose successive sizes are determined by a simple mathematical law.

It may be stated that in so far as wire gauges continue in use in the United States, the practice has been practically standardized to the use of the American wire gauge for wire used in electrical work.

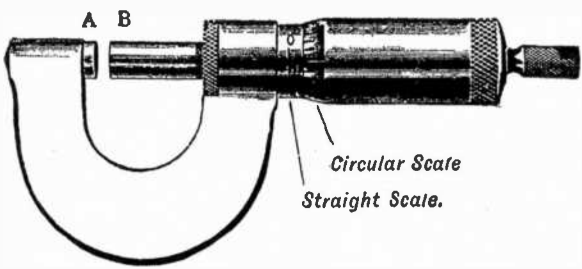


FIG. 5,068.—Micrometer screw gauge. It consists essentially of a screw whose thread is accurately turned to a pitch of some convenient fraction of an inch or centimeter. If the pitch of the screw in the gauge be 1/20th of an inch, and the circular scale consist of 50 divisions, then for each revolution of the screw, the surface B, will travel a distance equal to the pitch, that is 1/20th of an inch. The graduations on an instrument of this kind are generally 1/10th of an inch on the straight scale, with shorter lines to mark the half divisions. The thickness of a wire on the straight scale can therefore be read to the nearest 1/20th inch. Each division of the circular scale represents 1/50th of a revolution of the screw, which corresponds to a change in distance between A and B, of $\frac{1}{50}$ of $\frac{1}{20} = \frac{1}{1,000}$ in. If then the reading on the straight scale be 1 and on the circular scale 35, the distance between A and B, is $.1 + .035 = .135$ inch.

Sizes of stranded conductors larger than No. 0000 B. & S. are specified by the total cross section in circular mils.

It is becoming more and more the practice for the large electrical companies and others to omit gauge numbers and the stock sizes of copper wire used and specified by those who follow this practice are the B. & S. wire gauge sizes, to the nearest mil for the larger diameters and to a tenth of a mil for the smaller. Those who use the gauge numbers do not draw or measure wires to a greater accuracy than this and accordingly, a single system of sizes of copper wire is in use in this country, both by those who use gauge numbers and those who do not.

The Brown & Sharpe wire gauge has the property, in common with a number of other gauges, *that its sizes represent ap-*

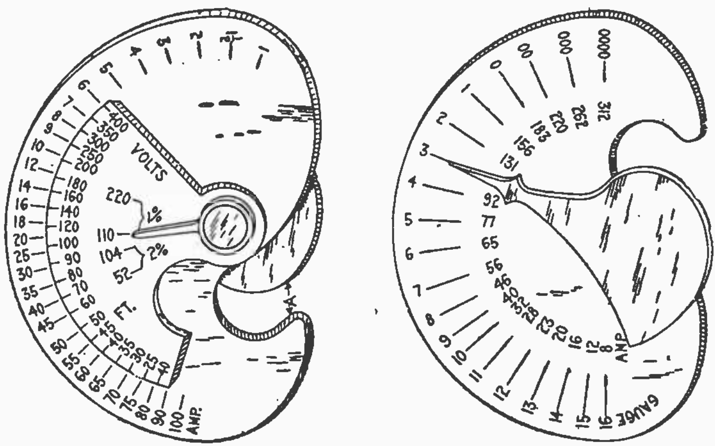
Fig. 5,069.—Brown and Sharpe (B. & S.), or American Standard wire gauge. This gauge was adopted by the brass manufacturers Jan., 1858. The cut is full size, and therefore shows the actual sizes corresponding to the gauge numbers.

proximately the successive steps in the process of wire drawing, also, like many other gauges, *its numbers are retrogressive, a larger number denoting a smaller wire,* corresponding to the operations of drawing.

Its sizes are not so arbitrary and the differences between successive diameters are nearer regular than those of other gauges, since it is based upon a simple mathematical law. The gauge is formed by the specification of two diameters and the law that a given number of intermediate diameters are formed by geometrical progression. Thus, the diameter of No. 0000 is defined as .4600 inch and of No. 36 as .0050 inch. There are 38 sizes between these two, hence the ratio of any diameter to the diameter of the next greater number =

$$\sqrt[39]{\frac{46}{.005}} = \sqrt[39]{.92} = 1.123$$

the square of this ratio = 1.2610. The sixth power of the ratio, that is,



FIGS. 5,070 and 5,071.—U. S. wireman's calculating gauge; views showing both sides. On the side shown in fig. 5,070, set the required number of feet on the small circle opposite the required number of amperes on the large circle, then set the small pointer at the required voltage and loss. Then on the other side (fig. 5,071) the large pointer will indicate the required size of wire in B. & S. gauge, and will also indicate the safe carrying capacity, while the wire may be gauged by slot A (fig. 5,070).

the ratio of any diameter to the diameter of the sixth greater number = 2.0050. The fact that this ratio is so nearly 2, is the basis of numerous useful relations which are given in the following "Wire table short cuts."

Wire Table Short Cuts.—Since the Brown & Sharpe wire gauge is formed by geometrical progression, the wire table is easily reproduced from the ratio and one of the sizes as a starting point.

There happen to be a number of approximate relations which make it possible practically to reproduce the wire table by remembering a few remarkably simple formulæ and data.

The resistance, mass, and cross section vary with the square of the diameter, hence by the use of the square of the ratio of one diameter to the next, viz.: 1.2610, it is possible to deduce the resistance, mass, and cross section of any size from the next. This number may be carried in the mind as approximately 1¼.

Furthermore, since the cube of this number is so nearly 2, it follows that every three gauge numbers, the resistance and mass per unit length and also the cross section are doubled or halved. The foregoing sentence is a concise expression of the chief wire table short cut.

It is easy to find, say, ohms per 1,000 feet mentally, starting from the values for No. 10, the approximate factors for finding values for the next three sizes after any given size, are 1.26, 1.6, 2.0

Furthermore, every ten gauge numbers, the resistance and mass per unit length and the cross section are approximately multiplied or divided by 10.

No. 10 copper wire has approximately a resistance of 1 ohm per 1,000 feet at 20° C., a diameter of 0.1 inch, and a cross section of 10,000 circular mils. The mass may also be remembered for No. 10, viz.: 31.4 pounds per 1,000 feet; but it will probably be found easier to remember it for No. 5. 100 pounds per 1,000 feet; or for No. 2, 200 pounds per 1,000 feet.

Between Nos. 6 and 12, inclusive, the reciprocal of the size number equals the diameter in inches, within 3 per cent.

The law of geometrical progression on which the gauge is based may be expressed in either of the three following manners:

1. The ratio of any diameter to the next smaller is a constant number;

2. The difference between any two successive diameters is a constant per cent of the smaller of the two diameters;

3. The difference between any two successive diameters is a constant ratio times the next smaller difference between two successive diameters.

Miscellaneous Wire Gauges.—The old English or London gauge, the sizes of which differ very little from those of the Birmingham gauge, has had considerable use in the past for brass and copper wires, and is now used to some extent in the drawing of brass wire for weaving.

It is nearly obsolete.

Stubs Steel Wire Gauge

Letter.	Size of Letter in Decimals.	No. of Wire Gauge.	Size of Number in Decimals.	No. of Wire Gauge.	Size of Number in Decimals.	No. of Wire Gauge.	Size of Number in Decimals.
Z	.413	1	.227	28	.139	55	.050
Y	.404	2	.219	29	.134	56	.045
X	.397	3	.212	30	.127	57	.042
W	.386	4	.207	31	.120	58	.041
V	.377	5	.204	32	.115	59	.040
U	.368	6	.201	33	.112	60	.039
T	.358	7	.199	34	.110	61	.038
S	.348	8	.197	35	.108	62	.037
R	.339	9	.194	36	.106	63	.036
Q	.332	10	.191	37	.103	64	.035
P	.323	11	.188	38	.101	65	.033
O	.316	12	.185	39	.099	66	.032
N	.302	13	.182	40	.097	67	.031
M	.295	14	.180	41	.095	68	.030
L	.290	15	.178	42	.092	69	.029
K	.281	16	.175	43	.088	70	.027
J	.277	17	.172	44	.085	71	.026
I	.272	18	.168	45	.081	72	.024
H	.266	19	.164	46	.079	73	.023
G	.261	20	.161	47	.077	74	.022
F	.257	21	.157	48	.075	75	.020
E	.250	22	.155	49	.072	76	.018
D	.246	23	.153	50	.069	77	.016
C	.242	24	.151	51	.066	78	.015
B	.238	25	.148	52	.063	79	.014
A	.234	26	.146	53	.058	80	.013
		27	.143	54	.055		

The following table gives the diameters, in decimal parts of an inch, of the various sizes of wire corresponding to the gauge numbers of the different standard wire gauges used in the United States.

Table of Various Wire Gauges

Number of Wire Gauge	American, or Brown & Sharpe (B. & S.)	Birmingham, or Stubs (B. W. G.)	Washburn & Moen Mfg. Co., Worcester, Mass.	Trenton Iron Co., Trenton, N. J.	G. W. Prentiss, Holyoke, Mass.	Old English, From Brass Mfrs' List	British Standard (S. W. G.)	Number of Wire Gauge
0000000							.500	0000000
000000			.460				.464	000000
00000			.430	.450			.432	00000
0000	.46000	.454	.393	.400			.400	0000
000	.40964	.425	.362	.360	.3586		.372	000
00	.36480	.380	.331	.330	.3282		.348	00
0	.32486	.340	.307	.305	.2994		.324	0
1	.28930	.300	.283	.285	.2777		.300	1
2	.25763	.284	.263	.265	.2591		.276	2
3	.22942	.259	.244	.245	.2401		.252	3
4	.20431	.238	.225	.225	.2230		.232	4
5	.18194	.220	.207	.205	.2047		.212	5
6	.16202	.203	.192	.190	.1885		.192	6
7	.14428	.180	.177	.175	.1758		.176	7
8	.12849	.165	.162	.160	.1605		.160	8
9	.11443	.148	.148	.145	.1471		.144	9
10	.10189	.134	.135	.130	.1351		.128	10
11	.090742	.120	.120	.1175	.1205		.116	11
12	.080808	.109	.105	.1050	.1065		.104	12
13	.071961	.095	.0920	.0925	.0928		.0920	13
14	.064084	.083	.0800	.0800	.0816	.08300	.0800	14
15	.057068	.072	.0720	.0700	.0726	.07200	.0720	15
16	.050820	.065	.0630	.0610	.0627	.06500	.0640	16
17	.045257	.058	.0540	.0525	.0546	.05800	.0560	17
18	.040303	.049	.0470	.0450	.0478	.04900	.0480	18
19	.035890	.042	.0410	.0400	.0411	.04000	.0400	19
20	.031961	.035	.0350	.0350	.0351	.03500	.0360	20
21	.028462	.032	.0320	.0310	.0321	.03150	.0320	21
22	.025347	.028	.0280	.0280	.0290	.02950	.0280	22
23	.022571	.025	.0250	.0250	.0261	.02700	.0240	23
24	.020100	.022	.0230	.0225	.0231	.02500	.0220	24
25	.017900	.020	.0200	.0200	.0212	.02300	.0200	25
26	.015940	.018	.0180	.0180	.0194	.02050	.0180	26
27	.014195	.016	.0170	.0170	.0182	.01875	.0164	27
28	.012641	.014	.0160	.0160	.0170	.01650	.0148	28
29	.011257	.013	.0150	.0150	.0163	.01550	.0136	29
30	.010025	.012	.0140	.0140	.0156	.01375	.0124	30
31	.008928	.010	.0130	.0130	.0146	.01225	.0116	31
32	.007950	.009	.0120	.0120	.0136	.01125	.0108	32
33	.007080	.008	.0110	.0110	.0130	.01025	.0100	33
34	.006305	.007	.0100	.0100	.0118	.00950	.0092	34
35	.005615	.005	.0095	.0095	.0109	.00900	.0084	35
36	.005000	.004	.0090	.0090	.0100	.00750	.0076	36
37	.004453		.0085	.0085	.0095	.00650	.0068	37
38	.003965		.0080	.0080	.0090	.00575	.0066	38
39	.003531		.0075	.0075	.0083	.00500	.0052	39
40	.003145		.0070	.0070	.0078	.00450	.0048	40
41							.0044	41
42							.0040	42

NOTE.—*The sizes of wire* are ordinarily expressed by an arbitrary series of numbers Unfortunately there are several independent numbering methods, so that it is always necessary to specify the method or wire gauge used. The above table gives the numbers and diameters in decimal parts of an inch for the various wire gauges in general use.

The Stubs steel wire gauge has a somewhat limited use for tool steel wire and drill rods.

The Standard wire gauge, otherwise known as the New British Standard, the English Legal Standard of the Imperial Wire Gauge, is the legal standard of Great Britain for all wires as fixed by order in Council, August 23, 1883. It was constructed by modifying the Birmingham Wire Gauge.

While the Standard wire gauge is the most used wire gauge in Great Britain, there is a tendency to adopt mils or decimal fractions of an inch rather than gauge numbers, the same as in the United States.

There was once a movement to bring the standard wire gauge into general use in the United States. It was adopted in 1885 by the National Telephone Exchange Association, and, in 1886, by the National Electric Light Association. The gauge, however, never came into general use.

From the foregoing considering the multiplicity of gauges, the importance is emphasized of specifying the gauge and of knowing what gauge to use.

In using the gauges known as Stubs gauges there should be constantly borne in mind the difference between the Stubs' Iron Wire Gauge and the Stubs' Steel Wire Gauge. The Stubs' Iron Wire Gauge is the one commonly known as the English Standard Wire, or Birmingham Gauge and designates the Stubs' *soft* wire sizes. The Stubs' Steel Wire Gauge is the one that is used in measuring drawn steel wire or drill rods of Stubs' make and is also used by many makers of American drill rods.

TEST QUESTIONS

1. *What confusion arose when wire gauges were first introduced?*
2. *What are the names given to the American wire gauge?*
3. *Is the American wire gauge a legalized gauge?*
4. *What is the American wire gauge now used for?*
5. *Upon what are the gauge numbers of the American wire gauge based?*
6. *How are the sizes of stranded conductors larger than No. 0000 A.w.g. measured?*
7. *Describe a micrometer screw gauge.*
8. *What do the numbers of the American wire gauge represent?*
9. *Are the numbers of the B. & S. gauge progressive or retrogressive?*
10. *Explain retrogressive gauge numbers.*
11. *Describe a calculating gauge, and explain how it works.*
12. *Give a number of wire table short cuts.*
13. *Name some miscellaneous wire gauges.*

14. *For what purpose has the Birmingham gauge been considerably used in the past?*

CHAPTER 103

Wires and Cables

The wireman who is called upon to plan and install a system of wiring will find it necessary first to have a knowledge of the various kinds of wire so as to select the one best suited for the work, and to be able to make simple calculations in order to determine the proper sizes of wire for the various circuits.

In order to avoid confusion students should be familiar with the following wire and cable definitions, which are taken from the Standards of the A. I. E. E.

Wire and Cable Definitions

Cable.—A stranded conductor (single conductor cable*) or a combination of conductors insulated from one another (multiple conductor cable).

*NOTE.—The first kind of cable is a single conductor, while the second kind is a group of several conductors. The component conductors of the second kind of cable may be either solid or stranded, and this kind of cable may or may not have a common insulating covering. The term cable is applied by some manufacturers to a solid wire heavily insulated and lead covered; this usage arises from the manner of the insulation, but such a conductor is not included under this definition of cable. The term cable is a general one, and in practice, it is usually applied only to the larger sizes. A small cable is called a stranded wire, or a cord, both of which are here defined. Cables may be bare or insulated, and the latter may be armored with lead, or with steel wires or bands.

Concentric Lay Cable.—A single conductor cable composed of a central core surrounded by one or more layers of helically laid wires.

Conductor.—A wire or combination of wires not insulated from one another, suitable for carrying a single electric current.

NOTE.—The term conductor is not to include a combination of conductors insulated from one another, which would be suitable for carrying several different electric currents. Rolled conductors, such as bus bars, are of course, conductors, but are not considered under the terminology here given.

Cord.—A small cable, very flexible and substantially insulated to withstand wear.

NOTE.—There is no sharp dividing line in respect to size between a cord and a cable, and likewise no sharp dividing line in respect to the character of insulation between a cord and a stranded wire. Rubber is used as the insulating material for many classes of cords.

Concentric Strand.—A central core surrounded by one or more layers of helically laid wires or groups of wires.

Bare Cable.—Any group of wires twisted together helically, or composed of any number of such groups. The term wire indicates the individual solid wires in a cable.

FIG. 5,072.—Apparatus Cable. *Used* for connecting machine terminals to brush holders, for transformer leads and similar purposes where great flexibility is required and the working pressure does not exceed 750 volts. One conductor. Sizes up to 2,000,000 c.m. Stranding, extra flexible. Insulation, varnished cambric or rubber compound. Thickness of insulation, same as code standard for 0-600 volt rubber. Covering over insulation, one dry cotton braid. (Sometimes a weatherproof braid is specified.)

Bunched Strand.—Sometimes applied to a collection of straight or twisted wires which are grouped together with little regard to their geometrical arrangement.

Direction of Lay.—The lateral direction in which the strands of a cable run over the top of the cable as they recede from an observer looking along the axis of the cable.

Duplex Cable.—Two insulated stranded conductors twisted together.

NOTE.—Duplex cables may or may not have a common insulating covering.

Factor of Assurance.—The factor of assurance of wire or cable insulation shall be the ratio of the voltage at which it is tested to that at which it is used

Insulation Resistance.—The electrical resistance in a conductor offered by its insulation, to an impressed voltage tending to produce a leakage of current through the same.

N-Conductor Cable.—A combination of N-conductors insulated from one another.

NOTE.—It is not intended that the name as here given be actually used. Instead, say, 1 conductor cable, 2 conductor cable, 3 conductor cable. etc. In referring to the general case the term "multiple conductor cable" should be used.

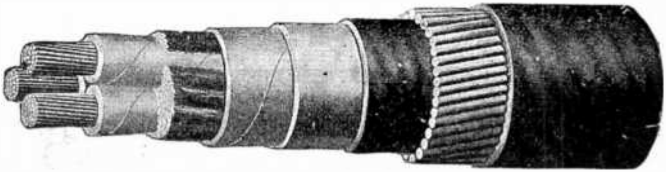


FIG. 5,073.—Armored or submarine cable. *Used* under water for crossing rivers, bays and lakes. Armored cables may be insulated with paper, varnished cambric or rubber compound. The lead·d or taped core is served with jute yarn, run through hot asphalt compound, then armored with galvanized steel wires, run through hot asphalt compound, served with two layers of yarn and finally run through asphalt compound. The asphalt and jute over the armor may be omitted, if desired.

FIG. 5,074.—Automobile lighting wire. *Used* for connecting automobile lights with the switch and source of cu rent supply. One wire 10 to 14 *A.w.g.* stranded. Insulation, "Black Core" rubber compound. Covering over insulation, one varnished soft cotton braid 1-64th in. thick. Outside covering one (2 coat) varnished braid, 1-64th in. thick.

N-Conductor Concentric Cable.—A cable composed of an insulated central conductor with (N-1) tubular stranded conductors laid over it concentrically and separated by layers of insulation.

NOTE.—This kind of cable usually has only two or three conductors. Such cables are used particularly for alternating currents. The remark on the expression "N conductor" given for the preceding definition also applies here.

Round Conductor.—Either a solid or stranded conductor of which the cross section is substantially circular.

Rope Lay Cable.—A single conductor cable composed of a central core surrounded by one or more layers of helically laid groups of wires.

NOTE.—This kind of cable differs from the preceding in that the main strands are themselves stranded.

Sector Cable.—A multiple conductor cable in which the cross section of each conductor is substantially a sector, an ellipse, or a figure intermediate between them.

NOTE.—Sector cables are used in order to obtain decreased overall diameter and thus permit the use of larger conductors in a cable of given diameter.

Split Conductor.—A conductor which is divided into two or more parts, separated from one another by insulation which is thin compared with the insulation around the conductor.

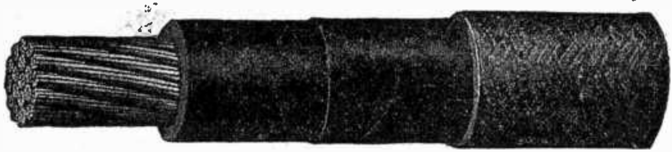


FIG. 5,075.—Automobile starting and charging cable. *Used* for connecting the batteries to the starting motor and dynamo, of a gasoline propelled car. One conductor, sizes 2 to 00 *A.w.g.* stranded. Insulation, "Black Core" rubber compound. Intermediate covering, one overlapping strip of varnished cambric. Overall covering, one (2 coat) varnished braid, 1-64th in. thick.

FIG. 5,076.—Basket weave armored cable. *It consists of* a wire braid similar in construction to the ordinary cotton braid, used for covering wires. It is usually made of galvanized soft steel wire, but it is sometimes made of brass or copper. The warp and woof of this fabric, each consists of between five and fourteen ends, depending upon the size of cable, the usual size of wire being .0126″ diam. The strands or ends are laid closely together, flat and parallel, firmly binding the core. Basket weave is used for two purposes. First as a mechanical protection, and second, as a means of grounding the outside of high voltage cables, in order to prevent static disturbances. The former application is by far the more important.

NOTE.—The term split conductor usually designates a conductor in two parts or splits, which may be either concentric or external to one another.

Strand.—*a.* One of the wires, or groups of wires of any stranded conductor. *b.* Group of single wires in one or more layers, twisted together helically and symmetrically with a uniform pitch around a single central wire or neutral axis. This construction is sometimes called concentric strand.

Stranded Conductor.—A conductor composed of a group of wires, or of any combination of groups of wires.

NOTE.—The wires in a stranded conductor are usually twisted or braided together.

Stranded Wire.—A group of small wires, used as a single wire.

NOTE.—A wire has been defined as a slender rod or filament of drawn metal. If such a filament be subdivided into several smaller filaments or strands, and is used as a single wire, it is called a stranded wire. There is no sharp dividing line of size between a stranded wire and a cable. If used as a wire, for example, in winding inductance coils or magnets, it is called a stranded wire and not a cable. If it be substantially insulated, it is called a cord.

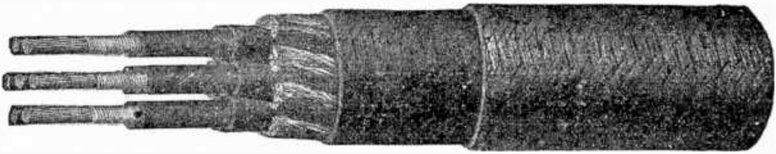


FIG. 5,077.—Border light cable. *Used* for stage lighting or other purposes where a flexible multiple conductor cable is required for electric lights. Number of conductors, three or more. Standard sizes, 12 and 14 *A.w.g.* stranded. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation one saturated braid. Grouping of conductors, twisted. Fillers dry jute. Covering overall, two saturated braids. The outer braid is sometimes saturated with a flameproof compound instead of the usual weatherproof compound.

FIG. 5,078.—Brewery cord. *Used* for extension lights in damp places and differs from ordinary lamp cord only in that the braids are weatherproof instead of dry glazed cotton. Two conductors. Range of sizes, 10 to 18 *A.w.g.* bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid. Grouping of conductors, twisted pair.

Triplex Cable.—Three insulated single conductor cables twisted together.

Twin Cable.—Two insulated stranded conductors laid parallel, having a common covering.

Twisted Pair.—A cable composed of two small insulated conductors, twisted together, without a common covering.

NOTE.—Triplex cables may or may not have a common insulating covering.

NOTE.—The two conductors of a "twisted pair" are usually substantially insulated so that the combination is a special case of a cord.

Twin Wire.—Two small insulated conductors laid parallel, having a common covering.

Wire.—A slender rod or filament of drawn metal.

NOTE.—The definition restricts the term to what would ordinarily be understood by the term solid wire. In the definition the word slender is used in the sense that the length is great in comparison with the diameter. If a wire be covered with insulation, it is properly called an insulated wire; while primarily the term wire refers to the metal: nevertheless, when the context shows that the wire is insulated, the term wire will be understood to include the insulation.

Standard Annealed Copper.—*a. General.* The following shall be taken as normal values for standard annealed copper.

FIG. 5,079.—Canvasite cord is a type of lamp cord specially adapted to rough usage. Two conductors. Range of sizes, 10 to 18 *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid. Grouping of conductors, twisted. Covering overall, one saturated braid.

b. Resistance.—At a temperature of 20° C., the resistance of a wire of standard annealed copper one meter in length and of a uniform section of 1 square millimeter is 1/58th ohm = 0.017241 ohm.

c. Density.—At a temperature of 20° C., the density of standard annealed copper is 8.89 grams per cubic centimeter.

d. Temperature Coefficient of Resistance.—At a temperature of 20° C., the constant mass temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is 0.00393 = 1/254.45 per degree centigrade.

e. Resistance of Standard Annealed Copper at 20° C.—As a consequence, it follows from (b) and (c) that, at a temperature of 20° C. the resistance of a wire of standard annealed copper of uniform section, one meter in length and weighing one gram, is 1/58×8.89 = 0.15328 ohm.

Copper Wire.—Copper is used in nearly all cases of wiring because it combines high electrical conductivity with good mechanical qualities and reasonable price. In conductivity it is only surpassed by silver, but the cost of the latter of course prohibits its use for wiring purposes.

Copper wire is used for electric light and power lines, for most telephone and some telegraph lines, and for all cases where low resistance is required at moderate cost.

Hard drawn copper wire is ductile, and has a high tensile strength; these properties allow it to be bent around corners and drawn through tubes without injury.

Pure annealed copper has a specific gravity of 8.89 at 60° Fahr. One cubic inch weighs .32 pound; its melting point is about 2,100° Fahr.

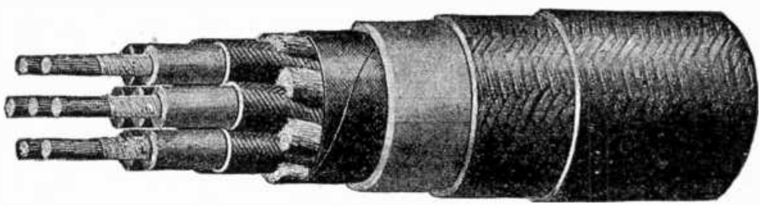


FIG. 5,080.—Car jumper cables. *Used* for connecting the control circuits of adjacent multiple unit cars. They are made flexible to withstand the constant swinging as they stretch from car to car. Number of conductors, five to thirty. Stranding, each conductor consists of 19 No. 24 *A.w.g.* wires. Separator, soft cotton wind. Insulation on each conductor, 30 per cent hevea rubber compound. Insulation thickness of each conductor 3/64″. Covering over insulation, one colored dry cotton braid. Fillers, dry jute. Cover over filler, one rubber filled tape. Belt over all conductors, 30 per cent hevea rubber compound. Covering overall, two saturated braids.

Good hard drawn copper has a tensile strength of about three times its own weight per mile length. Thus, a number 10 B. & S. gauge copper wire, weighing 166 lbs. per mile, will have a breaking strength equal to approximately 3×166=498 lbs.

Iron Wire.—This kind of wire is largely used for telegraph and telephone lines, although it is rapidly being replaced by copper in long lines.

There are three grades of iron wire:

1. ***Extra best best*** (***E. B. B.***) which has the highest conductivity and is the nearest to being uniform in quality, being both tough and pliable;

2. ***Best best*** (***B. B.***), which varies more in quality, is not so tough, and is lower in conductivity. *It is frequently sold as* ***E. B. B.***;

3. ***Best*** (***B.***), which is the poorest grade made, being more brittle, and lowest in conductivity. Iron wire should be well galvanized.

German Silver Wire.—German silver is an alloy, consisting of 18 to 30% nickel, and the balance about four parts copper to one part zinc. It is very largely used as a resistance material in making resistance coils, and is sold in the form of wire and strip. The resistance of this wire varies with its composition.

FIG. 5,081.—Car lighting wire. ***Used*** for wiring railroad cars illuminated by axle driven dynamos. One conductor. Standard sizes, 0 to 16 *A.w.g.* Insulation, 30 per cent hevea rubber compound. Covering over insulation, 16 to 8 *A.w.g.*, one saturated braid, 6 to 0 *A.w.g.*, two saturated braids.

The resistance of the 18% alloy at 25° C. is 18 times that of copper, and of the 30% alloy about 28 times that of copper.

The safe carrying capacity of the wire in spirals in open air for continuous duty is such that the circular mils per ampere varies from about 1,500 in No. 10 wire to about 475 in No. 30. For intermittent duty the capacity is twice as great.

Standard of Copper Wire Resistance.—Matthiessen's standard for resistance of copper wire is as follows: *A hard drawn copper wire one meter long, weighing one gramme, has a resistance of* .1469 *B. A. unit at* 32° *Fahr.* Relative conducting power: silver, 100; hard or un-annealed copper, 99.95; soft or annealed copper, 102.21.

A committee of the Am. Inst. Electrical Engineers recommends the following form of Matthiessen's standard, taking

8.89 as the specific gravity of pure copper: *A soft copper wire one meter long and one millimeter in diameter has an electrical resistance of .02057 B. A. unit at 0°C.** From this the resistance of a soft copper wire one foot long and .001 in. in diameter (mil foot) is 9.72 B. A. units at 0°.C.

For every degree Fahr., the resistance of copper wire increases .2222%. Thus a piece of copper wire having a resistance of 10 ohms at 32° would have a resistance of 11.11 ohms at 82°.

FIG. 5,082.—Single conductor code house wire. *Used* in pairs for house wiring or with twin wires for the neutral of three wire systems. One conductor, sizes, 0000 to 14 *A.w.g.*, solid. Insulation, "Black Core" rubber compound. Covering over insulation one saturated braid, two saturated braids or rubber filled tape and one saturated braid.

Relative Conductivity of Different Metals and Alloys.

(According to Lazare Weiler.)

Pure silver	100	Swedish iron	16
Pure copper	100	Pure platinum	10.6
Alloy, ½ copper, ½ silver	86.65	Copper with 10% nickel	10.6
Telephonic siliceous bronze	35	Pure lead	8.88
Pure zinc	29.9	Pure nickel	7.89
Brass with 35% zinc	21.5	Phosphor-bronze, 10% tin	3.88

Wires.—Copper is used more than any other metal for transmitting electrical energy, and for interior wiring it is used exclusively. Copper conductors should be of the highest commercial conductivity, not less than 97%.

For wires up to sizes as large as No. 8 B. & S. gauge, single wires may be used, but for larger sizes the necessary conductivity should be obtained by conductors made up of strands

*NOTE.—The international ohm ÷ B. A. ohm = 1 ÷ .9866. The B. A. ohm ÷ International ohm = 1 ÷ 1.0136. Hence, to reduce British Association ohms to International ohms, divide by 1.0136, or multiply by .9866.

of smaller wires. The size of these strands depends upon the size of the conductors and the conditions under which they are to be used.

Where conductors are very large (as for instance dynamo leads), and where it is essential that they be as flexible as possible, strands as small as No. 20 or 22 B. & S. gauge may be used.

Conductors for flexible cords, pendants, fixtures, etc., should also consist of very fine strands, so that they may be perfectly pliable and flexible.

FIG. 5,083.—Solid twin (flat) code house wire. ***Used*** for the same purpose as stranded twin code house wire. Two conductors, sizes 6 to 14 *A.w.g.* Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid. Grouping of conductors, parallel. Covering overall, one saturated braid.

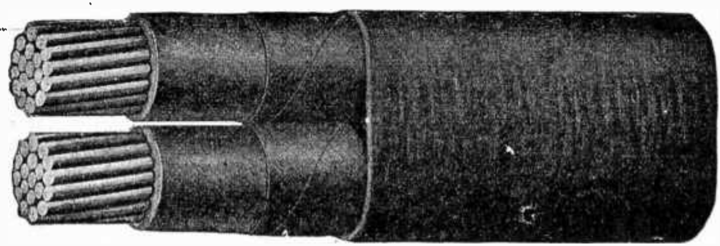


FIG. 5 084.—Twin flat wire. ***Used*** for wiring buildings and is useful where it is to be drawn into a conduit with a single conductor cable. Two conductors, sizes, 14 *A.w.g.* to 500,000 *c.m.*, stranded. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid except for 6 *A.w.g.* and larger where a rubber filled tape is used. Grouping of conductors, parallel. Covering overall, one saturated braid.

The individual strands for instance, for a No. 16 B. & S. gauge flexible cord should be as fine as No. 30.

NOTE.—Copper, aluminum and steel are the only materials in common commercial use for electric wires. The low conductivity and large size of aluminum and steel wires compared to copper, however, so increase the cost of insulation as to render their use in insulated wires, except in very special cases, inadvisable and uneconomical. Copper for electrical purposes should be absolutely pure as a very small amount of any impurity seriously affects the electrical conductivity.

Covered Conductors.—For most conditions of service, wires are protected with an insulating covering. Wires used in interior circuits should have a covering which shall act both as an electrical insulator and as a mechanical protection. In some instances, however, the insulating qualities are of secondary importance.

The various forms of covering now in use commercially for wires are:

1. Rubber;
2. Weather proof;

FIG. 5,085.—Fixture wire. *Used* in wiring electric light fixtures. One conductor, standard sizes, 16 and 18 *A.w.g.*, solid or stranded. Insulation, "Black Core" rubber compound. Covering over insulation, one saturated braid, at least $\frac{1}{64}$" thick.

FIG. 5,086.—Deck cable is a portable cable for rough usage in damp places. Two (continued) conductors, sizes 10 to 18 *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated braid. Fillers, dry jute. Grouping of conductors, twisted. Insulating belt, 'Black Core' rubber compound. Thickness of belt, $\frac{3}{64}$". Covering overall, one saturated braid.

3. Slow burning;
4. Slow burning weather proof;
5. Armored.

Rubber Covered Conductors.—This class of conductor consists of a tinned copper wire with a rubber covering, protected by an outside braiding of cotton saturated with a preservative compound.

Ques. What are the advantages of rubber insulation for wires?

Ans. It is water proof, flexible, fairly strong, and has high insulating qualities.

Ques. What are the disadvantages of rubber insulation?

Ans. It deteriorates more or less rapidly and is quickly injured by temperatures above 140° Fahr.

Ques. For what service are rubber covered conductors adapted?

Ans. For interior wiring.

FIG. 5,087.—Flame proof cable. *Used* about power houses in the vicinity of switchboards and apparatus where special fire proof protection is desired. This method of protection consists essentially in impregnating the braided covering with a flame proof paint, and may be used in connection with any conductors having braided covering, when so specified.

FIG. 5,088.—Heater cord. *Used* for the wiring of domestic heating apparatus, such as flatirons, stoves, etc., requiring over 250 watts. Two untinned conductors, sizes 10 to 18 *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one asbestos braid. Grouping of conductors, twisted. Covering overall, one glazed cotton braid.

Ques. Is pure rubber used?

Ans. No. The covering should be made from a compound containing from 20 to 35 per cent. of pure rubber.

It would be difficult to place pure rubber on a wire, and moreover a covering made of pure rubber would not be durable and would deteriorate

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NOTE.—*Tinning.*—Perfect tinning of the copper conductor for all rubber covered wires is absolutely necessary to insure great durability. The coating of the pure tin protects the copper from the action of the sulphur used and the minutest flaw in this coating will allow a chemical action to begin and the conductor will be gradually eaten away.

very rapidly, particularly at temperatures above 120° Fahr. Accordingly, it is mixed with other materials, such as French chalk, silicate of magnesia, sulphur, red lead, etc.

Weather Proof Wires.—This class of wire is protected from the weather by a water proof covering, consisting usually of braided cotton of two or three thicknesses saturated with a moisture resisting insulating compound.

Ques. Where are weather proof conductors used?

FIG. 5,089.—Lamp cord. *Used* for pendants in dry places and also for portables in dry places where the usage is not hard. Two untinned conductors, sizes 10 to 18 *A.w.g.*, bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one silk cotton, or mercerized cotton braid. Grouping of conductors, twisted pair. The braid is made in all standard colors.

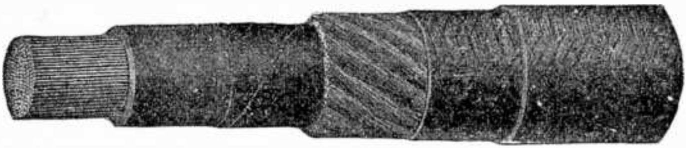


FIG. 5,090.—Third rail jumpers are used for joining sections of third rail at cross-overs, section gaps, and similar places where the third rail is discontinuous. One conductor, sizes 2,000,000 to 250,000 *c.m.* Insulation, 20 per cent hevea rubber compound. Covering over insulation, one rubber filled tape. Covering over tape, jute serving. Covering over jute, two saturated braids.

Ans. In places subject to dampness, such as cellars, tunnels, open sheds, etc.

Ques. What are the advantages of weather proof wire?

Ans. The insulation is cheap, very durable, and does not deteriorate unless exposed to high temperatures such as will melt the compound.

Ques. State the disadvantages.

Ans. The covering is more or less inflammable and is not very efficient as an insulator.

Ques. What precaution should be taken in using weather proof wires?

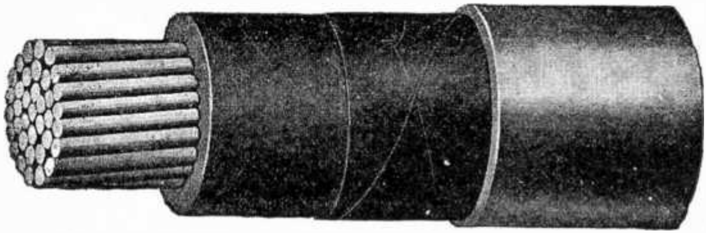


FIG. 5,091.—Stranded single conductor lead covered cable is similar to solid single conductor lead covered wire except that it has greater flexibility and is made in larger sizes. One conductor, sizes, 14 *A.w.g.* to 2,000,000 *c.m.* stranded. Insulation, "Black Core" rubber compound. Covering, one rubber filled tape or braid. Covering overall, lead sheath.

FIG. 5,092.—Three conductor lead covered cable, solid. ***Used*** for three-phase circuits under the same conditions of service as single conductor solid lead covered wire. Three conductors, sizes to 14 *A.w.g.* solid. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one rubber filled tape. Grouping of conductors, twisted. Fillers, jute. Covering over jute, one rubber filled tape. Covering overall, lead sheath.

Ans. On account of the inflammable character of the covering, care should be taken in wiring at points where any considerable number of wires are brought together, or where there is much wood work or other combustible material.

Ques. For what use are weather proof wires especially adapted?

Ans. For outside wiring where moisture is certain and where fire proof quality is not necessary.

Obviously wires of this class should not be used in conduits, nor in fact, in any way except exposed on glass or porcelain insulators.

Slow Burning Wire.—This class of wire is defined as: *one that will not carry fire.* The covering consists of layers of cotton or other thread, all the interstices of which are filled with

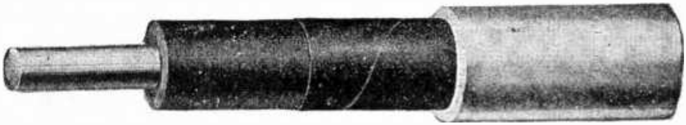


FIG. 5,093.—Solid single conductor lead covered wires. *Used* where conditions require a moderate degree of mechanical protection or insurance against the penetration of moisture, or both, as in outdoor ducts and manholes in wet locations. One conductor, sizes 4 to 14 *A.w.g.* solid. Insulation, "Black Core" rubber compound. Covering over insulation, one rubber filled tape or braid. Covering overall, lead sheath.

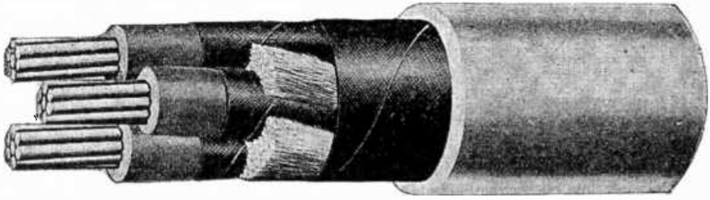


FIG. 5,094.—Three-conductor lead covered cable, stranded. *Used* for three-phase circuits where extra flexibility is required in the smaller sizes and always in the larger sizes where solid conductors would make the cable too stiff to handle. Three conductors, sizes 0000 to 14 *A.w.g.* Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one rubber filled tape. Grouping of conductors, twisted. Fillers, jute. Covering over jute, one rubber filled tape. Covering overall, lead sheath.

the fireproofing compound, or of material having equivalent fire resisting and insulating properties. The outer layer is braided and specially designed to withstand abrasion. The thickness of insulation must not be less than that required for slow burning weather proof wire and the outer surface must be finished smooth and hard.

Ques. Where should slow burning wires be used?

Ans. In hot dry places, where ordinary insulations would be injured, and where wires are bunched, as on the back of a large switchboard or in a wire tower.

A slow burning covering is considered good enough when the wires are entirely on insulating supports. Its main object is to prevent the copper conductors coming into contact with each other or anything else.

Ques. What must be done before using weather proof wire?

FIG. 5,095.—Concentric mine cable. This is used for the reels of gathering reel locomotives and for cutting machines. It has the advantage of being round and of small diameter. Two conductors. Stranding of center conductor, flexible. Stranding of outer conductor, ring of wires having total cross sectional area equal to that of center conductor. Covering of center conductor, rubber filled tape. Covering over outside conductor, belt of "Black Core" rubber compound. Covering over belt, rubber filled tape. Covering over tape, two extra tight water proof braids.

FIG. 5,096.—Packinghouse cord is flexible lamp cord made to withstand rough usage in damp places. Two untinned conductors, sizes 10 to 18 *A.w.g.* bunched. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated cotton braid. Grouping of conductors, twisted pair. Fillers, dry jute. Covering overall, 2 saturated cotton braids.

Ans. Permission to use the wire must first be obtained from the local Inspection Department.

Slow Burning Weather Proof Wire.—The covering of this type wire is a combination of the Underwriters' and weather proof insulations. The fireproof coating comprises a little more than half of the total covering. When the fireproof coating is placed on the outside, the wire is called "slow burning weather proof."

Ques. How does slow burning weather proof wire compare with weather proof wire?

Ans. It is less inflammable and less subject to softening under heat.

Ques. Where should slow burning weather proof wire be used?

FIG. 5,097.—Park Cable. *Used* for transmission and distribution where it is preferable to bury the cables directly in the ground rather than to put them in ducts. Any kind of cable will be furnished with park cable covering, but the following types are in general use for distribution purposes. Standard park cables (0-600 volts). One to three conductors. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, rubber filled tape. Covering over tape, lead sheath. Covering over lead sheath, asphalted jute. Protective armor, two galvanized steel tapes, wound in the same direction, the outer tape covering the spaces between turns of the inner tape. Outside covering, asphalted jute.

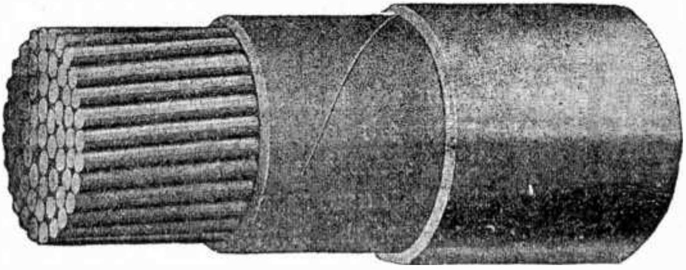


FIG. 5,098.—Paper insulated cables. *Used* for underground transmission and distribution, for which they have the advantages of cheapness, durability, low dielectric losses, low electrostatic capacity and high current-carrying capacity. The insulation consists of Manila paper applied helically to the conductor, and then saturated with a mineral oil compound which constitutes the essential insulation. In order to retain this oil the cable must have an oil-proof covering which is almost invariably a sheath of lead. Sizes from No. 6 *A.w.g.* to 2,000,000 *c.m.*, and with any number of conductors within the usual limits.

Ans. In places where the wires are to be run exposed and where moisture resisting quality is desired, also where at the same time it is desirable to avoid an excess of inflammable covering.

Ques. How should it be installed?

Ans. It should be set on glass or porcelain insulators.

Ques. For what service is slow burning weather proof wire not suited?

Ans. It is not adapted to outside work.

FIG. 5,099.—Rubber insulated signal wire for 660 volts or less. One or two conductors, sizes 0 to 18 *A.w.g.*, solid. Insulation on each conductor, Railway Signal Association compound. Covering over insulation, one cotton braid, 3/64" thick, weather proof.

FIG. 5,100.—Reinforced cord. *Used* in dry places for portable lamps, fans, heavy pendants and other electric devices for which type C Lamp Cords are inadequate. Two untinned conductors. sizes 10 to 18, *A.w.g.*, bunched Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one soft cotton braid. Grouping of conductors, twisted. Insulating belt, "Black Core" rubber compound. Covering over belt, one glazed cotton braid.

Stranding.—If a solid copper wire be made larger in diameter than .46 in. it becomes hard to splice and difficult to handle, owing to its size and stiffness. Conductors larger than this are nearly always built up of small wires twisted into a strand or cable. The flexibility of a cable will increase as the size of the constituent wires decreases or as the number of wires increases, and it will depend somewhat upon the method of laying up the cable.

While it is possible to build up a cable from any number of wires, there are certain combinations only that can be used to obtain a smooth and symmetrical cable. These combinations are governed by well established geometrical rules which should be observed whenever possible.

There are in general use in the United States two methods of specifying stranded conductor. The first and older method specifies a number of strands of such a size as to equal a regular gauge size or a round number of circular mils, such as

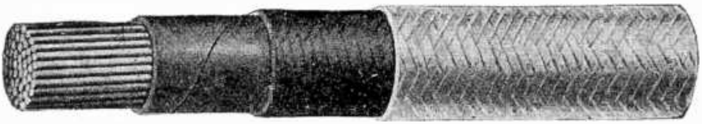


FIG. 5,101.—Station cable. *Used* for connecting apparatus and machinery in power stations and sub-stations. One conductor, sizes 2,000,000 to 250,000 *c.m.* Insulation, varnished cambric. Thickness of insulation, depends upon voltage and method of installation. Covering over insulation, one saturated cotton braid, and one flameproof braid.

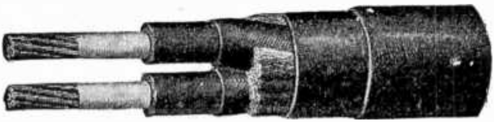


FIG. 5,102.—Stage cable. *Used* for the operation of movable lamps on theatre stages. Two untinned conductors, sizes 10 to 14 *A.w.g.*, bunched and 4 to 8 *A.w.g.*, rope stranded. Separator, soft cotton wind. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, one saturated cotton braid. Grouping of conductors, twisted. Fillers, dry jute. Covering overall, two saturated cotton braids.

250,000, 500,000, 1,000,000, etc. This method is objectionable as it almost invariably necessitates an odd size strand, causing delay in delivery and in some cases increased cost. The second method specifies a number of strands each of a standard gauge size. This method is preferable, and while it does not give stranded conductors equivalent to even gauge sizes, it is near enough for all practical engineering purposes.

Stranded conductors may either be concentric lay or rope lay. Concentric lay is commonly used where the number of strands is less than 127 and rope lay where it is more. The flexibility of a stranded conductor depends on the number of strands, not on the method of lay, *i.e.*, concentric or rope.

The best concentric stranding is made by using one wire as a center and twisting around it six wires constituting the first layer, then a layer of 12 wires, then 18, 24, 30, 36, etc., each layer being twisted in the opposite direction from the preceding. Centers of 3 or 4 wires may also be used.

In rope stranding the groups forming the rope are laid as concentric

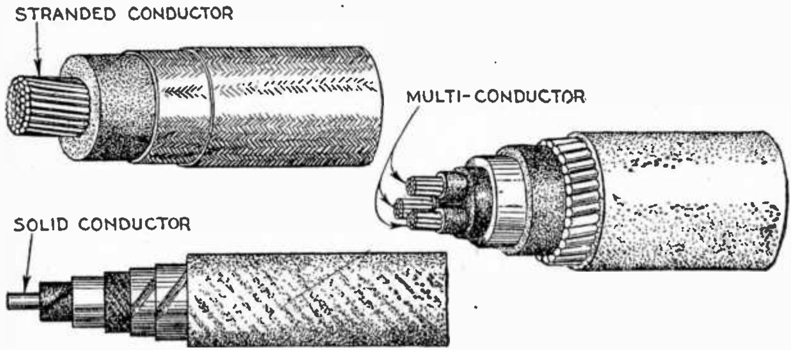


FIG. 5,103.—Stranded single conductor, double braided station cable.
FIG. 5,104.—Stranded multi-conductor band steel armored park cable.
FIG. 5,105.—Solid single conductor band steel armored park cable.

strands, and these strands may then be handled as individual wires are in concentric stranding. The number of combinations on rope lay are almost innumerable, but the series $7\times7-7\times19-7\times37$, etc. $19\times19-19\times37$, etc. $37\times37-37\times61$, etc., are the best. The term "bunching" or "bunched stranding" is applied to a collection of strands laid without regard to their geometrical arrangement. These wires are sometimes laid straight and held together with a wind or braid of cotton, or they are twisted together in a mass. The only excuse for this method of so-called stranding is cheapness.

The following table gives the number of wires in concentric stranding (or the groups of wires in rope stranding) using centers of 1, 3 or 4; also multipliers to obtain the outside diameter of the conductor.

FIG. 5,106.—Single conductor stranded code house cable. *Used* in pairs for house wiring, or with twin wires for the neutral of three wire systems. One conductor. Sizes, No. 14 *A.w.g.*, and all larger sizes, stranded. Insulation "Black Core" rubber compound. Covering over insulation, one saturated braid, two saturated braids or rubber filled tape and one saturated braid.

Number of Wires in Concentric Stranding

(According to Okonite)

Center of 1		Center of 3		Center of 4	
Number of Strands	Multiplier	Number of Strands	Multiplier	Number of Strands	Multiplier
1	1	3	2.1547	4	2.414
7	3	12	4.1547	14	4.414
19	5	27	6.1547	30	6.414
37	7	48	8.1547	52	8.414
61	9	75	10.1547	80	10.414
91	11	108	12.1547	114	12.414
127	13	147	14.1547	154	14.414
169	15	192	16.1547	200	16.414
217	17	243	18.1547	252	18.414

Examples:

Concentric Stranding.

Find diameter of conductor having:

37 strands No. 14 A.w.g. (.06408″)

Diameter = 7 × .06408″ = .4486″.

Table can also be used for multiple conductor cable, as follows:

Rope stranding:

Find diameter of conductor having:

7×19 (133) strands of No. 14 A. W. G. (.06408")

diameter = 3×5×.06408" = .9612"

Find diameter over conductors of a multiple conductor cable consisting of 27 No. 14 *A.w.g.* solid, each with 3/64" wall insulation plain:

No. 14 = .06408"

Insulation, 3/64"×2 = .09375"

Diameter over insulated conductor = .15783"

Diameter over conductors = 6.1547×.158" = .9724".

To obtain the outside diameter of the finished cable, addition must be made for tape, braid, lead or armor.

Due to the twist in the strands the weight of a stranded wire is greater than the equivalent solid wire. The resistance is also greater, as the current apparently follows the strands instead of flowing parallel with the axis of the wire.

FIG. 5,107.—Code house cable, three conductor solid. ***Used*** for wiring buildings especially for use with three phase machinery. Three conductors. Sizes, 20 to 14 *A.w.g.* Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, 2 to 6 *A.w.g.*, one rubber filled tape, 8 to 14 *A.w.g.*, one saturated braid. Grouping of conductors, twisted. Fillers, jute. Covering over jute, one rubber filled tape. Covering overall, one saturated cotton braid.

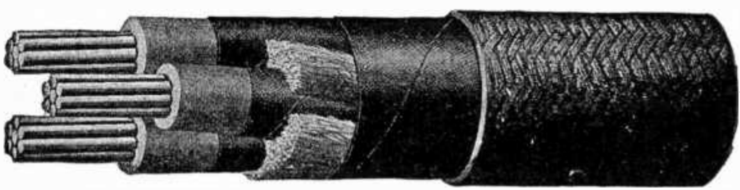


FIG. 5,108.—Three-conductor stranded code house cable. ***Used*** under the same conditions as solid three conductor code house cable unless greater flexibility is required, especially in the larger sizes. Three conductors, sizes 0000 to 14 *A.w.g.*, stranded. Insulation on each conductor, "Black Core" rubber compound. Covering over insulation, 0000 to 6 *A.w.g.*, one rubber filled tape, 8 to 14 *A.w.g.*, one saturated braid. Grouping of conductors, twisted. Fillers, jute. Covering over jute, one rubber filled tape. Covering overall, one saturated braid.

The generally accepted figures for increase of both weight and resistance over solid wire are 2% for concentric and 4.04% for rope stranding.

Cables.—By definition a cable is a single copper wire, or strand of such wires, heavily insulated and covered by a coated metal sheath or envelope, for the purpose of telegraphic communication or electrical distribution. There are numerous kinds of cables designed to meet the varied requirements. With respect to the conductor, cables may be classed as

1. Single conductor;
2. Multi-conductor.

The classification refers to the number of electrical paths and not the number of wires. Thus a single conductor cable may have only one large wire or for flexibility, the conductor is composed of a number of fine wires grouped together, stranded and covered by an outer insulation.

A multi-conductor cable consists of a number of individually insulated wires (either solid or stranded) which may or may not be grouped together within an outer covering.

Sometimes an outer sheath of lead, steel wires or bands is placed over the cable.

The term "cable" is a general one, and in practice, it is usually applied only to the larger sizes.

A small cable is called a stranded wire or a cord. A stranded wire is a group of small wires, used as a single wire. A cord is a small flexible insulated cable.

A stranded wire may or may not be insulated. A cord must be insulated. There is no sharp dividing line of size between a cable and a stranded wire, or between a stranded wire and a cord.

The accompanying cuts show the classification above mentioned.

132,000 Volt Single Conductor Oil Filled Cable.—While the power generated from local plants in heavy centers of industry and population is distributed locally at about 13,000 or 25,000 volts, system interconnection lines and long distance transmission lines require considerably higher pressures in the order of 66,000, 132,000 and 220,000 volts.

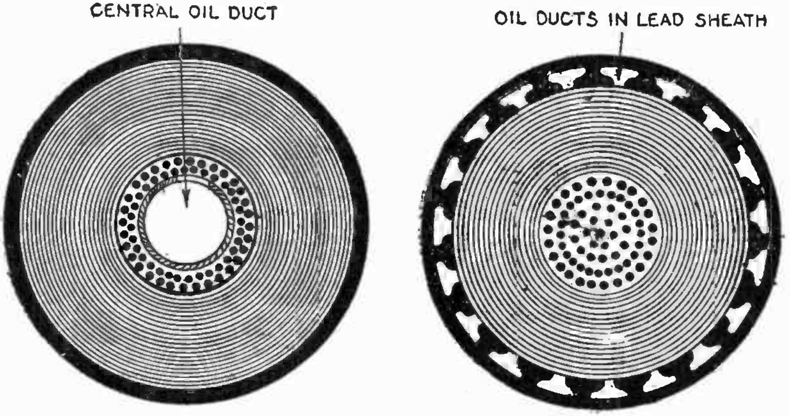
In most situations of heavily built up centers, it has been impossible in the past to tie the higher voltage lines directly to the distributing stations and substations, and recourse has been made to underground cable lines of 33,000, 45,000 and 66,000 volts connecting to the higher voltage overhead lines through transformers located at substations on the outskirts of the city.

One of the principal aims of the design of the new type or oil filled cable, which by one step doubles the highest underground operating voltage used heretofore, is to do away with these outside intermediate substations by bringing the higher voltages directly to the ultimate distributing centers. The economic and operating advantages thereby obtainable are savings of intermediate substations, transformers, switch gear and attendance, reduction in number of underground cables, savings in synchronous condensers increased efficiency, improved regulation and improved stability of parallel operation of local plants with the outside sources of power.

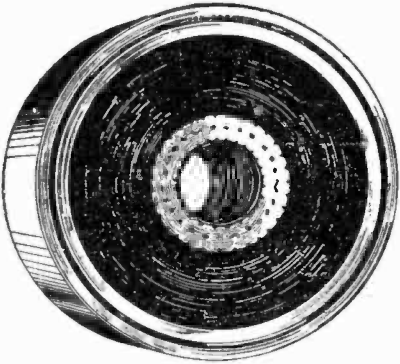
The final relative values of these savings will not be available until there is secured from actual experience the relative carrying capacity of the oil filled cables in contrast with the ordinary type of cables with solid insulation.

The theory of the oil filled cable is that *through its collapsible oil reservoirs it responds readily to volumetric changes in oil and cable due to temperature changes.*

In this manner, the whole cable is kept constantly filled with oil under pressure both in the hollow core of the conductor and throughout the surrounding insulation. The unique advantage of this type of construction, therefore, is that should the lead sheath be expanded or distorted, or the



FIGS. 5,109 and 5,110.—Two types of oil insulated cable. Fig. 5,109, central oil duct; fig 5,110, oil ducts in lead sheath.



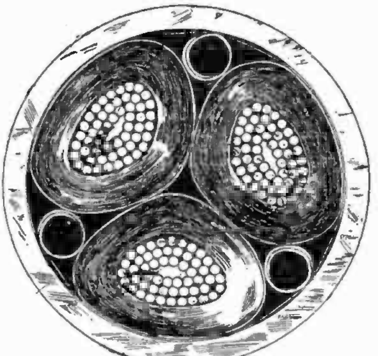


FIG. 5,111.—General Electric single conductor 132,000 volt cable showing construction.

FIG. 5,112.—General Electric three conductor 45,000 volt oil filled cable.

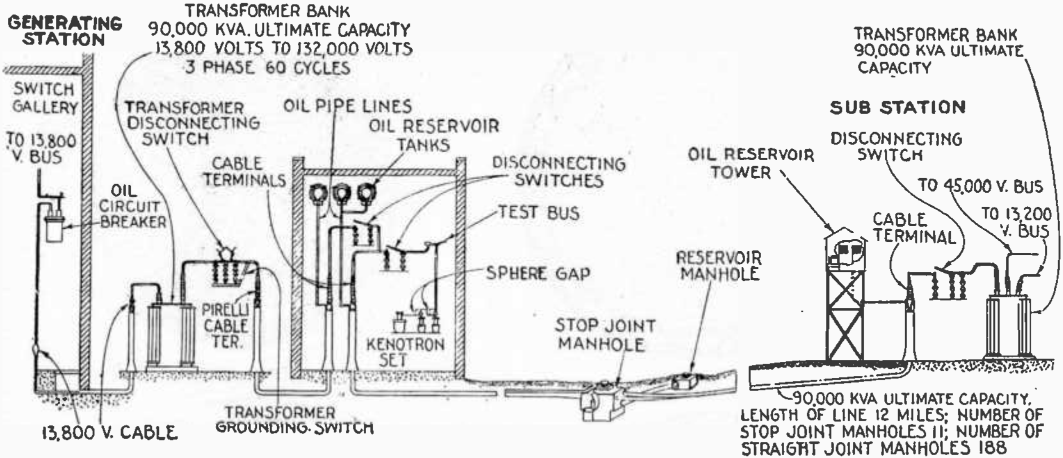


FIG. 5,113.—Diagram of oil insulated cable installation showing transformer banks, 90,000 *kva*. ultimate capacity; 13,800 volts to 132,000 volts, three phase, 60 cycles.

internal elements of the cable be displaced by temperature variation or other causes, the spaces thus formed will be immediately filled with oil, while in a solid insulation type voids would be formed, causing ionization and ultimate failure. It is thus evident that this new type of cable should be able to operate safely over a much larger range of copper temperature and therefore of load than a solid insulation type, even if the latter be operated at only 66,000 volts or less.

The principle is simple and consists in *having the cable connected to a reservoir which will receive the oil pushed out during the thermic expansion and give it back to the cable during the contraction.*

To obtain this action, it is necessary to have inside the cable a passage which connects the reservoir with every point of the dielectric. This feature can be obtained readily by stranding the copper wires of the conductor around a metal spiral, thus leaving a single central passage, as in fig. 5,109, or by shaping the lead sheath as in fig. 5,110, thus making several longitudinal paths which can be connected to the reservoir. This eliminates the danger of formation of empty spaces due to the contraction of the oil.

The presence of a longitudinal path makes possible the evacuation and impregnation of the cable from both ends after it has been leaded. On account of its small volume, laboratory pumps can be used and a high

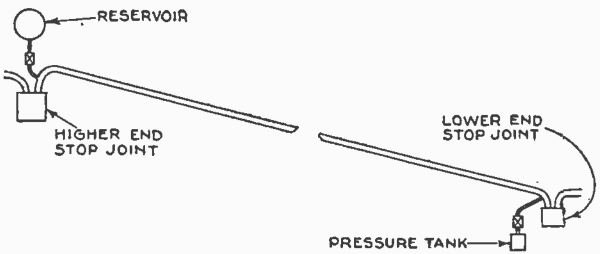


FIG. 5,114.—Diagram of one section of oil filled cable showing reservoir, pressure tank stop. joints, etc.

vacuum reached. In addition to this, a special process has been worked out to purify the oil from the gases in solution, before impregnating the paper. In this way it is possible to obtain a cable practically without any occluded gas from the start and also to maintain it in such condition during operation.

The pressure tank as shown in fig. 5,114, consists of a strong metal tank full of oil which has inside a certain number of air tight cells, with collapsible walls, full of gas. The tank is connected with the lower end of the cable and for this reason the oil in it and the gas inside the cells are subjected to the pressure corresponding to the static head of oil from the reservoir.

When the cable cools down, the pressure at the far end of the section drops below the static head and the gas enclosed in the collapsible cells increases in volume, and pushes out the oil from the tank into the cable.

At the first moment of cooling, the pressure tank is subjected to a hydrostatic pressure given by the head of oil from the feeding reservoir, and acts exactly as an open tank connected at the lower end of the section, at the same level as the feeding tank. In this first moment, therefore, half of the cable will be fed by the feeding tank and half by the pressure tank, but after a certain length of time, the pressure inside the tank and in the gas cells will be smaller on account of the volume of oil having been fed back to the line.

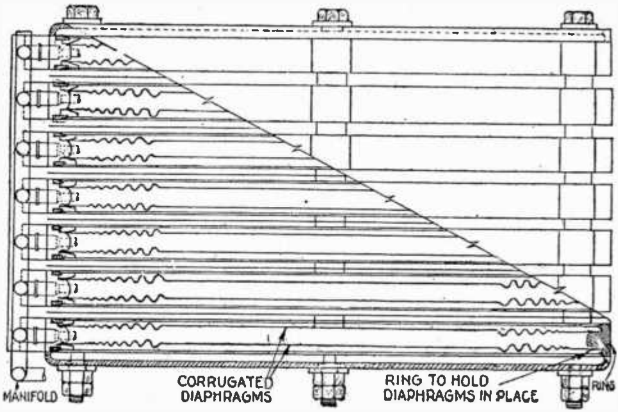


FIG. 5,115.—Feeding tank for oil filled cable.

Each standard section of the line consists essentially, as shown in fig. 5,114, of: 1, two stop joints which close the central oil passage in such a way that the oil of one section has no connection with the oil of the next section; 2, one set of feeding tanks which gives oil to the cables; and 3, in certain special conditions, a pressure tank which supplements the oil supply to the cable.

Code.

201. Gauges

a. All wire sizes are given in the American (B. & S.) gauge.

603. Varnished Cambric-Covered Wire. Type VC

This wire is not intended for use where moisture exists.

604. Asbestos-Covered Wire. Type A.

For asbestos covered fixture wire see section 608. For installation see Article 5.

This wire is especially useful in hot, dry places where ordinary coverings would perish, and where wires are bunched as on the back of a large switchboard or in a wire tower, so that the accumulations of rubber covering would result in an objectionable large mass of highly inflammable material. It is not suitable for outside work or where moisture exists.

Code.—*Continued.*

605. Slow-Burning Wire. Type SB

This wire is especially useful in hot, dry places where ordinary covering would perish, and where wires are bunched as on the back of a large switchboard or in a wire-tower, so that the accumulations of rubber covering would result in an objectionable large mass of highly inflammable material. It is not suitable for outside work or where moisture exists.

606. Slow-Burning Weather proof Wire. Type SBW

This wire is not suitable for outside work or where moisture exists.

607. Weatherproof Wire. Type WP

This wire is for use outdoors and elsewhere where moisture is certain, or corrosive vapors are present, and where fire-retardant qualities are not necessary.

d. The cords listed in the table are recognized in sizes of 18 B. & S. gauge and larger, except that types PO-64, PO-32, P-64, P-32, PWP-64 and PWP-32 are recognized in 18 gauge only, and types PO, P, PWP, and E are recognized in 16 gauge and larger.

614. Use of Flexible Cords

a. Flexible cord shall be used only for pendants, wiring of fixtures and portable devices.

e. Flexible cords shall be so connected to all fittings that the strain will be taken from the joints and terminal screws by a knot in the cord, winding with tape, a special fitting for the purpose, or other suitable means.

f. Flexible cords shall, where passing through covers of outlet boxes, be protected by approved bushings especially designed for this purpose; or the cover shall be provided with a smooth, well-rounded surface on which the cord will bear. So-called hard-rubber or composition bushings shall not be used.

g. Flexible cords used where the voltage between any two conductors exceeds 300 shall have insulating covering at least 3/64th-inch in thickness for all conductor sizes No. 8 and less, except where type S is used.

h. Flexible cords not smaller than No. 18 gauge, and flexible cord of smaller sizes approved for use with specific devices, may be attached to circuits fused at not over 15 amperes for not exceeding 150 volts and not over 10 amperes for not exceeding 300 volts, and shall be considered as protected by such circuit fuses. Flexible cords No. 18 gauge, or larger if required by column 1 of table 1 of section 612, may be approved for use with specific devices on the medium-duty appliance branch circuits described in section 1602 and which are fused at not over 25 amperes.

i. No wire smaller than No. 18 shall be used for fixture work or flexible cords, except as approved for specific devices.

TEST QUESTIONS

1. *What is a cable?*
2. *Define the term conductor.*
3. *What are the desirable features of copper which makes its use valuable for wires?*
4. *For what services are copper wires used?*

5. *What kind of wire is used for telegraph and telephone lines?*
6. *For what is German silver wire used?*
7. *Give Matthiessen's standard for resistance of copper wire.*
8. *State the relative conductivity of different metals and alloys.*
9. *What metal is used most for wires?*
10. *When are stranded conductors used instead of single conductors?*
11. *What protection is given to wires for most conditions of service?*
12. *Name the various forms of covering for wires.*
13. *What are the advantages of rubber insulation for wires?*
14. *What are weather proof wires, and where are they used?*
15. *What is a slow burning wire?*
16. *How does slow burning weather proof wire compare with weather proof wire?*
17. *Where should slow burning weather proof wire be used?*
18. *Is it possible to build up a cable from any number of wires?*
19. *Name two methods of specifying stranded conductor.*
20. *Is the weight of a stranded wire greater than that of the equivalent solid wire and why?*
21. *What is an oil filled cable and what is the oil used for?*
22. *Describe theory of the oil filled cables.*
23. *Are oil filled cables used for low or high voltage?*

CHAPTER 104

Joints and Taps

The author objects to the careless and erroneous use of the terms *joints* and *splices*. There is considerable difference between a *joint* and a *splice*.

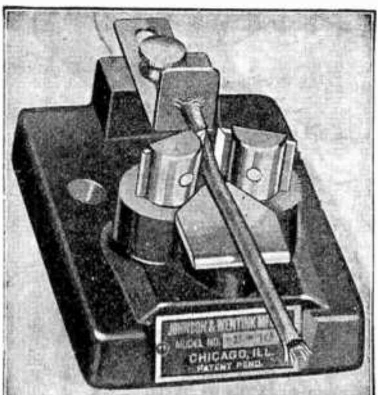


FIG. 5,116.—Martindale insulation scraper.

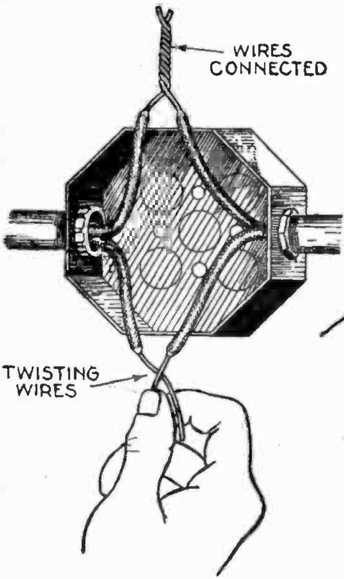
FIG. 5,117.—Austin cable ripper for removing outer braid.

By definition a joint is *the tying together of two single wire conductors so that the union will be good both mechanically and electrically.*

A splice is the interlaying of the strands of two stranded conductors so that the union will be good both mechanically and electrically.

Making a joint tap or splice comprises the operations of

1. Removing the insulation;
2. Cleaning the conductors;
3. Tying, or interlaying;



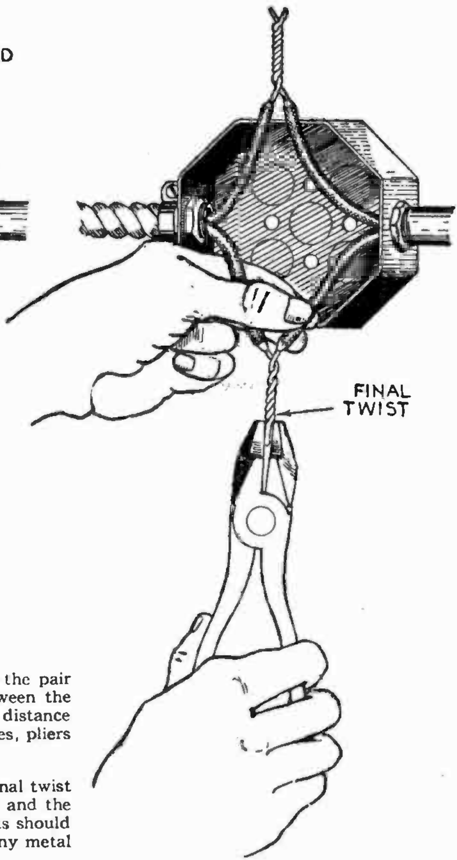


FIG. 5,118.—*Pig tail joint 1.* Cross the pair of conductors to be connected between the fingers and twist them together for a distance of at least an inch. For heavy wires, pliers must be used.

FIG. 5,119.—*Pig tail joint 2.* The final twist must be made with a pair of pliers and the excess wire cut off. The bare joints should now be pulled out of contact with any metal so that the circuit may be tested.

4. Soldering;
5. Tap(e)ing.

The subjects of splices, soldering and tap(e)ing are taken up in separate chapters.

Removing the Insulation.—In preparing insulated conductors for making joints or splices, the insulation must first be removed from each conductor a proper distance depending upon the type joint or splice to be made.

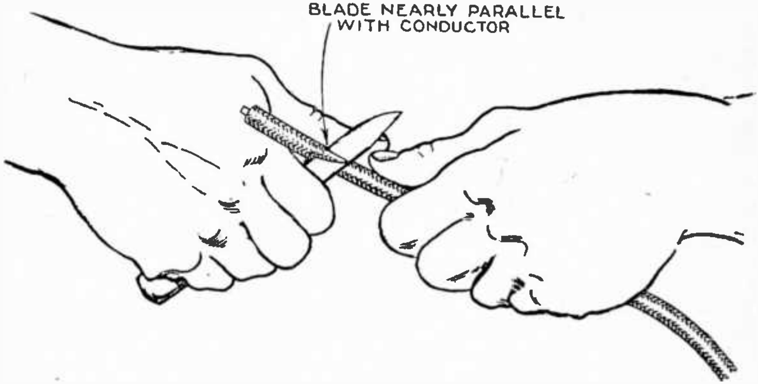


FIG. 5,120.—Method of using knife in stripping insulation. Hold the blade so that it will lie flat with the wire to avoid nicking the latter. Stripping with a knife is not recommended.

This process is sometimes called *skinning* or *stripping*. This operation is usually performed in a questionable manner by the use of an ordinary knife blade resulting in loss of time and probable nicking of the wire.

For a single wire conductor a form of scraper such as shown in fig. 5,116 should be used.

The method of using a ripper (fig. 5,117) is shown in fig. 5,121. The insulation of a duplex cable should first be ripped with a tool stick; then the insulation from the separate conductors is removed with a scraper.

If a knife must be used, do not cut insulation crosswise the wire, but parallel with the wire as in fig. 5,120.

Cleaning the Conductors.—After removing the insulation, the wires must be thoroughly cleaned to insure good electrical

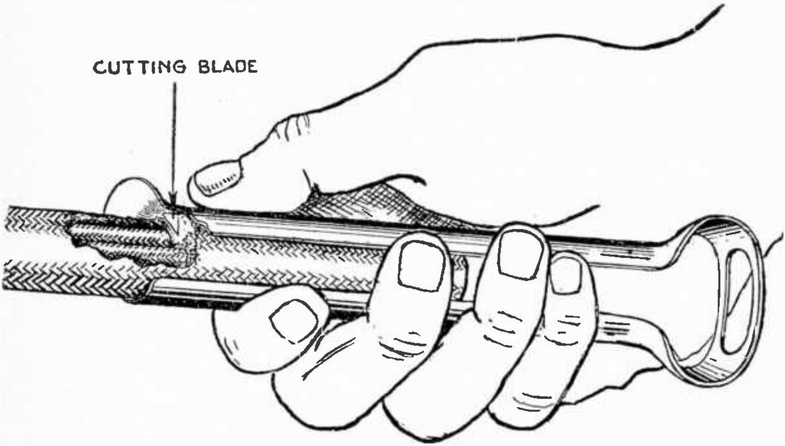
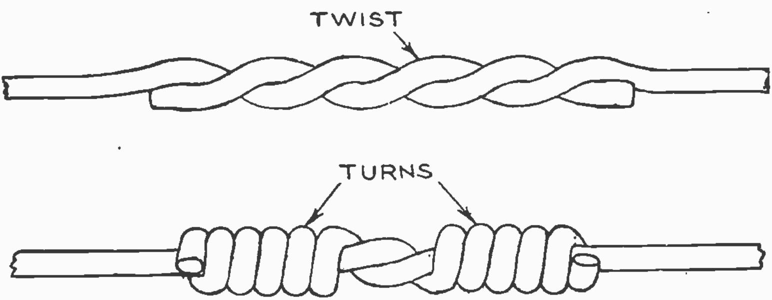
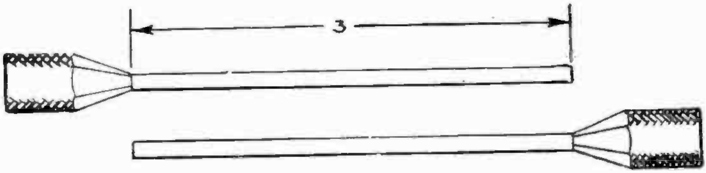


Fig. 5,121.—Method of using Austin cable ripper. ***In operation,*** squeeze and pull. This causes the cutter to sink into the outer braid and rip same.



Figs. 5,122 and 5,123.—Twists and turns. In making twists each wire is wrapped around the other, whereas in making turns one wire remains straight, the other wire being wrapped around the straight wire.



FIGS. 5,124 and 5,125.—*Bell hanger's joint 1.* Strip off 3 ins. of insulation from end of each wire and clean.

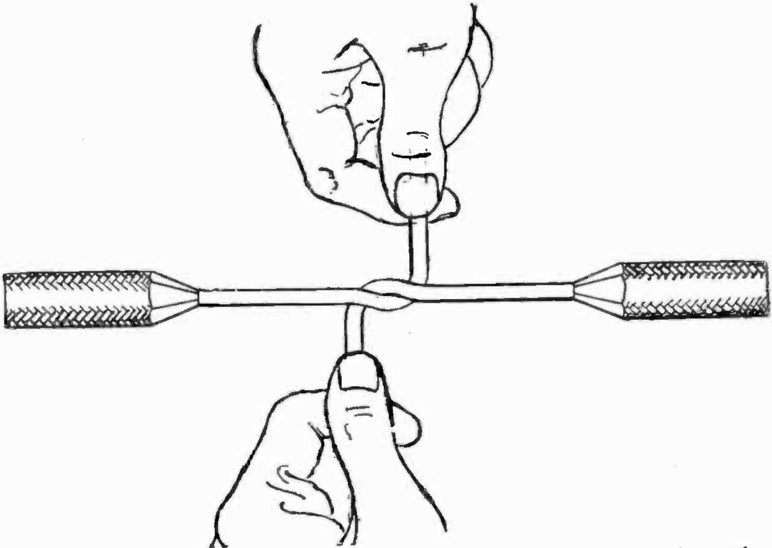


FIG. 5,126.—*Bell hanger's joint 2.* Bring wires together and make one turn as shown, then hold first wire with hand and twist second wire with pliers. Similarly twist first wire. The twisting may be done by hand for small wire, but for large wire, pliers are necessary.

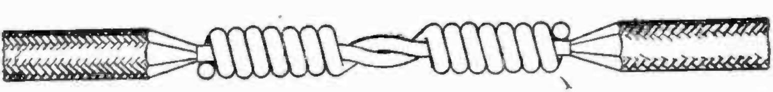
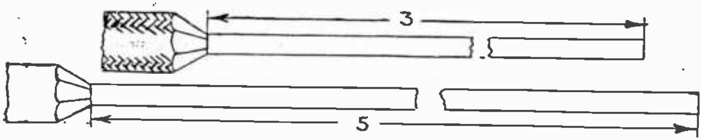


FIG. 5,127.—*Bell hanger's joint 3.* Appearance of completed joint before soldering and tap(e)ing.

contact between the ends of the wires and so that the solder will adhere properly. The wires may be cleaned by scraping.

If this be done with a knife, care should be taken to avoid nicking the wire. Sand paper may be used to clean the wires.



Figs. 5,128 and 5,129.—*Turn back joint 1.* Strip off 3 ins. of insulation from one wire and 5 ins. from the other and clean the exposed ends.

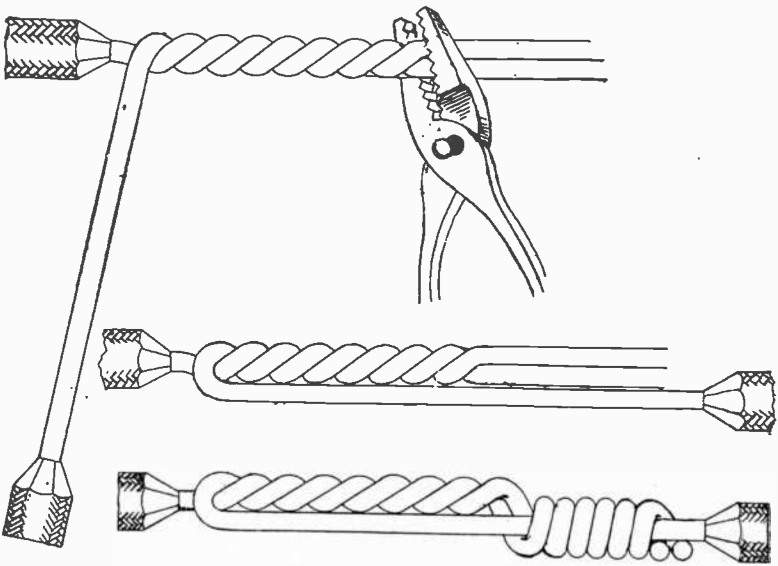


Fig. 5,130.—*Turn back joint 2.* With the ends of the wires together twist the wires, using pliers and leaving about one inch straight at the end.

Fig. 5,131.—*Turn back joint 3.* Turn back the long wire until it becomes parallel with the twists.

Fig. 5,132.—*Turn back joint 4.* Turn the two straight ends around the long wire between the twisted portion and the insulation, thus completing the joint. There should be enough straight wire left after twisting to make several turns.

Joints.—There is a multiplicity of joints designed to meet the requirements of different kinds of wiring. The duty to be performed by a joint determines the kind to be used.

In some cases all that is required is that the joint be electrically good as for instance the pig tail splice used in junction or fixture outlet boxes; in other cases, the joint must be both electrically and mechanically good, as for instance, joints on an overhead line must be made so that they will withstand considerable tensile stress due to weight of the suspended conductor.

There are a number of joints extensively used of which the following should be noted:

FIG. 5,133.—Western Union joint complete.

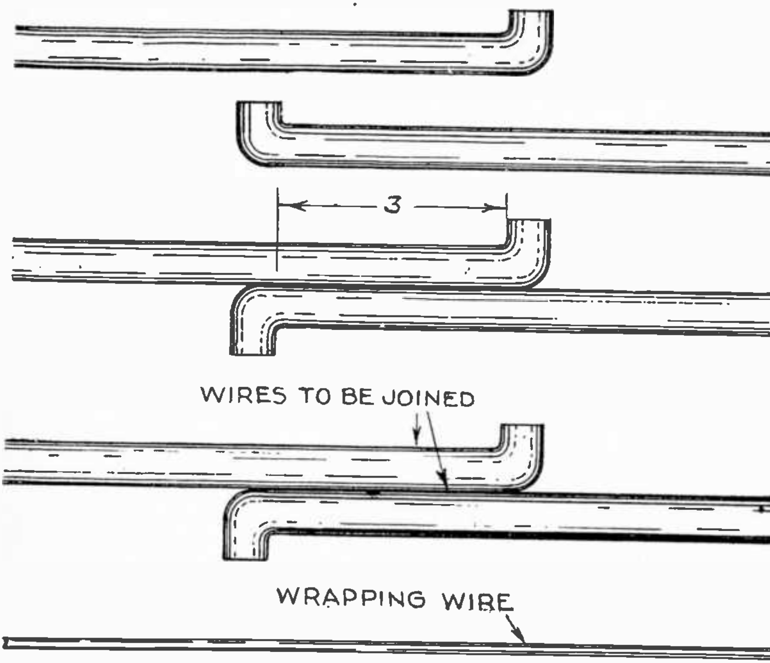
1. Pig tail;
2. Bell hanger's;
3. Western Union;
4. Turn back;
5. Britannia;
6. Scarfed;
7. Duplex.

The pig tail joint as before mentioned is suitable for service where there is no mechanical stress as where wires are to be connected in an outlet box, switch or conduit fitting. Figs. 5,118 and 5,119 show the method of making this joint.

The bell hanger's joint was, as its name implies, originally intended for bell circuits, however on account of its being not only electrically and mechanically strong, but also compact, it has numerous other uses where the tensile stress is not too great.

The joint consists of one twist and no less than five turns of each wire about the others. The difference between twists and turns is shown in figs. 5,122 and 5,123 and the method of making a bell hanger's joint in figs. 5,124 to 5,127.

The Western Union joint is a modified form of the bell hanger's joint. It is made in the same way as the bell hanger's joint with the exception that



FIGS. 5,134 and 5,135.—***Britannia joint 1.*** Bend up at right angles the end of each wire. Use a hand vise and hammer as a sharp bend cannot be made with pliers.

FIG. 5,136.—***Brittania joint 2.*** Place the wires together so that they overlap about 3 ins.

FIGS. 5,137 and 5,138.—***Britannia joint 3.*** Assuming the wires to be joined are No. 6, use a No. 18 wrapping wire. Take about 6 ft. of the wrapping wire, clean it and bend in half.

a number of twists are taken instead of one. The object of the extra twists is to make it more efficient mechanically as the tensile stress brought on these joints is considerable. Fig. 5,133 shows appearance of the completed joint.

The turn back joint is useful in connecting two wires that must be drawn taut.

The Britannia joint is sometimes used on overhead lines where considerable tensile strength is required. It is also used both for inside and outside wiring where single conductors of sizes No. 6 or larger are used. Figs. 5,134 to 5,141 show how the joint is made.

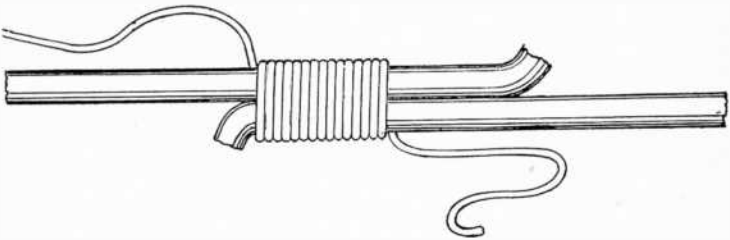


FIG. 5,139.—*Britannia joint 4.* Place the center of the wrapping wire at the center of the joint and wrap each half toward the ends of the joint.

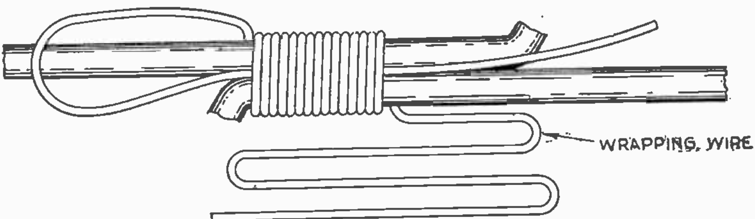


FIG. 5,140.—*Britannia joint 5.* After wrapping, force the free ends of the wrapping wire through the grooves formed by the wrap and large wires. Illustration shows one end being pulled through.

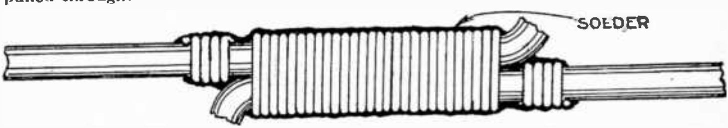
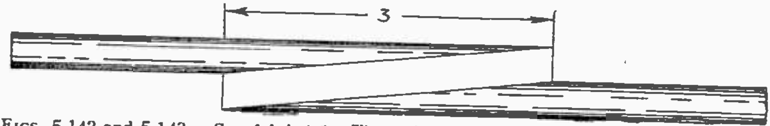


FIG. 5,141.—*Britannia joint 6.* With the portion of wrapping wire remaining after pulling through, make a few turns around the large wires at each end of the joint.

A scarfed joint is used on large wires where appearance and compactness are the main considerations and where the joint is not subject to any heavy tensile stress. The method of making the joint is shown in figs. 5,142 to 5,144.

A duplex joint is used in conduit systems where twin wires are used, that is, two wire cables. It will be seen from the illustration that the joint consists of two bell hanger's joints spaced so that they do not come opposite each other. See figs. 5,145 to 5,148.



FIGS. 5,142 and 5,143.—*Scarf joint 1.* The ends of the two wires to be joined are scarfed as here shown, that is, filed wedge shaped. The scarf should be about 3 ins. long bringing the ends to a fine point making a good fit. When filing, the ends of the conductors are most conveniently held by laying them in a groove in a block of wood. The wires when fitted together should appear like one continuous wire.

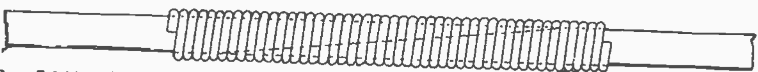
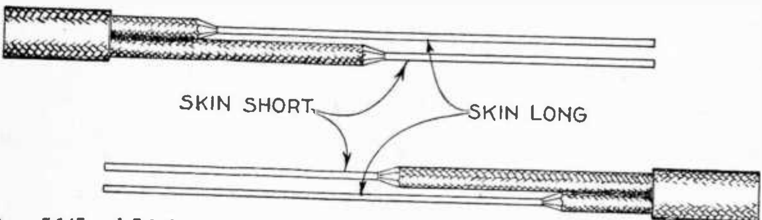
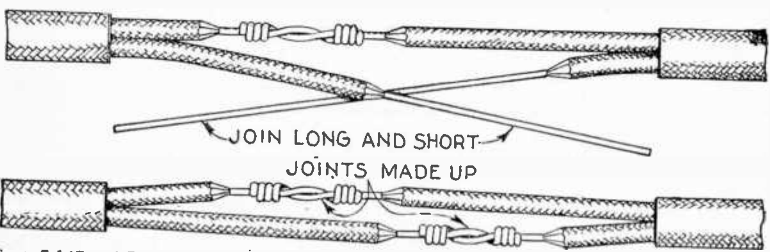


FIG. 5,144.—*Scarf joint 2.* Tin the ends, then wrap with No. 18 or No. 20 wire, starting at the middle of the joint and wrapping toward the ends similarly as with the Britannia joint, except that the ends instead of being pulled through are wrapped a few turns beyond the ends of the joint. Solder the joint.



FIGS. 5,145 and 5,146.—*Duplex joint 1.* Skin or remove about 3 ins. of the outer braid from each cable and remove insulation from each wire as shown, that is, so the joints will not come opposite each other.



FIGS. 5,147 and 5,148.—*Duplex joint 2.* Make up joints. Fig. 5,147 shows one joint made and fig. 5,148 both joints complete. Note that these joints do not come opposite each other, thus giving better insulation.

Taps.—By definition, a tap is *the connection of the end of one wire to some point along the run of another wire.*

As with joints, there are various taps to meet different conditions. The following should be noted.

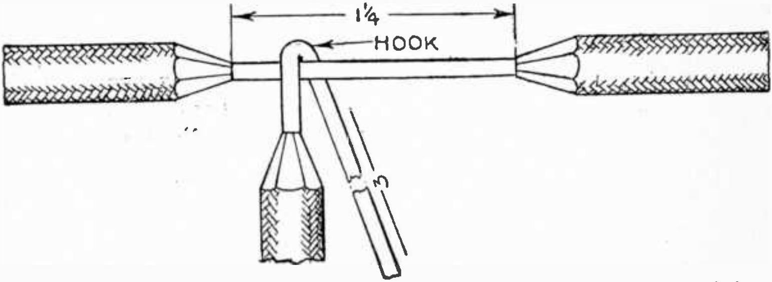


FIG. 5,149.—***Plain tap 1.*** Remove about 1¼ in. of insulation along the run wire and about 3 ins. at the end of the tap wire. Cross the wires about ¼ in. from insulation and take a *hook*.

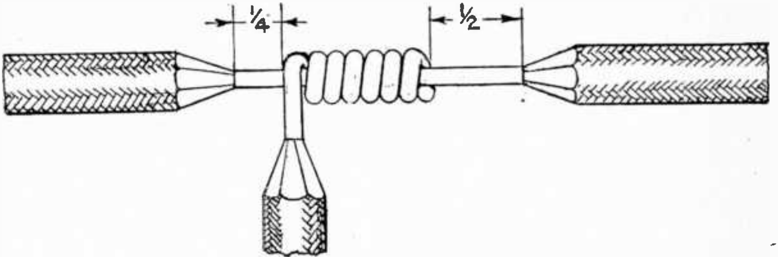


FIG. 5,150.—***Plain tap 2.*** Take 5 or 6 turns of the tap wire around the run wire. Note that the joint should terminate about ½ in. from the insulation on the run wire. This permits soldering without burning the insulation and gives better chance for tap(e)ing.

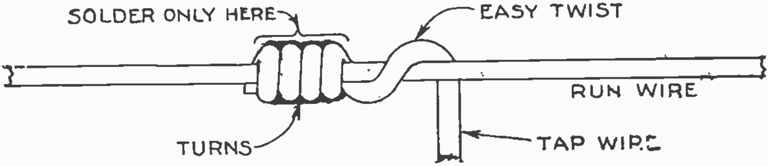
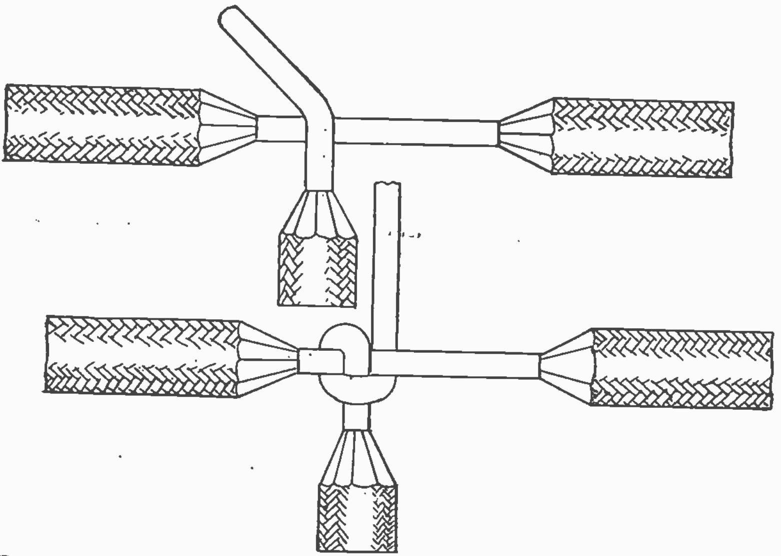


FIG. 5,151.—***Aerial tap.*** The long twist is to give flexibility. ***In making,*** the joint is soldered on the turns, the long twist being left free.

1. Plain;
2. Aerial;
3. Knotted;



FIGS. 5,152 and 5,153.—*Knotted tap 1.* Remove 1½ to 2 ins. of insulation from run wire and 3 ins. from tap wire. Make knot as shown in fig. 5,153 and note carefully how it is made.

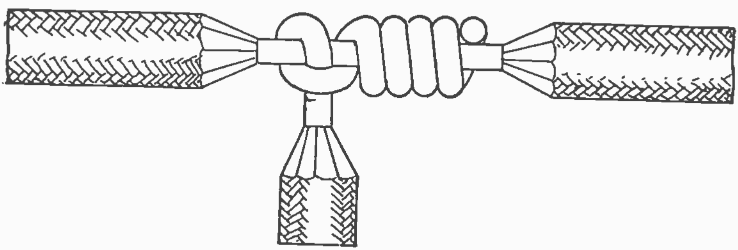


FIG. 5,154.—*Knotted tap 2.* Make several turns.

4. Cross;
    a. Double;
    b. Duplex;
5. Wrapped.

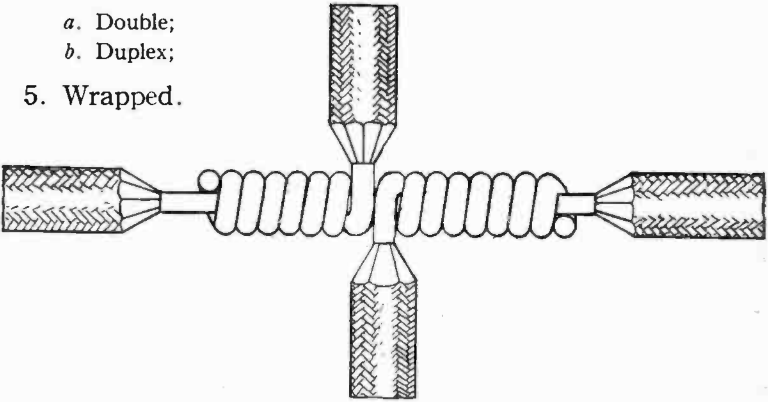


FIG. 5,155.—***Double cross tap***. For this tap remove about 2½ ins. of insulation from the run wire and about ¼ in. from each tap wire. Each tap is made as described for the plain taps; the taps starting at the middle of the joint and running in opposite directions.

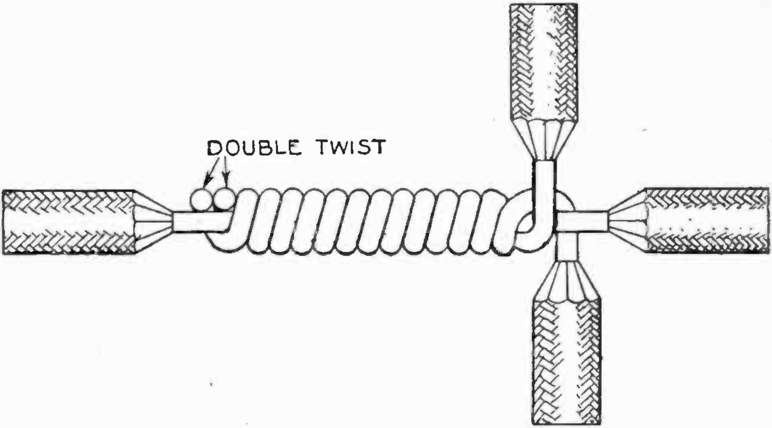
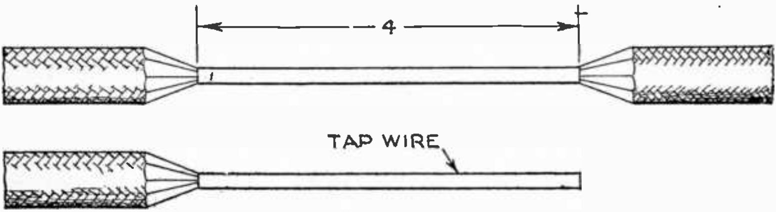


FIG. 5,156.—***Duplex cross tap***.—Remove about 2 ins. of insulation from the run wire and about 3 ins. from each tap wire. Bring the two tap wires across the run wire at one end of the joint and double twist the ends of the tap wires.

The plain tap is the one most frequently used and is quickly made without difficulty as is seen in figs. 5,149 and 5,150.

The aerial tap is intended for wires subjected to considerable movement. It is similar to the plain tap except that it has a long or easy twist as in fig. 5,151 to permit of movement.



FIGS. 5,157 and 5,158.—***Wrapped tap 1.*** Using a No. 6 wire remove about 4 ins. of insulation from both wires.

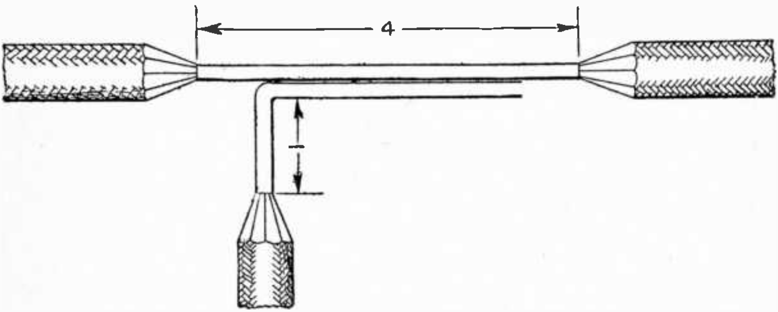


FIG. 5,159.—***Wrapped tap 2.*** Bend the tap wire in the shape of an L with bend about 1 in. from insulation and place it along the run wire as shown.

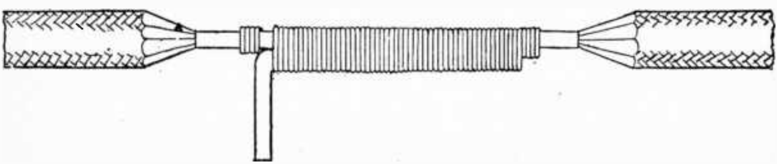


FIG. 5,160.—***Wrapped Tap 3.*** Wrap in a similar manner as described for the Britannia joint figs 5,139 to 5,141.

A knotted tap, as must be evident, is designed to take considerable tensile stress and is made as shown in figs. 5,152 to 5,154.

A double cross tap is simply a combination of two plain taps as shown in fig. 5,155.

The duplex cross tap is used where two wires are to be tapped at the same time, because it can be made quicker. Fig. 5,156 shows its features.

A wrapped tap is used on wires too large to wrap around the run wire. The joint is made as shown in figs. 5,157 to 5,160.

Code.

203. ***Wire Terminals, Splices and Joints***

a. Terminal parts by which wire connections are made shall insure thoroughly good connections even under hard usage. For currents above 30 amperes, lugs into which the connecting wires may be soldered, or approved solderless connectors, shall be provided. For currents of 30 amperes or less the parts to which wiring connections are made shall securely grip the conductors. Heavy clamps or screws with terminal plates having upturned lugs, or solderless connectors, may be used.

Lugs or clamps are not required when leads are provided as part of the device.

b. Wires shall be so spliced or joined as to be mechanically and electrically secure without solder. The joints shall then be soldered, unless made with a splicing device, and shall be covered with an insulation equal to that on the wires.

c. Stranded wires, other than those used in flexible cords, shall be soldered together before being fastened under clamps or binding screws.

TEST QUESTIONS

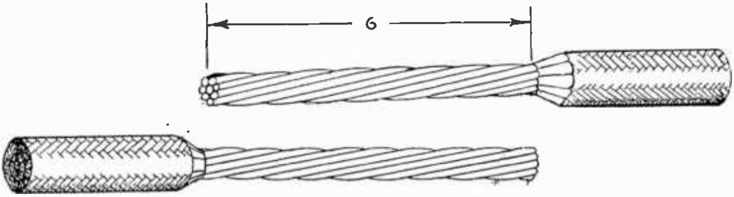
1. *What is the difference between a joint and a tap?*
2. *Name five operations to be performed in making a joint or tap.*
3. *What names are sometimes given to the operation of removing the insulation from the wire?*
4. *What is the usual though wrong way of removing insulation?*
5. *What should be done after removing the insulation?*

6. *What is the difference between a turn and a twist?*
7. *Describe the bell hanger's joint.*
8. *Describe the turn back joint.*
9. *For what is the pig tail joint suitable?*
10. *For what is a Britannia joint sometimes used?*
11. *What is a scarf joint?*
12. *Describe the operation of making a duplex cross tap.*
13. *Describe how the various taps are made.*
14. *What kind of tap is most frequently used?*
15. *For what is the aerial tap intended?*
16. *For what service is the knotted tap intended?*
17. *When is the duplex cross tap used?*
18. *What is the feature of the wrapped tap?*

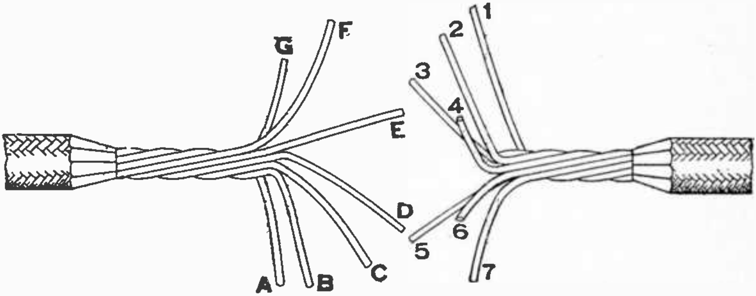
CHAPTER 105

Splices

As pointed out in the preceding chapter there is considerable difference between a *joint* and a *splice* yet the word *splice* is



FIGS. 5,161 and 5,162.—***Single wrapped splice 1.*** Remove about 6 ins. of insulation from each cable and clean each strand.



FIGS. 5,163 and 5,164 —***Single wrapped splice 2.*** Lay up (that is, wrap) the strands for a distance of about 2 ins. from the end of the insulation of each cable and *fan out* the strands to an angle of about 30°.

commonly though incorrectly used for *joint*. The latter term relates to single wire conductors and splice to multi-wire or stranded conductors.*

For this reason the author excludes splicing from the chapter on joints and taps as it is a different subject.

Running Butt Splice.—The term *running butt* relates to splices formed by butting together the ends of two cable lengths

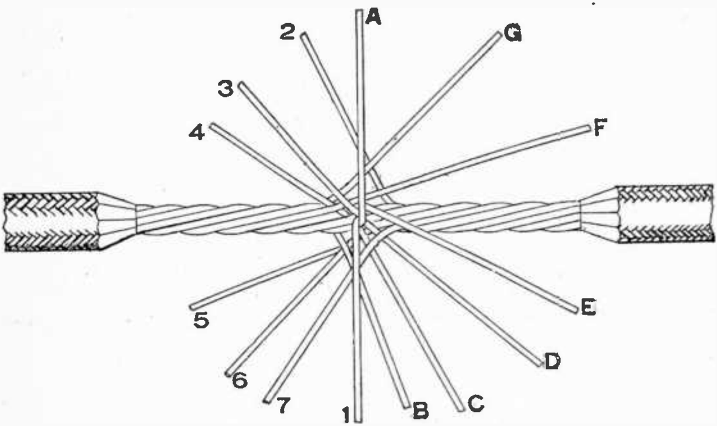


FIG. 5,165.—*Single wrapped splice 3.* Interweave the strands by bringing together the laid up sections, and in so doing see that one strand only of each wire passes between two strands of the other in each case. Make a *hook* by sharply bending say strands 1 and A.

to extend the run or length of circuit as distinguished from tap splices later described.

According to the method of wrapping the strands, running butt splices are classified as:

*NOTE.—*According to the dictionary,* the word splice is defined as *to unite (two ropes or parts of a rope) as by interweaving or intertwining the strands.* Since single wire conductors are not made up of strands the word splice does not apply to them.

1. Single wrapped;
2. Multiple wrapped.

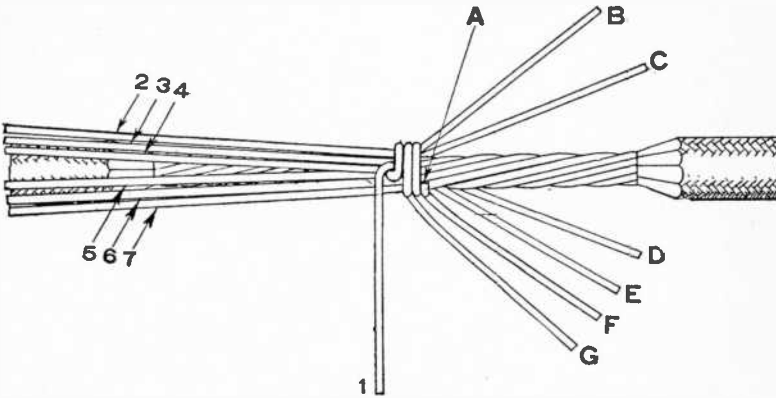


FIG. 5,166.—*Single wrapped splice 4.* Wrap tightly one strand as strand 1 around the laid up portion of the cable.

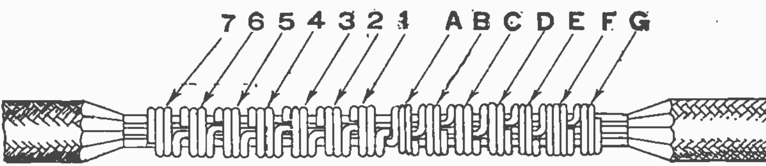
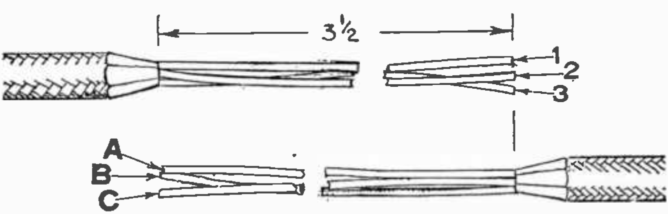


FIG. 5,167.—*Single wrapped splice 5.* Similarly as in fig. 5,166, wrap tightly each of the remaining strands of each cable around the laid up portion of the other cable.



FIGS. 5,168 and 5,169.—*Multiple wrapped splice 1.* Remove about 3½ ins. of insulation from each cable and clean each strand.

Single Wrapped Splice.—This kind of splice is used for large wires (No. 6 or larger) because it is easier to wrap a single wire at a turn than to wrap them all at once.

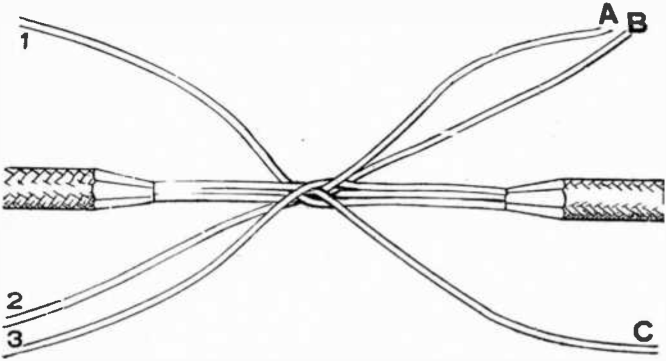


FIG. 5,170.—*Multiple wrapped splice 2.* Lay up the strands for a distance of 1 in. from the insulation. Fan the free ends and butt together properly intertwining the strands.

FIG 5,171.—*Multiple wrapped splice 3.* Wrap tightly the strands of one cable around the laid up portion of the other cable. Similarly wrap the strands of the other cable.

For a No. 4 or No. 6 wire the insulation is removed from the ends of the cable a distance of about 6 inches, larger sizes in proportion. The method of making a single wrapped splice is illustrated in figs. 5,161 to 5,167.

Multiple Wrapped Splices.—This method of wrapping is generally used on small cables because the strands are flexible and all can be wrapped in one operation. A three strand cable is selected so as to clearly show the method of wrapping.

In this splice all strands in each group are wrapped simultaneously and parallel with each other. Figs. 5,168 to 5,171 show the various operations. The strands are No. 20 wire and are exaggerated in size in the illustrations for clearness.

Tap Splices.—These are made when the end of one stranded conductor is to be connected at some point along the run of another stranded conductor.

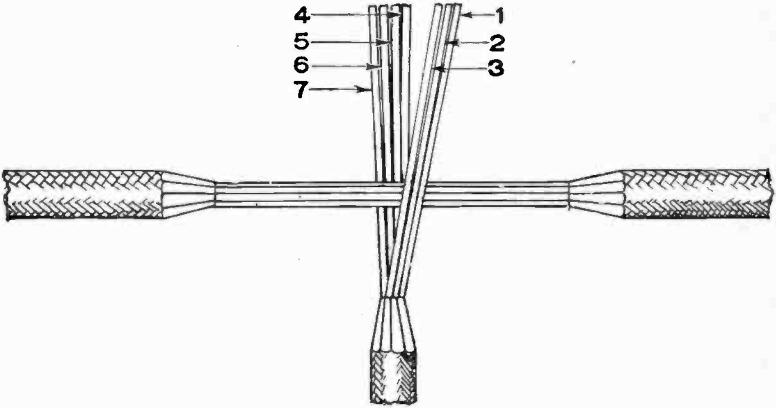


FIG. 5,172.—*Ordinary tap splice 1.* Remove insulation to a distance depending upon the size of the wires. Place tap conductor at center of splice and divide up the strands as shown.

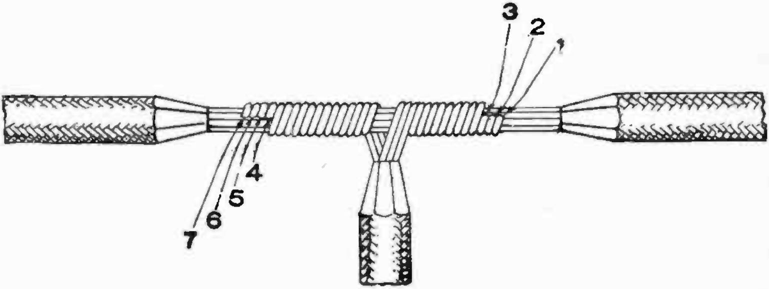


FIG. 5,173.—*Ordinary tap splice 2.* Wrap tightly strands in multiple as shown for small wires.

They may be classed as:

1. Ordinary;

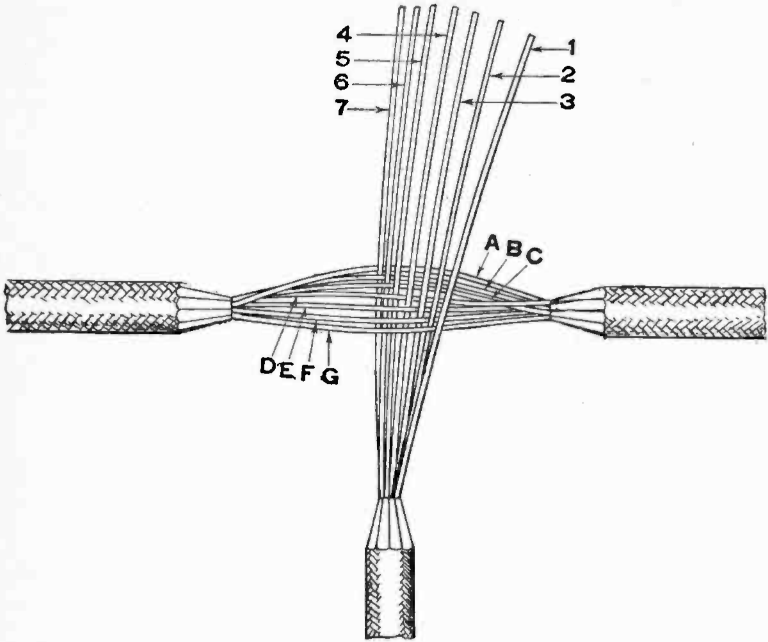


FIG. 5,174.—***Split tap splice 1.*** Remove insulation to a distance depending upon the size of the wires. Place tap conductor at center of splice and interweave the strands as shown.

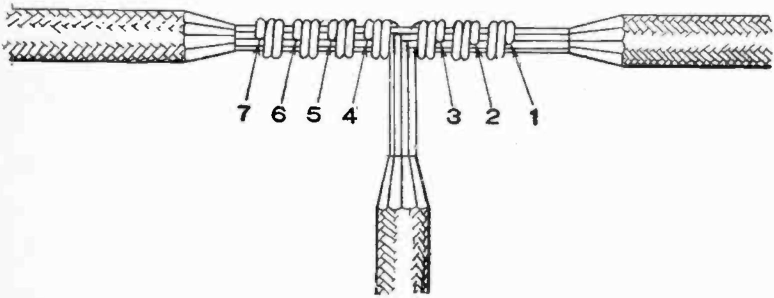


FIG. 5,175.—***Split tap splice 2.*** Wrap the strands on each side toward end of splice The illustration shows a single wrapped tap splice.

2. Split;
3. Y splice.

In the method of wrapping they may be either singly wrapped, or multiple wrapped, the choice depending on the size of the strands. The accompanying illustrations show the various tap splices.

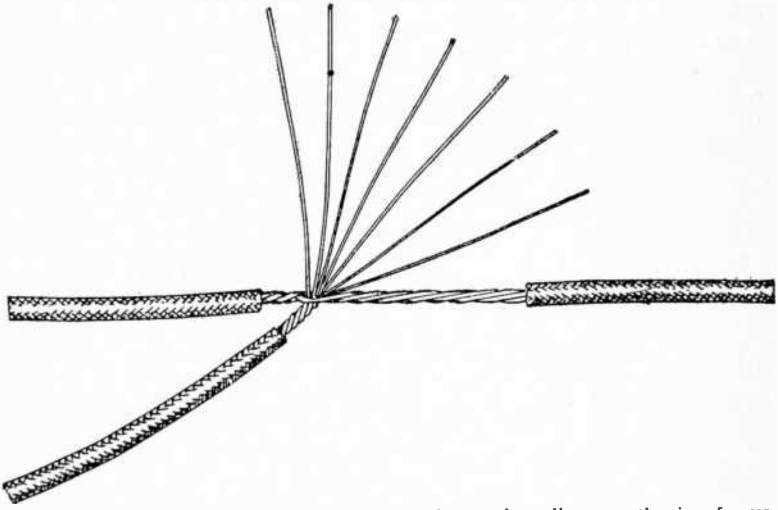


FIG. 5,176.—*Y splice 1.* Remove insulation to a distance depending upon the size of wires. Interweave the tap wire strands through the run wire strands at one end of the splice and twist up the run wire strands in the original directior.

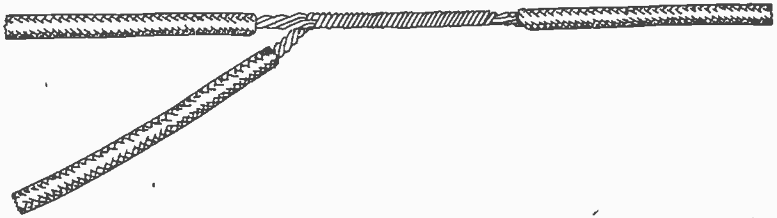


FIG. 5,177.—*Y splice 2.* Tightly wrap the strands of the tap wire around the run wire. either by the single or multiple method, depending upon the size of the wires.

TEST QUESTIONS

1. *What is the difference between a splice and a joint, or a tap?*
2. *What is a running butt splice?*
3. *Name two kinds of running butt splice.*
4. *Describe how to make the single wrapped splice and a multiple wrapped splice.*
5. *Describe how to make: 1, ordinary tap splice; 2, split tap splice.*

CHAPTER 106

Soldering and Tap(e)ing

By definition, soldering is the act or process of forming joints upon or between metallic surfaces, by means of a fusible alloy or solder, whose melting point is lower than that of the metals to be united.

Solder.—The word solder is a name for *any fusible alloy used to unite* different metal parts.

In electrical engineering the solder used is practically always an alloy of tin and lead. As the electrical conductivity of such an alloy is usually about one-seventh that of copper, the best joint between copper conductors is made *by bringing the copper surfaces as close together as possible and using a minimum of solder.*

Soldering.—Briefly the theory of soldering is that: *as the solder adheres to and unites with the surface of the copper when the bit is tinned, so will it adhere to and unite the surfaces of the metals to be soldered.*

The operations to be performed in soldering are:

1. Cleaning the surface to be soldered;
2. Heating the bit;
3. "Tinning" the bit;
4. Applying the flux;

5. Picking up solder;
6. Applying the bit.

These six operations constitute, in general, soldering. They are performed in various ways depending upon the nature of the work.

The essential conditions for successful soldering are:

1. Clean surfaces;
2. Correct temperature of bit;
3. Careful fluxing and tinning.

When these conditions are given proper attention the art of soldering without profanity, presents no difficulties.

Methods of Soldering.—There are several ways of performing the essential operations of soldering and as previously mentioned the choice depends upon the nature of the work. The methods mostly used are:

1. Soldering with bit;
2. Soldering with gasoline blow torch;
3. Soldering with alcohol blow torch;
4. Sweating.

all of which are later described in detail.

Soldering Fluxes.—The word *flux*, means a *substance applied to a metal to make solder flow readily on its surface.*

The action of a flux is largely that of cleaning the surface, and of reducing any oxide on the surface to the metallic state.

If a piece of sheet copper be carefully cleaned by means of emery cloth and heated over a gas flame, the surface will be seen to tarnish rapidly and assume a dark brown appearance. A small piece of resin dropped on the surface will melt, and when the liquid runs, the initial brightness of the surface will be found to reappear.

There are a number of fluxes suitable for various kinds of soldering, but pine amber resin is the best for electrical work as it does not cause corrosion. A corrosive flux, such as zinc chloride solution (killed spirits) should be strictly excluded from any electrical work. The nature of the solder often determines the flux. For soldering copper and brass, use sal-ammoniac as flux.

Soldering Bolts or Bits.—The erroneously called soldering "iron" or bit consists of a large piece of copper, drawn to a

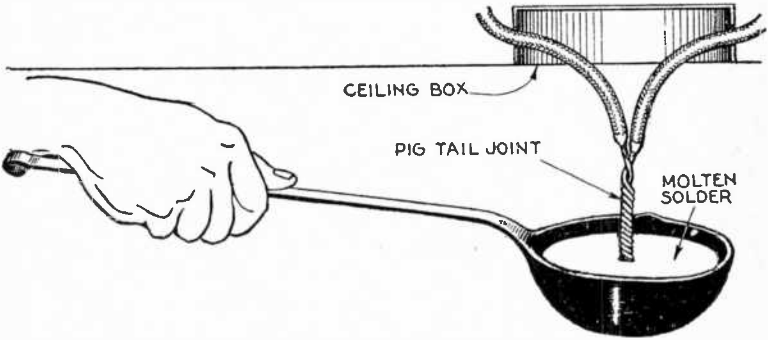


FIG. 5,178.--Use of soldering ladle in soldering an overhead pig tail joint as from a ceiling box. ***At the first dipping,*** perhaps too much solder will adhere to the joint and if so this may be corrected by subsequent dipping which heats up the twisted wires so that the excess solder will fall back into the ladle.

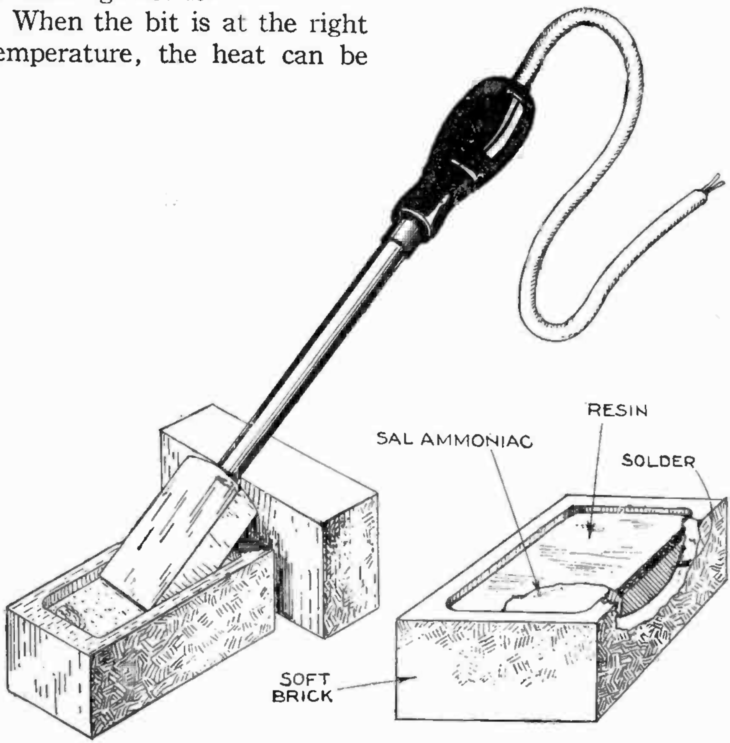
FIG. 5,179.—Ordinary soldering bit, incorrectly called *soldering iron*.

point or edge and fastened to an iron rod having a wooden handle. as shown in fig. 5,179.

Tinning the Bit.—Preliminary to soldering, *the bit must be coated with solder*, this operation being known as "tinning."

To tin a soldering bit, heat it in a fire or gas flame until hot enough to melt a stick of solder rapidly when it is lightly pressed against it.

When the bit is at the right temperature, the heat can be

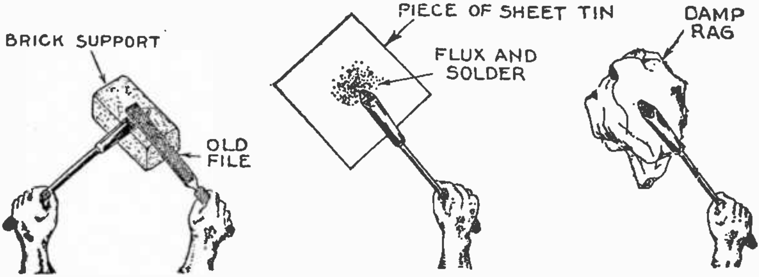


FIGS. 5.180 and 5,181.—Tinning block for electric soldering tool. It is made with two soft bricks. One brick is used to support the soldering tool, and the other to contain the tinning material and to furnish a material which will keep the copper bit bright enough to receive its coating of "tin." Fig. 5,181 shows part of the tinning brick in section, which is scooped out on top as shown by the lower line. Into one end of the hollow in the brick, some sal-ammoniac is placed to help tin the copper bit. Sal-ammoniac is a natural flux for copper and aids greatly in keeping the tool well tinned. Some melted solder is run into the hollow of the brick, and enough resin to fill the cavity nearly to the top.

felt when it is held close to the face, as in fig. 5,186. When hot enough clean up the surface of the copper with an old file, or scrape it on a brick.

If the temperature be too high, the copper surface will be found to tarnish immediately, in which case the soldering bit must be allowed to cool slightly and the cleaning repeated.

When the surface only tarnishes slowly, it is at the right temperature for tinning. Take a piece of *tin plate* (ignorantly called *sheet tin* or just "tin") and place on it some solder and flux, and rub the bit on same. The process of tinning is shown in figs. 5,182 to 5,184.



FIGS. 5,182 to 5,184.—"Tinning" the bit. Fig. 5,182, cleaning bit by filing working surfaces with an old file; fig. 5,183, rubbing the bit on the flux and solder, which may be conveniently placed on a piece of sheet tin as shown; fig. 5,184, removing surplus solder by giving each side of the bit a quick stroke over a damp rag.

After the molten metal has spread over the whole of the surface which it is desired to tin, the superfluous solder is wiped off with a clean damp rag.

The surface should present a bright silvery appearance when properly tinned.

Once a soldering bit has been well tinned care should be taken not to overheat it. If the bit at any time reach a red heat it will be necessary to repeat the whole tinning process before it is fit to be used again. No good work *can be done with an untinned or badly tinned bit.*

If the bit be forgotten and left in the fire, heat to redness and then plunge into cold water, when most of the hard oxidized surface will scale off. A soft coal fire will quickly destroy the tinning.

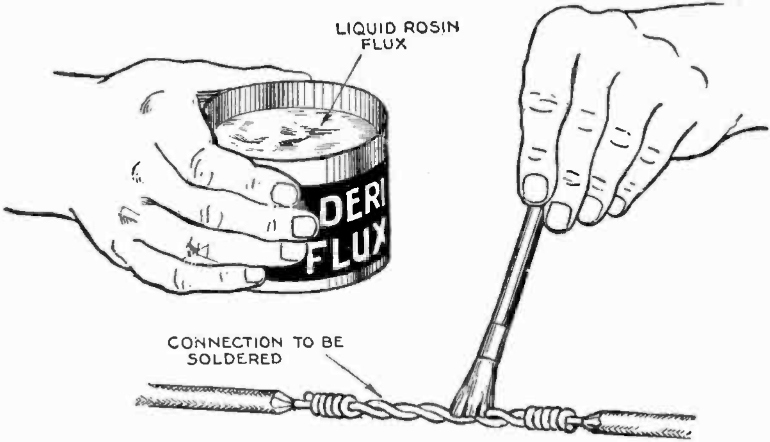


FIG. 5,185.—Method of applying liquid rosin flux with brush to wire connection to be soldered.

FIG. 5,186.—Method of judging the heat of a soldering bit by holding it near the face.

Applying the Flux.—Resin which is recommended as a flux comes in lumps, but it can be granulated by grinding it in a coffee grinder or by hammering.

The resin may be sprinkled over the surface to be soldered or may be applied in liquid form by dissolving in alcohol. In the liquid form it may be applied with a brush as in fig. 5,185. Resin is sometimes called *rosin*.

Applying the Solder.—The method used in applying the solder to the parts to be soldered depends upon the nature of the work. It may be applied by:

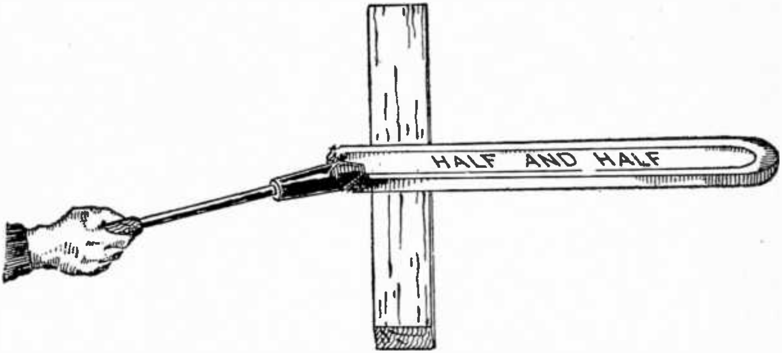
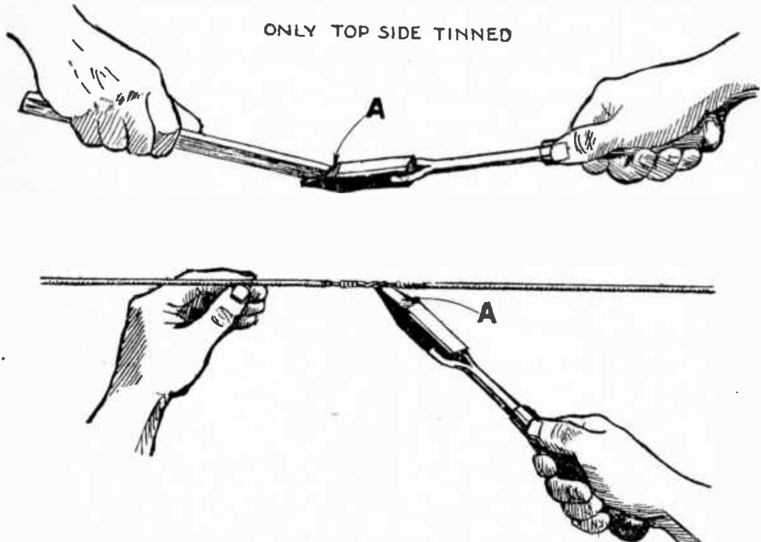


FIG. 5,187.—Picking up solder with a hot bit. This is the proper method for small work. Rest the bar of solder on some support as a brick or piece of wood and touch it with the end of the hot bit. Some of the solder will melt and remain on the bit. ***In picking up solder*** from the stick, care should be taken not to leave the bit in contact with the solder too long or some of it will drop off. The larger the bit and area tinned, the more solder will the bit hold.

NOTE.—***On electrical work*** the Underwriters' Code permits the use of a flux composed of chloride of zinc, alcohol, glycerine and water. This preparation is easily applied and remains in place. It permits the solder to flow freely and is not highly corrosive. This flux is made as follows: Zinc chloride, 5 parts; alcohol, 4 parts; glycerine, 3 parts. Anhydrous zinc chloride crystals should be used dissolved in alcohol. The glycerine makes the flux adhesive. To prevent the alcohol igniting, the mixture may be diluted with water. There are a number of prepared fluxes on the market, but are not to be recommended because of the ridiculously high prices demanded. ***For electrical work, especially when very small wires are used, rosin should be insisted upon to avoid any corrosion.*** No one flux can be assigned to any one metal as being peculiarly adapted or fitted to that metal for all purposes. The nature of the solder often determines the flux.

1. Picking up;
2. Melting on the work.

For soldering small wires, the first method is used. The solder is *picked up* as in fig. 5,187, and then applied to the joint, as in fig. 5,189. Since *heat rises*, the bit is more efficiently applied underneath the parts to be soldered. The difficulty encountered with such application is to retain



FIGS. 5,188 and 5,189.—Soldering small wire connections by the picking up method. Tin one side only of the bit. If the bit be already tinned on all four faces file bit clear down to copper on all but one side and apply solder as in fig. 5,188. The bit is now ready and may be used without the annoyance of the solder leaving the working face or dropping on the floor below.

the solder at the right place on the bit. This is accomplished by tinning only one face of the bit as **A** in fig. 5,188, which will cause the melted solder to remain on the upper or tinned face, so that the soldering is easily done as in fig. 5,189.

The second method of melting the solder on the work is a top method, that is the *stick* of solder is held on top of the work.

The bit is more efficiently applied from below as before stated, as it allows the heat to rise melting the solder and allowing it to flow into the

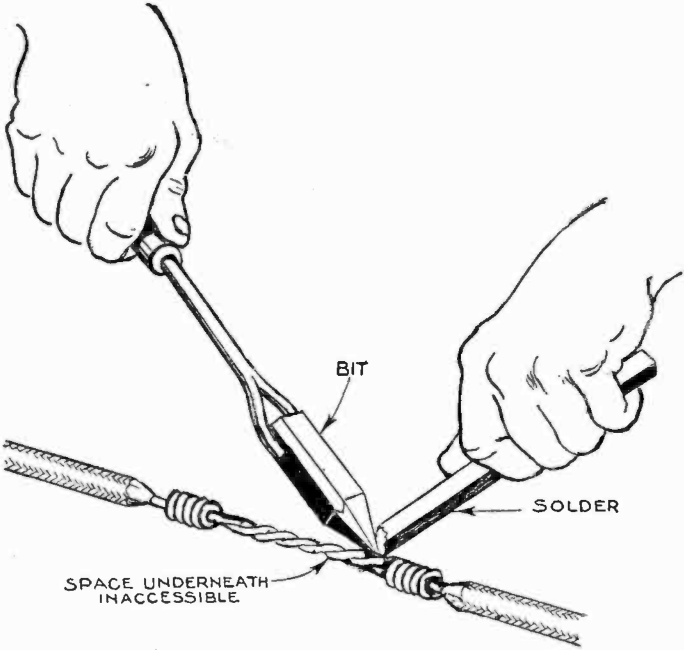


FIG. 5,190.—Method of soldering by melting the solder on the work. This is naturally a *top* method and requires a hotter bit than the picking up method shown in figs. 5,188 and 5,189.

crevices. When it is found impossible to apply the heat from below, the soldering copper may be placed at the top, as in fig. 5,190, in which case it will be found necessary to increase the heat of the copper.

Soldering with a Gasoline Blow Torch.—Instead of applying the heat for soldering with a bit, it is sometimes more conveniently done by applying the flame of a blow torch direct to the work.

The operation of a blow torch is explained in fig. 5,192, and of a gasoline

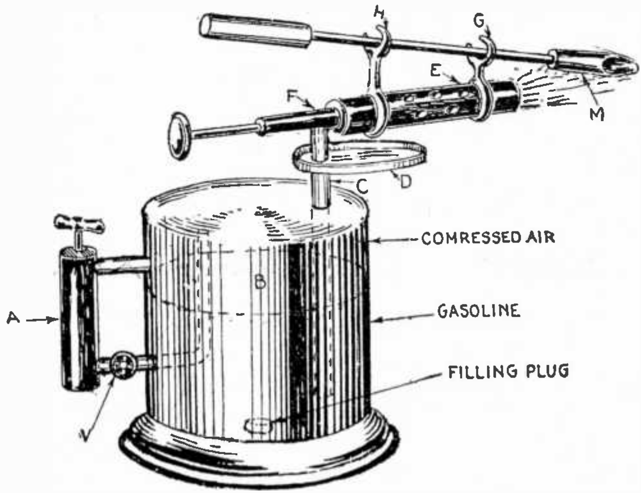


FIG. 5,191.—Gasoline torch with rests for holding soldering bit. *In construction* A, is a hand air pump, which may have automatic, or hand operated valve; B, is the reservoir containing gasoline and compressed air, the latter being furnished by the pump. A valve V, prevents leakage of the compressed air through pump. A pipe C, projects to bottom of reservoir, as indicated by dotted lines, and connects with vaporizer E, through needle valve F. A trough D, is for holding a small quantity of gasoline to heat vaporizer E, in starting. Two supports H and G, clamped to the vaporizer support a soldering bit so that it will rest in the flame in heating. *In operation*, the reservoir is filled about two-thirds full through filler plug and the pump given a few strokes to compress air in the top of reservoir. After heating vaporizer E, with a little gasoline placed in D, needle valve F, is opened slightly. The gasoline under pressure on the reservoir will flow through needle valve F, into the vaporizer and ignite. As the vapor becomes hotter the valve may be given more opening and when fully heated an almost colorless flame of great heat will issue from the end of the vaporizer. Air supply is admitted into the vaporizer through the small holes shown. In attaching the supports H, G, care should be taken not to cover any of the air holes, because this will cause a poor flame.

torch in fig. 5,191. After fluxing, the joint or splice is heated above the melting point of solder. The latter is applied from the top so that it will flow all over the wires and into the crevices.

For small wire connections a mouth or *pin flame* alcohol blow torch should be used as shown in fig. 5,192.

Sweating.—In this operation the surfaces to be joined are cleaned, heated, fluxed and covered with a film of solder. The soldered surfaces are then placed together and heated either

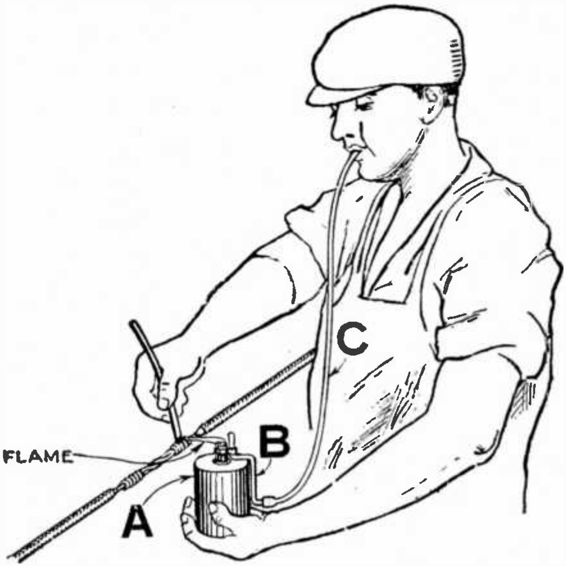
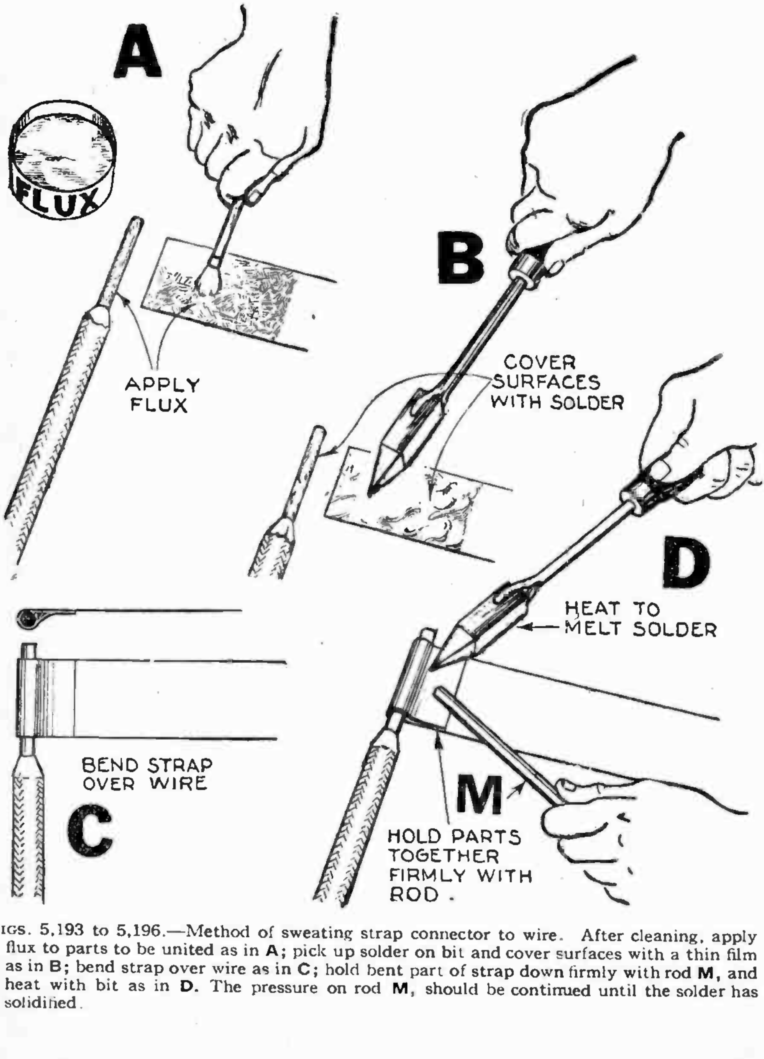


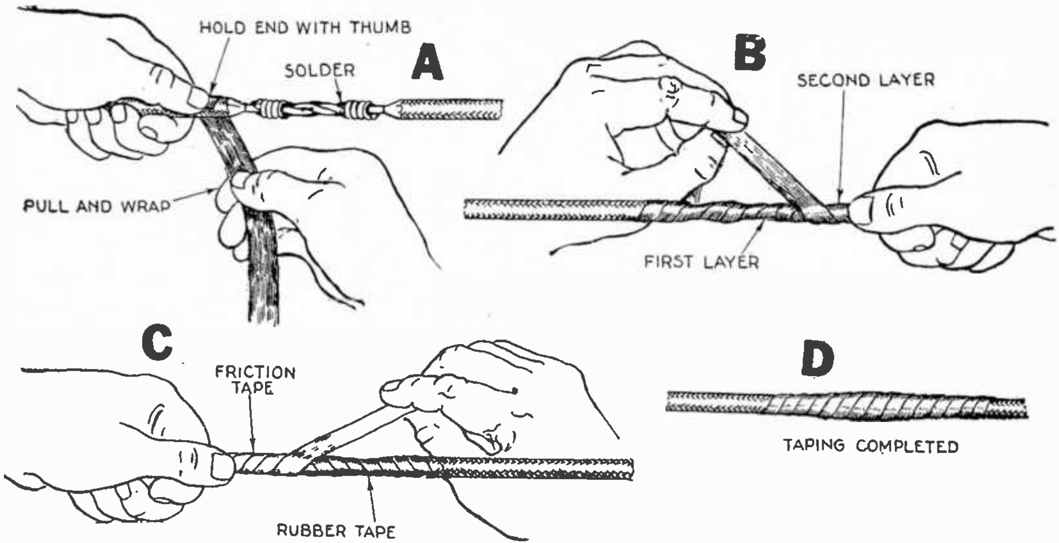
FIG. 5,192.—Pin flame alcohol blow torch. *It consists* of an ordinary wick torch A, provided with a blow pipe B, having a rubber tube extension, C, for blowing. *In operation*, the blowing pressure should be regulated so that the flame is drawn out to a sharp point. *In soldering*, a flame should be directed to the center of the joint and should be blown with sufficient pressure to bring the flame to a point. Use a piece of solder wire rather than a large stick of solder, thus avoiding the loss of considerable heat which takes place in heating the large stick of solder.

with a bit or blow torch until the solder melts and unites the two surfaces.

During the heating operation the surfaces should be held firmly together with clamps or other means. Figs. 5,193 to



FIGS. 5,193 to 5,196.—Method of sweating strap connector to wire. After cleaning, apply flux to parts to be united as in **A**; pick up solder on bit and cover surfaces with a thin film as in **B**; bend strap over wire as in **C**; hold bent part of strap down firmly with rod **M**, and heat with bit as in **D**. The pressure on rod **M**, should be contimued until the solder has solidified.



FIGS. 5,197 to 5,200.—Method of insulating a joint or splice. **A,** take a turn of the rubber tape over the insulated end of the wire and in starting, hold end of tape with thumb; **B,** wrap tape over the exposed connection and continue a turn over insulation at end, pulling tape in wrapping until it stretches to nearly half its original width; continue wrapping in reverse direction building up the rubber covering until it equals the thickness of the wire insulation; **C,** cover the rubber tape with two layers of friction tape; **D,** insulation or taping completed.

5,196 illustrate the joining of a strap connector to a wire by sweating.

Insulating or Tap(e)ing.—To complete the various joints, taps and splices described in the two preceding chapters, the exposed wires must be insulated.

To insulate, the exposed wires are wrapped first with rubber tape until this covering is equal in thickness to the regular insulation. Then about two layers of friction tape are wrapped over the rubber tape. The method of taping is shown in the accompanying illustration.

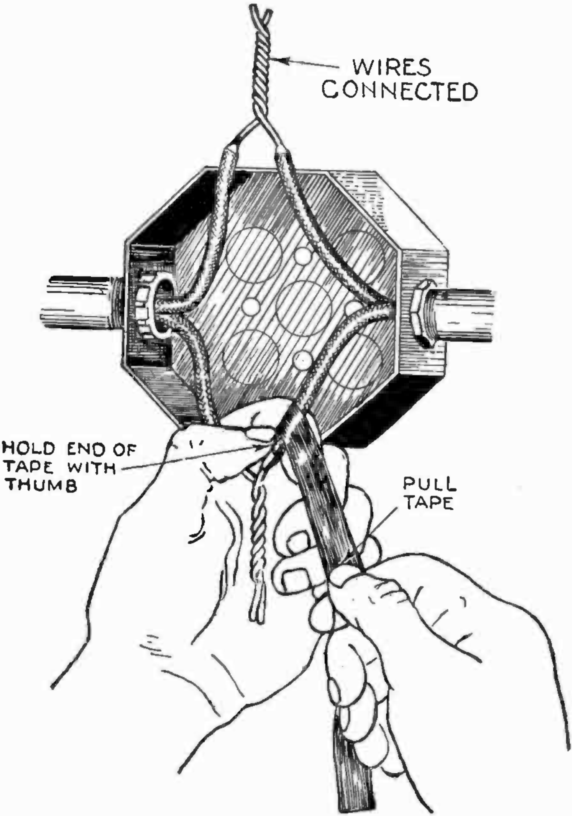


FIG. 5,201.—Method of starting tape in insulating a pig tail joint.

TEST QUESTIONS

1. *Give a definition of soldering.*
2. *What is solder?*
3. *What kind of solder should be used in electrical engineering, and why?*
4. *State briefly the theory of solder.*
5. *Name six operations to be performed in soldering.*
6. *What are the essential conditions for successful soldering?*
7. *Name four methods of soldering.*
8. *What is soldering flux and why used?*
9. *Describe the action of a flux.*
10. *What kinds of flux should not be used on electrical work and why?*
11. *What sometimes determines the kind of flux to be used?*
12. *What is the proper name for a so called soldering "iron"?*
13. *Describe the construction of a soldering bit.*
14. *What must be done preliminary to soldering?*
15. *Describe the method of tinning the bit.*
16. *How is the right temperature for a bit judged?*
17. *What happens if the temperature of the bit be too high?*
18. *How is the flux applied?*
19. *Upon what does the method of applying the solder depend?*
20. *Describe the "picking up" method of applying solder.*

21. *Describe the "melting on the work" method of applying solder.*
22. *What is the construction of a blow torch?*
23. *Describe the operation of sweating.*

CHAPTER 107

How to Read Plans

Wiring Terms.—There are a number of terms in general use relating to the work of wiring and the exact meaning of these terms is of importance to the electrician who installs any system of wiring. These definitions are from the National Electrical Code and are standard.

Definitions

Accessible.—(As applied to wiring methods, not permanently closed in by the structure or finish of the building; capable of being removed without disturbing the building structure or finish. (As applied to equipment.) Admitting close approach because not guarded by locked doors, elevation or other effective means. (See also Readily Accessible.)

Approved.—Acceptable to the authority enforcing this Code.

Branch Circuit.—That portion of a wiring system extending beyond the final automatic overload protective device of the circuit.

Lighting Branch Circuits.—Circuits supplying energy to lighting outlets only.

Appliance Branch Circuits.—Circuits supplying energy either to permanently wired appliances or to attachment plug receptacles, that is, appliance or convenience outlets or to a combination of permanently wired appliances and additional attachment plug outlets on the same circuit; such circuits to have no permanently connected lighting fixtures.

Building.—A structure which stands alone or which is cut off from adjoining structures by unpierced fire walls.

Cabinet.—An enclosure designed either for surface or flush mounting, and provided with a frame, matt or trim in which swinging doors are hung. (See cutout box.)

Cable.—A stranded conductor (single-conductor cable) or a combination of conductors insulated from one another (multiple-conductor cable).

Concealed.—Rendered inaccessible by the structure or finish of the building. Wires in concealed raceways are considered concealed, even though they may become accessible by withdrawing them.

Conductor.—A wire or cable or other form of metal suitable for carrying current.

Controller.—A device, or group of devices, which serve to govern, in some predetermined manner, electric power delivered to the device governed.

Cutout Box.—An enclosure designed for surface mounting and having swinging doors or covers secured directly to and telescoping with the walls of the box proper. (See cabinet.)

D.C. Neutral Grid.—A well grounded network of neutral conductors formed by connecting together within a given area all of the neutral conductors of a low-voltage direct-current supply system.

Dust-tight.—So constructed that dust will not enter the enclosing case.

Enclosed.—Surrounded by a case which will prevent accidental contact of a person with live parts.

Exposed.—Accessible; not concealed.

Feeder.—A stretch of wiring to which no connection is made except at its two ends.

Guarded.—Covered, shielded, fenced, enclosed, or otherwise protected, by means of suitable covers or casings, barriers, walls or screens, mats or platforms, to remove the liability of dangerous contact or approach by persons or objects to a point of danger.

Isolated Plant.—A private electrical installation deriving energy from its own generator driven by a prime mover.

Master Service.—The service conductors supplying a group of buildings under one management.

Motor Circuit Switch.—A switch used to stop a motor when at full running current, but not intended to open the motor circuit with stalled rotor current flowing. The switch may also serve to disconnect the motor and its controller when necessary for repairs, etc.

Outlet.—A point on the wiring system at which current is taken to supply fixtures, lamps, heaters, motors and current-consuming devices generally.

Panelboard.—A single panel, or a group of panel units designed for assembly in the form of a single panel; including buses and with or without switches and or automatic overload protective devices for the control of light, heat, or power circuits of small individual as well as aggregate capacity designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front. (See switchboard.)

Portable Appliance.—An appliance capable of being readily moved where established practice or the conditions of use make it necessary or convenient for it to be detached from its source of current by means of flexible cord and attachment plug.

Readily Accessible.—Capable of being reached quickly, for operation, renewal or inspection, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc.

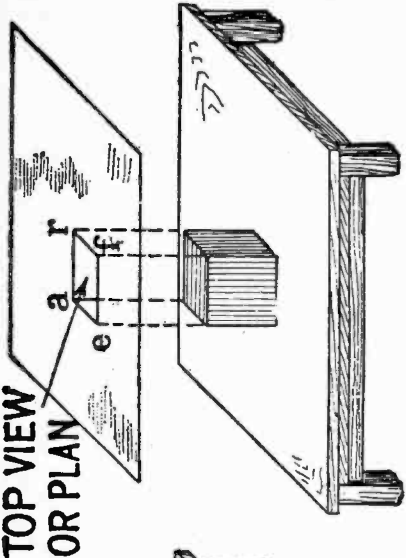
Secondary Neutral Grid.—A well grounded network of neutral conductors formed by connecting together within a given area all the neutral conductors of individual transformer secondaries of the supply system.

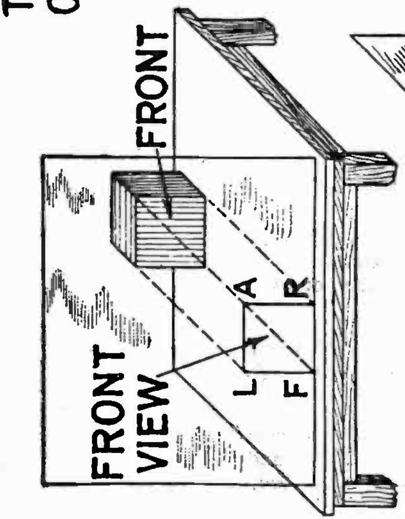
Service.—That portion of the supply conductors which extends from the street main or duct or transformers to the service switch, switches, or switchboard of the building supply.

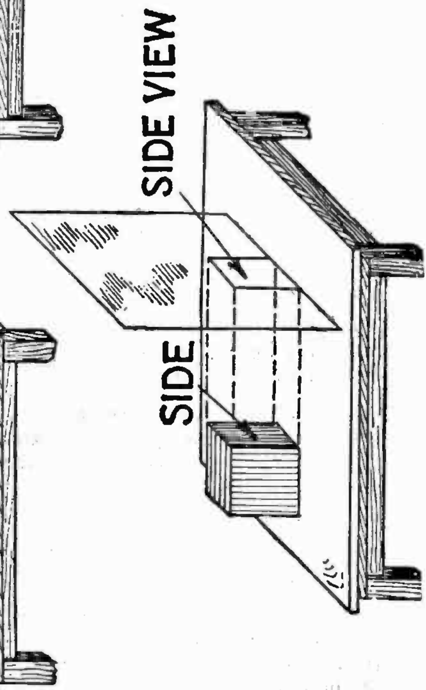
Sub-feeder.—Same class as a feeder, but is distinguished either by being one of two or more connecting links between the end of a single feeder, and several distributing mains, or by constituting an extension of a feeder.

Totally Enclosed Motor.—A motor which is so completely enclosed by integral or auxiliary covers as to practically prevent the circulation of air through the interior. Such a motor is not necessarily air-tight.

Voltage to Ground.—The voltage between the given conductor and that conductor of the circuit which is grounded; in ungrounded circuits, the greatest voltage between the given conductor and any other conductor of the circuit.







FIGS. 5,202 to 5,204.—Illustration of the various "views" of an object in orthographic projection by means of a pane of glass placed in the different planes of projection.

Waterproof.—So constructed or protected that moisture will not interfere with its successful operation.

Watertight.—So constructed that moisture will not enter the enclosing case.

How to Read Plans.—There are various ways of representing objects in drawings, such as:

1. Perspective;
2. Cabinet projection,
3. Isometric projection;
4. Orthographic projection;
5. Development of surfaces.

Of these methods, the first three may be classed as "pictorial" in that they show the entire visible portion of the object in one view, whereas the fourth requires several views to fully present the object and may be called "descriptive."

It is this latter method that is most generally used and which requires a little study to comprehend it. A knowledge of this method is necessary to read plans.

Orthographic Projection.—Isometric drawing and cabinet projection, while showing the object as it really appears to the eye of the observer, are neither of them very convenient methods to employ where it is necessary to measure every part of the drawing for the purpose of reproducing it.

Drawings suitable for this purpose, generally known as *working drawings*, are made by the method known as *orthographic projection*.

In cabinet or isometric projection, three sides of the object are shown in one view, while in a drawing made in orthographic projection, but one side of the object is shown in a single view.

To illustrate this, a clear pane of glass may be placed in front of the object intended to be represented.

In fig. 5,202 a cube is shown on a table; in front of it, parallel with one face (the front face) of the cube, the pane of glass is placed.

Now, when the observer looks directly at the front of an object from a considerable distance, he will see only one side, in this case only the front side of the cube.

The rays of light falling upon the cube are reflected into the eyes of the observer, and in this manner he sees the cube. The pane of glass, evidently, is placed so that the rays of light from the object will pass through the glass in straight lines, to the eye of the observer. The front side of the object, by its outline, may be traced upon the glass, and in this manner a figure drawn on it (in this case a square) which is the view of the object as seen from the front which in this case is called the *front elevation*.

One view, however, is not sufficient to show the real form of a solid figure. In a single view two dimensions only can be shown, length and height; hence the thickness of an object will have to be shown by still another view of it, as the top view or *plan*.

Now, place the pane in a horizontal position above the cube which is resting on the table, as in fig. 5,203 and, looking at it from above, directly over the top face of the cube, trace its outline upon the pane; as a result. a square figure is drawn upon the glass, which corresponds to the appearance of the cube, as seen from above. This square on the glass is the top view of the cube, or its *plan*.

Fig. 5,204 shows the manner in which a side view of the cube may be traced; the glass is placed on the side of the cube, which rests on the table as before, and the outline of the cube on the glass in this position is called its *side elevation*.

Usually either two of the above mentioned views will suffice to show all dimensions and forms of the object, but to completely represent complicated objects, three or four views may be required.

In complicated pieces of machinery, however, more views, three and even more may be required to adequately represent the proportions and form of the different parts.

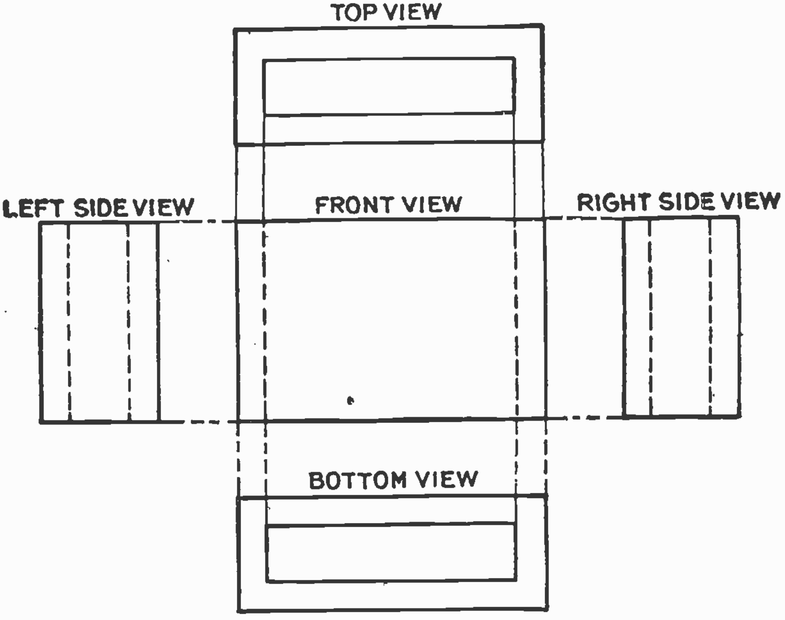
A drawing which represents the object as seen by an observer looking at it from the right side is called *the right side elevation* and a drawing showing the object as it appears to the observer looking at it from the left side is called *the left side elevation*.

In the case of a long object, a view at the end is called an *end view*.

A view of the object as seen from the rear is called the rear view or rear elevation, and a view from the bottom, the bottom view.

The different views of an object are always arranged on the drawing in a certain fixed and generally adopted manner, thus—

The front view is placed in the center; the right side view is placed to the right of the front view, and the left side view to the left; the top view is placed above the front view and the bottom view below it. The different views are placed directly opposite each other and are joined by dotted lines called *projection lines*.

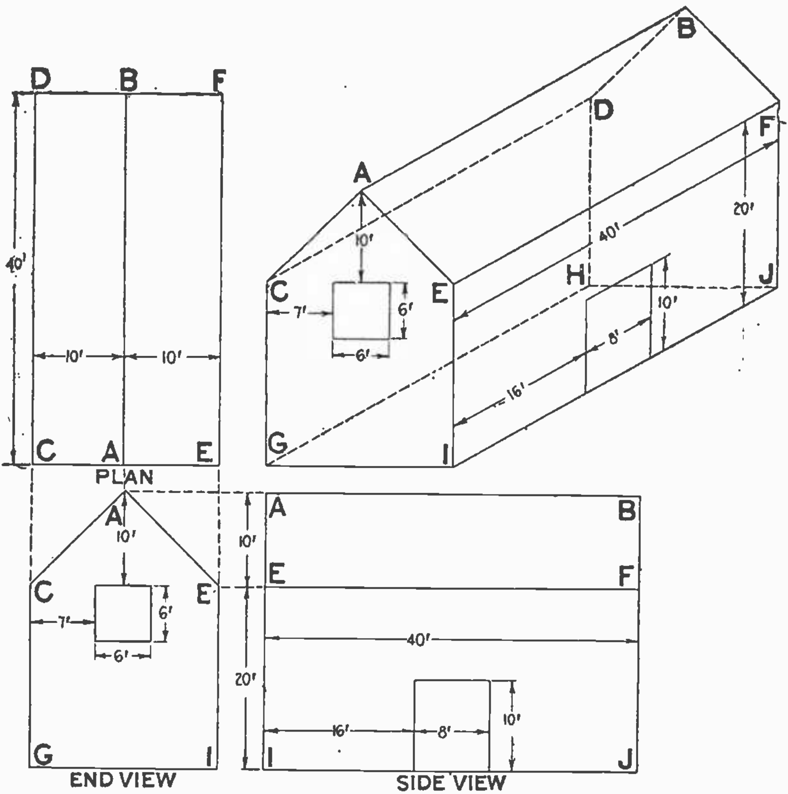


FIGS. 5,205 to 5,209.—Five views of an object as drawn in orthographic projection.

By the aid of projection lines, leading from one view to the other, as in figs. 5,205 to 5,209 measurements of one kind may be transmitted from one view to the other; thus, the height of different parts of an object may be transmitted from the front view to either one of the side views; in like manner the length of different parts of the object may be transmitted by the aid of projection lines, to the bottom view and top view.

It is often desirable to show lines belonging to an object, although they may not be directly visible. In figs. 5,205 to 5,209 the top view and the bottom view show plainly that the object is hollow; looking at the object from the front or from the sides, however, the observer could not see the inside edges of the object, unless it were made of some transparent material.

In projection drawing it is assumed for convenience that all objects are made of such material, transparent enough to show all hidden lines, no matter from which side the object is observed; these hidden lines are represented in the drawing by dotted lines.



FIGS. 5,210 to 5,213.—Cabinet projection outline drawing of a barn, and same drawn in orthographic projection.

To illustrate the method of orthographic projection one problem is given.

Problem.—Draw plan, end and front views of the barn shown in fig. 5,211.

The plan will consist simply of a rectangle CDFE (fig. 5,210), the length of whose sides being obtained from the dimensions in the orthographic projections. The end view is projected down from points C,A,E, of the plan, being identical with the end in fig. 5,211, because it is here drawn in the "OX, plane" which is the plane of the paper and accordingly is seen in true size.

Similarly for the side view project over the points A,E,I., of the end view and lay off AB, EF, and IJ, equal to 40 ft., the elevation of these lines being obtained from the given dimensions. The door is laid out in a similar manner.

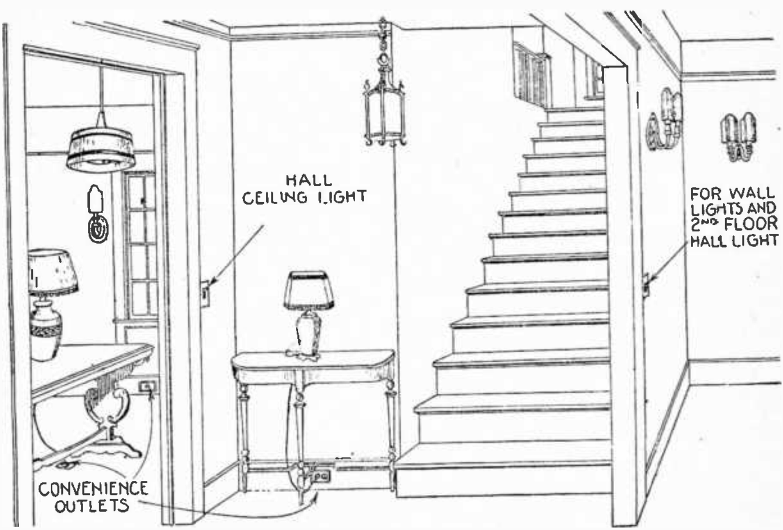


FIG. 5,214.—The vestibule and front hall.

Plans of a Dwelling.—To illustrate how to read blue prints

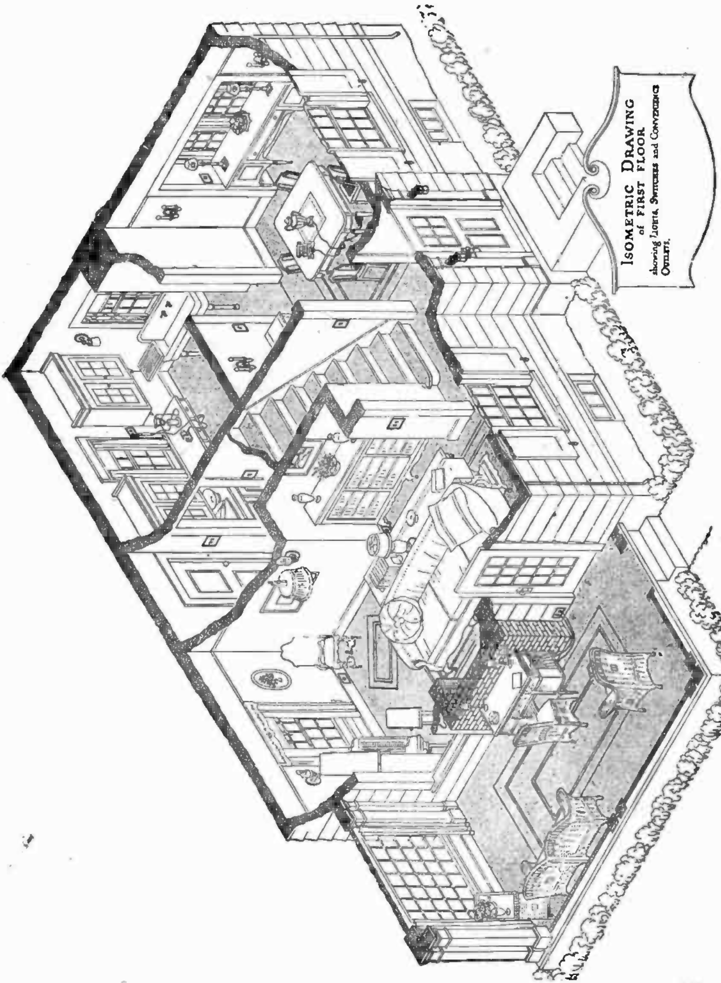
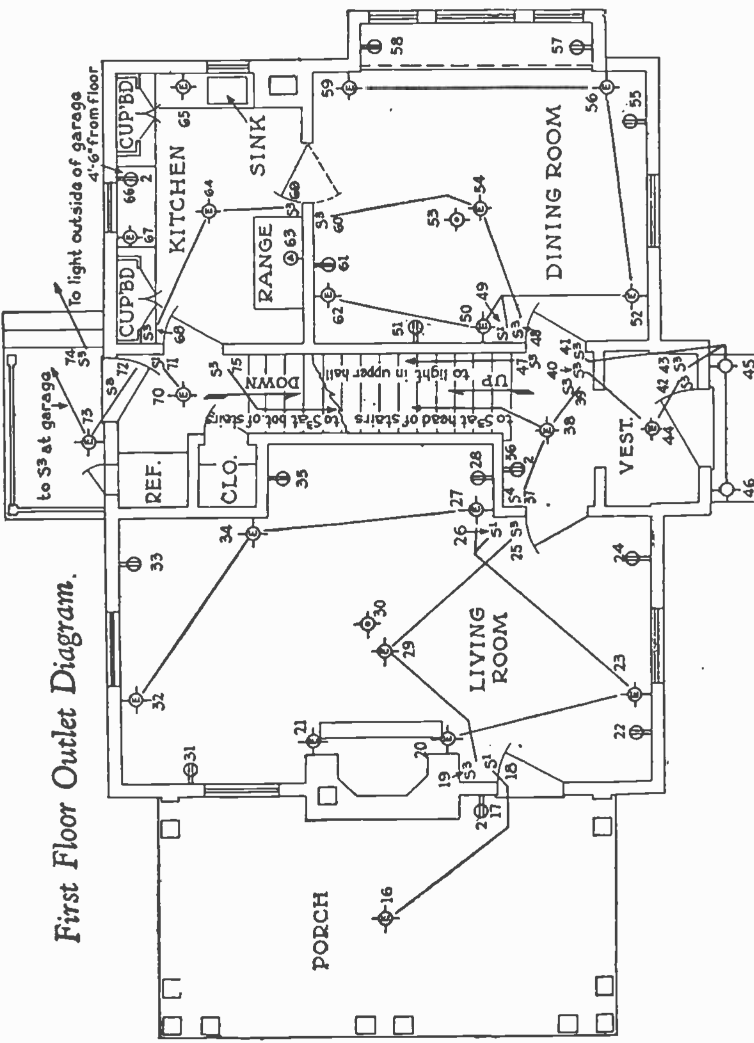


Fig. 5,215.—Isometric drawing of first floor showing lights, switches and convenience outlets.



First Floor Outlet Diagram.

FIG. 5.216.—First floor plan or outlet diagram.

and especially how the electric wiring installation is indicated, a set of "plans" is here given.

With respect to the wiring, the symbols show the location of the outlets to which the wiring must be brought and the number of lights for which provision must be made. It is accordingly necessary to know the meaning of the symbols or to have at hand a table of these symbols as given conveniently in this chapter. To assist the student in reading the plans, the building is first shown in cut away *isometric projection*, fig. 5,215, which gives the general appearance of the interior the same as a photograph.

First compare the isometric drawing fig. 5,215 of the first floor with the plan, fig. 5,216.

Key for First Floor


=Ceiling Outlet for Extensions (Elexits)


=Wall Outlets for Extensions (Elexits)


=Wall Outlet


=Single Convenience Outlet


=Double Convenience Outlet


=Floor Outlet


=Range Outlet

S^1 =Single-pole Tumbler Switch

S^2 =Double-pole Tumbler Switcl

S^3 =Three-way Tumbler Switch

S^4 =Four-way Tumbler Switch

Note.—Where Elexits are indicated other types of outlets may be substituted.

Specifications

VESTIBULE

42* 3-Way Tumbler Switch GE1690, controls No. 44 Ceiling Elexit.
43 3-Way Tumbler Switch GE1690, controls Nos. 45 and 46 Entrance Lights.
44 Ceiling Elexit LX200. 25-watt lamp is recommended.

*The numbers in the first column identify the outlets shown on floor plan.

Specifications—*Continued*

HALL

37 4-Way Tumbler Switch GE1691, controls No. 38 Ceiling Elexit.
39 3-Way Tumbler Switch GE1690, controls No. 38 Ceiling Elexit.
40 3-Way Tumbler Switch GE1690, controls No. 44 Vestibule Elexit.
41 3-Way Tumbler Switch GE1690, controls Nos. 45 and 46 Entrance Lights.
47 3-Way Tumbler Switch GE1690, controls No. 101 Upper Hall Ceiling Elexit.
36 Twin Convenience Outlet GE694, furnishes power for table lamp, vacuum cleaner, etc.
38 Ceiling Elexit LX200. 50-watt lamp is recommended.

LIVING ROOM

25 3-Way Tumbler Switch GE1690, controls No. 29 Ceiling Elexit.
19 3-Way Tumbler Switch GE1690, controls No. 29 Ceiling Elexit.
26 S-P. Tumbler Switch GE1688, controls Nos. 20, 21, 23, 27, 32 and 34 Wall Elexits.
18 S-P. Tumbler Switch GE1688, controls No. 16 Ceiling Elexit.
24 Single Convenience Outlet GE658
22 Single Convenience Outlet GE658
31 Single Convenience Outlet GE658
33 Single Convenience Outlet GE658
35 Single Convenience Outlet GE658
28 Single Convenience Outlet GE658
30 Single Convenience Outlet GE658
} furnishes power for portable lamps, electrically operated musical instruments, vacuum cleaners, fans, etc.
20 Wall Elexit LX111. 15-watt lamp is recommended.
21 Wall Elexit LX111. 15-watt lamp is recommended.
23 Wall Elexit LX111. 25-watt lamp is recommended.
27 Wall Elexit LX111. 25-watt lamp is recommended.
32 Wall Elexit LX111. 25-watt lamp is recommended.
34 Wall Elexit LX111. 25-watt lamp is recommended.
29 Ceiling Elexit LX200. 200-watt lamp is recommended.

SUN PORCH

17 Twin Convenience Outlet GE694, furnishes power for portable lamps, fan, cooking appliances, vacuum cleaner, etc.
16 Ceiling Elexit LX200. 75 watts if lamp is of diffusing quality, otherwise only 50, is recommended.

DINING ROOM

48 3-Way Tumbler Switch GE1690, controls No. 54 Ceiling Elexit.
60 3-Way Tumbler Switch GE1690, controls No. 54 Ceiling Elexit.
49 S-P. Tumbler Switch GE1688, controls Nos. 50, 52, 56, 59, 62, Wall Elexits.
51 Single Convenience Outlet GE658
55 Single Convenience Outlet GE658
57 Single Convenience Outlet GE658
58 Single Convenience Outlet GE658
61 Single Convenience Outlet GE658
53 Single Convenience Outlet GE658
} furnishes power for cooking appliances, electric candlesticks, glow heater, fan, vacuum cleaner, etc

The plan with the electric installations indicated on same is sometimes called an outlet diagram.

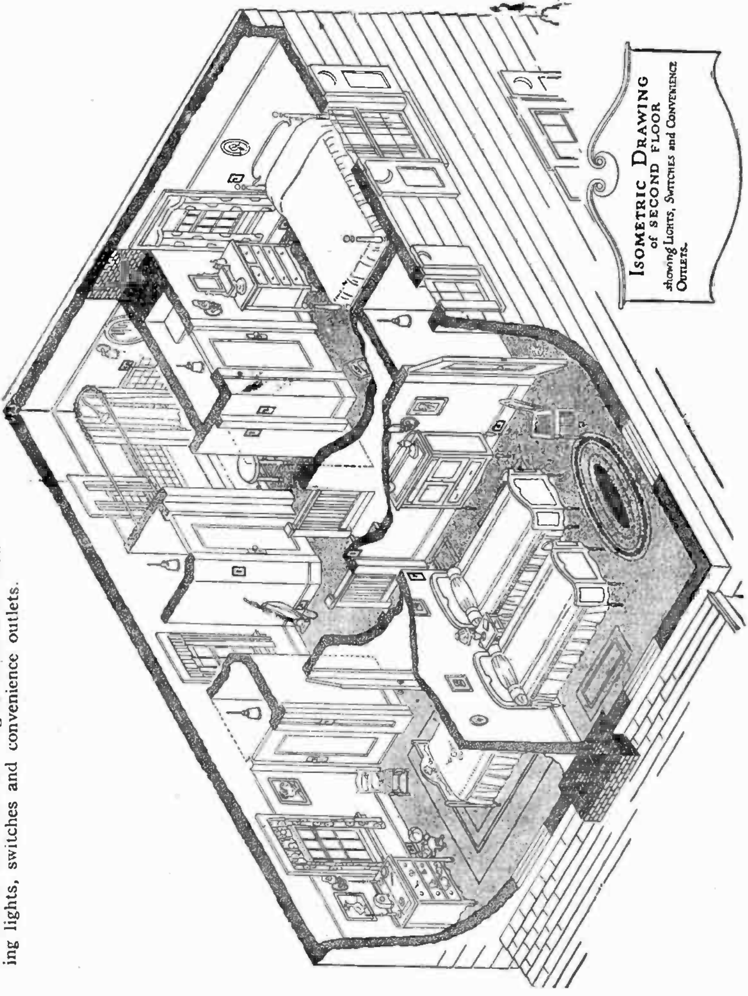


FIG. 5,217.—Isometric drawing of second floor showing lights, switches and convenience outlets.

Specifications—*Continued*

DINING ROOM (Continued)

50 Wall Elexit LX111. Two 15-watt lamps are recommended.
52 Wall Elexit LX111. Two 15-watt lamps are recommended.
56 Wall Elexit LX111. Two 15-watt lamps are recommended.
59 Wall Elexit LX111. Two 15-watt lamps are recommended.
62 Wall Elexit LX111. Two 15-watt lamps are recommended.
54 Ceiling Elexit LX200. Two 100-watt lamps in dome fixture are recommended.

KITCHEN

69 3-Way Tumbler Switch GE1690, controls No. 64 Ceiling Elexit.
68 3-Way Tumbler Switch GE1690, controls No. 64 Ceiling Elexit.
66 Twin Convenience Outlet GE694, furnishes power for fan, utility motor, beaters, iron, etc.
63 Special Convenience Outlet GE694, furnishes power for electric range.
65 Wall Elexit LX111. 25-watt lamp is recommended.
67 Wall Elexit LX111. 25-watt lamp is recommended.
64 Ceiling Elexit LX200. 100-watt lamp is recommended.

BACK HALL AND PORCH

75 3-Way Tumbler Switch GE1690, controls No. 12 Main Cellar Light.
71 Single-pole Tumbler Switch GE1688, controls No. 70 Hall Center Elexit.
72 3-Way Tumbler Switch GE1690, controls No. 73 Back Porch Light.
74 3-Way Tumbler Switch GE1690, controls No. 132 Light Outside Garage.
70 Ceiling Elexit LX200. 25-watt lamp is recommended.
73 Wall Elexit LX111. 25-watt lamp is recommended.

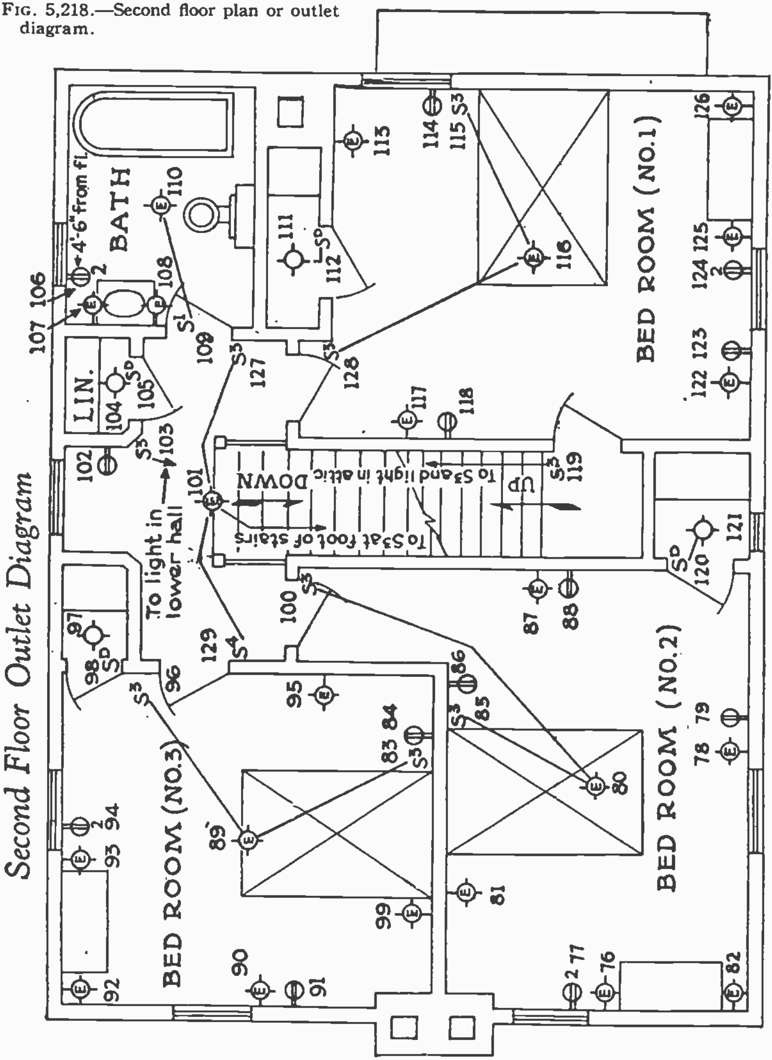
CELLAR

11 3-Way Tumbler Switch GE1690, controls No. 12 Main Cellar Light.
1 S-P. Surface Tumbler Switch GE970, controls No. 2 Heater Room Light.
5 S-P. Surface Tumbler Switch GE970, controls No. 4 Fuel Room Light.
7 S-P. Surface Tumbler Switch GE970, controls No. 6 Storage Room Light.
8 S-P. Surface Tumbler Switch GE970, controls No. 9 Laundry Light.
14 S-P. Surface Tumbler Switch GE970, controls No. 15 Vegetable Room Light.
3 Single Convenience Outlet GE658, furnishes power for trouble light, fan, etc.
10 Twin Convenience Outlet GE694 } furnishes power for electric tools, washing machine,
13 Twin Convenience Outlet GE694 } ironer, etc.
2 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.
4 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.
6 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.
9 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.
12 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.
15 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.

GARAGE

132 3-Way Tumbler Switch GE1690, controls No. 132 Light Outside Garage.
133 3-Way Tumbler Switch GE1690, controls No. 173 Back Porch Light.
134 S-P. Tumbler Switch GE1688, controls No. 137 Center Light.
135 Twin Convenience Outlet GE694, furnishes power for Tungar battery chargers, electric tools and appliances.
137 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.
138 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

FIG. 5,218.—Second floor plan or outlet diagram.



Next the view and plan of the second floor, figs. 5,217 and 5,218 should be compared. For convenience a key of the symbols used in each plan is given.

Accompanying the plans there should be a list of the wiring devices required and the control of each indicated as here given. The complete wiring system as indicated in the plans thus far given, represents an installation where every convenience is provided for.

With the realization, however, that convenience is a relative quantity, two alternative diagrams are presented on the following pages for the benefit of those who judge convenience from a somewhat different standard.

The first of these, illustrated in figs. 5,219 and 5,221, shows the ideal layout reduced to the bare necessities that will provide reasonable electrical convenience. As compared with a house wired in the usual imperfect way, this installation is desirable and serviceable.

The second alternative, shown in figs 5,223 and 5,224, may be characterized as a compromise between the two. It includes the essential conveniences of the first alternative and adds some of the contributions to comfort and security which go to make up the ideal wiring of the home.

Key for Second Floor

= Ceiling Outlet

= Ceiling Outlet for Extensions (Elexits)

= Wall Outlets for Extensions (Elexits)

= Single Convenience Outlet

= Double Convenience Outlet

S^1 = Single-pole Tumbler Switch

S^2 = Double-pole Tumbler Switch

S^3 = Three-way Tumbler Switch

$S4$ = Four-way Tumbler Switch

S^D = Door Switch

NOTE.—Where Elexits are indicated other types of outlets may be substituted.

Specifications

UPPER HALL

103 | 3-Way Tumbler Switch GE1690, controls No. 38 Lower Hall Light.
129 | 4-Way Tumbler Switch GE1691, controls No. 101 Upper Hall Light.
127 | 3-Way Tumbler Switch GE1690, controls No. 101 Upper Hal. Light.
102 | Single Convenience Outlet GE658, furnishes power for lamp, fan, vacuum cleaner, etc
101 | Ceiling Elexit LX200. 50-watt lamp is recommended.

LINEN CLOSET

105 | Door Switch GE273, controls No. 104 Drop Light.
104 | Ceiling Lamp Receptacle GE264. 25-watt lamp is recommended.

BATH ROOM

109 | S-P. Tumbler Switch GE1688, controls No. 110 Ceiling Elexit.
106 | Twin Convenience Outlet GE694, furnishes power for immersion heater, glow heater, etc.
107 | Wall Elexit LX111. 25-watt (brackets alone 50-watt) lamp is recommended.
108 | Wall Elexit LX111. 25-watt (brackets alone 50-watt) lamp is recommended.
110 | Ceiling Elexit LX200. 75-watt lamp is recommended.

BED ROOM NO. 1

128 | 3-Way Tumbler Switch GE1690, controls No. 116 Ceiling Elexit.
115 | 3-Way Tumbler Switch GE1690, controls No. 116 Ceiling Elexit.
112 | Door Switch GE273, controls No. 111 Closet Drop Light.
118 | Single Convenience Outlet GE658
123 | Single Convenience Outlet GE658
114 | Single Convenience Outlet GE658 } furnishes power for lamps, vacuum cleaner, sewing machine, etc.
124 | Twin Convenience Outlet GE694, furnishes power for lamps, toilet accessories, etc.
113 | Wall Elexit LX111. 25-watt lamp is recommended.
117 | Wall Elexit LX111. 25-watt lamp is recommended.
122 | Wall Elexit LX111. 25-watt lamp is recommended.
125 | Wall Elexit LX111. 25-watt lamp is recommended.
126 | Wall Elexit LX111. 25-watt lamp is recommended.
116 | Ceiling Elexit LX200. 100-watt lamp is recommended.
111 | Ceiling Lamp Receptacle GE264. 25-watt lamp is recommended.

*The numbers in the first column identify the outlets shown on floor plan.

Specifications—*Continued*

BED ROOM NO. 2

100 3-Way Tumbler Switch GE1690, controls No. 80 Ceiling Elexit.
85 3-Way Tumbler Switch GE1690, controls No. 80 Ceiling Elexit.

120 Door Switch GE273, controls No. 121 Closet Drop Light.

86 Single Convenience Outlet GE658
88 Single Convenience Outlet GE658
79 Single Convenience Outlet GE658
} furnishes power for lamps, vacuum cleaner, sewing machines, etc.

77 Twin Convenience Outlet GE694, furnishes power for lamps, toilet accessories, etc.

81 Wall Elexit LX111. 25-watt lamp is recommended.
76 Wall Elexit LX111. 25-watt lamp is recommended.
82 Wall Elexit LX111. 25-watt lamp is recommended.
78 Wall Elexit LX111. 25-watt lamp is recommended.
87 Wall Elexit LX111. 25-watt lamp is recommended.

80 Ceiling Elexit LX200. 100-watt lamp is recommended.
121 Ceiling Lamp Receptacle GE264. 25-watt lamp is recommended.

BED ROOM NO. 3

96 3-Way Tumbler Switch GE1690, controls No. 89 Ceiling Elexit.
83 3-Way Tumbler Switch GE1690, controls No. 89 Ceiling Elexit.

98 Door Switch GE273, controls No. 97 Closet Drop Light.

84 Single Convenience Outlet GE658
91 Single Convenience Outlet GE658
} furnishes power for lamps, electric toys, milk warmer, vacuum cleaner, etc.

94 Twin Convenience Outlet GE694, furnishes power for candlesticks, vibrator, glow heater, etc.

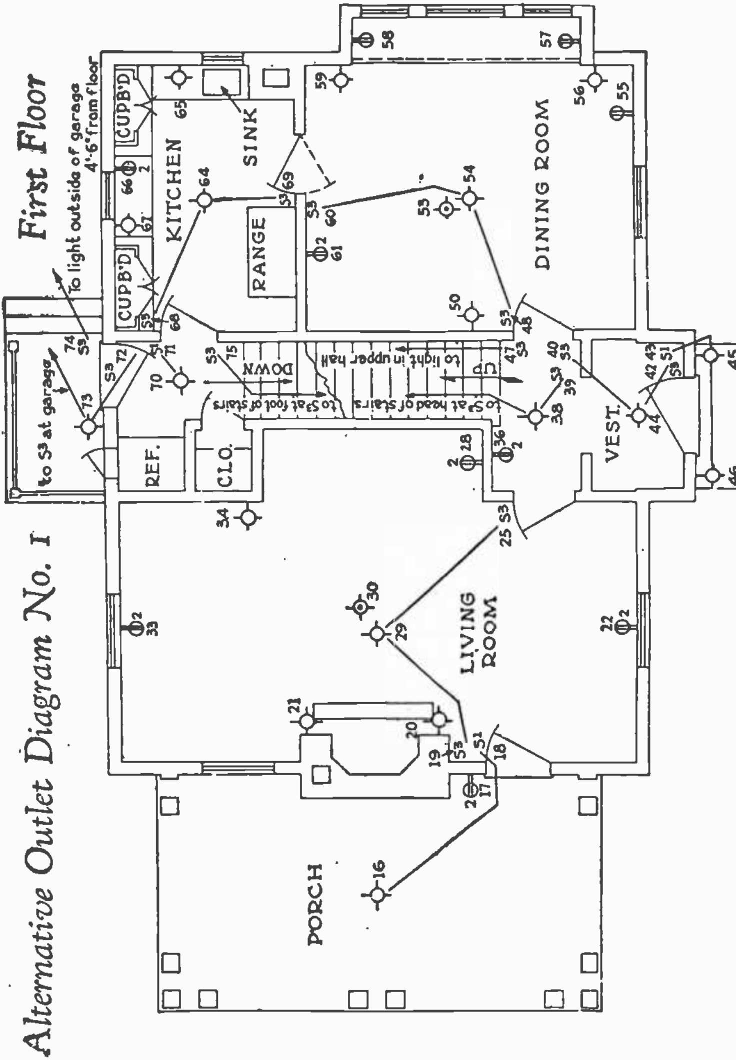
95 Wall Elexit LX111. 25-watt lamp is recommended.
99 Wall Elexit LX111. 25-watt lamp is recommended.
90 Wall Elexit LX111. 25-watt lamp is recommended.
92 Wall Elexit LX111. 25-watt lamp is recommended.
93 Wall Elexit LX111. 25-watt lamp is recommended.

89 Ceiling Elexit LX200. 75-watt lamp is recommended.
97 Ceiling Lamp Receptacle GE264. 25-watt lamp is recommended.

ATTIC

119 3-Way Tumbler Switch GE1690, controls Center Drop Light.
130 3-Way Tumbler Switch GE1690, controls Center Drop Light.

131 Ceiling Lamp Receptacle GE264. 75-watt lamp is recommended.



c. 5,219.—First floor alternative outlet diagram No. 1.

Key for First Floor

(*Alternative Diagram No.* 1)

 = Ceiling Outlet

 = Wall Outlet

 = Single Convenience Outlet

 = Double Convenience Outlet

 = Floor Outlet

S^1 = Single-pole Tumbler Switch

S^2 = Double-pole Tumbler Switch

S^3 = Three-way Tumbler Switch

S^4 = Four-way Tumbler Switch

Choosing a Lighting System.—The house shown on the accompanying pages was selected as being a universal and desirable type of the average one family residence. It is, however, more than an average residence. In so far as its adaptability to complete wiring is concerned, it is *every* home.

When the plans for a new house have been selected, take them to a qualified contractor. An evidence of his qualification will be his immediate grasp of the whole wiring system and his ability to adapt it to your future home.

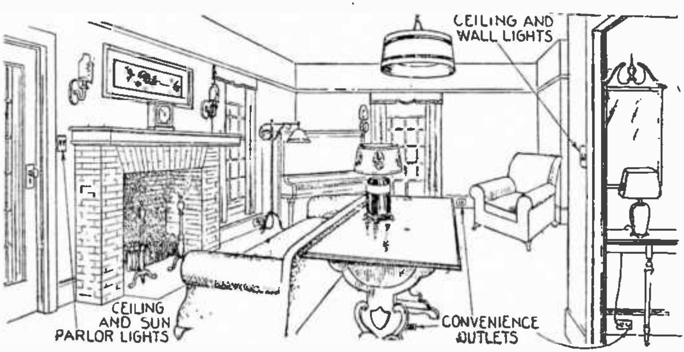


FIG. 5,220.—The living room.

Specifications for Alternative Diagram No. 1
First Floor

VESTIBULE

42 3-Way Tumbler Switch GE1690, controls No. 44 Ceiling Light.

43 S-P Tumbler Switch GE1688, controls Nos. 45 and 46 Entrance Lights.

44 Ceiling Lamp Receptacle GE264, 25-watt lamp is recommended.

HALL

39 3-Way Tumbler Switch GE1690, controls No. 38 Ceiling Light.

40 3-Way Tumbler Switch GE1690, controls No. 44 Vestibule Light

47 3-Way Tumbler Switch GE1690, controls No. 101 Upper Hall Ceiling Light.

36 Twin Convenience Outlet GE694, furnishes power for table lamp, vacuum cleaner, etc.

LIVING ROOM

25 3-Way Tumbler Switch GE1690, controls No. 29 Ceiling Light.

19 3-Way Tumbler Switch GE1690, controls No. 29 Ceiling Light.

18 S-P. Tumbler Switch GE1688, controls No. 16 Ceiling Light.

22 Twin Convenience Outlet GE694
33 Twin Convenience Outlet GE694
28 Twin Convenience Outlet GE694
30 Single Convenience Outlet GE658
} furnishes power for portable lamps, electrically operated musical instruments, vacuum cleaners, fans, etc.

20 Wall Fixture Outlet. 25-watt lamp is recommended.

KITCHEN

69 3-Way Tumbler Switch GE1690, controls No. 64 Ceiling Light.

68 3-Way Tumbler Switch GE1690, controls No. 64 Ceiling Light.

66 Twin Convenience Outlet GE694, furnishes power for fan, utility motor, beaters, iron, etc.

65 Wall Fixture Outlet. 25-watt lamp is recommended.

67 Wall Fixture Outlet. 25 watt lamp is recommended.

64 Ceiling Lamp Receptacle GE264. 100-watt lamp is recommended.

BACK HALL AND PORCH

75 3-Way Tumbler Switch GE1690, controls No. 12 Main Cellar Light.

71 S-P. Tumbler Switch GE1688, controls No. 70 Hall Center Light.

72 3-Way Tumbler Switch GE1690, controls No. 73 Back Porch Light.

74 3-Way Tumbler Switch GE1690, controls No. 132 Light Outside Garage.

70 Ceiling Fixture Outlet GE264. 25-watt lamp is recommended.

73 Wall Fixture Outlet. 25-watt lamp is recommended.

CELLAR

11 3-Way Tumbler Switch GE1690, controls No. 12 Main Cellar Light.

1 S-P Surface Tumbler Switch GE970, controls No. 2 Heater Room Light.

5 S-P. Surface Tumbler Switch GE970, controls No. 4 Fuel Room Light

7 S-P. Surface Tumbler Switch GE970, controls No. 6 Storage Room Light.

Specifications Alt. No. 1—*Continued*

41 Wall Fixture Outlet. 25-watt lamp is recommended.

34 Wall Fixture Outlet. 50-watt lamp is recommended.

29 Ceiling Lamp Receptacle GE264. 200-watt lamp is recommended.

SUN PORCH

17 Twin Convenience Outlet GE694, furnishes power for portable lamps, fan, cooking appliances, vacuum cleaner, etc.

16 Ceiling Lamp Receptacle GE264. 75-watt lamp is recommended.

DINING ROOM

48 3-Way Tumbler Switch GE1690, controls No. 54 Ceiling Light.

60 3-Way Tumbler Switch GE1690, controls No. 54 Ceiling Light.

55 Single Convenience Outlet GE658
57 Single Convenience Outlet GE658
58 Single Convenience Outlet GE658
61 Twin Convenience Outlet GE694
53 Single Convenience Outlet GE658
} furnishes power for cooking appliances, electric candle-sticks, glow heater, fan, vacuum cleaner, etc.

50 Wall Fixture Outlet. 30-watt lamp is recommended.

56 Wall Fixture Outlet. 30-watt lamp is recommended.

59 Wall Fixture Outlet. 30-watt lamp is recommended.

54 Ceiling Lamp Receptacle GE264. 100-watt lamp is recommended.

8 S-P. Surface Tumbler Switch GE970, controls No. 9 Laundry Light.

14 S-P. Surface Tumbler Switch GE970, controls No. 15 Vegetable Room Light.

3 Single Convenience Outlet GE658, furnishes power for trouble light, fan, etc.

10 Twin Convenience Outlet GE694
13 Twin Convenience Outlet GE694
} furnishes power for electric tools, washing machine, ironer, etc.

2 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.

4 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.

6 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.

9 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

12 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

15 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.

GARAGE

132 3-Way Tumbler Switch GE1690, controls No. 132 Light Outside Garage.

133 3-Way Tumbler Switch GE1690, controls No. 73 Back Porch Light.

134 S-P. Switch GE1688, controls No. 137 Center Light.

135 Twin Convenience Outlet GE694, furnishes power for Tungar battery chargers, electric tools and appliances.

137 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

138 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

*The numbers in this column identify the outlets shown on floor plan.

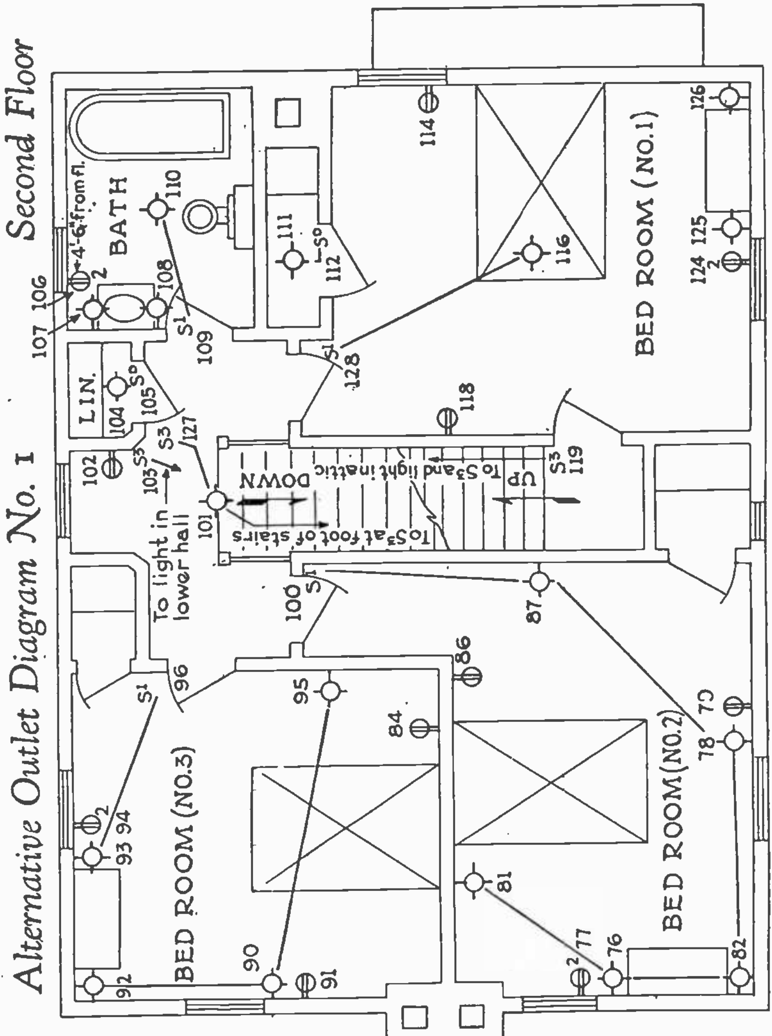


Fig. 5,221.—Second floor alternative outlet diagram No. 1.

Key for Second Floor

(Alternative Diagram No. 1)

= Ceiling Outlet

= Wall Outlet

= Single Convenience Outlet

= Double Convenience Outlet

S^1 = Single-pole Tumbler Switch

S^2 = Double-pole Tumbler Switch

S^3 = Three-way Tumbler Switch

S^4 = Four-way Tumbler Switch

S^D = Door Switch

As a further evidence of his standing, you will find him heartily appreciative of your desire to make your installation a permanent investment—not a cheap makeshift. His reputation depends in part on his customer's ultimate satisfaction.

The complete wiring system herein described, is the result of the best judgment of many people who are giving their lives to a study of the services that electricity can render, after carefully balancing the elements of convenience and cost.

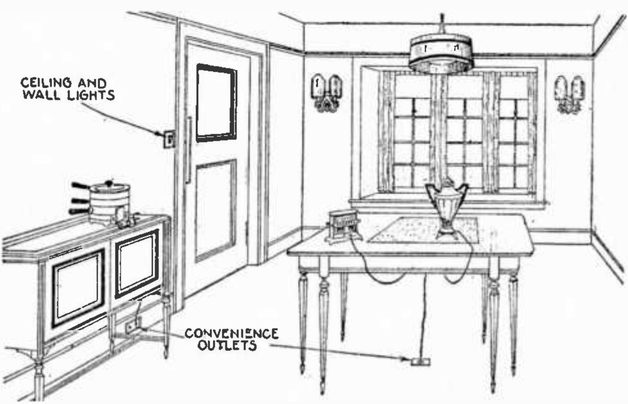


FIG. 5.222.—The dining room.

Specifications for Alternative Diagram No. 1
Second Floor

UPPER HALL

103	3-Way Tumbler Switch GE1690, controls No. 38 Lower Hall Light.
127	3-Way Tumbler Switch GE1690, controls No. 101 Upper Hall Light.
102	Single Convenience Outlet GE658, furnishes power for lamp, fan, vacuum cleaner, etc.
101	Ceiling Lamp Receptacle GE264. 50-watt lamp is recommended.

LINEN CLOSET

105	Door Switch GE273, controls No. 104 Drop Light.
104	Ceiling Lamp Receptacle GE264. 25-watt lamp is recommended.

BATH ROOM

109	S-P. Tumbler Switch GE1688, controls No. 110 Ceiling Light.
106	Twin Convenience Outlet GE694, furnishes power for immersion heater, glow heater, etc.

BED ROOM NO. 2

100	S-P. Tumbler Switch GE1688, controls Nos. 87, 78, 82, 76 and 81 Wall Lights.
86	Single Convenience Outlet GE658, furnishes power for lamps, vacuum cleaner, sewing machine, etc.
79	Single Convenience Outlet GE658 } furnishes power for lamps, toilet accessories, etc.
77	Twin Convenience Outlet GE694 }
81	Wall Fixture Outlet. 25-watt lamp is recommended.
76	Wall Fixture Outlet. 25-watt lamp is recommended.
82	Wall Fixture Outlet. 25-watt lamp is recommended.
78	Wall Fixture Outlet. 25-watt lamp is recommended.
87	Wall Fixture Outlet. 25-watt lamp is recommended.

BED ROOM NO. 3

96	S-P. Tumbler Switch GE1688, controls Nos. 93, 92, 90, 95 Wall Lights.

Specifications Alt. No. 1—*Continued*

107	Wall Fixture Outlet. 25-watt lamp is recommended.
108	Wall Fixture Outlet. 25-watt lamp is recommended.
110	Ceiling Lamp Receptacle GE264. 75-watt lamp is recommended.
	BED ROOM NO. 1
128	S-P. Tumbler Switch GE1688, controls No. 116 Ceiling Light.
112	Door Switch GE273, controls No. 111 Closet Drop Light.
118	Single Convenience Outlet GE658 } furnishes power for lamps, vacuum cleaner, sewing machine, etc.
114	Single Convenience Outlet GE658 }
124	Twin Convenience Outlet GE694, furnishes power for lamps, toilet accessories, etc.
125	Wall Fixture Outlet. 25-watt lamp is recommended.
126	Wall Fixture Outlet. 25-watt lamp is recommended.
116	Ceiling Lamp Receptacle CE264. 100-watt lamp is recommended.
111	Ceiling Lamp Receptacle CE264. 25-watt lamp is recommended.
84	Single Convenience Outlet GE658 } furnishes power for lamps, electric toys, milk warmer, vacuum cleaner, etc.
91	Single Convenience Outlet CE658 }
94	Twin Convenience Outlet GE694, furnishes power for candlesticks, vibrator, glow heater, etc.
95	Wall Fixture Outlet. 25-watt lamp is recommended.
90	Wall Fixture Outlet. 25-watt lamp is recommended.
92	Wall Fixture Outlet. 25-watt lamp is recommended.
93	Wall Fixture Cutlet. 25-watt lamp is recommended.
	ATTIC
119	3-Way Tumbler Switch GE1690 } controls Center Drop Light.
130	3-Way Tumbler Switch GE1690 }
131	Ceiling Lamp Receptacle CE264. 75-watt lamp is recommended.

*The numbers in this column identify the outlets shown on floor plan.

Specifications for Alternative Diagram No. 2

First Floor

*

VESTIBULE

42 3-Way Tumbler Switch GE1690, controls No. 44 Ceiling Elexit.
44 Ceiling Elexit LX200. 25-watt lamp is recommended.

HALL

39 3-Way Tumbler Switch GE1690, controls No. 38 Ceiling Elexit.
40 3-Way Tumbler Switch GE1690, controls No. 44 Vestibule Elexit.
41 S-P. Tumbler Switch GE1688, controls Nos. 45 and 46 Entrance Lights.
47 3-Way Tumbler Switch GE1690, controls No. 101 Upper Hall Ceiling Elexit.
36 Twin Convenience Outlet GE694, furnishes power for table lamps, vacuum cleaner, etc.
38 Ceiling Elexit LX200. 50-watt lamp is recommended.

LIVING ROOM

25 S-P. Tumbler Switch GE1688, controls No. 29 Ceiling Elexit.
19 S-P. Tumbler Switch GE1688, controls Nos. 21, 20, 23, 34 and 32 Wall Elexits.
18 S-P. Tumbler Switch GE1688, controls No. 16 Ceiling Elexit.
24 Single Convenience Outlet GE658
22 Single Convenience Outlet GE658
31 Single Convenience Outlet GE658
33 Single Convenience Outlet GE658
30 Single Convenience Outlet GE658
} furnishes power for portable lamps, electrically operated musical instruments, vacuum cleaner, fans, etc.

*

KITCHEN

69 3-Way Tumbler Switch GE1690, controls No. 64 Ceiling Elexit.
68 3-Way Tumbler Switch GE1690, controls No. 64 Ceiling Elexit.
66 Twin Convenience Outlet GE694, furnishes power for fan, utility motor, beaters, iron, etc.
63 Special Convenience Outlet GE694, furnishes power for electric range.
65 Wall Elexit LX111. 40-watt lamp is recommended.
67 Wall Elexit LX111. 40-watt lamp is recommended.
64 Ceiling Elexit LX200. 75-watt lamp is recommended.

BACK HALL AND PORCH

75 3-Way Tumbler Switch GE1690, controls No. 12 Main Cellar Light.
71 S-P. Tumbler Switch GE1688, controls No. 70 Hall Center Elexit.
72 3-Way Tumbler Switch GE1690, controls No. 73 Back Porch Light.
74 3-Way Tumbler Switch GE1690, controls No. 132 Light Outside Garage.
70 Ceiling Elexit LX200. 25-watt lamp is recommended.
73 Wall Elexit LX111. 25-watt lamp is recommended.

CELLAR

11 3-Way Tumbler Switch GE1690, controls No. 12 Main Cellar Light.
1 S-P. Surface Tumbler Switch CE920, controls No. 2 Heater Room Light.
5 S-P. Surface Tumbler Switch GE920, controls No. 4 Fuel Room Light.

Specifications Alt. No. 2—*Continued*

28 Single Convenience Outlet GE658

20 Wall Elexit LX111. 25-watt lamp is recommended.

21 Wall Elexit LX111. 25-watt lamp is recommended.

23 Wall Elexit LX111. 30-watt lamp is recommended.

32 Wall Elexit LX111. 30-watt lamp is recommended.

34 Wall Elexit LX111. 30-watt lamp is recommended.

29 Ceiling Elexit LX200. 150-watt lamp is recommended.

SUN PORCH

17 Twin Convenience Outlet GE694, furnishes power for portable lamps, fan, cooking appliances, vacuum cleaner, etc.

16 Ceiling Elexit LX200. 75-watt lamp is recommended.

DINING ROOM

48 S-P. Tumbler Switch GE1688, controls No. 54 Ceiling Elexit.

60 S-P. Tumbler Switch GE1688, controls Nos. 62, 52, 56, and 59 Wall Elexits.

55 Single Convenience Outlet GE658
57 Single Convenience Outlet GE658
58 Single Convenience Outlet GE658
53 Single Convenience Outlet GE658
61 Twin Convenience Outlet GE694
} furnishes power for cooking appliances, electric candlesticks, glow heaters, fan, vacuum cleaners, etc.

52 Wall Elexit LX111. 30-watt lamp is recommended.

56 Wall Elexit LX111. 30-watt lamp is recommended.

59 Wall Elexit LX111. 30-watt lamp is recommended.

62 Wall Elexit LX111. 30-watt lamp is recommended.

54 Ceiling Elexit LX200. 150-watt lamp is recommended.

7 S-P. Surface Tumbler Switch GE920, controls No. 6 Storage Room Light.

8 S-P. Surface Tumbler Switch GE920, controls No. 9 Laundry Room Light.

14 S-P. Surface Tumbler Switch GE920, controls No. 15 Vegetable Room Light.

3 Single Convenience Outlet CE658, furnishes power for trouble light, fan, etc.

10 Twin Convenience Outlet GE694
13 Twin Convenience Outlet CE694
} furnishes power for electric tools, washing machine, ironer, etc.

2 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.

4 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.

6 Ceiling Lamp Receptacle GE088. 25-watt lamp is recommended.

9 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

12 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

15 Ceiling Lamp Receptacle CE088. 25-watt lamp is recommended.

GARAGE

132 3-Way Tumbler Switch GE1690, controls No. 132 Light Outside Garage.

133 3-Way Tumbler Switch CE1690, controls No. 73 Back Porch Light.

134 S-P. Tumbler Switch CE1688, controls No. 137 Center Light.

135 Twin Convenience Cutlet CE694
136 Twin Convenience Cutlet CE694
} furnishes power for Tungar battery chargers, electric tools and appliances.

137 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

138 Ceiling Lamp Receptacle GE088. 75-watt lamp is recommended.

*The numbers in this column identify the outlets shown on floor plan.

Specifications for Alternative Diagram No. 2
Second Floor

UPPER HALL

103 3-Way Tumbler Switch GE1690, controls No. 38 Lower Hall Light.
129 4-Way Tumbler Switch GE1691, controls No. 101 Upper Hall Light.
127 3-Way Tumbler Switch GE1690, controls No. 101 Upper Hall Light.
102 Single Convenience Outlet GE658, furnishes power for lamp, fan, vacuum cleaner, etc.
101 Ceiling Elexit LX200. 50-watt lamp is recommended.

LINEN CLOSET

105 Door Switch GE273, controls No. 104 Drop Light.
104 Ceiling Lamp Receptacle GE264, 25-watt lamp is recommended.

BATH ROOM

109 S-P. Tumbler Switch GE1688, controls No. 110 Ceiling Elexit.
106 Twin Convenience Outlet GE694, furnishes power for immersion heater, glow heater, etc.

BED ROOM NO. 2

100 S-P. Tumbler Switch GE1688, controls No. 80 Ceiling Elexit.
120 Door Switch GE273, controls No. 121 Closet Drop Light.
86 Single Convenience Outlet GE658 }
88 Single Convenience Outlet GE658 } furnishes power for lamps, vacuum cleaner, sewing machine, etc.
79 Single Convenience Outlet GE658 }
77 Twin Convenience Outlet GE694, furnishes power for lamps, toilet accessories, etc.
76 Wall Elexit LX111. 25-watt lamp is recommended.
82 Wall Elexit LX111. 25-watt lamp is recommended.
78 Wall Elexit LX111. 25-watt lamp is recommended.
87 Wall Elexit LX111. 25-watt lamp is recommended.
80 Ceiling Elexit LX200. 75-watt lamp is recommended.
121 Ceiling Lamp Receptacle GE264. 25-watt lamp is recommended.

Specifications Alt. No. 2—*Continued*

107 Wall Elexit LX111. 25-watt lamp is recommended.
108 Wall Elexit LX111. 25-watt lamp is recommended.
110 Ceiling Elexit LX200. 75-watt lamp is recommended

BED ROOM NO. 2

128 S-P. Tumbler Switch GE1688, controls No. 116 Ceiling Elexit.
112 Door Switch GE273, controls No. 111 Closet Drop Light.
118 Single Convenience Outlet GE658 } furnishes power for lamps, vacuum cleaner, sewing machine, etc.
114 Single Convenience Outlet GE658 }
124 Twin Convenience Outlet GE694, furnishes power for lamps, toilet accessories, etc.
113 Wall Elexit LX111. 25-watt lamp is recommended.
117 Wall Elexit LX111. 25-watt lamp is recommended.
125 Wall Elexit LX111. 25-watt lamp is recommended.
126 Wall Elexit LX111. 25-watt lamp is recommended.
116 Ceiling Elexit LX200. 75-watt lamp is recommended.
111 Ceiling Lamp Receptacle GE264. 25-watt lamp is recommended.

BED ROOM NO. 3

96 S-P. Tumbler Switch GE1688, controls No. 89 Ceiling Elexit.
98 Door Switch GE273, controls No. 97 Closet Drop Light.
84 Single Convenience Outlet GE658 } furnishes power for lamps, electric toys, milk warmer, vacuum cleaner, etc.
91 Single Convenience Outlet GE658 }
94 Twin Convenience Outlet GE694, furnishes power for candlesticks, vibrator, glow heater, etc.
92 Wall Elexit LX111. 25-watt lamp is recommended.
93 Wall Elexit LX111. 25-watt lamp is recommended.
89 Ceiling Elexit LX200. 100-watt lamp is recommended.
97 Ceiling Lamp Receptacle GE264. 25-watt lamp is recommended.

ATTIC

119 3-Way Tumbler Switch GE1690, controls Center Drop Light.
130 3-Way Tumbler Switch GE1690, controls Center Drop Light.
131 Ceiling Lamp Receptacle GE264. 75-watt lamp is recommended. (White).

*The numbers in this column identify the outlets shown on floor plan.

Alternative Outlet Diagram No. 2

First Floor

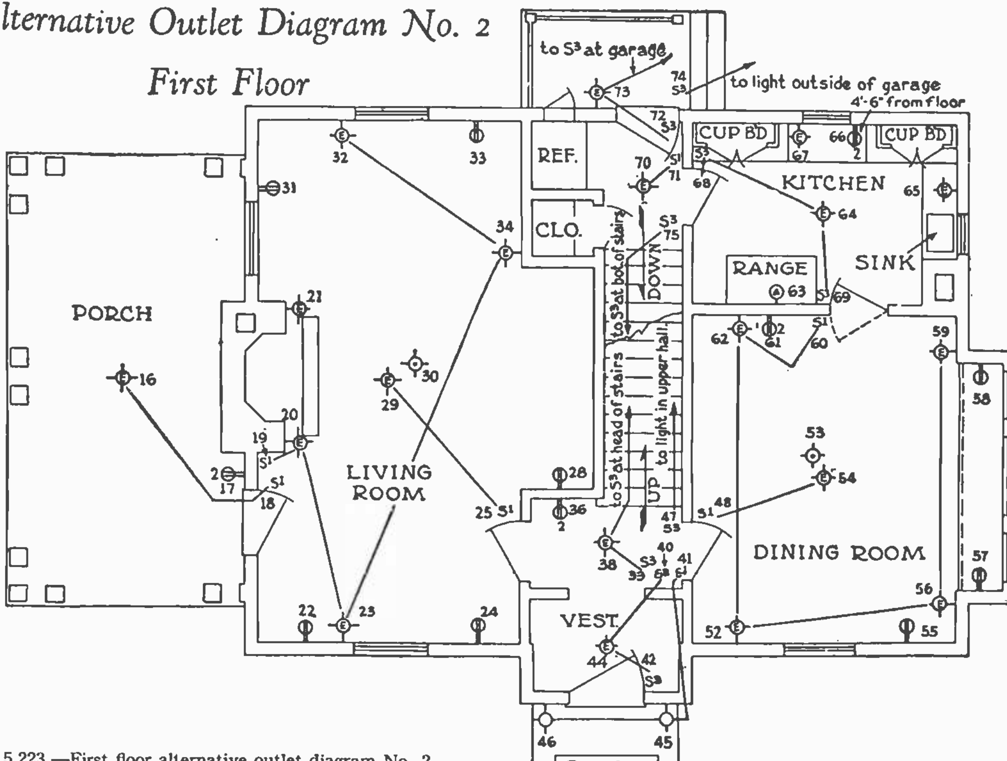


FIG. 5,223.—First floor alternative outlet diagram No. 2.

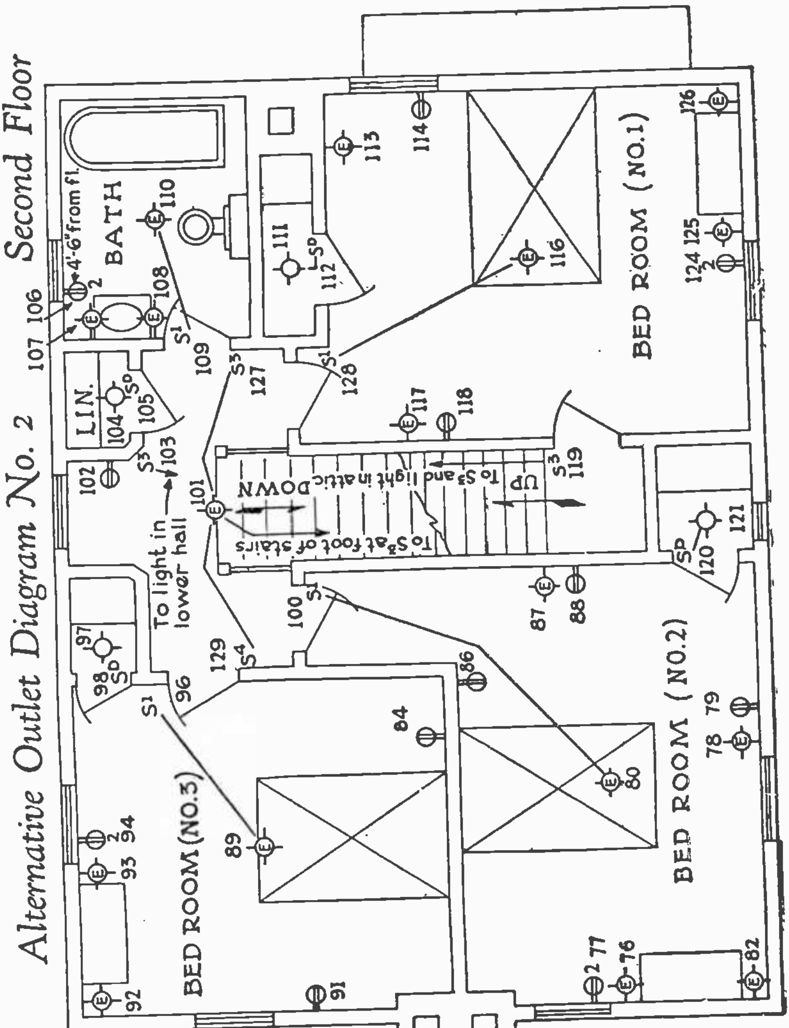


FIG. 5,224.—Second floor alternative outlet diagram No. 2

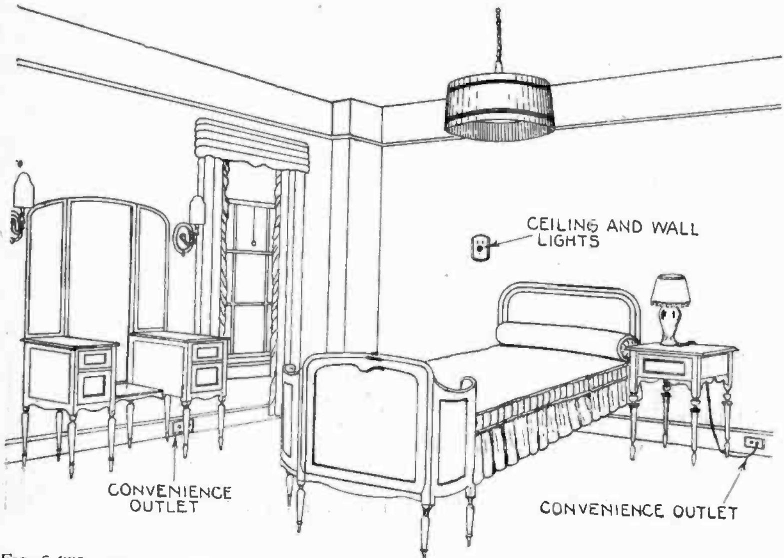


FIG. 5,225.—The bed room.

TEST QUESTIONS

1. *Give definitions of wiring terms.*
2. *Name five ways of representing objects in drawing.*
3. *Are pictorial methods or the descriptive method used?*
4. *What is orthographic projection?*
5. *What are the names given to orthographic projection?*
6. *Draw diagrams showing the three "views" employed in representing an object.*
7. *Give the names of the three "views."*
8. *What is assumed in making projection drawings?*
9. *Name the principal elements of a wiring system.*

CHAPTER 108

Inside Wiring Methods

(Classification)

The different methods of interior wiring may be conveniently grouped into the following general classes:

1. Open or exposed wiring

    a. On knobs;
    b. On cleats.

2. Wires run in mouldings

    a. Wooden mouldings;
    b. Metal mouldings.

3. Concealed knob and tube wiring
4. Flexible armored cable wiring
5. Flexible conduit wiring
6. Non-metallic sheathed cable
7. Rigid conduit
8. Wiring under floors

    a. Duct or rectangular conduit;
    b. Regular pipe conduit.

9. Wiring under plaster
10. House wiring
11. Power wiring

Each of these methods of wiring has its special application and frequently several are used in the same building. Some of these methods are not as safe as others, and are not permitted in certain localities.

The choice is governed by appearance, relative expense and suitability for the conditions to be met.

Detailed description of the various methods and instructions for installing are given in the chapters following.

Code.

Article 2. General

Throughout this Code the word "shall" is used to indicate requirements, while the word "should" is used to indicate recommendations, or that which is advised but not required. In general, recommendations have the form of fine-print notes or paragraphs supplementing the preceding text.

202. Voltages

a. Low potential shall mean 600 volts or less.

b. High potential shall mean between 601 volts and 5000 volts.

c. Extra high potential shall mean above 5000 volts.

d. In the preceding paragraphs the potential considered is that at which the circuit operates, whether it is supplied by a generator or by a transformer.

e. Throughout this code, unless otherwise specifically stipulated, the requirements shall be considered to be based upon the use of low-potential wiring devices, apparatus and appliances. High-potential and extra-high-potential systems are considered in Articles 3 and 50.

205. Approved Material, etc.

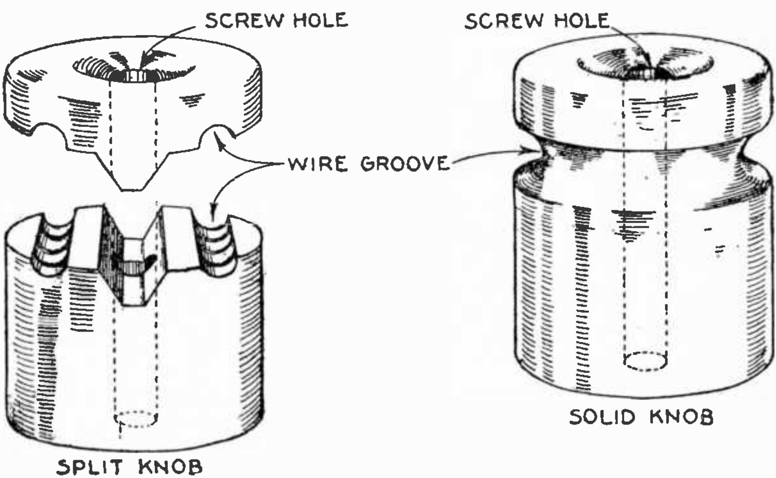
a. This code shall be understood to treat only of approved materials, devices, fittings, appliances, machinery, apparatus and methods.

CHAPTER 109

Open or Exposed Wiring

This method of wiring possesses the advantages of being cheap, durable and accessible.

It is used a great deal in factories, mills and buildings where the unsightly appearance of the wires exposed on the walls or ceilings is of no consequence.



FIGS. 5,226 to 5,228.—Two largely used types of knob. Figs. 5,226 and 5,227, split knob; fig. 5,228, solid knob.

There are two methods of open or exposed wiring, known as

1. Knob wiring;
2. Cleat wiring.

Knob Wiring.—This is the simplest and cheapest method.

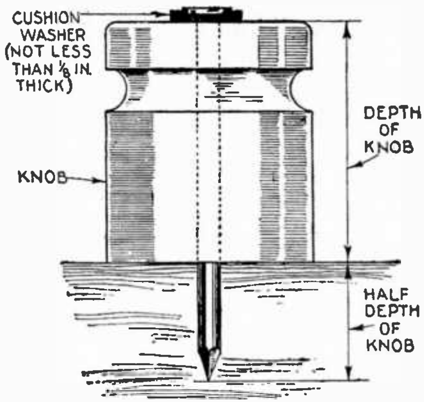


Fig. 5,229.—Method of fastening knob with nail. Note that the nail must penetrate the wood not less than ½ the depth of the knob.

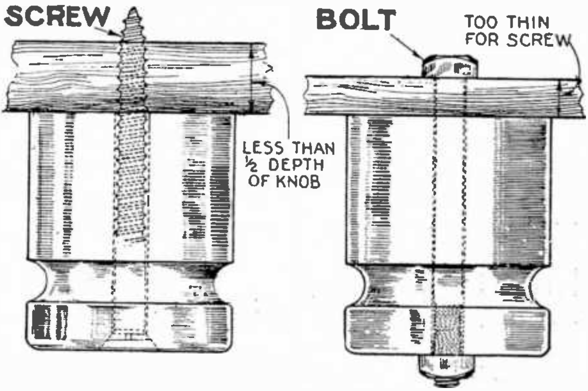
It is forbidden in some cities, except for temporary decorative work.

Figs. 5,226 to 5,228 show two types of knobs in general use, known as:

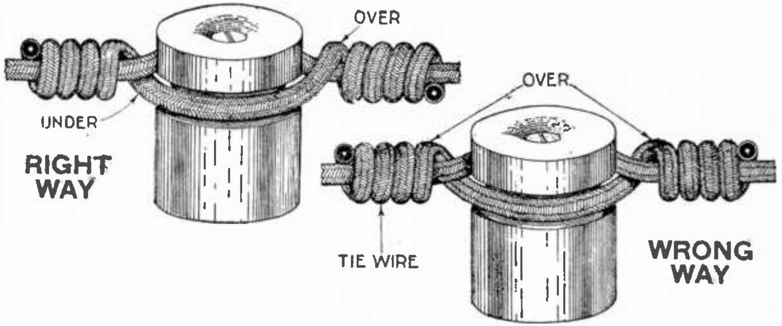
1. Split knob;
2. Solid knob.

For wires smaller than No. 8, use split knobs. Solid knobs are not used for wires smaller than No. 8 because experience has shown that the tie wire method of attachment is unsatisfactory for small wires.

Either nails or screws may be used to fasten knobs, preferably nails, because even though a screw will hold better, there is more chance of the screw being set up too tight resulting in frequent breakage of the insulator. When a nail is used a leather washer should be placed between the nail



FIGS. 5,230 and 5,231.—Screw and bolt method of fastening knobs. If the support be less than half the depth of the knob use a screw, as in fig. 5,230: if too thin for proper hold with a screw use a bolt as in fig. 5,231.



FIGS. 5 232 and 5,233.—Right and wrong methods of tying wires to grooved knobs, called *tying in*. In fig. 5,232, one end of the tie wire passes over the wire, the other passes under. Pliers must be used so that the wires will be firmly secured. In tying in the wires, the first and last knob should be tied in and the intermediate knobs tied in last. Where the wires are of a large size a block and tackle should be used, care being taken not to pull too tight as this will stretch the wire. The tie wires should be of solid wire and of the same size as the wire to be secured, one wire is passed underneath the wire and the other wire is passed over so that it is secured at both ends. Pliers should be used as tie wire cannot be properly secured by hand.

head and the insulator to form a cushion and protect the insulator from breakage. Fig. 5,229 shows the requirements for nail fastening.

In stringing the wire, it should be fastened to each knob by the methods shown in the accompanying illustrations.

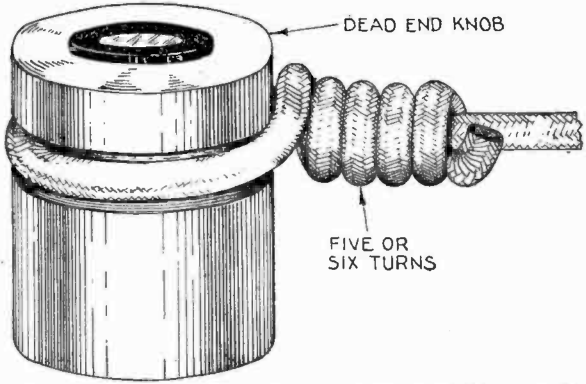
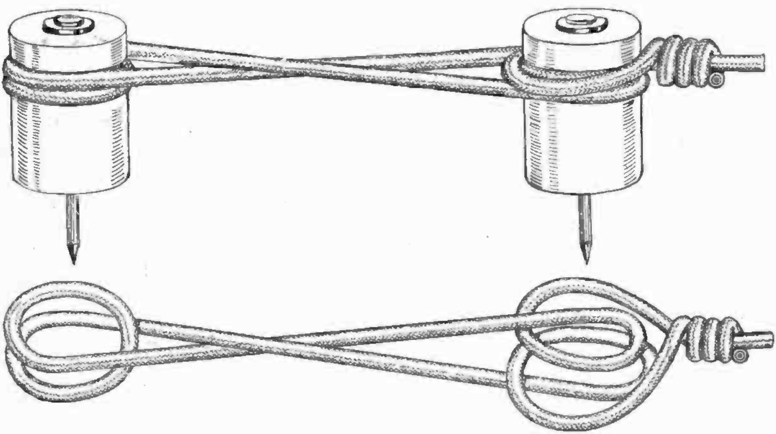


FIG. 5,234.—Method of making a dead end on one knob; light duty. After drawing up line wire tight make 5 or 6 complete turns as shown, bringing it up securely with a pair of pliers.



FIGS. 5,235 and 5,236.—Method of making a dead end on two knobs; heavy duty, and detail of the tie.

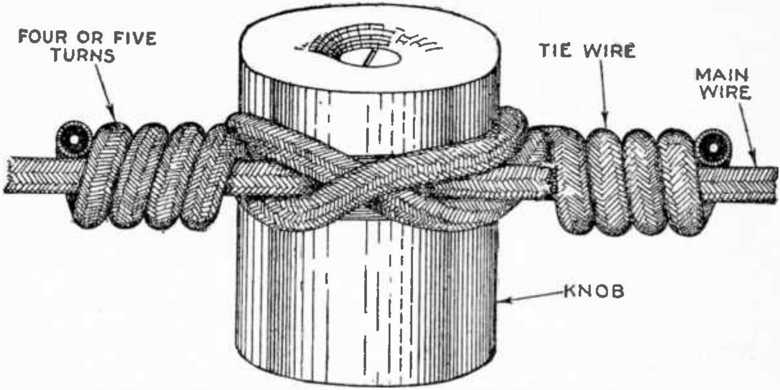
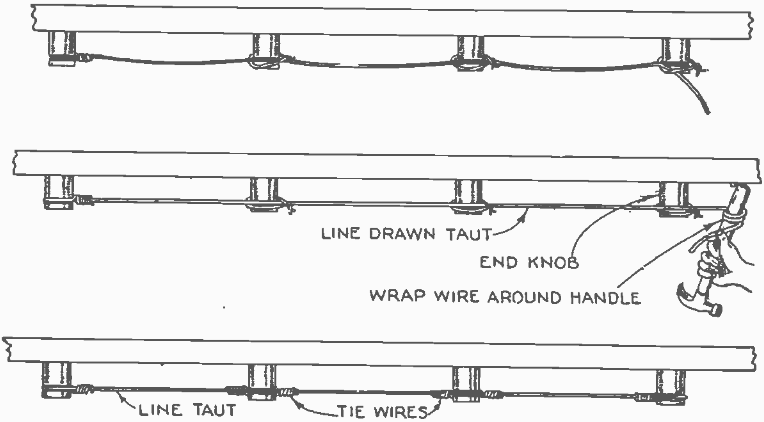
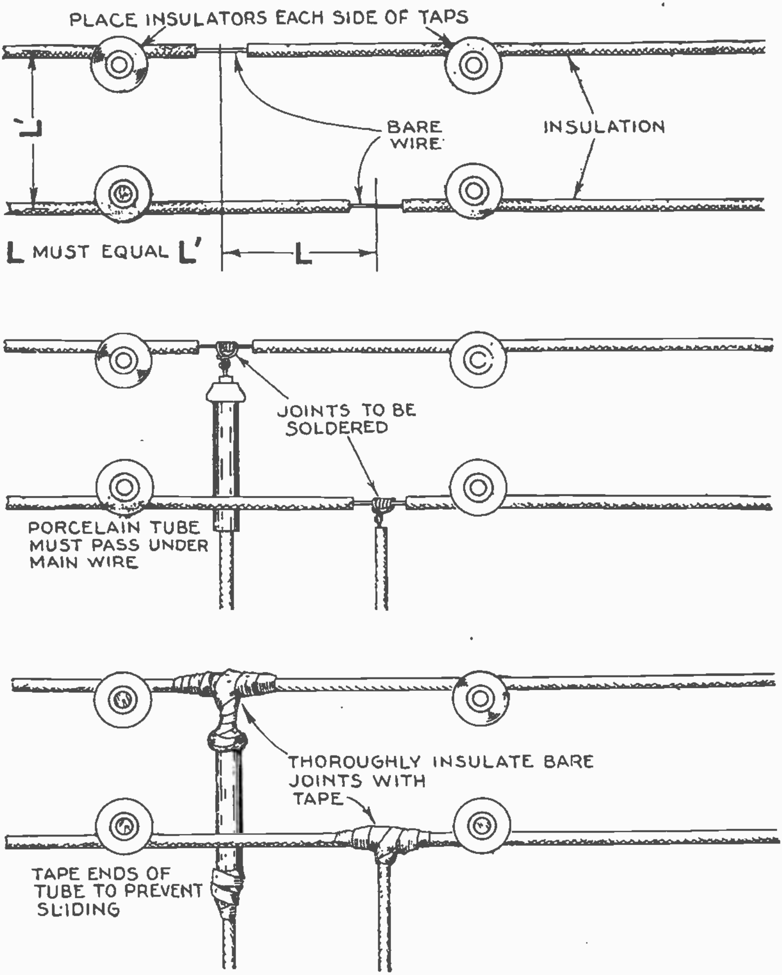


FIG. 5,237.—Another method of securing the line to knob by means of tie wires. Twist tie wire around main conductor four or five times on each side of knob. Do not twist main conductor around knob. Do not use bare wire in making a tie because in twisting it tightly it may cut the insulation and come in contact with the metal of the line wire, thus introducing a possible leakage path.



FIGS. 5,238 to 5,240.—Method of stringing the wire. Install the knobs in line, *spaced not over 4½ feet*. Attach the line to the end knob and temporarily secure it to the intermediate knobs with loose ties as in fig. 5,238. Draw up line taut to avoid sag as in fig. 5,239, then secure line to end knob and intermediate knobs as in fig. 5,240.



FIGS. 5,241 to 5,243.—Method of tapping for branch circuit. Install insulator each side of the taps, to take strain off main wires caused by branch circuit wires; as in fig. 5,241; reverse insulation and join branch wires using porcelain tube where one branch wire crosses a main wire, as in fig. 5,242; solder joints and insulate with tape as in fig. 5,243.

By definition a dead end is *the termination of a line wire on an insulator.*

The method of making a dead end is shown in fig. 5,234; where the strain is heavy on the wire two knobs are used as in fig. 5,235, the wire being attached to the knobs as shown in fig. 5,235.

In stringing the line a necessary requirement is that *the wire should be taut to avoid sag.*

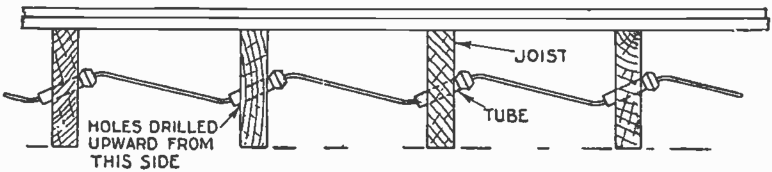
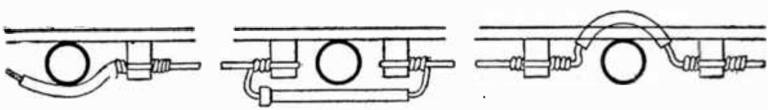


FIG. 5,244.—Method of passing wires through beams. Bore holes at a slight angle and insert tubes with heads upward.



FIGS. 5,245 to 5,247.—Methods of wiring across pipes. The wires should preferably run over rather than under the pipes. Fig. 5,245 shows crossing with circular loom, and fig. 5,246, one in which a tube is used. Both of these methods are satisfactory in the case of gas pipes, but for steam pipes or water pipes which are liable to leak or sweat and drip moisture, the crossing should be above as shown in fig. 5,247. On side walls where vertical wires run across horizontal water pipes, the latter should be enclosed and the moisture deflected to one side.

In order to do this without bringing too much strain on the wire and end insulators, the line should be first loosely attached to each knob by taking a loose turn with each tie wire as in fig. 5,238.

Now the line may be drawn up to the proper tension by wrapping the end of the wire around a hammer handle or stick as in fig. 5,239. Evidently and especially in the case of a long line, the wire is more easily drawn up to the proper tension than when not supported at intermediate points. Having attached the line to the end knob, it is now permanently tied to the intermediate knobs, the finished result being as shown in fig. 5,240.

In making a tap, *insulators must be placed on each side of the tap and the insulation removed from the wires, so spaced as in fig.* 5,241, *that the tapped wires will be the same distance apart as the main wires.*

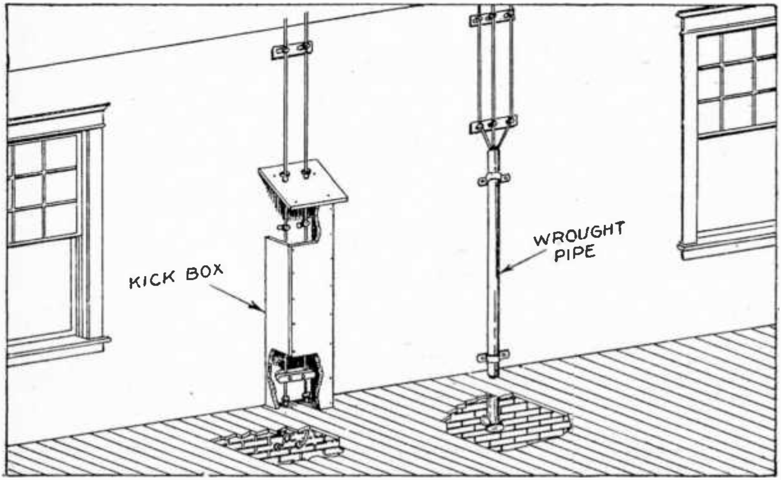


FIG. 5,248.—Method of protecting wires where they pass through floors. Install a kick box (or wrought pipe) extending upward 6 feet.

The illustrations, figs. 5,244 to 5,252, show methods of passing wires through beams, across pipes, through floors, etc. The method of installing a snap switch with insulating sub-base is shown in figs. 5,253 to 5,254.

Lamps may be connected with split knobs as shown in fig. 5,258. They may also be connected by the use of

1. Receptacles;
2. Rosettes.

The receptacle is ordinarily used as a light outlet. It is made of porcelain, and comes in two parts, which may be called the base and the cap.

The base contains the terminals which are spaced 2½ inches apart, so that the line wires may be connected directly to them, without changing

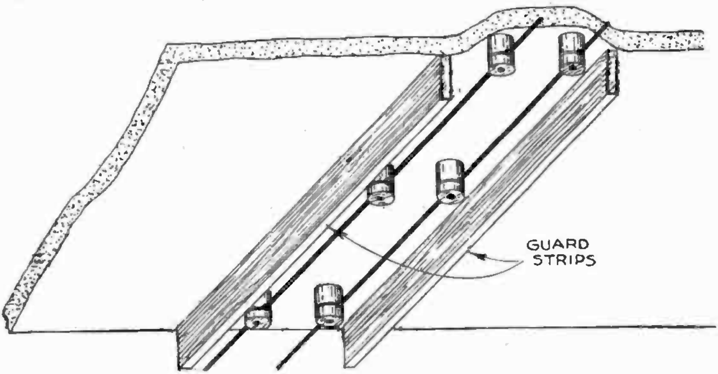
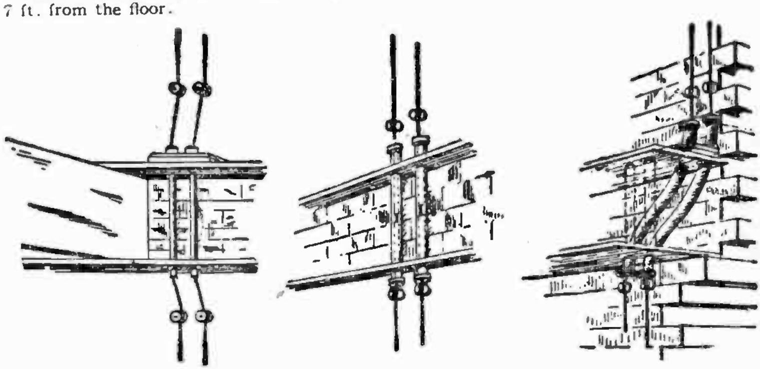
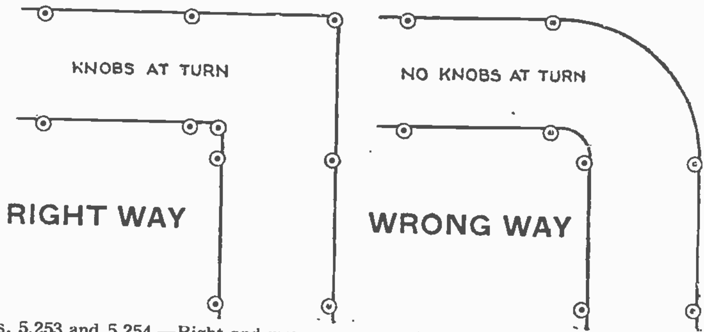


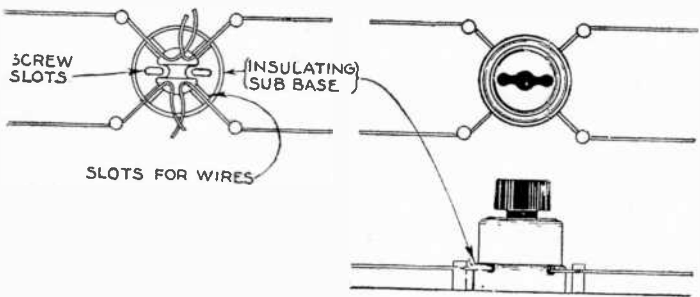
FIG. 5,249.—Method of protecting wiring on low beams or ceilings when they are not over 7 ft. from the floor.



FIGS. 5,250 to 5,252.—Methods of carrying wires through floors. *In passing* through floor, (or walls) the wires often come in contact with concealed pipes or other grounded materials hence the only way they can be properly protected is by making the bushing continuous. This may consist of continuous porcelain tubes as shown in fig. 5,250, or short bushings may be arranged in iron pipes as in fig. 5,251. The method followed in case of an offset in the wall is shown in fig. 5,252. Sometimes the floor can be taken up and an iron conduit, properly bent, put in place, the wires being reinforced with flexible tubing. Another method is to attach the wires to insulators; in this case the floor must not be put down until the wiring has been examined by the inspector.



FIGS. 5,253 and 5,254.—Right and wrong way to make a turn.



FIGS. 5,255 to 5,257.—Method of installing snap switch having insulating sub-base

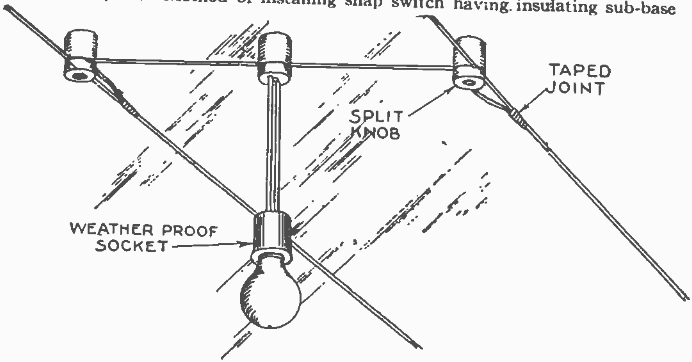
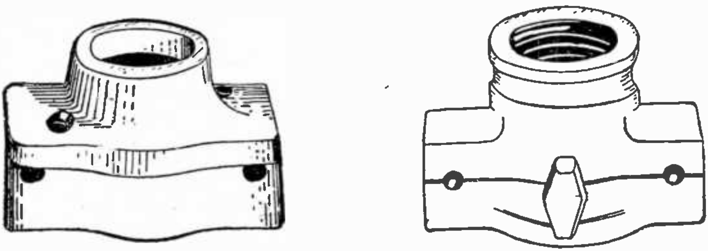


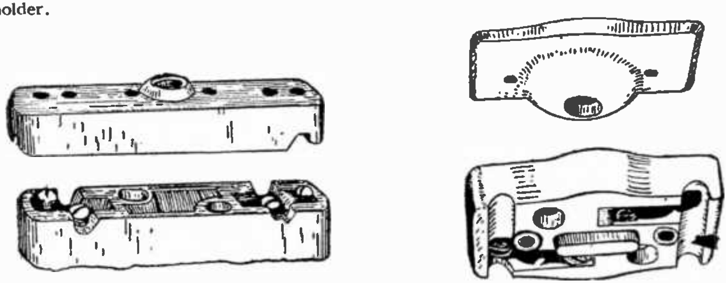
FIG. 5,258.—Method of connecting lamp in short weather proof pendant the uniformity of distance between wires. On the base are also mounted and connected the essential parts of the receptacle.

The cap is made to conceal the terminals and to cover up the "live" parts, so that one is less likely to come into contact with "live" or "charged" metal.

Receptacles are fastened to a surface with two No. 8 wood



FIGS. 5,259 and 5,260.—Plain and grooved receptacles. The groove is for holding a shade holder.



FIGS. 5,261 to 5,264.—Rosettes.

screws, the length of the screws depending upon the kind of surface.

Figs. 5,259 and 5,260 show plain and grooved shade holder type receptacles.

Rosettes *are made of porcelain in two parts called the base and the cap*, as shown in figs. 5.261 to 5,264.

They are used wherever a drop or extension cord is connected to the line. The base of this fitting contains two terminal blocks, so spaced that the line wires may be tapped without changing the distance between wires. Besides the terminal screw which holds the live wires, each terminal block has a screw for the fastening of the drop cord or extension cord wires. The cap covers the terminal blocks and has a hole for the drop or extension cord to pass through.

Although rosettes may be obtained either fused or unfused, the fused type is seldom used.

The usual practice is to connect 16 sockets to a branch circuit through fuseless rosettes so that the total wattage of the lamps in the branch

FIGS. 5,265 to 5,269.—Method of making the "Underwriters Knot" progressively shown.

circuit will not exceed 660. Sockets are usually considered as requiring not less than 40 watts each. The branch circuit is fused at its junction with the main circuit.

It is quite evident that considerable stress is placed on two little terminal screws to hold the weight of the cords and the light, and to withstand the occasional pull that accompanies the turning on or off of the lights. It would not take very long for one or both of the wires to loosen under the screw or to break away entirely. To prevent this trouble, and

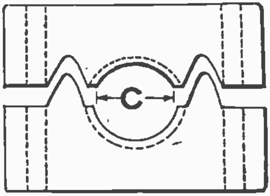
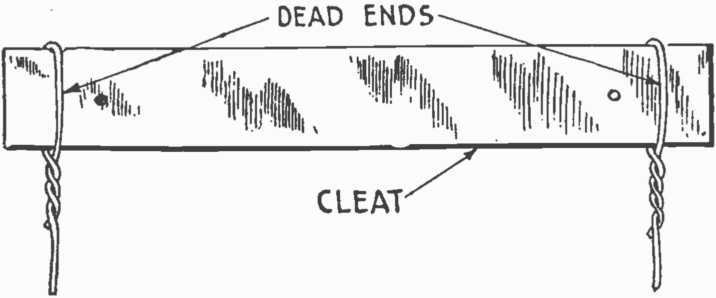


FIG. 5,270.—Common two wire cleat for wire sizes No. 14 to 10.

FIG. 5,271.—B. & D. one wire cleat for wires No. 8 to No. 0.



FIGS. 5,272.—Method of making a dead end in cleat wiring. The cut is self-explanatory and needs no further instructions.

at the same time to decrease the possible fire hazard, resulting from a loose connection, the Code requires a knot to be placed in all rosettes and pendant receptacles (except weather proof or pendant switches) so that the weight and pull will be on the knot instead of on the terminals.

The Code recommends a knot, called the "Underwriters Knot" which is easily made and is generally used by wiremen.

Five steps in the tying of this knot are shown in figs. 5,265 to 5,269.

Cleat Wiring.—By the use of cleats instead of knobs, both wires of a circuit are held at the correct distance apart by each cleat. Thus a cleat performs the duty of two knobs, that is, for wires No. 14 to No. 10. For larger wires (sizes No. 8 to

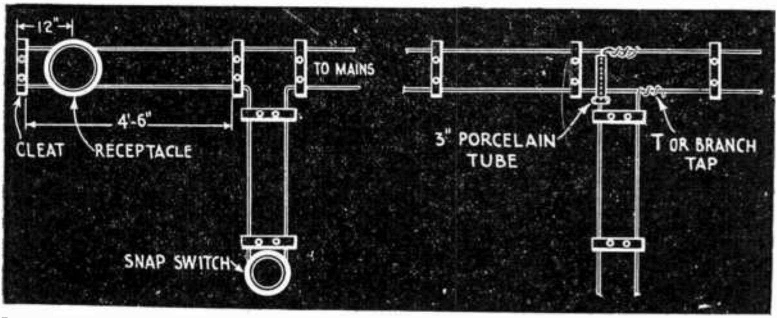


FIG. 5,273.—Cleat wiring for snap switch to operate receptacle. On long runs such as in factories, the wires should be dead ended to a cleat located not less than one ft. from the last light receptacle or drop.

FIG. 5,274.—Cleat wiring method of making a tap for branch circuit. Tubes should always be used, the tube being placed over the wire so that it rests upon the main wire, a cleat should then be installed so that the tube cannot slip away leaving the wires unprotected.

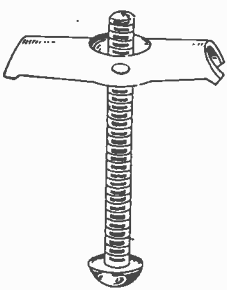


FIG. 5,275.—Toggle bolt for securing cleat to metal ceilings, or ceilings on which plaster is laid on metal lath. A hole is first punched in the ceiling with a 20 penny nail or a brad awl; the bolt is then inserted through the cleats and is shoved up into the ceiling.

No. 0) single wire cleats are used. Figs. 5,270 and 5,271 show the two type cleats.

Before fastening cleats, examine them closely for imperfections such as cracks, rough projections or sharp edges which might injure the insulation. When possible fasten cleats with nails using cushion washers. Of course, where the support is too thin for nails, screws or bolts must be used as explained for knobs. Cleats, the same as knobs, are spaced not more than 4½ ft. apart.

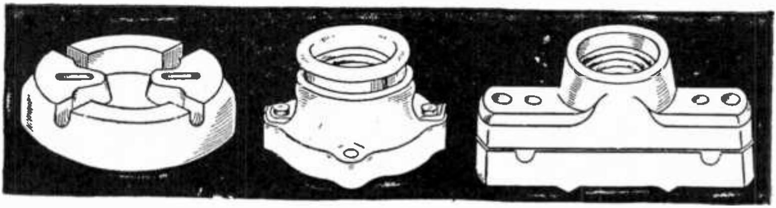
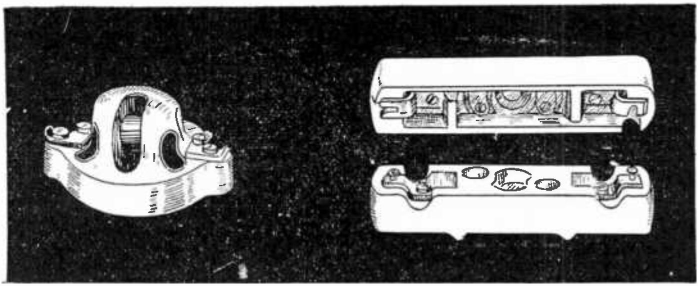


FIG. 5,276.—Snap switch sub-base as used under snap switches for cleat wiring.

FIGS. 5,277 and 5,278.—Exposed and concealed contact cleat receptacles. The concealed contacts are more desirable, as the live wires are protected.



FIGS. 5,279 to 5,281.—Open and concealed contact drop cord rosettes for cleat wiring. The open type is the more economical to use as it is in one piece but the covered or concealed is the safer.

In beginning to wire a line with cleats first locate the first cleat and make a dead end as shown in fig. 5,272.

The various operations in cleat wiring are very similar to those of knob wiring and need no further explanation. Some of them are shown in the accompanying illustrations.

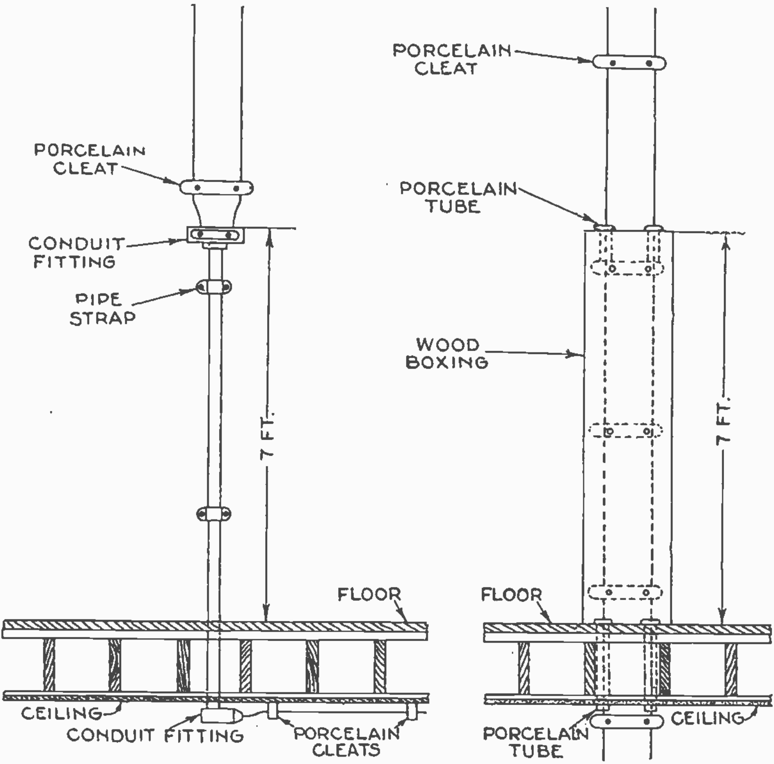


FIG. 5,282.—Cleat wiring with pipe kick box method of passing through floors showing conduit fitting where wires enter pipe.

FIG. 5,283.—Cleat wiring with wooden kick box protection where wires pass through floor showing porcelain tubes at the entrance of the kick box and where the wires pass through floor.

Code.

501. *Open wires*

a. Single wires may be installed as open wires upon walls and ceilings, when the provisions of the following paragraphs of this section shall be observed.

b. In dry places wires shall be of approved rubber-covered (R), slow-burning weatherproof (SBW), varnished-cambric insulated (VC), slow burning (SB) or asbestos-covered type (A).

c. In damp places or in buildings especially subject to moisture wires shall be of the rubber-covered type.

d. Wires subjected to corrosive vapors shall be of the weatherproof, varnished-cambric or rubber-covered type, as may be directed by the authority enforcing this code.

e. Where the environment is such that rapid deterioration of conductors or insulation is probable, the authority enforcing this code may require the wires to be suitably enclosed, coated or otherwise protected to better withstand the particular conditions of service.

f. Wires entering or leaving buildings or rooms subject to moisture or corrosive vapors shall have drip loops formed on them and shall then pass upward and inward from the outside of buildings, or from the rooms subject to moisture or corrosive vapors, through non-combustible, non-absorptive tubes.

g. Wires shall not be laid in plaster, cement or similar finish, nor fished for any great distance or where it will not be clearly evident that the rules have been complied with.

h. Wires shall not be fastened with staples.

i. Wires of No. 8 or larger supported on solid knobs shall be securely tied thereto. If wires are used for tying, they shall have an insulation of the same type as that of the wires which they confine.

j. Wires shall be rigidly supported; in dry places and for voltages not exceeding 300 volts shall be separated 2½ inches from each other and ½ inch from the surface wired over; and for voltages from 301 to 600 volts the wires shall be separated 4 inches from each other and 1 inch from the surface wired over. In damp places a separation of at least 1 inch from the surface wired over shall be maintained for all voltages.

> Rigid supporting requires under ordinary circumstances, when wiring over flat surfaces, supports at least every 4½ feet, this interval being shortened if the wires are liable to be disturbed. In buildings of mill construction, mains not smaller than No. 8, where not liable to be disturbed, may be separated about 6 inches and run direct from timber to timber, being supported from each timber only.

k. Open wires shall not be dead-ended at a rosette, socket or receptacle unless the last support is within 12 inches of the same.

l. Where open wires cross ceiling-joists and wall studs and are exposed to mechanical injury they shall be protected by one of the following methods. Wires within seven feet from the floor shall be considered exposed to mechanical injury.

1. By guard strips not less than ⅞ inch in thickness and at least as high as the insulating supports, placed on each side of and close to the wiring.

2. By a substantial running board back of the wires with side protections, made of at least one-half inch stock. Running boards shall extend at least one inch outside the wires, but not more than two inches and the protecting sides shall be at least two inches high and at least ⅞ inch thick.

3. By boxing made as above and furnished with cover kept at least one inch away from the wires within. Where protecting vertical wires on side walls the boxing shall be closed at the top and the holes through which the wires pass shall be bushed.

Code.—*Continued.*

4. By conduit in which case the rules for conduit shall be followed or by metal piping in which case the wires shall be encased in continuous lengths of approved flexible tubing. The wires passing through conduit or piping shall be so grouped that current in both directions is practically equal.

m. Where a change is made from open wiring to conduit or armored cable, an approved terminal fitting having a separate bushed hole for each wire shall be used, through which fitting the wires shall pass without splice, joint or tap. This terminal fitting need not be accessible.

n. Open wires located in damp places shall be so placed that an air space will be permanently maintained between them and pipes which they cross.

Wires run in close proximity to water pipes or tanks are considered to be exposed to moisture. It is recommended that wires be run over, rather than under, pipes upon which moisture is likely to gather or which may leak.

o. Open wires shall be separated from contact with walls, floors, timbers or partitions through which they pass by tubes or bushings composed of approved non-combustible, non-absorptive insulating material. If the bushing is shorter than the hole, a waterproof sleeve, such as an iron pipe, shall be inserted in the hole and an insulating bushing slipped into the sleeve at either end and in such a manner as to keep the wire absolutely out of contact with the sleeve.

p. Open wires shall be permanently separated from adjacent metallic piping or other conducting material, or from any exposed lighting, power or signal wire which approaches within 2 inches, by a firmly fixed and continuous non-conductor, additional to the insulation on the wire. Where an insulating tube is used, it shall be secured at the ends.

Deviations from this requirement may, where necessary, be allowed by the authority enforcing this code.

q. Open wires in accessible attics or roof spaces, shall be installed as follows:

1. When run within five feet of the floor or floor joists, through bored holes in rafters or studs, or when run through bored holes in floor joists, wires shall be protected by substantial running boards extending at least one inch on each side of the wire or wires and securely fastened in place.

2. When within five feet of floor or joist, across the face of rafters or studding, or across the top or face of floor joists, wire shall be protected by substantial guard strips at least as high as the wire.

3. When carried along the sides of rafters, studs or floor joists, neither guard strips, nor running boards shall be required.

r. Open wires shall not be placed in hoistways.

s. Supports shall be composed of approved non-combustible, non-absorptive insulating material, free from checks, rough projections or sharp edges which might injure the insulation on the conductor. If the supports are designed to grip the wires, either screws or nails may be used to fasten the supports in place. Nails or screws shall be long enough to penetrate the woodwork not less than ½ the depth of the knob and fully the thickness of the cleat. Cushion washers shall be used with nails.

t. Supports shall provide at least ¼ inch separation between the securing screw or nail and the wire, and shall be designed for two securing screws if the split-knob (or single-wire cleat) type intended for wires larger than No. 4.

u. Multiple-wire cleats shall be so designed as to separate the wires at least 2½ inches and maintain them at least ½ inch from the surface wired over. Such cleats shall not be employed to support wires operating at a potential exceeding 300 volts.

v. Knobs shall be so designed as to maintain the wire at least 1 inch from the surface wired over, and shall conform to the following minimum dimensions:

Knob Table

Size of Wire Inclusive.	Size of Base, Inches.			Solid Knobs, Groove, Inches.		Split Knobs, Thickness of Cap, Inches from Top of Wire Groove.
	Circular Knobs, Diameter.	Square Knobs or Single Wire Cleats.				
		Width.	Length.	Depth.	Diameter.	
14-10	1⅛	¾	1¾	3/16	¼	⅝
8-4	1½	⅞	2	5/16	5/16	⅝
2-00	2	1	2¼	7/16	⅝	⅝
000-300,000 C. M.	2½	1⅛	2¾	9/16	11/16	⅞
400,000-1,000,000 C. M.	3	1⅜	3¾	⅝	1¼	1

TEST QUESTIONS

1. *What are the advantages of open or exposed wiring?*
2. *Name two general methods of open or exposed wiring.*
3. *Is knob wiring allowed in all cities?*
4. *Name two kinds of knobs and the use of each kind.*
5. *How are knobs and cleats attached?*
6. *Explain the proper method of stringing the wire and fastening it to the knobs.*
7. *What is a dead turn and how is it made?*
8. *Illustrate by diagrams the method of tapping for branch circuits.*

9. *How are wires passed through beams?*
10. *Describe the method of protecting wires where they pass through floors.*
11. *How are lamps connected?*
12. *Describe the methods of protecting wires on low beams or ceilings.*
13. *How are wires carried through floors?*
14. *What is a receptacle?*
15. *Describe the construction of a rosette.*
16. *Describe the construction of two forms cf cleat.*
17. *Explain in detail how to make the Underwriter's knot.*
18. *What is a toggle bolt?*
19. *What two functions does a cleat perform?*
20. *Draw a diagram showing cleat wiring for snap switch to operate a receptacle.*
21. *What precaution should be taken before fastening cleats?*
22. *What is the best method of fastening cleats?*
23. *What is the maximum permissible spacing of cleats?*

CHAPTER 110

Wiring in Moulding

"Raceway Wiring"

The term *raceway* is now frequently used instead of moulding. By definition a moulding or raceway is *a protective covering for exposed wires.*

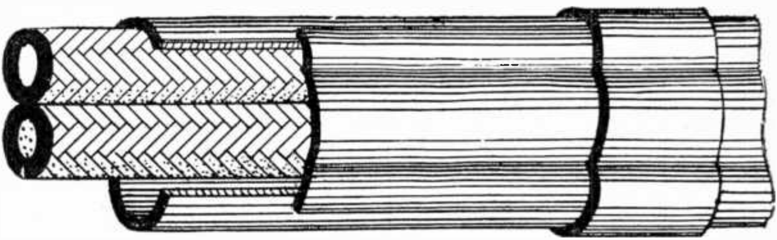


FIG. 5,284.—National small two piece moulding adapted to either *laying in* or *fishing*. This moulding may be screwed directly to the surface through the holes provided in the base or it may be secured by straps provided for the purpose.

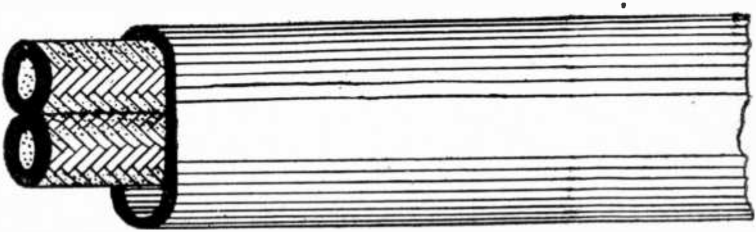
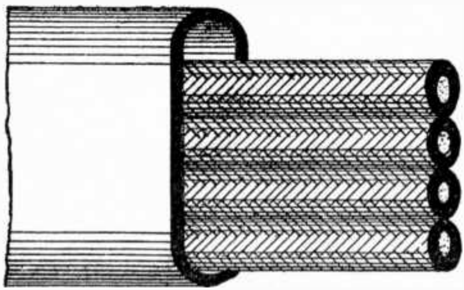


FIG. 5,285.—National two wire one piece moulding.

Mouldings may be divided into two classes with respect to the material of which they are constructed.

1. Wooden;
2. Metal.

Although the Code still permits the use of wooden moulding, it is prohibited in some cities by local ordinance and is now practically obsolete.



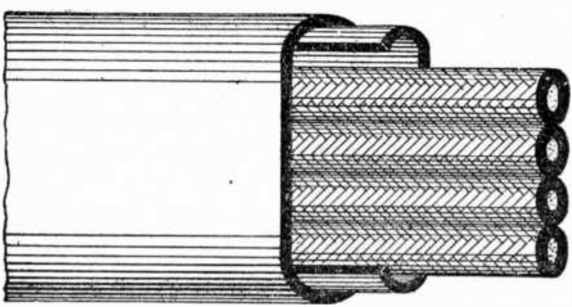


FIG. 5,286.—National four wire one piece metal moulding.
FIG. 5,287.—National four wire two piece metal moulding.

Raceway wiring (either wood or metal) should never be installed in damp places, because the wires are close together and moisture easily enters a raceway.

Metal Moulding.—This kind of casing for wires, also known as *raceway*, provides a metallic box-like covering which fits

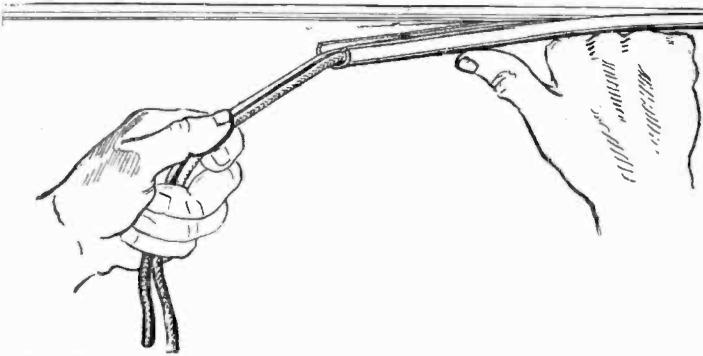


FIG. 5,288.—Method of *laying in* wires in National two piece moulding. After the wires are in place *snap* the cap over the base as shown. To perform this operation properly, place one hand under the capping, hold it at a slight angle with the base, press one end over the base, and at intervals of two or three inches, exert a steady pressure on the capping. Do not lay the capping squarely on top of the base and pound it. By the method shown the capping snaps quickly and easily over the base. Laying wires in long ceiling runs of moulding is accomplished easily in nearly the same manner as shown above, except that the wires should be guided and held in the capping by the hand which keeps it at an angle with the base.

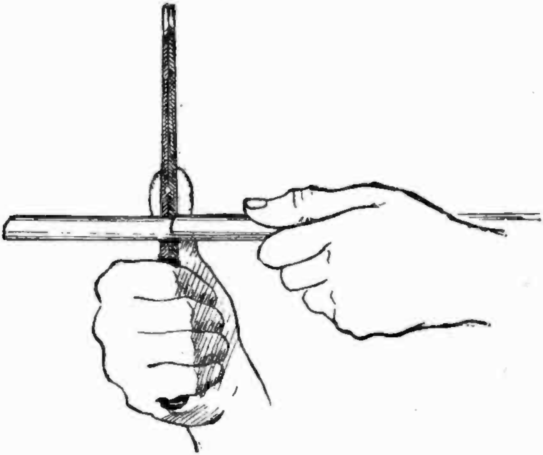
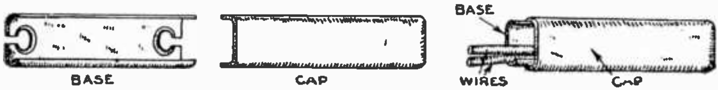


FIG. 5,289.—Method of cutting metal moulding with three cornered file. ***In cutting,*** use a small piece of capping for a straight edge, as shown; mark the base or capping deeply and break it off, being very careful to mark the moulding deeply on both sides.



FIGS. 5,290 to 5,292.—National metal moulding; two piece or *laying in* type. The two pieces are so formed as to *snap* together, the cap over the base as in fig. 5,292.

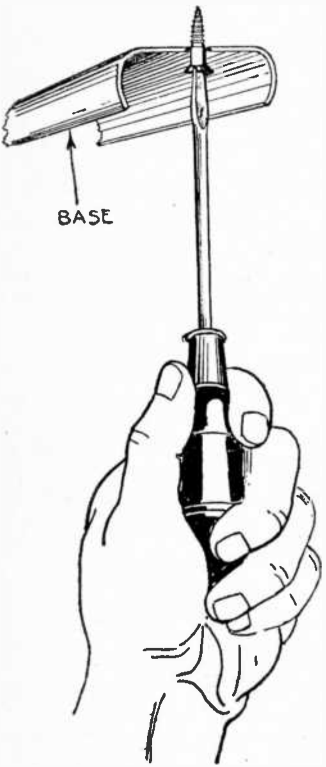


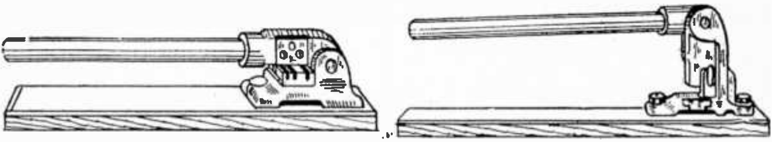
FIG. 5,293.—Method of attaching base of National two piece moulding to ceiling or wall.

snugly over the wires and protects them from injury. As compared with wooden moulding, the metal moulding takes up less room and has a better appearance. Two leading makes of metal moulding are illustrated to explain this method of wiring.

Metal mouldings are made in two types which differ greatly from each other, requiring different methods of inserting the wires as by

1. Laying in;
2. Fishing.

NOTE.—Method of removing capping from two piece moulding. *To remove,* lift the capping from the base at one end by prying with a screw driver, then slide the blade of the screw driver the full length between the capping and base.



FIGS. 5,294 amd 5,295.—Shear and punch for cutting and punching metal moulding.

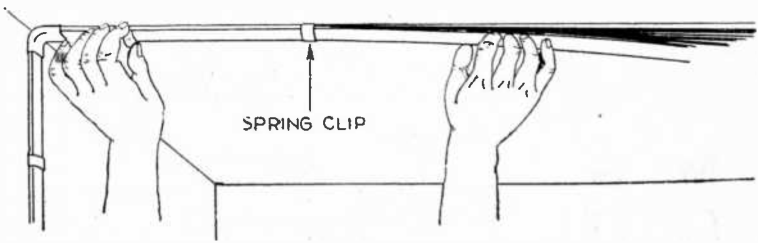
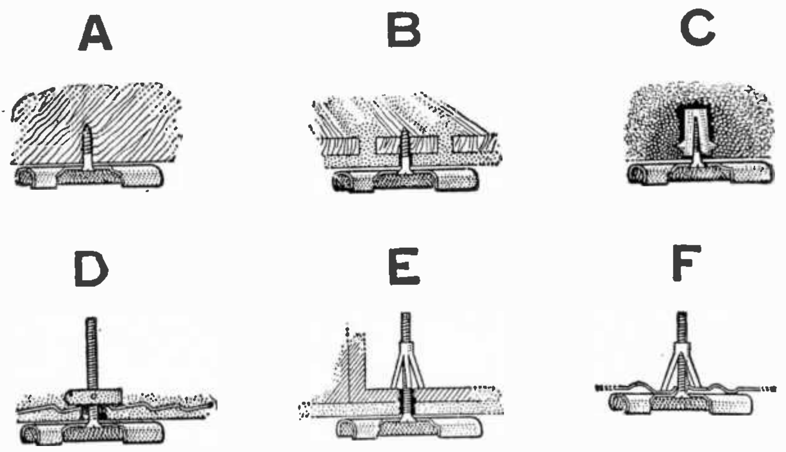


FIG. 5,296.—Method of "capping" ceiling run of National two piece moulding.



FIGS. 5,297 to 5,302.—Methods of supporting National metal moulding. A, *on wood*, use flat head screw; B, plaster on wood lath, use flat head wood screw; C, brick or concrete, use Crawlplug or lead shield; D, plaster or metal lath, use National toggle; E, hollow tile, use National spring head toggle; F, on metal ceiling, use National spring head toggle.

National Metal Moulding.—This moulding is made in two types, each in two wire and four wire sizes, giving the workman

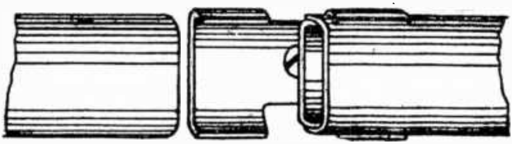
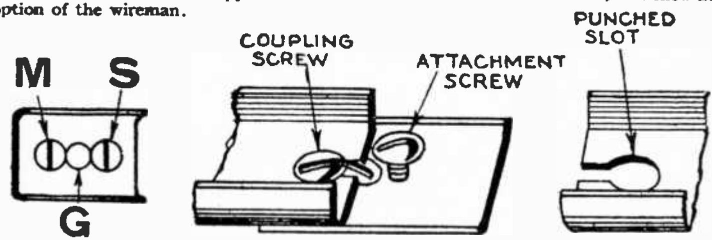


FIG. 5,303.—Method of coupling National metal moulding with support fitting. The joint is covered by a joint cap fitting. In this method of coupling, lengths of four-wire moulding can be snapped into the coupling only with cap and base assembled, and the wires fished through. The two wire moulding can be snapped into a special coupling fitting assembled, or the base alone can be supported; which allows the wires to be laid in, or fished at the option of the wireman.



FIGS. 5,304 to 5,306.—Base coupling fitting and method of coupling. This is for four wire moulding only. *To couple,* first punch key hole slots in the moulding base with hand punch. These slots fit around the two screws **M** and **S**, fig. 5,304. The center hole **G**, is for fastening the base to ceiling or wall. The base coupling can only be used when the base and cap are installed separately.

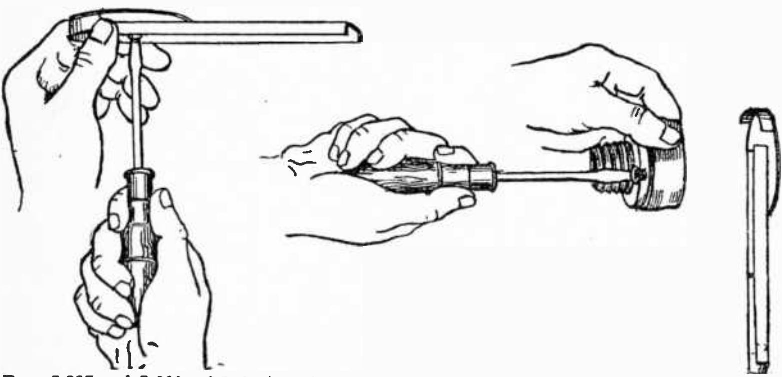
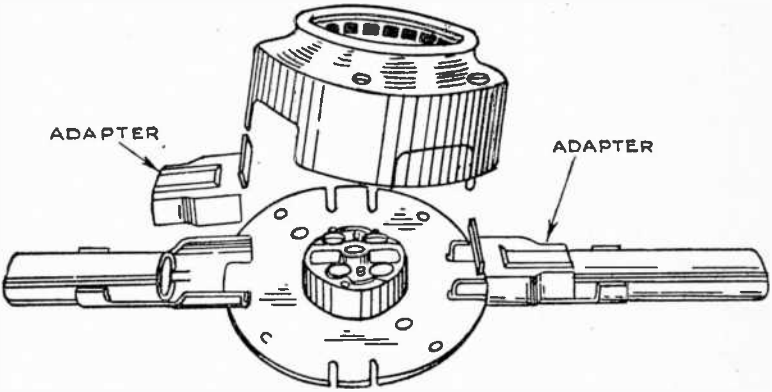


FIG. 5,307 and 5,308.—Methods of installing metal moulding device at the end of a run a choice of *laying in* or *fishing* wires. The laying in form consists of a *base* and *capping* or cover made of steel, as shown in figs. 5,290 and 5,291, and assembled as in fig. 5,292.

In the installation of the moulding, there are two methods of cutting the moulding—by hack saw or by a special shear.

If a hack saw be used, select only a fine toothed flexible hack saw with tempered edges; coarse toothed blades crack and break on moulding.

When cutting moulding with a hack saw it is not necessary to cut all the way into moulding, but only just nick the moulding, so if it be given

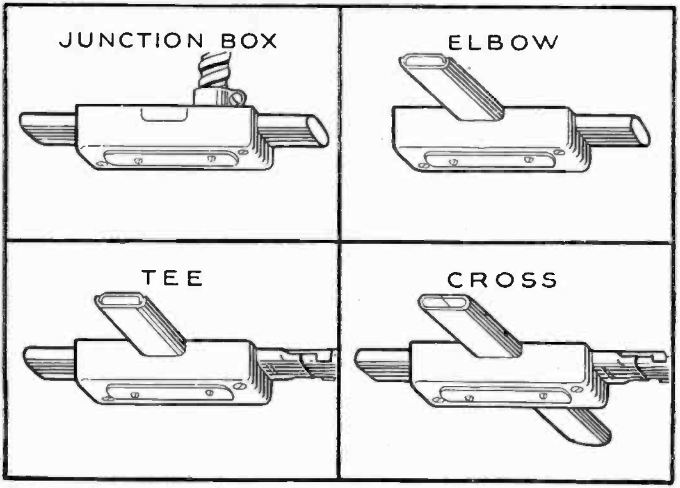


Figs. 5,309 to 5,311.—Method of connecting National two wire one or two piece mouldings into devices. The adapter takes these mouldings into all device twistouts. The large end of the adapter connects to all device bases by the push fit method (shown in figs. 5,334 to 5,338 for four wire moulding) and the two wire moulding snaps into the small end of it.

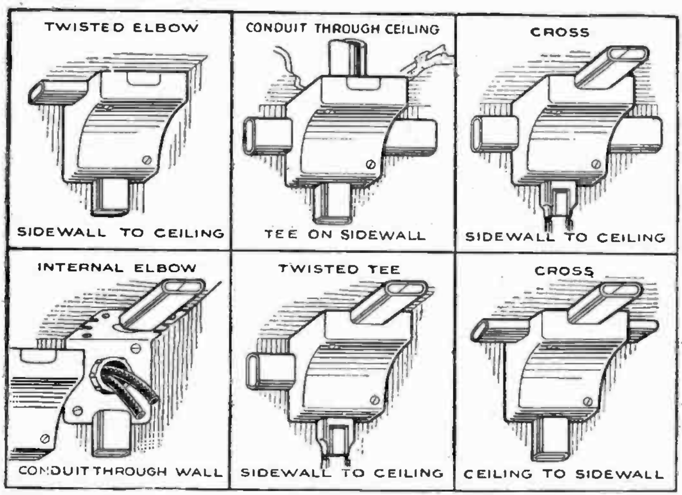
a slight up and down motion it will break apart. Files also may be used, the three cornered being the best. Holes must be punched in the base for screws, these can be made with a special punch or may be drilled by a twist drill in a brace or breast drill.

Bending.—The base and capping must be assembled and bent as one piece of moulding. The moulding is quite soft and is easily bent over the knee or the edge of a table; hickeys may be obtained for this purpose.

Avoid crossing the wires in the capping as this causes capping to bulge and short circuit. The moulding is coupled together by means of special couplings.



FIGS. 5,312 to 5,315.—Use of National utility box for junctions, branches and taps.



FIGS. 5,316 to 5,321.—Use of National cover box in surface installations.

In running around beams the base only is bent by cutting a 90° V with a hack saw at the bend. Both internal and external bends may be made by means of these notches. The capping is then laid in place after which the corners are covered over with special elbow covers.

The two piece moulding allows ready access to the wiring for extensions or inspection.

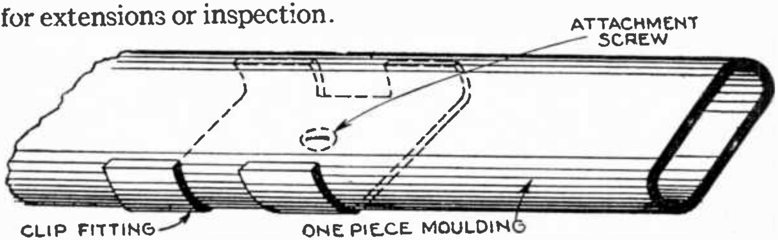
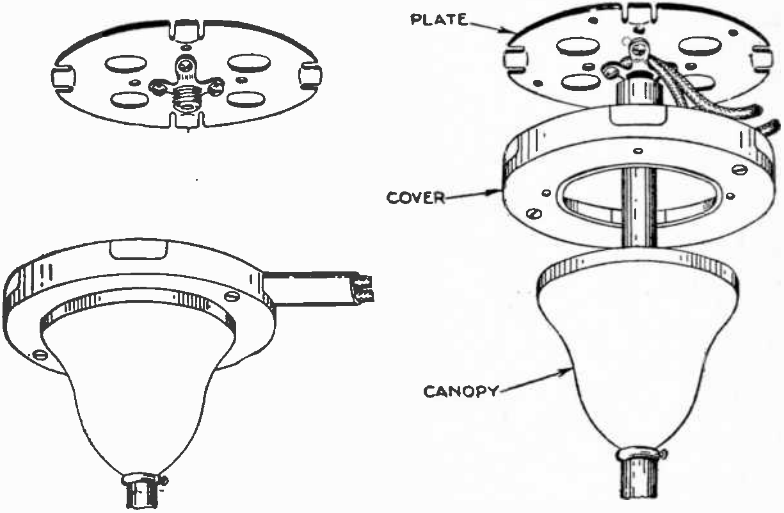


FIG. 5,322.—Method of supporting National *one* piece metal moulding with a spring clip fitting. First the fitting is attached to the ceiling or wall with a screw, then the run of moulding is "snapped" into the fitting.



FIGS. 5,323 to 5,325.—Method of connecting National moulding to fixture outlets and canopies, through canopy bases and fixture studs. Fig. 5,323, plate; fig. 5,324, fixture in place; fig. 5,325, cover and canopy ready for fastening.

It also permits addition of tunneled base devices to completed installa tions, and makes it possible to assemble a number of these devices on a length of moulding, as a unit, to be later placed in show windows, ètc.

The smallest size of National two piece moulding, shown in fig. 5,284, permits either *laying in* the wires then capping it, or *fishing* wires through the assembled moulding.

One piece mouldings consist of oval metal tubes in which ample room is provided for fishing wires.

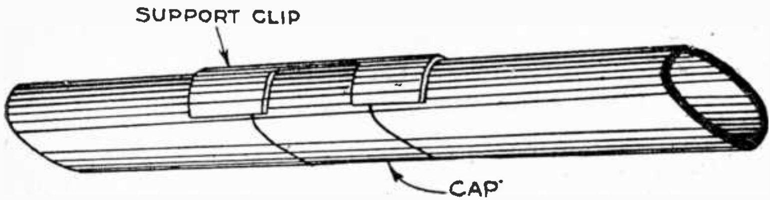
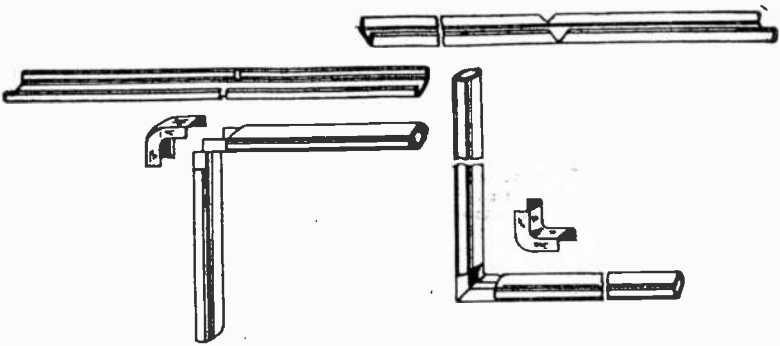


FIG. 5,326.—Method of coupling lengths of National one piece moulding with support fitting and coupling cap.

FIG. 5,327.—Correct use of bending tool in bending National moulding. ***In bending,*** the force should be applied near the bending tool; and when a screw hole comes within the length of the two wire two piece moulding to be bent, the pressure should not be exerted too suddenly.

A method of supporting one piece moulding with a spring clip fitting is shown in fig. 5,322. Lengths of one piece moulding are coupled as shown in fig. 5,326.

The two wire, one piece and four wire, two piece mouldings can be bent to an arc of 4 in. radius with the bending tool shown in fig. 5,327.



FIGS. 5,328 to 5,330.—Method of making external 90° angle by notching.

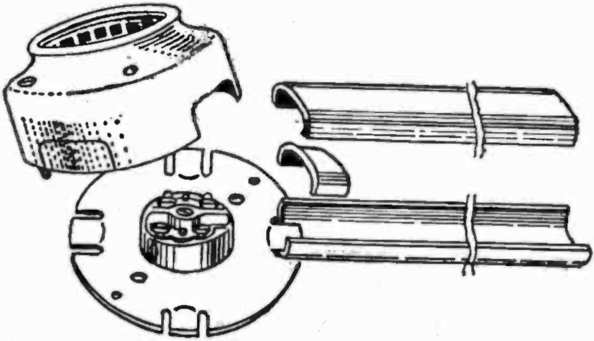
FIGS. 5,331 to 5,333.—Method of making internal 90° angle by notching.

These mouldings should be bent assembled to give the capping and base the same curve. It is not advisable to attempt bending the four wire one piece moulding.

90° as angles are made in four wire two piece moulding by notching. To make a 90° external angle by notching, saw a vertical slot down through the sides to the flat part of the base as in fig. 5,328, then, bend it around the angle as in fig. 5,330, and snap on a 90° external angle elbow cap, fig. 5,329.

To make a 90° internal angle by notching cut a V shaped notch from the sides of the base with a hacksaw or three cornered file, as in fig. 5,331, then bend the moulding into the angle, as in fig. 5,333, and snap on a 90° internal angle elbow cap, fig. 5,332.

There is a multiplicity of fittings for metal mouldings and no attempt is made to show all of them, but from the explanations and illustrations given the manipulation of the fittings must be apparent.



FIGS. 5,334 to 5,338.—Method of connecting National four wire, one and two piece mouldings into devices. These mouldings slide under the tongues in all device bases. Before finally placing the device cover, the twistout must be removed, as shown. The bushing is required when connecting into devices, to protect the wires from abrasion. As shown, it is inserted in the capping.

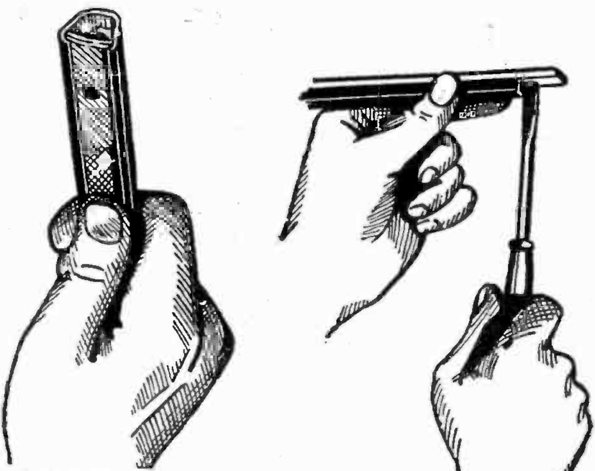
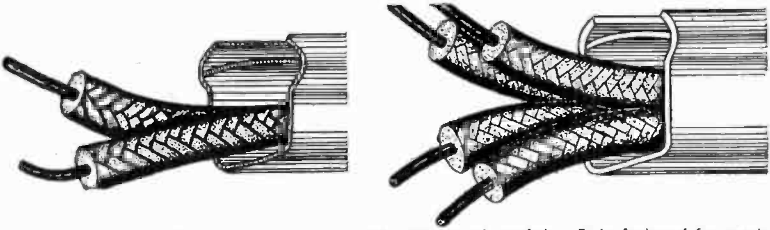
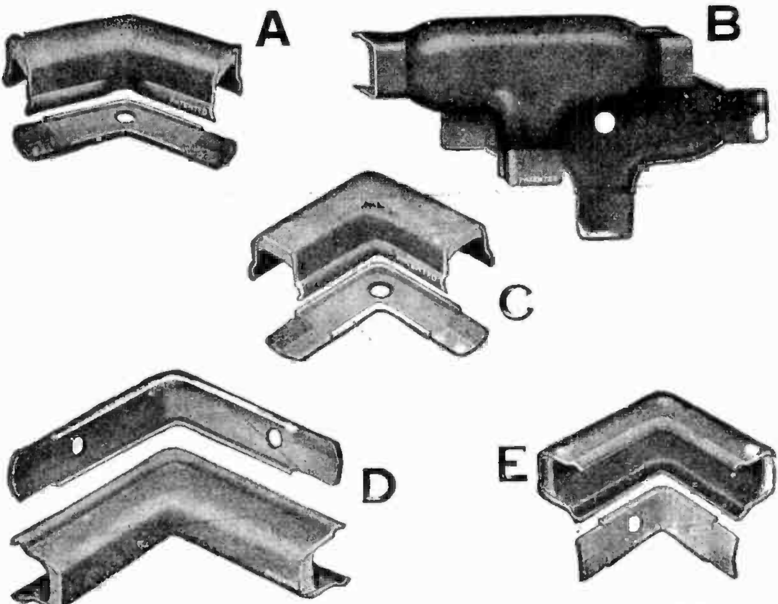


FIG. 5,339.—End of Wiremold moulding showing coupling.
FIG. 5,340.—Method of fastening end of Wiremold moulding to ceiling with screw.

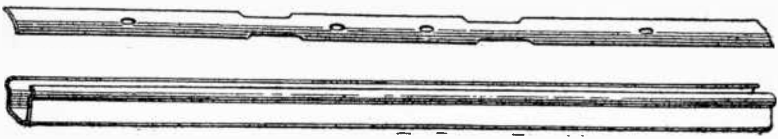
Wiremold Metal Moulding.—This type of moulding has no removable cap and is installed like wrought pipe except that



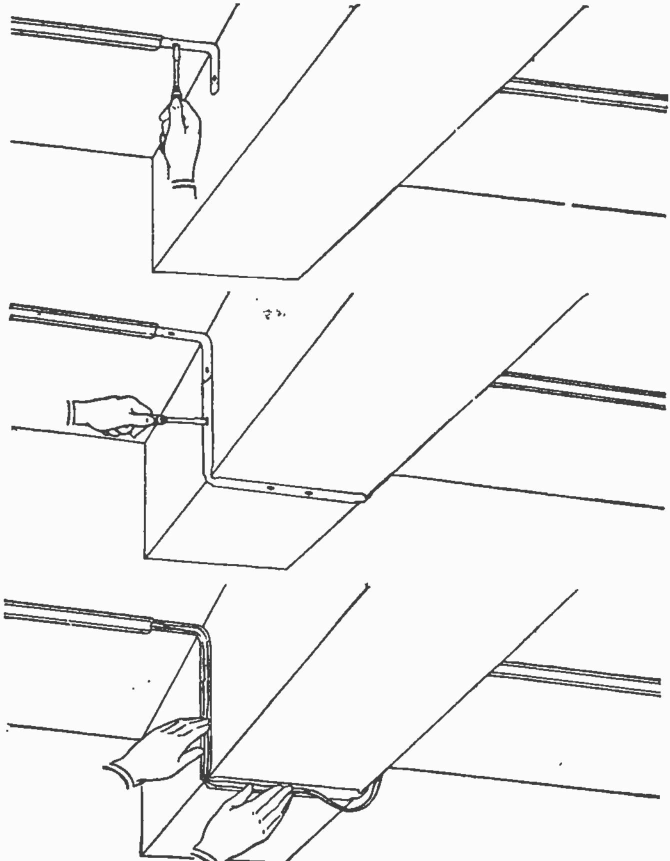
Figs. 5,341 and 5,342.—Two wire and four wire Wiremold conduit. It is designed for use in large installations requiring circuits of 2 or 4 wires, such as factories, railroad buildings, lofts, warehouses, department stores, office buildings, hospitals, school buildings and the like. Is also adapted for signal and call systems. It comes in 10 ft. lengths.



Figs. 5,343 to 5,347.—Wiremold angle fittings. **A**, 45° flat elbow; **B**, tee; **C**, 90° flat elbow; **D**, internal 90° elbow; **E**, external 90° elbow.



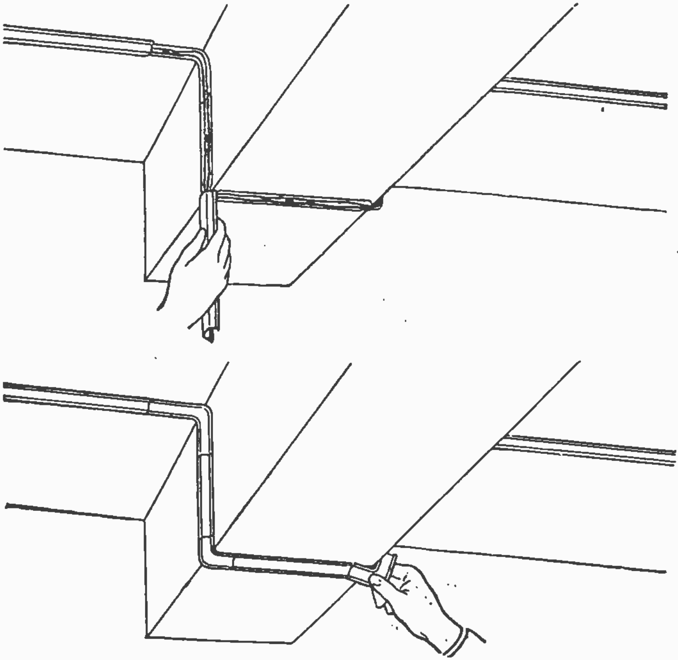
FIGS. 5,348 and 5,349.—Wiremold beam strap cover and base for passing around beams.



FIGS. 5,350 to 5,354.—Beam strap method of passing around beams with Wiremold wiring. The strap and cover used are shown in fig. 5,348 and 5,349. Operations: *1*, lay internal a "slip joint" is used for coupling lengths and for coupling with fittings rather than the threaded coupling required for pipe.

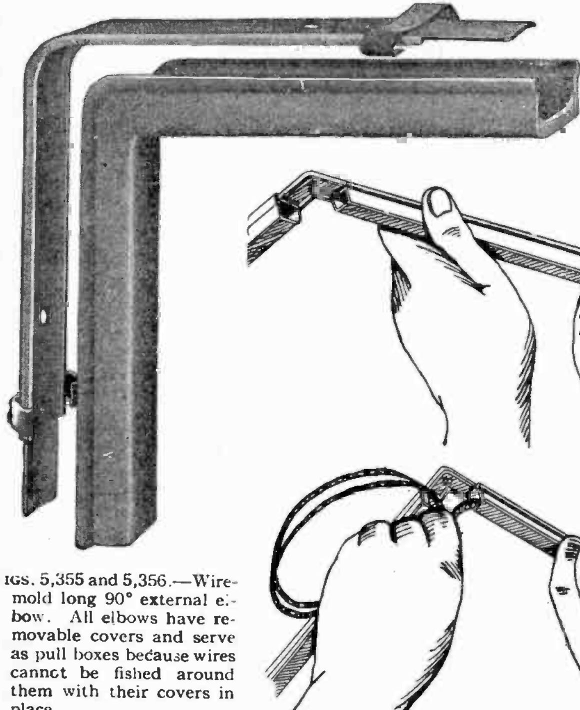
Fig. 5,341 shows the appearance of the moulding. Each length is furnished with a coupling as in fig. 5,339. To connect lengths of Wiremold conduit, first push the coupling part way out to the end of Wiremold conduit and fasten the coupling to the ceiling or wall as shown in fig. 5,340.

Slip the next length of the moulding over the edges of the coupling as in fig. 5,360, thus providing a concealed coupling as well as support at the

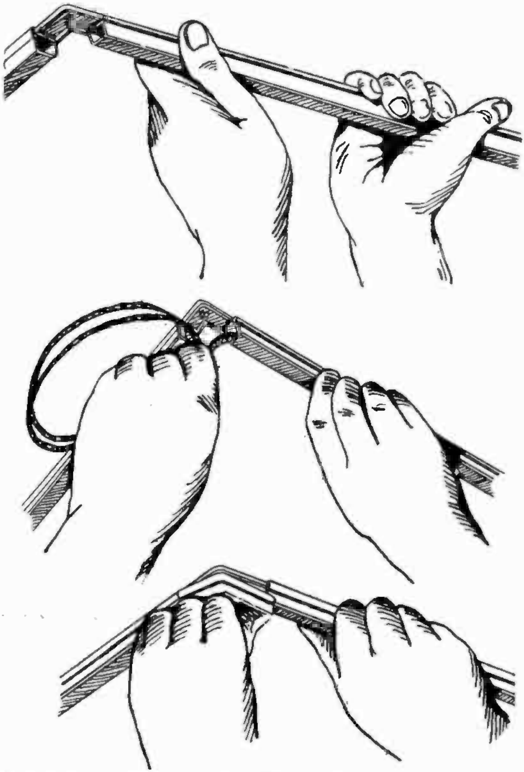


FIGS. 5,350 to 5,354.—*Text continued.*

elbow base in usual way, as in fig. 5,350; *2*, install screw-on beam strap base around beam, as in fig. 5,351; *3*, lay wires against base pieces, as in fig. 5,352; *4*, cut slide-on capping and slip on over base, as in fig. 5,353; *5*, snap on elbow covers, as in fig. 5,354.



FIGS. 5,355 and 5,356.—Wiremold long 90° external elbow. All elbows have removable covers and serve as pull boxes because wires cannot be fished around them with their covers in place.



FIGS. 5,357 to 5,359.—Method of making a 90° turn with a Wiremold flat 90° elbow. First assemble coupling tongues in base plate as in fig. 5,357, being careful that the coupling tongue goes *outside* the moulding base. After fastening the base plate to the wall with wood screw or toggle bolt, push in or fish in the wires as in fig. 5 358. Finally, snap on the elbow cover, breaking off the crescent shaped twistouts in the ends for use with the four wire moulding. Do not put covers on any of these fittings until wiring is completed.

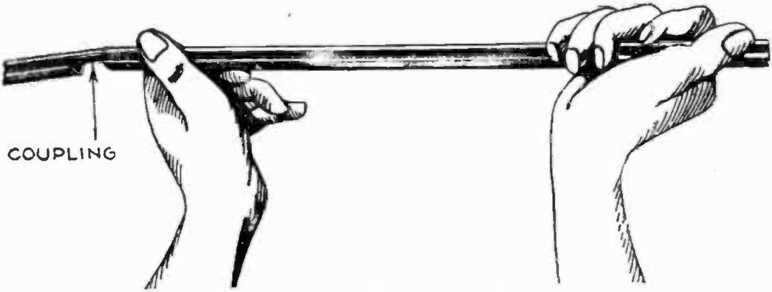
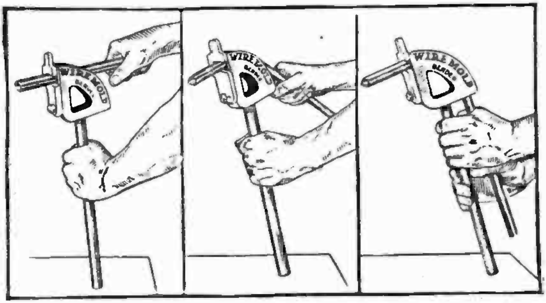


FIG. 5,360.—Slip joint method of coupling Wiremold moulding.



FIGS. 5,361 to 5,363.—Wiremold bender and its use. To make an internal bend or offset with Wiremold bender, put Wiremold conduit into the tool as shown in fig. 5,361, apply pressure close to the tool as in fig. 5,362, and finish bend as in fig. 5,363. External bends or offsets are made in same manner by simply reversing position of the moulding in the bender.

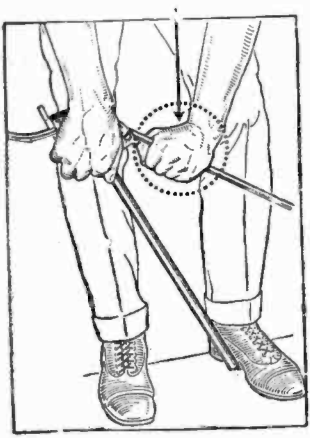


FIG. 5,364.—Method of making bends or offsets in the middle of a length of Wiremold moulding with bender on floor using foot support and applying pressure close to tool as indicated by arrow in circle end of each length. Between ends, the moulding is supported by clips.

When the moulding is imperfectly cut, a connection cover is snapped over adjoining ends.

Figs. 5,343 to 5,347 show elbows and tees used with Wiremold.

Code.

504. Surface Metal Raceways (Metal Moulding Work)

a. When wires are installed in surface metal raceways (metal moulding work), the provisions of the following paragraphs of this section shall be observed.

b. Raceways shall be of approved types and shall be used only in exposed dry locations and where the maximum difference of potential does not exceed 300 volts between conductors nor 150 volts to ground. They shall not be placed in hoistways nor where they may be subjected to severe mechanical injury nor where corrosive vapors are present. (For use in underplaster extensions see section 510 of this article.)

c. Wires shall be of approved rubber-covered type, and shall be continuous from outlet to outlet, or from fitting to fitting, no joints or taps being located in the raceway proper except that with metal raceway wires exposed to surrounding temperatures exceeding 120° F. (49° C.) shall be type (A) or type (SB).

d. Surface metal raceways shall not be used for wires larger than No. 8 or fused at more than 30 amperes nor for a number of wires greater than that for which the raceway is approved and in no case for more than nine wires.

e. Metal raceways shall be of such construction as will distinguish them from rigid conduit. All surfaces of raceway, elbows, bends and similar fittings shall be suitably protected from corrosion.

f. Metal raceways and their elbows, couplings and similar fittings shall be so designed that the sections can be electrically and mechanically coupled together, while protecting the wires from abrasion. Holes for screws or bolts inside the raceway shall be so designed that when screws or bolts are in place their heads will be flush with the metal surface.

g. Where alternating current is to be employed in connection with metal raceway work, all wires of a circuit shall be placed in one raceway, except as provided in section 510 of this article.

It is recommended that this course be pursued in the case of direct current also, in order to obviate induction troubles if a change is made to alternating current at some later date.

h. A metal raceway shall be continuous from outlet to outlet, or from approved fitting to approved fitting and shall be securely fastened in place. It may be extended through dry walls or dry partitions if in unbroken lengths where passing through; but, where the wall or partition is damp, or where the raceway passes through a floor, an iron pipe sleeve shall be placed over the raceway and shall extend clear of either side of the wall or partition, or from the ceiling below to a point at least 3 inches above the flooring. Where protection from mechanical injury is necessary, the iron pipe sleeve shall extend to a point at least 5 feet above the flooring.

Code.—Continued.

i. Metal raceways shall be grounded as prescribed in Article 9 of this code.

j. When combination metal raceways are used both for signal and for lighting and power circuits, the different systems shall be run in separate compartments, identified by sharply contrasting colors of the interior finish, and the same relative position of compartment shall be maintained throughout the premises, in which case the provisions of paragraph (*m*), section 503, and of paragraphs (*a*) to (*d*) inclusive, section 6003 of this code, shall be considered as having been observed. When such combination metal raceways are used, ten No. 14 wires shall be permitted in the compartment for light, heat and power circuits. Wires of light and power systems shall enter and leave combination raceways by means of conduit work. In all other respects, the provisions of this section covering single compartment raceways shall apply.

514. Surface Wooden Raceways

a. Wooden raceways shall be coated, externally and internally, with 2 layers of waterproofing, or shall be impregnated with a moisture repellant. The raceway shall be composed of two parts, a backing and a capping, and shall afford suitable protection against abrasion of wires. It shall be so constructed as to thoroughly encase the wire, having a barrier of not less than ½ inch in thickness between wires, and having exterior walls which under grooves shall be not less than ⅜ inch in thickness and on sides not less than ¼ inch in thickness.

It is recommended that only hardwood be used.

b. In installing surface wooden raceways the appropriate provisions of paragraphs (*b*) and (*c*) of section 504 shall be observed.

c. The entire raceway system shall be securely fastened in place.

TEST QUESTIONS

1. *What other term is used in place of mouldings?*
2. *What is the best kind of moulding to use?*
3. *How many wires are carried in metal moulding?*
4. *Give method of laying in wires in two piece moulding*
5. *How is metal moulding cut?*
6. *Describe the method of fastening moulding to ceilings or walls.*
7. *How are two lengths of moulding joined together?*
8. *Describe a special tool for cutting moulding.*
9. *Give various methods of supporting mouldings.*

10. *Describe the fittings used for coupling mouldings.*
11. *What kind of hack saw should be used in cutting mouldings?*
12. *Describe the method of bending moulding.*
13. *How is moulding run around beams?*
14. *What is the advantage of the two piece moulding?*
15. *Describe method of connecting moulding to fixture outlets.*
16. *What is the method of coupling one piece moulding?*
17. *How is the special bending tool used?*
18. *How are 90° angles made?*
19. *Describe some of the fittings used.*
20. *Give the method of connecting four wire, one and two piece mouldings into devices.*
21. *How does "wiremold" metal moulding differ from other mouldings?*
22. *Describe the various wiremould fittings.*
23. *How is wiremould run around beams?*

CHAPTER 111

Concealed Knob and Tube Wiring

This method of wiring should be discouraged as far as possible, as it is subject to mechanical injury, is liable to interference from rats, mice, etc. As the wires run according to

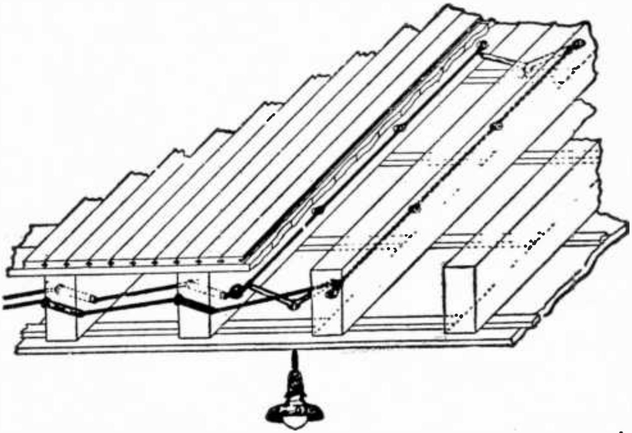
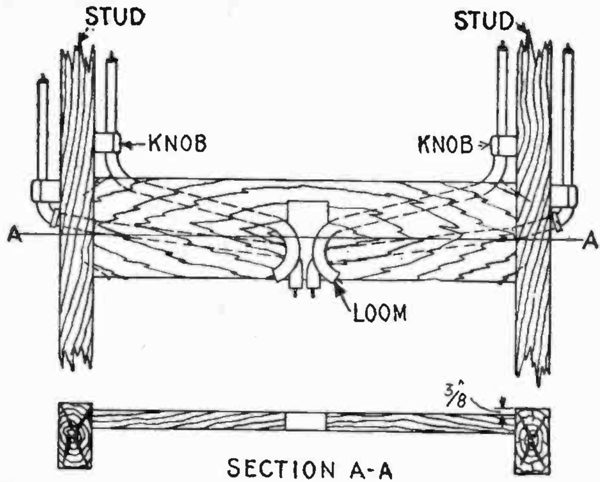
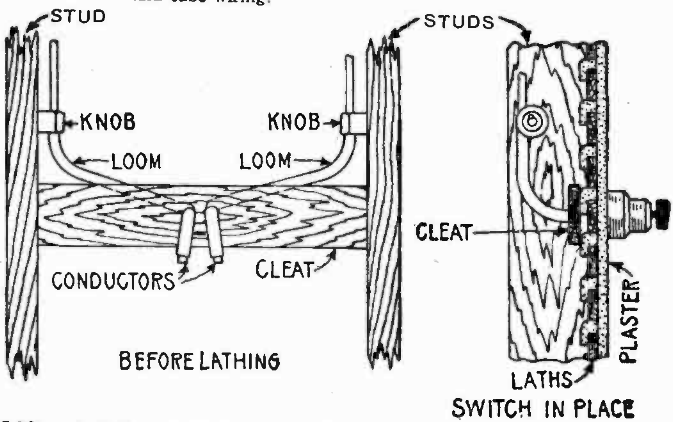


FIG. 5,365.—Concealed knob and tube wiring. The wires are carried on porcelain knobs attached to the beams. If run perpendicular to the beams, holes are bored in the latter and porcelain tubes with a shoulder at one end, inserted in the holes through which the wires pass. The use of split knobs does away with the necessity of using tie wires. The conductors must be at least 5 inches apart and it is better to support them on separate beams when possible.



FIGS. 5,366 and 5,367.—Elevation and sectional view showing arrangement of switch outlet in concealed knob and tube wiring.



FIGS. 5,368 and 5,369.—Arrangement of surface switch in concealed knob and tube wiring. For a surface snap switch outlet, an iron box is not necessary, but a 7/8 in. cleat must be installed to hold the tubing in place and to provide a proper support for the screws that hold the switch. In wiring old buildings where supporting cleats were not provided back of the plaster, a 3/4 in. wooden block or plate should be installed on the surface, to which the switch can be attached.

this method are liable to sag against beams, laths, etc., or are likely to be covered by shavings or other inflammable building material, a fire could easily result if the wires become overheated or short circuited.

Before installing concealed knob and tube wiring it should first be ascertained if this method be permitted by the local ordinances.

The following requirements should be especially noted.

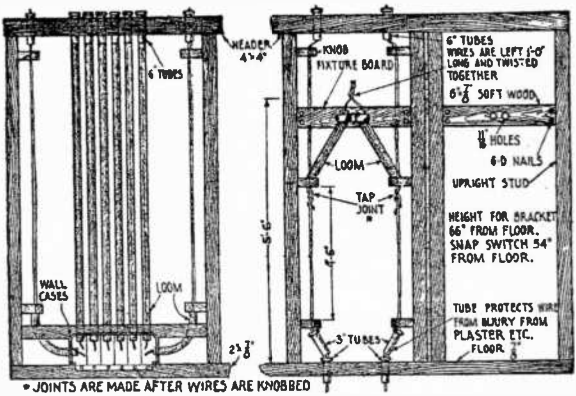


FIG. 5,370.—Method of installing wires where spacing of 5 ins. cannot be made. *All wires spaced less than 5 ins., must be encased in loom.* The loom must be continuous and in one piece from the tube to the wall case where at this point it must be secured by a clamp to the box. As shown, there is room for wires on the side of the studs; these wires need not be encased in loom.

FIG. 5,371.—Method of avoiding cross stud by locating wall cases a little above center of partition.

Code Requirements

Maximum pressure 300 volts between conductors; 150 volts to ground. Rubber covered wires.

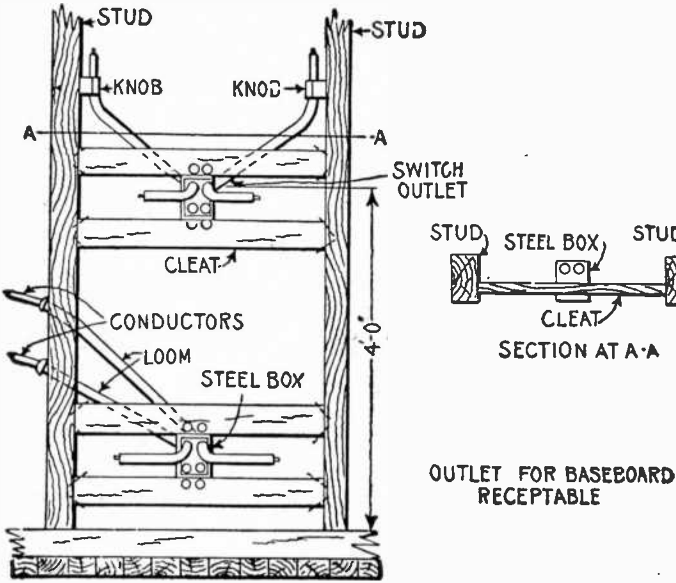
Spacing: 5 in. between wires; 1 in. from surface wired over.

Distance between supports not over 4½ ft.

Tube protection through cross timbers, etc.

The method of concealed knob and tube wiring consists in running the wires concealed between the floor beams and studs of a building, knobs being used to support the wires

FIG. 5,372.—Porcelain tube as used in knob and tube wiring. The standard tube as used in house wiring comes in all lengths and is 5/16 in. in diameter.

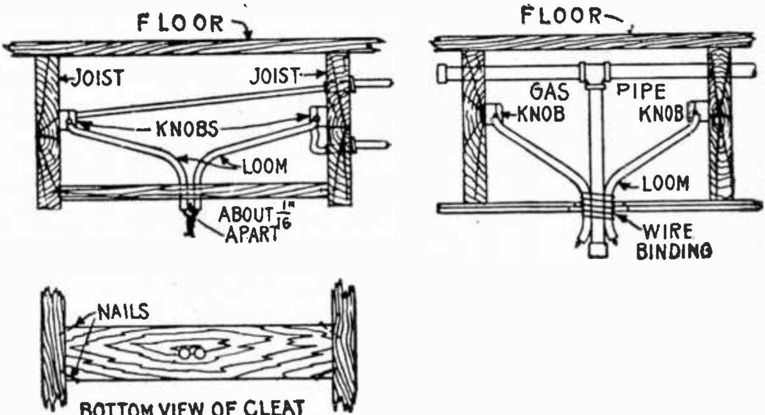


FIGS. 5,373 and 5,374.—Arrangement of switch and receptacle outlets in knob and tube wiring. *In wiring for switches,* flexible tubing must be used on the conductor ends from the last porcelain support, as shown, the same as on conductor ends for other outlets. A pressed steel switch box should be used to encase each flush switch mechanism, even though it already be encased in porcelain. A 7/8 in. wood cleat or cleats are arranged to support the switch box. These wooden cleats should not be set out flush with the outer edges of the studs, but should be set about 3/8 in. back as shown to allow a space in which the plaster can "grip."

when run parallel with the beams or studs, and porcelain tubes, when run at right angles through the beams or studs as shown in fig. 5,365.

The type of porcelain tube used is shown in fig. 5,372.

In wiring a house by the knob and tube method usually nothing need be disturbed on the first floor as the various outlets can be reached from the basement and from the second floor.



Figs. 5,375 to 5,377.—Methods of making fixture outlets in concealed knob and tube wiring. A cleat consisting of a piece of board at least ⅞ in. thick, should be nailed between the joists or studs into which the wood screws supporting the electrolier can be screwed. Holes are then bored through the cleat, through which the flexible tubing can pass. With a combination gas and electric fixture as shown in fig. 5,376, no cleat is necessary, because the gas pipe supports the fixture. The flexible tubing should be wired to the gas pipe, to prevent displacement by artisans who have occasion to work around the outlet.

For instance, if it be necessary to make an outlet for the center fixture in the parlor, a strip of flooring can be removed from the floor above so as to expose the beams. Then the wireman can bore two holes through each of the beams, insert porcelain tubes therein, slip the wires through the outlet and replace the strip of flooring.

Various simple methods may be employed for carrying the wires to the outlets on the side walls. For example: a small hole can be made in the wall, and the wire may be dropped through the space between the walls or it may be pulled up from the basement by means of a cord lowered with a weight attached to its end. Outlets for switches and base receptacles may be provided for, in a similar manner.

The accompanying illustrations show some of the principal operations to be performed in installing the wires. These are taken up in much greater detail in the chapter on house wiring.

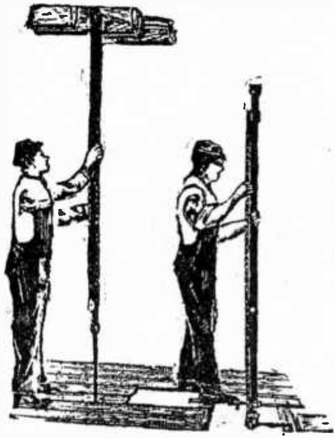


Fig. 5,378.—Boring machine for boring procelain tube holes for knob and tube work. It will bore a hole parallel with the floor (avoiding slanting tubes) and in less time than with a brace.

Fig. 5,379.—Electrician's bit designed for rough usage. *It has* a coarse worm and sharp cutter so that it will pull itself into the wood without much effort. Ordinary fine worm carpenter's bits are not suitable as they easily clog in the hole.

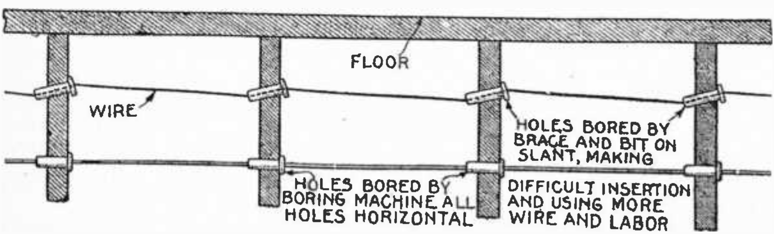


Fig. 5,380.—Comparison of porcelain tube holes as bored with brace and bit and with boring machine. The use of a brace and bit is not only a waste of time but makes an objectionable job.

Code.

502. Concealed knob and tube wiring

a. Single conductor wires mounted with knobs and tubes or run in non-metallic flexible tubing as in paragraph *e*, below, may be installed as concealed work in the hollow spaces of walls and ceilings, when the provisions of the following paragraphs of this section shall be observed.

b. Concealed knob and tube work shall not be used for systems of more than 300 volts between conductors or more than 150 volts to ground.

c. Supports shall conform to the requirements for knobs, tubes and bushings, as prescribed in section 501 of this code.

d. Wires shall be of approved rubber-covered type (R).

e. Wires shall be separated at least 5 inches and maintained at least 1 inch from the surface wired over. At distributing centers, meters, outlets, switches or other places where space is limited, and the 5 inch separation cannot be maintained, each wire shall be encased in a continuous length of approved flexible tubing.

It is recommended that wires be run singly on separate timbers or studding.

f. Where it is impracticable to employ insulating supports, the wires, if not exposed to moisture, may be fished if separately encased in approved flexible tubing extending in continuous lengths from one support to the next or to the outlet, or from one outlet to another; otherwise, approved conduit, approved armored cable, or approved non-metallic sheathed cable shall be used.

g. Where a change is made from concealed work to conduit or armored cable, an approved terminal fitting having a separate bushed hole for each wire shall be used, through which fitting the wires shall pass without splice, joint or tap. This terminal fitting need not be accessible.

h. In installing wires the precautions as to rigid supporting, separation between wires, clearance from foreign objects, drip loops where moisture or corrosive vapors are present, as prescribed in section 501, of this code shall be observed. Wires passing through cross timbers in plastered partitions shall be protected by an additional tube extending at least three inches above the timber.

i. Approved outlet boxes as required by paragraphs *a* and *b* of section 703 shall be installed at all outlets and switch points and the flexible tubing shall extend from the last knob into and be secured to such boxes.

TEST QUESTIONS

1. *What is the criticism of knob and tube wiring?*
2. *Explain the dangers connected with knob and tube wiring.*
3. *What should be done before installing knob and tube wiring?*
4. *Give the Code requirements for knob and tube wiring.*

5. *Describe briefly the knob and tube wiring system.*
6. *Draw a sketch showing arrangement of switch and receptacle outlets.*
7. *Describe the method of making fixture outlets.*
8. *Need anything be disturbed on the first floor in wiring a house by the knob and tube method?*
9. *How is a ceiling outlet made?*
10. *Describe methods of carrying wires to the outlets on side walls.*
11. *How should holes be bored through beams?*

CHAPTER 112

Wiring with Armored Cable

Armored cable consists of *a cable in which the conductor or conductors are covered by a specially wound steel casing.*

In the manufacture of armored cable the steel strip which forms the armor is rolled and galvanized; the conductors are twisted and covered and finally wrapped with the armor strip.

The shape given to this strip is the result of careful scientific study and test. It is this shape which gives strength and flexibility. On account of its flexibility armored cable is an ideal form of wiring for those types of installation where there are many turns and short runs. It is a very economical method of wiring finished buildings, as it can readily be installed without defacing walls or decorations.

Armored cable is manufactured with single or double strip armor but the single strip is the type generally used.

Single strip armored cable is formed of one continuous strip, with the edges rolled over to fit together; the convolutions are rounded.

Double strip armored cable has armor formed of two channel shaped metal strips, wound so that their upturned edges face and engage each other, giving an armor of double thickness and great flexibility.

It has flat convolutions which make fishing of wires and pulling through holes easy. The sectional view, fig. 5,381, shows the construction of armored cable.

While wiring with armored cable has not the advantage of the conduit systems, namely, that the wires can be withdrawn and new wires inserted without disturbing the building in any way whatever, yet it has many of the advantages of the flex-

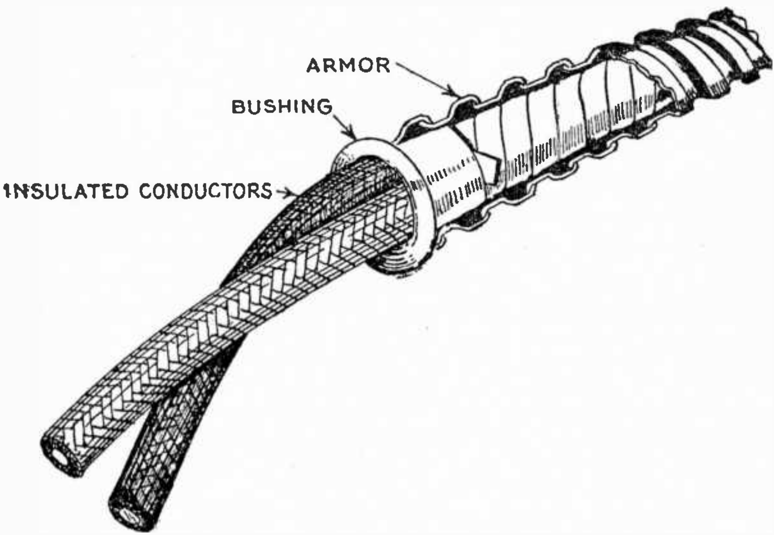


FIG. 5,381.—National armored cable showing insulation and construction of the armor.

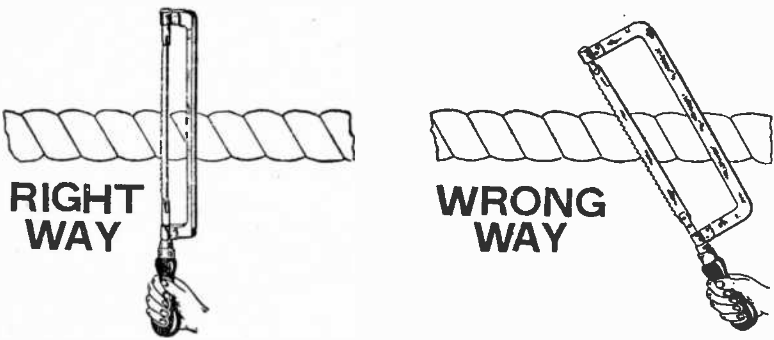
ible steel conduit, and it has some additional advantages of its own.

For instance, in a building already erected, this cable can be fished between the floors and in the partition walls, where it would be impossible to install either rigid conduit or flexible steel conduit without disturbing the floors or walls to an extent that would be objectionable.

Armored cable is less expensive than the rigid conduit or the flexible steel conduit, but more expensive than cleat wiring or knob and tube wiring, and is strongly recommended in preference to the latter.

Where the cable is subject to moisture, as on the outside of a building or underground, *lead covered-armored cable* must be used.

The difference between the latter and the ordinary armored cable is that a continuous lead sheath is placed over the wires and the whole is then covered with the flexible steel.



FIGS. 5,382 and 5,383.—Right and wrong way to cut armored cable.

Cutting Armored Cable.—In order to properly remove the metal casing or armor, a fine toothed hack saw should be used, (24 teeth to the inch) or a special tool, such as shown in 5,393.

The armor is cut diagonally across. The cut should not entirely cut through the sheath, but should be deep enough so that it will break if given a slight inward bend. Do not cut too deep as this may sever the wires or puncture the insulation.

Figs. 5,382 and 5,383 show right and wrong methods.

After armor sheath has been removed, the outer protecting braid must be removed from the duplex conductors. This is best done by making a slit one inch below the sheath about one inch long, and then by pulling the outer braid it will readily come off without much effort.

Before the cable is installed it should be examined at each end to see whether any part of the sheath punctures the insulation.

This is very important as grounds and short circuits are often thus accidentally made.

In order to protect the insulation on the conductor from being cut by the sharp edge of armor a bushing is inserted.

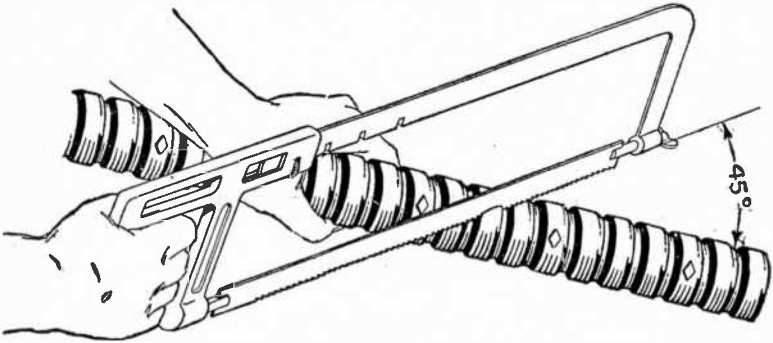


FIG. 5,384.—*Preparing National cable end for installation 1. Cut armor.* Quickest method of cutting armor is as shown, holding hacksaw at 45° angle to cable. The cut should be made several inches from the end to allow for making joint in outlet box.

The method of cutting, stripping and inserting the bushing is shown in figs. 5,384 to 5,391. The importance of bushing the end of a cable is shown in fig. 5,392.

Installation of Armored Cable.—In the work of installing the cable, the outlet boxes should be located and installed first. The boxes can thus be used as guides for boring the holes. It is advisable to bore all the holes before installing the cable.

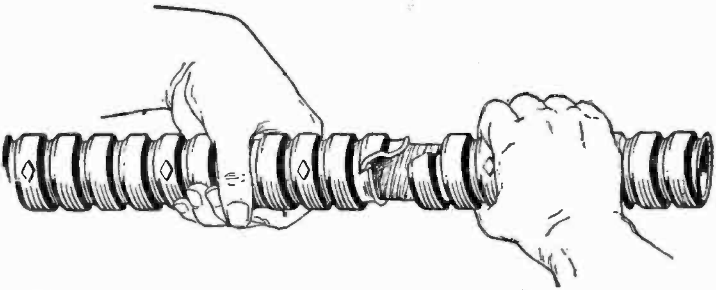


Fig. 5,385.—*Preparing National cable end for installation 2. Twist off armor.* It will easily twist off over conductors, after convolution has been sawed through.

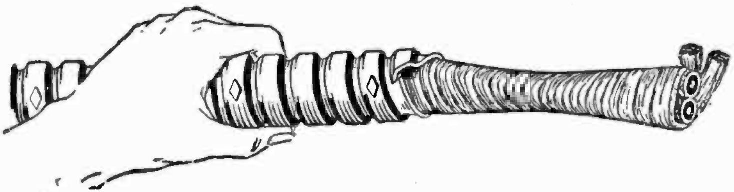


Fig. 5,386.—*Preparing National cable end for installation 3. Remove armor.* Underneath the armor is the *Kraft armor*, or protective covering wrapped over the insulated conductors.

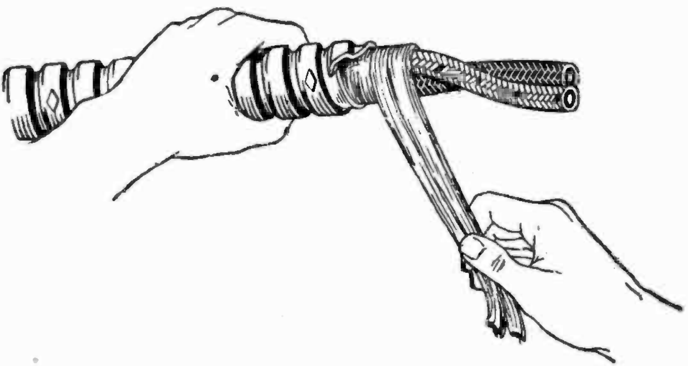


Fig. 5,387.—*Preparing National cable end for installation 4. Unwind protective covering.* This is easily done as shown.

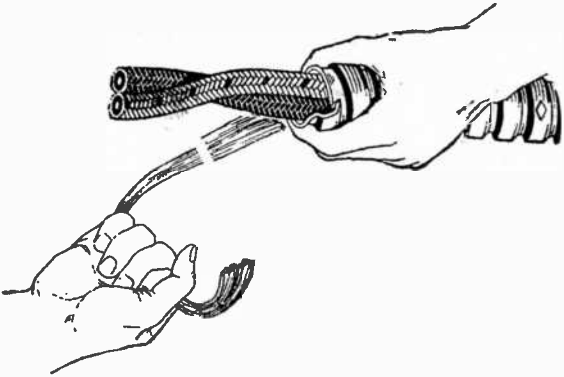
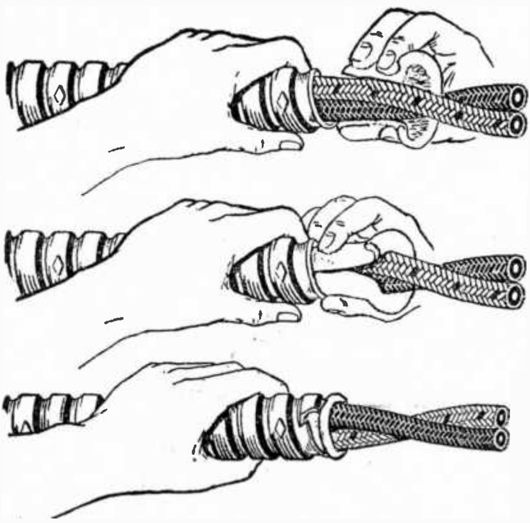


FIG. 5,388.—*Preparing National cable end for installation 5. Break off protective covering.* This will easily snap off by hand.



FIGS. 5,389 to 5,391.—*Preparing National cable for installation 6. Insert bushing.* This bushing protects the insulation from being cut by the edge of the armor. It is placed around the conductors as shown in figs. 5,389 and 5,390 and is pushed inside the armor as in fig. 5,391.

Holes should be bored through floor beams at right angles instead of inclined as it makes it easier to pull through the cable.

In order to avoid undue fatigue in boring, the holes may be bored between two outlets and then insert cable, rather than bore all the holes before inserting cable.

To insert cable, take the roll of cable and after preparing the end as explained in the preceding section, thread the cable

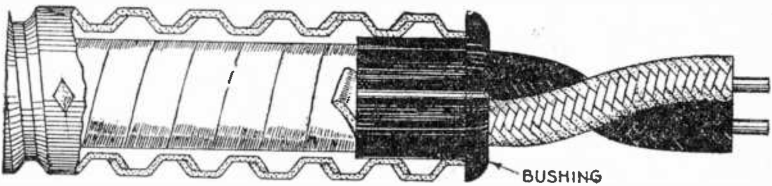


FIG. 5,392.—Detail of National armored cable with end cut and bushed, showing how the bushing protects the conductor insulation from the ragged edge of the cut armor.

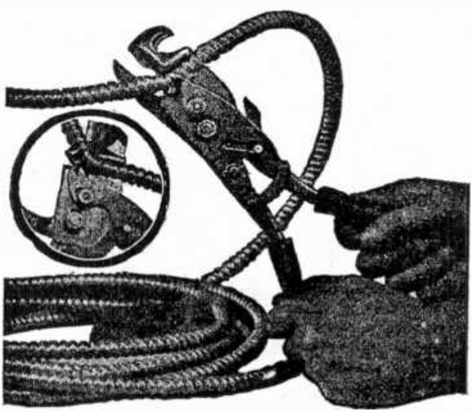


FIG. 5,393.—Austin armored cable tool. Strips the armor from any single strip armored cable in sizes 14-2, 14-3, or 12-2, without any possibility of injuring the insulation of the wire. Cuts cable, wire or non-metallic flexible conduit up to ½ in. outside diameter. Has auxiliary pliers with extra leverage. In using the cutter, slip the tool on the cable, open the handles as far as they will go, then close the handles. The armor is not severed cleanly, the cable slips out of the tool. Do not attempt to sharpen the blades; use new ones.

through the holes up to the outlet box and fasten it with a clamp or connector to the outlet box.

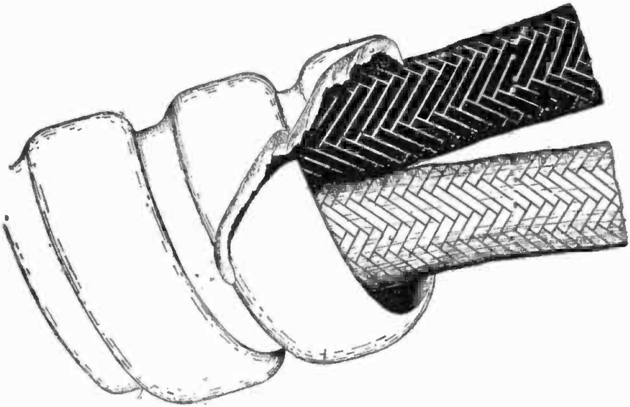


Fig. 5,394.—Armor as cut, showing the ragged edge along the cut. Unless a bushing be inserted to protect the conductor insulation from the ragged sharp edge of the armor, the insulation may be pierced, resulting in a short circuit.

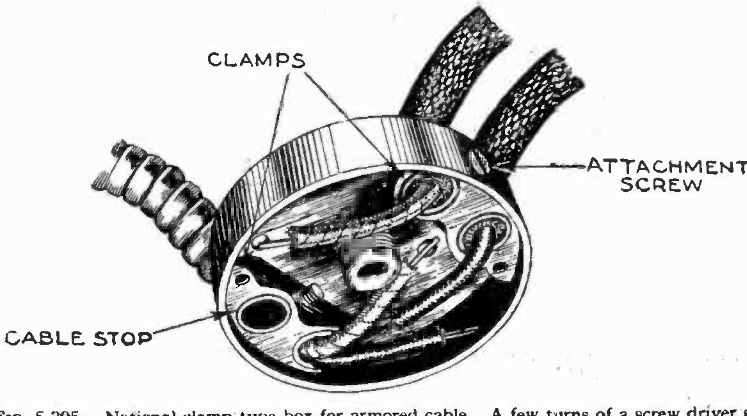
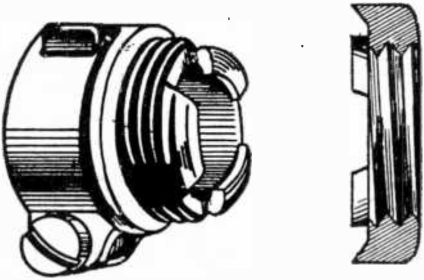


Fig. 5,395.—National clamp type box for armored cable. A few turns of a screw driver securely fastens the cable in place. This box will also take loom or both loom and armored cable in the same box.

Fig. 5,395 shows a box arranged for clamping. One form of connector is shown in figs. 5,396 and 5,397 and the method of connecting it to the cable and box in figs. 5,398 to 5,404. Another view of the box and completed connector is shown in fig. 5,404.

After fastening the cable to the outlet box, it is pulled fairly taut and cut off at the proper point to connect up with the other box.



FIGS. 5,396 and 5,397.—National connector and lock nut showing detector or lugs which engage with the end of bushing.

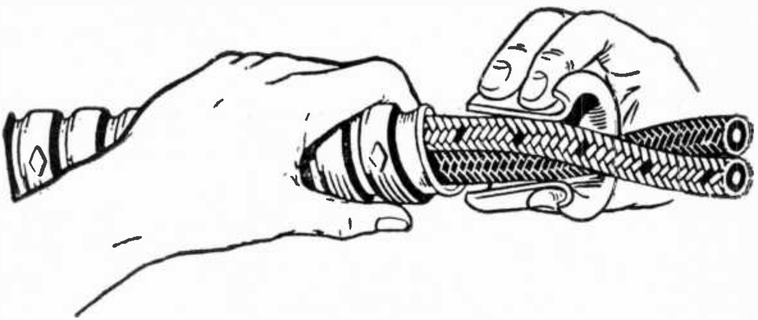


FIG. 5,398.—*Connecting cable with box 1.* Place bushing around conductors.

In cutting off the cable be careful to cut it off at the right length so that it will project into the box six inches, or far enough to properly make a joint.

If the cable be cut off too short it will be necessary to remove it and put in another cable of the right length as *joints are not allowed between boxes,* hence the importance of being careful to cut off the right length of cable.

When the cable runs parallel with joists or studs, it is fastened to them with pipe clamps.

In wiring an old house, the procedure is similar to that in a concealed knob and tube installation. The cable must be fished from outlet to outlet and then must be fastened into the outlet boxes.

Being metallically sheathed, the wires need no additional protection.

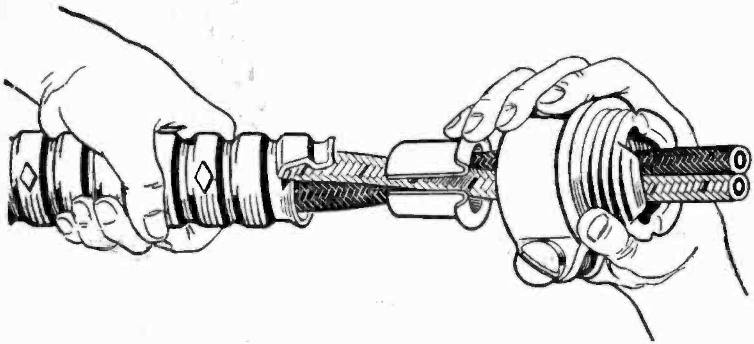


FIG. 5,399.—*Connecting cable with box 2.* Thread conductors through connector. The latter slides down on cable so that end holds the bushing in protective position inside of cable and the cutaways or open spaces between the lugs permit wireman or inspector to see that the bushing is in place.

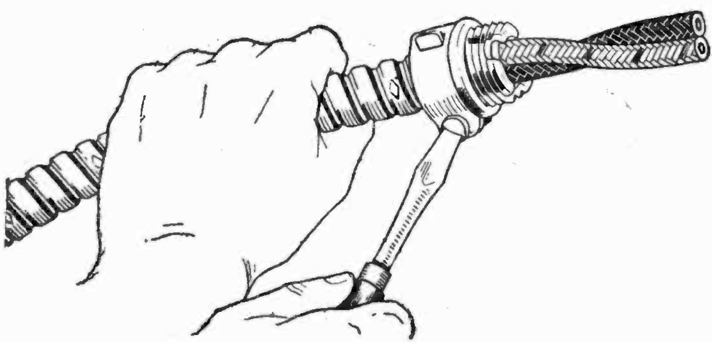
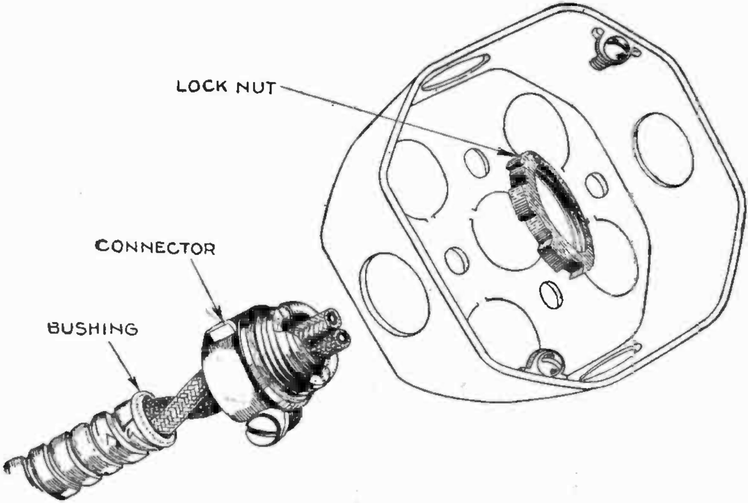


FIG. 5,400.—*Connecting cable with box 3.* Secure connector to cable by tightening screws.



Figs. 5,401 to 5,403.—*Connecting cable with box 4.* Thread conductors and end of connector through knockout of box and put on nut.

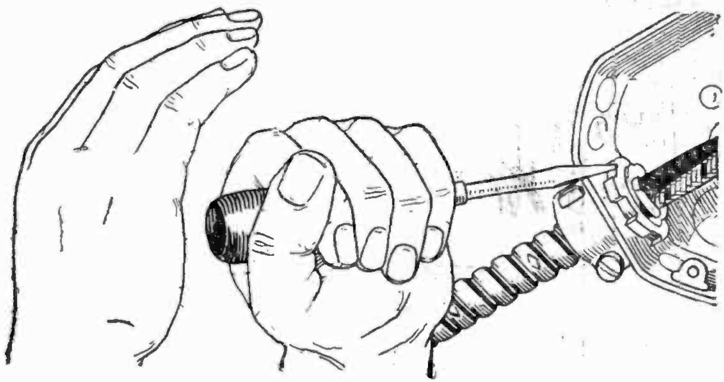


Fig. 5,404.—*Connecting cable with box 5.* Tighten lock nut. This finishes the operation. It will be noticed that the type nut shown can be tightened with a screw driver, which may be an easier method than using a wrench in cramped positions.

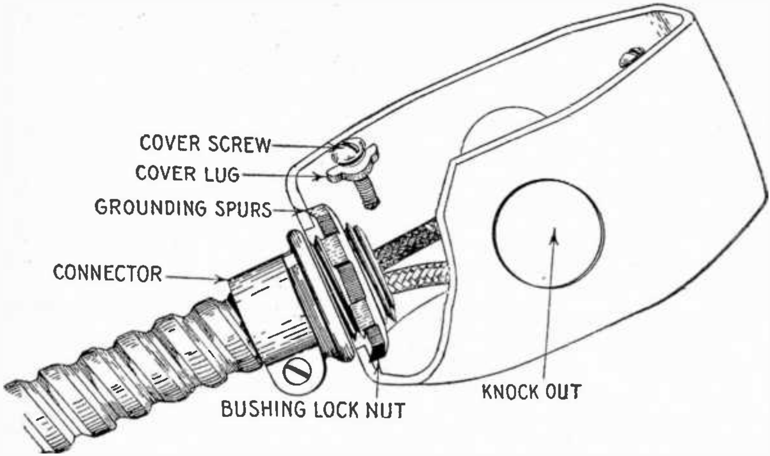


FIG. 5,405.—National connector connected to outlet box showing bushing.

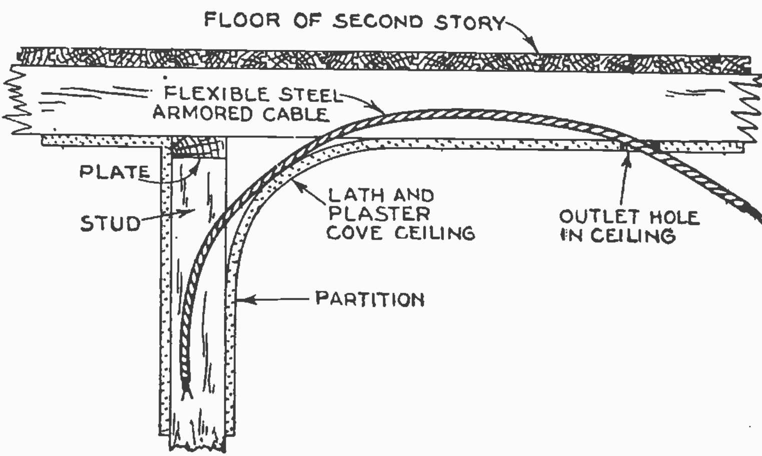


FIG. 5,406.—Method of passing armored cable through walls, ceilings, partitions, etc.

It is advisable to fasten the armored cable to timbers by means of pipe straps, wherever access permits this to be done.

Fig. 5,406 shows method of forcing armored cable around a cove ceiling.

Make all bends as gradual as possible to avoid opening the armor, as would occur at sharp bends. Secure the armored conductor at all exposed bends, and especially when it is used around machinery. Figs. 5,407 and 5,408 show right and wrong way to make a bend.

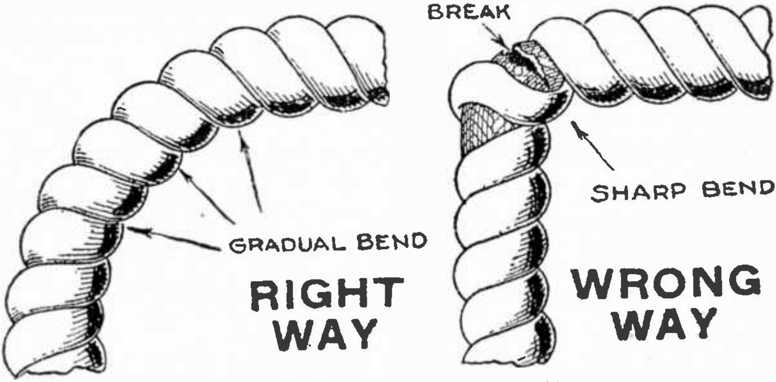


FIG. 5,407 and 5,408.—Right and wrong way to bend armored cable.

Code.

610. Armored Cable

For installation, see section 505.
For armored cord, see section 609.

a. The conductors shall comply with the requirements for rubber-covered wires of the specific type.

b. The cable shall have a continuous distinctive marking so that the maker may be readily identified.

505. Armored Cable.

a. When armored cable, types AC or ACL, is used as the wiring method, the provisions of the following paragraphs of this section shall be observed.

b. Armored cable shall not be used for systems of more than 600 volts nor where its surrounding temperature will exceed 120° F. (49° C.).

Code.—*Continued.*

c. Type AC armored cable may be used for open or concealed work in dry locations and may be fished; when run on walls of brick or similar masonry it may be embedded in the plaster finish.

d. Wires of armored cables shall be of rubber-covered type. The armored cable shall carry a distinctive marker throughout its entire length.

e. Approved outlet boxes or fittings shall be installed at all outlets and switch points as required by paragraphs (*a*) and (*b*) of section 703. The cable shall be continuous from outlet to outlet, or from fitting to fitting, and the armor shall be mechanically and electrically connected to all fittings in a manner to substantially close the openings at entrance points and to hold the cable securely. The entire cable system shall be secured in place by approved fastenings.

f. When in exposed or concealed wiring, cable is run through bored holes in studs, joists or similar wood members, such holes shall be bored at the approximate center of such timbers and not less than two inches from the nearest edge, if their depth will permit.

g. When the cable is employed in accessible attics or roof spaces, it shall be installed as follows:

> 1. When run within five feet of the floor or floor joists, through bored holes in rafters or studs, or when run through bored holes in floor joists, cable shall be protected by substantial running boards extending at least one inch on each side of the cable or cables, and be securely fastened in place.
>
> 2. When within five feet of floor or joist, across the face of rafters or studding. or across the top or face of floor joists, cable shall be protected by substantial guard strips at least as high as the cable.
>
> 3. When carried along the sides of rafters, studs or floor joists, neither guard strips, nor running boards shall be required.

h. All bends shall be so made that the armor of the cable will not be injured, and the radius of the curve of the inner edge of any bend shall be not less than five times the diameter of the cable.

i. At all points, where the armor terminates, additional protection shall be afforded to the conductors by approved connectors or clamps so that the conductor will be adequately bushed

j. Type ACL (having a lead sheath under the armor) shall be used in underground service runs and where other circuits are embedded in masonry, concrete, or fill in buildings in course of construction, and elsewhere, if the location is such that the cable will be exposed to the weather or to contiauous moisture or dampness.

k. For the use of armored cable in under-plaster extensions, see Section 510 of this Article.

l. Where alternating current is to be employed, all conductors of a circuit shall be contained within one armor except as provided in section 510 of this article.

> It is recommended that in the case of direct current also all conductors of a circuit be placed within one armor, in order to obviate induction troubles if a change is made to alternating current at a later date.

m. The armor shall be grounded as prescribed in Article 9 of this code.

TEST QUESTIONS

1. *Describe the construction of an armored cable.*
2. *Name two kinds of armored cable.*
3. *What are the advantages and disadvantages of armored cable?*
4. *Is armored cable as expensive as rigid or flexible conduit?*
5. *What kind of cable should be used in damp places?*
6. *Describe the proper method of cutting armored cable.*
7. *What should be done before installing cable?*
8. *How is the conductor insulation protected from the sharp edge at the end of the cable?*
9. *Describe the method of cutting, stripping and inserting the bushing.*
10. *Explain in detail the method of installing armored cable.*
11. *Explain how the cable is attached to an outlet box.*
12. *What precaution should be taken in cutting the cable?*
13. *If the cable be cut too short, what must be done?*
14. *How is the cable secured when it runs parallel with joists or studs?*
15. *What method is followed in wiring an old house?*
16. *How is a snake used in passing the cable through walls?*
17. *How should bends be made?*
18. *What happens to the cable if the bend be too short?*

19. *What should be done with exposed bends?*
20. *What should be done in order to avoid undue fatigue in boring holes?*
21. *Describe the method of inserting cable.*
22. *What tool is used in cutting a cable other than a hacksaw?*
23. *How is a connector secured to a cable?*

CHAPTER 113

Wiring in Flexible Conduit

A flexible conduit consists of a continuous flexible steel tube composed of convex and concave metal strips, wound spirally upon each other in such a way as to interlock their concave surfaces.

It possesses considerable strength and can be obtained in long lengths (50 to 200 feet); elbow fittings are not required as the conduit may be bent to almost any radius. The fissures of the conduit provide some ventilation; this is an advantage in some places and a disadvantage in others.

Flexible conduit should not be used in damp places because of the fissures through which moisture may enter.

Although flexible conduit is easy to handle, because it is flexible, it is not desirable to install an entire wiring job with this kind of conduit. It is better combined with rigid conduit for extensions having short and irregular runs, thus avoiding extra and difficult pipe fitting.

Flexible conduit provides a method of passing through joists and studs, avoiding notching. Flexible conduit is made in two types.

1. Single strip;
2. Double strip.

The single strip flexible conduit is made of *one* continuous length of electro-galvanized steel strip, with the edges turned to interlock, as shown in fig. 5,409.

This construction is approved for service under the most rigorous conditions—severe bending or pulling will not separate the joints. The uniform convolutions in single strip conduit have a flattened outside surface which makes the conduit easy to pull through holes and the smooth even inside surface allows wires to slide easily in fishing.

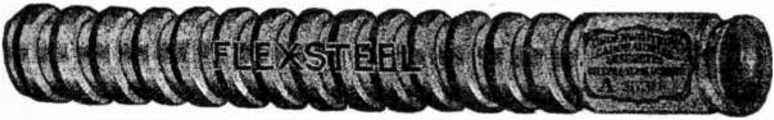


FIG. 5,409.—National single strip flexible conduit. Put up in 250 ft. lengths and where under 250 ft., in lengths that work out in multiples of 5 ft. from 100 to 250 ft.

Double strip flexible conduit is made of *two* electro-galvanized steel strips, turned at the edges, and wound so that the strips of the outside armor *key* into the edges of the inside strips, as shown in fig. 5,410.

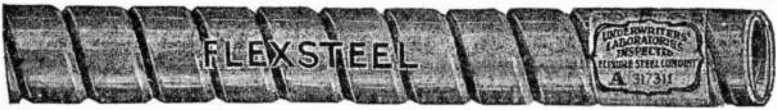


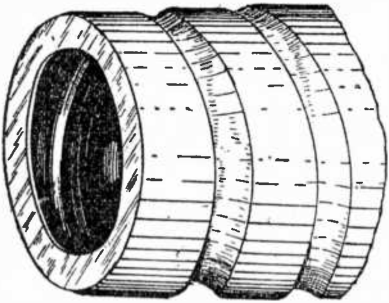
FIG. 5,410.—National double strip flexible conduit. Can be had in the same lengths as the single strip cable.

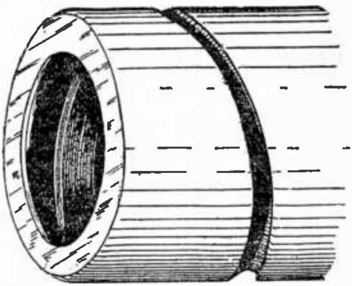
This gives a double armor for protection of conductors, having greater flexibility, and greater resistance to injury and strain. The long convolutions, flat inside and outside, permit the conduit to pull through holes easily, and provide a smooth wire channel through which to fish wires.

Flexible conduit is used to advantage in many cases where rigid conduits would not be desirable. It is especially adapted to completed buildings where it is desired to install the wiring by "fishing" without greatly disturbing the walls, floors or ceilings.

In installing flexible conduit, it is "fished" under floors, in partitions between the floor and ceiling, by making pockets in the floors, walls or ceilings, say every 15 or 20 feet, and fishing through first a stiff metal wire called a "snake," and then attaching the conduit to same and pulling the conduit in place from pocket to pocket.

On vertical runs, a chain or weighted string is used which is dropped from the outlet to the floor and its lower end located by sound of the chain end or weight striking the floor.





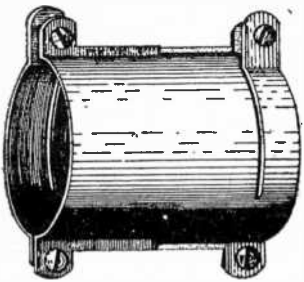
FIGS. 5,411 and 5,412.—Brass terminal bushings or ferrules. Fig. 5,411, single strip bushing; fig. 5,412, double strip bushing.

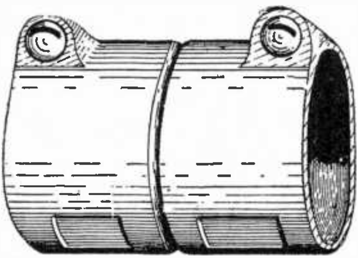
For quick and easy installation in making necessary connections various *fittings* are used with flexible conduit as with other systems. These fittings are suitable for armored cable as well as flexible conduit. They may be broadly classed as:

1. Terminal bushings;
2. Couplings;
3. Connectors;
4. Adapters.

Terminal Bushings or Ferrules.—These bushings are used to protect the conductors against abrasion from the raw edge of the cut armor. Two types of bushing are shown in figs. 5,411 and 5,412.

Couplings.—The object of a coupling is to connect two lengths of conduit. There are several types of coupling and they may be classified:





FIGS. 5,413 and 5,414.—National couplings for connecting flexible conduit to flexible conduit. Fig. 5,413, squeeze type; fig. 5,414, tangent screw type.

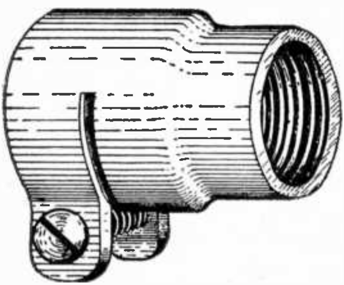


FIG. 5,415.—National squeeze type coupling for connecting flexible to rigid conduit.

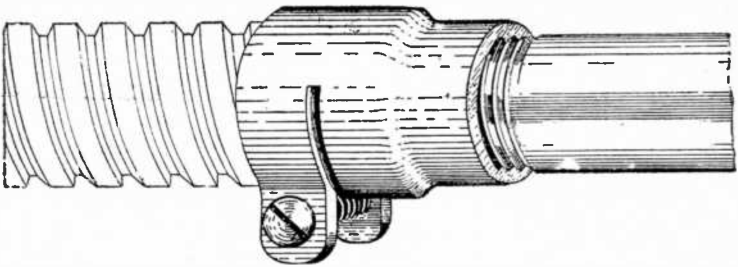
1. With respect to the conduit, as

   a. Single strip flexible to single strip flexible conduit
   b. Double " " " double " "
   c. Single " " " rigid conduit
   d. Double " " " " "

These various types of couplings are shown in figs. 5,413 to 5,415 and connections in figs. 5,418 and 5,419.

These couplings are an essential part of the economical installation of flexible conduit, as they make possible the use of short ends. At least one coupling should be ordered with every coil conduit.

Connectors.—These fittings are used for connecting the conduit to devices such as outlet boxes. There are several types adapted to the different requirements, and they may be classified as



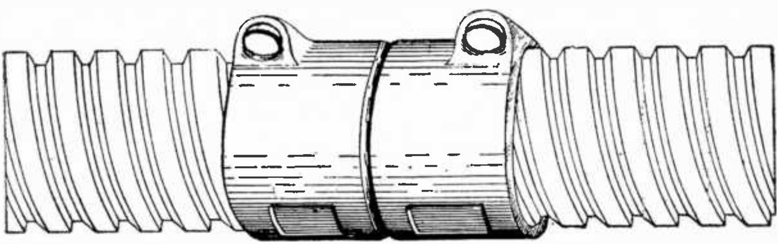


FIG. 5,416.—Flexible to flexible conduit connected by coupling.

FIG. 5,417.—Flexible to rigid conduit connected by coupling.

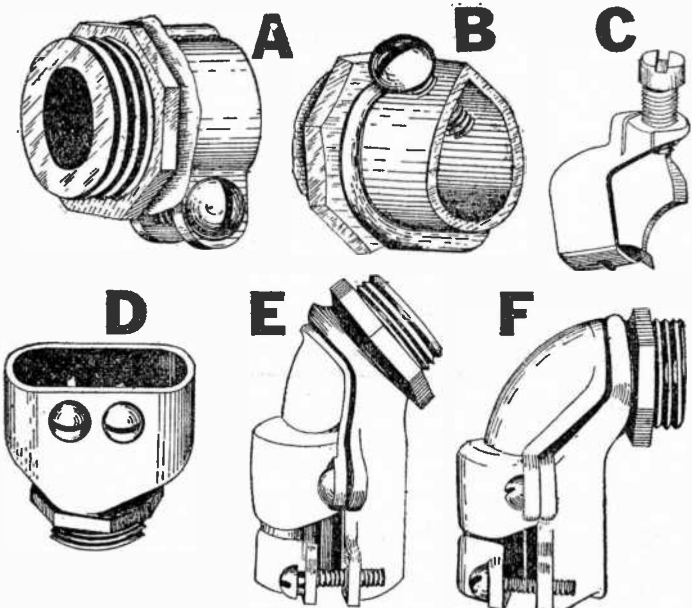
1. Squeeze;
2. Set screw;
3. Slip in;
4. Duplex;
5. Angle.

These various classes of connector are shown in figs. 5,418 to 5,423.

Squeeze connectors are designed to give a firm grip entirely around the armor. They are made of malleable iron, galvanized, and are supplied with lock nuts.

Set screw connectors are provided with a strong tangential screw which is forced between the armor and the side of the connector. As the screw normally follows the groove of the armor, it is virtually impossible for the armor to work loose.

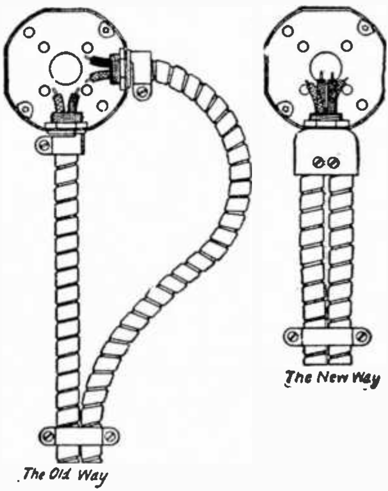
Slip in connectors are designed for quick work. This type connector



FIGS. 5,418 to 5,423.—Various General Electric connectors. A, squeeze; B, set screw; C slip in; D, duplex; E, 45° angle; F, 90° angle.

needs no lock nut, and is so easy to install that it is a valuable time saver. Just run the end of the conductor through the connector, slip the connector into the knock out and tighten the set screw. It is made of malleable iron, galvanized.

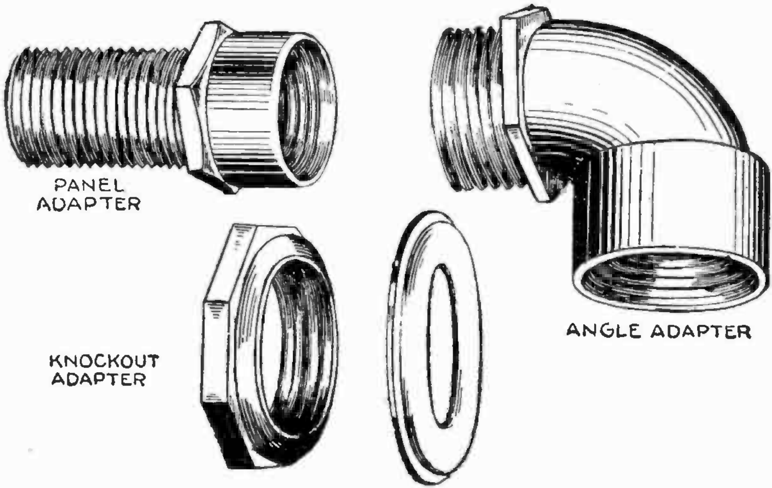
Duplex connectors are used in installations where it is desired to run two conductors into one knock out. One duplex in place of two separate connectors in two different knock outs, saves time in installing, makes a much neater job, saves cable, and doubles the effective number of outlets. This latter feature is quite important when one or two of the knock outs are inaccessible. The duplex is made of malleable iron, galvanized, and



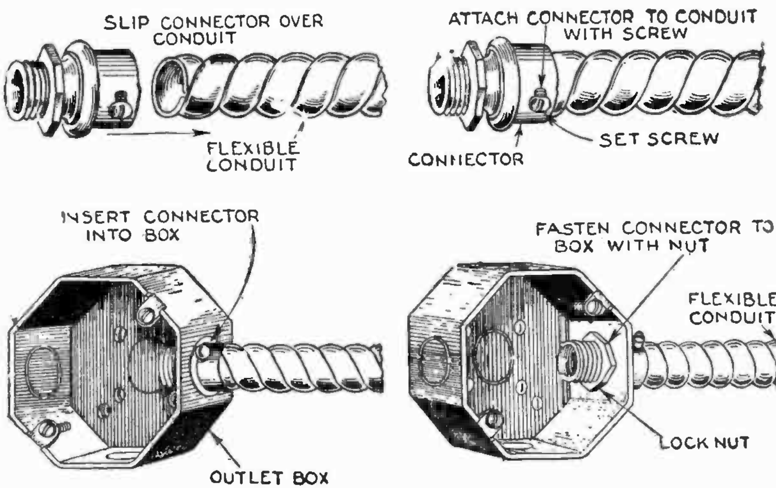
Figs. 5,424 and 5,425.—Comparison of separate and duplex connectors. The duplex connector takes less time to install than two single connectors, and insures a neater job. A saving of 6 ins. of cable is effected also, at every outlet of the kind indicated.

is of the tangential set screw type. The advantage of using a duplex instead of two connectors is shown in figs. 5,424 and 5,425.

Angle connectors are for the purpose of connecting the conduit at an angle to devices such as outlet boxes. They are designed to connect at angles of 45° and 90° as shown in figs. 5,422 and 5,423. In practically every flexible installation, a few of these convenient connectors will save time and make a better job, as they make possible close fitting work in cramped locations.



Figs. 5,426 to 5,429.—Various General Electric adapters.



Figs. 5,430 to 5,434.—Connecting flexible conduit to outlet box, showing the various operations.

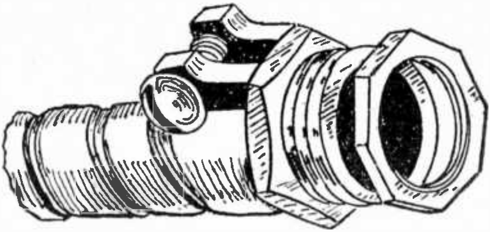
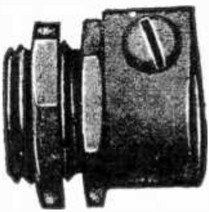
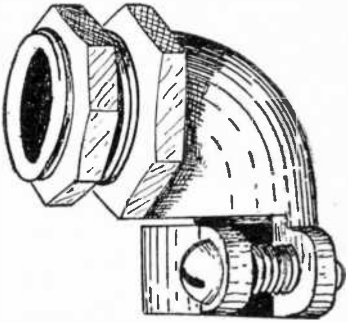
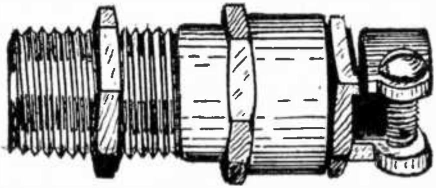


FIG. 5,435.—Rattan straight squeeze connector.





FIGS. 5,436 and 5,437.—Rattan connectors. Fig. 5,436 straight set screw connector; fig. 5,437, 90° angle squeeze connector.



FIGS. 5,438 and 5,439.—Rattan connectors. Fig. 5,438, 45° angle squeeze connector; fig. 5,439, straight panel box squeeze connector.

Adapters.—All threaded connectors for the prevailing sizes of armored conductors and flexible conduit are designed for ½ inch knockouts, but by the use of an adapter, it is possible to use them equally as well with ¾ inch knock outs.

It is an invaluable device for connecting armored conductors or flexible conduit to condulets which have only the ¾ inch knock out. Any threaded connector may be used as a *panel* connector by connecting with this adapter. This fitting converts any straight, threaded connector into a 90° angle connector. Figs. 5,426 to 5,429 show various types of adapters.

How to Connect Conduit to Outlet Box.—After cutting the conduit to proper length and reaming the end, the connector is slipped over the end of the conduit as in fig. 5,430, and fastened to the conduit as in fig. 5,431.

Insert the connector through the knock out in box and put on lock nut as in fig. 5,432. A bushing is next screwed on as in fig. 5,433. When a bushing is used, the lock nut may be placed either inside the box or on the outside.

Code.

The Code requirements for flexible conduit are given n the chapter on Rigid Conduit following.

TEST QUESTIONS

1. *What is a flexible conduit?*
2. *In what lengths is it manufactured?*
3. *Where should flexible conduit not be used?*
4. *Is it desirable to install an entire wiring job with flexible conduit?*
5. *Name two types of flexible conduit.*
6. *Where is flexible conduit used to advantage?*
7. *How is flexible conduit installed under floors, between partitions or between walls?*
8. *What is provided for quick and easy installation?*
9. *Classify the various fittings used.*
10. *What are terminal bushings or ferrules used for?*
11. *Name several types of couplings.*
12. *What is a connector, and what are the various types?*
13. *What are squeeze connectors used for?*
14. *What is the advantage of a slip in connector?*
15. *Explain the use of a duplex connector.*
16. *What is an adapter?*
17. *How is flexible conduit connected to an outlet box?*
18. *What should be removed from the box in order to connect a conduit?*
19. *Can a threaded connector be used as a panel connector?*
20. *Draw a sketch showing difference between separate and duplex connector.*

21. *What angles are angle connectors designed for?*
22. *What is the advantage of angle connectors?*
23. *Are the fissures in the conduit an advantage or a disadvantage?*

CHAPTER 114

Wiring with Non-Metallic Sheathed Cable

This type of cable is designed for the wiring of residences and similar buildings of frame or semi-frame construction

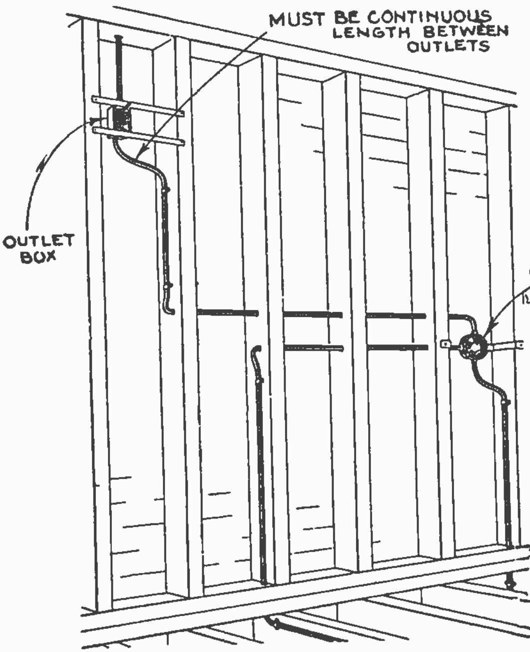
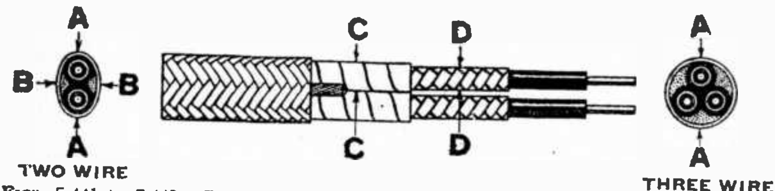


FIG. 5,440—Installation of non-metallic sheathed cable. Must be one continuous length between boxes.

which are generally classified as *dry locations*, and in which the difference in pressure between two conductors does not exceed 300 volts.



FIGS. 5,441 to 5,443.—Rome non-metallic sheathed cable. The cable is built up by first sheathing a rubber covered Code wire, in a tough, closely laid jacket of laminated kraft tape, which is permanently held in place by a cotton braid. After saturation with special compounds this semi-finished conductor is armored with a second jacket of long fibre kraft tape, and a fire and moisture resistant compound applied. Two or more of these heavily armored conductors are then gathered, with their reinforcing filler cords, under an extra heavy fabric braid, and the cable given two final impregnations of fire and moisture resistant compounds. Made with conductors ranging in size from No. 14 to No. 8. Reference letters indicate principal dimensions.

FIG. 5,444.—Passing non-metallic sheathed cable through holes bored in beams.

In addition to the usual secondary feeder and circuit wiring of residences and similar properties non-metallic sheathed cable is being widely used for installation of circuits for electric ranges and various other heavy duty domestic appliances.

Most inspection departments permit non-metallic sheathed cable to be installed in cellars, in accessible unfinished attics or roof spaces and in private garages of not more than two car capacity.

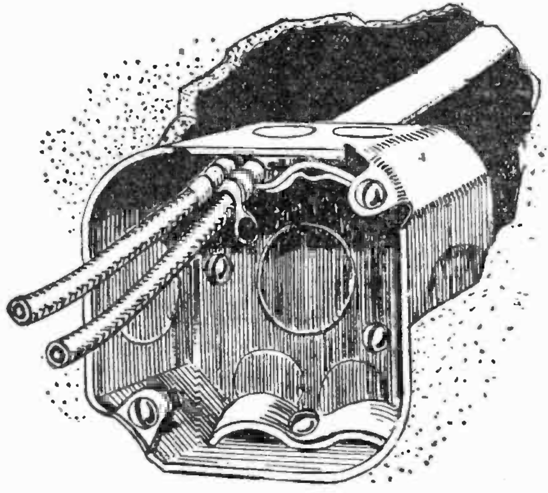


Fig. 5,445.—Romex outlet box for non-metallic sheathed cable.

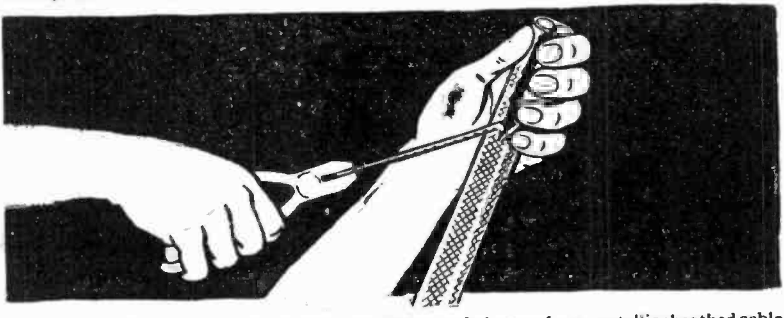


Fig. 5,446.—Method of removing sheath from ripper corded type of non-metallic sheathed cable by pulling the ripper cord.

The construction of a typical cable, as made by the Rome Wire Co., is shown in figs. 5,441 to 5,443.

Installation of Non-Metallic Sheathed Cable.—This type

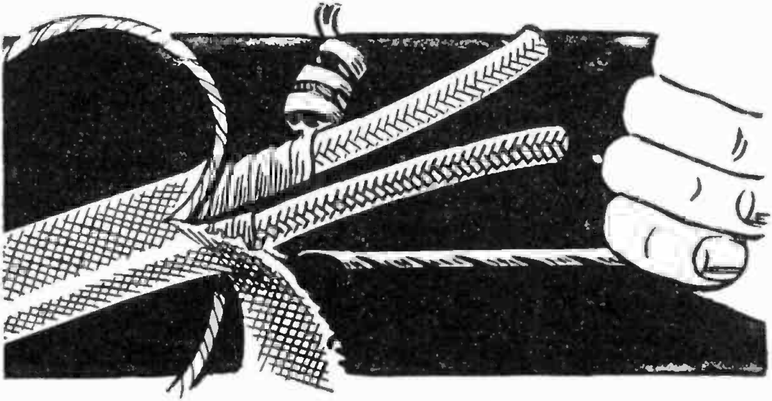


FIG. 5,447.—Method of removing undersheath of non-metallic sheathed cable.

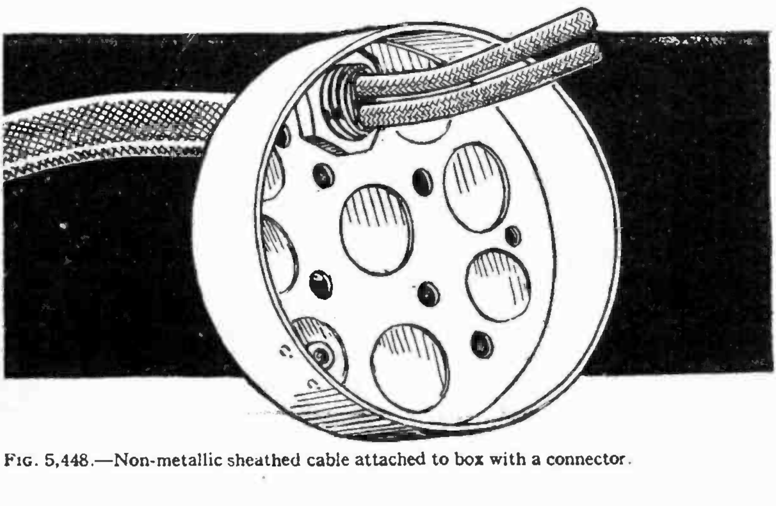


FIG. 5,448.—Non-metallic sheathed cable attached to box with a connector.

cable should be installed on the *loop system* only, that is, in continuous, unbroken runs from outlet to outlet and without joints or splices of any kind throughout the lengths between outlets, as is indicated in fig. 5,444.

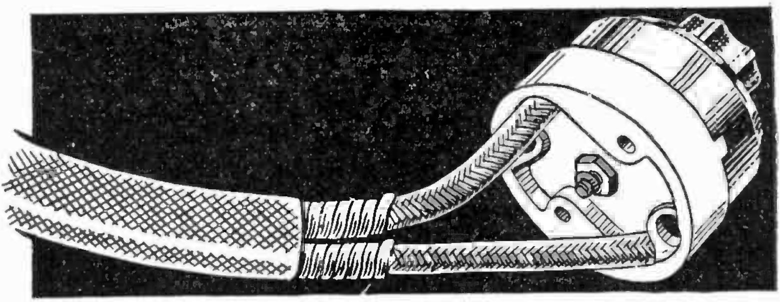
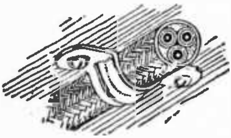


FIG. 5,449.—Non-metallic sheathed cable connected to a snap switch.

FIG 5,450.—Non-metallic sheathed cable run parallel with beams.

In fastening the cable, the method shown in fig. 5.451 will suffice where its appearance is not objectionable, but for a neat job, it should be done as in figs. 5,452 and 5,453.



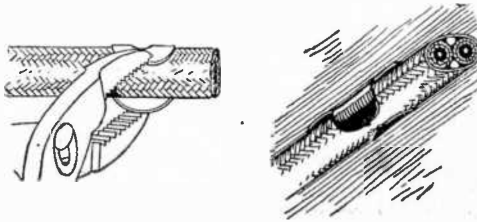
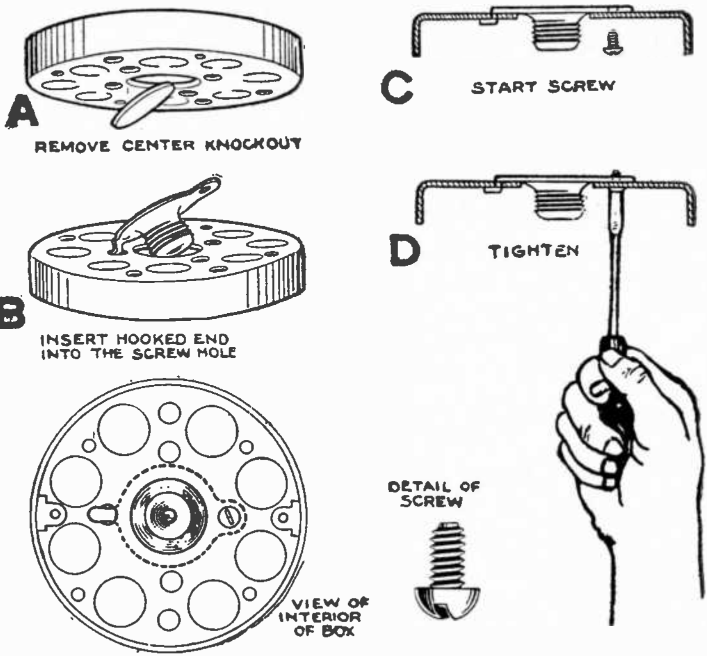


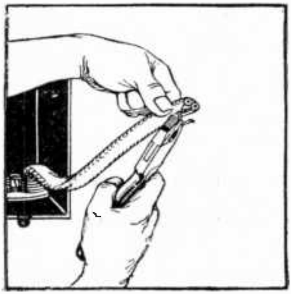
FIG. 5,451.—Method of fastening non-metallic sheathed cable with straps.

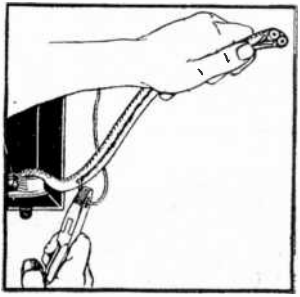
FIG. 5,452 and 5,453.—Method of fastening non-metallic sheathed cable with clips.

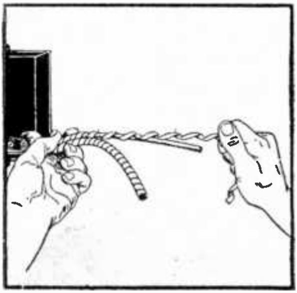


FIGS. 5,454 to 5,459.—Attachment of fixture stud to box.

Non-Metallic Sheathed Cable at Outlets.—Almost any type of outlet plate or box for armored cable may be used with the sheathed cable as the cable enters and is very tightly gripped by most clamping devices.







Figs. 5,460 to 5,462.—Stripping Rome non-metallic sheathed cable. Nick the end of "Romex" with a knife and grip either one of the ripped parts, as shown in fig. 5,460; rip open the desired length of the outer braid, as in fig. 5,461, and spin off the outer tape as in fig. 5,462. To provide plenty of room for splices and outlet boxes, the outside tape should be trimmed off back to the outer braid.

Fig. 5,463 shows typical outlet plate used at outlets on old jobs. Figs. 5,464 and 5,465 show types of pans or shallow boxes at outlets. When sheathed cable is used with a fitting having threaded hubs for conduit or with a box having knock outs for conduit, squeeze connectors shoud be used as shown in figs. 5,466 and 5,467.

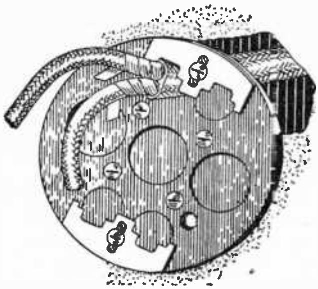
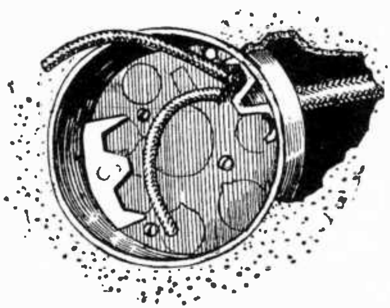


FIG. 5,463.—Typical outlet plate as used for RomeX, and other wire outlets upon old jobs. Romex plates are designed for use at such outlets where conditions do not require the use of an outlet box. Knockouts are provided, each of which will accommodate two non-metallic conduits. The special clamps securely hold the loom against all strains. A centrally located knockout is provided for gas pipe or fixture stud mounted on bar hanger. Clearance holes allow mounting fixture stud on the plate itself.



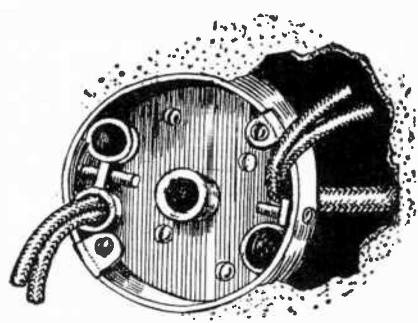
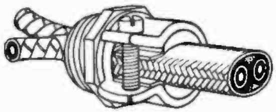
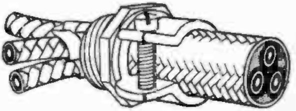


FIG. 5,464 and 5,465 —Shallow outlet boxes for non-metallic sheathed cable wire

Non-Metallic Sheathed Cable in Cellars.—In many localities the use of rigid conduit in cellars is required, but in districts where such rules do not exist most inspection departments permit the use of non-metallic sheathed cable, providing the cable be tightly strapped to the faces or to the sides of timbers when running with them or is well strapped to running boards or guard strips where carried across timbers, as shown in fig. 5,474.





FIGS. 5,466 and 5,467.—Connectors for two and three wire non-metallic sheathed cable.

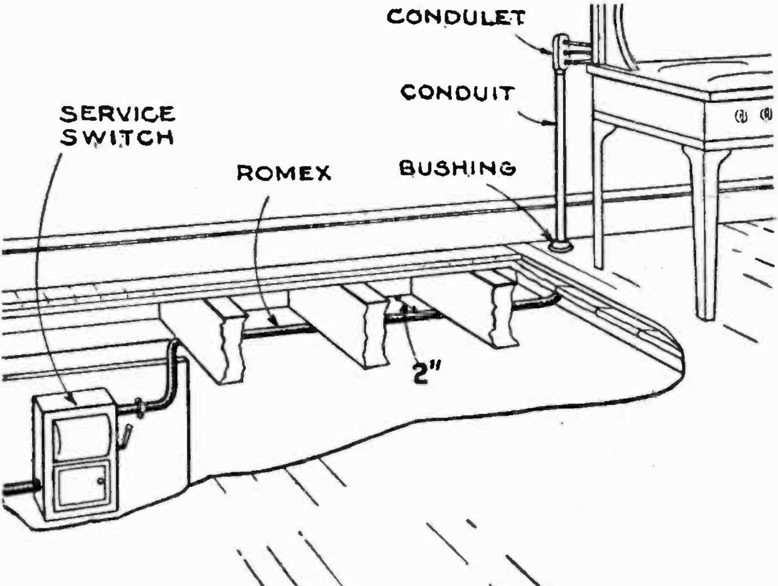
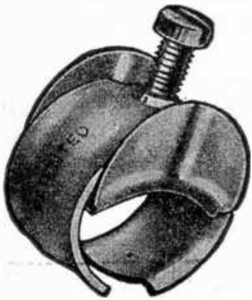


FIG. 5,468.—Wiring with Romex for service switch to electric range showing method of passing through floor, and terminal fitting.

Non-Metallic Sheathed Cable on Side Walls.—When used for open wiring in small private garages, basements, farm houses



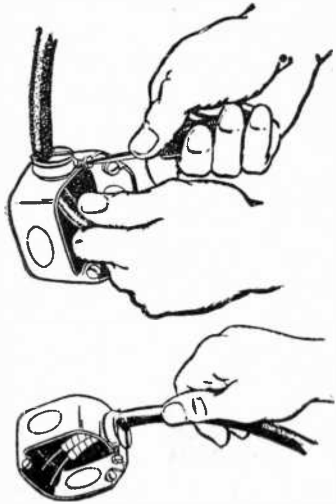
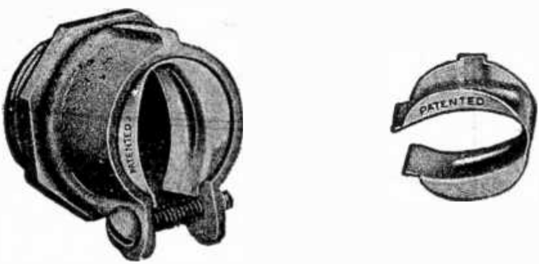


FIG. 5,469.—Steel City connector for non-metallic sheathed cables and flexible tubing. This connector can be installed outside or inside of a box.

FIGS. 5,470 and 5,471.—Method of installing Steel City connector for non-metallic sheathed cable and flexible tubing. ***To install,*** snap connector into knock out; insert cable or tubing and tighten screw.



FIGS. 5,472 and 5,473.—Steel City connector for non-metallic sheathed cable and flexible tubing. Fig. 5,472, connector assembled; fig. 5,473. The insert is so designed that the non-metallic flexible cable is held in the center of the connector so that when the strap is tightened down no sharp curve or bend is put in the conductor. The insert presents a long bearing surface to the conductor.

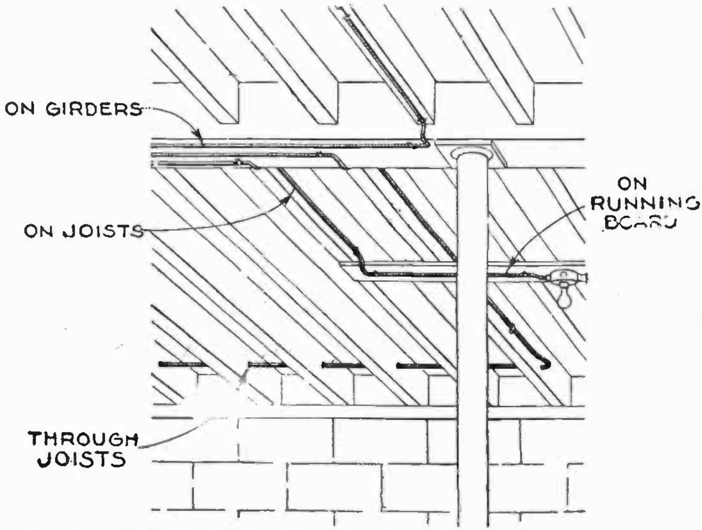


Fig. 5,474.—Method of running non-metallic sheathed cable in cellars.

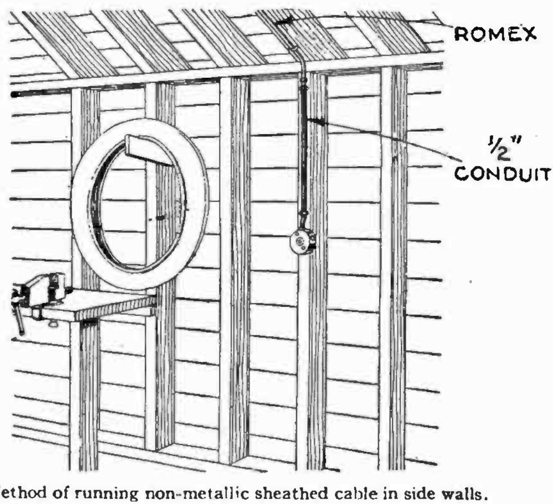


Fig. 5,475.—Method of running non-metallic sheathed cable in side walls.

and similar classes of property, non-metallic sheathed cable should be protected on side walls with either wood boxing, conduit or ordinary pipe extending upward to a point at least seven feet above the floor, similarly as shown on page 3,204.

Non-Metallic Sheathed Cable in Attics.—When run in accessible attics or roof spaces, non-metallic sheathed cable

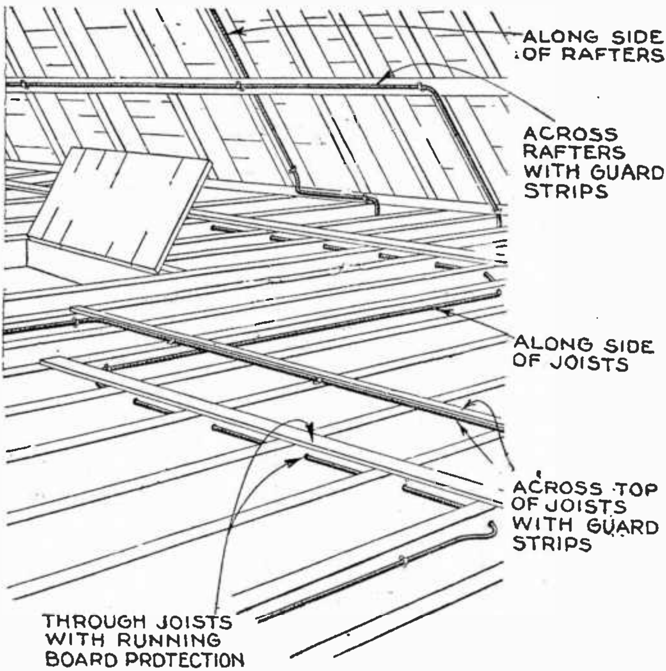


FIG. 5,476.—Method of running non-metallic sheathed cable in attics.

should preferably be either strapped to sides of joists, or if running at angles with the joists should be carried through bored holes and covered with a running board, as shown in fig. 5,476. Most inspection departments permit non-metallic sheathed cable to be run on top of timbers in attics only when runs are along under side of roof timbers or are well back from scuttle openings.

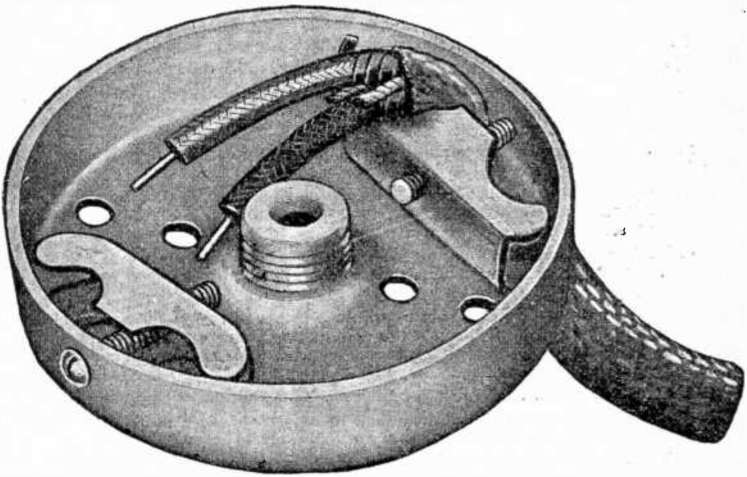


FIG. 5,477.—National outlet box for loom and loom wire. Double grip clamp for loom. Brass ferrule in addition should be used for armored cable. Extra knock outs for cable or loom and screw hole for extra clamp. This box also takes armored cable.

Code.

611. ***Non-Metallic Sheathed Cable***

For installation see section 507.

a. The conductors shall comply with the requirements for rubber-covered wires, except that no braid need be provided directly over the rubber covering.

b. Cable shall be of approved type, in sizes 14 to 4, inclusive, and in two or three-wire assemblies and in addition shall have an approved size of non-insulated copper conductor laid in next to the insulated conductor for grounding purposes.

c. The cable shall have a continuous distinctive marker so that the maker may be readily identified.

507. ***Non-Metallic Sheathed Cable.***

a. Cable shall not be used for circuits exceeding 300 volts between conductors nor 150 volts to ground.

Code.—Continued.

b. Cable shall only be used for wiring in residence buildings, and in outbuildings on the same premises, or for the wiring of office or mercantile occupancies in residence neighborhoods, which individual occupancies do not require more than four branch circuits.

c. Cable shall not be installed in masonry, concrete or fill in buildings in course of construction, nor where exposed to the weather, nor in continuously damp or moist locations.

d. Cable shall be of approved type, in sizes 14 to 4 inclusive and in two or three-wire assemblies and in addition shall have an approved size of non-insulated copper conductor laid in next to the insulated conductors to be used only for grounding purposes.

e. When employed for exposed wiring, cable shall be installed as follows:

1. Shall be mounted directly upon and unless substantial running boards are used, shall closely follow the surface of woodwork, plaster, cement, brick or other building finish.

2. Shall be secured between outlets with approved fastenings spaced at intervals not exceeding three feet.

3. Vertical runs shall be protected within five (5) feet of the floor by a rigid conduit or pipe, or a substantial wood or metal protecting strip, placed over the cable and securely fastened in place.

4. Horizontal runs within five (5) feet of the floor shall be protected as specified in paragraph (3) above, unless substantial protection is afforded by fixed furniture.

5. Where passing through floors or within 6 inches of floors, cable shall be protected by a length of rigid conduit or pipe passing through the floor, and extending at least 6 inches above the floor, in addition to the protection specified in sub-paragraph (3) above.

f. When employed in concealed wiring, cable shall be installed as follows:

1. In building under construction, shall be secured between outlets by approved fastenings spaced at intervals of not exceeding 4½ feet.

2. In finished buildings where impracticable to support the cable as specified in the preceding paragraph, cable may be fished from outlet to outlet.

g. Cable, exposed or concealed, shall be run in continuous lengths, without joints, splices, or taps, from outlet box to outlet box, or other approved terminal fittings, and shall be secured thereto by means of approved devices which substantially close the openings. Approved outlet boxes or fittings as required by paragraphs *a* and *b* of section 703 shall be installed at all outlets and switch points. The grounding conductor shall be connected to the boxes or fittings by approved means.

h. Bends in cable shall be so made and other handling shall be such that the protective coverings of the cable will not be injured, and no bend shall have a radius less than five times the diameter of the cable.

i. Shall not be buried in walls, floors, or ceilings of plaster, cement, or similar finish.

j. When non-metallic sheathed cable is installed in conduit or in surface or underfloor raceways, the provisions of sections 503, 504, and 506 of this article shall apply as far as practicable.

k. When in exposed or concealed wiring, cable is run through bored holes in studs, joists, or similar wood members, such holes shall be bored at the approximate center of such timbers and not less than two inches from the nearest edge, if their depth will permit.

l. Cable in accessible attics or roof spaces, shall be installed as follows:

1. When run within five feet of the floor or floor joists, through bored holes in rafters or studs, or when run through bored holes in floor joists, cable shall be

Code.—Continued.

protected by substantial running boards extending at least one inch on each side of the cable or cables and securely fastened in place.

2. When within five feet of floor or joist, across the face of rafters or studding, or across the top or face of floor joists, cable shall be protected by substantial guard strips at least as high as the cable.

3. When carried along the sides of rafters, studs or floor joists, neither guard strips, nor running boards shall be required.

m. Cable in unfinished cellars or basements, if not run through bored holes in beams or floor joists, shall be run on the under side of running boards not less than ⅞ inch by 1¾ inches when run at angles with floor joists or timbers, or on sides or faces of floor joists or timbers when run parallel with them. 3-wire assemblies of cables larger than No. 8 run at angles with floor joists or timbers need not have the guard rails specified in sub-paragraph 2 of the preceding paragraph.

n. In other places where subject to mechanical injury, cable shall be substantially protected by one of the above methods.

TEST QUESTIONS

1. *For what service conditions is non-metallic sheathed cable adapted?*
2. *Describe the construction of non-metallic sheathed cable.*
3. *Is non-metallic sheathed cable suitable for heavy duty domestic appliance circuits?*
4. *What is a ripper cord?*
5. *How is the under sheath removed from the conductors?*
6. *Describe in detail the method of connecting the cable to an outlet box.*
7. *What methods are used in fastening the cable?*
8. *Can the cable be used with any type of outlet box?*
9. *When should connectors be used?*
10. *What is an outlet plate?*
11. *Is non-metallic sheathed cable allowed in cellars in all localities?*

12. *Explain two types of connector used.*
13. *What method should be used when cable is run in attics?*
14. *What are the important requirements of inspection departments when non-metallic sheathed cable is run in attics?*

CHAPTER 115

Wiring in Rigid Conduit

By definition, rigid conduit commonly called pipe (but different from ordinary pipe used for other purposes) comes in lengths of 10 ft. or less, and must never be used in sizes smaller than one-half inch pipe or nominal size.

The purpose of electrical conduit is to provide a raceway, either underground or throughout a building for electric wires. The inside surface must be unobstructed, smooth and dry so as to facilitate the pulling in of wire without damage to the insulation and to protect it against deterioration and rot.

Conduit must be ductile. It must be soft enough to thread easily, yet not so soft that the dies will run rather than cut. This is most important in making joints. It is essential that the pipe bend easily without opening welds or flattening at bends.

Galvanized conduit is recommended for use where the conduit is subject to rough usage and where the utmost in rust prevention is desired. It is especially recommended for use in street work, in concrete or masonry construction.

The following table gives the *properties* of rigid conduit and by comparing this table with a table giving the properties of *standard wrought pipe* (see the author's **Engineers and Mechanics Guide**, volume No. 7, Page 2,908) it will be seen that rigid conduit has the same properties as standard wrought pipe (sometimes erroneously called wrought iron pipe).

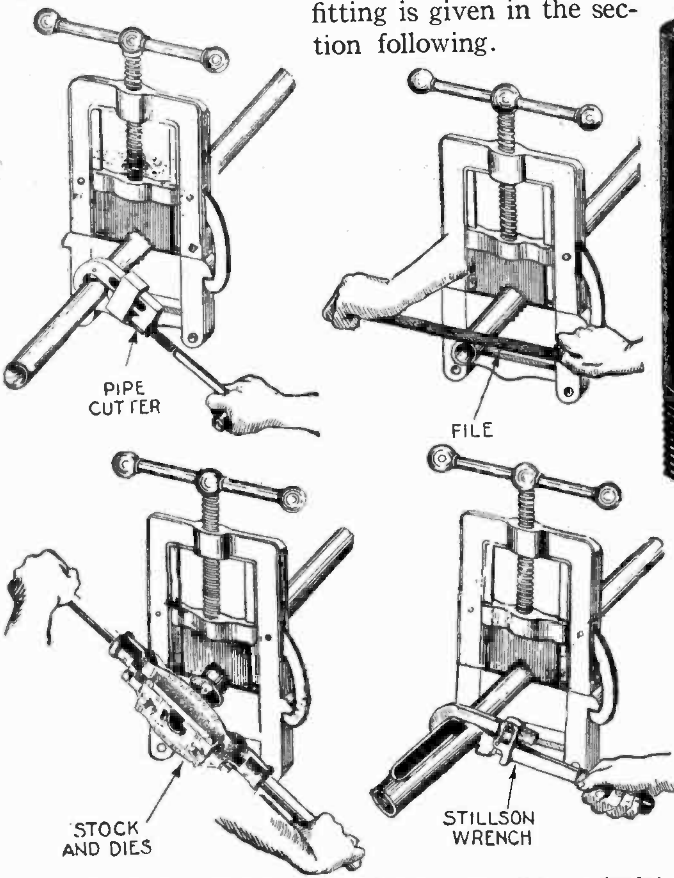
Properties of Rigid Conduit

Nominal Size	DIAMETERS		Thickness	WEIGHT PER FOOT			THREADS		COUPLINGS				ELBOWS			
	External	Internal		Plain Ends	Thread and Coupling Min.	Thread and Coupling Card	Threads per Inch	Length of Thread	Price Each	Nominal O. D.	Length	Weight Pounds	Price Each	Weight per 100 in Pounds	Radius Inches	Offset Inches
¼	.540	.364	.088	.424	.385	.426	18	.57	$0.05	.685	1.000	.043	$0.19	42	4.250	7.500
⅜	.675	.493	.091	.567	.515	.525	18	.57	.06	.875	1.125	.087	.19	53	4.250	7.500
½	.840	.622	.109	.850	.790	.859	14	.75	.07	1.063	1.375	.145	.19	75	4.250	7.375
¾	1.050	.824	.113	1.130	1.050	1.147	14	.76	.10	1.312	1⅝	.270	.25	120	5.375	8.375
1	1.315	1.049	.133	1.678	1.530	1.701	11½	.94	.13	1.576	1.875	.343	.37	200	5.750	9.500
1¼	1.660	1.380	.140	2.272	2.010	2.307	11½	.97	.17	1.950	2.125	.535	.45	300	7.250	10.875
1½	1.900	1.610	.145	2.717	2.490	2.768	11½	.98	.21	2.250	2.250	.750	.60	427	8.250	12.625
2	2.375	2.067	.154	3.652	3.340	3.770	11½	1.12	.28	2.812	2.625	1.25	1.10	700	9.500	15.250
2½	2.875	2.469	.203	5.793	5.270	5.905	8	1.51	.40	3.276	2.875	1.720	1.80	1300	10.500	17.375
3	3.500	3.068	.216	7.575	6.900	7.741	8	1.57	.60	3.948	3.125	2.500	4.80	1700	13.000	19.500
3½	4.000	3.548	.226	9.109	8.310	9.414	8	1.62	.80	4.591	3.625	4.241	10.60	2300	15.000	21.250
4	4.500	4.0.6	.237	10.790	9.820	11.125	8	1.67	1.00	5.091	3.625	4.741	12.25	2700	16.000	22.500
4½	5.000	4.506	.247	12.538	11.500	12.900	8	1.72	1.50	5.591	3.625	5.241	18.55	3100	18.000	24.375
5	5.563	5.047	.258	14.617	13.440	15.210	8	1.78	1.65	6.219	4.187	8.000	25.75	5500	24.000	32.000
6	6.625	6.065	.280	18.974	17.700	19.685	8	1.89	2.40	7.358	4.187	10.000	32.00	9000	30.000	39.750

NOTES—All weights and dimensions are nominal.
All weights given in pounds. All dimensions in inches.
The ends of all rigid conduit must be reamed on the inside to remove the burrs.
All rigid conduit ten feet (10′) long in finished lengths.
All sizes one and one-half inches (1½″) and under are bundled.
Conduit pipe is known and spoken of by its inside diameter.

The electrician who installs rigid conduit should be a good pipe fitter. For this reason, some helpful information on pipe fitting is given in the section following.

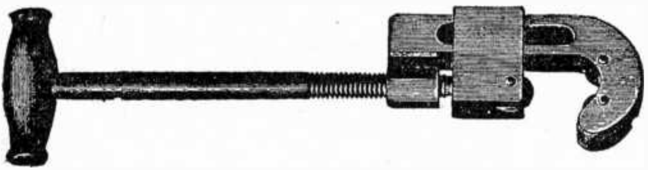
FIG. 5,478.—Rigid conduit. It is manufactured in 10 ft. lengths and comes threaded at both ends with coupling. It has practically the same proportions as standard wrought pipe.



FIGS. 5,479 to 5,482.—Principal operations in pipe fitting. The pipe after being marked to length by nicking with a file is put in a vise and cut with pipe cutter (or hack saw), fig. 5,479; burrs removed with file as in fig. 5,480. Next the thread is cut with stock and dies as in fig. 5,481 and *after carefully cleaning thread with stiff tooth brush,* and applying red lead or pipe cement to the thread just cut, the joint is made up with a Stillson wrench as in fig. 5,482. For interior work, the red lead or pipe cement is omitted, but should be used where conduit runs underground or where exposed to water.

Not all rigid conduit is made of steel, a limited amount being made of aluminum, which has advantages for special conditions.

Aluminum rigid conduit is manufactured in standard wrought pipe sizes and its dimensions are identical with those of steel conduit. It is furnished in ten foot lengths, and is enameled inside to conform with standard practice in manufacturing electrical conduit. It has standard pipe threads, each length being provided with a coupling. Aluminum conduit can be obtained in lengths up to 48 feet. It can be fitted and installed with the same tools and in the same manner as steel conduit.



FIGS. 5,483 and 5,484.—Two types of pipe cutter. Fig. 5,483, Barnes three wheel cutter; fig. 5,484, Saunders wheel and roller cutter.

Pipe Fitting.—The term "pipe fitting" includes the operations which must be performed in installing a pipe system as made up of pipe and fittings. These operations consist of:

1. Pipe cutting;
2. Pipe threading;
3. Pipe tapping;
4. Pipe bending;
5. Assembling.

Cutting.—The conduit should be cut with a hack saw unless the pipes are to be thoroughly reamed afterwards.

In the absence of a hack saw, cutting may be done with a pipe cutter. In either case the conduit is clamped in a pipe vise such as shown in fig. 5,485.

In securing the conduit in the vise, care should be taken (especially when threading) that the jaws hold the pipe sufficiently firmly to prevent slipping, but the clamp screw should not be turned enough to cause the jaw teeth to unduly dig into the pipe.

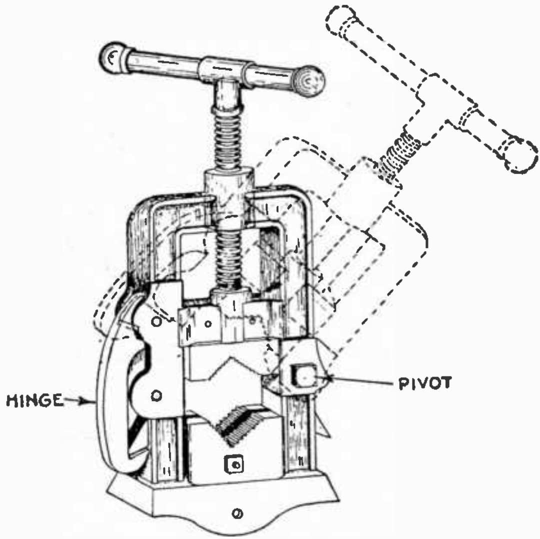


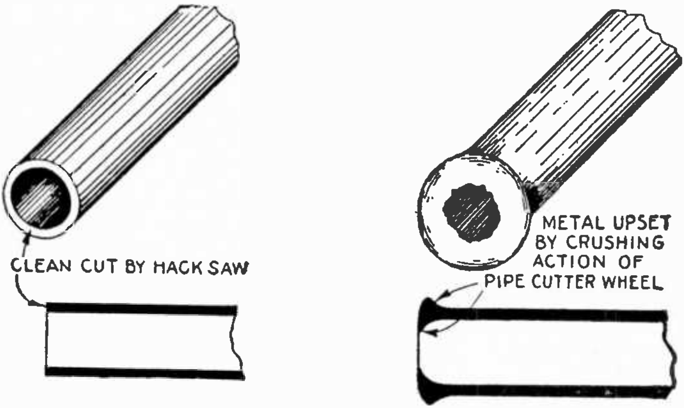
FIG. 5,485.—Ordinary pipe vise. *It consists of* a plain, or hinged (as shown), U-shape piece containing the clamp screw, the sides of which form guides for the upper jaws. The upper and lower jaws are provided with a series of rectangular teeth as shown. When the U piece is closed over the pipe, pin inserted, the teeth of both jaws are brought in firm contact with the pipe by screwing down the upper jaw thus holding the pipe firmly.

A pipe cutter is a tool which usually consists of a hook shaped frame on whose stem a slide can be moved by a screw. On the slide and frame several cutting discs or "wheels" are mounted and forced into the metal as the whole appliance is rotated about the pipe.

The operation of cutting a pipe can be done quicker with a pipe cutter than a hack saw, and for this reason the former is more frequently used, although it crushes the metal and leaves a shoulder on the outside and a burr on the inside of the pipe.

This does not apply to the knife type of pipe cutter. The appearance of the cuts made with hack saw and pipe cutter is shown in figs. 5,486 to 5,489.

The external shoulder must be removed to allow the pipe to enter the threading tool so no worry need be given that the



FIGS. 5,486 to 5,489.—Appearance of pipe end when cut by hack saw, and by pipe cutter. When a pipe cutter is used the internal burr must be removed by a burring reamer as in fig. 5,490, and the external burr by a file as in fig. 5,491.

workman will not do this, but *it should be ascertained* **by inspection** *that the internal burr is removed on every cut*, especially on conduit jobs to prevent the possibility of the burr cutting the insulation of the wires which would probably result in a short circuit.

The operation of removing an internal burr by reaming is shown in fig. 5,490.

NOTE.—*With a roller cutter* a cut at right angles to the conduit is always obtained; with a wheel cutter a little care in starting the cut is necessary.

The external burr or shoulder, caused by using a wheel pipe cutter, is removed with a file. Right and wrong methods of filing are shown in figs. 5,491 and 5,492.

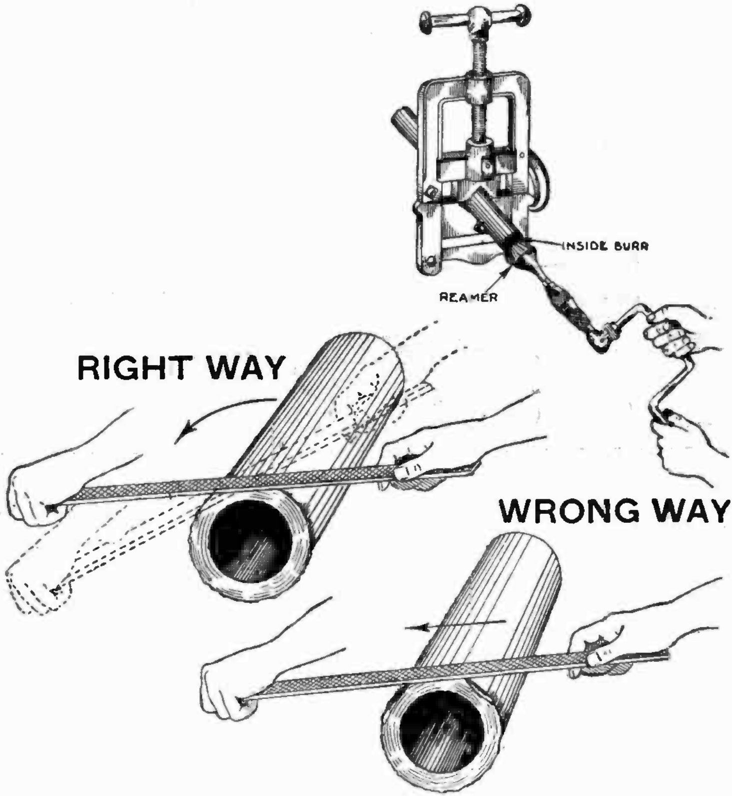
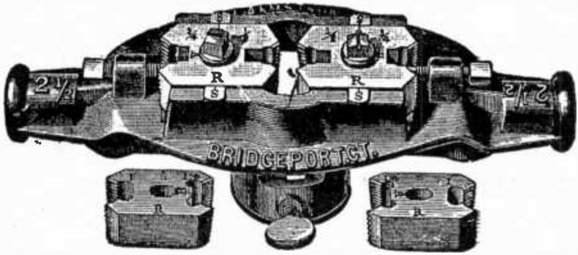


Fig. 5,490.–Method of removing burr from pipe end with brace and a burring reamer.

Figs. 5,491 and 5,492.—*Right* and *wrong* way of removing the shoulder left on pipe after cutting with a pipe cutter. Obviously at each stroke, the file should be given a turning motion as indicated by the arrow and dotted position in figure 5,491 removing the excess metal through an arc of the circumference. The position of pipe is changed in the vise from time to time, till the excess metal is removed all around the pipe. When the operation is done as in fig. 5,492, by moving the file in a straight line, it will result in a series of flat places.

Pipe Threading.—Having cut the pipe to proper length, filed off the outer shoulder and reamed out the burr, it is now ready for the threading operation. The Briggs threads may be cut on the pipe ends for screwing into the fittings either by means of

1. Hand stock and dies, or
2. Pipe threading machines.



FIGS. 5,493 to 5,495.—Armstrong *adjustable* pipe stock and dies for *double* ended dies. Each pair of dies, as shown, has one size thread at one end and another size at the other. Thus the two dies in the stock are in position for cutting ½-inch thread and by reversing them they will cut ¾-inch thread. The cut shows plainly the reference marks which must register with each other in adjusting the dies to standard size by means of the end set screws.

The hand stock and dies being portable, are generally used for small jobs, especially for threading pipe of the smaller sizes, although there are some geared forms suitable for large work without undue physical effort; the threading machines are for use in shops where a large amount of threading is done.

In cutting a thread use plenty of oil in starting and cutting the thread.

In starting, press the dies firmly against the pipe end until they "take hold." After a few turns blow out the chips and apply more oil. This

NOTE.—*There is a great variety of stocks and dies*, the types shown in figs. 5,493 to 5,495 being well adapted to ordinary work. It will be noted that the stock is *adjustable*, that is, the dies may be moved in or out to vary the diameter of the thread, thus loose or tight fit threads may be cut.

should be done two or three times before completing the cut. When complete blow out chips as clean as possible and back off the die. Avoid the frequent reversals usually made by some pipe fitters.

For lubrication, lard will be found preferable to oil. Apply the lard to the pipe end with a brush. In cutting the thread, the heat generated will melt the lard which will flow to the cutting edge of the die giving continuous lubrication instead of spasmodic flooding as is the case when using oil.*

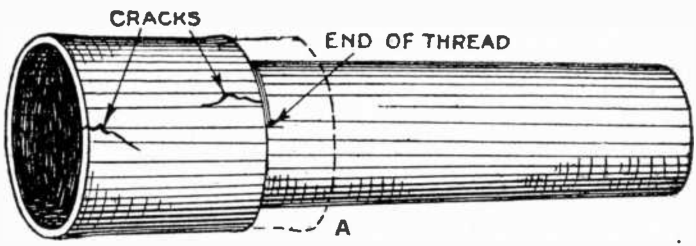


FIG. 5,496.—Makeshift nipple holder as used by some pipe fitters. *It consists of* a short length of pipe having a coupling on one end. *In operation*, one end of the nipple is screwed into the coupling, and the die applied to the other end. In doing this the turning force necessary to cut the thread being considerable, the coupling will be forced on the pipe (beyond the thread) to some position indicated by the dotted line *A*, straining the coupling beyond its elastic limit and probably cracking same as indicated. The nipple thus made is removed from the coupling and die by the aid of a Stillson wrench and some profanity. The coupling now being in a condition known to a certain class of workmen as "*on the hog*," it is replaced by a new one each time a nipple is to be cut. *In sending in the bill*, the waste of time and couplings are of no consequence to an unscrupulous mechanic, for these items are charged to the customer along with such things as candles, waste, charcoal, oil, matches, etc.—*at a very HANDSOME profit*.

Threading Nipples.—The pipe fitter usually makes any nipples required, but usually better nipples (especially the close and short variety) can be obtained from the supply house at less cost.

No pipe fitter deserving to be called such will attempt to cut nipples without a proper nipple holder, although some plumbers and some nondescripts are often guilty of such practice when working by the day instead of by the job.

*NOTE.—The author is indebted to Mr. Harbison, thread expert of the National Tube Co., for this suggestion.

The ordinary method of cutting nipples as indulged in by some plumbers and others as shown in fig. 5,496 *for lack of proper tools, is very unsatisfactory.*

In emergency, the proper way to cut a nipple with such a makeshift holder so as not to split the coupling is to use adjustable dies, as, for instance, the Armstrong pattern (figs. 5,493 to 5,495). First take a very light cut, then adjust dies and take one or more additional cuts to finish. The cost of a properly made nipple holder, such as shown in fig. 5,497, is so small that it should be included in every pipe threading outfit

Calculation of Offsets.—In pipe fitting the term *offset* may

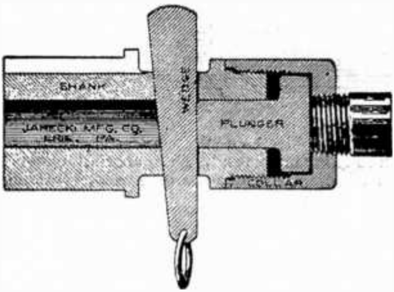


Fig. 5,497.—Jarecki nipple holder for threading close and short nipples.

be defined as *a change of direction (other than* 90°) *in a pipe bringing one part out of, but parallel with the line of another.*

Thus in fig. 5,498, it is necessary to change the position of pipe line L, at A, to same parallel position as that of line F, because of some obstruction such as the wall E, of the building. When the two lines L and F, are to be piped with elbows or bends other than 90°, the pipe fitter encounters a problem of finding the length of the pipe H, connecting the two elbows A and C, also to determine the distance EC, in order to fix the point A, so that the two elbows A and C, will be in alignment.

Of course in the triangle ABC, the length of pipe AC, and either offset (AB or BC that may be required) are quickly calculated by solving the triangle ABC, for the desired member, but this involves taking the square root which is not understood by every mechanic, hence an easier method will be given for those having limited knowledge of mathematics.

1st Method.

In the triangle ABC

$$\overline{AC}^2 = \overline{AB}^2 + \overline{BC}^2$$

from which

$$AC = \sqrt{\overline{AB}^2 + \overline{BC}^2}$$

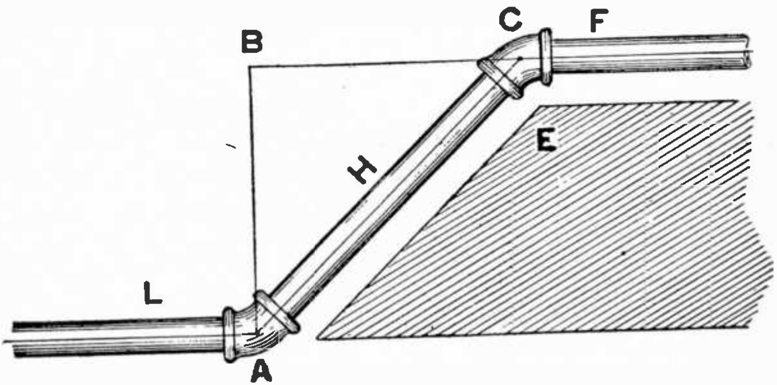


FIG. 5,498.—Pipe line connected with 45° elbows illustrating offsets and method of finding length of connecting pipe H.

Example.—If in fig. 5,498, the distance between pipe lines L and F be 20 ins. (offset AB) what length of pipe H, is required to connect with the 45° elbows A and C?

When 45° elbows are used both offsets are equal, hence substituting in equation (1)

$$AC = \sqrt{20^2 + 20^2} = \sqrt{800} = 28.28 \text{ ins.}$$

2nd Method.

The following rule will be found convenient for calculating 45° elbows.

Rule.—*For each inch of offset add $\frac{53}{128}$ of an inch and the result will be the length between centers of the elbows.*

Example.—Calculate length AC (center of elbows) of the preceding example by the above rule.

$$20\times\frac{53}{128}=\frac{1{,}060}{128}=8\tfrac{9}{32}$$

adding this to the offset

$$20+8\tfrac{9}{32}=28\tfrac{9}{32}$$

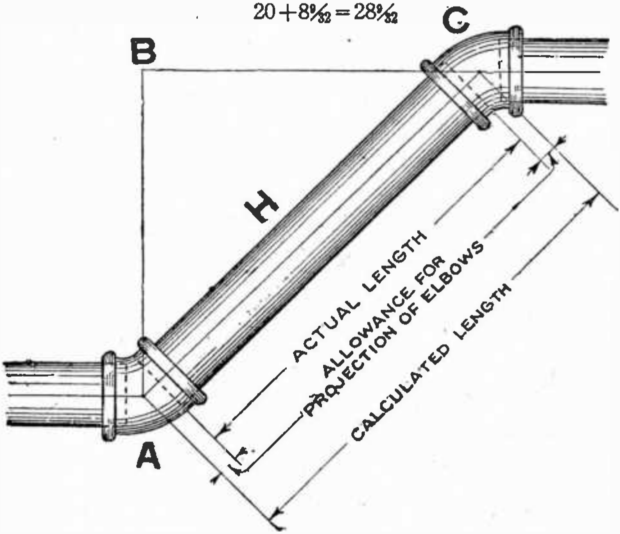


FIG. 5,499.—Calculated and actual length of connecting conduit with elbows other than 90°. Note carefully the allowances or deduction from calculated length for projection of elbows.

This is the calculated length, and to obtain the actual length, deduct the allowance for projection of the elbows as shown in fig. 5,499.

3rd Method.

This is for angles other than 45°, such as 22½, 11¼, etc., which the pipe fitter often encounters. For such, the distance between centers can easily be found by use of the following table of constants.

Elbow Constants

Angle of Elbow	Elbow Centers AC	Offset AB
60°	1.15	.58
45°	1.41	1.00
30°	2.00	1.73
22½°	2.61	2.41
11¼°	5.12	5.02
5⅜°	10.20	10.15

NOTE.—In the above table the letters refer to fig. 5,500.

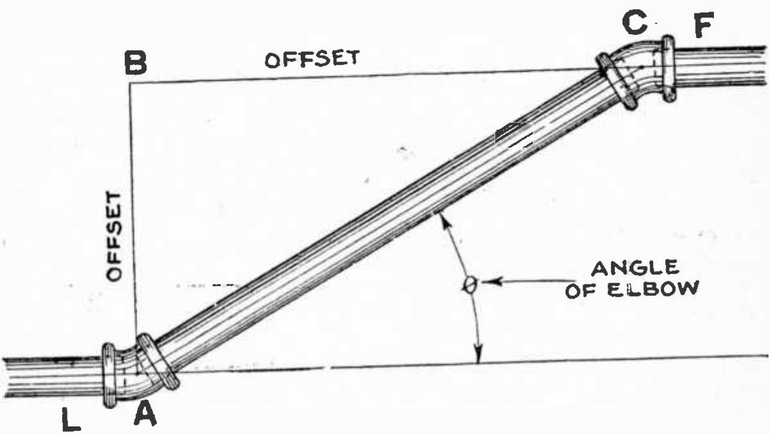


FIG. 5,500.—Diagram for elbow constants.

In using the above table, use is made of the rule which follows:

Rule.—*To find length between centers multiply offset by constant for the angle used.*

That is, referring to fig. 5,500.

AC = offset AB × constant for AC. . . . . (1)
BC = offset AB × constant for AB. . . . . (2)

Example.—If in fig. 5,500, the distance between pipe lines L and F, (offset AB) be 20 ins., what is length of offset BC, and distance AC, between center of elbows, for 22½° elbows?

In the table constant for AB, with 22½° elbow is 2.41. Substituting values in equation (2)

$$BC = 20 \times 2.41 = 48.2 \text{ ins.}$$

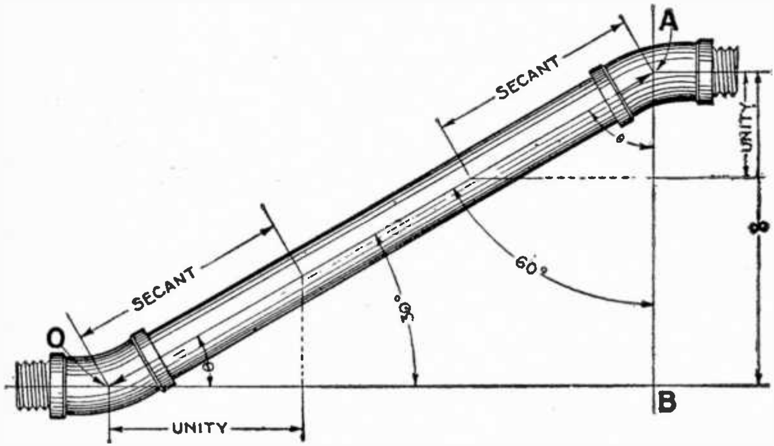


FIG. 5,501.—Two parallel conduit lines with 30° bends illustrating use of natural trigonometrical functions in finding offset and length of connecting pipe.

For distance AC, between centers of elbows, find in table constant for AC = 2.61. Substituting in equation (1)

$$AC = 20 \times 2.61 = 52.2 \text{ ins.}$$

4th Method.

Offsets may be calculated by aid of trigonometry as illustrated by the following example.

Example.—In fig. 5,501, two pipe lines 8 ins. apart are to be connected with 30° elbows. What is the length of the offset OB and connecting pipe OA?

From the accompanying table, tan. 60 = 1.732; length offset OB = 1.732 ×8 = 13.86 ins.

Again, from table sec. 60 = 2; length connecting pipe OA = 8×2 = 16 ins.

Natural Trigonometrical Functions

Degree	Sine	Cosine	Tangent	Secant	Degree	Sine	Cosine	Tangent	Secant
0	.00000	1.0000	.00000	1.0000	46	.7193	.6947	1.0355	1.4395
1	.01745	.9998	.01745	1.0001	47	.7314	.6820	1.0724	1.4663
2	.03490	.9994	.03492	1.0006	48	.7431	.6691	1.1106	1.4945
3	.05234	.9986	.05241	1.0014	49	.7547	.6561	1.1504	1.5242
4	.06976	.9976	.06993	1.0024	50	.7660	.6428	1.1918	1.5557
5	.08716	.9962	.08749	1.0038	51	.7771	.6293	1.2349	1.5890
6	.10453	.9945	.10510	1.0055	52	.7880	.6157	1.2799	1.6243
7	.12187	.9925	.12278	1.0075	53	.7986	.6018	1.3270	1.6616
8	.1392	.9903	.1405	1.0098	54	.8090	.5878	1.3764	1.7013
9	.1564	.9877	.1584	1.0125	55	.8192	.5736	1.4281	1.7434
10	.1736	.9848	.1763	1.0154	56	.8290	.5592	1.4826	1.7883
11	.1908	.9816	.1944	1.0187	57	.8387	.5446	1.5399	1.8361
12	.2079	.9781	.2126	1.0223	58	.8480	.5299	1.6003	1.8871
13	.2250	.9744	.2309	1.0263	59	.8572	.5150	1.6643	1.9416
14	.2419	.9703	.2493	1.0306	60	.8660	.5000	1.7321	2.0000
15	.2588	.9659	.2679	1.0353	61	.8746	.4848	1.8040	2.0627
16	.2756	.9613	.2867	1.0403	62	.8829	.4695	1.8807	2.1300
17	.2924	.9563	.3057	1.0457	63	.8910	.4540	1.9626	2.2027
18	.3090	.9511	.3249	1.0515	64	.8988	.4384	2.0503	2.2812
19	.3256	.9455	.3443	1.0576	65	.9063	.4226	2.1445	2.3662
20	.3420	.9397	.3640	1.0642	66	.9135	.4067	2.2460	2.4586
21	.3584	.9336	.3839	1.0711	67	.9205	.3907	2.3559	2.5593
22	.3746	.9272	.4040	1.0785	68	.9272	.3746	2.4751	2.6695
23	.3907	.9205	.4245	1.0864	69	.9336	.3584	2.6051	2.7904
24	.4067	.9135	.4452	1.0946	70	.9397	.3420	2.7475	2.9238
25	.4226	.9063	.4663	1.1034	71	.9455	.3256	2.9042	3.0715
26	.4384	.8988	.4877	1.1126	72	.9511	.3090	3.0777	3.2361
27	.4540	.8910	.5095	1.1223	73	.9563	.2924	3.2709	3.4203
28	.4695	.8829	.5317	1.1326	74	.9613	.2756	3.4874	3.6279
29	.4848	.8746	.5543	1.1433	75	.9659	.2588	3.7321	3.8637
30	.5000	.8660	.5774	1.1547	76	.9703	.2419	4.0108	4.1336
31	.5150	.8572	.6009	1.1666	77	.9744	.2250	4.3315	4.4454
32	.5299	.8480	.6249	1.1792	78	.9781	.2079	4.7046	4.8097
33	.5446	.8387	.6494	1.1924	79	.9816	.1908	5.1446	5.2408
34	.5592	.8290	.6745	1.2062	80	.9848	.1736	5.6713	5.7588
35	.5736	.8192	.7002	1.2208	81	.9877	.1564	6.3138	6.3924
36	.5878	.8090	.7265	1.2361	82	.9903	.1392	7.1154	7.1853
37	.6018	.7986	.7536	1.2521	83	.9925	.12187	8.1443	8.2055
38	.6157	.7880	.7813	1.2690	84	.9945	.10453	9.5144	9.5668
39	.6293	.7771	.8098	1.2867	85	.9962	.08716	11.4301	11.474
40	.6428	.7660	.8391	1.3054	86	.9976	.06976	14.3007	14.335
41	.6561	.7547	.8693	1.3250	87	.9986	.05234	19.0811	19.107
42	.6691	.7431	.9004	1.3456	88	.9994	.03490	28.6363	28.654
43	.6820	.7314	.9325	1.3673	89	.9998	.01745	57.2900	57.299
44	.6947	.7193	.9657	1.3902	90	1.0000	Inf.	Inf.	Inf.
45	.7071	.7071	1.0000	1.4142		—	—	—	—

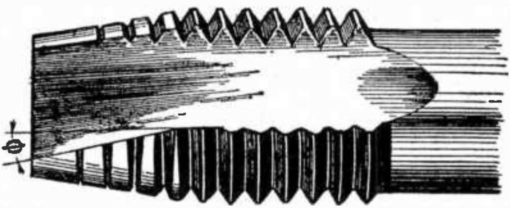
Pipe Tapping.—Frequently in pipe fitting, it is necessary to cut internal threads on pipes, as in making pipe headers, lubricator connections, etc. This is called *tapping*, and involves:

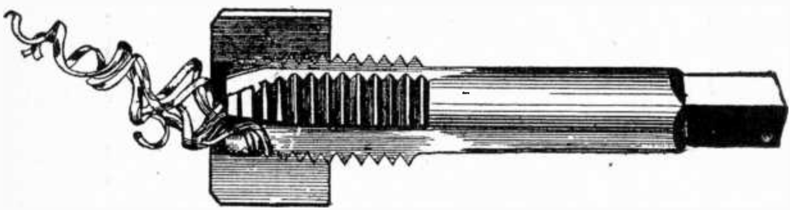
1. Drilling holes to correct diameter;
2. Sometimes reaming;
3. Cutting the internal threads by means of a *tap*.

It is first necessary to know what size hole is required for the size of tap.

The table on page 3,297 gives drill sizes which permit of direct tapping without reaming the hole beforehand.

The Briggs standard is the standard used in the United States.





FIGS. 5,502 and 5,503.—Greenfield "gun" tap and character of its cut. *This tap* differs from ordinary taps in that the cutting edges, are ground at an angle ϕ, to the axis of the tap. This causes the tap to cut with a shearing motion, that is, with the least resistance to the thrust. The angle of the flutes deflects the chips so that they curl out and ahead of the tap and do not collect and break up in the flutes.

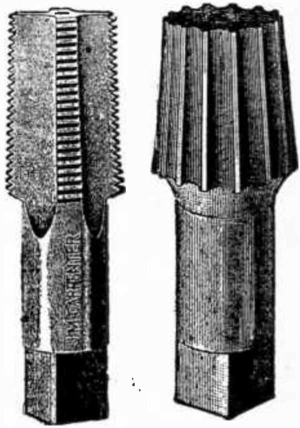
Drill Sizes for Briggs Standard Pipe Taps

(For direct tapping without reaming)

Size of pipe	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4
Size of drill	21/64	7/16	9/16	45/64	59/64	1 5/32	1 31/64	1 47/64	2 13/64	2 5/8	3 1/4	3 47/64	4 15/64

Drill Sizes for Pipe Taps

Size Tap Inches	BRIGGS STANDARD		BRITISH (Whitworth) STANDARD	
	Thread	Drill	Thread	Drill
1/8	27	21/64	28	5/16
1/4	18	27/64	19	7/16
3/8	18	9/16	19	9/16
1/2	14	11/16	14	23/32
5/8	....	....	14	25/32
3/4	14	29/32	14	31/32
7/8	....	....	14	1 1/16
1	11 1/2	1 1/8	11	1 3/16
1 1/4	11 1/2	1 15/32	11	1 1/2
1 1/2	11 1/2	1 23/32	11	1 23/32
1 3/4	.....	....	11	1 31/32
2	11 1/2	2 3/16	11	2 3/16
2 1/4	....	....	11	2 15/32
2 1/2	8	2 9/16	11	2 23/32
2 3/4	....	....	11	3 3/32
3	8	3 3/16	11	3 11/32
3 1/4	....	....	11	3 1/2
3 1/2	8	3 11/16	11	3 3/4
3 3/4	....	....	11	4
4	8	4 3/16	11	4 1/4
4 1/2	8	4 11/16	11	4 3/4
5	8	5 1/4	11	5 1/4
5 1/2	....	....	11	5 3/4
6	8	6 5/16	11	6 1/4
7	8	7 5/16	11	7 5/16
8	8	8 5/16	11	8 5/16
9	8	9 5/16	11	9 5/16
10	8	10 7/16	11	10 5/16



FIGS. 5,504 and 5,505.—Pipe tap and pipe reamer. Do not use a *straight* tap by mistake for a taper tap.

The table at the left (by Greenfield), gives drill sizes for pipe taps for both the Briggs or American Standard, and Whitworth, or British Standard.

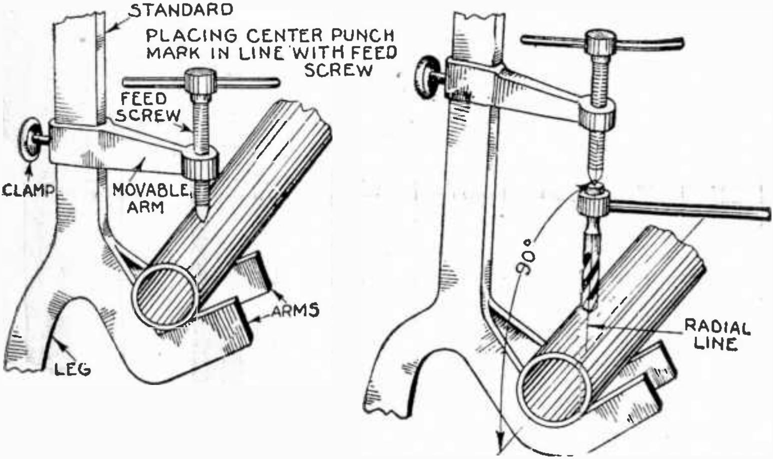
Figs. 5,504 and 5,505 show a pipe tap and reamer.

Since the thread is

tapered, it might be inferred that after drilling, the hole should be reamed with a tapered pipe reamer, but this is not necessary if the size of the drill be increased slightly.

In drilling a pipe for tapping, care should be taken that the drill be guided in a radial direction and perpendicular to the pipe axis.

Fig. 5,506 shows a pipe drilling crow designed for the purpose and fig.



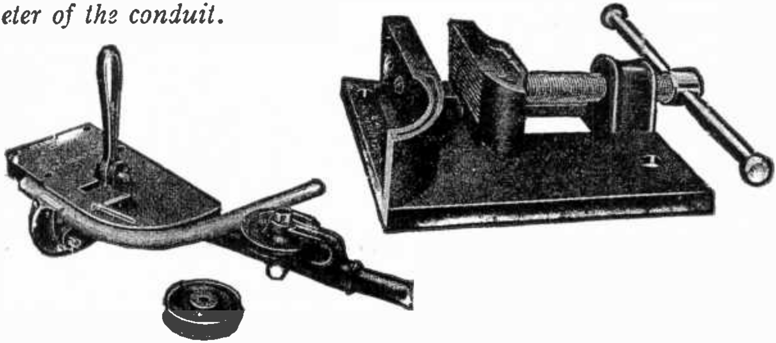
FIGS. 5,506 and 5,507.—Pipe drilling crow and method of using. *The illustrations* need no explanation.

5,507, pipe and drill in position. Of course where such device is not at hand, various makeshifts have to be resorted to.

Conduit Bending.—Instead of using fittings such as elbows, tees, Ys, etc., turns in the direction of the conduit are usually made by bending.

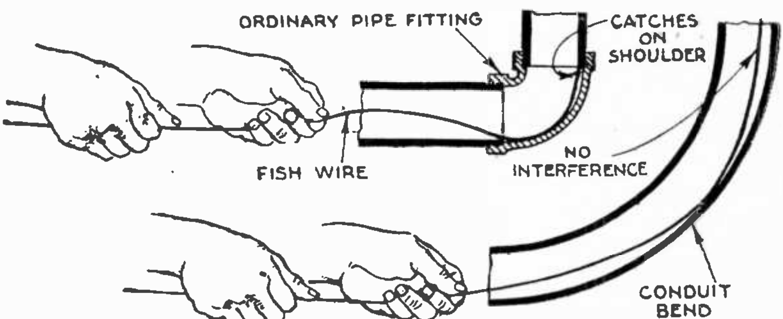
NOTE.—*It is highly important that threading dies* be kept in good working condition, for even with uniform pipe it is difficult to secure good threads if the chasers of a die be lacking in proper lip angle, clearance in lead or thread, have broken teeth, or if the die be lacking in chip space, sufficient number of chasers, etc.

To comply with the Code, *the radius of the curve of the inner edge of any bend shall not be less than six times the internal diameter of the conduit.*



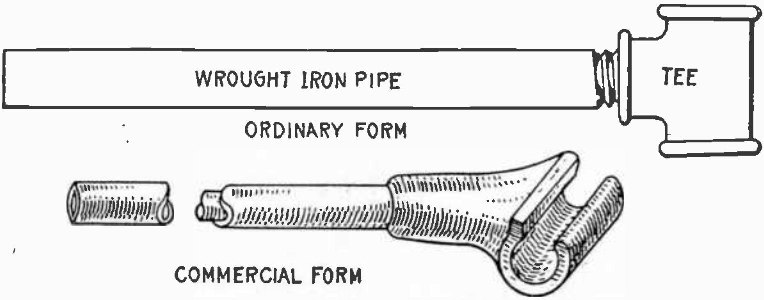
FIGS. 5,508 and 5,509.—Austin combination pipe vise and form bender. Without removing conduit from the vise it can be cut, threaded, reamed and bent. The tempered jaws can be replaced when worn out.

FIG. 5,510.—Austin conduit elbow former for ½ and ¾ conduit.



FIGS. 5,511 and 5,512.—Comparison of elbow fitting and conduit bend.

NOTE.—***For cutting threads on regular Bessemer steel pipe,*** each chaser should have a lip angle of 15 to 20 degrees; for open hearth, at least 25 degrees. By grinding a slightly curved lip of this angle, an easy cutting action is given to the chaser, similar to that of a properly ground lathe tool, and the effect of pushing the metal off instead of cutting it is avoided. If there be a square corner or shoulder at the top of the lip, this should be removed, as it forms a place where chips may lodge and pile up, resulting in torn threads and unnecessary friction and often in condemnation of the thread by the inspector in charge. Clearance is the space between the pipe threads and the teeth of the chaser.

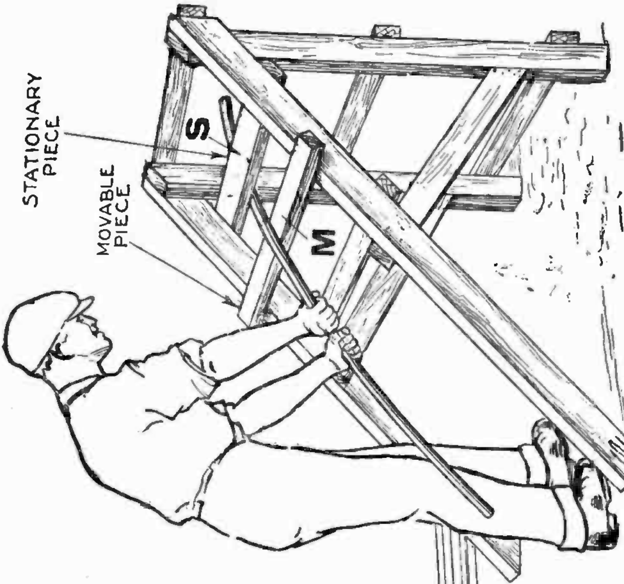


FIGS. 5,513 and 5,514.—Home made and commercial forms of hickey. The home made hickey consists of a piece of one inch steam pipe about three feet long with a one inch cast iron tee screwed onto one end of the pipe.

FIG. 5,515.—Method of bending conduit with a hickey. ***In bending,*** the conduit to be bent is placed on the floor and the tee slipped over it. The workman then places one foot on the conduit close to the tee, and pulls the handle of the bender toward him. As the bending progresses, the workman should take care to continually move the bender away from himself, to prevent buckling of the conduit.

This requirement precludes even the use of long sweep fittings. The reason for this is because the Code requires the conduit ***to be installed as a complete system without the wires.*** Accordingly, too much force would be required to pull the wires around bends sharper than specified which might injure the wire insulation. Moreover, if an ordinary pipe fitting were used instead of a conduit fitting, there would be difficulty in *fishing*, because the end of the fish wire would catch against the shoulder presented by the end of the conduit at the screwed joint as in fig. 5,511. This is avoided by bending the conduit as in fig. 5,512.

Various types of tools known as conduit benders are used to bend conduit. They may be classified as



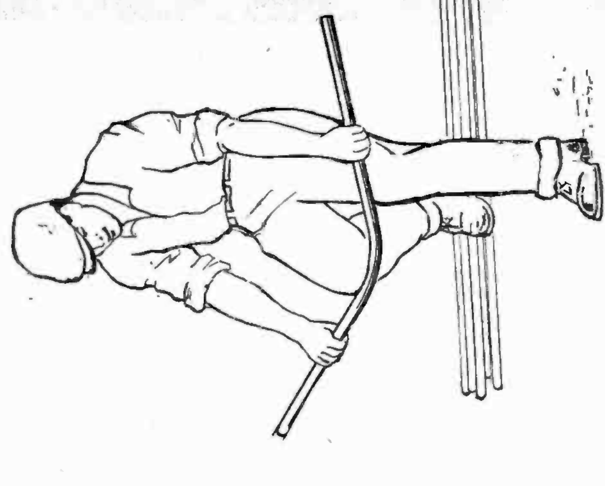


FIG. 5,516.—Method of bending small size conduit over the knee. FIG. 5,517.—Method of bending conduit on a rack.

1. Hickeys;
2. Racks;
3. Bending block and pins;
4. Geared benders;
5. Form benders;
6. Roller benders;
7. Inertia benders.

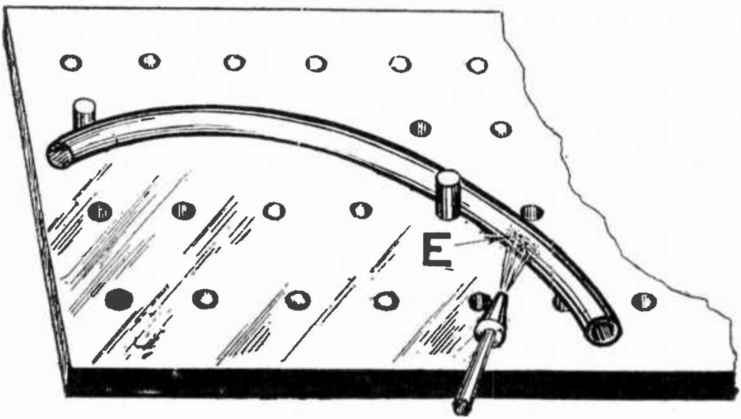
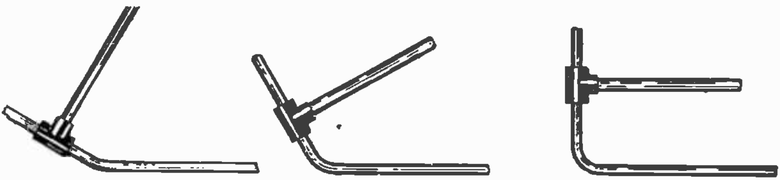


FIG 5,518 —Method of bending with bending block and pins. ***In bending,*** the pipe is heated in a small spot at a time on the inside of the bend, as shown by the shaded portion at E. If the heat extend around the outside of the pipe, this should be chilled with water immediately before bending, the object being to keep the outside cold to prevent flattening the pipe while the pressure of the bending causes the inside to upset and so furnishes the shorter radius for the inside. Only a very small portion of the pipe can be heated at a time and should the pressure cause the inside to start to kink at any point, that place must be immediately chilled with water, and the bending continued further along. On account of the constant shifting of the heat on a very small portion at a time, the use of an oil torch for heating is a great advantage, as it saves carrying the pipe to and from a forge, but the latter can be used if necessary.

A hickey is a form of hand bender consisting of a long lever having at one end a slot at right angles, which fits over and grips the conduit when pressure is brought on the lever or handle to bend the conduit. Fig. 5,513 shows a home made hickey constructed out of a length of pipe and a tee. A commercial form of hickey is shown in fig. 5,514. The method of using a hickey is illustrated in fig. 5,515.

A rack is any kind of a built up contrivance which provides two rigid points for engaging the conduit so that it will be held as in a vise, when pressure is applied to the conduit in bending. Fig. 5,517 shows one form of rack. In using this device the movable arm piece **M**, may be adjusted with respect to **S**, most suitable to the size conduit and radius of the required bend.

Bending with a bending block and pins is a simple method but requires a careful workman to get a smooth job, and though adaptable to the largest sizes of pipe, may require a tedious amount of work. Two pins are required for the necessary leverage to pull the pipe around. The plate is desirable for keeping the bend in a true plane. and to form a rigid support or anchorage for the pins. In the former method are substituted the



FIGS. 5,519 to 5,521.—Correct method of making a quarter bend with a hickey. The pipe should be marked at the place where the bend is to be made, grasp pipe with hickey and raise pipe from floor a few inches, shift hickey and bend conduit a little more; keep shifting hickey until the proper bend is made. *To make an offset:* Stand hickey on floor in an upright position with the bending part up, insert pipe into opening and pull down on the pipe, using the length of the pipe as a leverage, having made the bend as far as desired, turn the bend up and repeat as above.

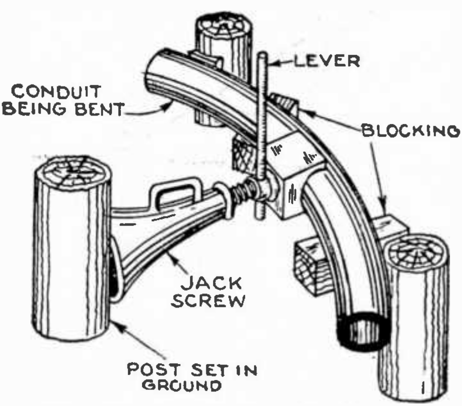


FIG. 5,522.—Method of bending with jack and post support, illustrating one form of geared bender.

parts **M** and **S** for the pins. This method of bending is shown in fig. 5,517.

Where a very heavy pressure is required as in bending large size conduit, some method of multiplying the force exerted by hand is necessary

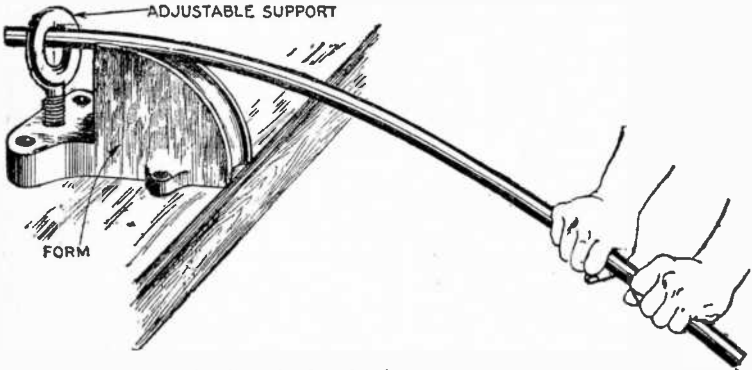


FIG. 5,523.—Method of bending with form bender.

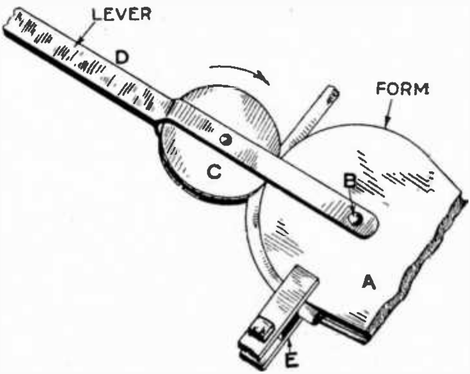
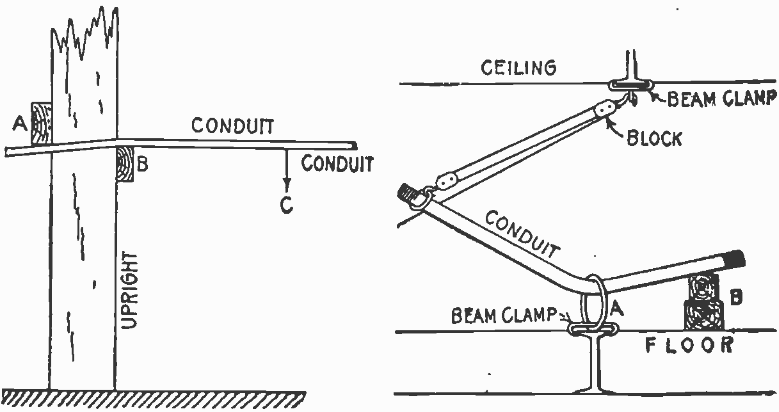


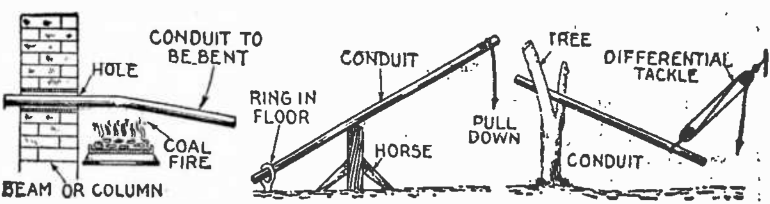
FIG. 5,524—Method of bending with a roller bender. *It consists of* a circular form **A**, with bending pulley **C**, radially hinged at **B**. Owing to the considerable effort required to bend pipe, the part **A**, must be very securely fastened to some rigid support. ***In bending***, the lever is brought over to the projection **E**, and pipe placed in position. Then the lever is forced around in the direction from **E**, toward the straight pipe thus bending the pipe to conform with the bending form. The pipe, of course, must first be filled with sand and capped to prevent buckling, and also heated if the bending radius be small enough to require heating.

as by utilizing a jack or differential chain gear. This method is shown in fig. 5,522 and of course there are many ways of rigging up the necessary supports for the conduit and jack.

A more refined method of bending is with a form bender in which the



Figs. 5,525 and 5,526.—Methods of bending large conduits. The conduit is placed under the block A and over the block B, and then bent by a downward pressure exerted at C, the conduit in the meantime being gradually advanced in the direction C, to give a curve of the required radius. The method shown in fig. 5,526, may be used wherever a ring A, can be attached to a beam or girder by means of clamps or otherwise to serve as a support.



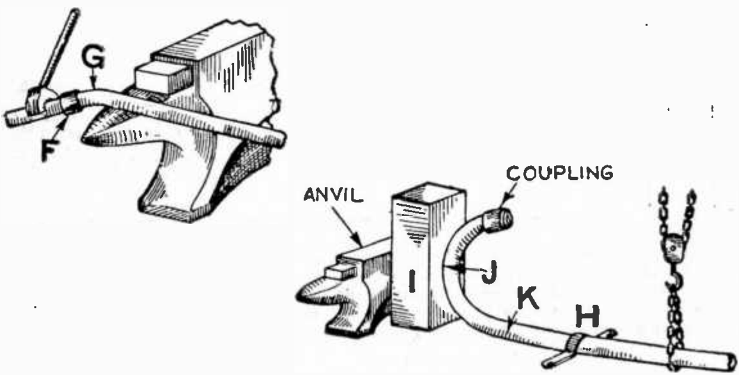
Figs. 5,527 to 5,529.—Methods of bending large conduits. Fig. 5,527, by heating. Large conduit such as sizes above 3 inches may be bent if they be first filled with dry sand to prevent kinking and heated until cherry red over a coal fire, then bending as shown. In fig. 5,528, the conduit is inserted into a ring secured to the floor and bent over a horse by pulling down on the end. Another method, as shown in fig. 5,529, consists of inserting the conduit in the V of a tree and bending by attaching block and tackle, worked by team of horses, or preferably by a differential tackle as shown.

conduit is form shaped to the right curve by the curve of the bender. The latter is shown in fig. 5,523 together with the method of bending.

In the roller bender, the force applied to a lever is transmitted to the conduit by a roller, which *rolls* the conduit to the required bend as shown in fig. 5,524.

A unique method of bending utilizes the force due to inertia of the pipe as it is struck against some hard surface. This method is illustrated in figs. 5,530 and 5,531.

Conduit Fittings.—By definition a conduit fitting is *a box-like device provided with projections which have female pipe*



FIGS. 5,530 and 5,531.—Inertia or anvil method of bending. In fig. 5 530 a coupling and short length of pipe are temporarily fitted on the end of the pipe, as shown at F. A short heat is taken close to the coupling at G, the pipe laid over the horn of an anvil, and with a swage and sledge the bend is started, turning the pipe over on its side if necessary to work out any kinks or flattening that may occur while this first bend is being made. The added section of pipe is then removed and a quite different method continues the work, as shown in fig. 5,531. The clamped band handle H, is now bolted on some distance back from the end, and the pipe itself is suspended by a block and sling, so that it may be easily raised and lowered as necessary, and must be hung from a support far enough above it so that it may be swung pendulum fashion through a swing of three or four feet. A heavy wood block I, for a "butting post" is leaned up against a convenient anvil or wall, as shown. A short heat is then taken on the pipe just beyond and adjoining the portion that was first bent. It is then swung like a ram against the block, and the force of the blow acting on the tangent of the first bend causes a continuation of the bending in this next section, while sufficient upsetting of the material takes place at the same time so that there is no flattening down of the outside, and the pipe holds up to its full form. This same procedure is continued for one section following another, and the pipe rolls up into form as shown at J, where in this case the shaded portion K, indicates the place where the bending is taking place.

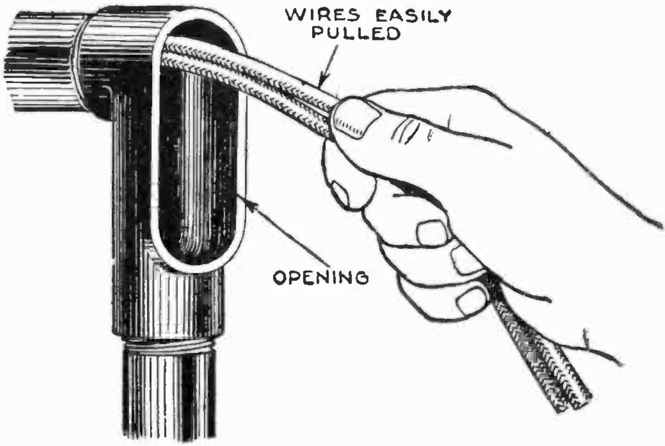


FIG. 5,532.—Conduit elbow with cover removed from opening. This makes the operation of *pulling* the wires through the conduit very easy and avoids chance of injuring the insulation if they were pulled around a sharp turn.

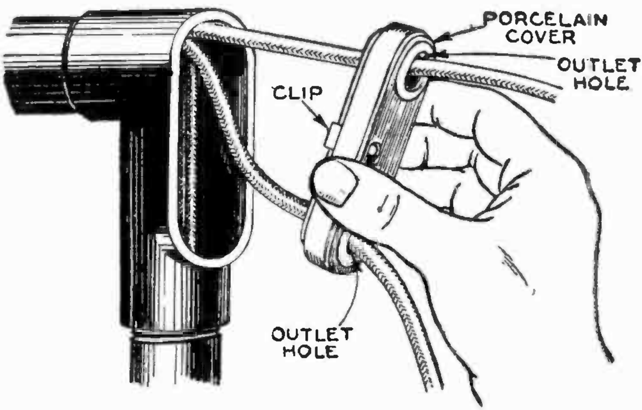


FIG. 5,533.—Conduit elbow with two wire porcelain cover showing circuit outlet provided by this type cover.

threads to which the conduit is screwed direct. They are similar to pipe fittings but modified to suit the condition for which they are intended.

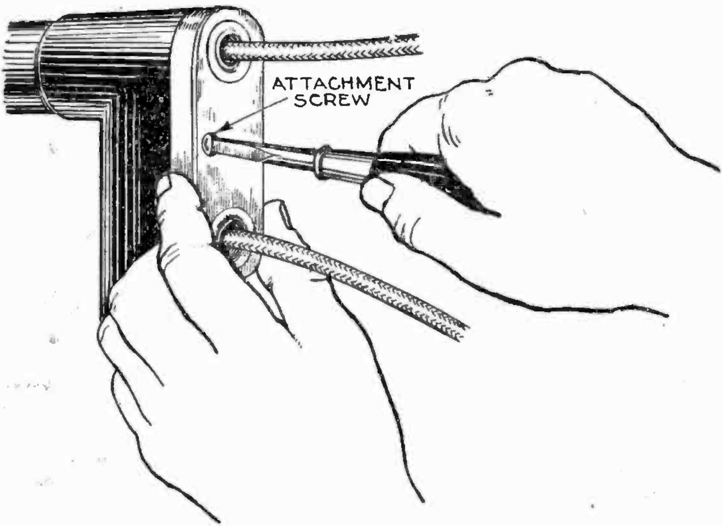
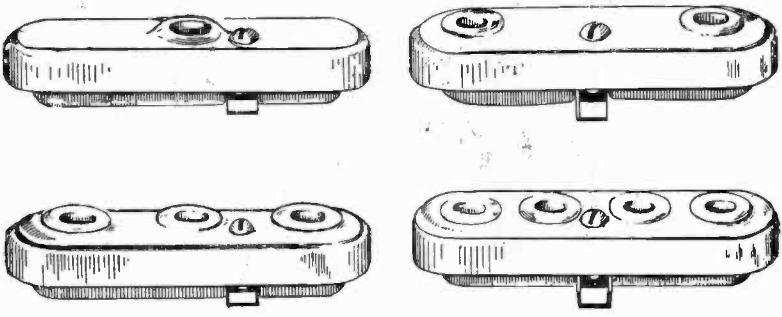
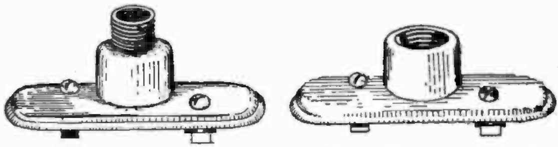


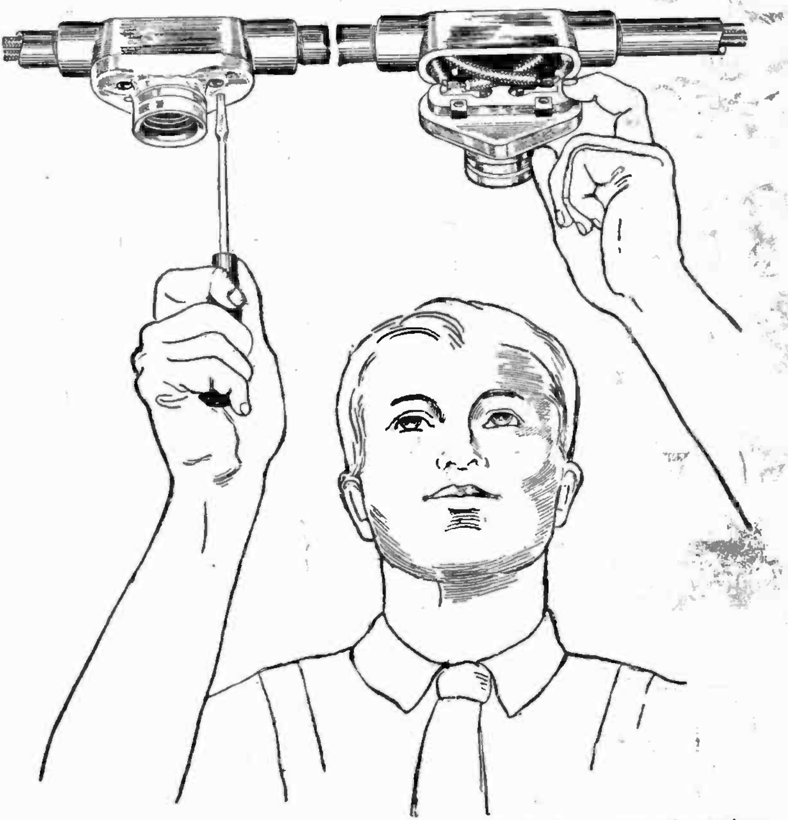
FIG. 5,534.—Conduit elbow with two wire porcelain cover showing method of attaching with screws.



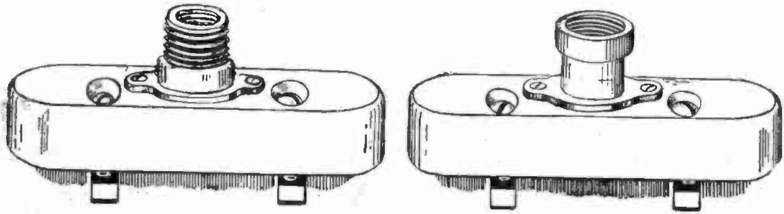
FIGS. 5,535 to 5,538.—Various covers with wire holes for conduit fitting, one to four holes.



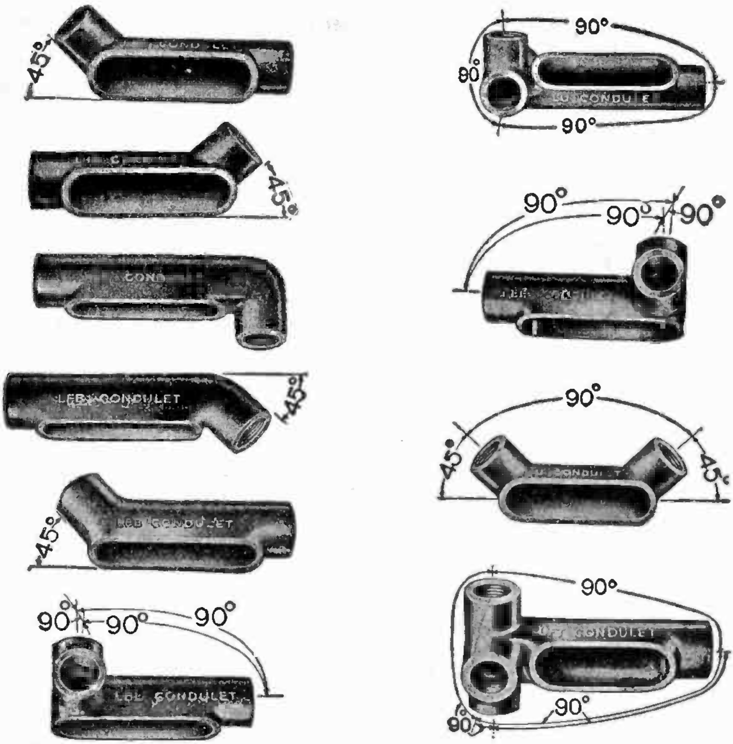
FIGS. 5,539 and 5,540.—Cast iron fixture covers. Fig. 5,539, male nipple; fig. 5,540 female nipple.



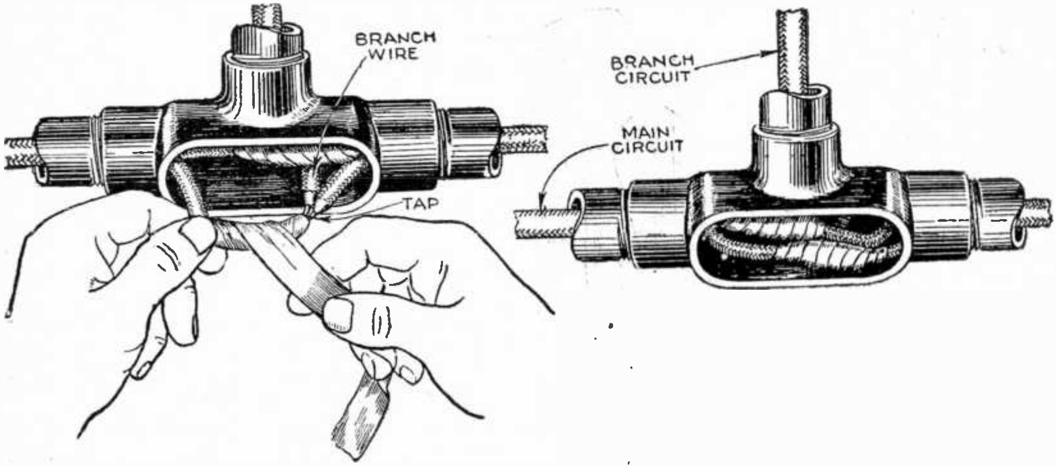
FIGS. 5,541 and 5,542.—Receptacle and cover showing method of connecting wires to base. The fitting shown is an *outlet coupling*.



FIGS. 5,543 and 5,544.—Porcelain fixture covers. Fig. 5,543, male nipple; fig. 5,544, female nipple.



FIGS 5,545 to 5,554.—Crouse-Hinds conduit fittings showing some of the many types.



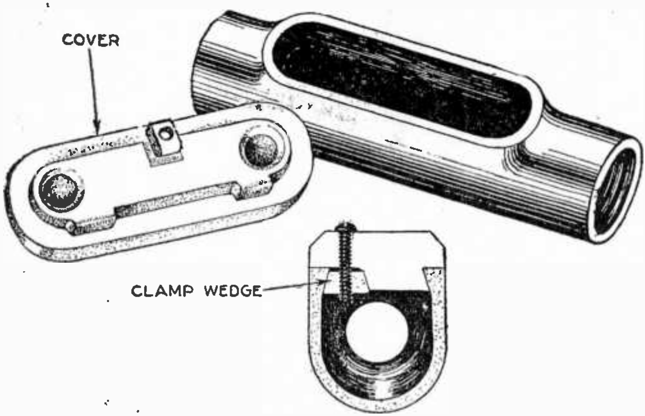
Figs. 5,555 and 5,556.—Conduit T, showing method of tapping a branch circuit.

There is a ridiculous variety of trade names given to these fittings by the manufacturers: they are best known as *conduit fittings*.

A large multiplicity of conduit fittings are available, designed for every condition met with in wiring. It is not the purpose of the author to waste space illustrating all of them, as a study of a few of the principal types will suffice.

A conduit fitting differs from an ordinary pipe fitting principally in that it has an opening with a removable cover.

The object of thus giving access to the interior is to permit pulling the wires as shown in fig. 5,532. A conduit fitting thus serves to join two lengths of conduit, and also as a *pull box*. Moreover, its utility is increased by the various forms of cover made to fit over the opening. For instance the type cover shown in fig. 5,533 provides an outlet for a branch circuit. Fig. 5,534 shows how the various covers are fastened by screws. Covers of this type are available with various numbers of holes; single hole covers are suitable for drop cord purposes.



FIGS. 5,557 to 5,559.—Crouse-Hinds, Obround pattern conduit fitting showing cover and method of fastening. The fitting shown is properly described by calling it an *outlet coupling*. The sectional view shows clearly the method of fastening the cover without resorting to internal lugs.

Another form of cover known as a receptacle cover provides connection for a light bulb. Figs. 5,541 and 5,542 show the cover.

To provide means for connecting fixtures along a conduit run, a type cover which may be called a fixture cover is used.

These are suitable for fastening fixtures either of the rigid or chain type Figs. 5,539 to 5,544 show cast iron and porcelain fixture covers.

The elbow shown in fig. 5,532 is a 90° elbow. There are numerous types of 90° elbow and elbows are also made 45°. Figs. 5,545 to 5,554, will give an idea of the great variety of conduit fittings available.

An example of a T fitting, showing how a branch circuit is tapped, is illustrated in figs. 5,555 and 5,556.

Code.

503. Conduit Work

a. When conduit work, rigid or flexible, is the wiring method employed, the provisions of the following paragraphs of this section shall be observed.

b. Rigid conduit tube and all elbows, bends, couplings and similar fittings which constitute a part of the conduit system shall, unless made of non-corrodible metal, be suitably protected against corrosion inside and outside, excluding threads at joints, by an approved coating of corrosion-resistive material such as zinc, or enamel, or by combinations of both.

c. Flexible metallic conduit and all couplings, connectors and similar fittings which constitute a part of the conduit system shall, unless made of non-corrodible metal, be suitably protected against corrosion by an approved coating of corrosion-resistive metal such as zinc.

d. No conduit smaller than ½ inch, electrical trade size, shall be used except as provided for under-plaster extensions in section 510 of this article.

e. Rigid conduit, as shipped, shall be in 10-foot lengths including couplings, with each end reamed and threaded, and shall have an interior coating of a character and appearance which will readily distinguish it from ordinary pipe commonly used for other than electrical purposes. One coupling shall be furnished with each length.

f. Bends of rigid or flexible metallic conduit shall be so made, that the conduit will not be injured. The radius of the curve of the inner edge of any bend shall be not less than six times the internal diameter of the conduit. Care shall be taken to see that bends in conduit are so made as to avoid reducing the internal diameter of the conduit at the bend.

g. Conduit shall be installed as a complete system without the wires, and shall be continuous, from outlet to outlet, and from fitting to fitting, and shall be mechanically and electrically connected to all fittings. The fittings connected to more than one run of conduit shall be so designed and connected that adequate electrical continuity from one conduit to another will be secured. The entire system shall be securely fastened in place.

h. Approved outlet boxes or fittings as required by paragraphs *a* and *b* of section 703 shall be installed at all outlets and switch points.

i. A run of conduit, between outlet and outlet or between fitting and fitting, shall include not more than the equivalent of 4 quarter bends, the bends at the outlets or junction boxes not being counted.

j. All ends of conduit shall be reamed to remove rough edges, and where a conduit enters a box or other fitting, an approved bushing shall be provided to protect the wire from abrasion, unless the design of the box or fittings is such as to afford equivalent protection.

k. Conduit shall be grounded as prescribed in article 9 of this code.

l. Conduit wire shall be of approved rubber-covered type (Types R, RD, etc.), or, if in a permanently dry location, may be of the varnished-cambric insulated type (Type VC). A double braid shall be provided for conductors larger than No. 8 and for all twin, twisted or multiple-conductor cables. Slow-burning insulation (Type SB wire) may, however, be used in permanently dry and excessively hot locations by permission of the authority enforcing this code. All wires of No. 6 or larger shall be stranded. There shall be no splice or tap within

Code.—Continued.

the conduit proper. With flexible metallic conduit in wet or damp places wires shall have lead coverings (Type RL).

m. Wires shall not be drawn in until all mechanical work on the building which is liable to injure the wires has been completed, as far as possible.

n. Wires of different systems shall not occupy the same conduit.

Different systems are those which derive their supply from (1) different sources of current, (2) transformers connected to separate primary circuits, or (3) transformers having different secondary voltages.

o. When alternating current is to be employed, all conductors of a circuit shall be placed within one conduit, except as provided in section 510 of this article.

It is recommended that this course be pursued in the case of direct current also, in order to obviate induction troubles if a change is made to alternating current at a later date.

p. Except in the case of stage pocket and border circuits and flasher and carriage-call wires and elevator control wires or by permission of the authority enforcing this code, one conduit shall not contain more wires than as specified in Table 1 of this section.

q. Size of Conduits for the Installation of Wires and Cables.

The following tables apply only to complete conduit systems, and do not apply to short sections of conduit used for the protection of exposed wiring from mechanical injury.

TABLE 1. TWO-WIRE AND THREE-WIRE SYSTEMS.

Size of Wire	Number of Wires in One Conduit								
	1	2	3	4	5	6	7	8	9
	Minimum Size of Conduit in Inches								
No. 14	½	½	½	¾	¾	1	1	1	1
12	½	½	¾	¾	¾	1	1	1	1¼
10	½	¾	¾	1	1	1	1¼	1¼	1¼
8	½	¾	1	1	1	1¼	1¼	1¼	1¼
6	½	1	1¼	1¼	1½	1½	2	2	2
5	¾	1¼	1¼	1¼	1½	2	2	2	2
4	¾	1¼	1¼	1½	2	2	2	2	2½
3	¾	1¼	1¼	1½	2	2	2	2½	2½
2	¾	1¼	1½	1½	2	2	2½	2½	2½
1	¾	1½	1½	2	2	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1¼	2	2½	2½	3	3	3½	3½	4
200000 C. M.	1¼	2	2½	2½	3	3	3½	3½	4
225000	1¼	2½	2½	3	3	3½			
250000	1¼	2½	2½	3	3	3½			
300000	1¼	2½	3	3	3½	3½			
350000	1¼	2½	3	3½	3½	4			
400000	1¼	3	3	3½	4	4			
450000	1½	3	3	3½	4	4½			
500000	1½	3	3	3½	4	4½			
550000	1½	3	3½	4	4½	5			
600000	2	3	3½	4	4½	5			

Code.—*Continued.*

TABLE 1. TWO-WIRE AND THREE-WIRE SYSTEMS,

Size of Wire	Number of Wires in One Conduit								
	1	2	3	4	5	6	7	8	9
	Minimum Size of Conduit in Inches								
650000	2	3½	3½	4					
700000	2	3½	3½	4½					
750000	2	3½	3½	4½					
800000	2	3½	4	4½					
850000	2	3½	4	4½					
900000	2	3½	4	4½					
950000	2	4	4	5					
1000000	2	4	4	5					
1100000	2½	4	4½	6					
1200000	2½	4½	4½	6					
1250000	2½	4½	4½	6					
1300000	2½	4½	5	6					
1400000	2½	4½	5	6					
1500000	2½	4½	5	6					
1600000	2½	5	5	6					
1700000	3	5	5	6					
1750000	3	5	5	6					
1800000	3	5	6	6					
1900000	3	5	6						
2000000	3	5	6						

TABLE 2. THREE-CONDUCTOR CONVERTIBLE SYSTEM.

Size of Wires				Size Conduit Electrical Trade Size
two	14	and one	10	¾ Inch
"	12	"	8	¾ "
"	10	"	6	1 "
"	8	"	4	1 "
"	6	"	2	1¼ "
"	5	"	1	1¼ "
"	4	"	0	1½ "
"	3	"	00	1½ "
"	2	"	000	1½ "
"	1	"	0000	2 "
"	0	"	250000	2 "
"	00	"	350000	2½ "
"	000	"	400000	2½ "
"	0000	"	550000	3 "
"	250000	"	600000	3 "
"	300000	"	800000	3 "
"	400000	"	1000000	3½ "
"	500000	"	1250000	4 "
"	600000	"	1500000	4 "
"	700000	"	1750000	4½ "
"	800000	"	2000000	4½

Code.—Continued.

TABLE 3. STAGE POCKET AND BORDER CIRCUITS, AND ELSEWHERE BY SPECIAL PERMISSION.

Size of Wire	Maximum Number of Wires in Conduit					
	Inch 1	Inch 1¼	Inch 1½	Inch 2	Inch 2½	Inch 3
14	11	19	26	43	61	95
12		15	21	34	50	77
10		12	16	27	38	60
8			13	22	31	49
6					14	22

Where single conductor, single braid, solid wires only are used, four No. 14 wires may be installed in a ½-inch conduit and up to seven No. 14 wires in a ¾-inch conduit. Three No. 12 wires may be installed in a ½-inch conduit, four No. 10 wires in a ¾-inch conduit and three No. 8 wires in a ¾-inch conduit.

For groups or combinations not included in the above tables, consult the authority enforcing this Code. For such groups or combinations, it is recommended that the conduit be of such size, that the sum of the cross-sectional areas of the several conductors will not be more than 40 per cent. of the interior cross-sectional area of the conduit.

r. Wires in vertical conduits shall be supported at the following intervals:

No. 14	to No. 0	not greater than 100 feet
No. 00	" No. 0000	" " " 80 "
No. 0000	" 350000 C. M.	" " " 60 "
350001 C. M.	" 500000 C. M.	" " " 50 "
500001 C. M.	" 750000 C. M.	" " " 40 "
	above 750000 C. M.	" " " 35 "

The following methods of supporting cables are recommended:

1. By approved clamping devices constructed of or employing insulating wedges inserted in the ends of the conduits.

2. By inserting junction boxes at the required intervals in which insulating supports of approved type are installed and secured in a satisfactory manner to withstand the weight of the conductors attached thereto, the boxes being provided with covers.

3. In approved junction boxes, by deflecting the cables not less than 90 degrees and carrying them horizontally to a distance not less than twice the diameter of the cable, the cables being carried on two or more insulating supports, and additionally secured thereto by the wires if desired.

s. Vertical wires of No. 1 or larger shall not be deflected where they enter or leave a cabinet unless a gutter having a width in accordance with the following table is provided.

Feeder Size (A.W. gauge)	Minimum Width of Gutter in Inches
1	3
0-200,000 cm.	4
211,600 cm. to 500,000 cm.	6
600,000 cm. to 900,000 cm.	8
1,000,000 cm. to 1,400,000 cm.	10
1,500,000 cm. to 2,000,000 cm.	12

TEST QUESTIONS

1. *Is there any difference between rigid conduit and ordinary wrought pipe?*
2. *What are the requirements for good rigid conduit?*
3. *What knowledge must the electrician possess to install rigid conduit?*
4. *What operations are included under the term "pipe fitting"?*
5. *How should conduit be cut?*
6. *If a pipe cutter be used, what precaution should be taken?*
7. *Describe the cutting of threads on conduit.*
8. *Give various methods for the calculation of offsets.*
9. *What are the natural trigonometrical functions and how are they used in the calculation of offsets?*
10. *In making turns in a conduit line, are such fittings as elbows used?*
11. *What is the minimum radius allowed by the Code?*
12. *Mention the various methods used in bending conduit.*
13. *What is a hickey?*
14. *Describe methods of bending conduit with a form bender and with a roller bender.*

15. *What is a conduit fitting?*
16. *How does a conduit fitting differ from an ordinary pipe fitting?*
17. *What is the object of giving access to the interior of a conduit fitting?*
18. *What are the various forms of covers used on conduit fittings?*
19. *Describe a receptacle cover.*
20. *How are wires connected to the base of a receptacle cover?*
21. *Describe in detail an outlet coupling.*
22. *Describe the method of tapping a branch circuit with conduit T.*
23. *What is the difference between a male nipple and a female nipple?*

VARIOUS LAMP CONTROL SCHEMES

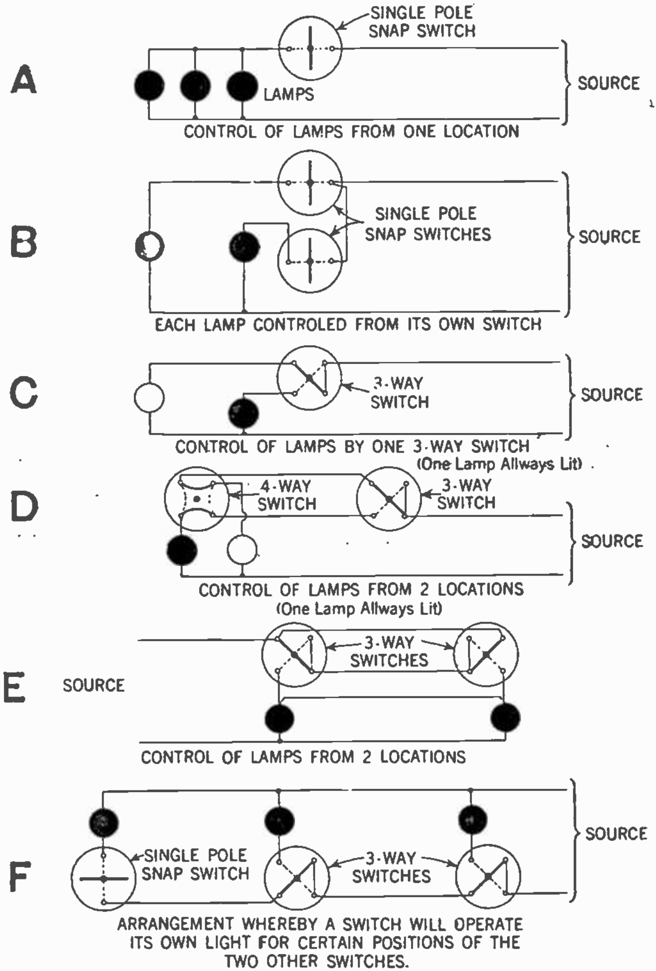


PLATE.—In the lamp control diagrams represented above, fig. A illustrates the connection when one single pole snap switch is used.

FIG. B shows how two lights (or two group of lights) can be controlled individually from a set of two single pole switches.

FIGS. C to F illustrate a series of special types of lamp control used in, for example, test circuits, or in any location where particular control schemes are desirable.

LAMP CONTROL FROM 2-LOCATIONS

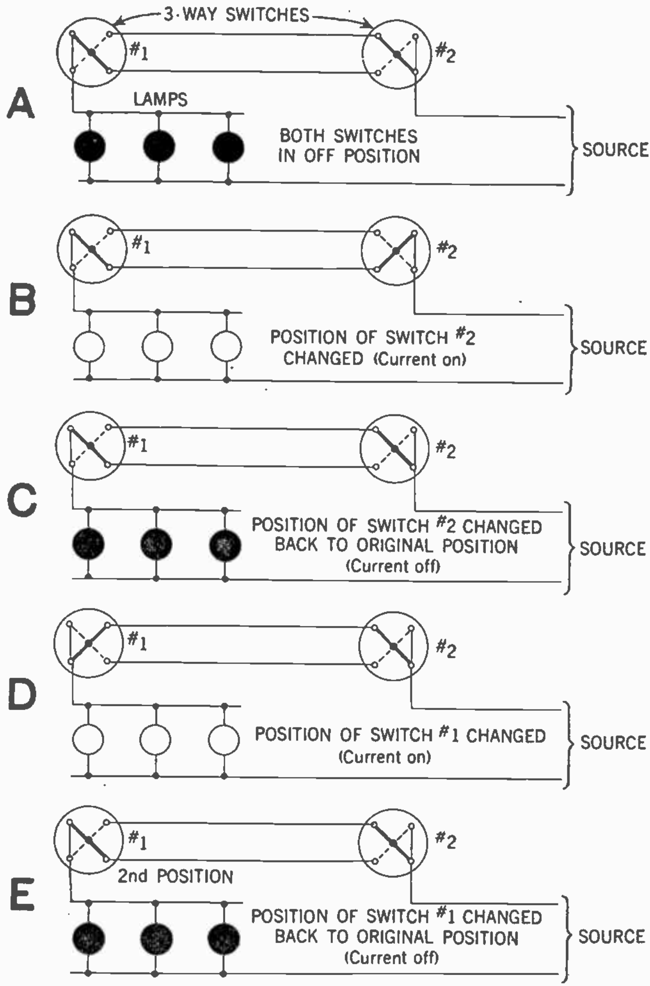
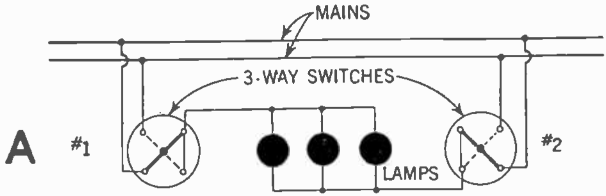
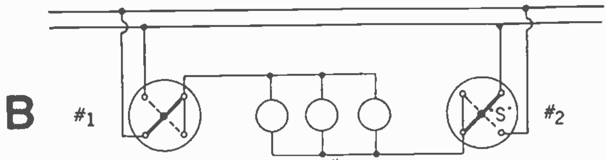


PLATE.—A convenient and often used method for control of a lamp or a group of lamps from two points by means of 3-way switches is shown in the diagrams. The lamps may be extinguished or lighted from either switch regardless of the position of the other. When both switches are in the positions shown in fig. A, the lamps are extinguished, and can be illuminated by the operation of switch No. 1 or 2. If as shown in diagram, No. 2 switch is operated the lamps will be illuminated, and can now be extinguished from either switch. A typical sequence of operation is shown diagramatically in figs. A to E.

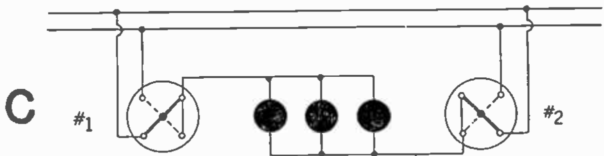
LAMP CONTROL FROM 2-LOCATIONS



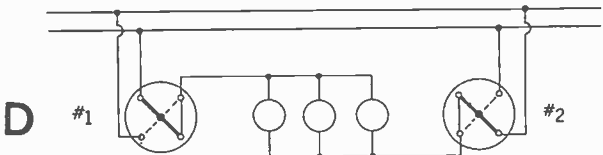
BOTH SWITCHES IN OFF POSITION



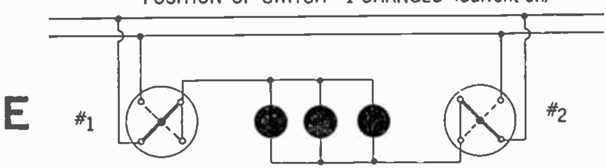
POSITION OF SWITCH #2 CHANGED (Current on)



POSITION OF SWITCH #2 CHANGED BACK TO ORIGINAL POSITION (Current off)



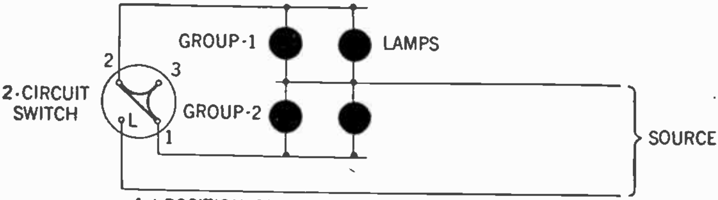
POSITION OF SWITCH #1 CHANGED (Current on)



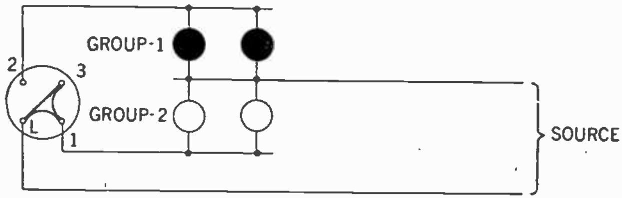
POSITION OF SWITCH #1 CHANGED BACK TO ORIGINAL POSITION
(Current off)

PLATE.—This connection provides an economical means of lamp control from two locations. Although not permissible under the National Electric Code it is shown only as an electrically possible circuit. As in the previous connections shown, both switches are in off position in fig. A, the lamps extinguished, and can be lit by operating either switch. If switch No. 2, fig. B. is operated to position "S" the lamps will be illuminated, and can be extinguished again from any one of the two switches. Figs. A to E inclusive shows the lamps lighted or extinguished, depending on position of switch No. 1, relative to the position of switch No. 2.

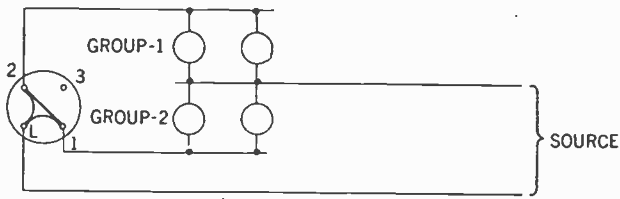
LAMP CONTROL FROM 2-CIRCUIT ELECTROLIER SWITCH



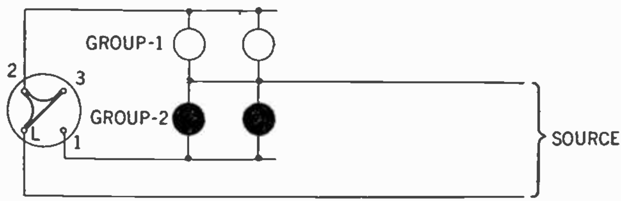
1st POSITION OF SWITCH



2nd POSITION OF SWITCH



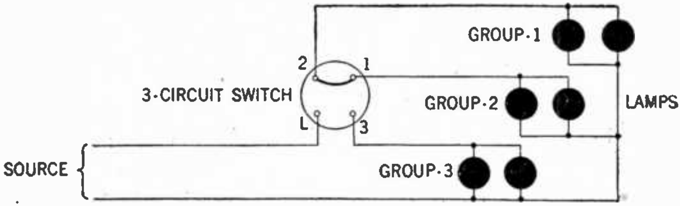
3rd POSITION OF SWITCH



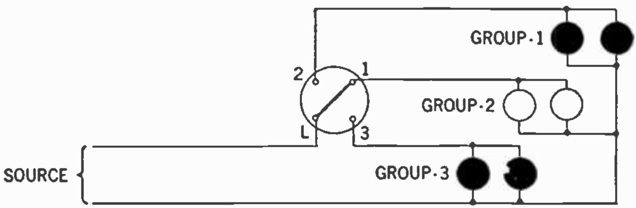
4th POSITION OF SWITCH

PLATE.—Large fixtures or electroliers are often wired so that lights can be controlled in two or more independent groups. As shown in the diagram the two groups of lamps are extinguished in the first position of the switch. When operating the switch to second position, group No. 2, will be illuminated. In the third position the maximum amount of brightness is obtained as both groups of lamps are illuminated, and finally in the fourth position, group No. 1 only is lit. This switch may not be considered as standard, it is only one of several arrangements.

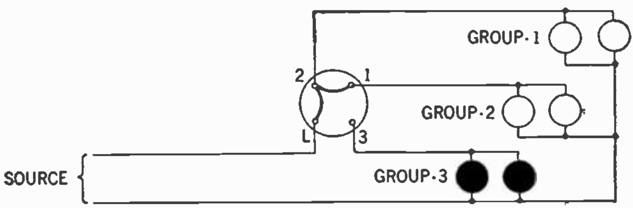
LAMP CONTROL FROM 3-CIRCUIT ELECTROLIER SWITCH



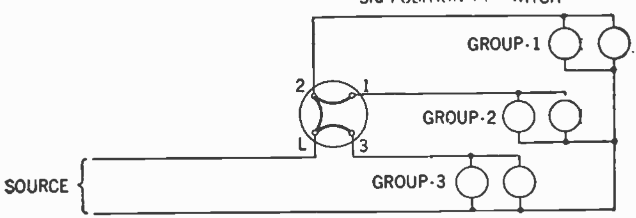
1st POSITION OF SWITCH



2nd POSITION OF SWITCH



3rd POSITION OF SWITCH

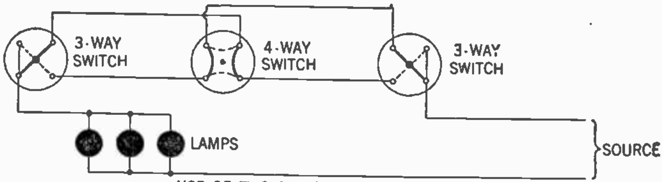


4th POSITION OF SWITCH

PLATE.—A 3-circuit electrolier switch from which three groups of lamps are controlled is shown above. The sequence of operation is depicted diagramatically and is principally the same as shown in the previous 2-circuit switch. In the 4th position maximum illumination is obtained, with all lamps lighted. The switch shown is typical only among a great variety of switches manufactured for electrolier or dome lamp control. The current carrying capacity of the switch as well as potential of the source to be connected should be considered for each individual application.

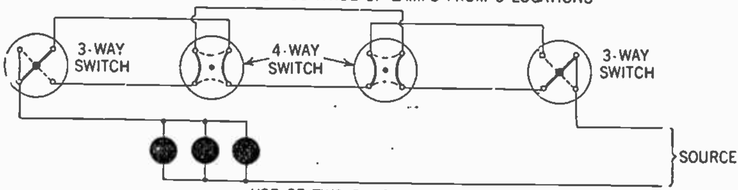
CONTROL OF LAMPS FROM MORE THAN ONE LOCATION BY MEANS OF 3 AND 4-WAY SWITCHES

A



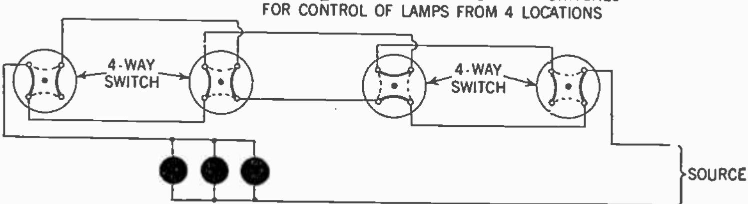
USE OF TWO 3-WAY AND ONE 4-WAY SWITCH FOR CONTROL OF LAMPS FROM 3 LOCATIONS

B



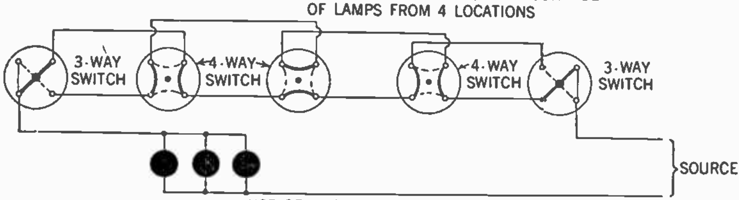
USE OF TWO 3-WAY AND TWO 4-WAY SWITCHES FOR CONTROL OF LAMPS FROM 4 LOCATIONS

C



USE OF FOUR 4-WAY SWITCHES FOR CONTROL OF LAMPS FROM 4 LOCATIONS

D



USE OF TWO 3-WAY AND THREE 4-WAY SWITCHES FOR CONTROL OF LAMPS FROM 5 LOCATIONS

PLATE.—The series of connection diagrams shown in figs. A to D, illustrate the conventional methods of lamp control when using 3- and 4-way switches. With reference to fig. A, it is obvious that for any additional point of control desired a 4-way switch connected the same as the middle switch must be used. See figs. B to D.

CENTRAL POINT LAMP CONTROL

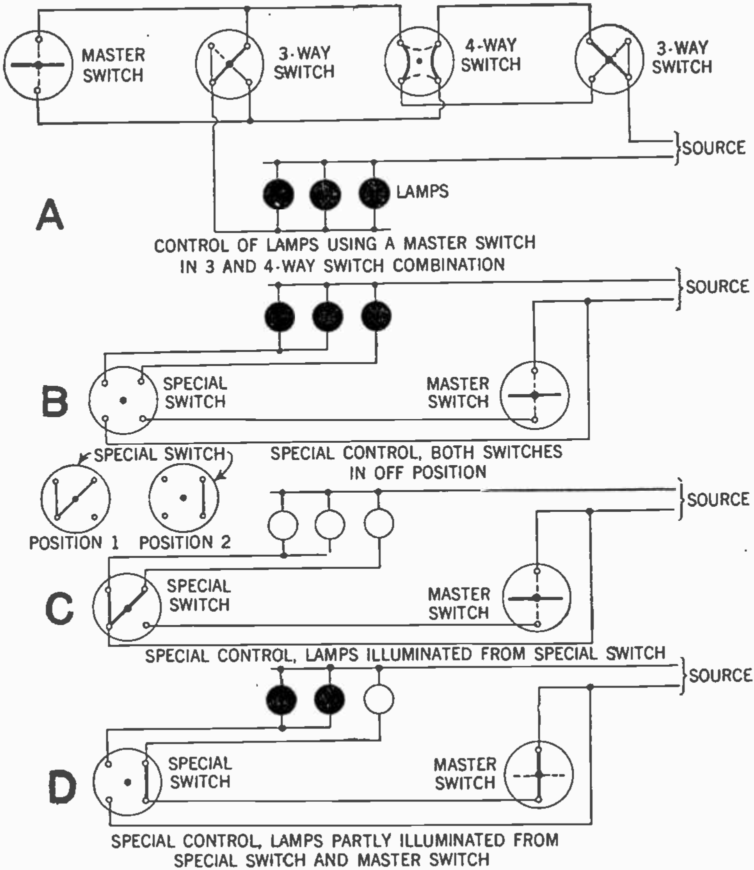


PLATE.—In residence lighting systems, it is often desirable to control all or part of the lamps from one central point (the owner's bedroom for example) irrespective of the position of the other switches used. This central point is as shown in the diagram provided with a master switch for complete control of the lamps. See fig. A. When control over a larger number of lamps is desired, it is necessary since the carrying capacity of the master switch is only about 15 amperes, to install a special form of switch, the connection of which is shown in figs. B to D. In this method the lamps are connected in two groups, the special switch is employed for the regular control of the lamps and each of these switches is connected to a common wire. By utilization of this form of control the lamps in each large fixture may conveniently be controlled from one point.

STAIR-WAY LAMP CONTROL WIRING

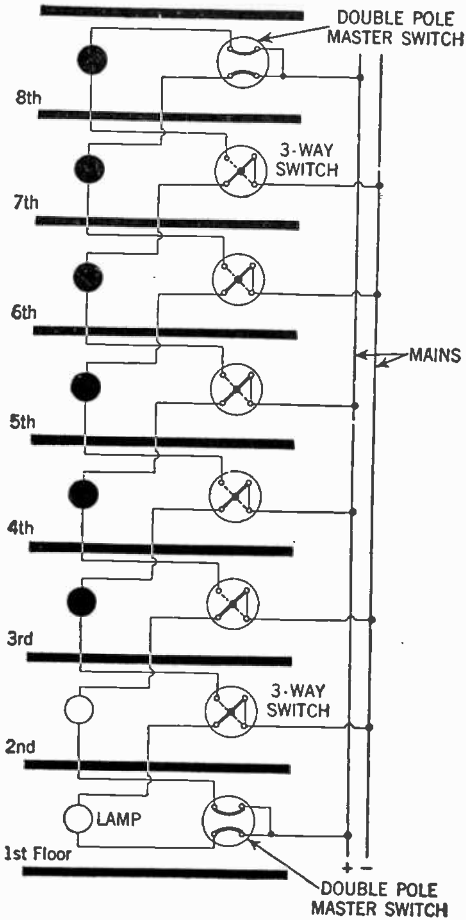


PLATE.—As shown in circuit diagram the switches used in this type of light control consist of two double pole switches, inter-connected on the first and last floor, and one 3-way switch for each floor. The sequence of operation is as follows: Closing switch on the first floor lights lamp on first and second floor. Turning the switch on the second floor extinguishes the light on the first floor and lights the lamp on the third floor, etc. This operation is continued until the top floor is reached, in other words the switch on each floor should be turned in passing. It can be readily seen that this light control arrangement lends itself to operation of lamps irrespective of number of floors encountered.

CHAPTER 116

House Wiring

The wiring of finished houses is not as easy as it may appear, as there are no two houses built alike, and there are no two wiremen who would wire the same house in the same manner.

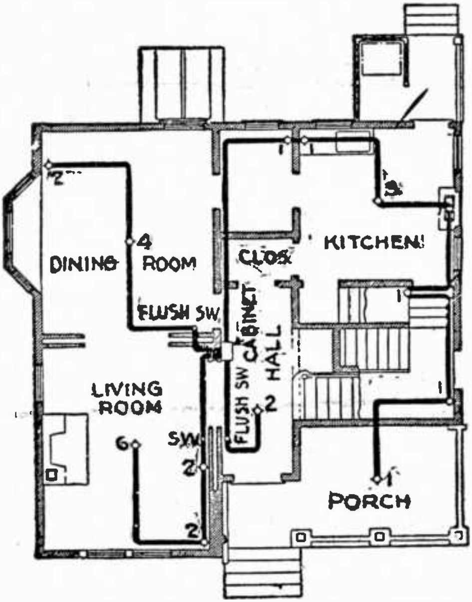


FIG. 5,560.—Plan showing one floor of a dwelling wired with conduits. The numbers on the various outlets indicate the number of lamps supplied. The wiring is carried out on the loop system, and it will be noticed that no branches are taken off between outlets. Four circuits are used in order that there may not be more than ten lamps on any one circuit.

Then there are numerous setbacks that make it difficult to proceed with the work quickly, such as parquet floors, double floors, clogged partitions and other obstructions which are met with but if the instructions be carefully followed no difficulty will be experienced.

By laying out the job and drawing a rough sketch much labor and material will be saved.

In many cases the only instructions given the electrician who does the wiring is simply a plan showing the location and number of lights, from

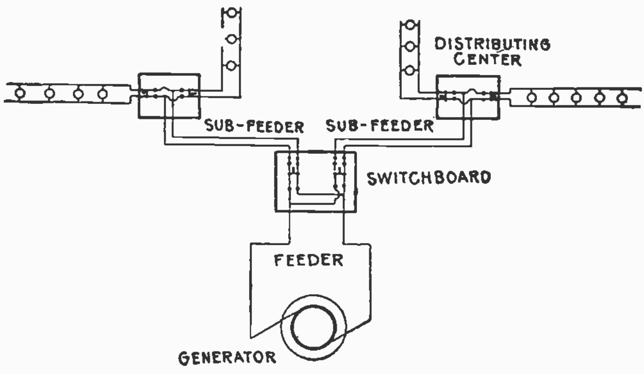
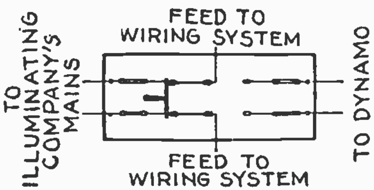


FIG. 5,561.—Two wire parallel system as used in isolated plant.



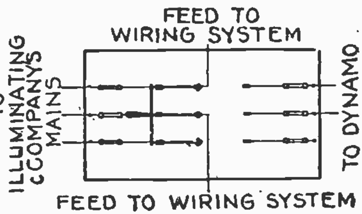


FIG 5,562.—Double throw switch for use in isolated plants when auxiliary power is used from the central station in case of breakdown.

FIG. 5,563.—Double throw three pole switch for use in isolated plants where auxiliary power is brought in through three wire system. The side of the switch controlling the current is bridged as shown.

which he must figure out how to install them using the least amount of material and labor consistent with a good installation that will pass inspection.

It should be ascertained how many sockets are to be attached to each outlet, as the code allows only 660 watts to each 2 wire circuit on 40 watts per socket; base plugs are counted as sockets.

After having laid out the number of lights per circuit and the number of circuits, the center of distribution should then be found—if a large house having over 4 circuits, it is advisable to install a panel board that will feed the various circuits; this panel should be installed at a central point.

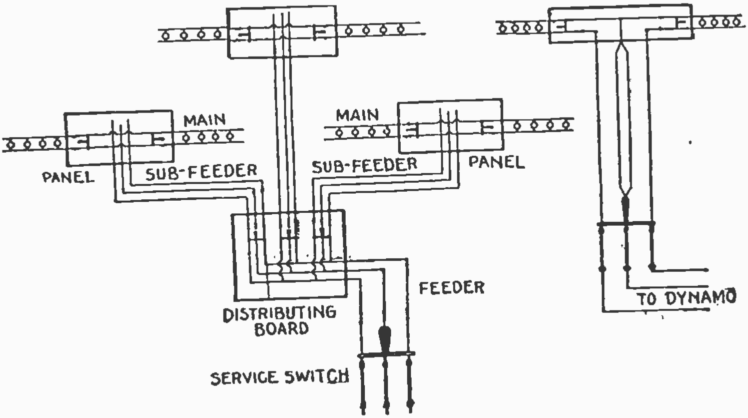


FIG. 5,564.—Three wire convertible, or three wire two wire system; used to advantage where power is supplied from an outside source and brought in through the three wire system. The only difference between the three wire convertible, and the straight three wire system is that the center or neutral wire of the mains and feeders should have a current capacity equal to the other two. *The reason* for this is that it allows the system to be readily changed over to a two wire system for use in connection with a private plant.

FIG. 5,565.—Diagram showing reinforcement of neutral wire necessary to change regular three wire system to two wire system. The capacity of the neutral wire must equal that of the sum of the two other wires.

Panel boards in loft buildings or in any building requiring 8 to 10 circuits to a floor should be distributed one to a floor.

In a building covering a large area it is often advisable to install two panels or centers to a floor, with two sets of feeders. It is advisable to keep circuit lengths down to 100 feet or less, and the judicious laying out of circuit centers will save many feet of wiring.

The distributing centers or cut out cabinets should be installed near a partition that is so located as to make the running of risers easy, and should be on an inside wall to guard against dampness.

If only one distributing point be used, it should be either in the cellar or attic and risers run to the different floors.

In private houses it is sometimes advisable to install only one panel for the entire house. This is good practice for a three story house not requiring over twelve circuits.

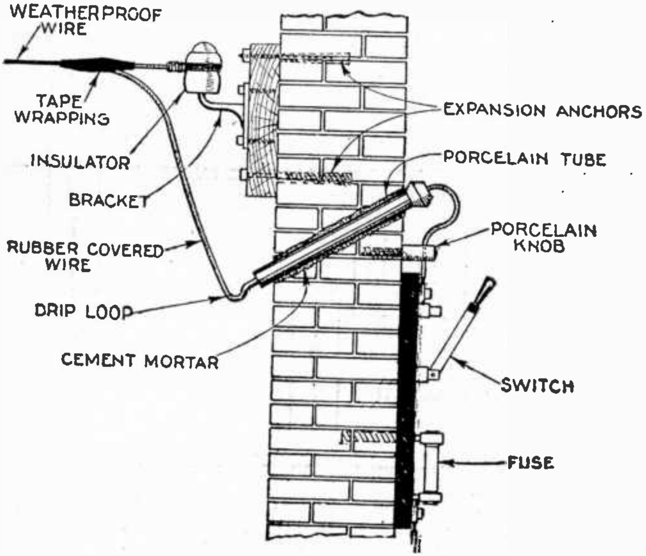


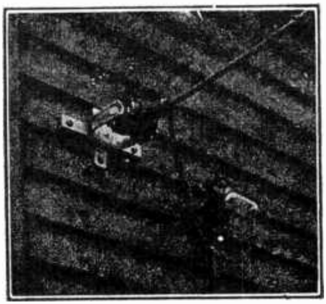
FIG. 5,526.—Tube service entrance for single wire installation.

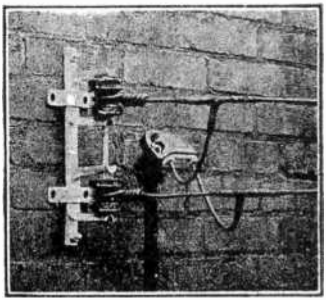
In some cases it is not advisable to install a panel, but to bring the wires down to the cellar, to the meter board where fuse blocks for the various circuits are installed on the meter board.

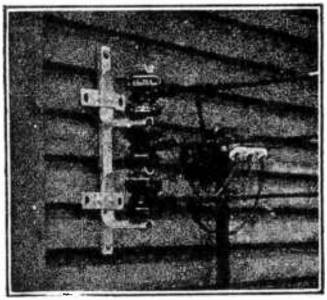
Service Connections.—By definition a *service* is *that portion of the supply conductors which extends from the street main or* *duct or transformers to the service switch, switches, or switchboard of the building supply.*

There are numerous methods of making service entrance into buildings, and they may be classified as

1. Tube;







FIGS. 5,567 to 5,569.—Pierce house racks and insulators for service connections showing one, two and three wire installations.

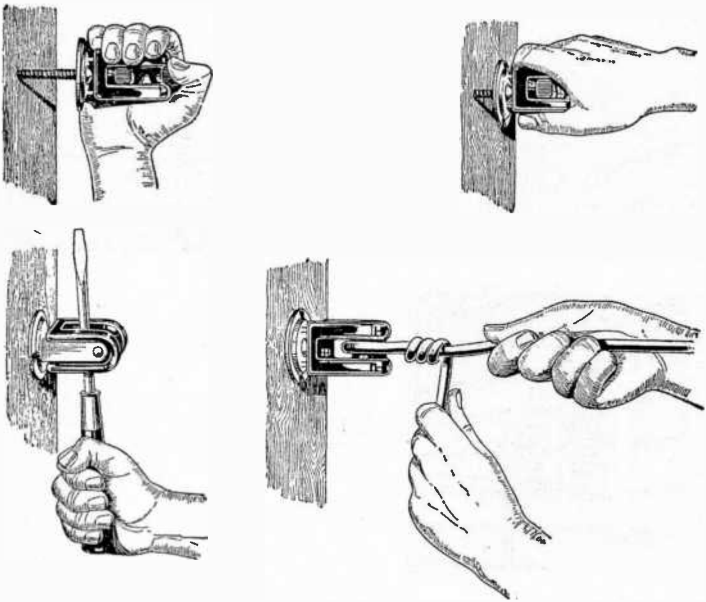
2. Conduit.

   a. Overhead;

   b. Underground.

Fig. 5,566 shows a tube service entrance for a single wire. The essential requirements are

1. Dead end insulator to carry the strain;
2. A connecting loop projecting downward forming a "drip";
3. Extra insulation as porcelain tube where wire passes through building;
4. Porcelain knob to keep wire away from wall and prevent strain on the switch connection;



FIGS. 5,570 to 5,573.—Method of installing Pierce wire holder insulator. First a jab, fig. 5,570; then a few turns, fig. 5,571; tighten with screw-driver, fig. 5,572; and tie in the line, fig. 5,573.

5. Cut out switch.

The conduit overhead service entrance is the most satisfactory method of bringing in service wires from overhead lines. If it become necessary to install new wires the change is more easily made than with the tube service.

Rigid conduit is used extending from the cut out switch to a point at least eight feet above the ground.

The wires enter the conduit through a fitting called a *service cap*, as shown in fig. 5,574 to protect the wires where they enter the conduit and also to prevent water entering the conduit.

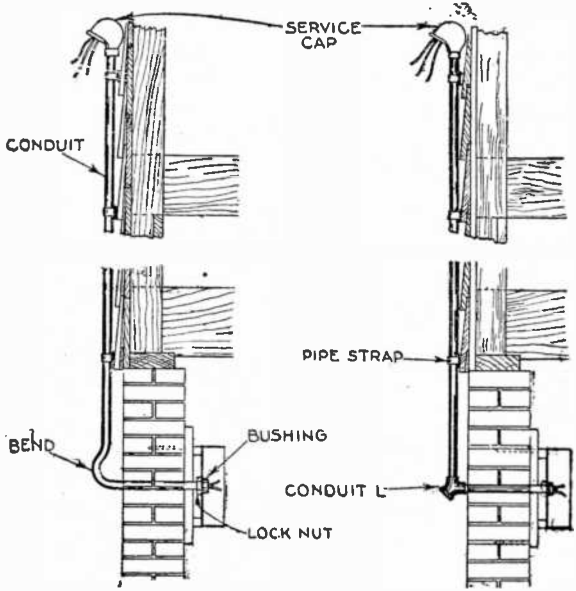


FIG. 5,574.—Service cap as used in overhead conduit service. Note porcelain with holes through which the wires enter.

FIG. 5,575.—Overhead conduit service entrance showing fittings used and connection with the switch box.

To install a conduit service entrance, a hole should be drilled or bored through the wall where the conduit is to pass.

The conduit may then be bent so that the end passing through the wall extends ⅜ inch inside the main line switch cabinet. Instead of bending the conduit, the turns may be made with an approved conduit L fitting (not a common pipe elbow) as shown in fig. 5,575.

The end of the conduit is secured to the switch box by means of a lock-nut and bushing. The locknut is screwed on the conduit before it enters the switch box. The bushing is placed on the end of the conduit inside of the switch box. This bushing is made to protect the wires where they leave the pipe, and should be screwed up tight with a pair of gas or combination pliers. The locknut is then drawn up against the wall of the cabinet until the conduit is held securely in the switch box.

That portion of the conduit which is on the outside of the building is held in place by means of pipe straps, which in turn are fastened with

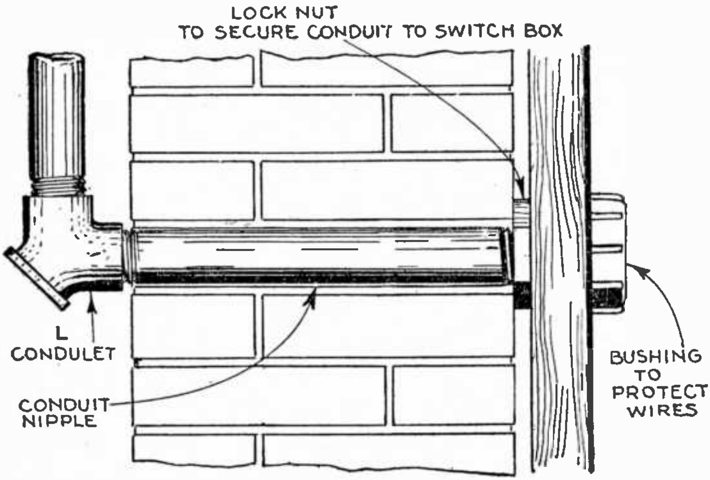


FIG. 5,576.—Fittings used in securing conduit to switch box.

screws. The L condulet must be of the weather proof type. Figs. 5,577 to 5,579 show one type of L condulet. This fitting is made weather-proof by placing a rubber gasket between the body of the fitting and the cover.

Underground service entrance consists of a run of conduit extending from the street manhole to the switch box.

Wires encased in a lead sheath are pulled in. These wires must be continuous without a splice. The conduit should be placed deep enough (at least 30 inches) so that there is little chance of anyone coming into contact with it, while digging the ground for pavement or other such purposes. Care should also be taken to close the openings around the conduit where it passes through the wall. The space between wires and conduit at either end should be sealed to prevent sewer gas entering the building.

Fig. 5,580 shows a typical underground service entrance.

Feeders and Mains.—In making a feeder layout for a large

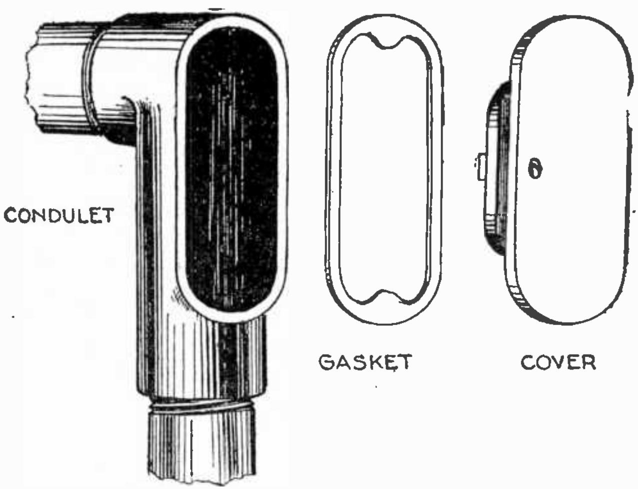


FIG. 5,577.—Weather proof L condulet for making 90° turn. It is the equivalent of a 90° pipe elbow designed to meet the electrical requrements.

FIGS. 5,578 and 5,579.—L condulet gasket and cover fastened with screws.

building, a good method is to draw an elevation of the building as in fig. 5,581, and note on each floor the current requirements.

The best plan is to furnish a feeder for every floor, especially in large installations. In smaller installations one or two feeders are sometimes all that are required.

Feeders for motors should be independent of lighting feeders. In calculating sizes, feeders requiring over 2 inch pipe should not be used. It is better to subdivide them, especially if there be many bends or offsets, since two inch pipe is about the limit in size for economical handling.

Feeders should radiate from a distributing panel, having a proper sized switch and fuse for each feeder.

If the system of wiring be such that auxiliary power is taken from a local lighting company, it is a good plan to have each circuit controlled by a double throw switch so that in case of overload, any circuit can be fed from the illuminating company's mains as in fig. 5,562.

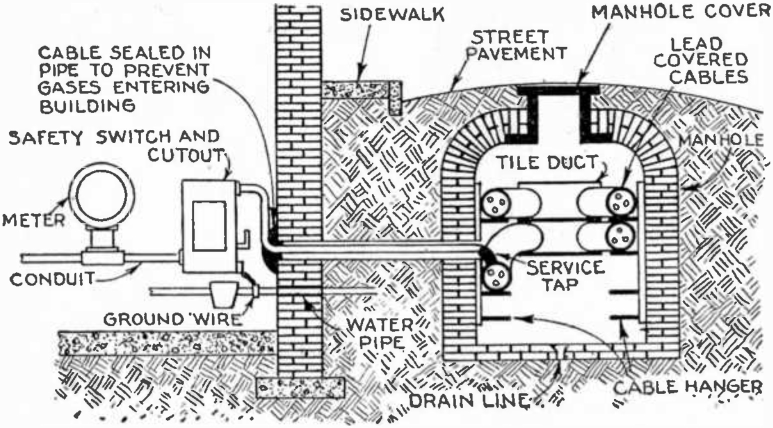


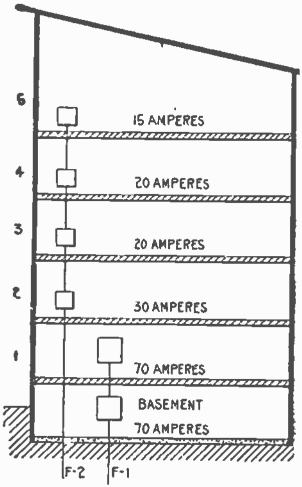
FIG. 5,580.—Underground service entrance.

It is advisable to install feeders and mains in conduit even though the circuit wires be run otherwise. Since the former carry the main supply of current it is important to have them well protected as they usually run up side walls.

The Underwriters make numerous restrictions against open or moulding work on brick walls and require good protection, and this is an additional reason for piping the mains and feeders.

In laying out the branch circuits, it is not good practice to use up the Underwriters' circuit allowance of 660 watts.

If a circuit be wired with the full allowance of lamps, no additions could be made without violating the *Code* requirements.



Locating Outlets.—If concealed wiring is to be installed, the outlets should be marked on the ceilings and walls with a pencil cross at the spot, marking also the location of switches, etc.

If a ceiling outlet is to be placed at the center of the ceiling, it is first located on the floor and then transferred to the ceiling by means of a plumb bob.

Furring Strips.—After locating the outlets a small portion of flooring is removed to find out whether or not there are seven-eighth inch furring strips between the joists and the ceiling plaster.

FIG. 5,581.—Diagram showing current required on each floor of building. A sketch of this kind is useful in laying out the feeder system.

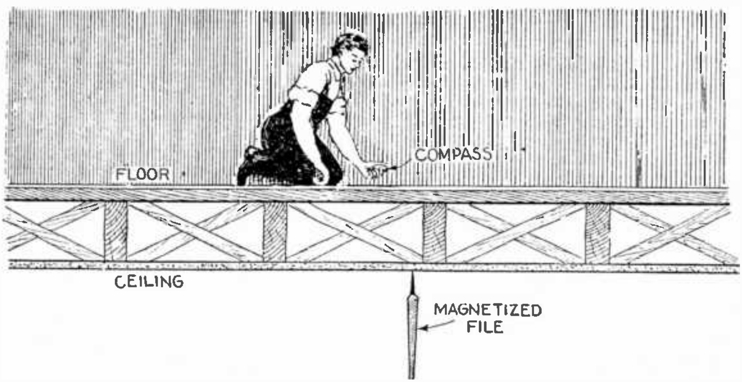


FIG. 5,582.—Method of locating outlet with a compass. A strongly magnetized file is placed at the point selected for outlet, then by exploring on the floor above with a compass, the needle will be agitated when moved directly over the file.

If a house have hot air registers set in the floors, they may be lifted up, instead of taking up flooring. If it be found that there are furring strips, much labor will be saved, as the wires may then be fished from outlet to outlet and little flooring need be removed. All houses, however, are not so built, so in case there be no furring strips it will be necessary to take up the floor and bore a hole in each joist or beam.

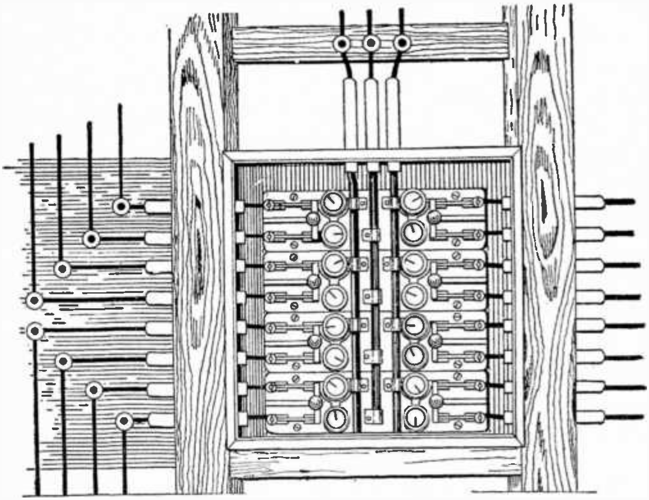


Fig. 5,583.—Installation of wooden cabinet containing fuses and cut out switches for each circuit. The term *cut out box* is usually applied to boxes designed for surface mounting and accommodating only a few circuits, but it is also frequently used to designate the smaller and cheaper forms of boxes used in concealed work. The above box is lined with asbestos or metal. The mains and the branch circuits are led into the box through porcelain tubes. The finished box has a wooden door lined with fireproof insulating material, such as slate or asbestos board, and is finished on the outside to harmonize with the adjacent trim.

Cutting the Outlets.—After locating the centers for the outlets, the plaster must be cut out so that the outlet box will set in.

For this purpose a special tool has been designed; this plaster drill is constructed so that it may be fitted over a gas pipe, the cutters are adjustable so that any size hole may be cut. A bell shaped cup catches any dirt that may be removed so that a neat and clean job is made if a

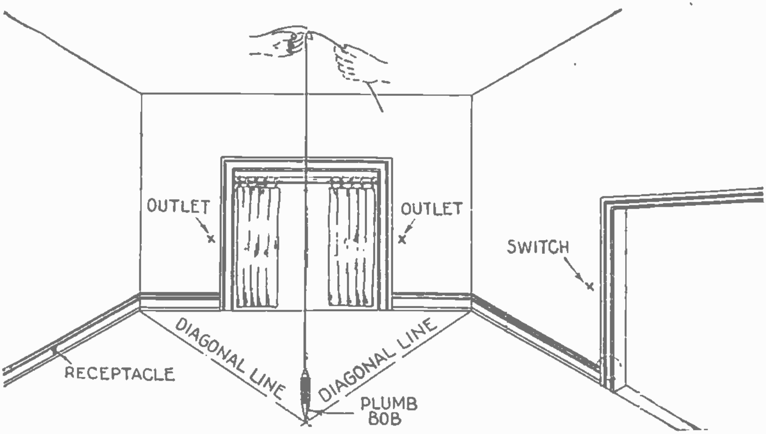


FIG. 5,584.—Marking for outlets and method of locating ceiling outlet on floor and transferring it to the ceiling with plumb bob.

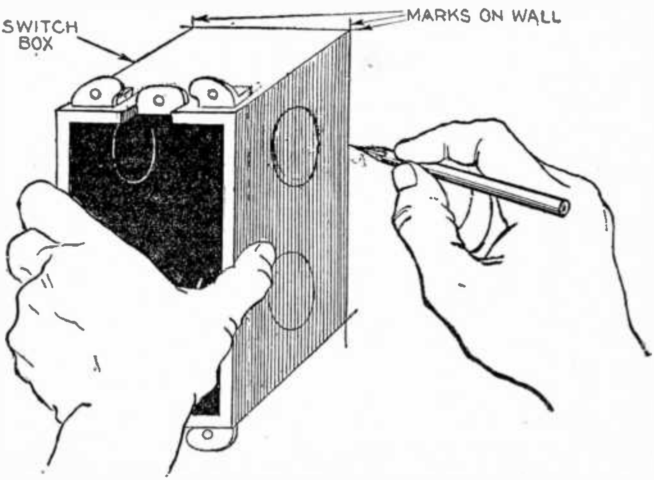
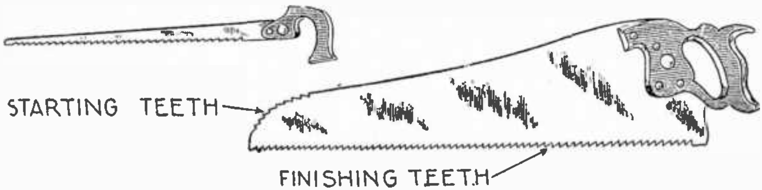


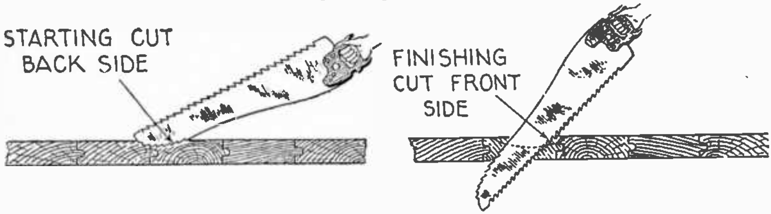
FIG. 5,585.—Marking plaster for fixture outlet box.

drill of this type be used. But if a plaster drill be not obtainable, the outlet box should be traced over with a pencil similarly as in fig: 5,585 and the plaster should be chiseled around this mark with a ¼ inch blade screw driver.

Taking Up Floor.—Various kinds of flooring are to be encountered in wiring houses.

In those built previous to 1875 the floor boards are as wide as 10 to 12″ and are smoothed edged, unlike the present day





Figs. 5,586 and 5,587.—Floor saws. Fig. 5,586, ordinary compass saw. It should be about 8 to 12 ins. long, very thin blade and tapered to ¼ in. at the end; fig. 5,587, special double edge saw for finished floors.

Figs. 5,588 and 5,589.—Method of working the double edge saw. Fig. 5,588, starting the cut with back edge; fig. 5,589 finishing cut with front edge.

type of board which has a tongue and groove. This type of flooring is very simple to take up.

If when cutting the outlets, a small hole be bored through the ceiling and the bit pushed up till it comes in contact with the flooring of the room above, and this flooring be also bored, it will show where to take up the flooring to install the wires when they run parallel with the joists. When the wires must run perpendicular to the beams all the flooring must be taken up so that the holes can be bored in the joists through which the wires must pass.

Floor planks are properly removed by driving the nails down with a nail set and lifting up the board.

If double floors be encountered, it will be found very difficult as double floors are constructed of hard wood such as oak, or maple, and must be handled with extreme care and patience. For this type of floor, the tongue is split by inserting a carpenter's floor scraping blade, which is a sheet of steel about $4 \times 6 \times 1/64''$. These can be purchased at any hardware store at a small sum.

The scraper should be hammered down so that the tongue is split, both sides of the board should be split, so that no difficulty will be experienced when lifting up the board.

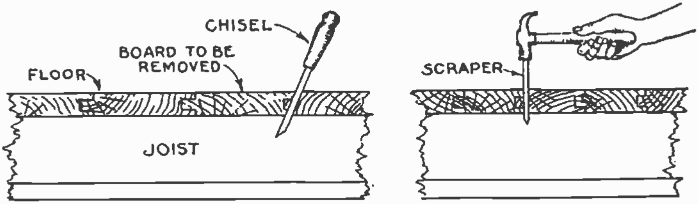


FIG. 5,590 and 5,591.—Two methods of cutting tongue of floor planks. Fig. 5,590, with chisel at angle—this cuts off tongue and also lower lip of adjacent plank; fig. 5,591, with scraper making a vertical cut.

After both sides of the board that is to be removed have been treated as above, a floor chisel should be inserted where the ends of the board meet with another and the board gently raised.

In raising the board, it is better to take time and proceed cautiously, as the finest floors may easily be ruined by having one board split, chipped or marred.

Before the boards are removed, they should be numbered or marked so that they will go back in place without any confusion. They should be placed in a safe place until ready to lay back the floor.

Holes for wires should be bored in the center of the joists so that when laying back the flooring, the nails will not penetrate the metal sheath and short circuit or ground the wires.

Cutting Pockets.—The center of each pocket is indicated by the small hole which was bored through the flooring when cutting the ceiling outlets.

In opening a pocket ¼ in. holes are bored to insert a keyhole saw through

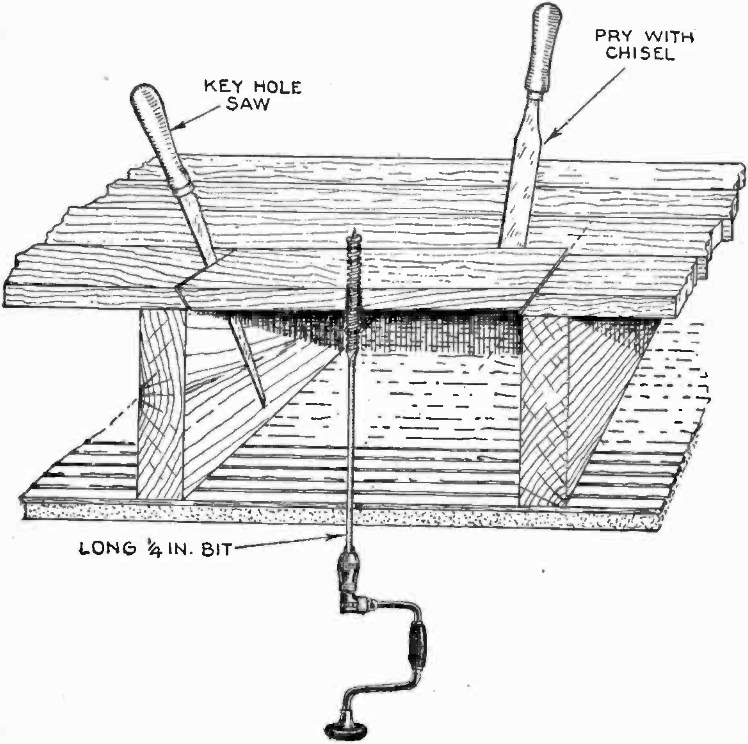


Fig. 5,592.—Sectional view showing method of cutting a pocket or opening in floor for the insertion of wires.

the joint between two boards at each end of the pocket, and as near the beams as possible, then the board is cut at an angle as indicated in fig. 5,592.

Next saw the tongue of the matched board on each side and pry up the boards with a chisel. Having taken up the boards, nail a cleat on the side of each joist as in fig. 5,593 so that when the floor is laid back there will be a good support.

A base board is next installed as in fig. 5,593 to give a secure hold for the

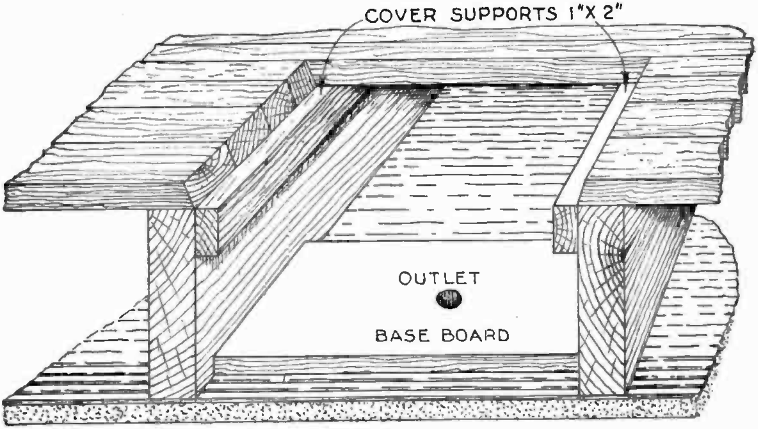


FIG. 5,593.—View of outlet pocket showing base board, and cover supports in position.

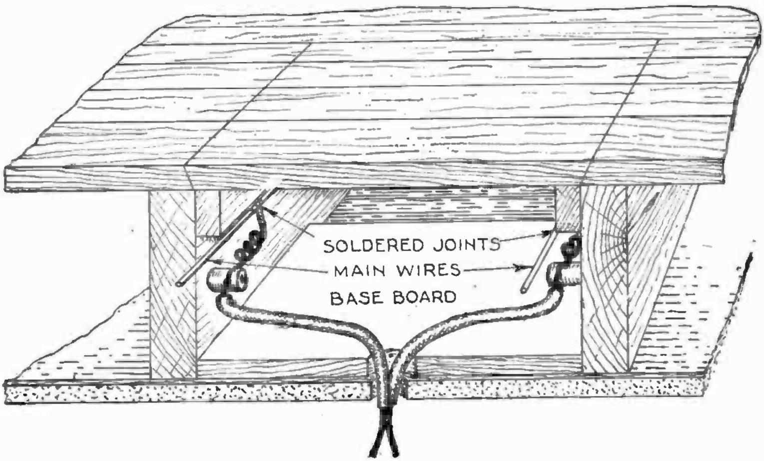
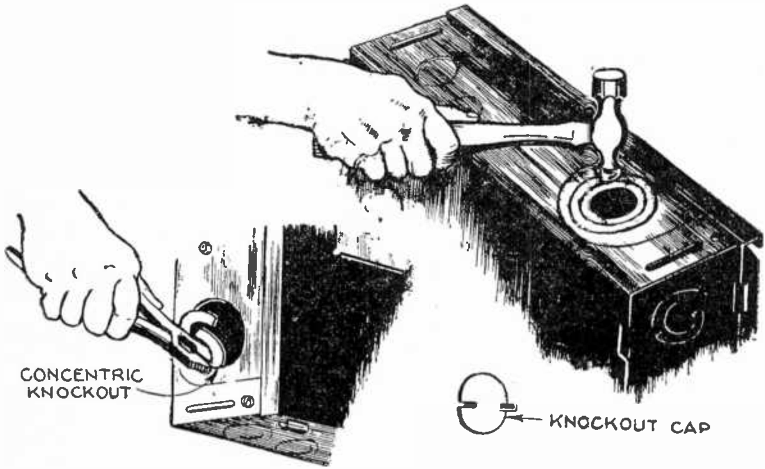


FIG. 5,594.—View of completed pocket and ceiling outlet showing method of bringing out the wires.

screws used in fastening the fixtures. Two holes are then bored diagonally with an $^{11}/_{16}$ inch bit, inserting the bit in the small hole bored in the ceiling as in fig. 5,592. The outlet wires are then tied around the knobs, the upper ends being bared and tapped on to the main wire. A piece of loom is slipped on each outlet wire after which it is thrust through the outlet as in fig. 5,594.



FIGS. 5,595 to 5,597.—Methods of removing knockouts and detail of knockout cap. Knockouts are ½ inch, ¾ inch and 1 inch in size for the accommodation of different sizes of pipes. There are also concentric knockouts which make it possible to accommodate any one of several sizes of conduit. Not more than the necessary number of knockouts should be uncovered. In case some that are not used are removed, the holes must be closed. This can be done by inserting a knockout cap.

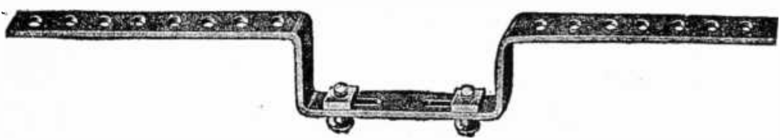


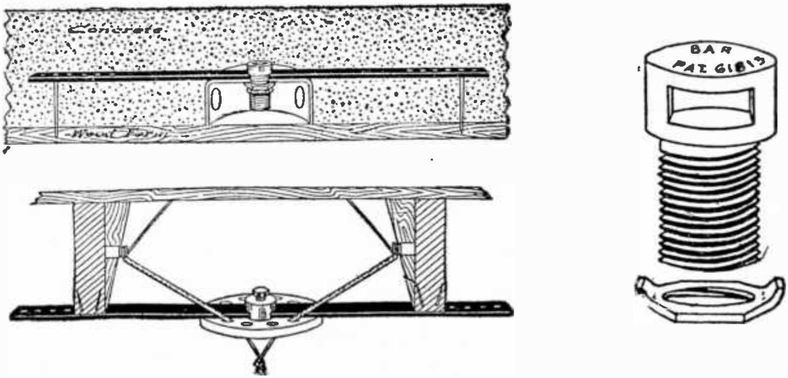
FIG. 5,598.—Austin universal box cleat used chiefly for side wall construction; can also be used on ceiling work. By nailing it across the front of joists a flush position for the box is obtained.

Installing Outlet Boxes.—To comply with the *Code* a box called an outlet box must be installed at each outlet.

Outlet boxes for loom wire are shallow iron boxes about ½ inch deep and made in two diameters, 3½ inch and 4 inch.

The base of the smaller box ordinarily has one knockout for a ½ inch pipe at its center. This is to allow a gas pipe to pass into the same outlet, if necessary. There are also six knockouts for loom to pass into the outlet.

The larger box is similar to the 3½ inch size, but there are eight knockouts for loom. No knockouts are placed in the side wall of either box.



FIGS. 5,599 to 5,602.—Application of Austin straight bar hanger and view of stud and locknut. All four knockouts are accessible in standard outlet boxes; especially suited to loom box, all eight knockouts can be used.

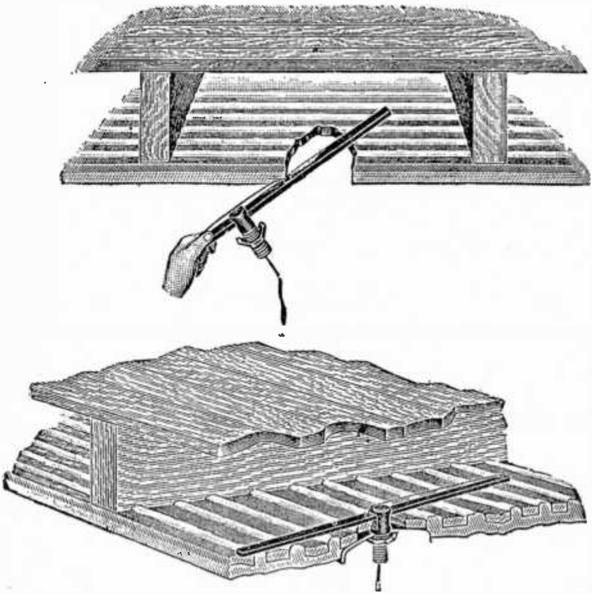
One knockout is removed for each wire, but no more should be removed than are necessary. If more be removed than are used, the box will be condemned by the inspector, unless the holes be plugged with metal.

Some boxes are equipped with clamps for fastening the loom, others are plain, and some other means of holding the loom in place is needed.

Each box has small holes in the base for fastening fixture studs and for fastening the box to a hanger. Some cities require deep outlet boxes for certain light outlets, such as for bracket lights. These boxes are 3 and

4 inches in size and about 1½ inches deep. They are made in several shapes, such as round, octagonal and square.

For light outlets, the round and octagonal boxes seem to be preferred. This is probably due to the fact that the covers or trims for the round box also fit the octagonal, while the square box requires a different cover.



FIGS. 5,603 and 5,604.—Austin "Economy" old work hanger. *Application:* The plaster is opened only large enough to permit the stud to pass through. The stud is then slipped up the end of the bar as shown and the assembly slipped through the hole. When the box is in a horizontal position, the wire leader is drawn through the stud. This slides the bar into position and centers the stud on the bar. The outlet box is fastened to the stud with a locknut and secured tightly in place.

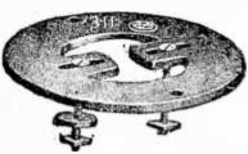
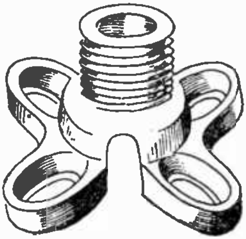


FIG. 5,605.—Adapting ring.

The base and the walls contain knockouts ranging from the loom size to the ¾ inch pipe size. Outlet boxes like loom boxes are punched for fastening fixture studs, and also for fastening to outlet box hangers.



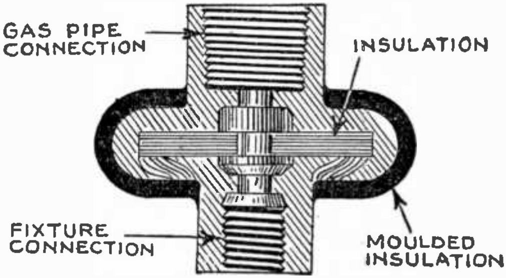


Fig. 5,606.—Fixture stud for supporting fixtures to outlet boxes.

Fig. 5,607.—Insulating joint. This fitting is used for fixture work. Insulating joint should be tested before being used.

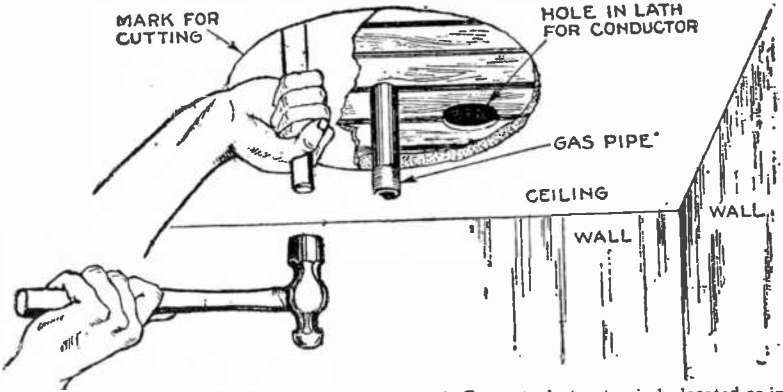


Fig. 5,608.—***Method of installing outlet box.*** *1.* Cut out plaster to circle located as in fig. 5,584. After lath is exposed, remove a small piece of lath, or bore holes in lath for the flexible conductor entrance. These holes should register with the two knockouts previously removed from the box for the entrance of the conductors. The size of the cut out plaster is exaggerated for clearness.

Fig. 5,582 shows the method of locating an outlet box.

After the plaster has been removed, the outlet box should be set in, so that it will fit snugly.

The *Code* requires that the lower edge of all outlet boxes should not be set back in plaster any farther than ¼ inch.

The box should be fitted to the hole in the plaster, and the lath should then be marked and notched out with a jack knife to allow the cable to

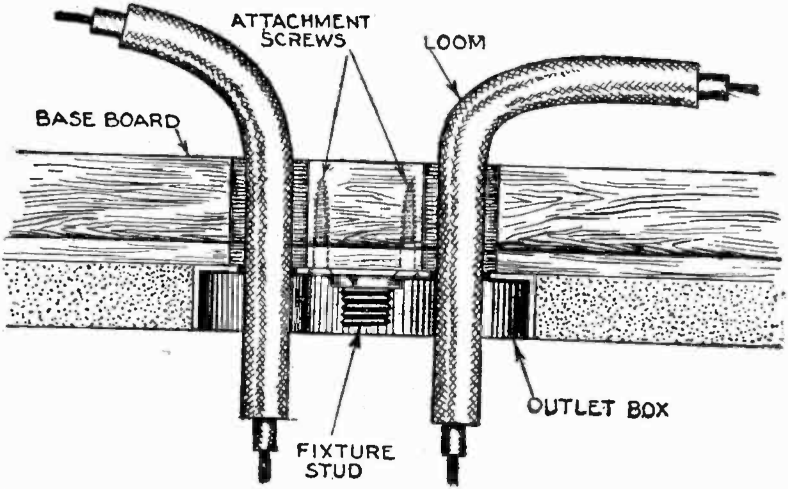


FIG. 5,609.—***Method of installing outlet box.*** *2.* Place box in position so that the holes from which knockouts were removed register with the holes cut out of lath. Secure box to cleat with screws having previously attached the fixture stud as shown.

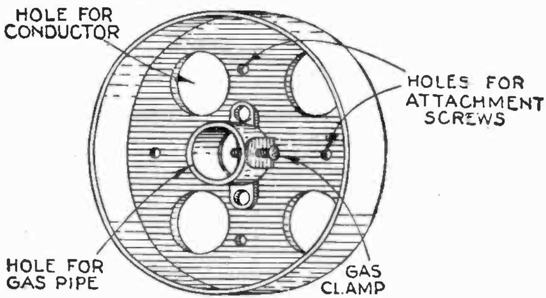
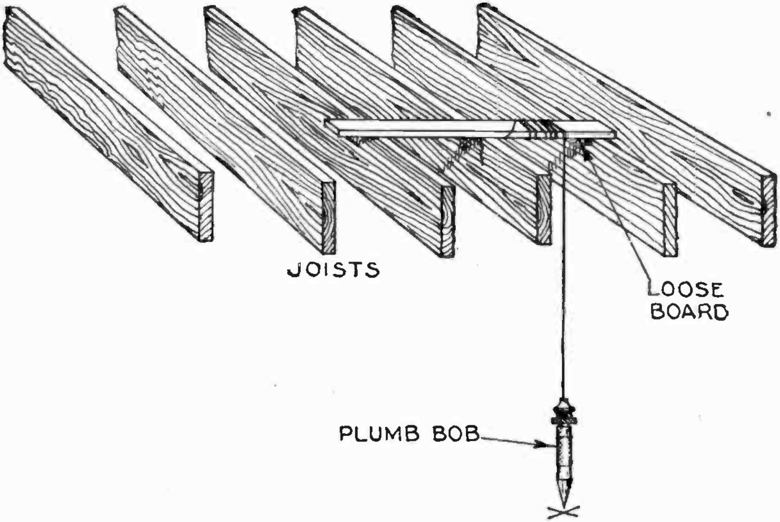
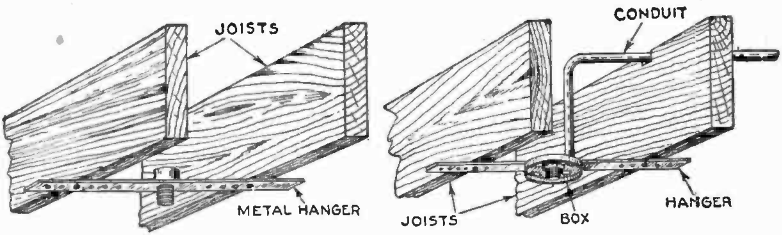


FIG. 5,610.—View of outlet box with gas clamp attached, the fitting used when installing box at gas outlet.

properly pass through into the box. Securing outlet boxes to laths is not allowed as this is not considered as a support, and in time will loosen up the plaster.





FIGS. 5,611 to 5,613.—Method of installing an outlet box in unfinished frame building. Having marked the position of the fixture outlet on the floor as in fig. 5,611, remove necessary knockouts from box and attach fixture stud. Nail a metal adjustable box hanger (if available) to the under side of joists, as in fig. 5,612, so that center of hanger will come in correct position. Attach box to hanger, as in fig. 5,613. If the box hanger have a fixture stud, none is required in the box, but the center knockout must be removed, and the box attached to hanger with locknut on the hanger fixture stud. Pass through box the flexible conductors or attach conduit as in fig. 5,613.

The only places where a board is not required is where an outlet happens to be located on a beam, joist or stud. Side lights can be located on upright studs which are the best supports to be obtained. It is not always possible to locate outlets on joists, and still have the outlet in the center, for this reason outlet boards should be installed. These should be very carefully installed so as not to mar the ceiling.

Where the outlet is to be made to existing gas pipe outlets combination boxes should be used. No board is required, and the box must be securely fastened to the gas pipe.

Where the plaster is broken it should be repaired with plaster of Paris.

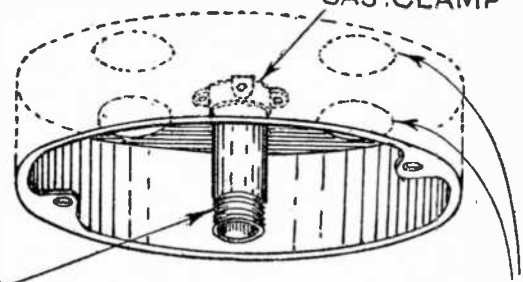


FIG. 5,614.—Outlet box installed at gas outlet.

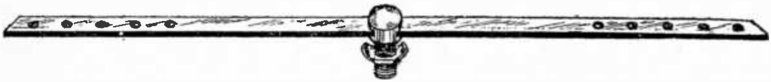
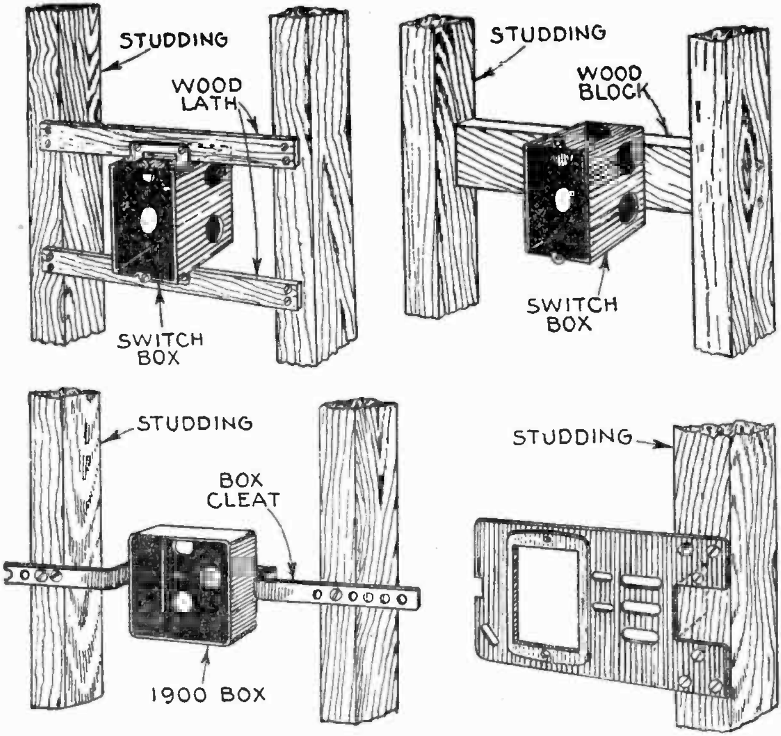


FIG. 5,615.—Austin straight bar hanger and stud. The stud is slotted allowing free movement along the bar, yet may be easily tightened by the locknut in any selected place, making it possible to set box at desired spot although conduit may bear a little off length.

There is a multiplicity of outlet box types designed to meet the varied requirements.

Cutting Out Switch Box Outlets.—This is a difficult operation and must be performed carefully.

After having first ascertained that it is possible to drop down the partition, 54 inches is measured up from the floor, the



FIGS. 5,616 to 5,619.—Methods of installing switch box in unfinished wall. Fig. 5,616 using wooden laths; fig. 5,617 wooden block at back of box; fig. 5,618 metal box cleat; fig. 5,619 combination switch cover.

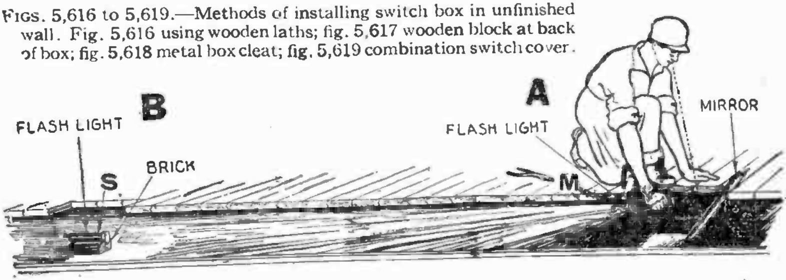
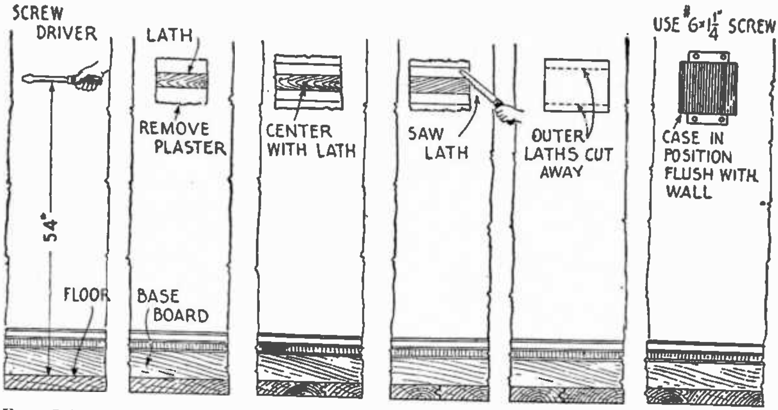
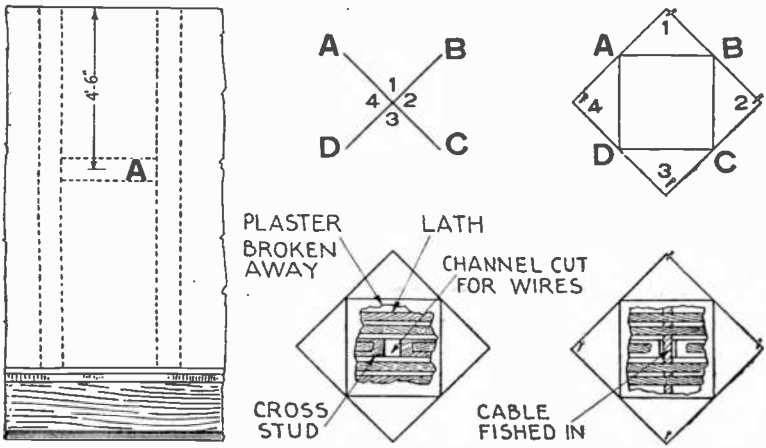


FIG. 5,620.—Exploring with flash light and mirror. If there be only one pocket cut, place mirror and hold flash light as at A. In case there be a second pocket as at B, the flash light may be placed at S. supported on a brick or other object.

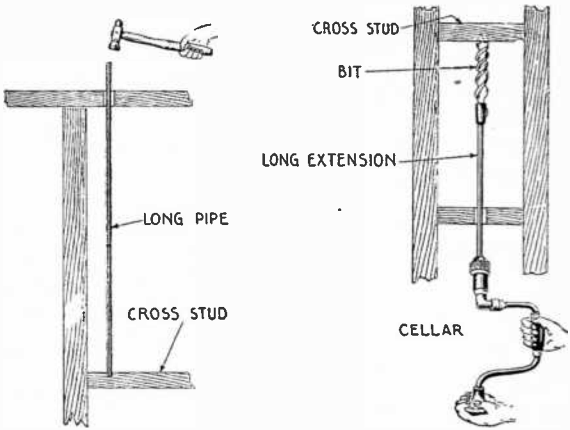


FIGS. 5,621 to 5,626.—Method of cutting out wall case outlet as described in the accompanying text.



FIGS. 5,627 to 5,631.—Method of passing by cross stud in partition when plaster must be cut. Locate cross stud as in fig. 5,627, 4½ ft. below ceiling. With a sharp knife cut wall paper along two diagonals AC, and BD. Thoroughly moisten paper with a sponge. Peel back the ends 1,2.3,4, to the position shown in fig. 5,629 and fasten with pins. Cut out plaster is punctured with a screw driver. If the screw driver go between the lath, another hole should be punctured, and so on until the plaster has been broken away and shows a whole lath; now take the wall case and center the lath with the center of the wall case, with a pencil, run over the outer edges of the wall case.

Now with a hammer and screw driver, carefully chisel out the plaster on the pencil lines. After the plaster has been removed, with a fine key hole saw,



FIGS. 5,633 and 5,634.—Two methods of passing by cross stud in partition: 1, by inserting from above a long pipe and breaking stud by hammering; 2, by boring up from cellar with brace and bit having a long extension.

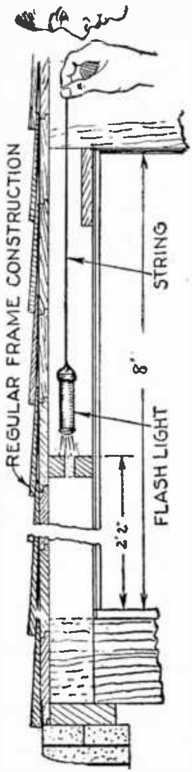
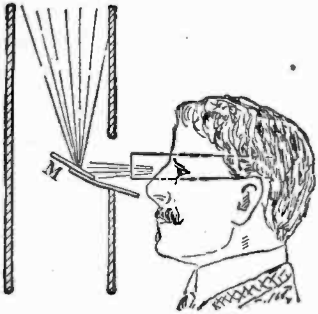


FIG. 5,632.—Exploring with flash light in side wall of house.

FIGS. 5,627 to 5,631.—*Text continued.*

the plaster in the square thus opened and cut a channel in the cross stud as in fig. 5,630. Fish in the cable as in fig. 5,631, replaster and fold back wall paper, pasting it to cover the square just plastered.



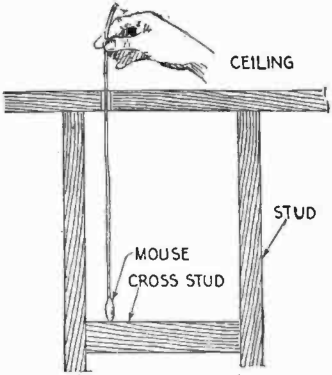
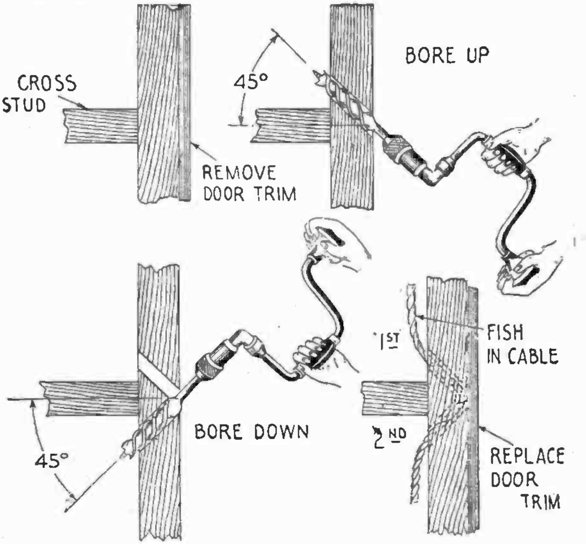


FIG. 5,635.—Device for examining partition interiors. A pocket flash lamp and a little mirror are the only apparatus required to inspect the interior of a wall or partition which would ordinarily be inaccessible. For fishing wires, retrieving cable and inspecting finished work, the lamp and mirror will be found most useful.

FIG. 5,636.—Exploring in partition for cross stud.



FIGS. 5,637 to 5,640.—Method of passing by cross stud in partition when wires are run next to a door.

carefully cut away the center whole lath, after this has been cut away, the other lath should be trimmed with a sharp jack knife so that the box fits snugly. The ears of the box should be adjusted so that the box fits just flush with the finished plaster. Now screw box to lath with 1¼ inch No. 6 wood screws, any larger than these will crack the lath.

Obstructions in Partitions.—In the older houses constructed when builders had some regard for strength, partitions were reinforced with cross studs so that it is impossible to get by them.

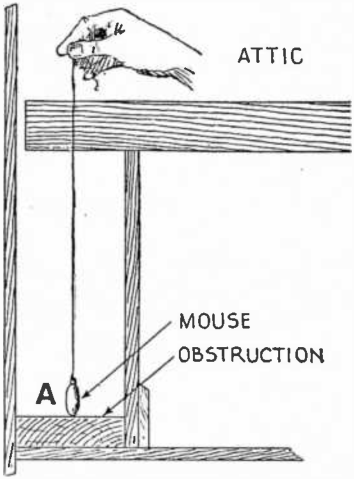
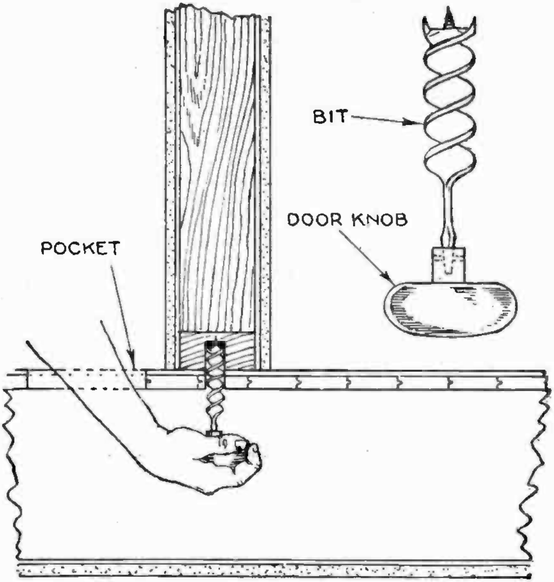


FIG. 5,641.—Exploring between inner and outer walls with mouse. At A, an obstruction is encountered. This must be cut or bored to permit wires to pass. It may be reached by removing the base board, or may be bored from above with a multi-extension bit.

When a cross stud is encountered, the switch outlet may be located above the stud, the standard height being 54 inches above the floor.

Before attempting to drop down a partition it should first be ascertained whether or not a cross stud or concrete, mineral wool, brick or rubbish filling, is in the partition. A hole is drilled in the top header of the partition and a string with a lead weight lowered, if the weight reach the floor (this can be ascertained by sound) the partition is clear.



FIGS. 5,642 and 5,643.—Boring through partition shoe with "door knob bit" so as not to disturb base board when wires are to be run from floor pocket into partition. Fig. 5,643, detail of door knob bit.

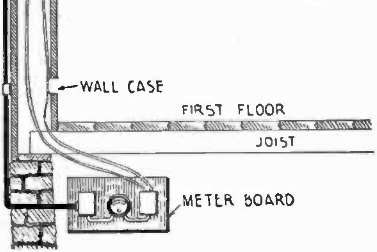
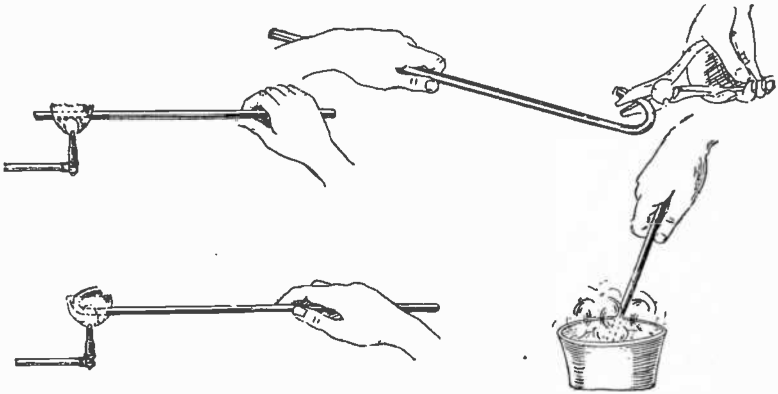


FIG. 5,614.—Method of dropping down a partition that has headers, also showing method of bringing circuits down to meter.

Dropping Wires Down Outer Walls.—First a hole should be bored in the header and the mouse lowered until it reaches the cellar, or hits an obstruction.

Usually obstructions are encountered as fire stops are placed at each floor to prevent the enclosed space acting as a flue in case of fire. These stops usually consist of 2×4 strips or brick. To reach them the base-board must be removed. This is easily pried off with a floor chisel, some-



FIGS. 5,645 to 5,648.—Method of making a snake. Hold wire in flame till cherry red (fig. 5,645) bend to shape (fig. 5,646); heat again (fig. 5,647), and submerge end in cold water while cherry red (fig. 5,648).

FIGS. 5,649 and 5,650.—Open and closed snake hooks. ***The open hook*** is used in hooking one snake to another. ***The closed hook*** is used for fishing.

times it is necessary to set in the nails with a nail set. If walls be of brick, the entire distance from attic to cellar may be fished with a steel fish or snake wire, as the laths are attached to a ⅞ strip which is nailed to the brick.

Fishing.—This is a method of running wires through walls, floors and ducts by the aid of another wire called a *snake* or fish wire attached to the conductors, threaded and drawn through in advance.

Snake or fish wires are made of the best steel and tempered in oil. All snakes should have a hook bent at each end, and to do this the wire must first be annealed.

The proper method of annealing is to hold the end of the snake in the flame of a torch until it becomes cherry red, then bend into shape, heat again to cherry red color and quickly insert the heated end in a pail of water; this hardens the wire, so that the hook will not pull apart.

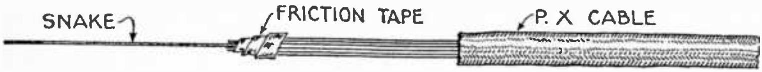


FIG. 5,651.—Method of taping end of snake.

FIG. 5,652.—Method of attaching wires to snake for pulling.

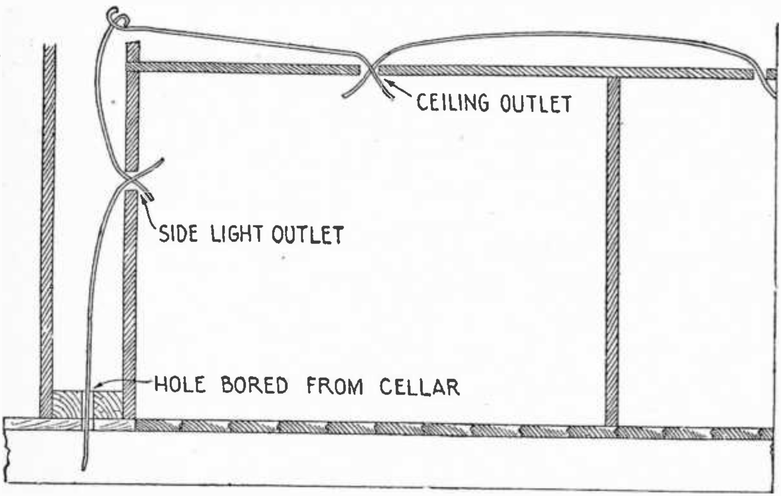
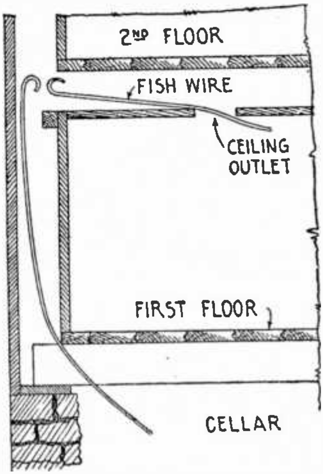


FIG. 5,653.—Fishing from outlet to outlet.

Snake wire may be obtained in various shapes but the type best adapted for house work is 1/8 inch wide, 1/16 inch thick.

The proper way to attach the wires to be pulled into the snake is to just loop them through the hook of the snake and fold them over with pliers.

If wires are to be pulled through a long run, they should be taped.



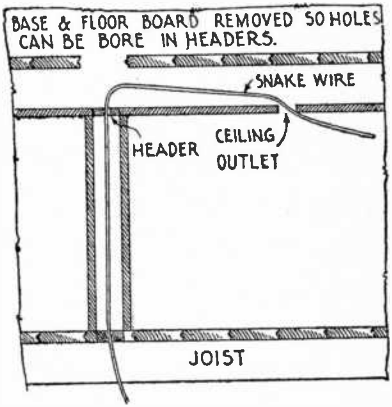


FIG. 5,654.—Method of fishing in wires without removing floors or base board. The fish or snake wire is pushed up from cellar and hooked as shown. This method is only possible when there are no headers.

FIG. 5,655.—Method of fishing in wires through headers.

In fishing in a house constructed with furring strips between the joists and ceilings there will be plenty of room to draw through the loom or cable.

Furring strips in old houses having single floors will be found to run parallel with the floor boards.

After having cut the outlet as just described, a steel wire or snake is inserted into the hole so that it may be pushed into the space made by the furring strip, having inserted the end of the snake, it is gently pushed as far as desired; if the snake encounter an obstruction, it may be caught against a piece of plaster or become twisted.

With a little practice a snake may be fished over 50 ft. with ease, having reached the outlet, another snake or piece of wire is pushed up into the hole at the outlet and the snake is *hooked*, and then gently drawn through the outlet; the wires are then attached and pulled through. If a man be at each end considerable labor will be saved.

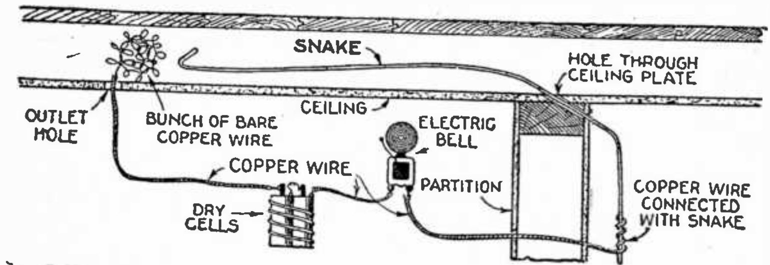
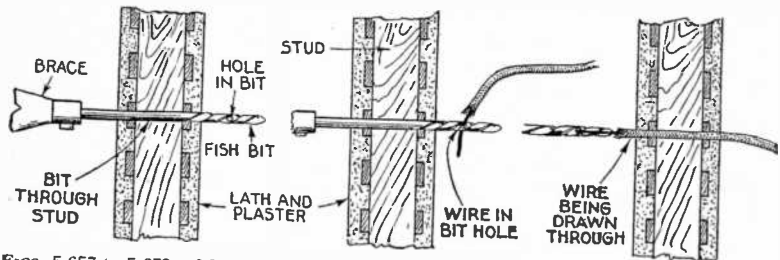


FIG. 5,656.—Method of fishing with snake and electric bell.



FIGS. 5,657 to 5,659.—Method of using steel fish bit. After boring through as in fig. 5,657, thread end of wire through hole in bit (fig. 5,658), and withdraw bit bringing with it the wire that is to be passed through the bored hole as in fig. 5,659.

When pulling through the wires it is also necessary that some one be at each end so that one may feed the wires in and the other will pull them out.

The wires should be gently pulled so no damage will be done to the plastered ceiling.

If, in pulling the snake, the wires get stuck, the snake and the wires should be pulled back and forth as most likely the wires are caught against a plaster clinker. This operation will break off clinkers.

Sometimes a whole house may be fished without taking up any floors. but it may be necessary to take off base boards and flooring to drop down to the meter board or switch outlets.

Sometimes it is necessary to use two snakes on long runs and hook them underneath the ceiling.

In this case the ends of the snakes should be connected to a bell and battery so the bell will ring when the ends touch each other.

Switches for Lighting Installation.—Plug fuse switches are only approved for use on voltages up to 125 volts and to stand a load of 30 amperes.

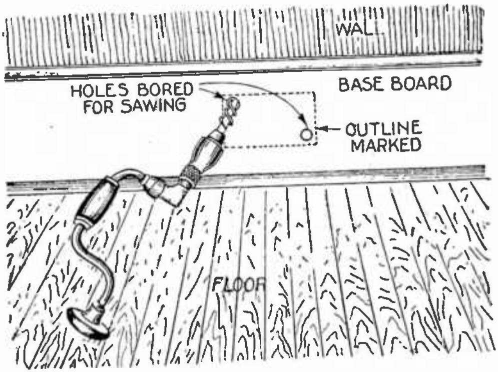


Fig. 5,660.—Installing switch box in base board. 1, mark outline of box on base board; 2, bore two holes as shown to start saw; 3, saw to outline; 4, clear opening to bring box flush; 5, install box in opening after removing suitable knockouts.

In the case of a fair size residence a 30 ampere switch of the plug type could probably be used (note types of switches optional with local central stations).

In the case of a large installation having a load exceeding 30 amperes, cartridge fuse switches and cut outs must be used.

These are designed for pressures up to 600 volts.

Cut out boxes usually have ½ in. knockouts; if a larger size conduit be used, these knockouts must be enlarged by reaming unless boxes with larger size knockouts be obtained. The conduit is secured to the box by two lock nuts and a bushing.

Wires leaving the cut out box should pass through porcelain insulators or bushings.

The box should be secured to the board by means of ¾″ wood screws.

The switch or cut out should be secured in the box by means of holes drilled or punched through the box, wood screws passing through the cut out box and screwed into the wood meter board will securely hold any cut out or switch.

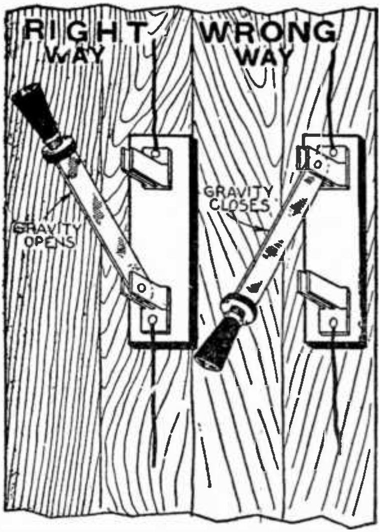


FIG. 5,661.—*Right* and *wrong* way of installing knife switches. They should always be installed so that gravity tends to open them, otherwise when the hinges become worn, the switch might close.

Installation of Knife Switches.—When installed in a vertical position, the switch should be so placed that gravity will tend to open it.

Where a three wire switch is used, the middle or neutral fuse clip must be made solid so that no fuse may be installed in the center clip (this is for lighting installations on a single phase or a *d.c.* system).

Installing Flush Switches and Receptacles in Wall Cases.—Care should be taken that the switch fits flush with the edge of the plaster. In order for the switch to fit flush, the case should fit flush, otherwise it will be necessary to insert small washers under the switch ears.

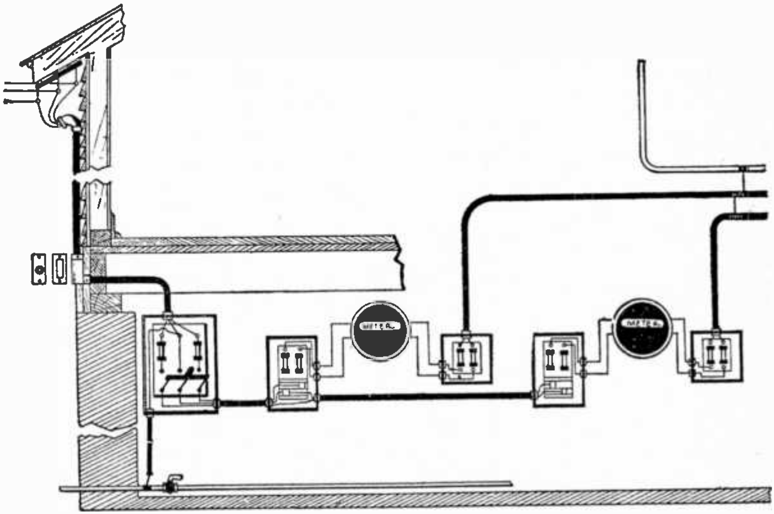


FIG. 5,662.—Two family house meter board arrangement as used throughout Connecticut; note method of service pipe and meter loop arrangement.

Switch plates will not fit properly unless the switch be flush; if the switch be not flush, the plate will buckle and bend in the center.

Perfect fitting switch plates give an artistic and workmanlike appearance to any installation.

Meter Boards.—A meter board should be constructed of seven-eighths inch soft wood (pine) of sufficient size to accommodate the meter and cut-out boxes.

Secure the board against the foundation wall of the building. Paint board two coats of black asphaltum or other insulating paint. Do not nail boards to foundation wall unless there be an air space back of it. The use of 2×4 studs makes a secure board. For one single meter, a board 24×18 is amply large with room to spare for future additions. The main switch is mounted on the left side of the board. All modern meters feed the left for mains, and feed out to the right for house cut outs. Do not place a meter board any higher than 7 ft., or lower than 4½ ft.

Replacing Floors and Trim.—In replacing floors, small finishing nails should be used; these are inconspicuous and will not split the wood while being driven.

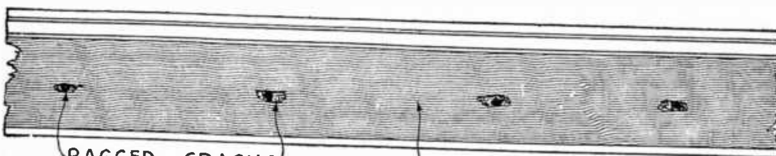


FIG. 5,663.—Appearance of a varnished base board after nails are driven out. The proper way is to leave nails in the board, cutting them off close with cutting pliers.

When replacing base boards and other finished trim that has been pried off do not attempt to drive back the nails, but cut them off with cutting pliers, as driving the nails back will knock off large chips from the trim.

After the nails have been cut off, the head of the nail should be set in with a nail set and a new nail driven in the same hole.

Hard wood floors and trim should be gone over with floor wax to remove all scratches and mars.

Drop Cords.—Where the wires enter a socket, rosette, or an outlet box, they should be relieved of any strain by making an Underwriter's knot so that the weight of the socket, shade and lamp will not be on the joint.

Square or granny knots are not approved, sockets may be obtained with strain relief devices attached.

Stripping Drop Cord.—With a sharp knife cut around the outer braid

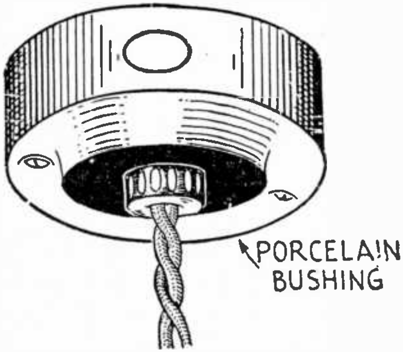
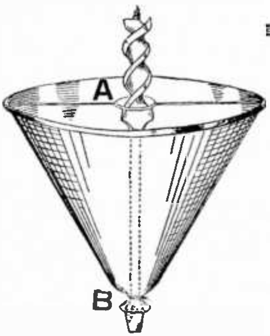
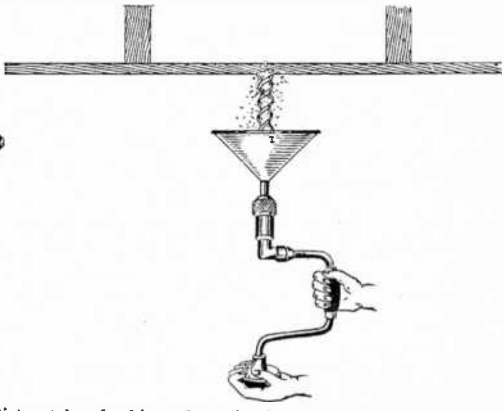


FIG. 5,664.—Drop cord fixture leaving conduit outlet box cover. A porcelain bushing must be used with all metal covers.





FIGS. 5,665 and 5,666.—Cone dirt catcher for bit and application in boring ceiling outlets. *It consists of* a suitable size cone, made of stiff cardboard and provided with a guide A, to hold it central with the bit. Attached to the lower end is a cloth tube B, which is fastened with a string to the shank. Fig. 5,666 shows the cone in use.

just deep enough to cut the braid and re-enforced rubber covering. Then cut a slit parallel with the cord just deep enough to cut only the outer braid. Remove outer braid and with each hand, pull on each wire and re-enforced rubber braid will fall away. About 2 ins. is sufficient for sockets, and rosettes; 6 ins. to be allowed where the cord is to be spliced to other wires such as in outlet boxes, etc.

Uses of Drop Cord.—For inside of residences, re-enforced cotton cord can be used with a light outer braid. For factories, the heavy type should be used. For cellars, the slicked or weather proof type should be used. For bakeries or places where wires are subjected to a great heat or where the cord is attached to heating appliances, regular asbestos heating cord must be used.

For auto garages, extra heavy marine deck cable should be used, or the same encased in a specially wound metallic sheath.

For show windows B. X. drop cord must be used.

Clusters of more than one light must not be attached to drop cords.

Drop cords may be extended from their outlets to another position by means of ceiling buttons.

Fixture Wiring.—Chain fixtures must be wired with flexible cord preferably single conductors so that each one may be laced through each link of the fixture chain. Chain fixtures are suitable for show windows.

One-eighth inch trade size sockets should be used so that loops may be screwed into the socket caps.

Chain fixtures that are attached to concealed knob and tube wiring or wooden moulding may be attached with fixture crow feet or tripods.

If the ceiling be of metal or plaster containing metal lath, a fibre or rubber canopy insulator must be used. Brackets or side wall fixtures must be wired with No. 18 fixture (solid) wire or larger. The ends of all pipes and bodies being reamed so that the burrs will not cut into the insulation. Pendants or fixtures that are constructed of tubing must be wired with solid fixture wire.

Combination fixtures that are attached to gas pipes must be equipped with insulating joints so that the fixture will be perfectly insulated and free from grounds, likewise must all fixtures that are attached to metal outlet boxes of B. X. and conduit wiring or knob and tube wiring where the fixture is to be secured to a gas pipe.

Fusing of House Circuits.—For lighting circuits no fuse larger than 10 amperes may be used except with special permission from the local inspector or where all the lights are controlled by one switch; also no lighting circuit should have a load in excess of 660 watts except in factories where all the

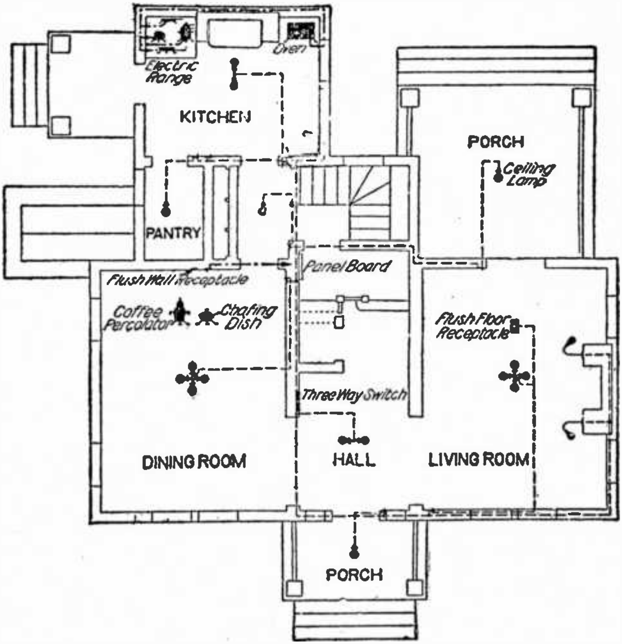


FIG. 5,667.—Wiring for heat appliances; plan of first floor. The location of the outlets is of importance. Usually a flush receptacle in the base board meets the requirements. Where several heating circuits are used it is essential that an appliance taking a large current be not placed on the regular lighting circuit. To guard against this possibility, special receptacles should be installed, constructed for plugs which will not fit any other receptacle.

lights are connected with porcelain sockets and a wire not smaller than a No. 14 is used, but in houses the 660 watt rule must prevail.

Thus on a 110 volt system it is best to figure 7 amperes per circuit.

For each circuit a cut out must be provided. These cut outs must be installed in metal cabinets or boxes and preferably mounted directly on the meter board. Cut out boxes should not be mounted any higher than 7 ft. from the floor and no lower than 4½ ft.

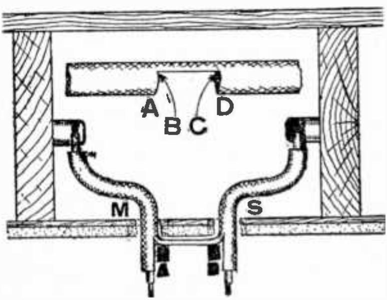
If the cut outs be grouped in one box, all over 4 circuits must have a box with a gutter around it unless a box be made so that the wires enter opposite the cut out terminals.

The use of water or gas pipe fittings on services is prohibited.

Main switches should be fused in accordance with the carrying capacity of the wires to which they are connected, according to the following:

Fusing Table

Load (amperes)....	1	3	6	10	15	20	25	30
Fuse (amperes).....	3	6	10	15	20	25	30	35



FIGS. 5,668 and 5,669.—One method of preventing flexible tubing working through the plaster. Where separate outlet holes are bored as at M and S, cut the tubing along the line ABCD, as in the detail fig. 5,668. When the tubing is placed in position the narrow strip connecting BC will prevent the tubing working up through the plaster.

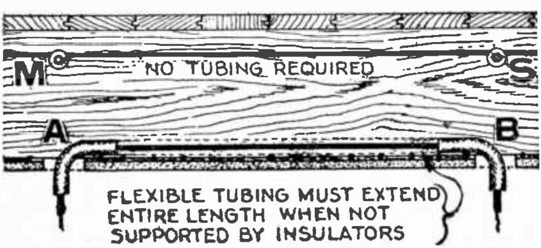


FIG. 5,670.—Supported and unsupported conductors illustrating the requirement as to flexible tubing. Unless the wire be supported on insulators as M and S, so that it will not come less than 1 in. from the wood work, it must be encased in flexible tubing extending the entire length between outlets. Putting in short pieces of tubing at the outlets as at A and B, will not pass inspection.

Types of Fuses.—Plug fuses are largely used for loads up to 30 amperes at pressures up to 125 volts.

Cartridge fuses are used up to 1,000 amperes and up to 100,000 volts. Drop cord rosettes used in mills are fused with fuse wire or links which screw under the terminals on the rosette. The largest size fuse wire permissible is 3 amp. size.

Small transformers for wireless work, bell ringing, etc., should be fused with the minimum size fuse permissible, which is 3 amperes.

Notes

NOTE.—Sewer catch basin covers and street manhole covers may be used as a bending device, the pipe being inserted through the holes in the covers, and weight borne down on pipe.

NOTE.—*To prevent terminal lugs becoming dirty* and covered with solder they should be covered with laundry soap before applying heat of torch.

NOTE.—*A handy angle soldering copper* may be made from an ordinary soldering copper by cutting a 90° V notch at about the middle of the copper and bending over 90°.

NOTE.—*Metal tubing* may be easily broken apart if a notch be filed all around the outer surface with a 3 cornered file.

NOTE.—*An old umbrella* inverted and hung on a gas fixture will prevent dirt and plaster falling on the floor while cutting out around gas pipes.

NOTE.—*Temporary service* may be obtained from burnt out plug fuses by inserting a penny under the blown out fuse and screwing same down well.

NOTE.—*To prevent ceilings and walls becoming scorched* while soldering with a torch, a sheet of asbestos board should be held around and above joint to be soldered; sheet tin may be substituted.

NOTE.—By cutting off the head of a tenpenny nail and inserting nail in a brace, it may be used as a wood drill through any kind of soft wood; try it.

NOTE.—*Broken screws or bolts* may be removed if a slot be cut into the screw with a hack saw; use the thumb nail as a guide for the saw, after a deep slot is cut, insert screw driver into slot and remove broken screws.

NOTE.—*Locking screws that work loose*, such as on fans and motors, may be locked in place if chisel marks be made opposite the slots.

NOTE.—*Mica washers* may be obtained from old burnt out fuse plugs, for repairing electric irons and appliances.

NOTE.—*When short a lock nut*, rather than go back to the shop, cut a lock nut from a coupling with a hack saw.

NOTE.—*Porcelain tubes* may be cut off if they be scratched with a file and heated in a flame; a sharp blow at point of scratch, when cooled, will break off part not desired

Notes.—Continued.

NOTE.—***Pulling in wires*** in fixture arms after first having tried to push wires in. If found difficult, drop a piece of pull chain, such as used on pull chain sockets; this will easily slide through any bend; attach wires to end and pull through.

NOTE.—***Splits in hard wood floors*** and trim may easily be repaired by using common pins in the same manner as nails.

NOTE.—***Plaster of Paris*** may be prevented hardening by mixing a little lime with the plaster. Plaster surfaces may be smoothed off with a brush soaked in water.

NOTE.—***Stillson wrench jaws*** that do not grip can be made like new by filing out the jaws with a three cornered file.

NOTE.—***A brick drill*** may be easily made from any piece of scrap water pipe by cutting a number of notches on the end; use a hack saw and a three cornered file.

NOTE.—***Wood bits*** may be sharpened with a fine manicuring file; never file the outer surface of a bit as it makes the cutters smaller and will be more difficult to turn bit through hole, as twist of bit is larger.

NOTE.—Vinegar (white) may be used as a substitute soldering flux, so may bicarbonate of soda or borax.

NOTE.—***Stripped threads*** on screws or bolts may be replaced by filling in worn and stripped threads with hard solder and rethreading.

NOTE.—***Driving a nail in brick walls.*** If it do not hold, another nail should be driven diagonally across the nail so that it will cross and bind the nail; this method is very effective and secure.

NOTE.—***A 20 penny nail*** makes a good substitute for a prick punch for punching holes in cut out boxes. Nails also may be used as nail sets.

NOTE.—***A good meter board*** paint may be made by dissolving lamp black in gasoline. This also makes a good motor paint.

NOTE.—***Cutting a line shafting.*** To cut off a section of line shafting, a hack saw should be held on the place to be cut and the shaft should be run by power; this will cut off the shaft smoothly and quickly.

NOTE.—Old broom sticks cut up into pieces 4 inches long are good plugs for concrete walls to fasten outlet boxes and pipe, etc.

NOTE.—***Knife sharpener.*** A common porcelain tube may be used for the frequent sharpening of a knife blade dulled by scraping insulation and wires.

Code.

Article 4, Services and Service Equipment (not over 600 Volts).

401. General.

a. The wiring in any building or group of buildings, including the service connections thereto, shall be so arranged as not to serve as a shunt around any street fuse or switch.

Code.—*Continued.*

b. No overhead service, no underground service, and no service from an isolated plant shall supply one building through another, except when such buildings are under single occupancy or management. Conductors in conduit or duct placed under 2 inches of concrete beneath a building, or buried in 2 inches of brick or concrete within a wall, shall be considered outside the building.

c. No building shall be supplied from the same exterior distribution system through more than one set of service conductors, unless a separate service is required for fire pumps, or for emergency lights, as required by Section 3902, or unless capacity or emergency requirements make multiple services desirable, or unless there are different transformers or sets of multiphase transformers.

d. If supplied by more than one set of service leads at the same side of a building, the service equipments shall be grouped (except for fire-pump service, which may be isolated) and the type of service separately indicated.

402. *Overhead, from Main to Building.*

a. Approved weatherproof or approved rubber covering shall be employed on single wires, and approved rubber covering on multiple-conductor cables. Wires shall not be smaller than No. 10 if of soft copper, or smaller than No. 12 if of medium or hard-drawn copper.

b. Wires or cables shall not approach nearer than 8 feet to buildings over which they pass, and if attached to roofs thereof, shall be supported on substantial structures.

It is recommended that wires passing over a building be supported on structures which are independent of the building.

c. When a service from overhead supply wires to a building is carried underground, the portion of the wires underground and running up the pole to a point at least 8 feet above the ground shall be suitably protected from mechanical injury and shall be protected from moisture by a covering of lead or other means approved for the purpose.

d. Multiple-conductor cables shall be kept at least 6 inches from adjacent woodwork and at least 12 inches from overhanging projections of combustible material, unless fittings approved for the purpose are used.

403. *On Exterior of Building.*

a. Wires or cables which are liable to contact with awnings, swinging signs, shutters or other movable objects, shall be enclosed in approved conduit. All conduit systems on exterior of buildings shall be made weatherproof.

b. Open wires shall not be within 8 feet from the ground, shall not be readily accessible and shall not be subject to mechanical disturbance. If exposed to the weather they shall be supported on approved insulators, racks, brackets, or other supports approved for the purpose. Such supports shall be placed at intervals not exceeding 9 feet and shall separate the wires at least 6 inches from each other and at least 2 inches from the surface wired over; provided, however, that supports may be placed at intervals not exceeding 15 feet if they hold the wires at least 12 inches apart. Open wires if not exposed to the weather may be supported on glass or porcelain knobs placed at intervals not exceeding 4½ feet and maintaining the wires at least 1 inch from the surface wired over.

c. Multiple-conductor cables run on the exterior of building walls shall not be within 8 feet from the ground, shall not be readily accessible, and shall not be subject to mechanical disturbance. They shall be supported at intervals not exceeding 15 feet. Unless provided with metal sheath or armor they shall be mounted upon insulating supports so as to be separated at least 2 inches from the surface wired over.

Code.—Continued.

d. Open wires on exterior of buildings shall have approved rubber or weatherproof coverings for single wires and approved rubber coverings for multiple-conductor cables.

e. Rigid conduit systems made weatherproof shall be used for wiring on exterior of building where open wiring cannot readily comply with the above requirements or where the voltage exceeds 600, and may be used in lieu of such open wiring under any conditions.

404. Entrance.

a. All service wires shall enter the building at a point as near as practicable to the location of the service switch. Service conductors may be run through but shall not be run within a building wall unless in conduit embedded in brick, tile, concrete, or other fire resistive construction, or unless protected by fuses at the outer end of the service conduit.

b. Wires entering building shall be rubber covered from the point of support on the outside of the building nearest the entrance to the building. The service wires shall be not smaller than No. 8.

c. Where a run of grounded rigid service conduit is interrupted by metallic flexible conduit the two ends of rigid conduit thus interrupted on the end of the rigid conduit and the service entrance cabinet if the flexible conduit shall be connected thereto shall be bonded together by a copper wire not smaller than No. 8 using approved clamps or other approved means, and both the bonding devices and bonding wire shall if exposed to mechanical injury be effectively protected therefrom.

d. Overhead wires shall enter buildings only in rigid conduit or as separate individual wires. Where open wires are used, drip loops shall be formed on the individual wires which shall then pass upward and inward through slanting, non-combustible, non-absorptive insulating tubes. Where rigid conduit is used it shall have weatherproof threaded joints and be equipped with approved service head.

Where service switch is inside building, it is recommended that conductors entering the building from overhead lines be encased in approved rigid metal conduit.

e. Where a conduit enters from an underground distribution system, the end within the building shall be sealed with suitable compound so as to prevent the entrance of moisture and gases.

f. Where conduit is used to contain service conductors, the inner end of the service conduit shall enter a terminal box or service switch cabinet or be made up directly to an equivalent device, enclosing all live metal parts, and shall be electrically connected to the box or equivalent device, unless isolated from conducting surfaces and unexposed to contact by persons or materials which may be in contact also with other conducting surfaces, including the terminal box or equivalent device.

g. Service conduit shall be grounded unless isolated from grounded surfaces, and unexposed to contact by persons or materials which may be in contact with other conducting surfaces, and containing no wire of more than 150 volts to ground and no wire of an ungrounded circuit exposed to or connected to other circuits of more than 150 volts to ground. Conduit and metal pipe if not electrically connected to an interior conduit system shall be considered sufficiently grounded if containing lead-sheathed cable bonded to a continuous underground lead-sheathed cable system.

It is sometimes advisable to insulate interior conduit or sheathing from service conduit or sheathing to prevent burnouts of small interior conduit, armored cable sheaths, or metal moulding by large currents which might flow from exterior conduit to interior conduit and waterpipes.

Code.—Continued.

405. Service Equipment.

a. In this section the word "switch" shall be construed as including a circuit-breaker that is capable of manual operation.

b. A service switch shall be provided for each set of service conductors and shall indicate plainly whether it is open or closed. The switch or switches shall be placed at the nearest readily accessible point to the entrance of the service, either inside or outside the building wall and shall be of a type approved for the prevailing conditions such as exposure to the weather. This switch shall be installed in one of the following ways:

1. As an air-break or oil-immersed switch enclosed in a metal case;

2. As an air-break or oil-immersed switch mounted on a switchboard or panel-board which is accessible to qualified persons only.

c. A service switch shall simultaneously interrupt all conductors of the circuit in which it is inserted and disconnect the meter and overload protective devices, except that

1. Where the switch, fuses and meter are combined in an approved device or compact combination of such devices having no live parts or wiring exposed, and capable of being sealed or locked, the switch may be so connected that it will not disconnect the fuses or the meter from the supply line; and the potential coils of the meter may be connected on the supply side of the service cutout:

2. Where the switch and fuses are mounted in an approved cabinet having no live parts or wiring exposed and capable of being sealed or locked, the switch blade may be omitted in any grounded conductor of a direct-current or single-phase circuit or any grounded neutral if other approved means is provided within the cabinet for disconnecting such conductor.

3. Where a service switch is mounted on a switchboard, the switch blade in the grounded conductor may be omitted if other approved means is provided on the switchboard to disconnect the grounded conductor.

4. In buildings served through 2, 3, or 4 meters from a single set of service conductors not exceeding 150 volts to ground, the service conductors may be run to a separate switch and cutout for each meter if grouped at the point of entrance. The service run shall be continuous to the last service switch and cutout or to the bus on a switchboard, but taps may be made to the individual service switches.

In installations involving more than 4 meters the entire current shall be taken through one main entrance switch.

5. A switch controlling a 3-wire direct-current or a 3-wire single-phase system may be so designed that one outside conductor can be opened without opening the other.

d. A service switch shall be enclosed and externally operable unless made inaccessible to other than qualified persons. A service switch shall be readily accessible and externally operable unless additional switches are provided for control of all individual feeders and circuits supplied through it, as recommended below.

It is recommended that where the current of a single circuit, or group of circuits, is separately metered, as in apartment-house installations, a switch and cutout be installed to control each separately metered installation; the switch and cutout being enclosed and the switch being externally operable. The location of this switch and cutout may, or may not, be close to the meter.

Code.—*Continued.*

e. The service switch shall have sufficient capacity to rupture a current equal to the capacity of the cutout base or to the rating of other type of protective device in series with it.

f. Each ungrounded service conductor shall be protected by a fuse or automatic overload circuit-breaker arranged to cut off the current from all circuits fed through it, and from all devices in such circuits other than the service switch and, under the conditions specified in paragraph (c) 1, of this section, the meter. Fuses, where used, shall be controlled by the service switch except where they are located at the outer end of the service conduit or as specified in paragraph (c) 1 of this section. A circuit-breaker, where used, shall be controlled by the service switch unless it is manually operable.

g. When the service fuses are locked or sealed or are located at the outer end of the service conduit, branch fuses connected on load side of meter shall be accessible to persons concerned and shall be enclosed in an approved casing or cabinet. If the installation consists of a single branch circuit, fuses shall be inserted in series with the service fuses and shall be of smaller capacity. These fuses need not be at the meter but shall be accessible.

h. No fuse or automatic overload circuit-breaker shall be placed in a grounded service wire except a circuit-breaker which simultaneously opens all conductors of the circuit.

i. Where not located on a switchboard or panelboard, accessible only to qualified persons, live parts of switches, buses, fuses, cutout bases, and automatic overload circuit-breakers shall be enclosed so that they will not be exposed to accidental contact. The enclosure shall be grounded in accordance with the method for equipment grounding given in Article 9.

Exception:

Grounding may be omitted where enclosures are isolated from conducting surfaces and unexposed to contact by persons or materials that may be in contact with other conducting surfaces including other enclosures, conduit, etc. and where also the voltage does not exceed 150 volts to ground and no contained live parts are connected to ungrounded circuits exposed to more than 150 volts to ground.

j. A manually operable automatic overload circuit-breaker may be used in place of both service switch and fuse, and shall be of a type approved for this use.

k. In a property comprising more than one building under single management and which has a generating plant or is served by a master service, the conductors running from one building to another shall not be considered as service conductors, in that fuses or automatic overload circuit-breakers will not be required where these supply the wiring installation within any building, provided that the fuses or circuit-breakers next back on these conductors properly protect the conductors within that building, and provided that each such set of conductors is separately controlled by a suitable feeder-control switch which is readily accessible to those persons using that installation. Such switch may be located at the entrance of the conductors to the individual building or farther back on the feeder concerned. This rule includes garages and similar outbuildings of residential installations.

l. When service wires carry a voltage exceeding 600 volts between conductors, the requirements of section 5,009 of Article 50 of this Code shall apply.

406. Hazardous Locations.

a. Service entrance equipment shall not be placed in the class I locations defined in paragraph (b) of section 3,201 of article 32 of this code. (See paragraph b section 3,203.).

b. When it is necessary to place service entrance equipment in the class II or class III location defined in paragraphs (c) and (d) respectively of section 3,201, the provisions of paragraph (b), section 3,204, and paragraph (b), section 3,205, respectively, shall be observed.

Code.—Continued.

613. *Demand Calculations for Feeder Sizes.*

a. General and definitions.

Demand Factor. The demand factor of any system or part of a system, is the ratio of the maximum demand of the system, or part of a system, to the total connected load of the system, or of the part of the system under consideration.

1. This section discusses "estimated or calculated" demand factors rather than measured demand and corresponding demand factors according to the above definition.

2. For conciseness the calculated demand factor will be referred to hereafter in this section as the "demand."

3. The "demand" values given in the following paragraphs of this section are those percentages of the total load upon the conductors as computed on the basis of watts for the area and the occupancy as in the following and which may reasonably be expected under the conditions indicated.

4. The word "Area" means gross area, which shall be determined by the outside dimensions of the building and by the number of floors. Unoccupied cellars, unfinished attics, and open porches need not be included in this computation.

5. All conductors of an interior wiring system, also including overhead service conductors between the service head and the service switch, and underground conductors between buildings under one ownership or management, mains, feeders and sub-feeders, up to the final distributing center, are referred to herein as feeders.

b. Scope and application.

Voltage drop due to length of feeders has not been considered. However, it is recommended that the outside feeder conductors shall be of such size as to cause not more than 3% voltage drop up to the final distributing point on any feeder after the demand, if any, has been applied.

1. This rule applies to an interior wiring system which supplies both lights and appliances on the same circuits, but does not include capacity for industrial or other apparatus requiring special circuits. The calculation of current load for ranges is treated in item 15 of the Table of paragraph d-3 of this section.

2. The values and "demands" set forth in this section are based on average load conditions and may be used safely for all installations which have been adequately designed. However, if at any time after the equipment is put in service it shall be found that conductors are of insufficient capacity to carry the actual load without over-fusing, they shall be increased to comply with the requirements for overload protection applying thereto. In any event the size of feeders shall be sufficient to carry, without overheating, the loads imposed upon them.

It is recommended that a diagram showing contemplated feeder details be furnished the authority enforcing this code as necessary advance information. This to show:

Area in square feet
Computed load
Demand selected
Load after applying demand
Sizes of conductors

Code.—Continued.

c. To determine the size of feeders that supply both light and power loads, the current in amperes for the lighting load shall be determined as specified herein, the current in amperes for the power load as specified in paragraph k of section 808, of this code, and the sum of these shall determine the size in accordance with section 612 of this article.

d. 1. The current load for lighting and appliances shall be determined in accordance with the following tables and under conditions specified for each, unless the authority enforcing this code shall decide that conditions require larger sizes and shall specify the sizes to be used.

2. Current-carrying capacities to prevent overheating shall be determined in accordance with section 612 of this article.

3. The sizes of feeders shall be not smaller than as determined by the areas supplied, multiplied by the "demand" values tabulated below representing the watts or fractions of a watt per unit of area for each kind of building and occupancy served.

Table of Required Minimum Watts Per Unit Area and Demand Factors Applying Thereto

1. Buildings constructed and used for single family dwellings:

One watt per square foot, plus 1,000 watts for appliances.

For area of 2,000 or less square feet, demand 100; for all excess over 2,000 square feet, 60.

2. Buildings constructed and used for multi-family dwellings (other than hotels): One watt per square foot, plus 1,000 watts per apartment for appliances.

For area of 2,000 square feet, or less—demand 100.

For that part of the area in excess of the first 2,000 square feet, a demand of 70, provided the number of apartments does not exceed ten. If the number of apartments is between 11 and 40, the second factor (70) shall be 60. For 41 or more apartments, the second factor (70) shall be 50. The demand for each feeder shall be determined in the same manner, i.e., by the area and the number of apartments supplied.

3. Apartments Hotels (having provision for individual electric cooking):

One watt per square foot, plus 1,000 watts per apartment for appliances.

For area of 2,000 square feet or less, demand 100.

For that part of the area in excess of 2,000 square feet, a demand of 70, provided the number of apartments does not exceed 10. If the number of apartments is between 11 and 40, the second factor (70) shall be 60. For 41 or more apartments, the second factor (70) shall be 50.

4. Hotels (having no provision for individual electric cooking):

One watt per square foot, except for the ballrooms.

For areas 10,000 square feet or less per feeder, demand 100.

For that part of the area in excess of 10,000 square feet and not more than 50,000 square feet per feeder, a demand of 80.

For the excess above 50,000 square feet per feeder, a demand of 70.

5. Stores and Department Stores (excluding Display Cases and Show-Window Lighting): Two watts per square foot.

To this shall be added an allowance for special display lighting as follows:

Counter Cases (silent salesmen): 25 watts per linear foot.

Wall or Standing Display Cases: 50 watts per linear foot.

Code.—*Continued.*

Show Windows: See Item No. 6 below. Demand 100.

6. Show Windows: 200 watts per linear foot, measured horizontally along the base of the show window—demand 100.

7. Office Buildings: 2 watts per square foot.

For areas 10,000 square feet or less per feeder—demand 100.

For all excess above 10,000 square feet per feeder—demand 70.

8. Industrial Commercial (Loft) Buildings: One watt per square foot—demand 100.

For the purpose of this section an industrial commercial building is defined as a building of more than one floor used for manufacturing or merchandising, occupied by more than one tenant.

9. Garages: ½ watt per square foot, exclusive of the machine shop or display rooms if any—demand 100.

10. Hospitals (except in the operating suite and X-ray department): ¾ watt per square foot.

For areas of 25,000 square feet or less per feeder—demand 100.

For the excess area above 25,000 square feet per feeder—demand 60.

11. Schools: 1⅓ watts per square foot. For areas of 10,000 square feet or less per feeder—demand 100.

For the excess area above 10,000 square feet per feeder—demand 50.

12. Storage Warehouses: ¼ watt per square foot.

For areas of 50,000 square feet or less per feeder—demand 100.

For the excess area above 50,000 square feet per feeder—demand 50.

13. Factory Buildings: Feeder sizes shall be based on the specific load which they are to serve.

For the purpose of this section a factory is defined as a building or a portion of a building occupied by one tenant, which is used for manufacturing purposes.

14. Other Kinds of Buildings and Occupancies: Theatres, churches, and other places of public assemblage, ballrooms, dance halls, restaurants, club and lodge rooms, community centers, armories, libraries, operating suites and X-ray departments in hospitals, etc., and buildings for special purposes, such as banks, motion picture studios, etc., vary so widely due to geographical location, individual requirements, architectural and ornamental treatment, that no standard has been established upon which the watts per square foot may be determined with accuracy. Therefore, the feeders for these and other buildings or occupancies not listed above, shall be determined by the specific load which they are to serve and as ordinarily computed. This applies also to special uses, such as flood and outline lighting, signs, etc.

15. Electrically Heated Cooking and Baking Appliances: The sizes of feeders supplying electrically heated cooking and baking appliances, each rated at more than 1,650 watts may be determined on the basis of the demand values shown in the following table:

Number Ranges		Demand Factor	Number Ranges		Demand Factor
1	—	100	14	—	42
2	—	100	15	—	40
3	—	95	16	—	39
4	—	90	17	—	38
5	—	85	18	—	37

Code.—*Continued.*

Number Ranges		Demand Factor	Number Ranges		Demand Factor
6	—	80	19	—	36
7	—	75	20	—	35
8	—	65	21	—	34
9	—	55	22	—	33
10	—	52	23	—	32
11	—	48	24	—	31
12	—	46	25	—	30
13	—	44	Over 25	—	30

The following examples illustrate the application of the table. In these examples the 2-wire system has been used solely for simplicity of illustrations. The same general method of calculation may be applied to other systems of distribution, such as 3, 4 or 5-wire.

Example No. 1. A dwelling having an area of 4,500 square feet, exclusive of unoccupied cellars, unfinished attics, and open porches.

AREA IN SQUARE FEET, 4,500 x 1 watt—sq. ft. =4,500 watts
Allowance for appliances =1,000 watts

COMPUTED LOAD =5,500 watts

DEMAND SELECTED FOR THIS OCCUPANCY, first 2000 square feet—Demand 100. Excess above 2,000 square feet—Demand 60.

4,500 square feet area
—2,000 square feet at 1 watt—sq. ft. x 1 (Demand 100) =2,000 watts

2,500 square feet at 1 watt—sq. ft. x 0.6 (Demand 60) =1,500 watts
Allowance for appliances 1,000 watts

LOAD AFTER APPLYING DEMAND 4,500 watts

For 110-volt, 2-wire system:
4,500 watts ÷110 volts =40.9 amperes.

SIZE OF CONDUCTORS =2-No. 6.
(From table No. 612 of allowable carrying capacities of wires.)

For 220-volt, 2-wire system:
4,500 watts ÷220 volts =20.45 amperes.

SIZE OF CONDUCTORS =2-No. 10.
(From table No. 612 of allowable carrying capacities of wires.)

For 110-220-volt, 3-wire system:
4,500 watts ÷2 x 110 volts =20.45 amperes.

SIZE OF CONDUCTORS =3-No. 10.

For 100-220 volts, 4-wire, 3-phase system:
4500 ÷3 x 110 volts =13.63 amperes.

SIZE OF CONDUCTORS =4-No. 14.

(From table No. 612 of allowable carrying capacities of wires.)

The above calculation does not take account of ranges or other appliances using more than 1,650 watts each.

Code.—*Continued.*

Article 7. Boxes, Cabinets, and Outlet and Terminal Fittings.

701. Construction of Outlet, Switch, Junction and Pull Boxes and Outlet and Terminal Fittings.

a. Boxes and fittings unless of corrosion resistive metal shall be well galvanized, enameled, or otherwise properly coated, inside and out, to prevent oxidation.

It is recommended that the protective coating he of conductive material, such as cadmium, tin or zinc, in order to secure better electrical contact.

b. Boxes and fittings not over 100 cubic inches in size, shall be composed of pressed steel, not less than No. 14 U. S. Sheet Steel Gauge (0.078 inch) in thickness or of cast metal, having a wall thickness of not less than ⅛ inch.

c. Boxes of over 100 cubic inches in size shall be composed of metal and shall conform to the requirements for cabinets and cutout boxes, except that the covers may consist of single flat sheets secured to the box proper by screws, or bolts instead of hinges. Boxes having covers of this form are for use only for enclosing joints in wires or to facilitate the drawing in of wires or cables. They are not intended to enclose switches, cutouts or other control devices.

d. Covers of boxes and fittings shall be of a thickness at least that specified for the walls of boxes of the same material as that used for the cover and of the size under consideration, or shall be lined with firmly attached insulating material not less than 1/32 inch in thickness. Covers of porcelain or other approved insulating material may be used if of such form and thickness as to afford the requisite protection and strength.

e. Covers of outlet boxes and outlet fittings having holes through which flexible cord pendants may pass, shall be provided with approved bushings or shall have smooth, well-rounded surfaces, upon which the cord may bear. Where wires other than flexible cord may pass through a metal cover, there shall be provided a separate hole for each wire, said hole being equipped with a non-combustible, non-absorptive insulating bushing.

f. Flush switch and receptacle plates, if of metal, shall be not less than 0.04 inch in thickness.

g. A fixture stud which is not an integral part of the outlet box shall be composed of steel, malleable iron or other approved material.

h. Outlet boxes intended for use where gas outlets are present shall be so designed that they may be securely fastened to the gas pipes in an approved manner.

i. Boxes and fittings intended for outdoor use shall be of approved weatherproof type.

702. Construction of Cabinets and Cutout Boxes.

a. Metal cabinets and cutout boxes shall be well galvanized, plated with cadmium or other approved metallic finish, enameled or otherwise properly coated, inside and out, to prevent oxidation.

It is recommended that the protective coating be of conductive material, such as cadmium, tin or zinc, in order to secure better electrical contact.

b. The design and construction of cabinets and cutout boxes shall be such as to secure ample strength and rigidity.

c. Wooden and (or) composition cabinets, whether for flush or surface mounting, shall be of rigid and substantial design. Doors shall fit closely. The requirements for spacings, barriers and other details of construction, given elsewhere in this section, shall be followed, so far as they apply. Wooden cabinets shall be composed of well-seasoned material at least ¾ inch in thickness, thoroughly filled and painted. They shall be lined throughout with a non-combustible material, such as ⅛ inch rigid asbestos board firmly secured in place. Linings of slate, marble or approved composition shall be at least ¼ inch in thickness. Sheet metal lining shall be at least .063 in thickness. (No. 16 U. S. sheet metal gauge.)

d. Composition cabinets shall be submitted for approval prior to installation.

Code.—Continued.

e. The spacing within cabinets and cutout boxes shall be sufficient to provide ample room for the distribution of wires and cables placed in them, and for a separation between metal parts of devices and apparatus mounted within them as follows:

1. There shall be an air space of at least 1/16 inch, except at points of support, between the case of the device and the wall of any metal cabinet or cutout box, on which the device is mounted.

2. There shall be an air space of at least 1 inch between any live metal part (including live metal parts of enclosed fuses) and the door, unless the door is lined with an approved insulating material or is of a thickness of metal not less than No. 12 U. S. sheet metal gauge (0.109 inch), when the air space shall be not less than ½ inch.

3. There shall be a space of at least 2 inches between open link fuses and metal lined walls or metal, metal lined or glass paneled doors.

4. Except as noted above, there shall be an air space of at least ½ inch between the walls, back, gutter partition, if of metal, or door of any cabinet or cutout box and the nearest exposed current-carrying part of devices mounted within the cabinet where the potentials do not exceed 250 volts. This spacing shall be increased to at least one inch where the potentials exceed 250 volts.

f. Cabinets and cutout boxes shall be deep enough to allow of the closing of the doors when 30-ampere branch circuit panelboard switches are in any position, or when combination cutout switches are in any position, or when other single throw switches are opened as far as their construction will permit.

g. Cabinets and cutout boxes which contain devices or apparatus connected within the cabinet or box to the wires of more than four circuits, including branch circuits, meter loops, sub-feeder circuits, power circuits and similar circuits, but not including the supply circuit or a continuation thereof, shall have back wiring spaces or one or more side wiring spaces, side gutters or wiring compartments, unless the wires leave the cabinet or cutout box directly opposite their terminal connections.

h. Side wiring spaces, side gutters or side wiring compartments of cabinets shall be rendered tight enclosures by means of covers, barriers or partitions extending from the bases of the devices, contained in the cabinet, to the door, frame, or sides of the cabinet, provided, however, that where the enclosure contains only those wires or cables which are led from the cabinet at points directly opposite their terminal connections to devices within the cabinet, such covers, barriers or partitions may be omitted. Partially enclosed back wiring spaces shall be provided with covers to complete the enclosure.

i. Cabinets and cutout boxes intended for outdoor use shall be of approved weatherproof type

703. *Installation of Boxes, Cabinets, and Outlet and Terminal Fittings.*

a. At each outlet, switch, or junction point of conduit, metal raceway, armored cable or non-metallic sheathed cable, and at each outlet and switch point of concealed knob-and-tube work, an approved box shall be installed. In completed installations, the box shall be provided with a cover, unless a fixture canopy is present.

b. Outlet boxes for concealed work shall have an internal depth of at least 1½ inches, except that where the installation of such a box will result in injury to the building structure, a box of not less than ½ inch internal depth may be installed.

c. An approved outlet or terminal fitting shall be used at ends of conduit, armored cable and metal raceway systems from which wires are run without splice to appliances or to knob-and-tube wiring. The fitting shall provide a bushed hole for each wire. It need not be accessible when in knob-and-tube-work. Such fittings shall not be used at outlets for fixtures.

Code.—*Continued.*

d. Approved metal supports shall be used in new work for boxes and fittings which are not secured to a stud, joist, or similar fixed structural unit. Blocks of wood at least ⅞-inch in thickness may be used for supports if the blocks are rigidly secured to such structural units. Lath, of wood, metal, or composition, shall not be considered a fixed structural unit.

e. Boxes used to enclose flush devices shall be of such type that the devices will be completely enclosed on back and sides, and that substantial support for the devices will be provided. Screws for supporting the box shall not be used for the attachment of the device contained therein. Floor-outlet boxes shall be so designed as to protect receptacles and attachment plugs from mechanical injury and moisture.

f. Covers of outlet boxes and outlet fittings having holes through which flexible cord pendants pass, shall be provided with approved bushings or shall have smooth, well-rounded surfaces on which the cord may bear. Where wires, other than flexible cord pass through a metal cover, there shall be provided a separate hole for each wire, said hole being equipped with a non-combustible, non-absorptive insulating bushing.

g. Boxes, cabinets and fittings shall be securely fastened in place. Boxes and fittings not over 100 cubic inches in size and which are attached to firmly secured, exposed conduit by threading or other connection approved for the purpose are considered as so fastened.

h. Outlet boxes used where gas outlets are present shall be so fastened to the gas pipes as to be mechanically secure.

i. Junction boxes shall be so installed that the wiring contained in them may be rendered accessible without removing any part of the building.

j. Boxes, cabinets and fittings when installed in walls or ceilings shall be so installed that the front edge of the fitting will not set back of the finished surface more than ¼ inch. On wooden walls or ceilings, the front edges of the fitting shall be flush with the finished surface, or project therefrom. A plaster surface which is broken or incomplete shall be repaired, so that there will be no gaps or open spaces at the edge of the fitting. These requirements do not apply to walls or ceilings composed of concrete, tile or other non-combustible material.

k. In moist places, boxes, cabinets, and fittings shall be so placed or equipped as to prevent moisture from entering and accumulating within the device.

l. Openings in boxes, cabinets and fittings shall be equipped, either separately or as a part of the fitting, with couplings or bushings which will serve to secure the conduit, raceway, armored cable, non-metallic sheathed cable, or flexible tubing to the fitting, and including open wires shall close the opening adequately, and at the same time protect the wires from abrasion. Where a hardwood cabinet is used, as provided for in section 805-e, each opening shall be equipped with a non-combustible, non-absorptive insulating bushing which shall fit securely in the opening and be so closed by the wire, and tape, if necessary, as to fit tightly. In dry places where open work or knob and tube work is used, approved flexible tubing may be employed as an insulating bushing if it extends from the last insulating support and is firmly secured in place.

m. Unused openings in boxes, cabinets and fittings shall be effectively closed by metal plugs or plates affording protection substantially equivalent to that of the wall of the fitting.

n. Metal boxes, cabinets, and fittings shall be grounded where used with conduit, armored cable or metal raceway, or elsewhere when and in the manner specified in sections 904 and 905 of this Code. Boxes, cabinets and fittings used with grounded conduit, armored cable and metal raceways are considered to be grounded by the connection to the conduit, cable or raceway.

For special provisions in hazardous locations see Article 32.

o. In making a surface extension from an existing outlet of concealed wiring, a box, extension ring or blank cover shall be mounted over the original box and electrically and mechanically secured to it. The extension shall then be connected to this box in the manner prescribed for the method of wiring employed in making the extension.

Code.—Continued.

1202. Installation of Switches—General.

For hazardous locations see article 32 of this Code.

a. Switches or manual circuit-breakers shall not be placed where exposed to mechanical injury, nor in the immediate vicinity of easily ignitable material. When the above conditions cannot be complied with, switches, circuit-breakers, and similar devices, unless of the oil-immersed type, shall be enclosed in approved metal boxes or cabinets, and shall be of the externally operable type.

b. Except as provided in paragraph d of this section, switches or manually operated circuit-breakers shall be placed only in dry, accessible places, and be grouped as far as possible.

c. Switches or manually operated circuit-breakers, when located where exposed to moisture, as in basements and in similar places, shall be mounted in approved boxes or cabinets, and when located in wet places or outside buildings, shall be mounted in approved weatherproof switch boxes or cabinets.

d. Enclosures for switches or circuit-breakers on circuits, any wire of which operates at over 150 volts to ground, except where accessible only to qualified operators, shall be grounded as provided in article 9 of this code.

e. Switches operating at over 150 volts to ground shall be of the enclosed type externally operable, except where accessible only to qualified persons.

1204. Number of Poles Required for Switches and Circuit-Breakers.

a. Switches, when installed, shall disconnect all ungrounded wires of the circuit which they control.

b. Three-way and four-way switches shall be classed single pole switches and shall be so wired that only one pole of the circuit will be carried to the switch.

c. On constant-potential circuits, all service switches and all switches controlling circuits supplying current to motors or heating devices, unless otherwise provided in this code, shall be so arranged that the opening of the switch will disconnect all the ungrounded wires.

d. Where a circuit-breaker serves as a switch, it shall conform to the requirements of this section as to the number of poles.

1205. Mounting of Snap Switches.

a. Sub-bases of non-combustible, non-absorptive insulating material, which will separate the wires at least ½ inch from the surface wired over, shall be installed under all snap switches used in open work. Sub-bases shall also be used in wooden raceway work; but they may be made of hardwood or they may be omitted if the switch is approved for mounting directly on the moulding.

1206. Special Types of Switches.

a. Time switches, sign flashers and similar appliances shall be of approved design and enclosed in approved cabinets.

1207. Marking.

a. Switches shall be marked with the current and voltage for which they are designed.

Article 13. Switchboards and Panelboards.

This article does not apply to switchboards or portions thereof used exclusively to control signal circuits operated by batteries, but does apply to the charging panels where current is taken from light or power circuits.

For special provisions for hazardous locations see Article 32.

Code.—*Continued.*

1301. Switchboards: Location and Accessibility.

a. Switchboards shall be so placed as to reduce to a minimum the danger of communicating fire to adjacent combustible material.

b. Switchboards shall not be built up to a non-fireproof ceiling, a space of 3 feet being left, if possible, between the ceiling and the board. The space back of the board shall be kept clear of rubbish and shall not be used for storage.

c. Switchboards shall be accessible from all sides when the connections are on the back.

It is recommended that al. switchboards be set out from the wall, but they may be placed against a brick or stone wall when the wiring is entirely on the face.

d. Switchboards shall be so located that they will not be exposed to moisture.

e. Switchboard frames and structures supporting switching equipment shall be grounded, except that the frames for d-c single-polarity switchboards may be insulated for the full voltage of the circuit in lieu of grounding.

1302. Switchboards: Material and Wiring.

a. The bases of switchboards shall be made of non-combustible material.

b. Busbars, if rigidly mounted, may be of bare metal.

c. If the wiring is on the back, there shall be a clear space of at least 18 inches between the wall and the apparatus on the rear of board.

d. Insulated conductors where closely grouped as in rear of switchboards shall each have a substantial flameproof outer covering.

e. Flameprooflng shall be stripped back on all conductors a sufficient distance from the terminals to give the necessary insulation for the voltage of the circuit on which the conductor is used.

f. Instruments, pilot lights, potential transformers, and other switchboard devices with potential coils (except where the operation of the protective device might introduce a hazard in the operation of devices, or when the switchboard is inaccessible to other than qualified persons) shall be supplied by a circuit that is protected by standard automatic overload protective devices of a rating not larger than 15 amperes except that for ratings of two amperes or less special enclosed types of fuses may be used.

g. Instruments, meters and relays mounted on switchboards, shall comply with the requirements of section 906, paragraph n, unless inaccessible to other than qualified persons, in which case the following requirements may be followed in lieu thereof:

For alternating-current circuits:

1. The secondary circuits of current and potential instrument transformers shall be grounded.

2. Instrument, meter and relay cases (whether operated from current and potential transformers, or connected directly in the primary circuit) on switchboards having no live parts on the front of the panels shall be grounded, where operating with current-carrying parts not exceeding 750 volts to ground.

3. Instrument, meter and relay cases (whether operated from current and potential transformers or connected directly in the primary circuit) on switchboards having live parts on the front of panels shall not be grounded where operating with current-carrying parts not exceeding 750 volts to ground. Rubber mats, or other suitable floor insulation, shall be provided for the operator if the voltage to ground exceeds 150.

4. Instrument, meter and relay cases on circuits, exceeding 750 volts to ground shall be isolated by elevation or protected by suitable barriers, grounded metal or insulating covers or guards.

Code.—Continued.

For direct-current circuits:

Instrument, meter and relay cases shall not be grounded. If the voltage of the circuit is less than 750 volts but above 150 volts to ground, rubber mats or other suitable floor insulation shall be provided for the operator. If the voltage to ground exceeds 750 volts, cases shall be isolated by elevation or protected by suitable barriers, grounded metal or insulating covers, or by guards.

h. The conductors of remote-control switch circuits will be considered as suitably protected by fuses rated at not more than 750% of the same carrying capacity of the conductors as given in section 612 of article 6.

i. Switchboards which have any exposed live parts above 150 volts to ground (or live parts on ungrounded circuits exposed to a higher voltage to ground) shall be located only where under competent supervision and accessible only to qualified persons.

For switchboards having exposed live parts of lower voltages, see sections 405, 805 and 1202.

1303. Panelboards.

a. The requirements of this section shall apply to all panel and distributing boards used for the control of light and power circuits, but not to such switchboards in central stations, substations or isolated plants as directly control energy derived from generators or transforming devices.

b. Switches, fuses and cutout bases used on panelboards, shall conform to the requirements of articles 12 and 8, respectively, of this code, so far as they apply.

c. In the relative arrangement of cartridge fuses and switches the fuses shall be placed on the load side of the switches except in the case of service switches, where the requirements of Article 4 shall be observed. Branch switches shall be so arranged that the blades, if exposed during operation, will be dead when the switches are open.

d. When there are exposed live metal parts on the back of board, a space of at least ½ inch shall be provided between such live metal parts and the cabinet in which the board is mounted.

e. The following minimum distances between bare live metal parts (busbars, etc.) shall be maintained:

Between parts of opposite polarity except at switches and circuit-breakers.

	When mounted on the same surface	When held free in air
Not over 125 volts	¾ inch	½ inch
Not over 250 volts	1¼ inch	¾ inch
Not over 600 volts	2 inch	1 inch

At switches, enclosed fuses, etc., parts of the same polarity may be placed as close together as convenience in handling will allow.

It should be noted that the above distances are the minimum allowable, and it is recommended that greater distances be adopted wherever the conditions will permit.

f. Panelboards so installed as to be exposed to excessive moisture shall be enclosed in approved weatherproof cabinets.

Article 14. Fixtures, Lamp-Holding Devices, Plug Receptacles and Other Outlet Devices.

For special provisions for hazardous locations see Article 32.

1401. Construction of Lighting Fixtures.

a. Fixtures shall be composed of metal or wood, or such other material as may have been submitted for examination and approved. Materials other than metal shall be re-enforced by metal or the fixtures shall be otherwise constructed to secure the requisite mechanical strength.

Code.—Continued.

b. In all fixtures not made entirely of metal wire-ways shall be lined with metal unless approved armored conductors with suitable fittings are used. This requirement shall not apply to wire-ways in glass, marble or similar non-absorptive non-combustible insulating material.

c. All methods of fastening arms, sockets, bodies, supports, and receptacles by threading, soldering, brazing or otherwise, shall be such as to secure in every case ample strength and reliability, and to prevent turning. Screw joints shall have not less than five threads engaging. Tubing used in making threaded arms and stems shall be composed of metal having a thickness not less than .040 inch. It shall not be kinked, flattened or cracked.

d. All burrs and fins in wire-ways shall be removed and all sharp edges rounded, where practicable, so that wires may be drawn in and withdrawn without injury. Fittings having smooth, rounded edges shall be placed at entrance to casings of fixture stems.

e. Fixtures exposed to moisture, whether located indoors or outdoors, shall be so constructed that water cannot enter or accumulate in the wire-ways, lamp holders or other electrical parts.

f. Fixture studs which are not parts of outlet boxes, hickeys, tripods, and crowfeet shall be made of steel, malleable iron or other approved material.

g. All fixtures shall, where practicable, be sufficiently ventilated. All forms of fixtures in which the wiring is liable to be exposed to temperatures in excess of 120° F. (49° C.) shall be so designed or ventilated and installed as to operate at temperatures which will not cause deterioration of the wiring.

h. Canopies and outlet boxes shall, taken together, provide ample space for the reception of the wires and their connecting devices.

i. Receptacles having exposed terminals shall not be placed in canopies unless completely enclosed in metal.

j. Canopy insulators, used where insulating joints are required, shall be of approved type and shall be securely fastened in place, so as to separate the canopies effectively and permanently from the conducting surfaces from which they are intended to be insulated.

A strip of a good grade of hard fiber, 1/16 inch in thickness, securely attached to the canopy at the ends and at intermediate points in such a manner that the strip will extend at least 3/16 inch beyond the upper edge of the canopy rim, will be accepted. Where this is impracticable, a flat sheet of such fiber, cut to conform to the general outline of the canopy and having the edges of the sheet at least flush with the edges of the canopy, may be employed, if permanently attached to the canopy.

k. Insulating joints shall be composed of materials especially approved for the purpose. Those which are not designed to be mounted with screws or bolts shall have a substantial exterior metal casing, insulated from both screw connections.

1402. Wiring of Lighting Fixtures.

a. No conductor shall be smaller than No. 18. On chains or other movable parts stranded conductors shall be used, unless the wires are completely enclosed in metal. Where the fixture is externally wired, wires shall be secured in a manner which will not tend to cut or abrade the insulation, and shall be protected from abrasion where they pass through sheet metal pans, canopies, etc. No splice or tap shall be located within an arm or a stem.

It is recommended that approved splicing devices or approved plug connections be used for attaching the fixture wires to the circuit wires.

b. Each fixture shall be so wired that all screw shells of lamp holders are connected to the same fixture stem wire or supply wire or terminal. A fixture stem wire or supply wire connected to the screw shells of lamp holders shall be identified by means of a white or natural gray covering, or by means of a tracer thread contrasting with the color of the covering. In fixtures having wire-ways of such size that it is impracticable to pull in separate conductors without injury to the insulation, the identification may consist of a band of paint contrasting with the

Code.—Continued.

color of the covering and located as near as possible to the point where the wire leaves the fixture. If a white or natural gray covering is employed the covering of all other fixture stem or supply wires in the fixture shall be of a contrasting color. If a tracer thread is employed there shall be no such thread in the covering of any other fixture stem or supply wire. A terminal attached to the screw shells of sockets shall be marked in the manner specified in paragraphs d to m of section 206 of article 2 of this code.

c. Chain fixtures shall be wired with flexible conductors so arranged that the weight of the fixture will not put tension on the conductor.

d. Approved fixture wire, approved flexible cord or approved rubber covered wire shall be employed, unless the wiring is exposed to temperatures in excess of 120° F. (49° C.) in which case conductors having slow burning or other heat resisting covering shall be used. All fixtures in dry places designed for or used with Mogul base lamps shall be considered as being exposed to these high temperatures. Fixtures intended for outdoor use shall be wired with approved rubber-covered conductors. Wire shall always be so disposed as to avoid exposure to high temperatures as far as practicable. Fixtures intended for use in rooms where inflammable gases may exist shall consist of rigid stems, internally wired with approved rubber covered conductors, soldered directly to the circuit wires, and shall be equipped with vaportight globes.

e. Fixture wires, or the individual conductors of flexible cords used where the voltage between any two conductors or between any conductor and the ground is over 300 volts, shall have insulation at least 3/64 inch in thickness for sizes No. 8 and smaller unless type S cord is used.

f. Wires of different systems shall not be contained in or attached to a fixture.

g. All wiring shall be free from short-circuits and grounds, and shall be tested for these defects prior to being connected to the circuit.

h. Fixtures, including lamp holders and lamp bases if within reach of grounded surfaces, shall be so designed and installed that no current-carrying parts will normally be exposed externally.

1403. Installation of Lighting Fixtures.

a. Fixtures on circuits above 150 volts to ground and all electrical fixtures used with conduit, armored cable or metal raceways, not exempted from grounding elsewhere in this Code shall be grounded.

b. Fixtures used with knob and tube work, non-metallic sheathed cable or wooden raceways shall be grounded except as described below:

1. Fixtures mounted on metal or metal lath ceilings or side walls may be insulated from their supports, and from the metal lath by the use of approved insulating joints or fixture supports and approved canopy insulators.

2. Fixtures not mounted on metal or metal lath ceilings or side walls need be neither insulated nor grounded.

c. Gas piping to which fixtures are attached shall be grounded as provided for in Article 9, unless the fixtures are insulated therefrom or are grounded by one of the other means specified in the following paragraph. Gas piping need not be insulated from otherwise well-grounded fixtures. Combination gas and electric fixtures shall not be installed.

d. Fixtures shall be considered as grounded when mechanically connected in a permanent and effective manner to metal conduit, tubing, armored cable, a metal-raceway system, the grounding conductor of non-metallic sheathed cable, a separate grounding wire not smaller than No. 14, or to gas piping, which are grounded in the manner specified in article 9 of this code.

e. No externally wired fixtures shall be located in the immediate vicinity of specially inflammable material; nor shall any externally wired fixture other than of the chain type be placed in a show window. Armored-cord pendants shall be considered to be internally wired fixtures.

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f. Where a gas pipe, outlet box or other fitting which will provide proper support is required by this code or is present, the fixture shall be attached thereto; otherwise the fixture shall be attached to a wooden base block not less than ¾ in thickness supported independently of the screws supporting the fixtures.

g. Gas pipes shall be covered with insulating tubing back of an insulating joint or blind hickey. Where outlet tubes are used they shall be of sufficient length to extend beyond the joint or hickey, and shall be firmly secured in place.

h. Fixtures shall be so installed that the connections between the fixtures, and the branch circuit wires will be easily accessible for inspection without requiring the disconnecting of any portion of the wiring, unless the fixture is attached by an approved plugging device.

1404. Construction of Lamp-Holding Devices and Plug Receptacles.

a. Lamp-holding devices shall be classed according to diameters of lamp bases, as Candelabra, Intermediate, Medium and Mogul base, to be known respectively as ½ inch, 21/32 inch 1 inch, and 1½ inch nominal sizes, with ratings, as specified in the table following this paragraph. Switched lamp-holders shall be of such construction that the switching mechanism interrupts the electrical connection to the center contact. The switching mechanism shall not interrupt the electrical connection to the screw shell unless connection to the center contact is simultaneously interrupted.

Class	Nominal Diam.	Watts	Volts	Ratings Key Max. Amp. at any Voltage	Watts	Volts	Ratings Keyless Max. Amp. at any Voltage
Candelabra...	½ in.	75	125	¾	75	125	1
Intermediate..	21/32 in.	75	125	¾	75	250	1
Medium......	1 in.	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.

For exceptions for Medium-Base Key Sockets and Receptacles see Article 40, Small Isolated Plants.

Receptacles for Attachment Plugs (Appliance and Convenience Outlets) are strongly recommended in order to facilitate the use of electrical appliances which, otherwise, must be connected to sockets designed primarily only for lamp holders.

If lamp holders must be used for the attachment of flexible cords they should be rated at 600 watts.

b. The inside of metal shells shall be lined with insulating material, which shall absolutely prevent the shell from becoming a part of the circuit, even though the wires inside the sockets should become loosened or detached from their position under the terminal screws.

c. The lining shall not extend beyond the metal shell more than ⅛ inch, but shall prevent any current-carrying part of the lamp base from being exposed when a lamp is in the socket.

d. The cap also shall be lined.

Code.—Continued.

In sockets and receptacles of standard forms a ring of any material inserted between an outer metal shell of the device, and the inner screw shell for insulating purposes and separable from the device as a whole, is considered an undesirable form of construction. This does not apply to the use of rings in lamp clusters or in devices where the outer shell is of porcelain or of moulded composition, where such rings serve to hold the several porcelain or composition parts together, and are thus a necessary part of the whole structure of the device.

e. The socket as a whole shall be so put together that parts will not rattle loose or fall apart under the most severe conditions they are likely to meet in practice. The base of the socket shall be secured or held in the shell in such a manner as to prevent turning or displacement relative to the shell.

f. Lead wires furnished as a part of weatherproof sockets and intended to be exposed after installation shall be of approved stranded, rubber-covered wire, not less than No. 14 gauge (No. 18 gauge for candelabra sockets), and shall be sealed in place.

g. If the socket is not attached to a fixture, the inlet shall be equipped with an approved insulating bushing which, if threaded, shall not be smaller than ⅜ inch in size. The edges of bushings shall be rounded and all inside fins removed in order to provide a smooth bearing surface for the wire.

It is recommended that bushings having holes 9/32 inch in diameter be employed with plain pendant cord, and holes 13/32 inch in diameter with re-enforced cord.

1405. Installation of Lamp-Holding Devices and Plug Receptacles.

a. Sockets and receptacles installed over specially inflammable material shall be of the keyless type and, unless individual switches are provided, shall be located at least 7½ feet above the floor, or shall be otherwise so located or guarded that the lamps cannot readily be backed out by hand.

b. When necessary to prevent portable lamps from coming into contact with inflammable material, or to protect them from breakage, their flexible cord leads shall be equipped with handle, socket and substantial guard, the guard being securely attached to socket or handle.

c. Weatherproof sockets, especially approved for the location, shall be employed in damp or wet places or where corrosive vapors exist. If not attached to fixtures, they shall be hung from separate stranded wires not less than No. 14, which are soldered directly to the circuit wires, but supported independently thereof.

It is recommended that these wires be twisted together if the pendant is longer than 3 feet.

d. Receptacles shall be supported in the same manner as specified for fixtures in section 1403-g of this code.

e. Flush receptacles shall be enclosed in approved metal boxes in addition to the insulating enclosure of the receptacle mechanism.

f. Attachment plugs and receptacles located in floors shall be inclosed in approved metal boxes especially designed for the purpose. Where the location is free from mechanical injury or moisture, a departure from this requirement may be permitted by the authority enforcing this code.

g. Receptacles of the Edison-base type shall be installed only for use as lamp holders. Receptacles installed for the attachment of portable cords shall be of a type not suitable for use with Edison-base screw shells.

1406. Rosettes.

a. When designed for use with exposed wiring, rosettes shall be provided with bases which shall have at least two holes for supporting screws, shall be high enough to keep the wires

Code.—Continued.

and terminals at least ½ inch from the surface wired over, and shall have a porcelain lug under each terminal to prevent the rosette being placed over projections which would reduce the separation to less than ½ inch.

b. When designed for use with conduit boxes or wire raceways, rosette bases shall be high enough to keep wires and terminals at least ⅜ inch from the surface wired over.

c. Fuseless rosettes shall be rated at 660 watts, 250 volts, with a maximum current rating of 6 amperes.

d. Fused rosettes shall not be installed.

802. Link Fuses.

a. Link fuses shall not be used when of capacities of 300 amperes or less. When used in capacities of from 301 to 1,500 amperes, they shall be rated to correspond to the ratings of cutout bases as given in the table of paragraph a, section 801, of this code.

b. Contact surfaces or tips of link fuses shall be of copper or aluminum, having good electrical connections with the fusible part of the strip.

c. Link fuses shall be stamped with 80% of the maximum current which they can carry indefinitely, thus allowing about 25% overload before the fuse melts.

d. Link fuses may be used only when mounted on approved bases which, except on switchboards, shall be placed in approved cutout boxes or cabinets. A space of at least 2 inches shall be provided between the open-link fuses and metal, or metal-lined walls or metal, metal-lined or glass-paneled doors of cabinets or cutout boxes.

803. Enclosed Fuses.

a. The requirements of paragraphs c to g inclusive, of this section, do not apply to fuses for attachment plugs, car-lighting cutouts, nor to protective devices for signal systems.

b. The casings of enclosed fuses shall be sufficiently tight so that lint and dust cannot collect around the fusible link and become ignited when the fuse is blown. For non-renewable fuses the fusible wire shall be attached to the terminals in such a way as to make it difficult for it to be replaced when melted.

c. Enclosed fuses shall be classified to correspond with the different classes of cutouts, and shall be so designed that it will be impossible to put any fuse of a given class into a cutout which is designed for a current or voltage lower than that of the class to which the fuse belongs.

d. Enclosed fuses shall be marked with the words "N. E. Code Std." All fuses shall be marked with the ampere capacity. On ferrule contact fuses this marking shall be on the tube or ferrules, and on knife blade fuses on the tubes or caps. In addition to the above marking each cartridge enclosed fuse shall be provided with a paper label, red for 600-volt fuses, navy blue for 250-volt fuses of 15 amperes or less capacity and green for 250-volt fuses of over 15 amperes capacity. The label for cartridge fuses shall bear the following: the name or trademark of the manufacturer and the voltage for which the fuse is designed.

e. Plug fuses of 15 amperes capacity or less shall be distinguished from those of larger capacity as follows: by an hexagonal opening in the cap through which the mica or similar window shows; or by an hexagonal shaped recess in the top of fuses having porcelain or moulded composition tops, and when labels are used with such plug fuses the labels shall also be hexagonal in shape and fill the recess; or on plugs having solid metal caps, by an hexagonal impression either raised or lowered on the caps.

f. The fuse terminals shall be sufficiently heavy to insure mechanical strength and rigidity. The styles of enclosed plug and cartridge fuse terminals, except for use in sealable service and meter cutouts, shall be as follows:
Not over 250 volts.

Code.—*Continued.*

0–30 Amps.	A. Cartridge fuse (ferrule contact). B. Approved plugs or cartridge fuses in approved casings for Edison plug cutouts not exceeding 125 volts, but including any feeder or circuit of a system having a grounded neutral, if no wire of the feeder or circuit exceeds 125 volts to ground.
31–60 "	Cartridge fuse (ferrule contact) for use also in approved casings for large size Edison plug type 250-volt cutouts.
61–100 " 101–200 " 201–400 " 401–600 "	Cartridge fuse (knife blade contact).

Not over 600 volts.

0–30 Amps. 31–60 "	Cartridge fuse (ferrule contact).
61–100 " 101–200 " 201–400 " 401–600 "	Cartridge fuse (knife-blade contact).

g. Cartridge enclosed fuses and corresponding cutout bases, except for sealable service and meter cutouts, shall conform to the dimensions given in the table, page 94 of the code.

805. General: Use of Automatic Overload Protective Devices.

a. In general, automatic overload protective devices shall be provided in all constant potential interior wiring systems, and shall be of such character and so placed as to protect each ungrounded conductor.

c. In general a conductor shall be considered as properly protected by the automatic overload protective device employed in series with it when the automatic overload protective device is so selected and adjusted as to open and interrupt the circuit at a predetermined overload.

j. Cabinets shall in all cases be placed in a vertical position except by special permission and under conditions whereby automatic overload protective devices installed in such cabinets are thoroughly safeguarded from attendant hazards.

m. Fixture wires or flexible cords of No. 16 or No. 18 gauge shall be considered as protected by 15-ampere fuses. Flexible cords of No. 18 gauge or larger, approved for use with specific devices which may be used on the medium-duty appliance branch circuits described in Section 1602, shall be considered as protected by the 25-ampere fuses of such circuits.

n. Fused rosettes shall not be used.

807. Lighting and Appliance Branch Circuits.

a. For the purpose of this section the terms "Outlets" and "Appliances" shall be defined as follows:

"Outlet"—

An outlet is that fixed point on a branch circuit at which current is taken to supply lighting fixtures or appliances.

"Appliances"—

Appliances are current consuming devices for domestic or general commercial use, such as heating, cooking and small motor operated devices, etc.

b. All ungrounded wires of a branch circuit shall be protected by fuses or circuit-breakers. When the grounded conductor is identified and properly connected, branch circuits shall be so protected in the ungrounded wires only. In locations where the conditions of grounding or the liability of the reversal of connections warrants, the inspection department may require,

Code.—Continued.

on systems having a grounded neutral or having one side grounded, that both wires of two-wire branch circuits shall be so protected, even though the grounded conductor is identified and properly connected.

c. Two-wire branch circuits on ungrounded systems shall be protected by a fuse in each wire.

d. Circuit-breakers, if used in lieu of fuses, shall be of a type specifically approved for this purpose.

e. Three-wire branch circuits may be run from direct-current or single-phase alternating-current systems having a grounded neutral, in which case the neutrals of the branch circuits shall not be inter-connected except at the center of distribution.

f. Branch circuits in general, and except as described elsewhere in this code, shall be protected by fuses of no greater rated capacity than

15 amperes .... at 125 volts or less
10 amperes .... at 126 to 250 volts

g. In general, on a two-wire branch circuit and on either side of a three-wire branch circuit the number of outlets shall not exceed 12.

For lighting branch circuits and combination lighting and appliance branch circuits and appliance branch circuits which do not supply floor areas greater than 1,200 square feet per circuit, the above outlet restriction may be waived, provided such circuits do not have connected loads greater than 15 amperes for lighting branch circuits nor greater than 10 amperes for combination lighting and appliance branch circuits.

It is understood that by connected load is meant fixed load, exclusive of loads which may be connected to appliance outlets.

h. Branch circuits supplying only sockets or receptacles of the mogul type shall have the wires protected by fuses having a rated capacity not greater than

40 amperes .... at 125 volts or less
20 amperes .... at 126 to 250 volts

i. If protected by 40 or 20 ampere fuses as above, wire not smaller than No. 12 shall be used for wiring fixtures with mogul sockets and receptacles and may also be used for taps not over 18 inches long from the circuit wires to the points of suspension of the fixtures.

j. The number of mogul sockets on a 2-wire branch circuit and on either side of a 3-wire branch circuit shall not exceed eight (8) except by permission of the authority enforcing this code.

1604. Wires Supplying Electrically Heated Appliances.

a. Wires supplying stationary electrically heated appliances shall, if not in conduit, be so located as to be protected from mechanical injury and moisture.

b. Where the surrounding temperature of fixed wires exceeds 120° F. (49° C.), types A or SB wires shall be used. In all other cases the type of insulation on fixed wires shall be that specified elsewhere in this code for the conditions which prevail.

c. Wires supplying smoothing irons and all other portable electrical heating appliances which are rated at more than 50 watts and which produce temperatures in excess of 250° F. (121° C.) on surfaces with which the wire is liable to be in contact, shall be approved heater cord, Type H. For other portable electrical heating appliances approved lamp cord, Type C, or other cord specially approved for the purpose may be used.

1605. Special Provisions for Electrically Heated Appliances.

a. Each electrically heated appliance which is obviously intended by size, weight and service to be secured in a fixed position shall be so placed as to furnish ample protection between the appliance and adjacent combustible material.

b. Each smoothing iron and other portable electrically heated appliance, which is intended

Code.—*Continued.*

to be applied to combustible material, shall be equipped and used with an approved stand, which may be a separate device or may be a part of the appliance.

c. In other than residence occupancies each such electrically heated appliance or group of such electrically heated appliances shall be used with an approved signal, unless the appliance is provided with approved integral temperature-limiting device.

d. Subdivided circuits of electrically heated appliances need not be separately fused, but individual heating elements of such electrically heated appliances shall be fused if they are rated at more than 30 amperes.

1606. Grounding.

a. Appliances shall be grounded if and as specified in article 9 of this code. See Grounding Chapter.

TEST QUESTIONS

1. *How can much labor and material be saved in starting a house wiring job?*
2. *If an installation require over four circuits, what should be provided?*
3. *How should a panel board be installed?*
4. *How many panel boards should be installed in large loft buildings?*
5. *If only one distributing point be used, where should it be located?*
6. *What is a service connection?*
7. *Name several methods of making a service connection.*
8. *What are the essential requirements of tube service?*
9. *Describe in detail the method of installing a conduit service.*
10. *What fittings are used on the service entrance?*
11. *How is the end of the conduit secured to the switch box?*
12. *Describe an underground service entrance.*
13. *How is a feeder layout for a large building made?*

14. *How many feeders should be provided in a large building?*
15. *What provision should be made for motors?*
16. *How should feeders be located?*
17. *Why is it not good practice to use up the 660 watt allowance on branch circuits?*
18. *Describe the method of cutting outlets.*
19. *How should a ceiling outlet be located?*
20. *Describe the method of taking up flooring.*
21. *What difficulty is experienced in taking up double flooring?*
22. *Describe two methods of cutting tongue off floor planks.*
23. *What should be done before the boards are removed?*
24. *Where should holes for wires be bored in joists?*
25. *How is the center of a pocket indicated?*
26. *Describe each operation in detail in cutting a pocket.*
27. *What must be installed at each outlet?*
28. *Describe an outlet box.*
29. *What is a knockout?*
30. *How are outlet boxes attached?*
31. *What is a fixture stud?*
32. *How should the wires be brought into an outlet box?*
33. *Give methods of installing outlet boxes in unfinished frame buildings.*
34. *Give method of cutting out switch box outlets.*
35. *How is the space between floor and ceiling explored?*
36. *What is the method of passing by cross stud in partition when plaster must be cut?*
37. *What is a mouse?*

38. *Give method of passing by cross stud in partition when wires are run next to a door.*
39. *Give various methods of overcoming obstructions in partitions.*
40. *Describe the operation of dropping wires down outer walls.*
41. *What kinds of obstructions are encountered along the outer walls?*
42. *Define the term "fishing."*
43. *Give method of fishing from outlet to outlet.*
44. *How are wires fished without removing floors or base boards?*
45. *Give some points on switches for lighting installations.*
46. *Describe the right and wrong way of installing a knife switch.*

CHAPTER 117

Wiring Under Floors

The problem of arranging wiring under floors with a multiplicity of floor outlets spaced so that they will meet the probable requirements of modern commercial buildings in capacity, flexibility and convenience has led to the development of under floor wiring systems.

In these systems two forms of conduit* are used:

1. Duct or rectangular conduit;
2. Regular pipe conduit.

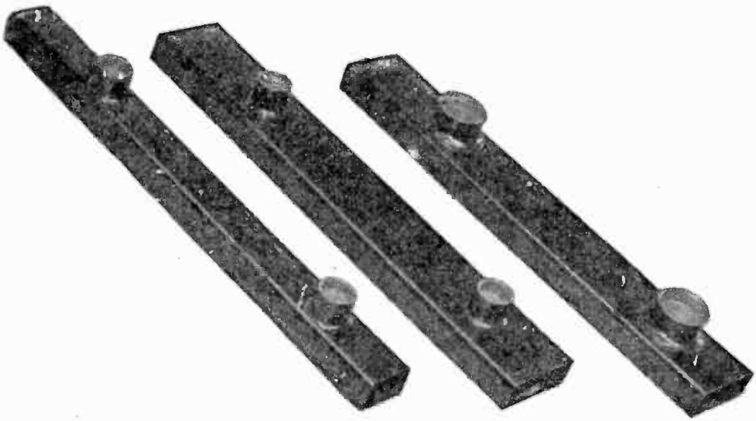
A typical under floor system consists of a network of rectangular steel ducts, single or multiple, embedded in the floor.

Each length of duct is equipped with outlet extensions applied in the course of manufacture, at minimum cost, at specified regular uniform intervals. The advantage of under floor ducts in office buildings is obvious. The practical advantage, economy and convenience of these pre-set, regularly spaced inserts should be just as apparent. Confusion, dirt and noise are practically eliminated in making connections after completion of the building. Flexibility in use is inherent in the principle of under floor distribution and is made fully available by the pre-set insert feature.

*NOTE.—Called ***under floor raceways*** by the Code.

Figs. 5,671 to 5,673 show the proportions of the duct and the outlets. These ducts come in 10 ft. lengths and the outlets are usually spaced 2 ft. apart.

The sectional view, fig. 5,674, shows one of these outlets with wires passing through it. The outlet as seen has a screw thread. Of course all these outlets will not be used and accordingly plugs are provided to close those not in use. Figs. 5,6 5 to 5,678 show plug in duct, parts and wrench.



FIGS. 5,671 to 5,673.—Walker under floor duct showing outlets. *Standard sizes* No. 1, 1⅞×1¼"; No. 2, 3⅛×1¼'.

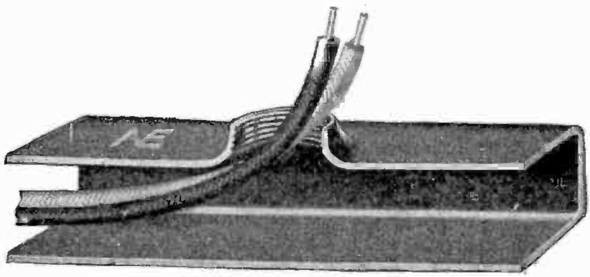
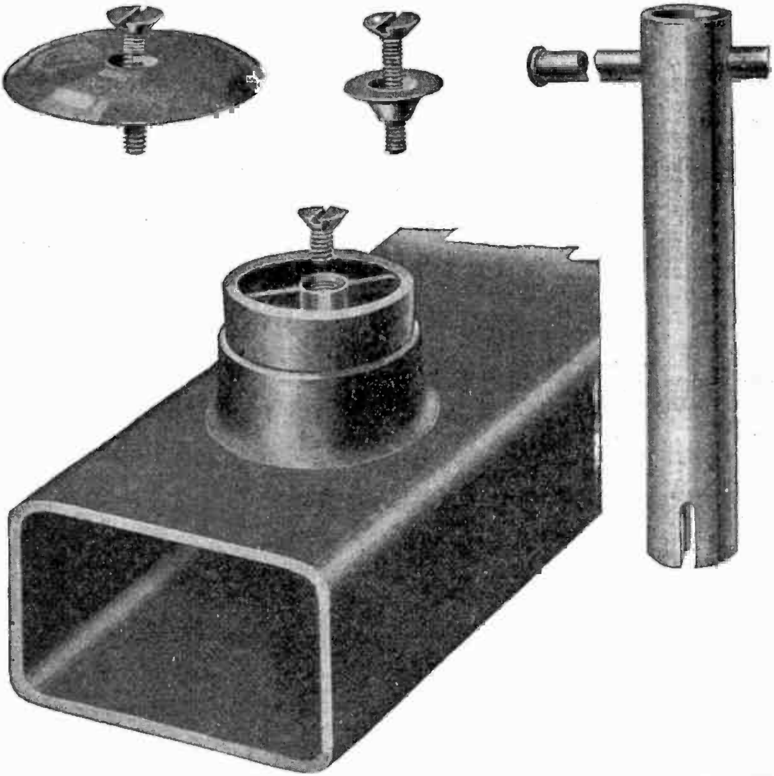


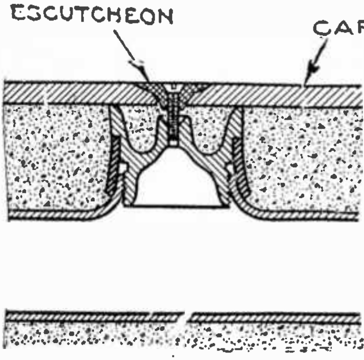
FIG. 5,674.—Sectional view of National duct showing threaded outlet. The sweeping curve is to facilitate pulling the wires.

Fig. 5,683 shows one type of plug.

As shown, the duct is embedded in concrete fill with plugs screwed down into the duct outlets. Plugs may or may not be concealed by floor construction, and marker screw can be elevated to show at floor when required. The construction of the plug is plainly shown in the illustration. The position of the plug is indicated on the floor by the marker screw as shown in fig. 5,679.



FIGS. 5,675 to 5,678.—National duct with plug in outlet, wrench, and parts. Fig. 5,675 shows abandoned outlet plate and fig. 5,676, floor covering escutcheon, fig. 5.678 shows the wrench.



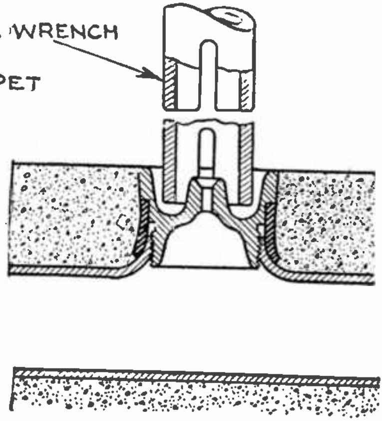
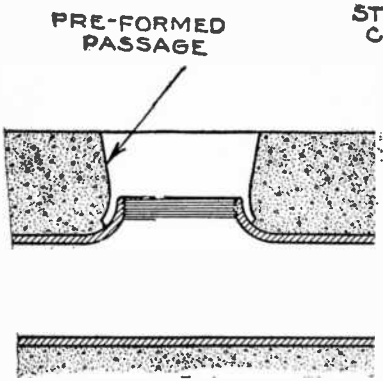


FIG. 5,679.—National type A plug showing application of floor covering escutcheon. When marker screw is to show through floor coverings of linoleum, rubber, cork tile, or carpet, the escutcheon as here shown is used to protect such floor coverings from fraying.

FIG. 5,680.—National type A plug showing application of plug remover wrench.



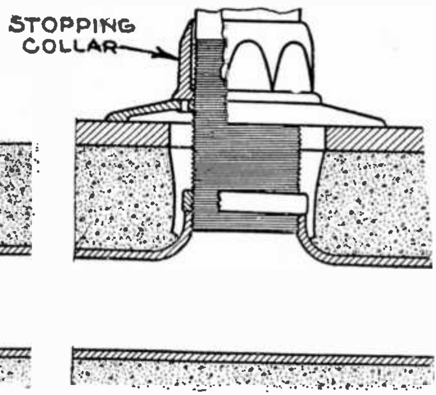


FIG. 5,681.—National duct embedded in concrete showing pre-formed passage through the concrete formed by plug when concrete was poured.

FIG. 5,682.—National service extension assembly showing stopping collar and attachment to duct.

When duct outlet is to be used for service, it is necessary to remove small amount of concrete from top depression of plug in order to use the plug removal wrench.

Plug can be readily screwed from the duct and concrete with plug removal wrench of which the socket end is shown in fig. 5,680. The removal of the plug leaves a neat pre-formed passage through the concrete to duct outlet. The void in concrete around rim of duct is a catch-all for dirt and small particles. Fig. 5,681 shows the outlet with plug removed. The service extension assembly as shown in fig. 5,682, directly engages the duct outlet without use of any form of adapter, insuring positive protective grounding, as required in National Electrical Code. The stopping collar is sweated in place in manufacture, and serves as a gauge so that service extension pipe will always be turned into duct outlet to proper depth.

Fig. 5,683 shows an abandoned outlet.

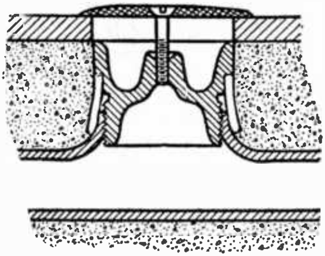


FIG. 5,683.—National type A plug showing abandoned outlet plate.

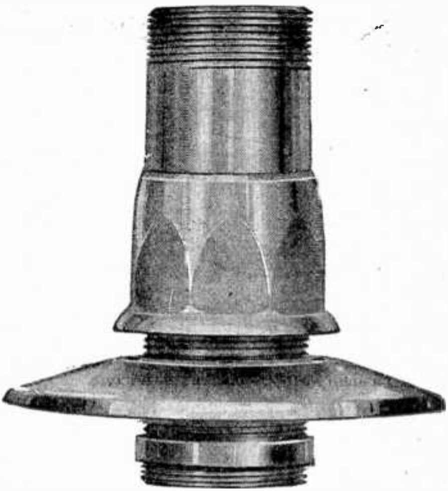
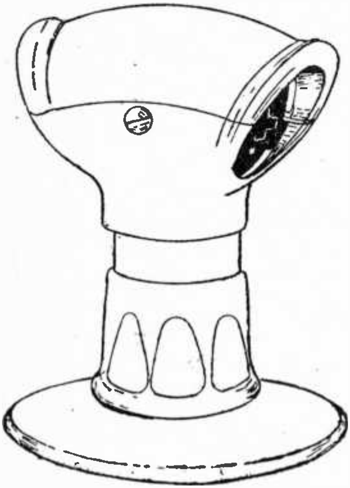
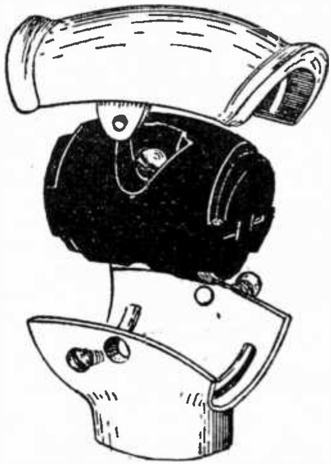


FIG. 5,684.—National service extension assembly. It is adjustable to accommodate floor thicknesses approximately 1 to 2 ins. above the duct. The stopping collar is sweated in place to insure proper depth engagement with duct outlet. When service pipe is screwed into outlet to shoulder engagement, a very tight joint is effected. The floor flange is screwed down to a bearing on finished floor surface, further stabilizing extension assembly. It is provided with holes for spanner wrench, so that by use of the wrench considerable pressure can be applied between floor flange and finished floor, giving extra strength to whole installation. Locking collar is jammed against floor flange by turning it down with other end of spanner wrench. Besides acting as a locknut for floor flange, it hides spanner wrench holes, and the unused threads on service extension pipe.

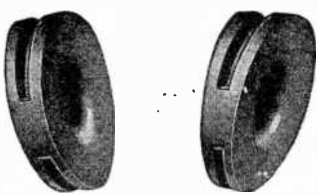
When outlet is abandoned, the plug is screwed again into duct outlet, and an abandoned outlet plate is pulled tight over opening in floor material, by tightening marker screw into plug. The assembly is shown more in detail in fig. 5,683.

Duct Fittings.—Since the service extension assembly and service fittings frequently occupy positions under desks or in foot space, they are purposely designed to be *kick proof*.





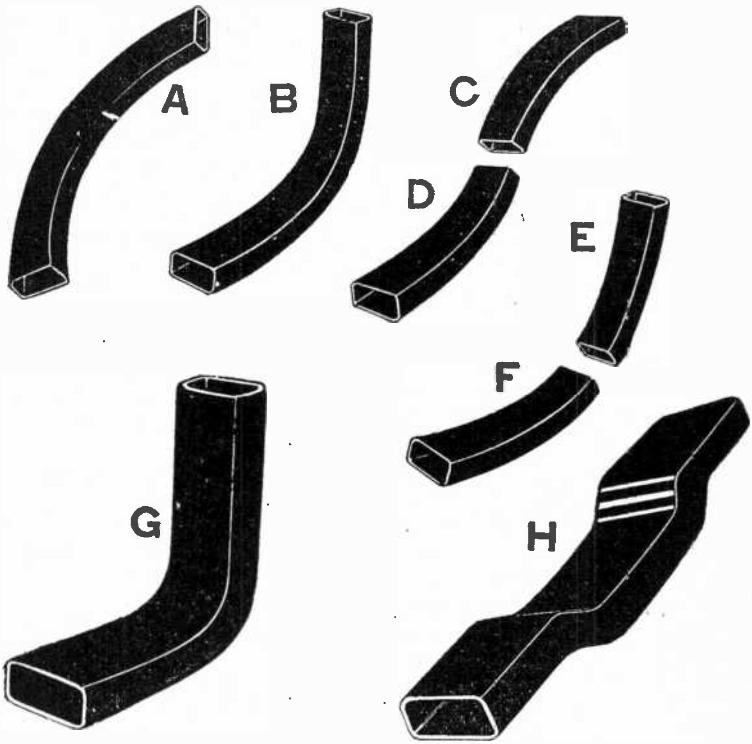
FIGS. 5,685 and 5,686.—National service head shown assembled and disassembled. It is used either for high or low voltage from duct. The double T slot receptacle shown in fig. 5,686 is for high voltage service.



FIGS. 5,687 and 5,688.—National fibre bushings for service fitting used in place of double T slot receptacle for low voltage service. It prevents contact and abrasion between edges of head outlet and wires.

They will stand any reasonable abuse in connection with exposed position. Ribs at two ends of opening prevent desk occupant's feet injuring connection. Attachment plug is sufficiently protected so that the feet will not strike the plug itself, thereby eliminating interruptions to service.

There are numerous patterns of elbows and offsets as shown in figs. 5,689 to 5,696 making it easy to change the direction of the duct in laying.



FIGS. 5,689 to 5,696.—National duct elbows and offsets. Fig. **A**, flat floor elbow; fig. **B**, long pattern 90° vertical wall elbow; can be sawed in sections as in figs. **C** to **F**, to meet requirements; fig. **G**, short radius 90° vertical wall elbow; fig. **H**, cross under offset.

When an outlet is to be connected at the end of duct a fitting such as shown in fig. 5,700 is used. Numerous miscellaneous fittings are shown in figs. 5,701 to 5,706.

Floor Junction Box.—The complete unit comprises the box proper and outlet assembly. The latter is shown in fig. 5,698.

The assembly is installed flush with surface of finished concrete or wood floors. When floor coverings are used, however, the brass ring is forced up, using novel arrangement of screws. Floor covering is then cut to fit around brass ring, and it is replaced in position and drawn down flush with newly installed floor covering. Rim of brass ring holds floor covering down securely,

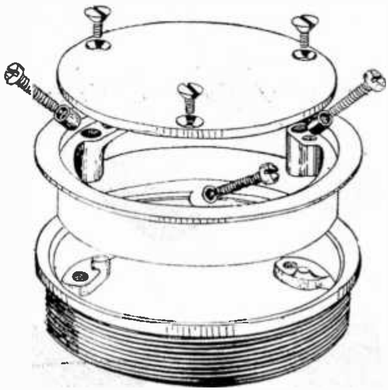


FIG. 5,697.—National standard junction box outlet assembly, for use with finished surface concrete floors, or where floor coverings of linoleum, rubber tile, cork tile, or carpet are laid. The assembly is installed flush with surface of finished concrete or wood floors. When floor coverings are used, however, the brass ring is forced up, using novel arrangement of screws. Floor covering is then cut to fit around brass ring, and it is replaced in position and drawn down flush with newly installed floor covering. Rim of brass ring holds floor covering down securely, and renders the box waterproof.

and renders the box waterproof. An entire unit consisting of a double box and outlet assemblies is shown in fig. 5,698. It is levelled by adjusting the three long set screws, located around edge upon which the box rests.

Under Floor Duct Layout.—Floor plans, conditions and service requirements are apt to vary so widely that but one general

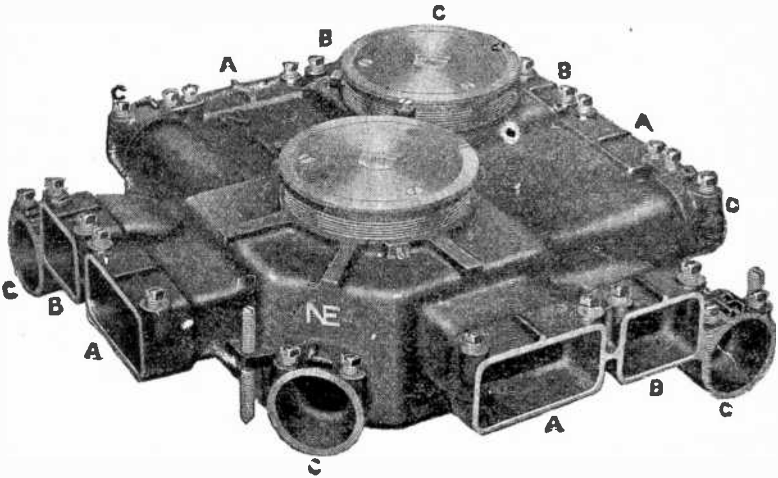


FIG. 5,698.—National 4 way floor junction box. ***It is in reality*** two boxes and two sets of cross overs, in a one piece casting, one box and cross over to be used for high voltage and the other box and cross over to be used for low voltage. No communication is to be had between the high and low voltage boxes (in accordance with rules of the Code). All openings A, receive large duct intended for low voltage wiring. Openings B, receive small duct intended for high voltage wiring. Conduit openings C, receive conduit, nominally 1¼ inch for high and low voltage service to system. The two outlet assemblies installed in the box are shown in detail in fig. 5,697. Unused duct openings in box should be closed with duct opening plug shown in fig. 5,699, and unused openings for conduit should be closed with conduit opening plug and adapter.

FIG. 5,699.—National type B plug. When adjusted it protrudes very slightly above top rim of duct outlet. This shallow plug is intended for use where duct is installed under wood or marble, as it is impracticable to cut a number of holes in the underside or through these materials to fit over a type A plug protruding above level of concrete fill; when the type B plug is used, holes need be cut only where duct outlet is to be used for service. Other outlets are located by marker screws, or by measurement.

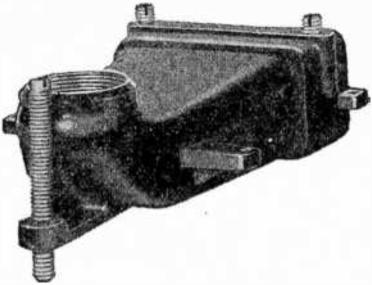
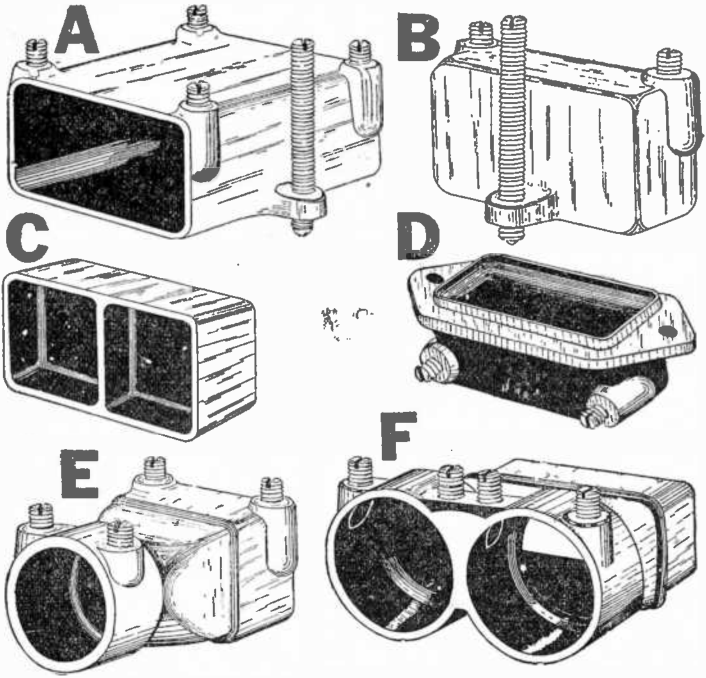
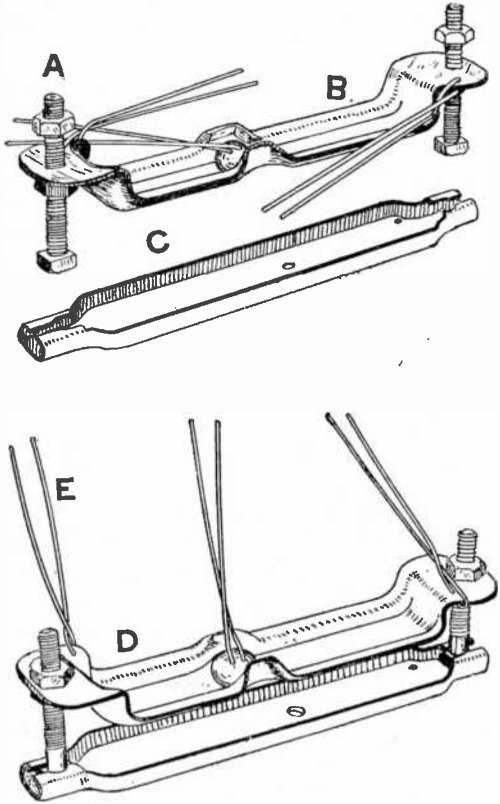


FIG. 5,700.—National duct end outlet with height adjusting screw. It fits on end of the duc and receives standard duct outlet plug.



FIGS. 5,701 to 5,706.—Miscellaneous National duct fittings.

rule can be laid down to govern all jobs in the matter of layout. That is, the layout need not necessarily take care of all possible conditions, but may provide only for all reasonable probabilities, leaving improbable possibilities to be taken care of if they materialize.



Example. — An 18-foot bay would seem to require for 100% coverage three runs of duct with 4 ft. 6 in. spacing, but two runs, five feet from the wall and five feet from the columns, will usually be sufficient to meet actual requirements. The reason for this becomes apparent when it is considered that a single row of desks would almost surely be placed near the wall, a second row in corresponding position near the columns and a third row, if needed, would have to be doubled with one of the other rows, the double row using a single run of duct. Similarly a 30-foot space would seem to require five runs of duct whereas three runs will cover the probable service demands.

FIGS. 5,707 to 5,709.—National duct saddle support, disassembled and assembled. **A**, height adjustment nuts; **B**, saddle slips into place when adjusting nuts are loose; **C**, base members of saddle support are installed on floor as early as possible, to indicate lines of duct, thus avoiding interference of other trades' work; **D**, seats in saddle for duct are stamped accurately, and hold ducts in proper relation to each other, as well as to the finished floor; **E**, tie wires to be twisted over top of ducts to hold them firmly in saddle.

Aside from the factor just mentioned, layouts will generally come under one of four classifications, governed by policy and specific conditions.

1. General coverage of entire, net, usable floor area.

2. Full coverage of certain parts of floor area where demands for service will be greatest.

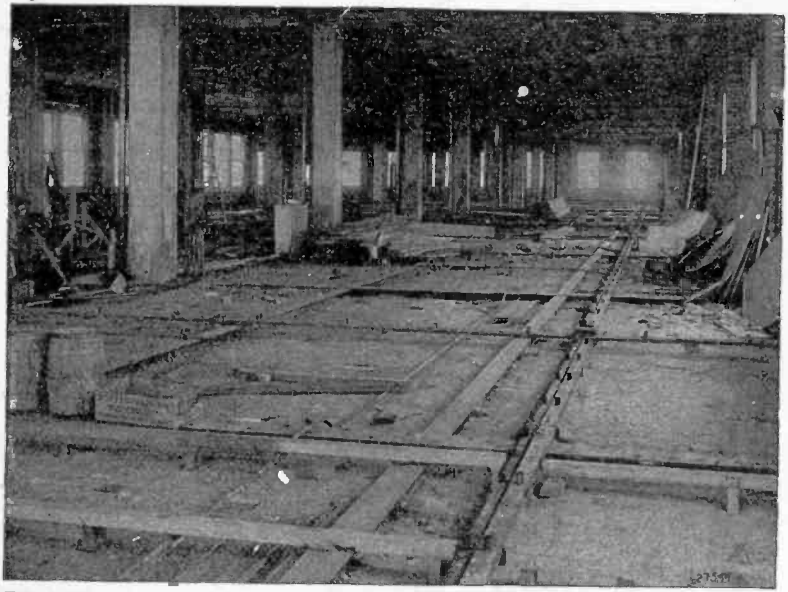


FIG. 5,710.—Example of the use of under floor duct for service around the outside walls of a building where demand for telephone and signal service at least, is apt to be heaviest. This plan gives only a minimum of coverage but does give flexibility. A further point of interest is the use of double size duct for low tension wires—an example of the adaptability of the system to varying service requirements.

3. Under floor duct around the outer wall when service demands are concentrated there. This plan is in general adequate only where space is definitely planned in small units but is extremely flexible and economical for such areas.

4. This class includes all special plans such as those for stores or banking floors where the layout definitely follows the equipment plan.

Another important factor is the number and location of home run or feeder conduits or ducts.

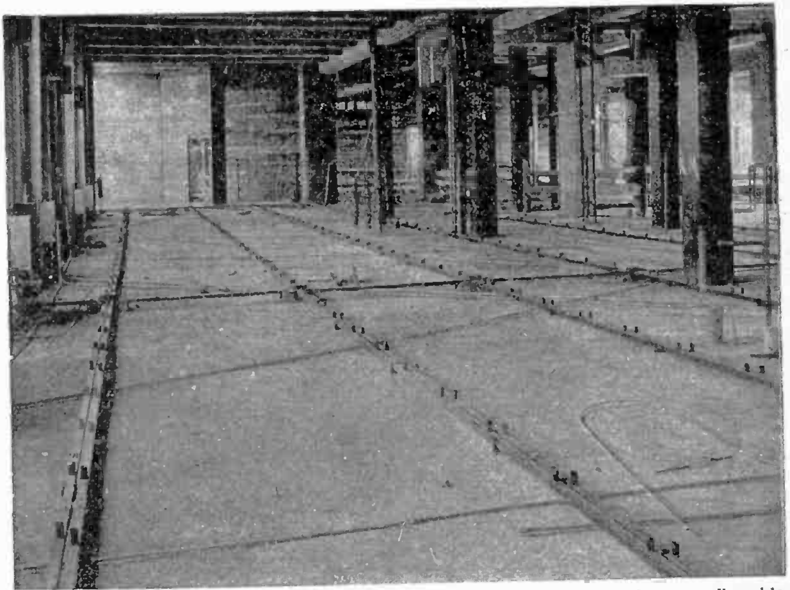


FIG. 5,711.—Walker duct under floor installation so designed as to adequately cover all usable areas making provision for any and all requirements for the life of the building. Double size ducts are used at important feeder points of the telephone and signal duct system. Each sub-panel is fed by a separate riser; cross run feeds are alternately for light current and low tension.

In planning a round conduit system the rated capacity of a conduit may be utilized and in the case of a lighting current system the full capacity of each circuit available may be used.

In the case of under floor ducts, however, every outlet utilized should be a separate circuit as far as the nearest junction box. Therefore, junction boxes and home runs should be spaced, as a rule, not more than thirty or forty feet apart. If these home runs feed more than two parallel runs of under floor duct they should be somewhat more frequent.

This is particularly true of a lighting current system as the Code permits only ten No. 14 wires in any one run of under floor duct between junction boxes. Hence lighting home runs should not be expected, regardless of conductor capacity, to serve more than five possible outlets in each direction from each box served by that particular feeder. General practice has been to space junction boxes from twenty to forty feet apart and provide feeders of 1 inch or 1¼ inch pipe for each separate system (lighting, telephone, low tension) at each box or at every other box. If possible connections to low tension cabinets should be duct.

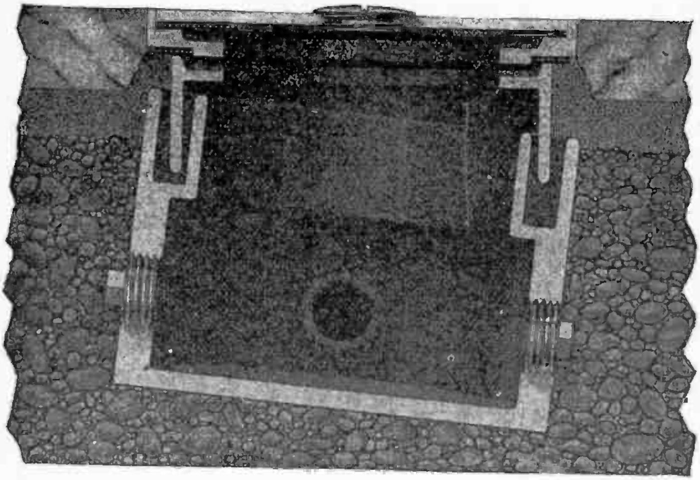


FIG. 5,712.—Fullman adjustable floor outlet. The box body is shown out of level which is the usual condition. The adjusting ring is set level with the finished floor line. Note how the adjusting ring *dips* into the groove deeper on the high side of the box body. When the cement in the groove of the box body hardens, the two parts are united just like a solid casting. The cover plate is in alignment with the finished marble floor. The brass flange ring protects the edge of marble floor from chipping upon repeated removal of cover plate.

Code.

506. ***Underfloor Raceways.***

a. Underfloor raceways shall be used only in dry locations, free from corrosive, hazardous and extra hazardous conditions, in buildings of fire-resistive construction and where embedded in concrete or concrete fill of floors which are of sufficient thickness to exceed the height of

Code.—Continued.

raceways at all points. They shall not be used for circuits of more than 300 volts nor for any wire larger than No. 8 nor any wire protected by an automatic overload protective device exceeding 30 amperes.

b. Underfloor raceways shall be of an approved type and may be placed in the concrete fill between the rough and the finished floor when there is at least 1 inch of concrete placed above the raceway, except that with a duct of approximately round or half round section, or of flat top section not exceeding 1½ inches in width, this may be reduced to ¾ inch. Upper surface of flat top ducts shall not be more than 4 inches wide nor shall be placed side by side without at least ½ inch of intervening concrete, or unless cover depth is increased to 1½ inches. Open-bottom types of underfloor raceways shall not be used in floors of monolithic construction.

c. Open-bottom types of underfloor raceways shall not be used in shallow floor concrete fills unless proper cover is maintained and a smooth pad of 1 inch concrete having a margin of at least 1 inch on either side of the raceway, or unless approved fittings are used which will protect the wiring from contact with piping structural steel or other obstructions, except that where transverse conduit is encountered the pad thickness may be reduced to ¼ inch. Open-bottom type shall have under it the above required pad except where approved fittings are so installed as to protect the wiring from contact with and leakages to piping, structural steel or other obstructions below.

d. Underfloor raceways shall be laid so that a straight line from the center of one junction box to the center of the next junction box will coincide with the center line of the raceway. Raceways shall be made mechanically secure to prevent disturbing this alignment during construction.

e. All joints along edges of raceways and between raceways, couplings and junction boxes, and between the junction boxes cover plate and cover ring shall be filled with an approved waterproof cement, but with metal raceway this shall not interrupt the required electrical continuity of the raceway. Approved fittings may be used to take the place of waterproof cement between junction boxes, cover plate and cover ring. Raceways, with their fittings, should be so arranged, that there will be no low points, or traps in the raceway run. Crossing shall be avoided wherever practical.

f. Where raceways are run at other angles, than right angles, special fittings shall be provided, if in the judgment of the authority enforcing this regulation, those are necessary. Connections between raceways and distribution center, or the side wall outlets, shall be by means of conduit or approved fittings. Electrical continuity shall be maintained for metal raceways and fittings. At every end of line of duct, a fitting shall be installed extending through the floor to mark the line of the duct. Where a duct line is interrupted by another duct line, but continues in a straight line beyond, and has junction boxes or outlets on either side of the crossing line, no markers shall be deemed necessary at the interrupting point. Dead ends of ducts shall be closed.

g. Inserts for outlets and junction boxes shall be made in an approved manner, with approved fittings, and shall make a tight contact with the raceway. In the case of metal raceways, inserts and junction boxes shall be of metal, electrically continuous with the raceways. Inserts in fibre raceways shall be screwed into the fibre and shall not be set until floor is laid unless inserts are made mechanically secure by separately grouting them in. All inserts and junction boxes shall be carefully leveled to the floor grade and sealed with an approved watertight plug.

h. Care shall be exercised in setting inserts and when cutting through the raceway wall that chips and other dirt do not fall into the raceway. Special tools designed to eliminate this and to prevent the tools entering the raceway and injuring wires already there, shall be employed.

i. Underfloor metal raceways, and all metal fittings, shall be of a type, and of such material, or protected by such coatings, as shall suitably resist corrosion, and any coating shall be such as will resist removal by ordinary handling.

Code.—Continued.

j. Underfloor metal raceways shall be continuous from outlet to outlet, or from approved fitting to approved fitting.

k. Underfloor raceways of metal shall be electrically continuous and grounded as prescribed for other metal wiring raceways in article 9 of this code, and at a point as near as practical to the source of supply.

l. A combination type of underfloor raceway may be used for both signalling, and lighting and power wiring systems provided the different wiring systems are run in separate compartments, and the same relative position of compartments is maintained throughout the premises.

m. Where open-bottom raceways are used approved, double braid rubber-covered wires, type RD, armored cable or non-metallic sheathed cable shall be used. Where it is impossible to install the required pad for crossing conduits or structural steel, only armored cable or non-metallic sheathed cable shall be used. Wherever armored cable is used it shall be grounded in accordance with article 9 of this code.

For closed-bottom raceways approved rubber-covered wires, type R shall be used, or type RD, armored cable or non-metallic sheathed cable shall be used.

n. Wires used in underfloor raceways, either open or closed bottom shall be continuous from outlet to outlet, or from junction box to junction box, or from junction box to outlet. Wires shall have no joints or taps located in the raceway proper, nor at inserts. Joints or taps shall be made in junction boxes by splicing and soldering, or by use of an approved fitting, approved for the purpose. Armored cable and non-metallic sheathed cable shall be secured at the outlets by approved fittings.

When an outlet is discontinued the wires feeding that outlet should be removed from the raceway.

o. Not more than ten wires shall be placed in any one raceway, nor shall the combined cross-sectional area of all conductors exceed 30 per cent of the interior cross-sectional area of the raceway; where only armored cable or non-metallic sheathed cable is contained this shall not apply. Wires or interior wiring systems not electrically connected to each other within the building shall not be contained within the same raceway.

p. Wires shall not be drawn in until all mechanical work on the building which is liable to injure the wires has been completed, so far as practical.

q. Where alternating current is to be employed for wires within a metal raceway the wires and circuits shall be so grouped that the current in one direction is substantially the same as that in the opposite direction.

TEST QUESTIONS

1. *Name two types of wiring systems for wiring under floors.*
2. *Describe a typical under floor system.*
3. *What name is given by the Code for under floor systems?*
4. *Describe under floor duct.*
5. *How is the duct installed?*
6. *Describe two types of plug used.*
7. *What must be done when a duct outlet is to be used for service?*
8. *Describe a surface extension.*
9. *Name the various fittings used with duct.*
10. *What kind of a fitting is used when an outlet is to be connected at the end of a duct?*
11. *Describe an under floor junction box.*
12. *Can any rules be given for making under floor layouts?*
13. *Name four classes of layouts.*
14. *Name an important factor to be considered in making a layout.*
15. *What spacing should be given to junction boxes?*
16. *How many wires does the Code permit in a single duct?*
17. *Must a layout necessarily take care of all possible conditions?*
18. *What are the features of under floor duct around outer wall arrangement?*
19. *Describe some typical under floor duct installations.*

20. *What should be considered in planning a round conduit system?*
21. *In under floor ducts should every outlet utilized have a separate circuit?*
22. *What is a home run?*
23. *How many outlets should be served by a lighting home run?*

CHAPTER 118

Wiring Under Plaster

For wiring under plaster extensions, the Code specifies that such extensions *shall be run in rigid or flexible conduit, armored cable, metal mouldings, or electrical metallic tubing of approved standard types.*

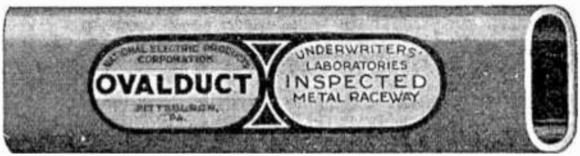


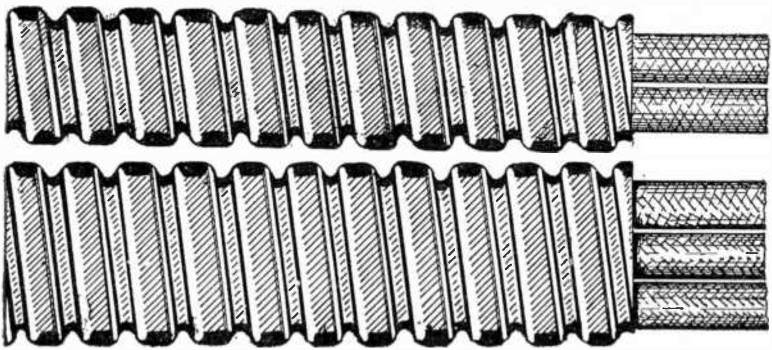
FIG. 5,713.—National "Ovalduct" flat under plaster raceway. ***It consists of*** a welded rigid tube, with an oval cross section 13/32 inch high x 31/32 inch wide, shallow enough so that it can be embedded in, and completely covered by plaster of ordinary thickness, when fastened directly to fireproof under body of concrete, tile or brick. Ovalduct is furnished in ten foot lengths, ten lengths to a bundle.

For under plaster work the various forms of flexible conduit are made flat or oval shaped so that when installed, the conduit will not project outside the surface of the plaster. National "Ovalduct" is an example of under plaster flat raceway. Its general appearance is shown in fig. 5,713.

For installations where close bends are required, such as dropping under exposed ceiling beams, or passing around projecting columns, on walls, and for fished work, a flexible or armored flat cable as shown in figs. 5,714 and 5,715 is used.

It is recommended that three wire flat conduit or cable be used instead of the two wire, because in many instances the third wire is required for switch control. When the two wire conduit or cable is used, it is necessary to install an extra run to carry the third wire when that wire is required.

Fittings and Outlet Boxes.—Flat raceway devices and fittings include a switch box 1½ inches deep, round outlet boxes ¾ inch deep, a sleeve coupling for joining two lengths of raceway or an elbow to raceway, a 45° flat elbow, a 90° vertical elbow, fastenings, and connectors which make it possible to extend flat raceway from any other type of raceway or wiring system.



FIGS. 5,714 and 5,715.—Flat armored cable for under plaster work. *Made* with three conductors in sizes 14 and 12; also with two conductors in sizes 14, 12 and 10.

FIG. 5,716.—National squeeze type coupling.

FIG. 5,717.—National 90° elbow.

For joining lengths of flat raceway a coupling which slides over the raceway end is used, as shown in fig. 5,716. It makes a secure grounded connection when screws at sides are tightened. Joins two elbows, or raceway and one elbow in the same manner.

Fig. 5,717 shows a 90° elbow used for both external and internal angles. It is joined to the raceway or to a second elbow by the coupling shown in fig. 5,716. It also fits into connectors.

The 45° flat elbow shown in fig. 5,718 is also joined to the raceway or to a second elbow by the coupling.

The type outlet box used is similar to the ordinary box with exception that it is made shallow and has oval instead of round knockouts in the side, so shaped to fit the oval raceway or cable.

Fig. 5,719, shows a typical box.

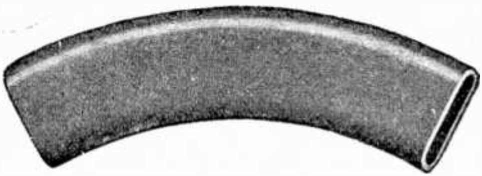


FIG. 5,718.—National 45° flat elbow.

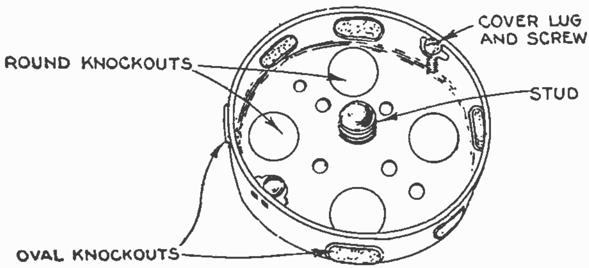
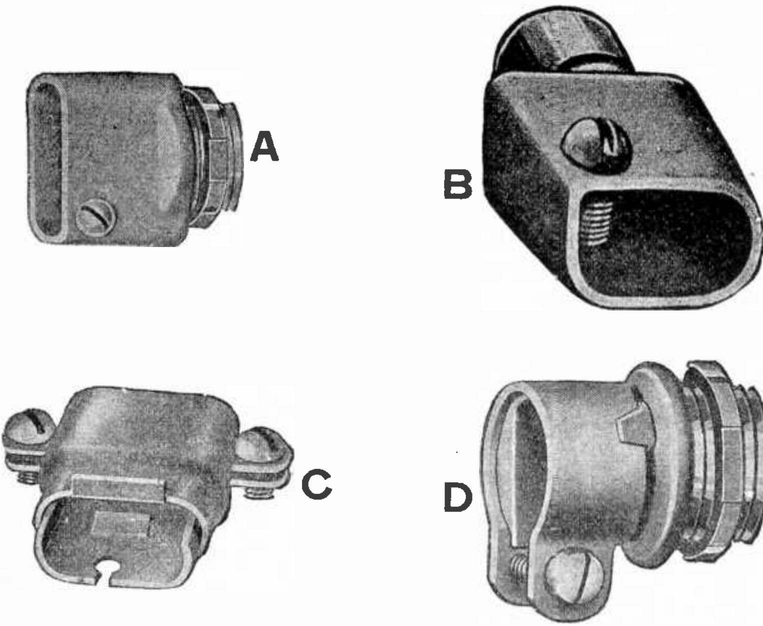


FIG. 5,719.—Shallow outlet box for oval conduit or oval armored cable. *Proportions*, [illegible] inch deep overall. ⅜ inch male fixture stud which is part of the box. Four ½ inch knock outs in bottom and six oval knock outs in side spaced at 45°. Cover lugs and screws will take standard 4 inch round covers. Use oval connector.

Numerous types of connectors are shown in figs. 5,720 to 5,723.

Conduit Riser.—The most important unit of permanent conduit installation used in conjunction with easily changed ceiling and wall under plaster extensions of oval raceway or oval cable, is the *conduit riser*.

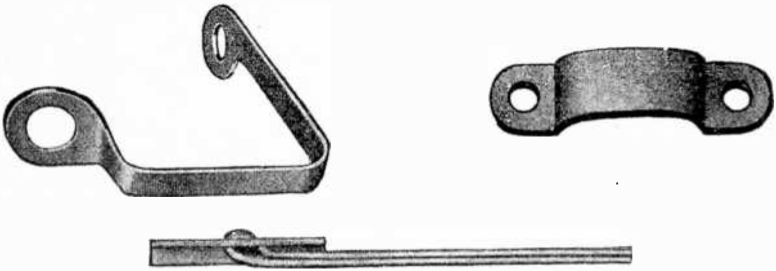


Figs. 5,720 to 5,723.—National connectors. **A**, straight box connector, set screw type; **B**, cable box connector, set screw type; **C**, connector for metal moulding boxes; **D**, straight box connector, squeeze type.

This consists of conduit turned up from run in floor fill, into a convenience outlet 12 inches up the side wall or column, conduit extended thence up wall into permanent switch outlet located at usual height of 4½ feet from floor, and thence extended further up wall, terminating in junction or *pull box* near ceiling, as shown in fig. 5,728.

When *riser* is used with oval raceway extensions, a 90° vertical elbow is run into a knockout in uppermost wall of *pull box* with a connector which permits elbow to pivot.

This allows oval raceway ceiling extension to run in a straight line from the elbow to location of the nearest outlet. When a *riser* is used for oval flexible cable ceiling extensions, space above *pull box* being open for reasons stated, oval cable ceiling extensions are started directly from box connector inserted in top wall of *pull box*.



FIGS. 5,724 to 5,726.—National fastenings. Fig. 5,724, two hole fastening strap; fig. 5,725, two hole strap; fig. 5,726, wire toggle. The wire toggle is for fastening all sizes of oval armored cable to metal lath or tile. Insert toggle through hole, spread wire around the cable and twist with pliers. Twist wires at one side of cable to keep ends within plaster thickness.

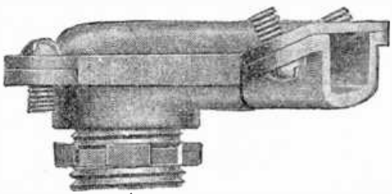
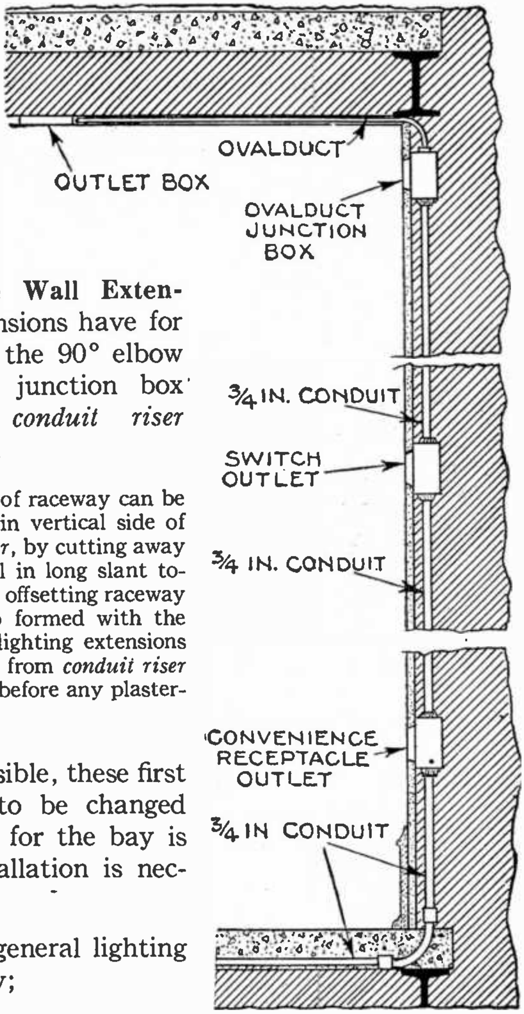


FIG. 5,727.—National 90° angle box connector. Will take oval raceway and elbows into ½ in. conduit knockouts or when used with pipe coupling, connects oval raceway and elbows direct to ½ in. conduit.

NOTE.—*It is recommended* that two *conduit risers* of the same kind as the one described, be installed diagonally from each other, in each bay of the office space under consideration. This avoids crossing oval raceway or oval flexible cable under dropped beams in ceilings, and locates permanent *riser* switch outlets and convenience outlets, so that the minimum number of extensions will have to be made, when partitions required by the tenant layout divide the space. *Conduit risers* should be located at points on walls or columns where dividing partitions are not likely to run vertically up wall with them, as this immediately renders permanent switch outlet and convenience outlet useless, and necessitates installation of extensions which might not have been needed had positions of *risers* been chosen more carefully.



Ceiling and Side Wall Extensions.—Ceiling extensions have for their starting point the 90° elbow fastened in ceiling junction box which terminates *conduit riser* shown in fig. 5,728.

Side wall extension of raceway can be run out of knockout in vertical side of any box of *conduit riser*, by cutting away under plaster material in long slant toward back of box, and offsetting raceway flatwise into angle so formed with the wall surface. Initial lighting extensions are run with raceway from *conduit riser* or *risers* in each bay, before any plastering is done.

Although it is possible, these first outlets may have to be changed when tenant layout for the bay is obtained, their installation is necessary

1. To give some general lighting arrangement for bay;

FIG. 5,728.—Conduit riser or starting point of under plaster wiring extension.

2. To provide lighting for a large space, in case dividing partitions are not required;

3. It is important as means of securing sufficient thickness of plaster over the entire space to conceal the raceway, so that when plaster is channelled in different locations for final

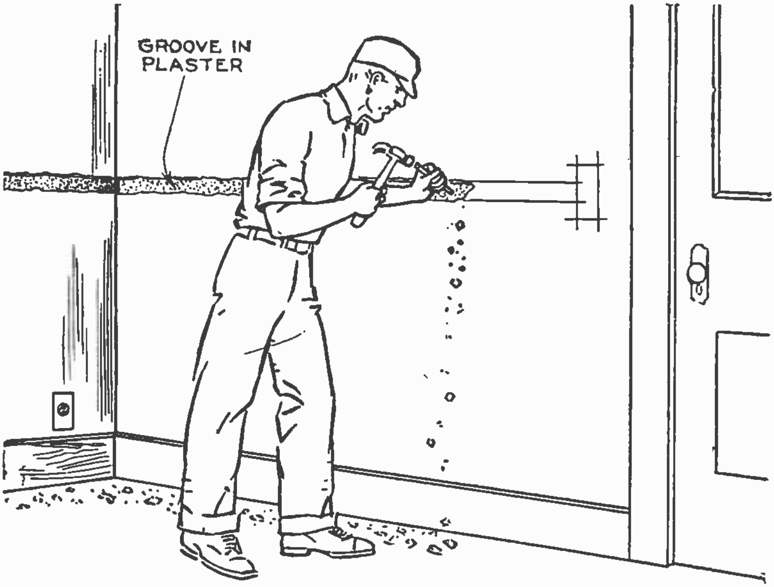


FIG. 5,729.—Method of channeling plaster groove for oval raceway or oval armored cable This operation is performed with a cold chisel and hammer, the channel limit front being marked as seen at the right.

lighting extensions, there will be ample plaster in which to embed the duct.

It should be noted, that when making any raceway or cable extensions, after plastering has been completed, only the plaster need be grooved. After duct has been laid in plaster groove, a little plaster patching is sufficient to cover it and restore original smoothness of ceiling.

For either oval raceway or oval flexible cable extensions, a 90° angle connector may be inserted in box knockout, and the raceway or cable extensions started from it. Two wire oval cable will require a smaller size connector of this type than the one suitable for both oval raceway and three wire oval flexible cable.

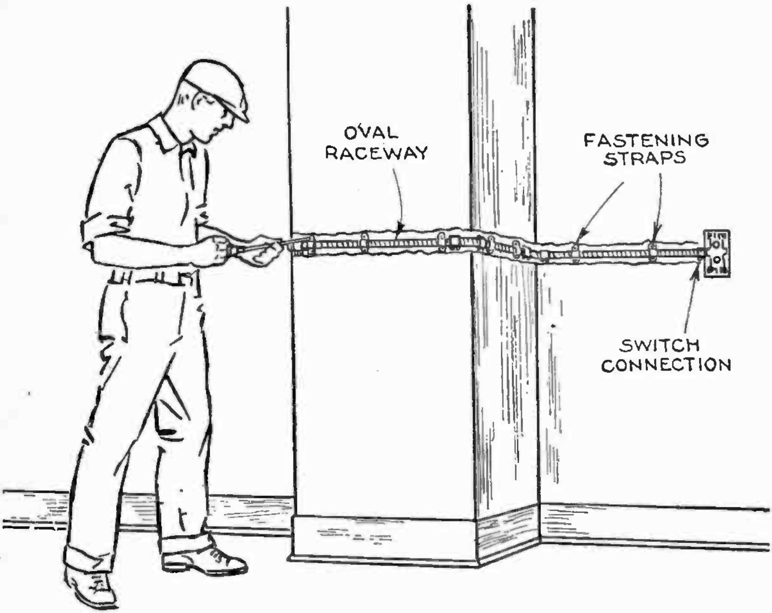


FIG. 5,730.—Method of fastening oval raceway with straps in channel cut in plaster. The illustration shows the end of the raceway joined to a switch box with a connector.

After installing the raceway, a fish cable is used in pulling in the conductors. Fig. 5,732 shows the operation of inserting the fish cable in the raceway and fig. 5,733, detail of fish cable.

Instead of using elbows, turns are frequently made by bending the raceway as shown in fig. 5,734.

If the bending be carefully done, the raceway will not be distorted. While it is possible to bend the raceway flatwise, this requires special tools and equipment, in order to retain proper cross sectional dimensions, hence the practice is not recommended for the field. Because of the complicated method which must be followed, the manufactured flat elbow as shown in fig. 5,718 is generally used for flat bends.

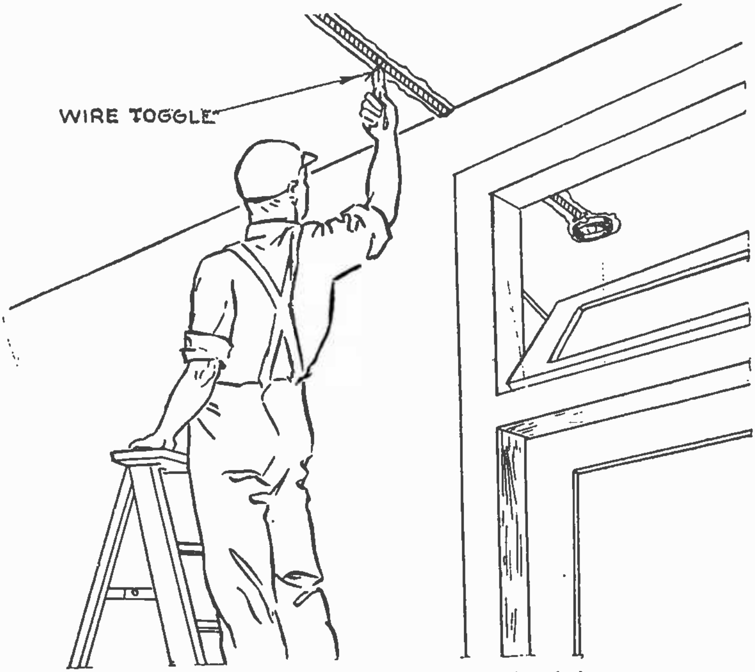


FIG. 5,731.—Method of fastening oval raceway with wire toggle to lath.

NOTE.—*The thickness of plaster* and of lath and plaster in installing under plaster wiring should first be determined. Formerly the thickness of plaster and lath was about 1 inch, but the practice now is to cut the thickness down as much as possible and in some cases of unscrupulous contractors it requires a stretch of the imagination to regard it as plastering. Accordingly, before attempting to install under plaster wiring the thickness of the plaster should be determined. To install under plaster wiring, the plaster is first channeled out from conduit riser outlet to end of the extension. Fig. 5,729 shows this operation. After the channel is completed from the riser outlet box to the end of the extension, the raceway is fastened in the channel with straps as shown in fig. 5,730. For a ceiling extension the raceway is fastened with

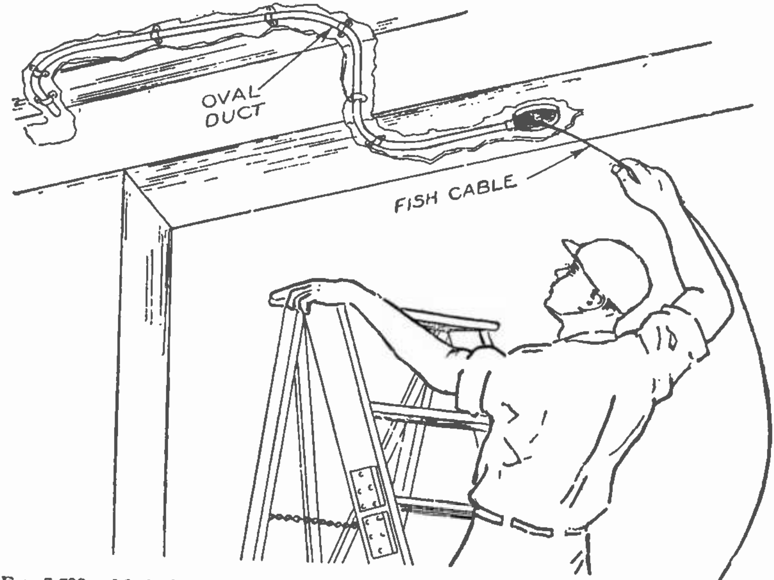


FIG. 5,732.—Method of inserting fish cable in raceway.

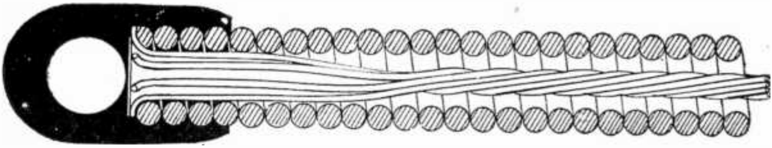


FIG. 5,733.—National fish cable used for pulling in conductors in oval raceway. *It consists of* stranded cable of piano wire enclosed in outside helix of the same material; ends of both stranded cable and outside helix are fastened securely into heads, or eyes at each end. It is tested to 350 lbs. pull. When it is pushed through raceway, wires can be attached to specially shaped head, or eye, at either end, and pulled through raceway, without use of usual cord. This cable is made flexible enough to fish through 5 elbows. Attach conductors directly to end eye of cable.

NOTE.—*Continued.*

a wire toggle as in fig. 5,731. This toggle is shown in detail in fig. 5,726. The extension in fig. 5,731 passes through a partition and is joined at its end to an outlet box, as seen through the transom. This box is ¾ inch deep and its edges should be flush with the surface of the plaster.

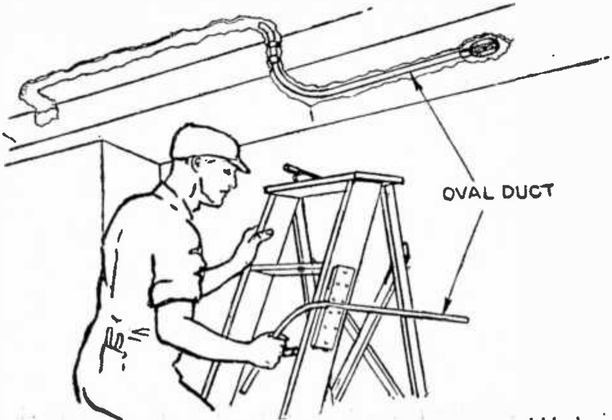


FIG. 5,734.—Method of bending flat raceway edgewise between grooved blocks. Two wood blocks are secured to step ladder or work bench, with grooved ends adjacent, to hold raceway during bending operation. They are mounted with sufficient space between to allow for insertion of raceway from the side, which eliminates awkward operation of sliding raceway lengthwise through groove. After the raceway has been inserted in groove between blocks, it can be bent to any desired radius and degree of angle at any point in the length, by exerting downward pressure on it in short *hitches*.

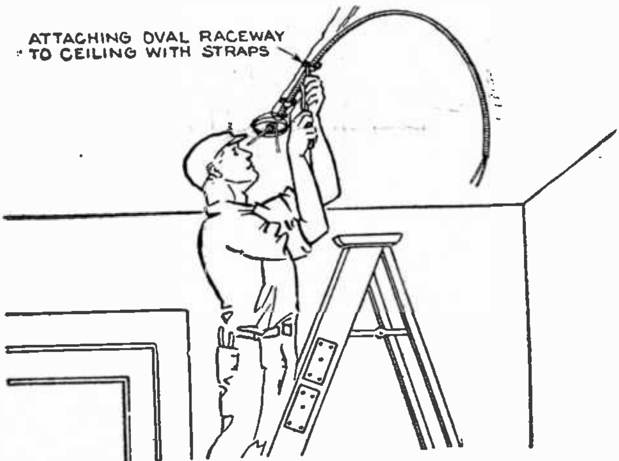


FIG. 5,735.—Method of fastening flat armored cable in plaster groove on concrete ceiling. Note connection of the cable with outlet box.

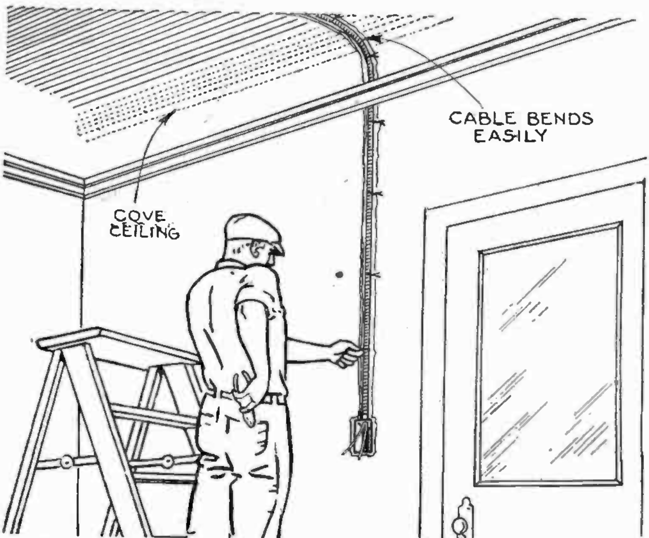


FIG. 5,736.—Oval cable installed on cove ceiling illustrating its flexibility.

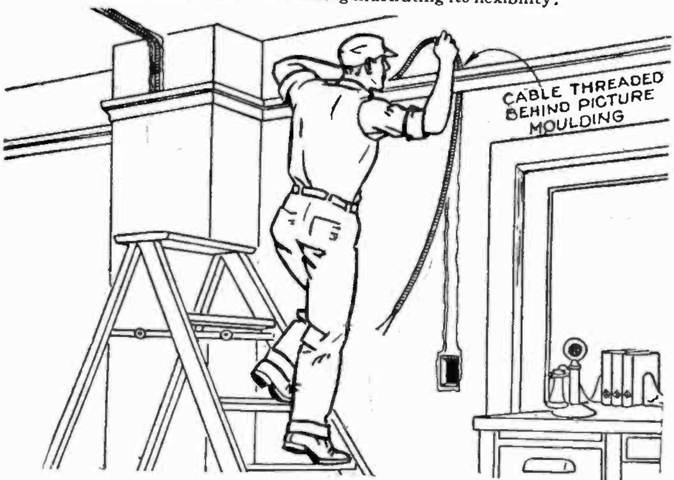


FIG. 5,737.—Oval cable run horizontally behind picture moulding with sharp bends.

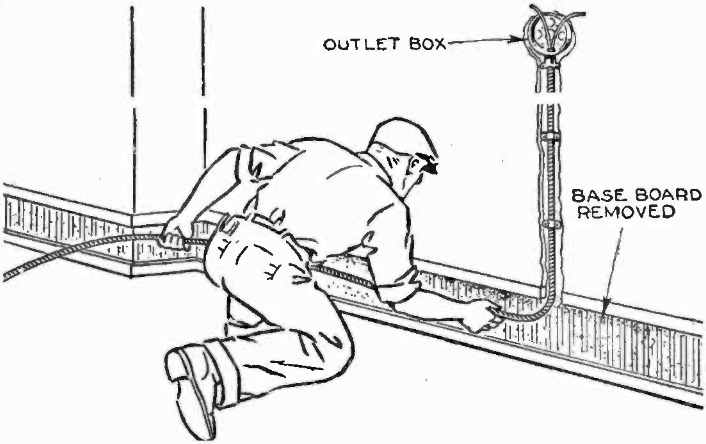


FIG. 5,738.—Oval cable run behind baseboard.

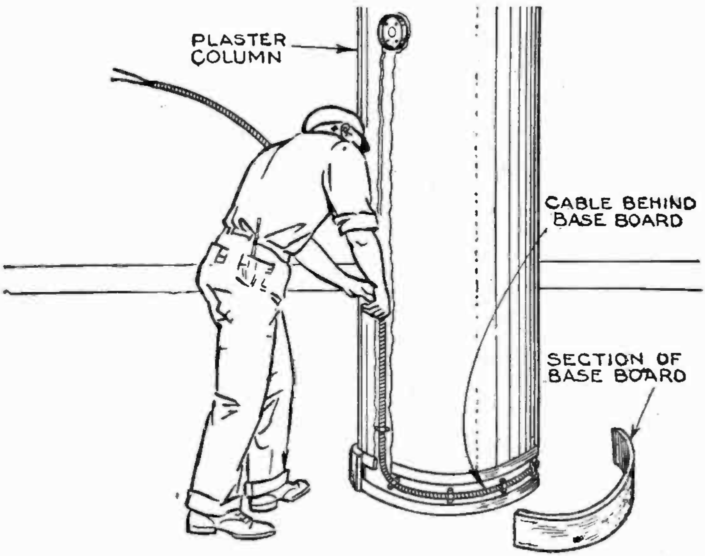


FIG. 5,739.—Oval cable circling round column behind baseboard.

Under Plaster Extensions with Flat Armored Cable.—This flat cable, shown in figs. 5,714 and 5,715 is very flexible and is embedded in plaster in the same manner as described for flat raceways. It renders lighting installations subject to easy change for tenant requirements. Same shallow fittings are used, excepting a few items, and are interchangeable for both wiring materials.

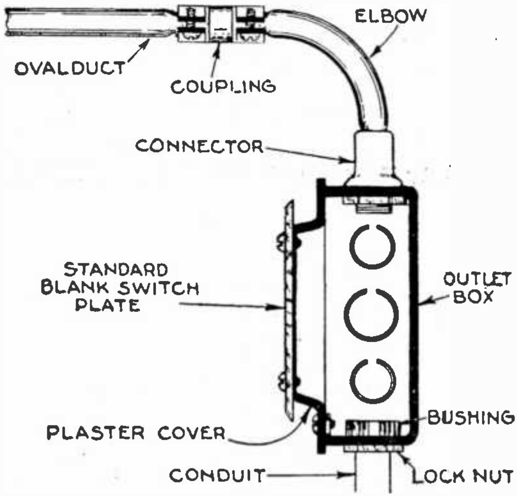
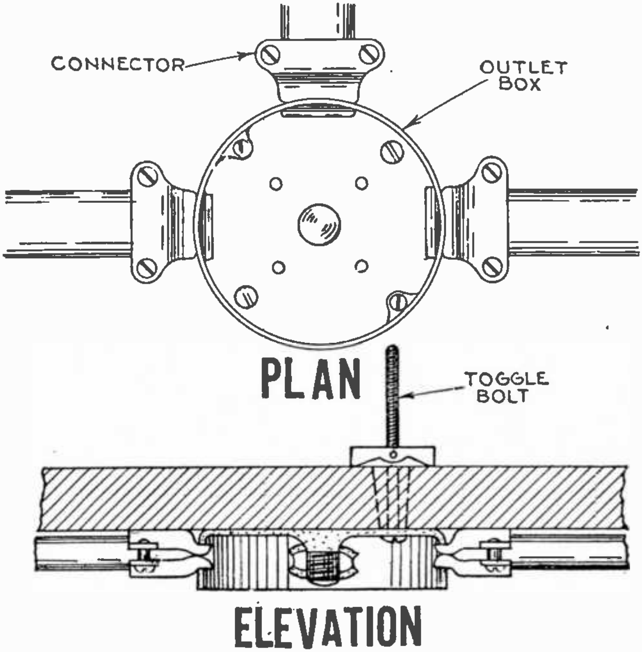


FIG. 5,740.—Outlet box at end of conduit riser, showing connection with oval raceway by means of a connector, elbow and coupling.

In conjunction with *conduit riser* shown in fig. 5,728 ceiling extensions of oval cable in office bay are started from straight or 90° angle connector inserted in top knockout of *riser* ceiling junction box. Side wall extensions of oval cable can be started from side knockouts of any *riser* box by cutting away enough concrete or tile at side of box. to allow room for oval cable to be bent into a straight box connector fastened in a side knock out of box.

Two applications of oval cable are shown in figs. 5,736 and 5,737, which avoids bending or use of fittings as would be necessary with raceway wiring.

In the operations shown in figs. 5,738 and 5,739 it is seen how much time is saved due to the flexible cables. Wire toggles may be used for fastening



FIGS. 5,741 and 5,742.—Connection of extension branch to extension run of raceway with outlet box, also method of fastening the box on tile with toggle bolt.

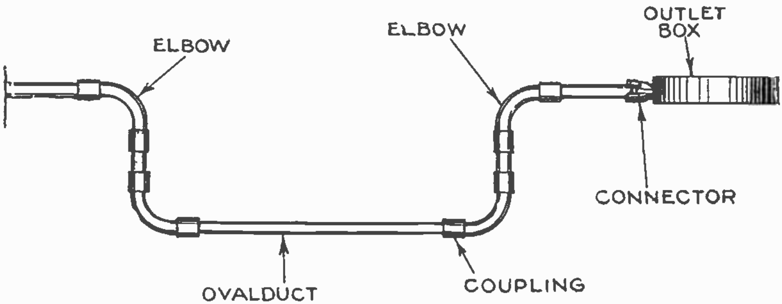
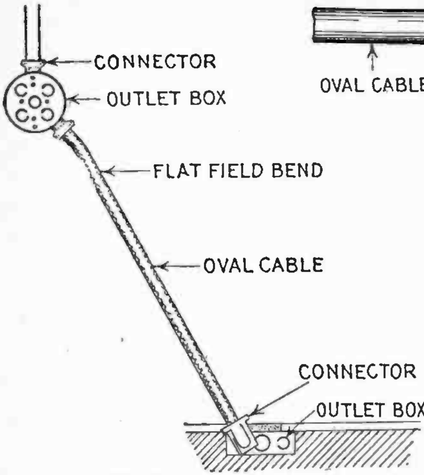


FIG. 5,743.—Offset made in oval raceway by means of fittings.



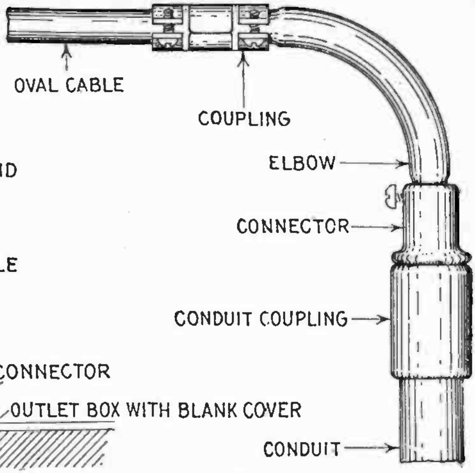


FIG. 5,744.—Two lighting outlets served from the same junction box.
FIG. 5,745.—Oval raceway ceiling extension connected directly to conduit riser.

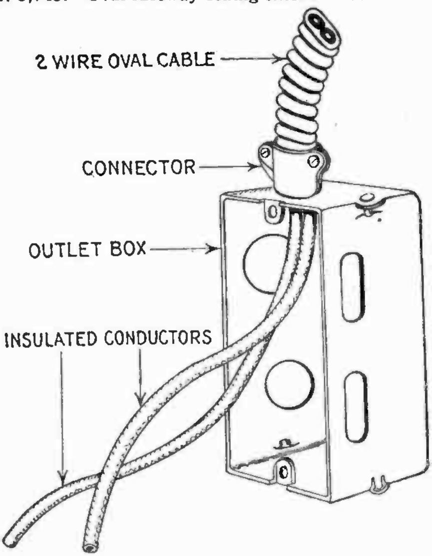


FIG. 5,746.—Oval armored cable switch box installed with switch leg of two wire oval cable.

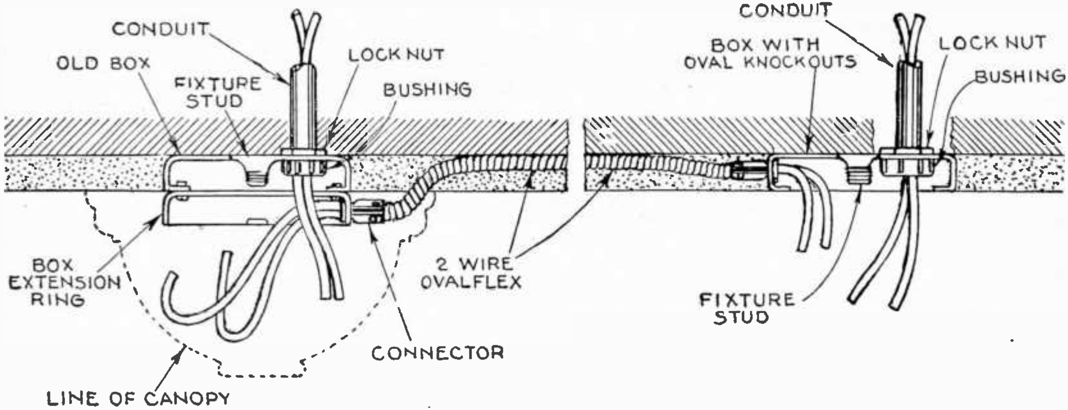


FIG. 5,747.—Oval armored cable extended from an old outlet to serve a new outlet shown at the right of cut. At the left is an extnsion ring mounted on box left in ceiling. This method may be used only when the box is 4 inches in diameter, and the canopy is large enough to cover portion of oval cable projecting out of plaster. To extend oval cable from old outlet box embedded in concrete ceiling, remove the plaster, raise cover, and substitute for it an extension ring when box is 4-inch octagon or round; or substitute a cover having oval knockouts, when box s 4-inch square.

oval cable to tile, wire lath, and under plaster surfaces of similar construction. Straps of one or two screw type with expansion screws or wood plugs, are intended for fastening the cable to under plaster surfaces of concrete or brick. Some contractors prefer to drive case hardened nails into concrete to secure straps, instead of screws and expansion shields.

Code.

510. Underplaster Extensions. (Concealed)

a. Lighting Branch Circuits, Combination Lighting and Appliance Branch Circuits, and Ordinary and Medium-Duty Appliance Branch Circuits may be installed as underplaster or concealed extensions of existing similar branch circuits in buildings of fire resistive construction when the provisions of the following paragrapbs of the section are observed.

Code.—Continued.

b. Such extensions shall be run in rigid or flexible conduit, armored cable, metal moldings, or electrical metallic tubing, of approved standard types. Standard sizes of conduit, cable, molding or tubing shall be used except that for single wires only, conduits or tubing may be not smaller than 5/16 inch. Raceways especially approved for this use may also be employed.

c. Such extensions shall be laid on the face of masonry or other material of which the walls and ceilings are composed and shall then be buried in the plaster finish. They shall not be run outside of the floor or suite in which they originate.

d. The methods of installation for such extensions shall be as given in the appropriate sections of this article for the kind of raceway employed, except that raceways may be used for single conductors even when alternating current is employed.

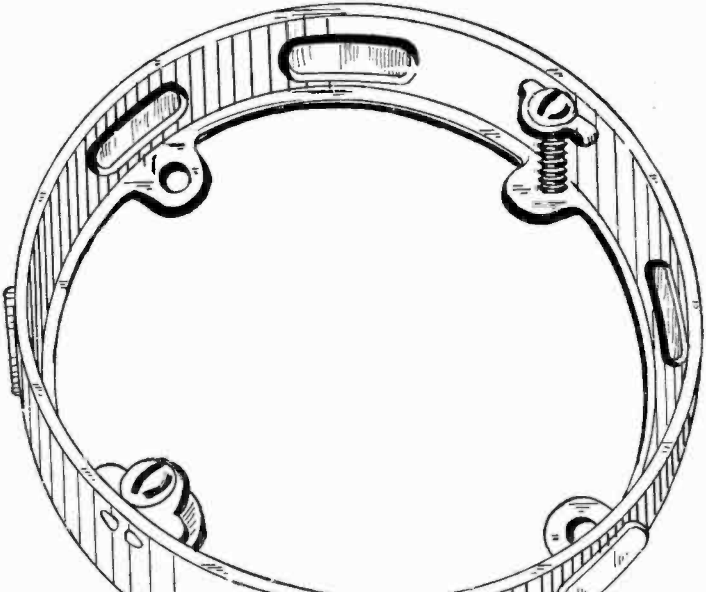


FIG. 5,748.—National extension ring for Ovalduct. 4 in. diameter, ¾ in. deep over all. Six oval knock outs in side spaced at 45°. Will fit any 4 in. octagon or round box and is provided with four fastening lugs to permit turning the ring in line with Ovalduct runs. Cover lugs and screws will take standard 4 in. round covers.

TEST QUESTIONS

1. *What are the Code requirements for wiring under plaster?*
2. *What form of conduit is used for under plaster work?*
3. *What should be used for close bends?*
4. *What kind of fittings are used?*
5. *Describe the squeeze type coupling.*
6. *Describe the kind of outlet box used for oval armored cable.*
7. *Describe a conduit riser.*
8. *What kind of a fitting should be used when riser is used with oval raceway extensions?*
9. *When should two conduit risers be used?*
10. *Give the method of channeling plaster grooves for oval raceway.*
11. *How is the raceway fastened in the groove cut in the plaster?*
12. *Give the method of inserting fish cable in raceway.*
13. *How is flat raceway bent edgewise?*
14. *What is the method of fastening flat armored cable in plaster?*
15. *What kind of fittings are used for under plaster extensions with flat armored cable?*
16. *Describe the method of connecting an outlet box at end of conduit riser.*
17. *What is the method of fastening an outlet box on tile?*
18. *How is an offset made with oval raceway?*
19. *Give sketch showing two lighting outlets connected to the same junction box.*

20. *Make layout showing oval raceway ceiling extension connected direct to conduit riser.*
21. *How is a switch box for oval armored cable installed?*
22. *Make a sketch showing oval cable run behind baseboard.*
23. *How is oval cable run behind picture mouldings when there are sharp bends?*

CHAPTER 119

Grounding

The term grounding as here used is defined as: *the intentional connection of a circuit to the earth for the purpose of insuring safety from shock.*

Thus, if any live conductor be efficiently connected to earth, a person touching the conductor cannot receive a shock, since there is no difference of pressure between the earth on which he is standing and the conductor which he is touching.

The principal reason for grounding a circuit is that of shock.

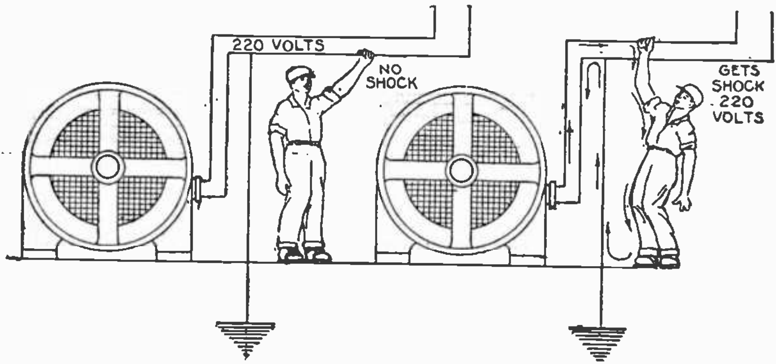
A person touching a circuit at any two points between which there is a difference of pressure, will receive a shock. The danger or severity of shock from touching simultaneously two live wires of a circuit is not affected by grounding the circuit, but the danger of severity of shock from touching simultaneously either wire and the ground does depend upon whether the circuit be grounded or not.

It should be noted that the sensitiveness of different people to shock varies a great deal and that the severity of a shock depends as much on the surface resistance of the skin (whether dry or wet) and on the parts and organs of the body through which the current passes, as on the voltage It is therefore impossible to say that any voltage used in practice is so low that under no condition can it give a dangerous shock. However, considering ordinary conditions and the result of a majority of the shocks, circuits of voltages up to and including 220 volts may be considered as not liable to cause a serious shock, whether grounded or ungrounded, and may be referred to as *low voltage circuits*.

When a circuit is intentionally grounded, the voltage of the grounded point is made permanently that of the earth and the voltage of every other point of the circuit becomes fixed with respect to the ground.

When one conductor is grounded it depends upon which conductor a person touches as to whether he receives a shock, as in figs. 5,749 and 5,750.

The reason he receives no shock in fig. 5,749 is because the connecting of a point on the circuit conductor to the earth, insures that the point, on the conductor, and the earth will always be at (practically) the same voltage. It insures that there can be no voltage between them. Since there can be no



FIGS. 5,749 and 5,750.—Low voltage system with one conductor grounded. If a person touch the grounded wire as in fig. 5,749, he will not receive a shock, but if he touch the other wire he will receive a shock, as in fig. 5,750.

voltage between the grounded point of the circuit conductor and the earth, a person in contact with the earth could touch the grounded point of the conductor without danger of being shocked—without danger of current flowing through him.

Another way of looking at it is to consider that the ground wire, from the conductor to earth, forms a shunt around the person who is touching the conductor and that practically all of the current which flows to ground will flow through the ground wire and practically none through the person.

Danger arises in an ungrounded low voltage circuit when a high voltage wire comes in contact with one of the wires of the low voltage circuit, as in fig. 5,751.

This danger is avoided by grounding one wire of the low voltage curcuit as in fig. 5,752.

In grounding, two kinds of grounds are to be distinguished:

1. Grounding of conductor;

2. Grounding of conduit or other forms of containers for wires.

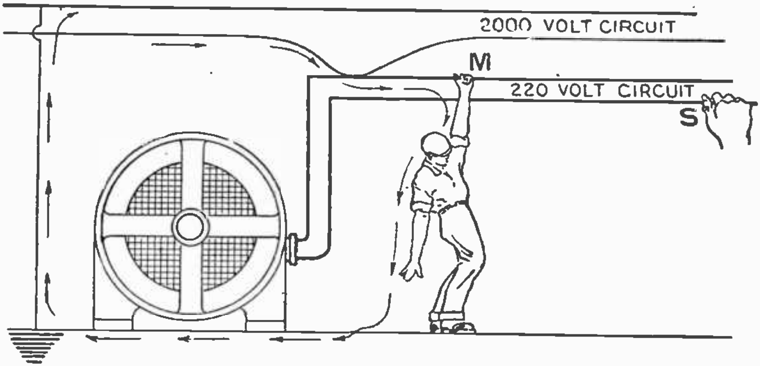


FIG. 5,751.—Ungrounded low voltage circuit in contact with a grounded high voltage circuit. A person gets a 2,000 volt shock if he touch wire M, and a 2,220 volt shock if he touch wire S.

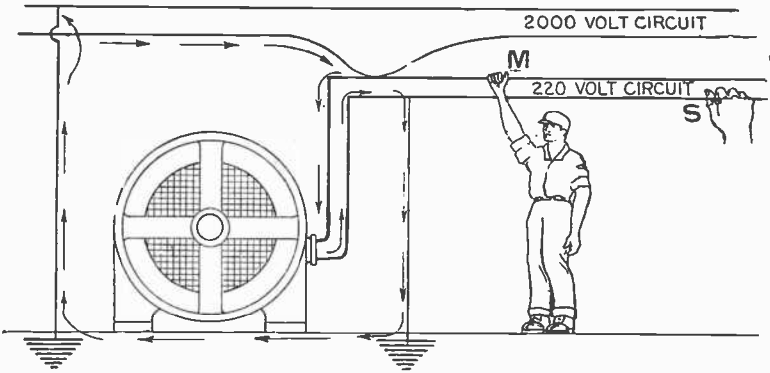


FIG. 5,752.—Grounded low voltage circuit in contact with a grounded high voltage circuit. A person gets a small shock if he touch wire M, and no shock if he touch wire S.

The reason why a conduit should be grounded is because in case of a short between the conduit and one of its wires, and the external circuit come in contact with a wire on a grounded high tension circuit a person touching the conduit would be subject to the high voltage, as indicated in fig. 5,753.

Ground Wire.—This wire is used to connect a circuit conductor, conduit, or other device to an earth plate, water pipe, etc. The ground wire used must not be smaller than No. 10 copper.

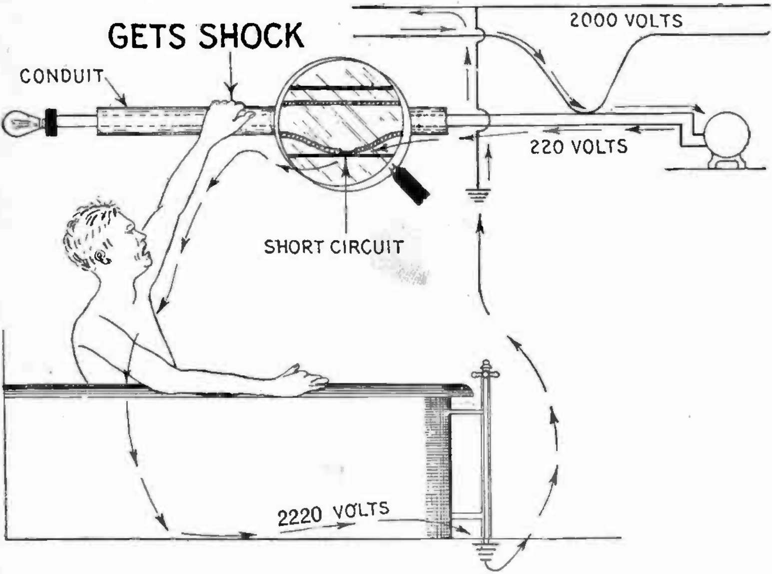


FIG. 5,753.—Diagram illustrating the importance of grounding conduit or external metal covering on lighting circuits.

Larger sizes of wire may be used, and are required for large service installations. The size of wire required for grounding is determined by the ampere capacity of the service wires. This ground wire need not have any insulation, and may be fastened to the building with nails or staples or with cleats or knobs.

One end of the ground should be sweated to a lug and the lug should be bolted to the service switch cabinet. All service switch cabinets are arranged for grounding. The other end should be sweated to a ground clamp. The wire should be run as straight as possible to a water pipe and be fastened to the latter on the street side of the meter. If the distance to a pipe on the street side of the meter be considerable, and a cold water pipe on the house side of the meter be available, the ground wire may be attached to the latter and a copper jumper should then be placed around the meter.

When the neutral wire is grounded, No. 8 copper wire, rubber covered, single braid, must be used, and it should be encased in conduit from the service switch to the ground clamp.

Ground Connection.—Generally a water pipe is selected for a ground connection in house wiring installations. In the absence of which, efficient connection can be made as by means of embedded plates or pipes driven in the ground.

Driven pipes possess many advantages over other methods which have been used, such as buried plates, buried strips, coils of wire, and the various patented ground electrodes commonly advertised.

Chief among the advantages are the low cost of the pipes as compared with the other forms of ground electrodes, and the simplicity of driving a pipe compared with the task of excavating for and installing the buried form of ground electrode. Moreover, the ground area required by a driven pipe is small, a decided advantage in some places where excavation is out of the question because of restricted space or pavements.

Another noteworthy advantage is that the connection between the ground wire and the driven pipe can be made above the surface of the ground, which affords easy inspection and testing, and eliminates the possibility of a defect being obscure, such as a ground wire broken below the ground surface by corrosion or by mechanical thrusts and shifting caused by frost.

An analysis of the electrical resistance to earth formed by the different types of grounds shows that the driven pipe compares very favorably with any of its competitors. It has, also, the outstanding advantage that two or more pipes may be driven and connected in parallel at a cost usually less than that of one of the buried types of grounds, and thus it is possible to obtain a very much lower ground resistance with driven pipes than with the other types for a given cost.

Where permanent moisture is at a considerable depth in the soil, the

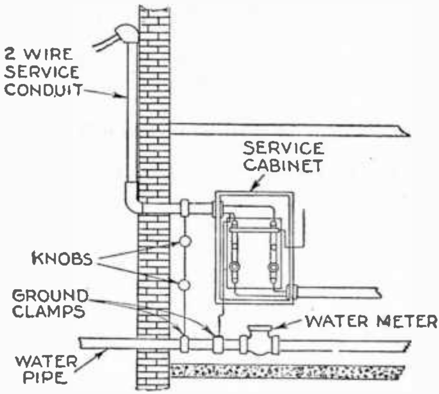
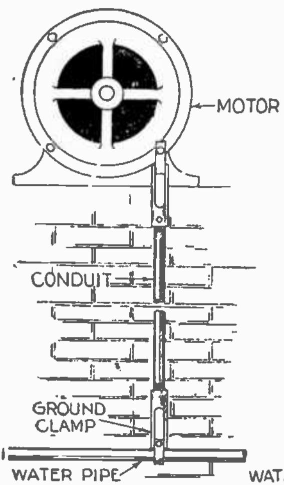


FIG. 5,754.—Method of grounding neutral and service cabinet. Some cities permit grounding to cold water pipes without *jumping* the water meter. Whether or not meters should be jumped depends upon their construction.



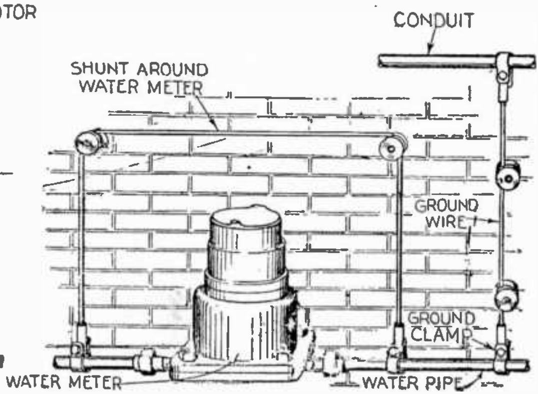


FIG. 5,755.—Method of grounding a motor frame.

FIG. 5,756.—Method of grounding conduit system to water pipe.

driven pipe has an obvious advantage, being capable of reaching depths of twenty feet or more where the soil is of friable texture.

Copper clad steel ground rods have been used in a few cases and in general have the same characteristics as pipe.

They have the additional advantage of resisting corrosion over a somewhat longer period, and they also allow a simple soldered connection to the copper ground wire. Their cost, however, is considerably more than even the extra heavy galvanized pipe for a given diameter.

Apparently there has not been enough experience with the copper clad steel rods in actual service to say definitely whether their extra expense is justified by added life. Considered on the same cost basis as the standard iron pipes, the copper clad rods would be entitled to favor.

NOTE.—*An efficient earth plate* can be made of copper sheet No. 16 gauge, some 2 square m in area, to which the earth connection of, say, No. 0 gauge is soldered across its whole width, and may also, with advantage, be riveted. The plate should be placed in a hole in the ground with some 60 cm. depth of coke or charcoal, crushed to pieces the size of a pea, below it, and with the same amount of coke or charcoal above it. The hole must be of sufficient depth to reach to permanently damp earth, and is filled in after the plate and coke have been placed in position. If no suitable permanently damp earth can be reached, it may be necessary to run a water pipe to the plate in order to keep the surrounding ground moist.

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ARTICLE 9. GROUNDING.

NOTE.—The whole subject of grounding of equipment and appliances in interior wiring systems including methods of grounding by means of auxiliary conductors, what fixed equipment should be grounded and whether portables in domestic establishments need be grounded and if so how, is to be submitted to a general conference during 1928 with a view to a special report to the next meeting of the Electrical Committee—N. F. P. A., and appropriate action for the next edition of this Code.

901. General.

a. Where low-potential circuits, arresters, equipment, conduit, armored cable, metal raceways and the like are grounded as a protective measure, they shall be so arranged that there will be no objectionable passage of current over the grounding conductors. The temporary currents, which are set up under accidental conditions while the grounding conductors are performing their intended functions, are not to be considered as objectionable. Where an objectionable flow of current occurs over a grounding conductor, due to the use of multiple grounds, (1) one or more of such grounds shall be abandoned, or (2) their location shall be changed, or (3) the continuity of the conductor connecting the grounding connections shall be suitably interrupted, or (4) other means shall be taken to limit the current.

b. The grounding connection, including electrode and grounding conductor, shall be permanent and effective and shall always be made on a continuous-metallic underground water piping

Code.—Continued.

system if one is available. The protective grounding of electrical circuits and equipment to water piping systems, when done in accordance with this article, is essential, since such grounding offers the most efficient protection to life and property and it is not injurious to the piping system. In the absence of such a water piping system, a system ground conductor or a secondary neutral grid shall be used if available.

c. Where such a water piping system, a system ground conductor, or a secondary neutral grid is not available the grounding connection shall be made in a manner to secure the most suitable ground and, by one of the following methods:

1. A continuous metallic underground steam piping system;
2. A continuous metallic underground gas piping system;
3. The metal frame of the building;
4. A local metallic underground piping system, metal well casing and the like;
5. An artificial ground whose electrode consists of driven pipe, driven rod, buried plate, or other devices approved for the purpose.

d. Where artificial grounds are used they shall, as far as practicable, be embedded below permanent moisture level. Each electrode shall present not less than 2 square feet of surface to exterior soil. Electrodes of plate copper shall be at least .06 inch in thickness. Electrodes of iron or steel plates shall be at least ¼ inch in thickness. Electrodes of iron or steel pipe shall be galvanized and not less than ¾ inch internal diameter. Electrodes of rods of steel or iron shall be at least ¾ inch minimum cross-section dimension. Approved non-ferrous rods used for electrodes shall be not less than ½ inch in diameter. Driven electrodes of pipe or rods, when of less than standard commercial length, shall preferably be of one piece and shall be driven, except where rock bottom is encountered, to a depth of at least eight feet regardless of size or number of pipes or rods used.

e. The combined resistance of an individual grounding conductor and its connection with the ground shall not exceed 3 ohms for water-pipe or other continuous underground metallic-piping electrodes, nor 25 ohms for artificial grounds. Where resort must be had to artificial grounds the number of electrodes shall be determined as follows: not more than one is required for lightning arresters except where for large current capacity. Not more than one is required for conduit, equipment and other non-current carrying parts. Not more than one is required for grounding low-voltage alternating-current distribution circuits where such ground connection constitutes one of a multiplicity of grounds on the same circuit; but otherwise at least two electrodes shall be provided and shall be at least 6 feet apart and at least 6 feet from other grounding electrodes. The combined area in contact with exterior soil shall be not less than four square feet. If the resistance to ground is in excess of 3 ohms the grounding conductor, except in rural districts, shall be protected and guarded by being enclosed in insulating conduit or moulding to protect persons from injury by coming in contact with it.

It is recommended that ground connections when installed be tested for resistance unless multiple grounding to water piping system is used.

f. Where a system ground conductor or secondary neutral grid is employed it shall be effectively grounded at intervals which will satisfy the requirements as to current-carrying capacity and resistance prescribed in this article.

902. Grounding for Distribution Systems and Interior Wiring.

a. Two-wire direct current systems supplying interior wiring systems and operating at not to exceed 300 volts between wires shall be grounded on one conductor and at the supply station but not at individual services.

It is recommended that 2-wire direct-current systems be grounded if a neutral point can be established and if the maximum difference of potential between

Code.—Continued.

the neutral point and any other point on the circuit does not exceed 300 volts. It is recommended that 2-wire direct-current systems be not grounded if the potential to ground of either conductor would exceed 300 volts after grounding.

b. Three-wire direct-current systems supplying interior wiring systems shall be grounded on the neutral at one or more supply stations but shall not be grounded at individual service entrances.

c. Secondary alternating-current distribution systems supplying interior wiring systems shall be grounded on one conductor if they can be so grounded that the maximum voltage to ground does not exceed 150. Similar systems operating with the voltage to ground exceeding 150 volts may be grounded.

It is recommended that such systems be grounded as provided herein, if the difference of potential exceeds 150 volts, but does not exceed 300 volts.

d. The ground connection for a grounded-secondary alternating-current distribution system shall be made, except as provided below, on every individual service. Additional ground connections may be made on the leads of the transformer or transformers or at one or more points on the system. By permission of the authority enforcing this code (1) any individual ground connection may be omitted provided there are other good ground connections or (2) transformer or system grounding solely may be used.

e. Electric furnace circuits need not be grounded.

f. Where transformers supply a common set of distribution mains, such fuses as are installed shall be so placed as not to leave any portion of the secondary system without ground protection after they have been blown.

g. For alternating-current interior wiring systems the conductor to be grounded shall be as follows:

1. Single-phase, 2-wire; the identified conductor.
2. Single-phase, 3-wire; the identified neutral conductor.
3. Multiphase systems having one wire common to all others; the identified common conductor.

903. Method of Grounding Circuits.

a. Where a grounding connection is made on an interior wiring system, it shall be made on the line side of the service switch, and before the interior wiring system is put in use. It shall always be made upon the identified wire, commonly known as "the white wire."

b. The grounded conductor of an interior wiring system shall be connected from one point only within building to the grounding electrode or electrodes.

904. Grounding for Metal Enclosures, Coverings and Fixed Equipment.

a. Exposed non-current carrying metal parts of fixed equipment, such as the frames and metal exteriors of generators, motors, transformers, controllers, fixed appliances, lighting fixtures, conduit, armor of cable, metal raceways, and the like but not including lined covers of surface type snap switches nor lined shells of standard sockets, shall be grounded and the point of attachment of the grounding conductor for service conduit systems, devices and appliances shall be accessible. The point of attachment of the grounding conductors for conduit, armored cable, metal raceways and the like shall be such that no part is grounded through a run of smaller size.

b. The following exceptions are permitted where the voltage of contained conductors does not exceed 150 to ground, and the contained conductors are on grounded circuits or on circuits unexposed to voltages above 150 to ground, and the installation is not in an industrial establishment, nor in a moist, corrosive, hazardous, or conductive location, the following need not be grounded, but in all cases may be grounded.

Code.—*Continued.*

1. Service runs of conduit, under the further conditions stated in Section 404, paragraph g, of article 4.

2. Runs of less than 25 feet of conduit, armor of cable, metal raceways, etc., when these runs are free from metallic contact with the ground and from adjacent grounded metal and are guarded when within reach from grounded surfaces.

3. Boxes, cabinets, outlet and terminal fittings.

4. Objects exempted from grounding by other rules of this Code.

Conductive Locations are defined as

1. Any room, all or part of which is below normal ground level.

2. Laundries, kitchens, bath rooms.

3. Ground floors of garages, stables and outbuildings with earth or concrete floor.

4. Rooms having floors, walls, or ceilings containing metal lath, metal reinforcement or metal covering.

5. Any particular location so designated by the authority having jurisdiction.

905. Method of Grounding Metal Enclosures, Coverings and Fixed Equipment.

For the purpose of this section, fixed equipment devices and appliances shall include all motors, heaters, ranges, fixtures, pendant sockets and all other similar devices which have a metallic exterior and which are connected to the circuit by permanent wires, i. e., without attachment plugs.

a. Where the service conduit or service cable sheath is grounded, its grounding conductor shall be run from it directly to the ground, no portion of the service switch box, or house conduit being interposed in the grounding circuit. The following exceptions are permitted: Where the service switch box or house conduit is grounded, and is installed in dry, non-corrosive locations, the service switch box may be interposed in the grounding circuit of the service conduit provided that bonding jumpers or ground clamps or logs or devices approved for the purpose are used.

b. Where sections of conduit, armored cable, metal raceways and equipment are grounded they shall be either bonded together and grounded or each section or piece grounded separately.

c. The service conduit, service cable sheath, equipment and the like may use the conductor which grounds the system and its electrode for grounding provided that the system is grounded at two or more locations not in the same building to a continuous metallic underground piping system, otherwise where grounded they shall each have a separate grounding conductor and where artificial grounds are used they shall each have a separate electrode.

d. Metal enclosures and coverings for conductors, and separate grounding wires run in wire assemblies with the circuit conductors, are considered as suitable grounding conductors for protective grounding of fixed equipment, devices and appliances, when installed and used in compliance with the requirements of Article 5 of this Code.

906. Grounding Conductors.

a. The conductor for grounding a copper conductor of an interior wiring system shall be of copper and shall be without joint or splice. The conductor for grounding conduit, equipment and other non-current carrying parts may be of copper, or may be a metal pipe or rigid electric conduit, except that under conditions favorable to corrosion, copper only shall be used.

b. On all service-entrance conduit and where an interior wiring system operates at over 150 volts to ground and pipe, conduit or raceway is used as the grounding conductor for fixed equipment, conduits, raceways and fittings, approved bonding jumpers, or other approved devices shall be used. Such bonding jumpers shall not be required with properly cleaned threaded

Code.—Continued.

joints, made up tight, on pipe, conduit or fittings, nor, except for service conduit, when approved threadless joints made up tight to pipe, conduit or fittings, or when two locknuts are used.

c. No automatic cutout, or switch for interior wiring systems shall be placed in a grounding conductor, unless the opening of the cutout or switch disconnects all sources of energy.

d. The installation of the grounding conductor for systems, when not consisting of or enclosed in metallic piping, and the insulating covering of the conductor shall comply with all requirements of this Code applying to wires of the voltage of the circuit to which the grounding conductor is attached. Where a wire for grounding an interior wiring system is installed in metallic piping and is bonded to it at both ends a bare copper conductor may be used.

e. Approved ground clamps or other approved fittings shall be used and unless approved for general use without protection they shall be protected from ordinary mechanical injury by being placed where they are not liable to be damaged or by being enclosed in metal, wood or equivalent protective covering. Grounding wires smaller than No. 4, within five (5) feet from the floor, shall be protected from ordinary mechanical injury by being enclosed in metal, wood, or equivalent protective covering. Lightning-arrester grounding wires shall be protected by non-magnetic material, unless the grounding conductor is electrically connected to both ends of the protective covering.

f. The path to ground provided by a system grounding conductor shall, in general, have current-carrying capacity sufficient to insure the continuity and continued effectiveness of the path under conditions of excess current caused by accidental grounding of any normally ungrounded conductor of the circuit or the system to which it is electrically connected.

g. The grounding conductor for a direct-current system shall have a current-carrying capacity not less than that of the largest feeder of the same system leaving the station. In no case shall the grounding conductor be smaller than No. 8.

h. The grounding conductor for an alternating-current circuit or system shall have a current-carrying capacity not less than one-fifth that of the conductor to which it is attached. In no case shall the grounding conductor be smaller than No. 8.

i. The grounding conductor for a lightning arrester shall not be connected to an artificial ground electrode which is used for circuits or equipment and the like, but shall be kept at a distance of at least 20 feet where practicable. The grounding conductor shall have a current-carrying capacity sufficient to insure the continuity and continued effectiveness of the path to ground under conditions of excess current caused by or following the discharge of the arrester. No individual grounding conductor shall be smaller than No. 6.

j. For grounding service conduit of size not larger than 1½ inches, the grounding wire shall be not smaller than No. 8; for two-inch conduit the grounding wire shall be not smaller than No. 4; for larger conduits not smaller than No. 2.

k. The size of the wire or the pipe used for grounding interior conduit, armored cable, metal raceway, equipment and the like, shall be not less than that given in the following table:

Capacity of nearest cutout protecting conductor in conduit, armored cable, metal raceway, equipment and the like.	Size of copper wire.	Nominal size of pipe
0 to 30 amperes	Not less than two sizes smaller than that of current-carrying conductors.	½ inch.
31 to 100 amperes	No. 10	½ inch
101 to 200 amperes	No. 6	½ inch
201 to 500 amperes	No. 4	¾ inch
over 500 amperes	No. 2	1 inch

Code.—Continued.

l. For grounding portable or pendant equipment the conductors to which are protected by fuses or circuit-breakers not greater than 15 amperes, No. 18 copper wire may be used. For grounding fixtures No. 14 or larger shall be used except that a smaller wire may be permitted for the grounding conductor of non-metallic sheathed cable. For grounding portable equipment fused for more than 15 amperes, the above table shall be followed.

m. The grounding conductors for circuits, conduit, equipment, and the like shall not be connected to lightning rods.

n. Instruments, meters, or relays which operate with windings or working parts at 300 volts or more to ground shall have the cases and other exposed bare metal parts grounded unless isolated by elevation or protected by suitable insulating barriers or guards, except where inaccessible to other than qualified persons, in which case this requirement is made only when the voltage to ground exceeds 750. Where instruments, meters or relays are operated from current or potential instrument transformers, on circuits of 300 volts or more to ground, having ungrounded secondary circuits and ungrounded primary circuits, the cases and other exposed bare metal parts shall be grounded. The grounding conductor for cases and for secondary circuits of instrument transformers shall be not smaller than No. 12.

For exception, see paragraph g of section 1,302, of article 13 of this Code.

o. Secondaries of current and potential instrument transformers and the cases of instruments connected to such circuits shall, when grounded, have separate grounding conductors, and shall not be connected with a grounding conductor used for other circuits or for conduit, equipment and the like, except where a general ground bus is provided.

907. Grounding Connections.

a. Where a non-conductive protective coating such as paint or enamel is used to protect the equipment, conduit-couplings and fittings, such coating shall be completely removed from threads and other surfaces in order to insure a good contact between ground clamp and equipment. Pipes and rods used as ground electrodes shall have clean metal surfaces, and shall not be covered with paint, enamel, or other poorly conducting materials.

b. At supply stations, grounding conductors for circuits, equipment and lightning arresters shall be permanently and effectively connected to all available active, continuous, metallic underground piping systems between which no appreciable difference of potential normally exists; otherwise to one system only. Elsewhere than at supply stations, the grounding conductor shall be connected to at least one such piping system, if available. (Gas piping shall be avoided wherever practicable, except as provided in paragraph *e* of this section.) Where underground metallic piping systems are not available, other grounds which will provide the desired permanence and conductance may be permitted.

c. The point of connection to the water piping system shall be located on the street side of the water meter or at a water pipe near the equipment to be grounded, in which case the connection with the piping system shall be made continuous and permanent, by bonding all parts of the piping system which are liable to become physically disconnected, such as at meters and service unions, by means of a suitable shunt whose joints, current carrying capacity, and mechanical protection shall be not less than that required for the grounding conductor. Where practicable the point of connection shall be readily accessible.

d. The grounding conductor shall be attached to the pipe or rod (1) by means of an approved bolted clamp to which the conductor is soldered or otherwise connected in an approved manner or (2) by means of a brass plug screwed into the pipe and provided with a lug to receive the conductor or (3) by other approved means.

e. Gas piping systems within buildings connected to continuous-metallic underground exterior systems may be used as a ground electrode but only when water piping is not available. Gas piping, however, may serve as the sole ground for small fixtures located at a considerable distance from water piping. Where gas piping on the house side of the meter is

Code.—*Continued.*

utilized for grounding small fixtures it shall be bonded to the water piping system at their points of entrance. If no water piping is available a bonding jumper around the gas meter shall be used. Where grounding connection is made to gas piping, except for such small fixtures, it shall follow the same requirements as for water piping in paragraph *c*, of this section, except that the connection shall always be made on the street side of the meter. Gas piping need not be insulated from otherwise well-grounded fixtures.

f. Rails or other grounded conductors of electric railway circuits shall not be used as a ground for other than railway lightning arresters and railway equipment, conduit, armored cable, metal raceway and the like, when other effective grounds are available and in no case shall such rails or other grounded conductors of railway circuits be used for grounding electrode for interior wiring systems other than those supplied from the railway circuit itself.

908. Method of Grounding Portable Equipment in Industrial Establishments.

For the purpose of this section an industrial establishment is defined as a building (other than office or exhibit space) where persons are employed in manufacturing processes or material handling as distinguished from dwellings, offices, public utilities and like occupancies.

a. In industrial establishments portable devices, having exposed metal parts, used in industrial operations shall

1. be equipped with a cord containing an additional insulated conductor to be used for grounding purposes only and easily distinguishable from the circuit conductors, or with metal armor such as type CA, PA, etc.;

2. be equipped with non-reversible polarized attachment plug properly fastened to the terminals of the cord;

3. have the grounding conductor (wire or metal armor) connected to the frame or casing of the appliance and to the grounding pole of the plug, and

4. shall have the grounding pole of the receptacle grounded as required in this article.

Appliances to which this rule applies are those which are electrically operated or motor-driven, and are of a portable nature, such as drills, grinders, glue pots, heaters, soldering irons, pumps, air compressors, hammers, conveyors, elevators, hand and stand lamps, and other similar portable hand tools and devices. Exempted are fan motors, pressing irons, and those appliances which are so located as to be ordinarily out of reach, infrequently handled during manufacturing operations or regularly employed in non-conductive locations.

The use of portable devices on circuits operating in excess of 300 volts to ground, is not recommended.

TEST QUESTIONS

1. *Define the term grounding.*
2. *What is the principal reason for grounding a circuit?*
3. *When a conductor is grounded what is the condition for receiving a shock?*
4. *Name two kinds of grounds.*

5. *Why should a conduit be grounded?*
6. *What is a ground wire used for?*
7. *What size of ground wire should be used?*
8. *How should a ground wire be connected?*
9. *What is usually selected for making a ground connection?*
10. *Do driven pipes possess many advantages over other methods for ground?*
11. *What is the chief advantage of a pipe ground?*
12. *Is a large ground area required for a driven pipe?*
13. *Give method of grounding a motor.*
14. *Do copper clad steel ground rods make good ground?*

CHAPTER 120

Power Wiring

Wiring of Motors.—For the proper protection of operators and machines, certain provisions should be made in wiring which are also necessary in order that the installation will conform to the requirements of the Code.

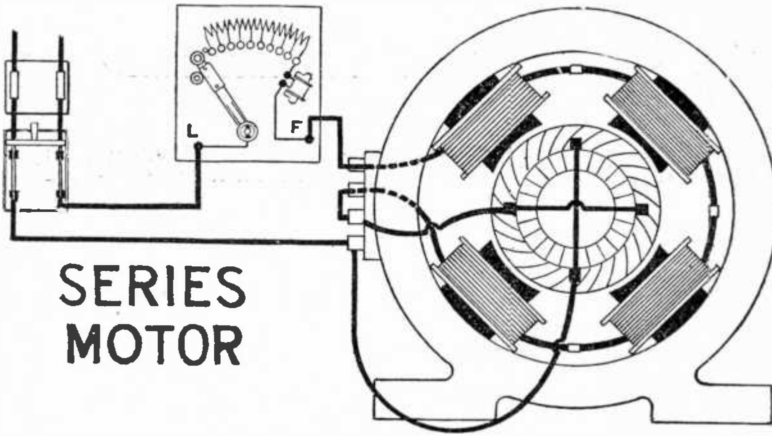


FIG. 5,757.—Wiring diagram of a series motor. There is but one circuit through the starting box, armature and field winding, the armature and field winding being connected in series. Where motors of this type are of 3.5 *h.p.* in size and above, they can generally be determined by inspection, by noting if the machine have only main poles, as shown, and if the field and armature leads be the same size. A test can be made with a lamp and circuit having machine voltage. If the motor be of the series type, the lamp should light up to full brilliancy when connected across either the field or armature terminals excepting in the case of very small machines.

The constantly increasing use of higher and still higher voltages for electrical distribution systems and the tremendous capacity of the present day sources of supply, are creating a persistent demand for more adequate protective grounding circuits and equipment.

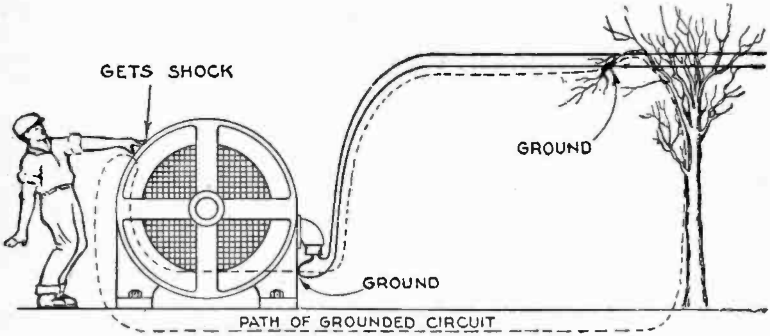


FIG. 5,758.—Operator getting a shock due to ground on machine and line.

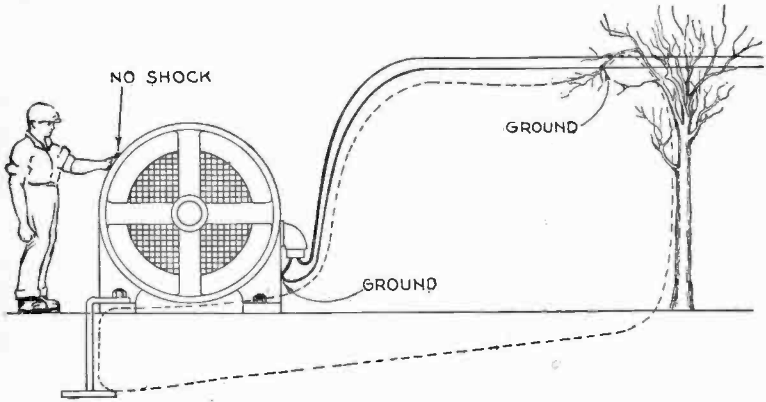


FIG. 5,759.—Motor with grounded frame showing protection to operator.

The improvements most urgently needed are better mechanical protection for the ground wires and their connections and better methods of connecting the ground wires to water pipes and conduits.

Figs. 5,758 and 5,759 show reason for grounding machines and fig. 5,760 necessity for insulation when frame is not grounded.

Motors of ¼ horse power or over should not be installed on lighting circuits.

General Suggestions for Installing Motors.—Make the run

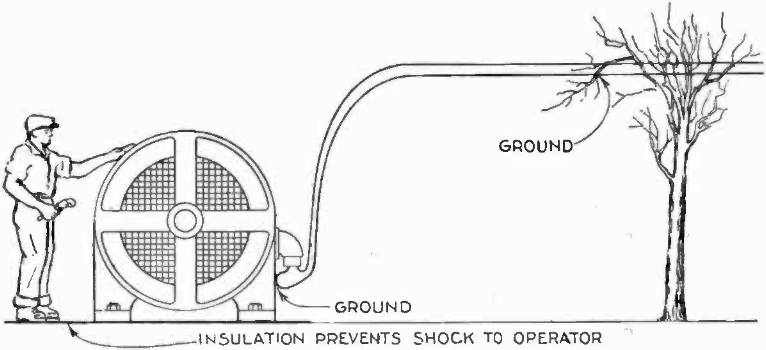


FIG. 5,760.—Motor on insulated floor showing protection to operator.

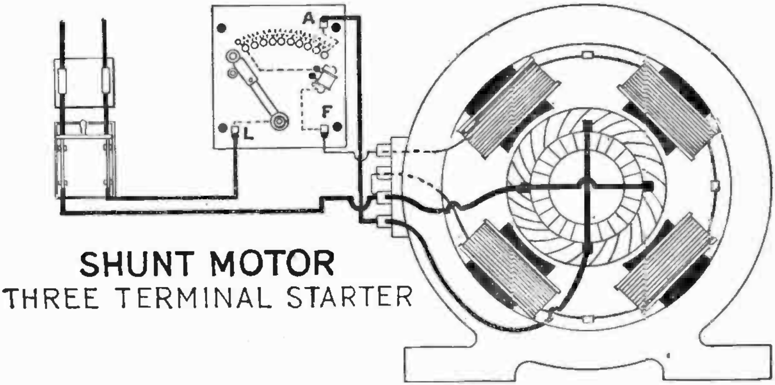


FIG. 5,761.—Wiring diagram of a shunt motor, with a three terminal starter. In this machine there are two circuits: 1, in which the rheostat resistance and armature are connected in series; 2, in which the shunt field is connected in parallel with the armature circuit. Large size wire is used in the armature circuit and small size wire in the field circuit.

from mains or distribution center as short as possible to save materials and to reduce loss of voltage.

Locate starting boxes about 54 ins. from floor to bottom of starter. Conduit should be used to run down walls across floors to motors. If the length of conduit be less than 10 ft. it need not be grounded, but if there be several lengths of conduit and their total length be over 10 ft. it is suggested that they be all bonded together as if they were one continuous piece of conduit.

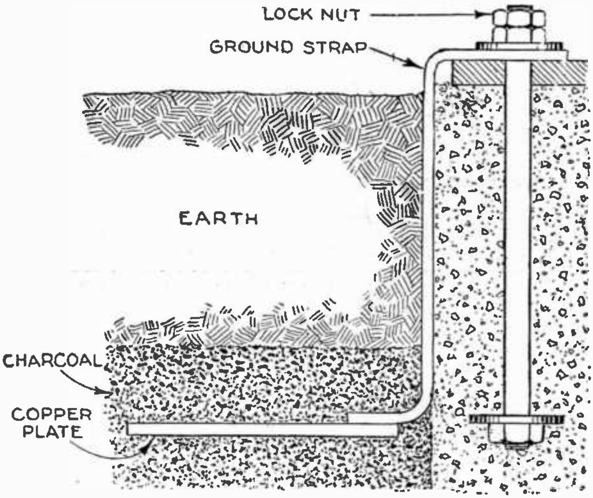


FIG. 5,762.—Ground strap and copper plate embedded in charcoal.

When installing a motor always level the motor, for if motor be not leveled it will make a lot of noise and cause the bearings to wear on one side; also the belt will have a tendency to slip off.

If a motor is to be set on a ceiling of plaster, first secure a couple of planks not less than 2×4, to the joists, by means of lag screws that are screwed in, not hammered in, so that they will be secure. The motor should then be taken apart and assembled. First the base is screwed to the planks, then the frame is secured to the base. One end plate is installed, the armature inserted, then the other end plate is put on. Always make sure that the oil wells are in the proper positions.

The use of flexible metallic conduit is suggested when it is impossible to bend conduit in awkward positions.

The use of special cable connectors at motor outlets is suggested so that in case the motor is to be removed it will be easy to disconnect it.

The use of non-metallic sheathed cable from wall to the motor is not recommended, as it is more desirable to run conduit up to motor terminal block.

Always secure motor to the floor or foundations with lag screws or bolts; never use nails.

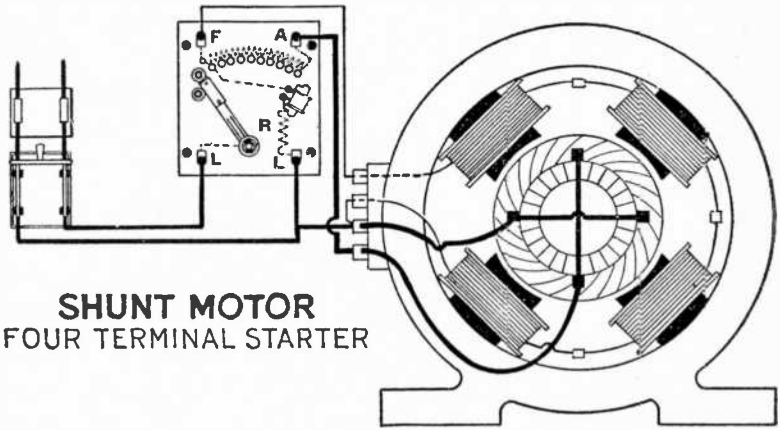


Fig. 5,763.—Wiring diagram of a shunt motor, with a four terminal starter. In the four terminal type of starting box, the holding coil is connected in series with the field and a high resistance, and across the line circuit.

D.C. Motors.—Direct current power systems are always two wire, the three wire never being used except on a combination load of light and power.

Motors of ¼ horse power or over must be started by means of a starting rheostat. This rheostat must be placed on a slate base, marble or asbestos, mounted on a metal cabinet or box with a hinged cover. Also a fused switch must be placed before the starting box to cut off all current entering the box and motor. All switches must be installed in a metal cabinet.

All motors controlled by controllers, self starters, etc., must also have an additional switch to cut off the power supply. This switch is not necessary if an automatic circuit breaker be placed in the circuit before the starting box.

The full load current or the amount of current consumed by the motor while running can be found on the motor name plate or by consulting the table on page 3,059.

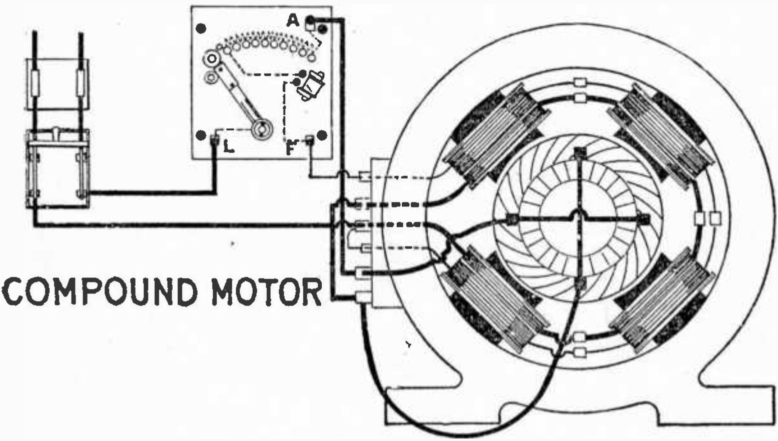


FIG. 5,764.—Wiring diagram of a compound motor. In this motor the series winding is connected up the same as for the series motor, and the shunt winding same as for the shunt motor. The same type starting box is used on both shunt and compound motors.

D.c. motors over ¼ *h.p.* should be connected to 220 volts or over if available.

Small motors under ¼ *h.p.* may operate at 110 volts, but any size above ¼ *h.p.* results in poor efficiency of the motor.

Where the run from power panel or distribution center to motors is of considerable length it is necessary to increase the size of wire in accordance with the drop, otherwise the loss of voltage will reduce the speed and efficiency of the motor.

It is suggested that a main distribution be installed at a central point where the wires enter the building or near the generator. From this point, sub-mains can be run to various sub-feeders, to distribution panels, to feed the various motors.

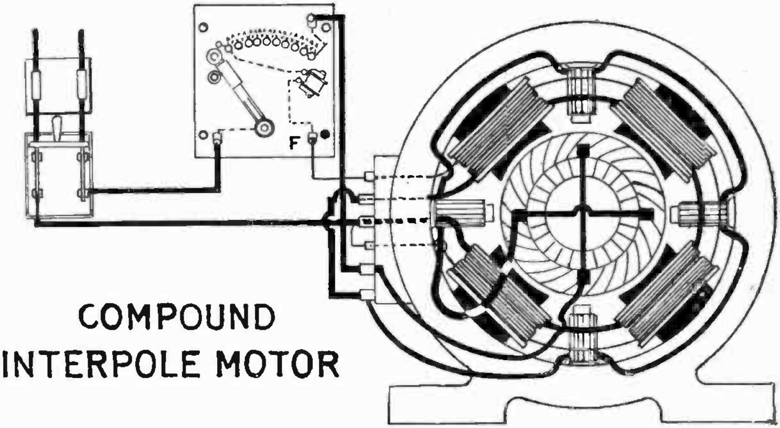


FIG. 5,765.—Wiring diagram of compound interpole motor. A three terminal starter is used, the various connections being plainly shown in the illustration.

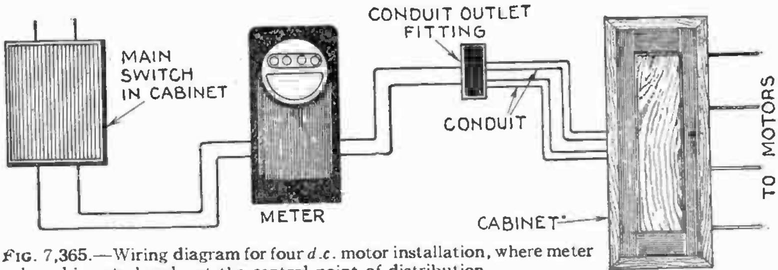


FIG. 7,365.—Wiring diagram for four *d.c.* motor installation, where meter board is not placed at the central point of distribution.

Where the starting box is exposed to flying chips of metal or metal dust, it must be enclosed in a metal box, otherwise the metal will short circuit the resistance wires, resulting in a serious damage to the motor and starting box.

A good suggestion is to place the switch and starter in the same cabinet. This saves an extra box and makes a much neater and compact job.

A.C. Motors.—In figuring wire sizes for one motor *a.c.* installations, the following from the *Code* should be noted:

Where a rubber covered wire carries the current of only one *a.c.* motor of the type requiring large starting currents, it may be protected by a fuse or circuit breaker without time limit device, rated in accordance with table of carrying capacities of weather proof wires on page 3,058.

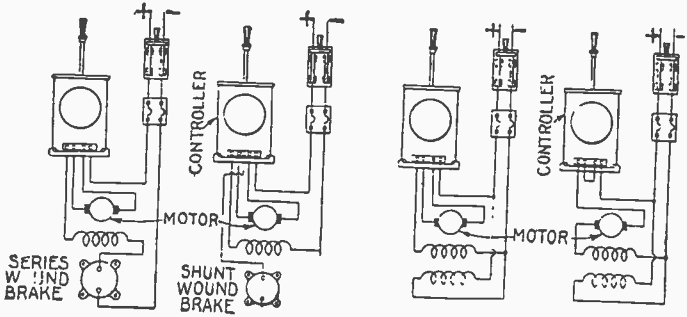


FIG. 5,767.—Diagram showing controller connected to crane series motor and series brake. *In operation,* motor reverses when controller is reversed. Brake is applied with controller in off position and is released on first step of controller.

FIG. 5,768.—Diagram showing controller connected to crane series motor and shunt brake. *In operation,* motor reverses when controller is reversed. Brake is applied with controller in off position and is released on first step of controller. Extra contact rings or flexible conductor required for shunt brake.

FIG. 5,769.—Diagram showing controller connected to crane compound motor, so arranged that motor reverses when controller is reversed.

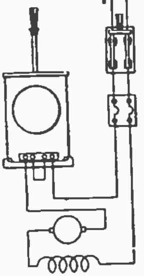
FIG. 5,770.—Diagram showing controller connected to crane compound motor so arranged that motor does not reverse when controller is reversed.

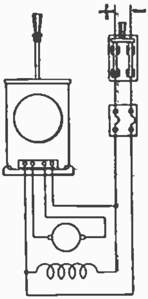
Its rating is higher than the values given in the table for rubber covered wires. The motors referred to above requiring large starting current are: 1, ***single phase, split phase*** types above 5 *h.p.* consume several times as much current in starting as in running; 2, ***two and three phase, squirrel cage*** and ***slip ring*** types also require a large starting current.

The foregoing rule has been adopted so that wires may be fused for a higher rating to allow for the heavy momentary starting current. In this connection it should be noted that the motor while running must be protected with a running fuse rated in accordance with the carrying capacity of the wire.

Wiring for Single Phase Motors.—Nearly all single phase motors of standard manufacture are equipped with winding leads brought out to the terminal block of the motor so that the motor windings may be transposed to a higher or lower voltage.

For instance, a 110-220 volt motor may be run on either voltage by simply transposing connections. The same applies to a 440 volt motor that may be transposed to a 220 volt connection.





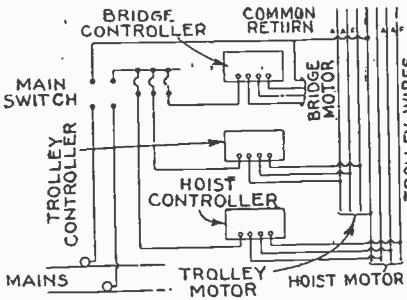


FIG. 5,771.—Diagram showing controller connected to crane series motor so that motor does not reverse when controller is reversed.

FIG. 5,772.—Diagram showing controller connected to crane shunt motor so that motor reverses when controller is reversed.

FIG. 5,773.—Diagram of connections of three motor electric overhead traveling crane.

If both voltages be available, it is suggested that the motor be attached to the higher voltage as the motor will consume approximately half as much current while running, and will also operate at a higher efficiency; another consideration is that it will require a smaller size wire for connecting than if it were used on a lower voltage; also smaller sizes of wire require smaller sizes of conduit.

Single phase motors up to 3 *h.p.* may be started by means of double pole switches; they should be of the knife type, which also must be enclosed in an iron box.

Above 3 *h.p.* motors must be started by means of a resistance starter so that the starting currents will be reduced to a minimum. Also this starter must be equipped with a no-voltage release so that if the current fail while the motor is in operation the no-voltage release will release the handle, a spring causing it to fly back to its original starting position.

Small motors of 3 *h.p.* or more should be protected by means of a no-voltage release circuit breaker that is connected in the mains. This does not apply to elevator motors.

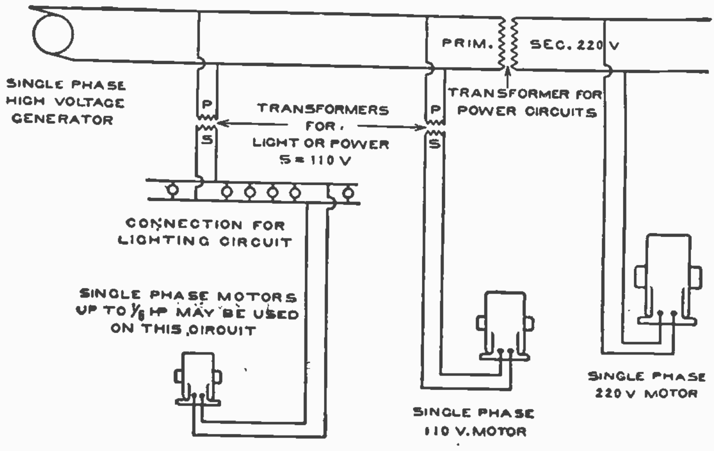


FIG. 5,774.—Wiring diagram showing method of connecting single phase motors on single phase circuit.

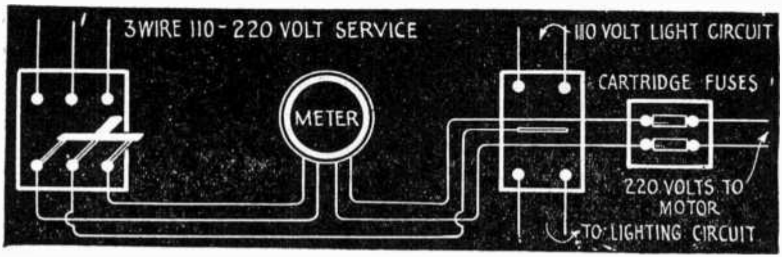


FIG. 5,775—Wiring diagram for a 110-220 volt three wire circuit for light and power.

It should be noted that in installations having only one motor, the main switch at point of entrance must not be used for starting or stopping the motor, but that an independent switch must be placed in an accessible place near the motor to control same.

Split phase and other types of single phase motors may be reversed by shifting brushes or their connections.

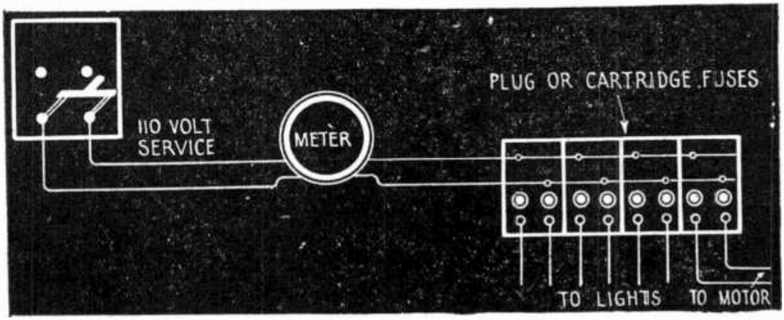
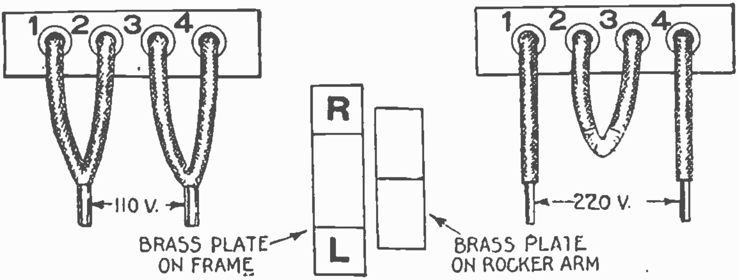


FIG 5,776.—Wiring diagram for motor on a 110 volt lighting circuit.



FIGS. 5,777 to 5,780.—Bell single phase motor terminal block and method of connecting. There are four leads marked 1, 2, 3 and 4 as shown. If motor is to operate on 110 volts, connect leads No. 1 and 2 together, and 3 and 4 together as in fig. 5,777, and then connect to lines. If motor is to operate on 220 volts, connect No. 2 and 3 leads together, and tape them up, and connect No. 1 and 4 to the lines, as in fig. 5,780. ***For right hand operation,*** loosen the screw that holds the rocker-arm that supports the brushes, and turn same so that mark on brass plate on rocker-arm is opposite mark on brass plate on frame marked R, then tighten screw. ***For left hand operation,*** move rocker-arm until mark on brass plate is opposite mark on brass plate on frame marked L. Always start motor at first without belt on pulley, and see that it comes up to speed, and that the short-circuiting device short-circuits the commutator.

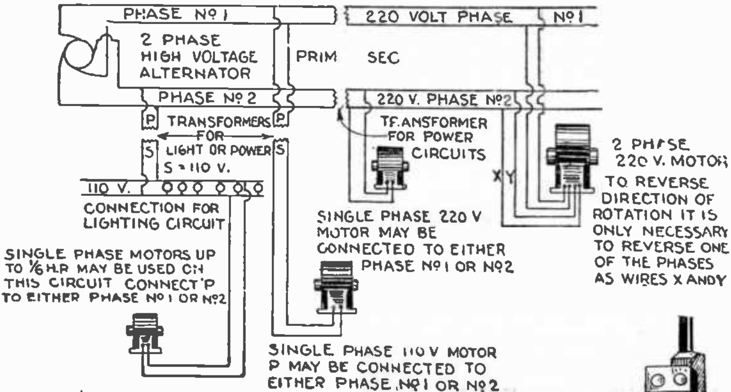


FIG. 5,781.—Wiring diagram showing method of connecting single and two phase motors on *two phase* circuit.

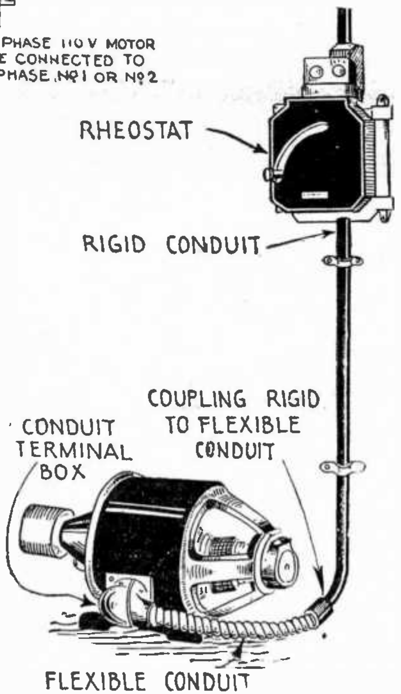


FIG. 5,782.—Method of wiring motor using rigid and flexible conduit between rheostat and motor.

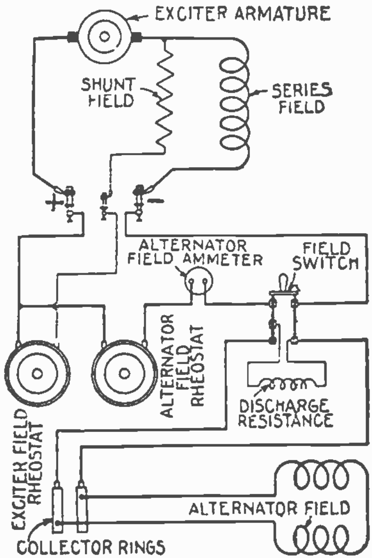


FIG. 5,783.—Connections of a single phase alternator and exciter.

Motors that are started by means of starters or regulators must have a switch to cut off any power entering motor or devices. This switch shall be placed at a point before live wires enter either motor or device.

Where single phase motors are attached to lighting circuits of 110-220 volts service, 3 wire system, the lighting load should be evenly distributed to two or more circuits so that the load shall be equally balanced on both sides of the 3 wire system. The lights being connected to the 110 volt sides while the motor is connected to the 220 volt side, as in fig. 5,775.

For loads of lights and motors, where the service is 2 wire, 110 volt, use diagram fig. 5,776, making a special circuit for motor.

Figs. 5,785 and 5,786 show method of connecting single phase motors to polyphase systems.

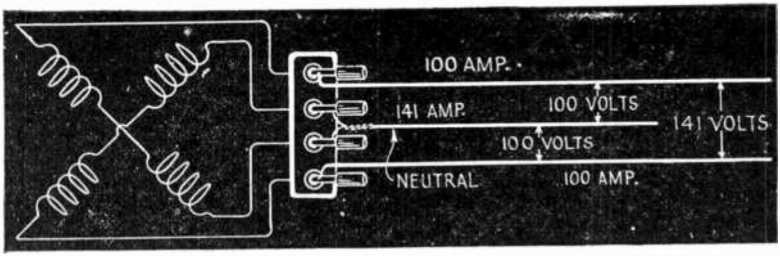
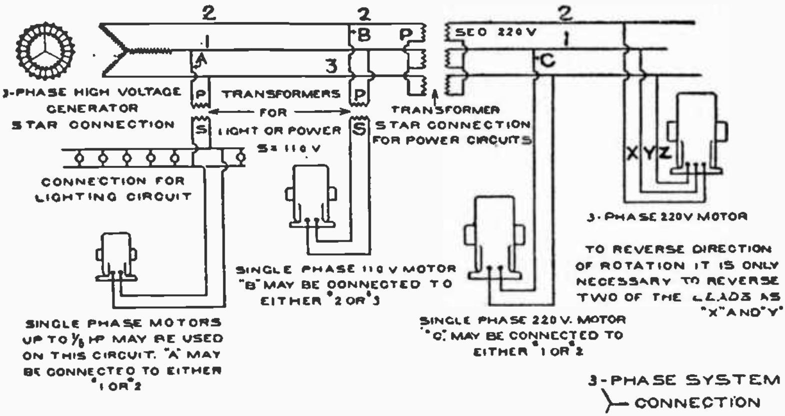


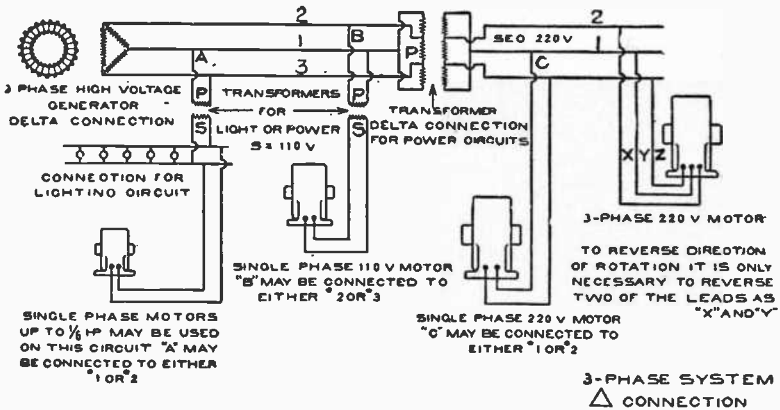
FIG. 5,784.—Two phase three wire alternator terminal connections. ***This system*** is used principally on power loads, where the load is balanced. The central wire of a 2 phase 3 wire system carries 1.41 more current than each of the two outside wires. The voltage across the two outside wires is 1.41 more than the voltage across any of the two outside wires and the neutral wire. Single phase current should never be taken from a three wire two phase system as this will unbalance the line and cause the prime mover to heat up and cause a low power factor.

The rules apply also to the three wire *d.c.* system.

Wiring for Polyphase Motors.—Two and three phase motors



FIGS. 5,785 and 5,786.—Wiring diagrams showing method of connecting single phase and three phase motors on *three phase star connection* circuit.



FIGS. 5,787 and 5,788.—Wiring diagrams showing method of connecting single phase and three phase motors on *three phase delta connection* circuit.

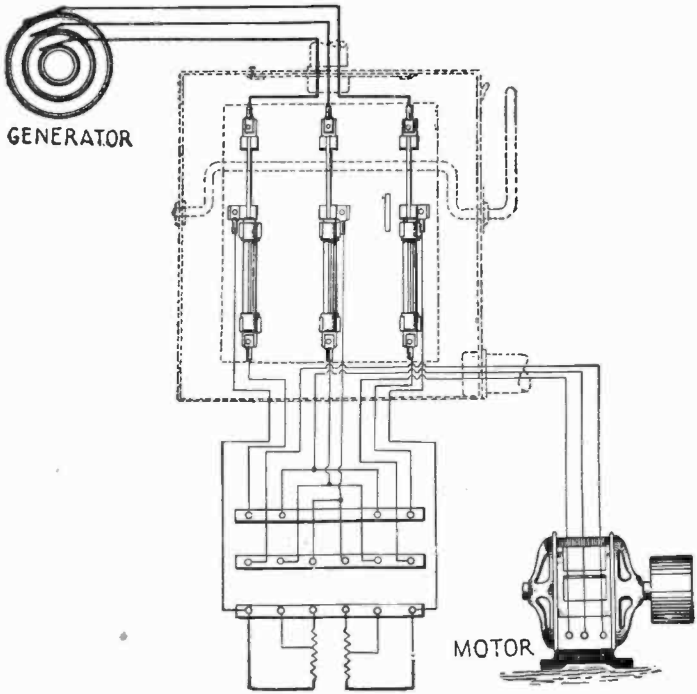


FIG. 5,789.—Diagram showing square D, compensator switch connected ahead of a starting compensator on a three wire two phase system.

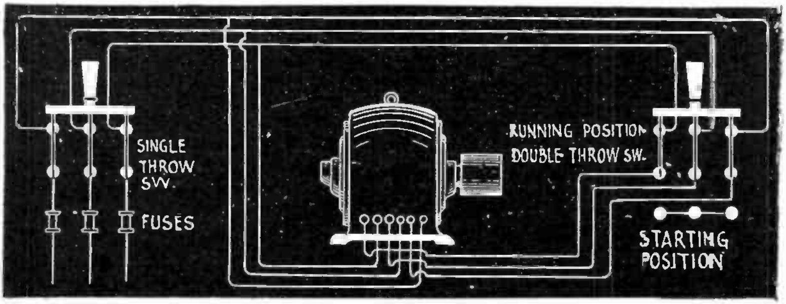


FIG. 5,790.—Diagram of connections for three phase motor YΔ connections.

are practically alike in principle but differ in their windings. The following are the requirements:

Polyphase motors over 7½ *h.p.* must be started by means of a starting compensator.

Motors up to 3 *h.p.* may be thrown directly on the line by means of knife switches; from 3-5 *h.p.* special starting switches must be used.

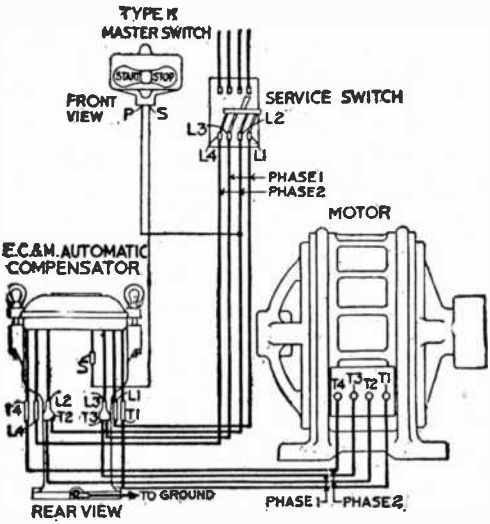


FIG. 5,791.—Connection diagram of two phase no voltage release.

All starters of the knife switch type must be enclosed in metal cabinets.

Running fuses of starting compensators although mounted on compensators must be enclosed in metal cabinets the same as other cabinets.

All frames of compensators must be grounded.

Starting switches of motors of the compensator type must have an additional switch to cut off all current from the motor.

All compensators must be equipped with no voltage release.

Small motors of 3 *h.p.* or more must be protected by a no-voltage release circuit breaker in the mains or each individual motor may be equipped with a no-voltage release.

Transformer Sizes for A.C. Motors.—For the larger motors, the capacity of the transformers in *kw.* should equal the output of the motor in *h.p.* Small motors should be supplied with a somewhat larger transformer capacity, especially if, as is desirable, they be expected to run most of the time near full load, or slight overload. For commercial motors from three

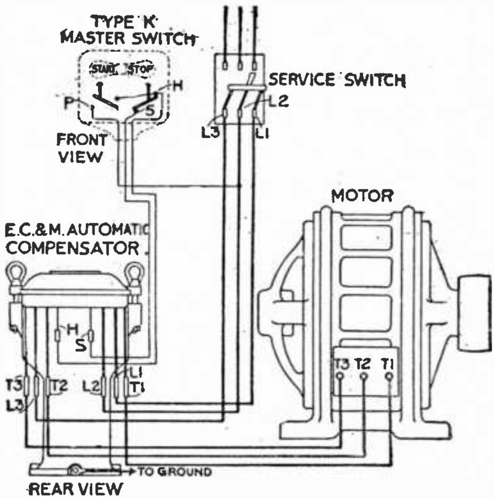
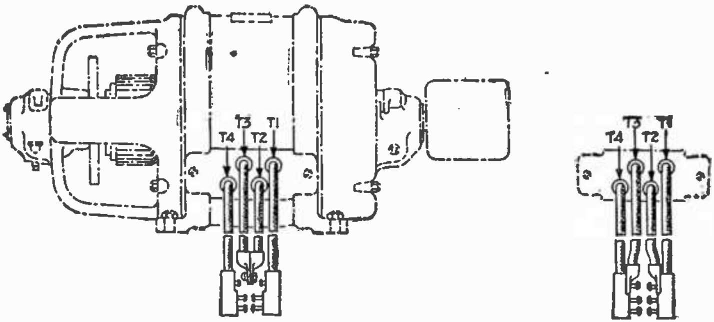


FIG. 5,792.—Connection diagram of three phase no voltage protection.

phase systems, three single phase units or one three phase unit are recommended. The three phase transformer is very compact and the wiring simple, but the advantage of using three single phase transformers is that in case one burn out, the motor may be operated with the other two at reduced speed.



Figs. 5,793 and 5,794.—General Electric single phase, constant speed repulsion induction motor. For standard direction of rotation (220 volts) connect line leads to large terminals T4, and T1, as shown. For 110 volts standard rotation, connect T3, to T4, and T2, to T1. *Clockwise rotation:* To reverse standard rotation, simply shift yoke to reverse running mark; no change of leads is necessary.

Current per Phase in Motor Circuits

H.P.	110 Volts			220 Volts			440 Volts		
	1-ph.	2-ph.	3-ph.	1-ph.	2-ph.	3-ph.	-ph.	2-ph.	3-ph.
1	12.72	5.57	6.43	6 36	2.78	3.22	3 18	1 39	1 61
2	23.80	10.[illegible]0	11.54	11.90	5.05	5.77	5 95	2 52	2.89
3	34 30	14 24	16.44	17.15	7.12	8.22	8.53	3 56	4 11
5	52.30	22.92	26.50	26.15	11.46	13.25	13 67	5 73	6 63
7½	68.75	34.42	39.70	34.37	17.21	19 85	17 19	8 60	9 93
10	90.60	45 30	52.40	45.30	22.65	26.20	22.65	11 32	13 10
15	132.8	66.40	76 80	66.4	33 20	38 40	33 2	16 60	19.20
20	175.2	87.4	101.3	87 6	43 70	50.70	43 8	21 85	25.35
25	219.0	109.6	126 7	109 5	54.8	63 4	54 7	27.4	31.70
30	263.0	131.5	152.0	131.5	65 8	76 0	65 8	32.9	38.0
35	321.0	160.5	185.8	160 5	80 2	92.9	80 0	40 1	46.4
40	350.0	175.0	202.1	175.0	87 5	101.0	87 5	43.7	50.5
45	394.0	197.0	227 6	197.0	98.5	113.8	98 5	49.3	56.9
50	428.0	214.0	247.2	214.0	107.0	123.6	107 0	53.5	61.8
60	513.0	256.5	296.2	256.5	128.2	148.1	128.2	64.1	74.1
70	611.0	306.0	353.0	305.5	153.0	176.5	152 7	76.3	88 3
75	656.0	328 0	379.1	328.0	164.0	189.5	164 0	82 0	94.7

Code.

Article 10. Rotating Machinery and Its Control Apparatus

For special provisions for hazardous locations see Article 32.

1001. General.

a. Machines shall be provided with suitable drip pans if required by the authority enforcing this code.

Code.—*Continued.*

b. Live parts of rotating equipment of more than 150 volts to ground, except slip rings and brush rigging which do not extend beyond the frames of induction motors, shall not be exposed to accidental contact where accessible to unqualified persons. For the purpose of this rule, ungrounded circuits fed from transformers or overhead supply circuits are considered as being more than 150 volts to ground.

c. If terminal blocks are used they shall be composed of approved non-combustible, non-absorptive insulating material, such as slate, marble or porcelain.

d. Where the wiring to fixed motors is accessible to unqualified persons and is in conduit, armored cable, metal raceways or similar construction, terminal enclosures or housings of substantial metal construction shall be provided at the motor terminals. The conduit, armored cable or metal raceways shall be mechanically and electrically connected to the terminal enclosures or housings. The terminal enclosures or housings shall be of ample size to properly make connections.

e. Soft rubber bushings may be used to protect lead wires where they pass through the frame, provided they will not be exposed to oils, grease, oily vapors or other substances having a deleterious effect on rubber. Where so exposed, bushings composed of porcelain, micanite or hard wood treated with a preservative shall be used.

1002. Generators (Other than in Central Stations).

a. Generators shall be located in dry places. They shall not be placed in a room where any hazardous process is carried on, nor where they will be exposed to inflammable gases or flyings of combustible materials.

It is recommended that waterproof covers be provided for use in an emergency.

b. Constant-potential generators, except alternating-current machines and their exciters, shall be protected from excessive currents by automatic circuit-breakers or fuses. Single-pole protection shall be accepted for 2-wire direct-current generators if the protective device is actuated by the entire current generated, except that in the shunt field. The protective device shall not open the shunt field.

c. If a generator not electrically driven supplies a 2-wire grounded system, the protective device shall be so placed as to disconnect the generator from all wires of the circuit.

d. Two-wire, direct-current generators, used in conjunction with balancer sets to obtain neutrals for 3-wire systems, shall be equipped with protective devices which will disconnect the 3-wire systems in the case of excessive unbalancing of voltages.

e. Three-wire, direct-current generators, whether compound of shunt wound, shall be equipped with protective devices, one in each armature lead and so connected as to be actuated by the entire current from the armature. Such protective device shall consist either of a double-pole, double-coil, overload circuit-breaker, or of a 4-pole circuit-breaker connected in the main and equalizer leads and tripped by two overload devices, one in each armature lead. Such protective devices shall be so interlocked that no one pole can be opened without simultaneously disconnecting both leads of the armature from the system.

f. The frame shall be grounded in the manner prescribed in Article 9 if the generator operates at a voltage in excess of 150 volts and is accessible to other than qualified persons. Where the frame is not grounded, it shall be permanently and effectively insulated from ground; and rubber mats or other suitable floor insulation shall be provided for the operator if the voltage to ground exceeds 150.

g. Each generator shall be provided with a name-plate giving the maker's name, the rating in kilowatts, if direct current, or kilovolt-amperes, if alternating current, the normal volts and amperes corresponding to the rating, and the revolutions per minute.

Code.—Continued.

1003. Motors

a. Motors shall not be operated in series-multiple or multiple-series except on constant-potential systems where permission has been granted by the authority enforcing this code.

b. For installation of motors in hazardous and extrahazardous places, see Article 32.

c. Each motor with its controller shall be provided with a separate disconnecting means, except as provided below. The disconnecting means shall be of such design and so installed that when it is in the open position it will disconnect both the controller and the motor from all ungrounded supply wires.

In the following cases a single disconnecting means may serve a group of motors.

(1) Motors which drive the several parts of a single machine of apparatus, such as cranes, hoists, metal and woodworking machines, etc. See Article 30.

(2) Groups of small motors under the protection of one set of automatic overload protective devices, as permitted elsewhere in the Code.

(3) Groups of motors in a single room within sight or the disconnecting means.

(4) Motors which are each controlled by a knife or snap switch alone.

d. For connected loads of 50 H.P. and less, and also where the controller does not open all ungrounded main leads to a motor, a motor-circuit switch shall be used as the disconnecting means except that a plug connector may be used with portable apparatus. For larger loads, where the controller opens all the ungrounded wires and all auxiliary circuits are fused, a disconnecting switch may be used. For a small motor, where permitted by the authority enforcing this code, plug fuses may serve as the disconnecting means. For motors controlled solely by a knife or snap switch, the disconnecting means may be at the distribution center.

By main leads to the motor is meant all armature circuits (not including shunt-field circuits) in the case of D.C. motors, and all primary leads (not including the secondary leads of slip-ring motors or the field leads of synchronous motors) in the case of A.C. motors.

e. The disconnecting means shall be of the indicating type, and in its open position make all ungrounded conductors of the controllers and motor "dead." One pole of the motor controller and one pole of the disconnecting means may be placed in a permanently grounded conductor of circuits supplying current to motor, provided these devices are so designed that the pole in the grounded conductors cannot be opened without opening simultaneously all of the conductors of the circuit. The disconnecting means shall have a continuous duty rating of at least 115% of the name-plate current rating of the motor and be located within sight of the controller or arranged to be locked in the open position.

f. A single-pole switch may be used as controller in an ungrounded wire of a 2-wire motor not larger than ¼ H.P. operating at not more than 300 volts.

g. A motor and its driven machinery shall be within sight of the point where the motor is controlled, unless permission to locate the control point elsewhere is given by the authority enforcing this code. For exception see Article 32.

h. A double-throw switch used to shunt the motor protective device during the starting period shall be of such type that it cannot be left in the starting position.

i. Adjustable-speed motors, if controlled by means of a field regulation, shall be so equipped and connected that they cannot be started under weakened field, unless this safeguard is incorporated in the design of the machine.

j. The control circuits of electrically operated speed-limiting devices and remote-control switches shall be in conduit.

k. Alternating-current motors operating freight or passenger elevators or cranes that are dependent on phase relation for the direction of rotation shall be protected by approved automatic circuit-breakers (or reverse-phase relays) operative in the event of any phase reversal

Code.—*Continued.*

that would cause a reverse motor rotation, or in the event of the motor being connected to the line single-phase.

l. The frame, except for portable motors, shall be grounded unless the motor is inaccessible to other than qualified persons, by reason of guarding or isolation. Where the frame is not grounded, owing to the motor being inaccessible to unqualified persons, it shall be permanently and effectively insulated from ground; and rubber mats, or other suitable floor insulation, shall be provided for the operator if the voltage to ground exceeds 150 volts. The frames of portable motors which operate at more than 150 volts shall be guarded or grounded.

m. Each motor shall be provided with a name plate giving the maker's name, the rating in volts and amperes, including those for the secondary of a slip-ring type motor, the normal full-load speed and the interval during which it can operate, starting cold. The time interval given shall be either 5, 10, 15, 30, 60 or 120 minutes, or continuous.

1004. Control Apparatus.

a. Control apparatus, otber than auto-transformers, shall conform to the requirements of Articles 12 and 17 of this code.

b. The control apparatus shall have a continuous-duty rating of not less than 115% of the name-plate current rating of the motor.

1005. Auto-Transformer Starters

a. Auto-transformer starters shall have no exposed live parts unless in suitable separate enclosures.

b. Cases for coils or switches shall afford access to the interior for inspection and oil renewal, and shall be so constructed that when mounted on a plane surface the case will make contact with such surface only at points of support. An air space of at least ¼ inch shall be maintained between case and surface.

c. The oil tank shall be marked in a suitable manner to indicate the proper oil level. When such device carries a visual oil indicator, the marking shall be for the proper oil level with the starter assembled. If the visual indicator is not used, markings shall indicate the oil level prior to assembling.

d. The switch shall provide an off position, a running position and at least one starting position. It shall be so designed that it cannot rest in a starting position, or in any position which will render inoperative the overload protective devices in the circuit.

e. Cases for coils and switches of auto-transformer starters shall be grounded as required in sections 904 and 905 of Article 9 of this code.

TEST QUESTIONS

1. *In wiring motors, what provision is urgently needed for ground wires?*
2. *Should motors of* ¼ h.p. *or over be installed on lighting circuits?*
3. *Give a wiring diagram for series motor and for a shunt motor.*
4. *How should starting boxes be located?*

5. *Make sketch showing ground connection for motor.*
6. *What should be used at motor outlet?*
7. *Give wiring diagram of compound motor.*
8. *How must* d.c. *motors of over* ¼ h.p. *be started?*
9. *How should a rheostat be mounted?*
10. *What must be provided for motors controlled by controllers, self-starters, etc.?*
11. *When is a cut out switch not necessary?*
12. *What should be done where the motor is at considerable distance from the power panel?*
13. *Draw wiring diagram for a four* d.c. *motor installation, where meter board is not placed at the central point of distribution.*
14. *What are the Code requirements for wire sizes for* a.c. *motors?*
15. *How are the leads arranged on single phase motors?*
16. *What type of double pole switch should be used for starting single phase motors?*
17. *Draw a diagram showing method of connecting single phase motors on single phase circuit.*
18. *How are single phase motors connected on two phase circuit?*
19. *Draw diagram showing two phase three wire alternator terminal connections.*
20. *How do two and three phase motors differ?*
21. *How should polyphase motors of over* 7½ h.p. *be started?*
22. *Can motors up to* 3 h.p. *be thrown directly on the line?*
23. *Draw connection diagram showing three phase motor wiring with no voltage protection.*

CHAPTER 121

Overhead Systems

There are various kinds of transmission lines in which the wires are suspended overhead on poles, towers or other methods of support. They are known as overhead systems and may be classed

1. With respect to the voltage, as

    a. Low voltage.
    b. Medium voltage.
    c. High voltage (high tension).

2. With respect to length of line, as

    a. Short lines.
    b. Lines of moderate length.
    c. Long distance.

3. With respect to service, as

    a. Telephone.
    b. Telegraph.
    c. Light.
    d. Power,
    etc.

4. With respect to the current, as

a. Direct current { two wire / three wire

b. Alternating current { single phase / two phase / three phase

5. With respect to the method of support, as

a. Pole line.

b. Transmission tower.

c. Catenary.

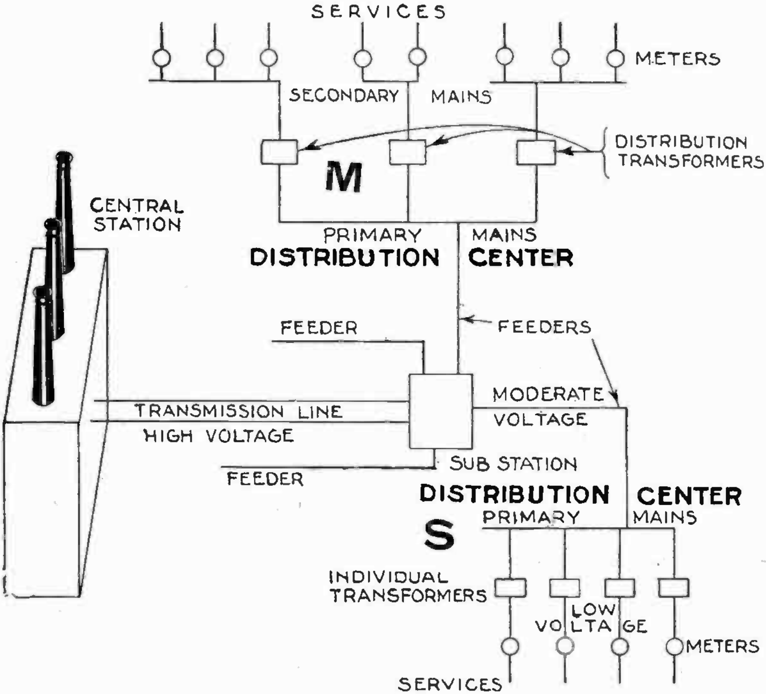


FIG. 5,795.—Diagram of a typical overhead transmission and distribution system.

6. With respect to the circuit, as

   a. Metallic.
   b. Ground return.

A typical overhead system for light and power consists of

1. Transmission line;
2. Feeders;
3. Primary mains;
4. Secondary mains.

Fig. 5,795 shows the elements of such a system.

Starting at the central station, the alternators of moderate voltage produce the current. This voltage is for lines of moderate or long distance stepped up by transformers in the central station in amount depending upon the length of the transmission line.

The voltages ordinarily used for transmission lines are as given in the following table:

Transmission Line Voltages

Length of Line	Voltages
1 to 3 miles	550 or 2,200 volts
3 " 5 "	2,200 " 6,600 "
5 " 10 "	6,600 " 13,200 "
10 " 15 "	13,200 " 22,000 "
15 " 20 "	22,000 " 33,000 "
20 " 30 "	33,000 " 44,000 "
30 " 50 "	44,000 " 66,000 "
50 " 75 "	66,000 " 88,000 "
75 " 100 "	88,000 " 110,000 "
100 " 150 "	110,000 " 132,000 "
150 " 250 "	132,000 " 154,000 "
250 " 350 "	154,000 " 220,000 "

The amount and cost of power to be transmitted is an important factor in determining the economic transmission voltage.

For average conditions isolated from existing transmission lines the voltages shown in the table have been quite generally used. For exceptional cases, exceptional values will be used.

Example: If 40,000 *kva*. be transmitted 20 miles, 66,000 volts or higher might be used. On the other hand, if a very small amount of power be transmitted, lower voltages would probably be selected.

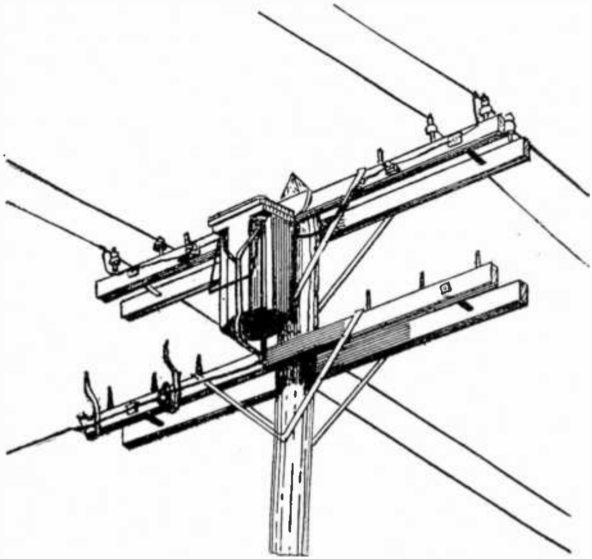


FIG. 5,796.—One 2,300 volt transformer on line.

At the sub-station the current coming in over the transmission line at high voltage is "stepped down" by transformers

*NOTE.—The use of 187,000 volts is likely to occur only in case it be found necessary to have a voltage between 154,000 and 220,000 volts.

to a pressure suitable for the feeders. According to H. B. Gear, a rule of thumb allowance is *about* 1,000 *volts per mile length of transmission.**

This gives a conductor too small for short lines transmitting considerable power. Accordingly for short lines, a somewhat higher voltage should be selected.

The feeders lead from the sub-station to the distribution centers, each distribution center having a separate feeder and no branch circuit should be tapped to the feeders between the sub-station and the distribution center.

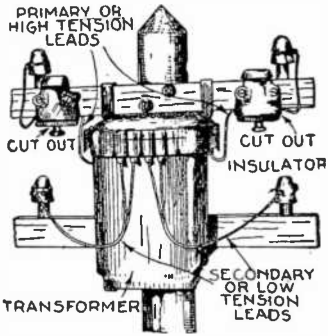


FIG. 5,797.—Installation of a transformer on pole; view showing method of attachment and disposition of the primary and secondary leads, cut outs, etc.

The object of this is to prevent undue drop along the feeders. The voltage at the distribution center should be maintained constant for all loads and this is usually accomplished by means of feeder voltage regulators located at the sub-station and fully described in Chapter 79.

Each feeder, terminating at a distribution center, is connected to the primary mains.

*NOTE.—*The above rule* is based on the fact that with copper conductors a pressure of 1,000 volts *per* mile, and a current density of 1 amp. per 1,000 *cir. mils*, the energy loss will be about 10 per cent.

Along the primary mains, conductors are tapped at various points. In fig. 5,795, the feeder **M**, is tapped at several points, each line connecting with a distribution transformer which reduces the pressure for the secondary mains. Each distribution transformer serves several customers as shown. A slightly different scheme is used for distribution center **S**. Here individual transformers are used for each service. The distributors and individual transformers step down the voltage from usually 2,300 volts to 115 or 230 volts.

The foregoing general description of a simple overhead systen is intended to illustrate transmission and distribution principles. Of course in practice an infinite variety of hook-ups can be used to meet the varied conditions to be met with. The object in view, in the selection of any particular system, is to transmit the current from the central station to the customer in the most efficient manner and with the least expense.

TEST QUESTIONS

1. *Give classification of overhead systems.*
2. *Draw a diagram of a typical overhead transmission and distribution system.*
3. *Give transmission line voltages for lines ranging from 1 mile to 350 miles.*
4. *What are the functions of a sub-station?*
5. *What is a rule of thumb allowance for voltage per mile of transmission line?*

CHAPTER 122

Pole Line Materials

For lines of low and moderate voltage, poles are used to support the conductors. To meet the varied conditions several types of poles are used. They may be classed, with respect to materials, as

1. Wooden;
2. Steel;
3. Concrete.

Wooden poles are the ones mostly used.

In tropical countries, however, such as India, Central America, etc., where wood is rapidly destroyed by the ravages of white ants and other insects, steel poles are almost exclusively used for telegraph, telephone, and other electric transmission lines.

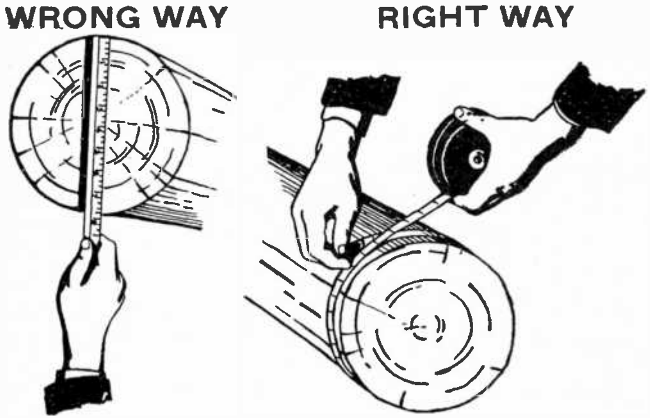
Wooden Poles.—The properties required in these poles are strength, comparative lightness in weight, durability, straightness, a gradual and well defined taper and an abundant and accessible supply.

These requisite properties, especially that of durability, restrict the number of species which can be used for poles, and about 80 per cent of the poles used in the United States are cut from two classes of timber. These two classes are chestnut and cedar, and of the two approximately five times as much cedar as chestnut is used.

According to wire capacity, poles are divided into several classes, as

Class A.—Poles to be used in lines carrying or ultimately to carry forty wires.

Class B.—Poles to be used in lines carrying or ultimately to carry from twenty-one to forty wires.



FIGS. 5,798 and 5,799.—Right and wrong way to measure tops or butts. The terms 5 in. top, 20 ft.; 7 in. top, 30 ft. are used to designate the size of poles, but the diameter measurement is not a correct means of determining the size of a top, because the tops are not exact circles. Instead, the size of a top or butt is determined by the circumference measurement on all poles 15 ft. and longer.

Class C.—Poles to be used in lines carrying or ultimately to carry from thirteen to twenty wires.

Class D.—Poles to be used in lines carrying or ultimately to carry from seven to twelve wires.

Class E.—Poles to be used in lines carrying or ultimately to carry from three to six wires.

Class F & G.—Poles to be used in lines of two wires, the wires being carried on brackets.

The following table gives standard specifications for Western red cedar "class" poles according to N. E. L. A. and American Tel. & Tel. Co.

Minimum Dimensions of Pole—Circumference in Inches

Length of Pole in Feet	CLASS A Top	CLASS A 6-ft from Butt	CLASS B Top	CLASS B 6-ft. from Butt	CLASS C Top	CLASS C 6-ft. from Butt	CLASS D Top	CLASS E Top	CLASS F Top	CLASS G Top
20	24	33	22	29	18¾	27	18½	15½	15½	12½
22	24	34	22	30	18¾	28½	18½	15½	15½	12½
25	24	36	22	32	18¾	30	18¾	17¼	15½	12½
30	24	40	22	36	18¾	33	18¾	18¾	18¾	
35	24	43	22	38	18¾	36	18¾	18¾	18¾	
40	24	47	22	43	18¾	40	18¾	18¾	18¾	
45	24	50	22	47	18¾	43	22	22	18¾	
50	24	53	22	50	18¾	46	22	22	18¾	
55	24	56	22	53	18¾	49	22	22	18¾	
60	24	59	22	56					18¾	

Pole Preparation.—In the production of poles it is necessary that they pass through various stages of preparation, such as:

1. Cutting;
2. Peeling;
3. Seasoning.

Poles should be cut in winter, because at this time of the year wood destroying insects and fungi are least active and drying is slow, which is advantageous.

The object of peeling is to facilitate drying or seasoning, and when the poles are to be treated with preservative, it is absolutely necessary in order to secure penetration of the liquid. The poles should be peeled immediately after cutting.

When a tree is cut, it immediately begins to lose water.

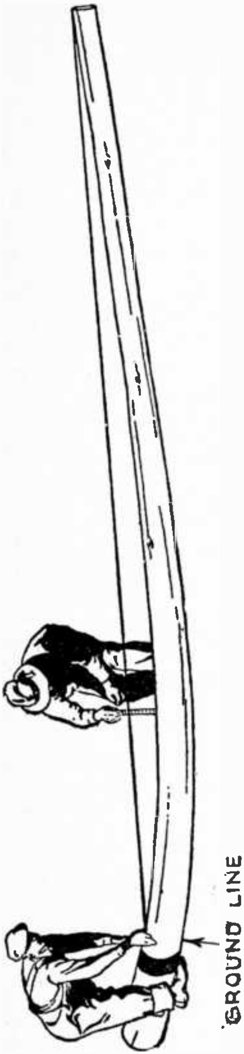


FIG. 5,800.—Method of measuring sweep. *To measure* the amount of sweep in a pole, a tape is stretched tight from the top to a point six ft. from the butt end. A rule can then be used to determine the amount of sweep at the greatest distance between the pole and tape.

This loss of water is termed *seasoning*, and is accompanied by other changes in the wood, such as oxidation of the wood substances and fixation of inorganic and organic compounds.

As moisture is an essential factor in the development of fungous growth, the proper drying of a pole prevents injury from decay. The strength of a pole is increased by seasoning, and as the weight of the pole is decreased, the shipping charges on it are reduced.

During the seasoning process water leaves the cell cavities and if continued sufficiently, the cell walls.

Other changes occurring are the splitting or checking of the cell walls and the rupturing of the bordered pits.

All these changes increase the air spaces in the wood and facilitate the entrance of preservative liquids.

The most common method of seasoning poles is to pile them in the open air.

Wood Preservation.—There are several processes which may be successfully employed for the preservation of poles or other exposed timber. The best known of these are the creosoting, burnettizing, kyanizing, carbolizing, and vulcanizing processes.

The method of treatment employed by some large pole concerns is as follows: The butt ends of the poles are first immersed to the proper depth in heated creosote, ranging in temperature from 212° to 230° F. These temperatures while allowing a suitable range above the boiling point of water, keep to a minimum the amount of volatilization of the lighter toxic constituents of the preservative which would otherwise be lost in the atmosphere. The heat of the preservative being conducted into the timber, expands the air within the cells and vaporizes moisture or sap which might be present.

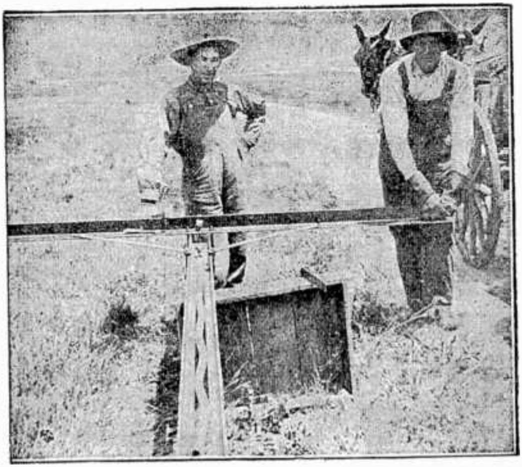


FIG. 5,801.—*Erecting Bates steel pole 1.* Attaching an angle iron cross arm.

In the heat treatment, the vapor formed by the expanding of the air within the cells is forced from the timber and escapes. After the timber is heated for a minimum of four hours, the hot preservative is withdrawn and cold preservative introduced into the tanks. This change of temperature causes a contraction of the expanded air in the cells of the wood, which in turn forms a vacuum, drawing the surrounding preservative well into the timber.

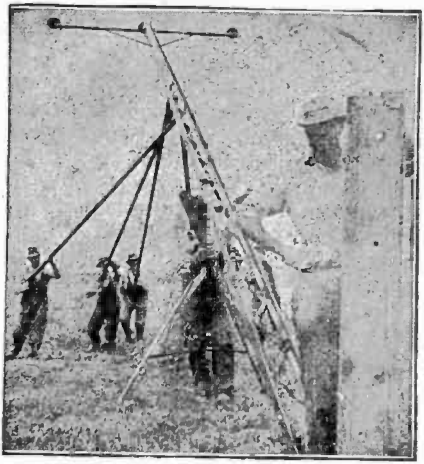


FIG. 5,802.—*Erecting Bates steel pole 2.* Raising the pole by the use of pike poles.

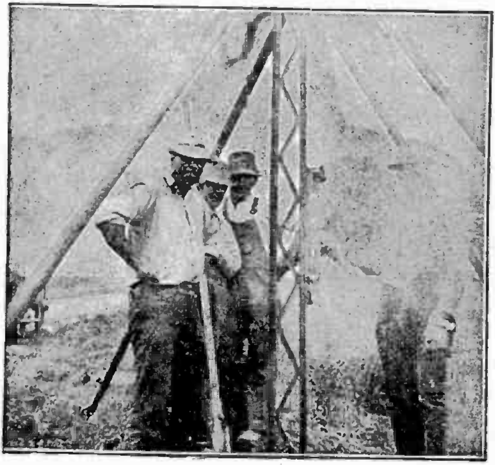


FIG. 5,803.—*Erecting Bates steel pole 3.* A one piece single pole held plumb by temporary stays while the concrete foundation is constructed.

Steel Poles.—On account of the increasing cost of wood and the relatively short life of wooden poles, steel poles are extensively used. The various types may be classed as:

1. Tubular;
2. Structural;
3. Expanded.

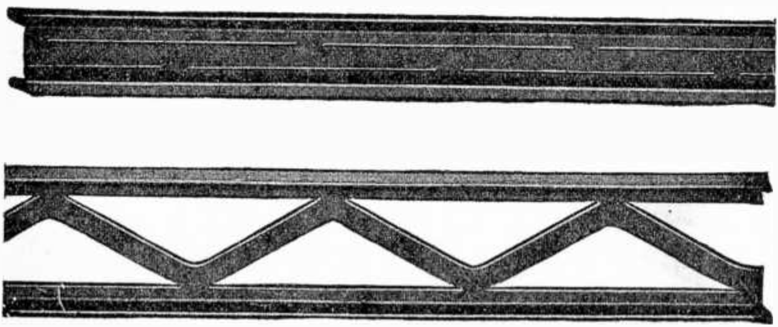
Tubular poles consist of sections of steel pipe of varying diameter with the largest diameter at the butt. One end is expanded wider than the other and is used as the base of the pole.

Latticed steel poles are made by a large number of manufacturers, this being a type of construction in universal use. The design and adaptation are so diversified that no detail can be given.

FIG. 5,804.—*Erecting Bates steel pole 1.* Pole as erected showing foundation, also a method of climbing by means of Bates pole climbers.

When using this type of pole, as in using other types of pole, it is a matter of calculating the loads which are to be placed upon the structure, necessary clearances and factors of safety, and from this the structure itself can be chosen from standard types or designed by any competent structural engineer.

The expanded type is made from an I-beam by cutting and

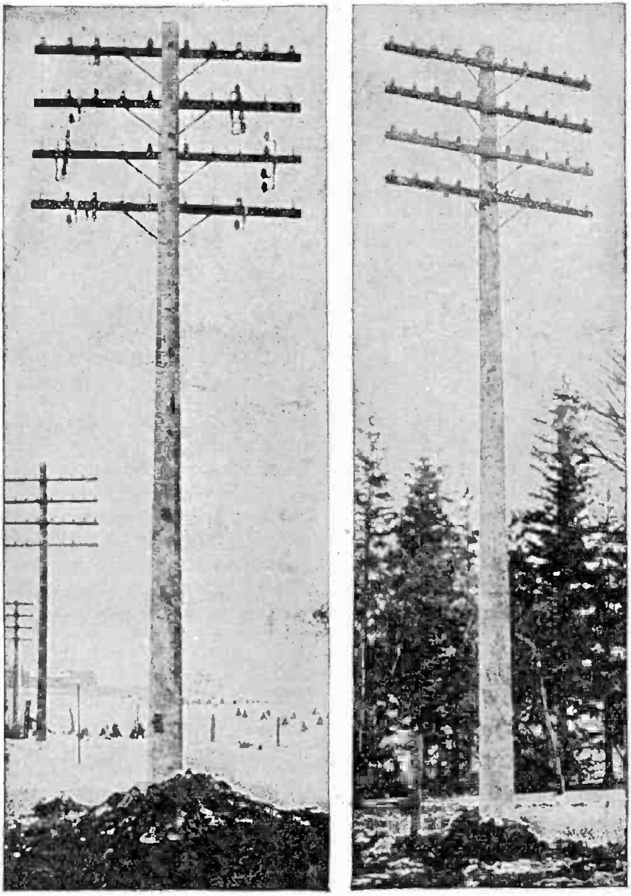


FIGS. 5,805 and 5,806.—Method of making Bates expanded steel truss pole. The pole is manufactured from rolled "H" sections designed for poles. The section is first sheared through the web by a rotary shear, leaving intact portions at fixed intervals throughout the length of the section, as in fig. 5,805. The section is then heated to a cherry red color, and is then charged into an expanding machine, which automatically grips the flanges throughout their entire length and expands the section to the desired dimension while hot. Expanding the sheared web causes the middle portion of the web to take the zigzag form, as in fig. 5,806, and thus creates a series of triangles in alignment and produces a strong, one piece steel truss.

expanding the web, making what is termed an "expanded steel truss pole."

Figs. 5,805 and 5,806 illustrate the manufacture of this type pole.

Concrete Poles.—These poles are very durable and will outlast any wooden poles. While wood has been most widely used, on account of its low first cost, concrete possesses advantages which are being given increasing attention where long life, greater strength and increasing safety factors must be considered.



Figs. 5,807 and 5,808.—Westinghouse hollow concrete poles in telephone service. These poles are suitable for telegraph, trolley and transmission.

Among these advantages is the fact that a carefully worked out design can be commercially produced with unvarying certainty, thus insuring a fixed safety factor. Furthermore, the growing scarcity of timber is leading progressive companies to install experimental lines of concrete poles, so that they may have an opportunity to study this type of construction first hand before economic factors force them to adopt concrete for all their lines.

So far as is known, reinforced concrete poles are not subject to the ordinary action of the elements. Water tends to harden concrete and does not affect the reinforcing steel, since it is entirely embedded and therefore inaccessible to it and the air.

There are two general types of concrete poles:

1. Solid;
2. Hollow.

The solid type is made in a trough form and is reinforced by steel rods running lengthwise.

In the manufacture of hollow concrete poles, the reinforcing steel, after being accurately computed for the particular class of pole to be made, is held rigidly in the place it was designed to occupy, so that the actual tests of strength check the design very closely. The complete reinforcing cage is then placed in a horizontal form and held at the desired distance from the surface of the form by concrete buttons which become part of the finished wall of the pole. Concrete is added and the entire form rotated at high speed developing centrifugal force sufficient to compact the concrete into a very dense wall, leaving a hollow opening in the center running through the length of the pole.

Cross Arms.—The familiar cross arms for stringing wires are usually attached to the poles before they are erected. They are commonly made from yellow pine wood, generally 3¼×4¼ inches, and are freely coated with good mineral paint as a preservative.

Attachment is made to the pole by cutting a *gain* one inch deep and of sufficient breadth to allow the longest side of the cross arm to fit accurately. It is then secured in place by a lag screw with a square head, so that it may be driven into place with a wrench.

The cross arm is further secured to the poles with braces. Fig. 5,809 shows a typical arm and fig. 5,810 the method of fastening to pole.

Pins and Insulators.—The cross arms are bored with holes

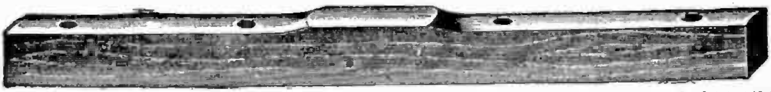


Fig. 5,809.—Cross arm which carries the insulator pins. The standard cross arm is 3¼×4¼ ins., double painted, and bored for 1½ in. pins and two ½ in. bolt holes. Telephone arms are 2¾×3¾ ins., bored for 1¼ in. pins and two ½ in. bolts.

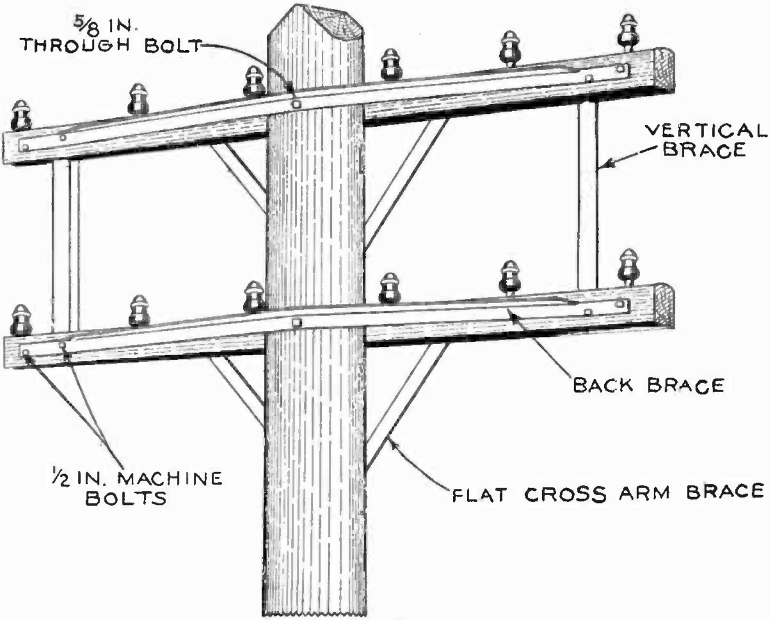
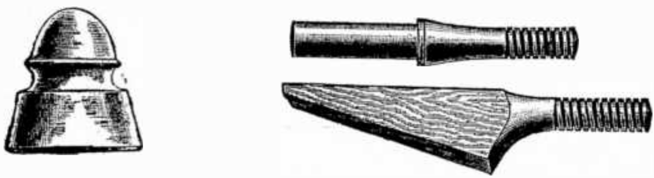


Fig. 5,810.—Method of fastening cross arm to pole. ***In addition*** to direct bolting, the cross arm is further secured to the pole with braces 30 ins. long, ¼ in. thick and 1¼ in. wide, according to standard specifications. Holes are bored at points one in. from either end, one for attaching to the pole, the other for attaching to the cross arm; two braces forming a triangle with the cross arm for the base and with the apex at the point of connection to the pole.

for the insertion of the insulator pins, which are made of locust wood and threaded at the upper end to receive the glass insulators.

The cross arm is made of such a length as to accommodate the number of pins to be inserted. An arm for two pins is made three feet long, according to the standard usually followed, with holes for the pins at center points three inches from either end and a space of 28 inches between them in the center.

Figs. 5,811 to 5,813 show a glass insulator, pin and bracket such as is used on telephone and telegraph lines.



Figs. 5,811 to 5,813.—Glass insulator and insulator pin and bracket. The insulator here shown is of the pony double petticoat type. Insulator pins are used with cross arms, brackets are attached direct to the pole.

Insulators.—Glass and porcelain are employed almost universally for supporting overhead wires. Insulators made of these materials are superior to those made of other material such as hard rubber, or various compounds of vegetable or mineral matter, with the exception perhaps of mica insulators used on the feeders or electric railway lines.

Glass insulators are generally used on low tension lines, and porcelain insulators on high tension lines, the latter type being usually stronger and less brittle. Porcelain is more expensive than glass, and its opacity prevents the detection of internal defects which would be readily observed through glass.

An insulator which has one, two or three deep flanges or "petticoats" around the base for the purpose of increasing the leakage path from the line to the pin is called a petticoat insulator.

Both glass and porcelain insulators may be the double or triple petticoat type which may be cast or moulded solid, or made in two or more parts which are subsequently cemented together.

Figs. 5,814 and 5,815 show these types of insulator.

There are numerous types of insulators adapted in design to the various conditions met with.

Guys for Poles.—Where poles are subject to severe strains which might throw them down and break the wires, guy cables are largely employed, these being attached near the top and

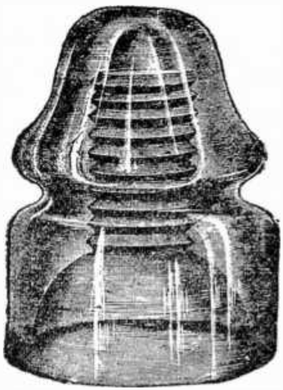


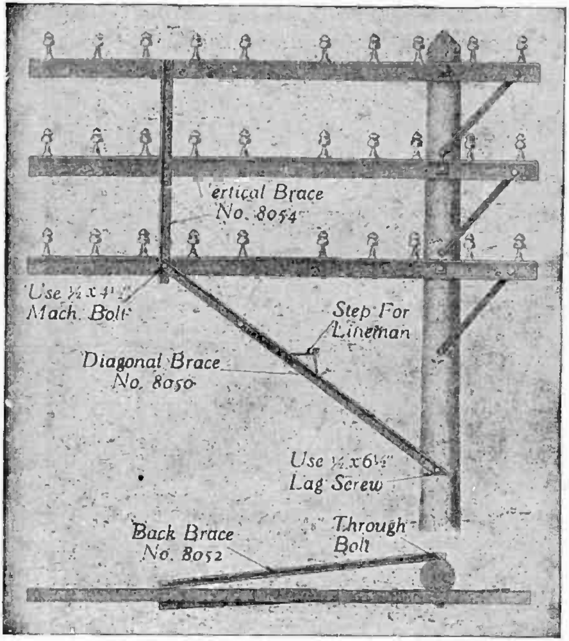
FIG. 5,814.—Telephone and telegraph line glass insulator.
FIG. 5,815.—Type of insulator used in making a transposition.

secured either to the base of the next pole, to a suitable guy stub or post, or to a guy anchor, which is buried about eight feet in the earth and held down by stones and concrete.

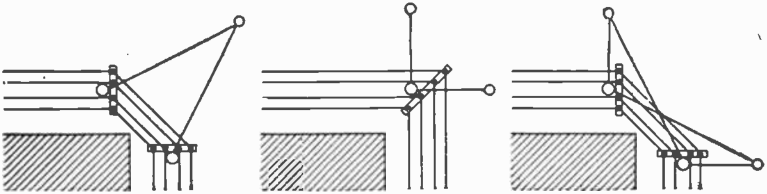
Poles should be guyed at corners in order to thoroughly secure the poles so that no strain may come on the cornerwise span. It is also necessary to guy a line where it is to be deflected from a straight path, as when rounding a hill, water course or railway curve, in order to neutralize the pull of the wires, tending to incline the poles toward the center on which the arc is described; also when descending a hill.

The methods of guying poles are shown in the accompanying cuts.

Guy Stubs and Anchor Logs.—In guying a line under such conditions, each pole is connected by a suitable cable to a guy post or "stub," or to an anchor log.



FIGS. 5,816 and 5,817.—Hubbard tee pole braces. The vertical brace shown is designed for 3 arms spaced 12 ins. apart, or 2 arms on 24 in. centers, additional arms being cared for by placing other vertical braces in *series* with the first. The vertical brace is made of 1¾ × 1¾ × ¼ in. angle and is provided with poles for ½ in. bolts. The diagonal brace is intended for use on both the 6 and 10 pin arms. It is provided with a step for the line man and may be used on either side of the pole. It is fastened to the side of the pole by a ½ in. lag screw, and to the cross arm by a ½ in. machine bolt. The diagonal brace is made of 2 × 2 × 3/16 in. angle steel. The back braces are attached to the pole by the ⅝ in. cross arm through bolt and to the cross arm by a ½ in. machine bolt. Back braces are made of 2 × 2 × ⅛ in. angle steel.



FIGS. 5,818 to 5,820.—Methods of guying corner poles. The proper guying of corner and terminal poles is especially important; on corners and curves, the guys should be stronger and more frequent and should be placed at the outer side as shown in the diagrams.

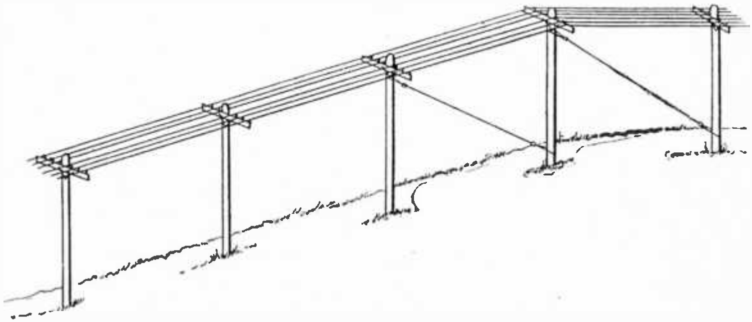


FIG. 5,821.—Head and foot guying of a pole line in descending a hill.

FIG. 5,822.—Guy anchor log in position.

Standard rules specify stubs between 18 and 25 feet, with exact limits as to circumference measurements at the top and at a point 6 feet from the butt, according to the kind of wood used. Figs. 5,822 and 5,823 show two types of anchor.

FIG. 5,823.—Stombaugh guy anchor. It is made of cast iron and can be screwed into the ground like an auger.

TEST QUESTIONS

1. *What range of voltage is employed on pole lines?*
2. *Name three classes of poles.*
3. *What kind of pole is mostly used?*
4. *What are the properties required in wooden poles?*
5. *How are wooden poles classed according to wire capacity?*
6. *Draw a sketch showing right and wrong way to measure pole butts.*
7. *How is the sweep of a pole measured?*
8. *Name the several methods of wood preservation.*
9. *Describe the preservation method employed by some large pole concerns.*
10. *Describe pole climbers.*
11. *Describe the method of erecting steel poles.*
12. *How is an expanded steel truss pole made?*
13. *Describe another type of steel pole largely used.*
14. *What may be said with respect to concrete poles?*
15. *What are the advantages of concrete poles?*
16. *Name the two general types of concrete poles?*
17. *Give the construction of the solid type of concrete pole.*
18. *How is a hollow concrete pole made?*
19. *What are cross arms?*
20. *How are the wires attached to the cross arms?*
21. *What materials are used for insulators?*
22. *What provision is made where poles are exposed to severe strains?*
23. *Describe the various methods of guying poles.*

CHAPTER 123

Erecting Pole Lines

Before starting an erecting job, ascertain whether or not all necessary permits have been secured in order that the work may be done in accordance with the detail plans.

If any part of the proposed work requiring a permit be not covered by a permit, do not begin operations until everything is covered by permits.

Ordering Poles.—Car load lots should be specified. A schedule should be attached to the order covering the shipment to be made, delivery points, and the required date at each delivery point.

Pole storage yards should be provided at delivery points, and the poles should be hauled from these yards to the stake, either by the company's forces or a teaming contractor, depending on which is more economical.

Where poles are obtained locally it is desirable to have them delivered at the stake by the supplier and orders for poles should so specify, if conditions permit.

The person making deliveries should be furnished with a location or stake list showing the length and class of pole to be delivered at each stake, and the date when delivery is required.

The delivery of poles in piles along a route should be avoided where practicable.

Unloading Poles from Cars.—In many cases poles may be unloaded to advantage by local contract. There are several methods of unloading poles as

1. By cutting the stakes;
2. By dragging off car end;

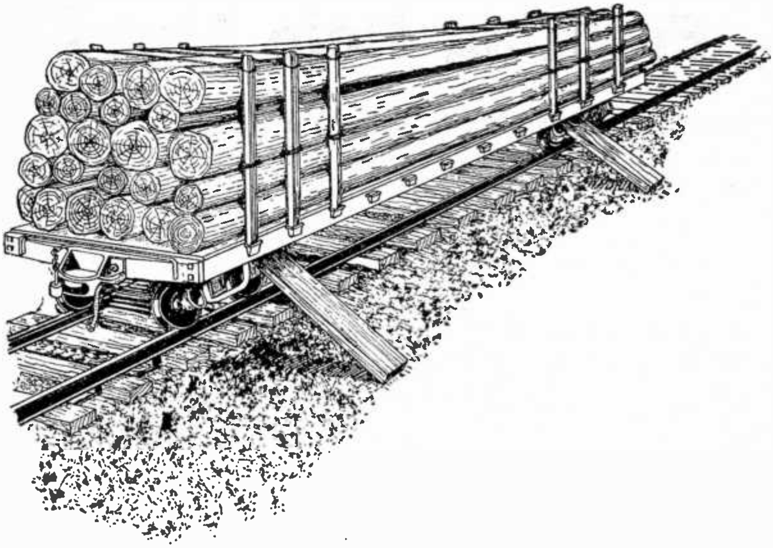


FIG. 5,824.—Unloading poles. *1st Method.* First cut stakes on one side of car, then cut tie wires on other side, allowing poles to roll off. This is a dangerous method. For safety see that the stakes have amply strong tie wires at top and at center of stakes. Where any doubt exists regarding their strength pass a one inch rope or 6,000 lb., or larger, strand over the load at each end of the car, and secure it so that the load is bound in place.

3. By means of pole derrick;
4. By lowering with rope.

These methods are shown in figs 5,824 to 5,827.

Storing of Poles.—Where poles are to remain in the yard for a considerable period of time, they should be sorted according to different classes and lengths and placed on skids. Make the skids of old poles where practicable and space them about fifteen feet apart in a location where water does not accumulate.

The end poles of the pile should be prevented rolling by means of blocks spiked to the skids or stakes driven into the ground. Where piles are more than one pole high, each layer should be carefully "nested" on the layers beneath. Butts of poles should be reversed on alternate layers when the pile will be four or more layers high.

Locating Poles and Stubs.—In general, measure off the span

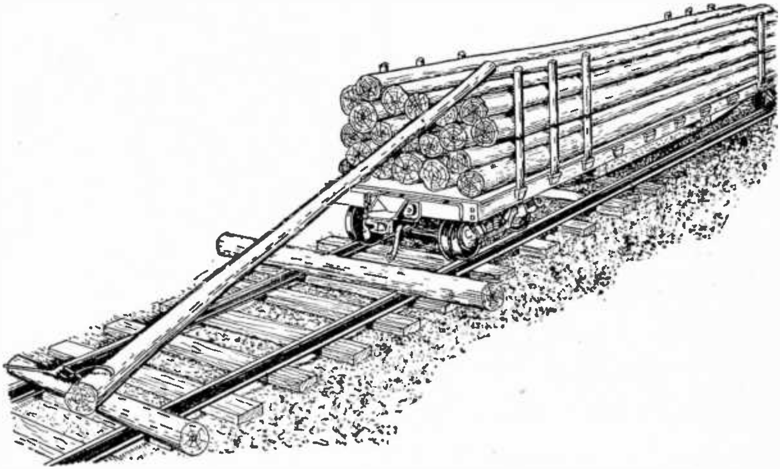


FIG. 5,825.—Unloading poles. *2nd Method.* Dragging poles off the end of the car. Lay temporary skids across the tracks at the end of the car, as shown. Attach pole tongs, rope sling or chain to end of pole and pull pole off the end of car so that it lands on the skids. Where this procedure would be liable to break the pole, the end of the pole which is last to leave the load should be lowered to the ground. Pole tongs attached to a rope may be used for this purpose; take a turn around the top of a stake with the rope where necessary, to prevent the pole descending too fast. Roll the poles clear of the tracks.

lengths specified for the line until an obstacle or a fixed pole location, such as a corner, dead end, or crossing is reached.

Locate a pole at a satisfactory distance from the obstacle or at the fixed location. If it be then found that the span adjacent to this pole be 10% over or 20% under the specified length of span, relocate a sufficient number of the adjoining poles so as to make all spans come within the desired locations.

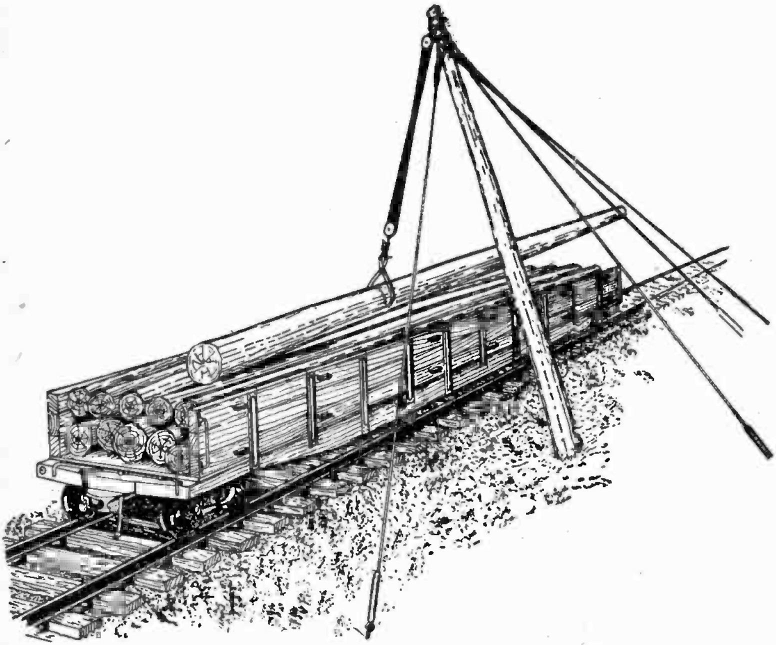


FIG. 5,826.—Unloading poles. *3rd Method.* Use a pole derrick or gin pole.

Drive stakes at the proposed pole and stub locations.

Where the line requires poles of different heights for grading, the pole height required should be marked on the corresponding pole location stake.

The number of poles specified per mile should, in general, not be increased or decreased by more than one pole, except where long span construction occurs. Locate poles in line, except corner poles.

Locate terminal poles so as to obtain good guying facilities and so that if there be an underground connection, the conditions will be favorable for building the subsidiary conduit and pulling in the cable.

Along the highway, except in municipalities, locate line close to the highway fence line, but avoid, so far as practicable, having cross arms overhang private property. When conditions permit, locate poles at transverse fence or property lines.

Where local regulations provide a definite location for pole

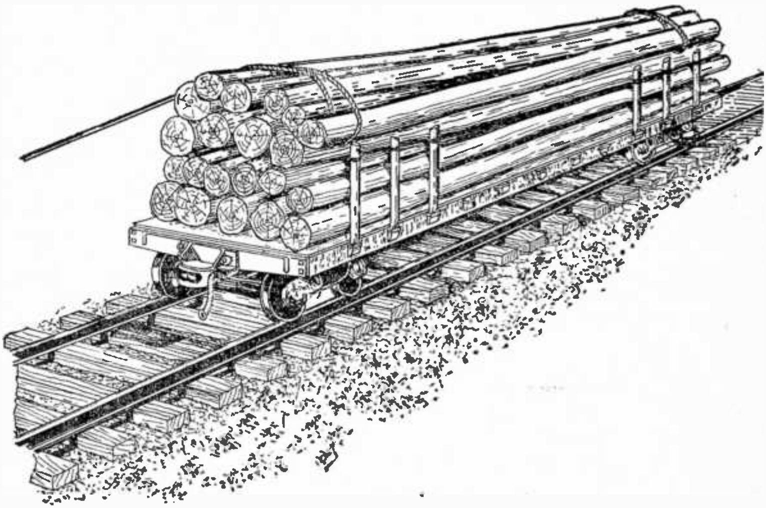


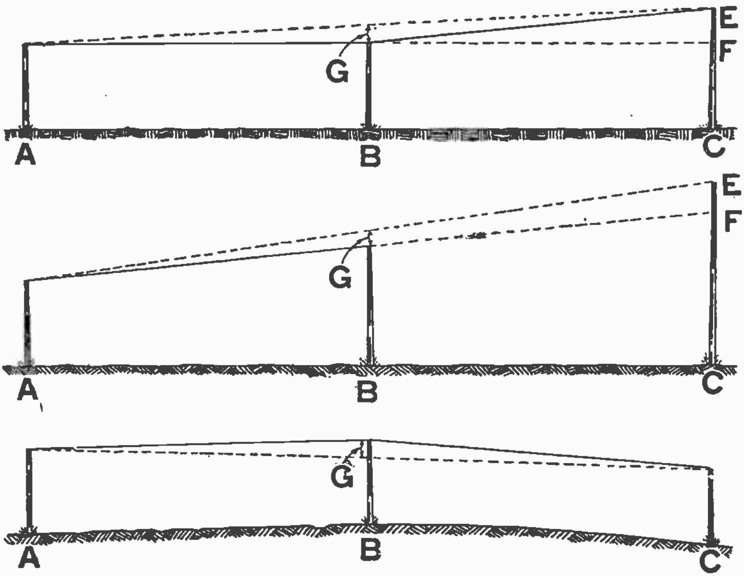
FIG. 5,827.—Unloading poles. *4th Method.* Lowering poles to ground by ropes. At each end of the car secure the end of a rope to the top of a sound stake on the side of the car opposite the unloading side. Pass these ropes over the load and under the first pole to be unloaded. Then bring them back to the opposite side of the car, take a turn around the top of the stakes and pass the ends to a man whose duty it is to tend them. Cut the tops off the stakes on the unloading side at a point just below the top layer of poles. Ease off on the ropes, thus allowing the first pole to roll over the edge of the load. Pay out the rope slowly until the pole touches the ground. Roll the pole clear of the rope and repeat the operation with the poles on top layer, rolling them to the edge of the load with cant hooks or peavies. Similarly unload the remaining layers, cutting stakes at proper level for each layer.

lines, for example, at a fixed distance from the center of the highway, the regulations must be complied with.

Poles on highways outside of incorporated limits should be placed between the drainage ditch and fence line or highway limits. Do not set poles between drainage ditch and highway without special approval of county or state authorities.

Avoid long curves, a line should consist of straight sections and corners. Avoid locating poles in inaccessible places, such as marshes, steep banks, etc.

Avoid the use of long or short poles for grading the line by shifting the stake locations (but not more than 10% over or 20% under the specified



FIGS. 5,828 to 5,830.—Change of grade diagrams. *By definition* a "change of grade" is *a change in the slope of a line which results in an up pull or a down pull at a pole*, as shown in the diagrams. At up pulls G, the change of grade on pole B, is approximately equal to one-half the distance EF. The point F, is located by sighting across the tops of poles (or rods) A and B. At down pulls G, the change of grade on pole B, may be found directly by sighting across the tops of poles (or rods) A and C.

span length) so as to keep poles off the summits of mounds and the bottoms of depressions.

Avoid pole locations which will involve the wires in tree branches or foliage where pruning rights will be difficult to obtain. Locate exchange poles so as to facilitate joint use.

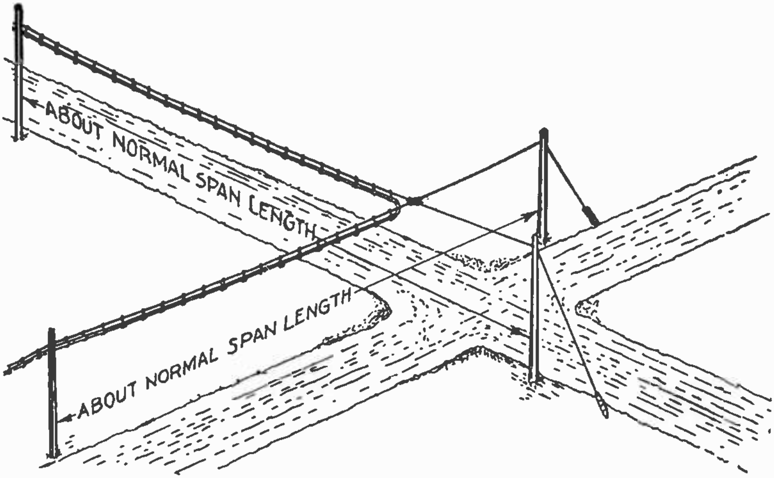


FIG. 5,831.—Main aerial cable turn at street corners. Use a single pole corner if guying conditions permit. At street corners, where conditions such as radius curbs, sewer inlets, etc., will not permit a single pole corner, and at other locations where it is not practicable to make a single pole corner, make the corner as here shown.

Pole Location at Corners.—Locate corner poles so as to obtain good guying facilities. Corner poles should be "set in" to give the proper rake, where conditions are favorable and appearances permit, as shown in fig. 5,861.

In open wire lines use a single pole corner where the pull is less than 40 feet. Where the pull on a single pole would be 40 feet or greater, in general make the corner on two poles. Where a two pole corner is impracticable, a single pole corner with special cross arm construction may be used.

Grading the Line.—A line should follow the general contour of the ground over which it passes, avoiding, however, any

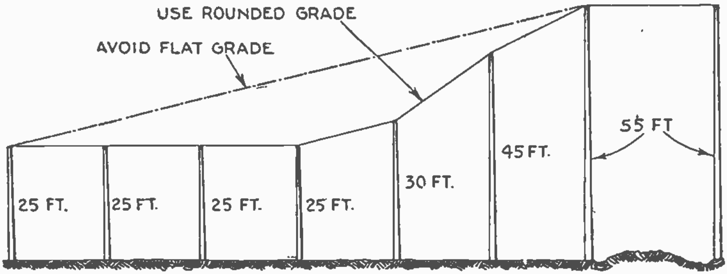


FIG. 5,832.—Rounded and flat grades. A rounded grade is one which has a change of grade on practically every pole, whereas a flat grade has a change of grade on the first and last poles only of a slope. It will be noted that the rounded grade requires fewer high poles than the flat grade.

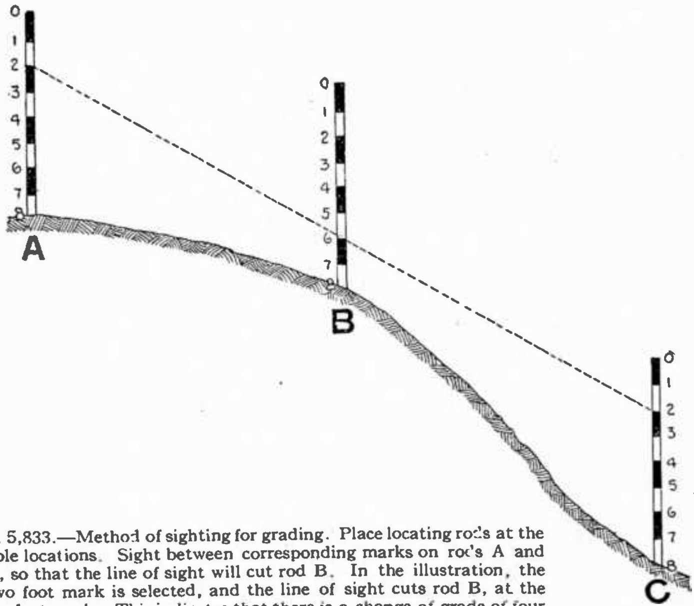


FIG. 5,833.—Method of sighting for grading. Place locating rods at the pole locations. Sight between corresponding marks on rods A and C, so that the line of sight will cut rod B. In the illustration, the two foot mark is selected, and the line of sight cuts rod B, at the six foot mark. This indicates that there is a change of grade of four ft. (6 ft.—2 ft.) on stake B. If it be desired to have the pole tops in line, pole B, should be four feet shorter than poles A and C. If the change in grade be found to be in excess of the allowable limits, it would then be necessary to select a pole of such length as would bring the change of grade within the allowable limits.

abrupt dips or rises which would cause excessive pull on tie wires, pins, or other attachments on the pole. In all cases, poles should be made as short as the required clearances and allowable change of grade on each pole will permit.

Where it is necessary to increase or decrease the height of attachments on poles in order to obtain required clearances, the change should be made by using *rounded* grades, rather than *flat* grades, as shown in fig. 5,832. The method of sighting for grading is shown in fig. 5,833.

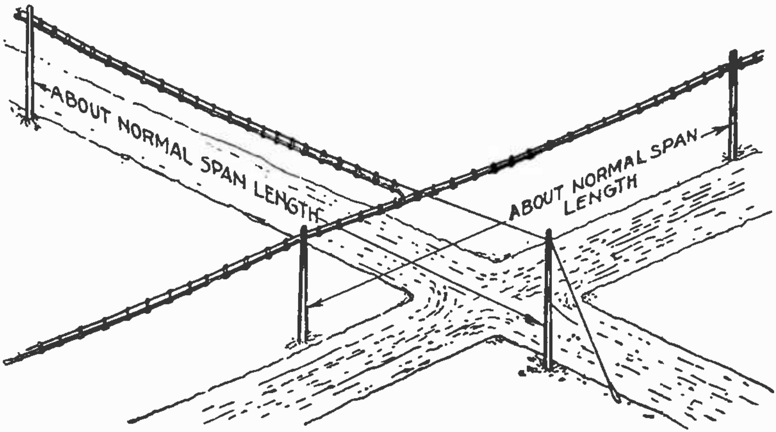


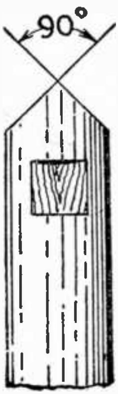
FIG. 5,834.—Branch aerial cable turn at street corners.

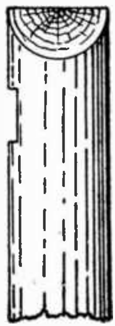
Framing Poles.—This work should be performed before setting. Where practical it should be done in the pole yard. If done on the job, the work should be so arranged as not to interfere with the men setting poles. Where framing is done in the yard or on streets, remove the chips at the end of each day's work.

Creosoted poles are delivered with the gains and other framing already cut. In no case should the creosoted surface of the pole be penetrated.

Framing poles consists of several operations:

1. Trimming;
2. Shaving;
3. Roofing;
4. Gaining;
5. Boring.





FIGS. 5,835 and 5,836.—*Roofing*. Turn the pole so that the face (or inside of the sweep) is up and hold the pole in that position either by blocking or by placing the top of the pole in a gaining buck. Mark the angle of the roof (90°) and cut it with a saw, taking care not to splinter the wood at the bottom of the cut.

Trimming.—Trim off all knots, and cut off all projecting parts of the butt which would interfere with the pole entering a full sized hole. Do not decrease any dimension which would reduce the life of the pole. Trimming includes stripping off all the bark; it is necessary in order to reveal defects in the pole, prevent decay and make the pole safer for the lineman.

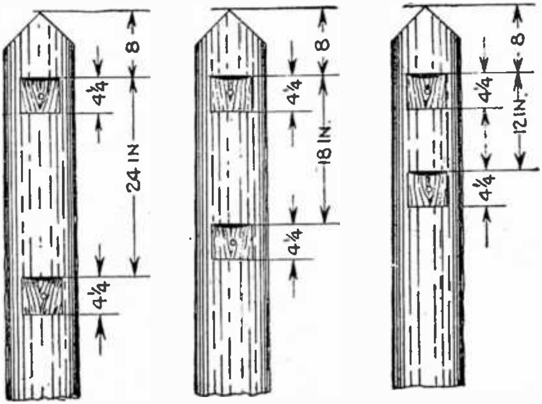
Shaving.—This operation is performed with a draw knife but should be done only when required. Shave only the section of pole or stub which is to extend above the ground or is to be treated.

Roofing.—This operation consists in forming a roof in the top of the pole. This is done by sawing the two sides of the pole top at the angle shown in figs. 5,835 and 5,836. Note that the ridge is at right angles to the gains.

Gaining.—By definition a gain is *the notch cut into the pole into which the cross arm is placed when mounted.* Gains are cut to provide a flat surface to help maintain the arms in alignment.

Cutting a gain consists in first sawing along the upper and lower edges of the gain with a hand saw, and then chiseling out the round portion and making a flat recess.

It is good practice to hollow out the gains slightly in the center to insure a snug fit of the cross arm, thereby preventing its rocking from side to side The operation is shown in detail in figs. 5,837 to 5,839.



FIGS. 5,837 to 5,839.—***Gaining.*** Locate gains on the inside of the *sweep* on curved poles. Measure distances accurately and cut gain so that a tight fit is obtained when cross arms are placed. ***In general,*** space gains 24 ins. apart, top to top of gain. With approval of supervisor, this distance may be reduced to 18 or 12 ins. to obtain proper clearance. Where phantom transposition brackets are to be placed, the cross arm spacing must not be less than 24 ins. Where A or B transposition brackets are to be placed, the cross arm spacing must not be less than 18 ins. On jointly used poles cut gain for telephone cross arm so that the clearance between this cross arm and the nearest cross arm or attachment of the electric company, will comply with the local regulations.

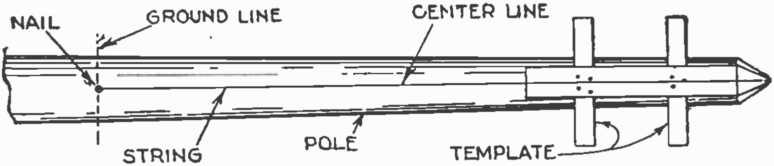


FIG. 5,840.—Gain template and method of aligning on pole. If the arms of the template be made of flexible material such as sheet metal, they may be bent to conform with the pole surface, thus permitting the gain lines to be scribed with precision.

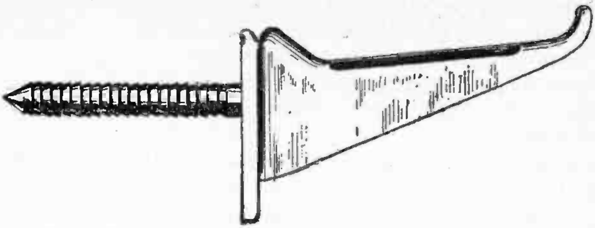


FIG. 5,841.—Hubbard "Pierce" detachable pole step.

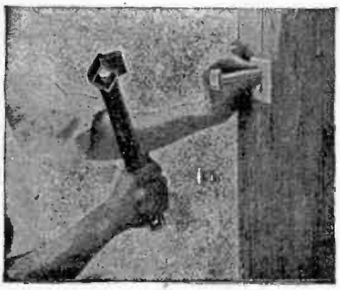


FIG. 5,842.—Installing Pierce detachable step. ***Step 1.*** Slip the plate over the lag and drive the lag screw until the plate bites into the pole.

FIG. 5,843.—Installing Pierce detachable step. ***Step 2.*** The step slips down in a groove on each side of the lag screw head.

FIG. 5,844.—Installing Pierce detachable step. ***Step 3.*** The lineman attaches the steps as he climbs the pole.

FIG. 5,845.—Removing Pierce detachable step. ***Step 4.*** After the lineman is finished working on the pole, he removes the steps and carries them away.

Where the line is to carry only cable or distribution wires attached to brackets, no gains are necessary unless the municipality requires one.

Boring.—A hole should be bored for a ⅝ in. cross arm bolt in the center of each gain. The hole should be so bored that when the cross arm is drawn up tight, the bolt will be at right angles to the face of the cross-arm. Where practicable, holes for cable suspension clamp bolts and pole steps should be bored before the pole is erected. The last operation completes the work of framing.

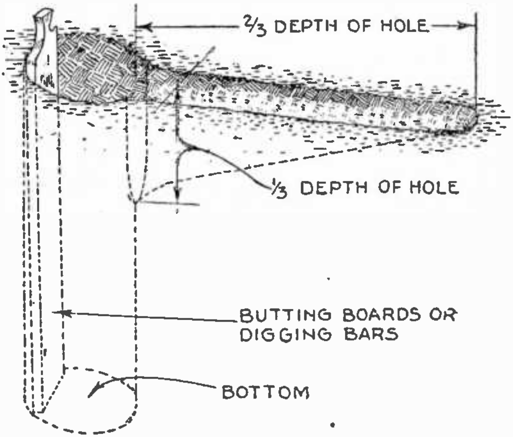


FIG. 5,846.—Digging a hole for a large pole. Where a large pole is to be erected with pikes, or any pole is to be raised with a bull rope, dig a trench extending from the hole, in line with the direction from which the pole is to be raised.

Stepping the Poles.—Poles which require frequent climbing should be provided with steps to prevent damage to the pole from the climbing spurs of the workman. The steps should be spaced 18 ins. apart and located alternately on opposite sides of the pole.

The lowest step is placed not less than 6½ ft. from the ground. A form of detachable pole step is shown in fig. 5,841.

Digging Pole Holes.—When stakes are used to show pole locations, dig hole around the stage as a center. Where no stakes are used, holes should be dug where directed.

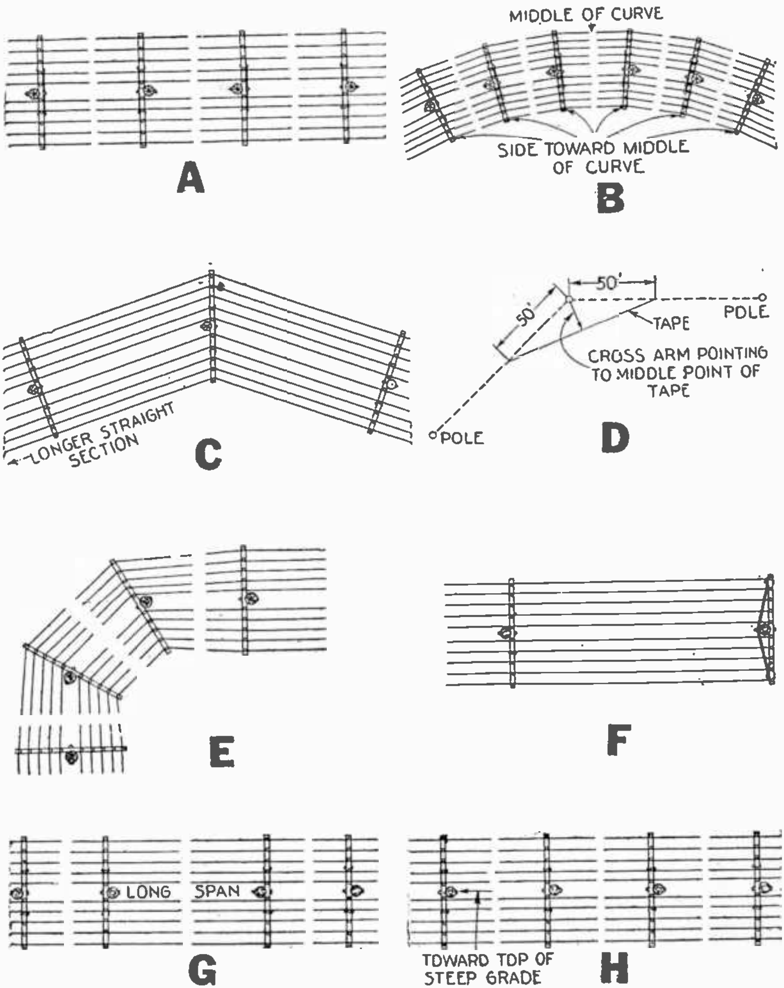
The holes must be dug large enough to permit the free entrance of the pole without cutting down its normal circumference at the butt, and of sufficient size to permit tamping throughout their entire depth. The sides of the holes must be straight.

The following table gives the depth of holes for various poles set in level ground except that unguyed stubs and corner poles must be set deeper by 6 ins. or more, according to the nature of the soil.

Depth of Holes for Poles

POLE LENGTH IN FEET	SETTING IN EARTH DEPTH IN FEET	SETTING IN ROCK DEPTH IN FEET
20	4	3
22	4	3
25	5	3
30	5½	3½
35	6	4
40	6	4
45	6½	4½
50	7	4½
55	7½	5
60	8	5
65	8½	6
70	9	6
75	9½	6
80	10	7
85	10½	7
90	11	7

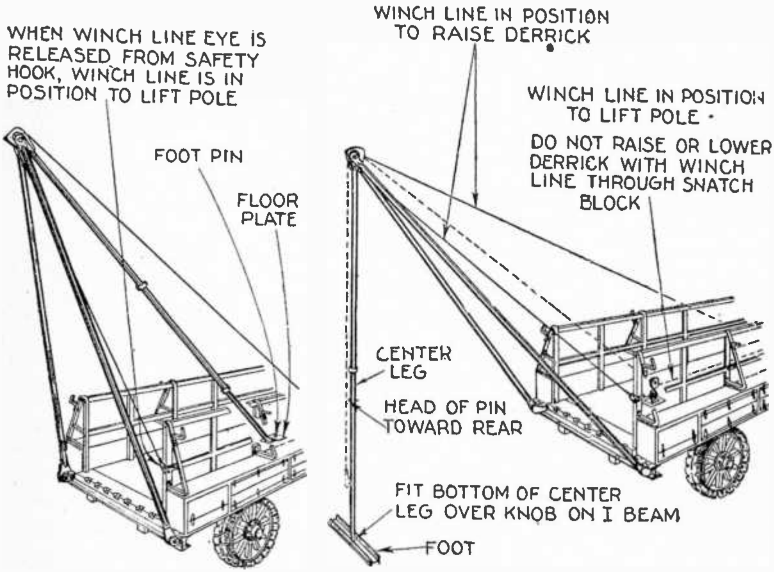
NOTE.—***Dig just enough holes each day*** to permit the pole erecting gang to do a full day's work. Where holes remain open at the end of the day's work, cover them well or guard them to prevent accidents. Where conditions require it, the holes should be covered with substantial planking immediately after they have been dug.



FIGS. 5,847 to 5,854.—How to face cross arms. **A**, on straight section; **B**, on curve; **C**, at corner; **D**, two pole corner; **E**, at dead ends, toward end of line on last 2 poles; **F**, at long spans, away from long span; **G**, at steep grades, toward top of grade; **H**, on grade.

In ordinary soil use a hole boring machine, or shovel, digging spoon and digging bars.

In soft soil, which caves while digging, use a barrel with the heads removed, or a split iron cylinder to act as shoring. The barrel may be left in place after the pole is erected. Where the earth is soft and the load on the pole will be heavy, dig the hole large enough so that a foundation of rock, concrete or plank may be placed at the bottom of the hole to keep the pole from sinking.



FIGS. 5,855 and 5,856.—*Erecting poles, 1st Method.*

Facing Poles.—By definition the face of a pole is *the side of the pole on which the cross arms are attached.*

Set the poles so that ridge of pole roof is in line with lead. Ridge of junction pole roof should be in line with main lead. Ridge of stub roof should be in line with guy. The proper facing of the cross arms is shown in figs. 5,847 to 5,854.

Erecting Poles.—In general, the method to be employed in

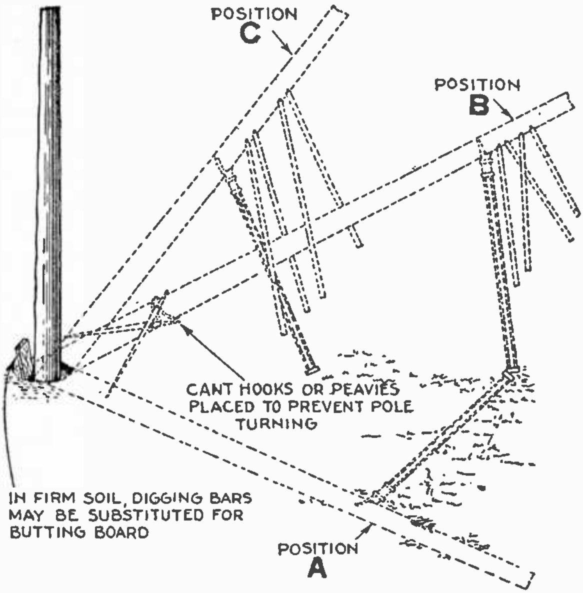


FIG. 5,857.—*Erecting poles, 2nd Method.* Place butting board (used in soft soil) or digging bars (used in firm soil) in the hole. Move pole into place with butt against butting board. Place deadman or jenny in position along the ground where footing will be secure, and station a man to attend it. Position *A*. Lift pole and deadman to position *B*. If pole be brought into place on a dinkey, lift top of pole and place deadman underneath. Place 2 cant hooks or peavies, one to pull against the other so as to serve as a means to prevent the pole turning as it is being raised. The cant hooks or peavies should be placed about 2 feet above probable ground line. When a pole is treated, the hooks must not penetrate the treated wood. Station a man to hold the hooks as the pole is being raised. Place pike poles near the top of pole, one on each side, to steady the pole as it rises and the others underneath the pole. At this stage, the side pikes should be held with the two hands separated and the lift pikes should be held in the hollow formed by clasped hands. Raise the pole, then move the deadman down until it supports the pole again. Position C. In changing the location of the deadman, keep it in instant readiness to support the entire weight of the pole. Pole may be lifted from position B, to position C, by hand, if more convenient. Apply pikes further down the pole. Position C. Shift the pikes one at a time. Raise the pole again. When the pole passes the 45° angle, the men on lift pikes may work to better advantage if they use one hand to support the butt of the pike at the level of the shoulder and the other hand to guide the pike. Repeat this operation until the pole can be piked directly into the hole. When the pole commences to slide into the hole, remove the deadman so that it will not interfere with the movement of the pole. Line up pole with cant hooks or peavies and steady it with pikes while backfilling and tamping.

erecting poles depends upon the size and weight of the pole and upon conditions encountered at the pole locations. Where practicable, the cross arms should be placed before the pole is erected. The following methods are given to cover various conditions met with.

First Method.—Setting by pole derrick operated by power winch on automobile truck. This method, as shown in figs. 5,855 and 5,856, will prove to be the most economical and safest way of erecting poles in practically

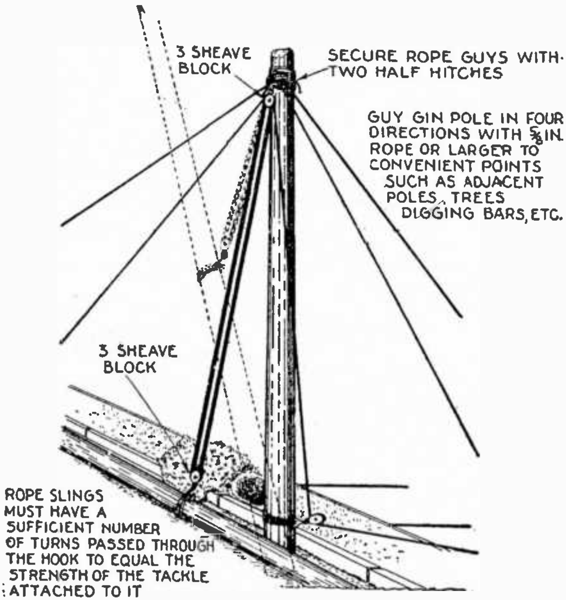


FIG. 5,858.—***Erecting poles, 3rd Method.*** Erect a gin pole of suitable length as near as practicable to the hole which has been dug for the line pole. Where there is danger that the gin pole butt will slip to one side under load, dig a shallow hole for the gin pole butt. Where there is no danger of this, the gin pole butt may be set on the ground, or on a plank if the soil be soft. Guy the gin pole as shown. Attach blocks to gin pole about 6 ins. from top of pole. Attach lower end of tackle to line pole just above *balance point*. Haul away on tackle, guiding the pole as it rises, either by pressure on the butt or by pike poles . Lower pole into hole. Line up pole with cant hooks or peavies and steady it with pikes while back-filling and tamping.

all cases where poles heavier than 25 foot cedar poles and not exceeding 45 feet in length are to be handled.

Second Method.—Setting with pikes. The success of this method, shown in fig. 5,857, and safety of the men employing it, depend upon the intelligent co-operation of the men. Each man should be assigned to a definite part of the work and should make himself proficient in it. Climbers or body belts should not be worn while piking poles. Nothing should be left under foot where it might cause men engaged in piking poles to trip

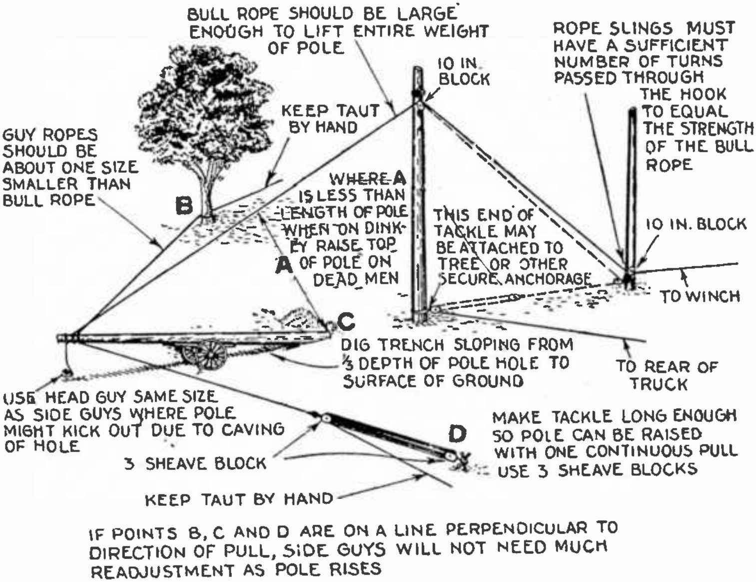


FIG. 5,859.—***Erecting poles, 4th Method.*** Trench the hole as in fig. 5,846. Place butting board firmly in the hole so that it will not kick across the hole and block it. Move the pole into position so that the lower portion lies in the trench with the butt firmly against butting board. See that the anchorage, slings and tackle are in good condition and of sufficient strength. Make set up about as shown. Dotted lines show set up used where a winch is not available. Take great care to have ropes and anchorages strong enough. Serious accident might result if one of them give away. Station men to tend guy poles. Take a strain on bull rope. If top of pole tend to swing out of line of pull, bring it back by easing off or taking in slack on side guys. Haul away slowly on bull rope, keeping pole in line with pull until pole slides into hole. Line up pole with cant hooks or peavies and steady it with pikes while backfilling and tamping.

Light weight poles (25 foot cedar and smaller) may be set by hand without the use of a deadman or cant hooks. Two pike poles are sufficient. For medium weight poles proceed as explained in fig. 5,857.

Third Method.—*Setting with gin pole.* When the pole is too long or too heavy to use the first method, or the gang is too small to use the second method, a gin pole is used to advantage. This method is explained in fig. 5,858.

Fourth Method.—*Setting with bull rope.* This method may be used for heavy poles, where owing to obstruction or lack of men, other methods are not practicable. In this method a nearby pole is used to support a

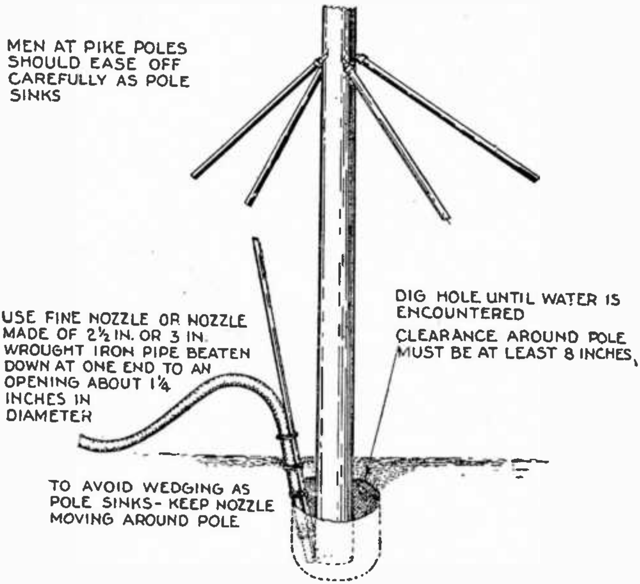
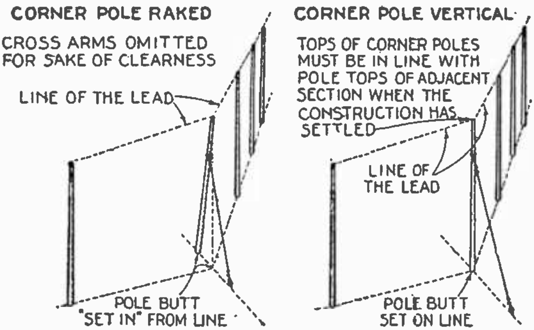
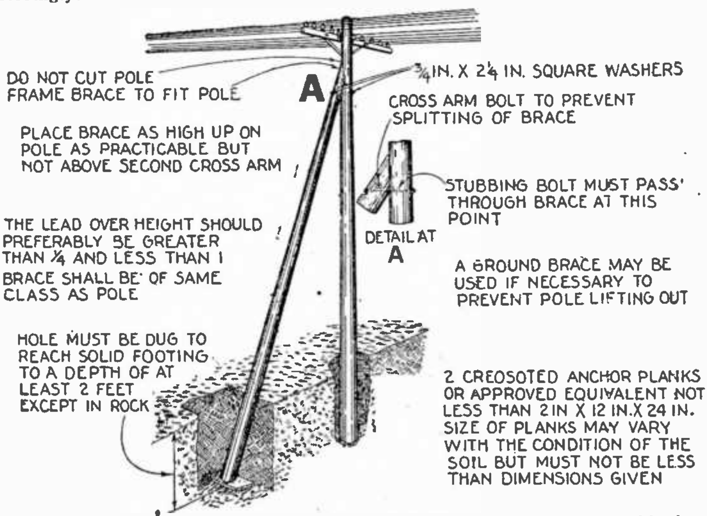


FIG. 5,860.—***Erecting poles, 5th Method.*** Dig hole of sufficient diameter to give approximately an 8 in. clearance about the pole until the soil begins to cave or until water is encountered. Set pole in this hole and hold it upright with pike poles. Direct a stream of water from a nozzle lashed to a short pike pole handle into the soil at the butt of the pole. The pole is gradually undermined and sinks. During this operation move the nozzle around the butt to avoid wedging and ease off carefully on the pike poles. A pressure of 40 lbs. per sq. in. has been found to work out well with this method, although a quantity of water is more essential than a high pressure. When the pole has sunk to the desired depth, reduce the water pressure, remove the nozzle and shut off the water entirely. Shovel back the overflow of sediment around the pole. Usually no tamping is required.



FIGS. 5,861 and 5,862.—Treatment of guyed poles at corner. When placing guys, pull over tops of all poles so that when the load is put on and the anchors and guys have settled, the pole tops will have come back into line. Under average conditions pole tops should be pulled over an amount approximately equal to the diameter of the pole top. When conditions are such that more or less yield is expected from anchor and guy, this amount may be modified accordingly.



FIGS. 5,863 and 5,864.—Pole brace. Place brace as high up on pole as practicable, but not above second cross-arm. Brace hole must be dug to reach solid footing. Depth should be at least 2 ft. except in rock. Two creosoted anchor planks or approved equivalent not less than 2×12×24 ins. Size of planks may vary with the condition of the soil, but must not be less than dimensions given snatch block for the bull rope. Where obstructions do not prevent raising pole with butt at hole proceed as in fig. 5,859.

Fifth Method.—Setting with water jet. Where digging hole to full depth by shovel is impracticable because of caving soil or sub-surface water, the method shown in fig. 5,860 should be used.

Rake.—Where practicable corner and dead end guyed poles should be raked by "setting in" the butts by an amount not exceeding 1 foot for every 20 feet of pole length. Conditions in towns and cities may require that all poles be set vertically. See figs. 5,861 and 5,862.

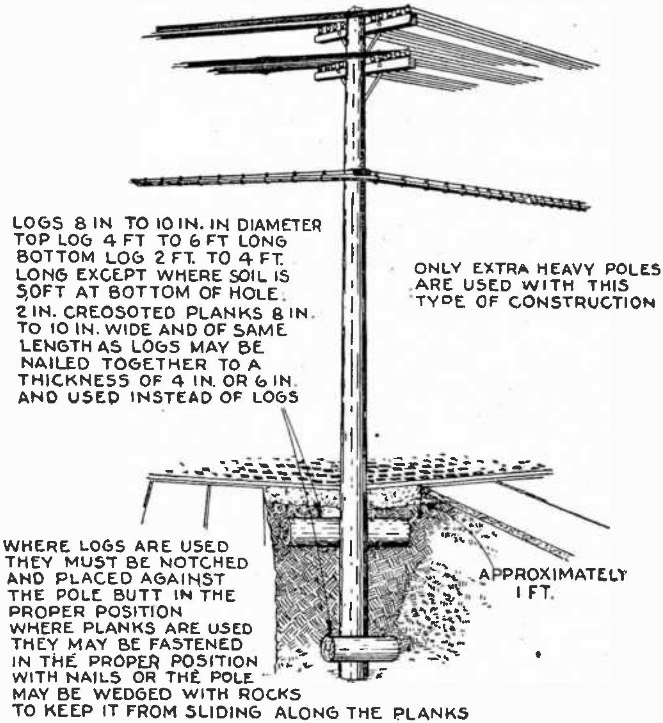
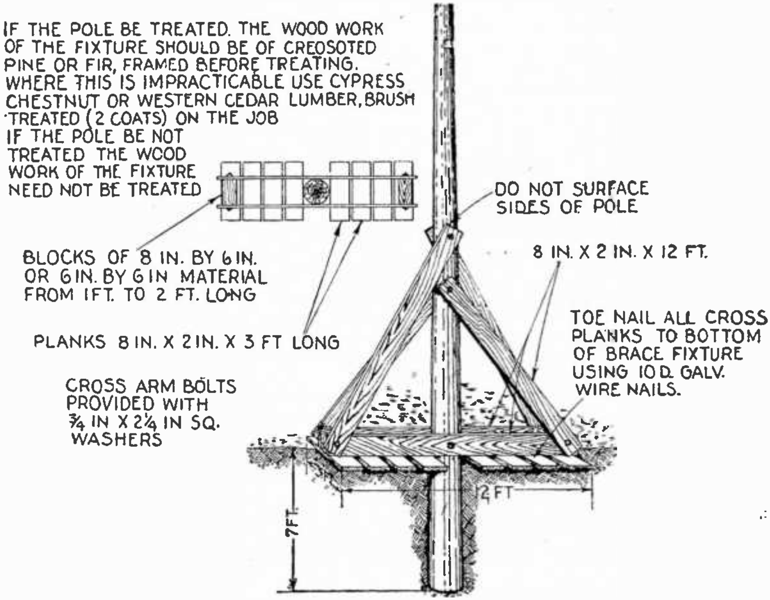


FIG. 5,865.—Method of ground bracing at corners where guy wires are not permitted.

Poles supported by pole braces should be set vertically. Ground braced poles should have their butts set in line. Their tops should be set out of line away from the *pull* by an amount equal to the *give* which is expected to take place when the pole has settled under load.

Backfilling and Tamping.—After the pole is placed in position, fill in the hole with earth, thoroughly tamping it meanwhile. Where conditions permit, use coarse soil or gravel at the top of the hole in filling. Wedge rock firmly around poles that are set in solid rock. In rural districts, bank the soil around the pole above ground level and pack it firmly. In urban districts, do not bank excess earth around the base of the pole. Cart it away.



Figs. 5,866 and 5,867.—Swamp rig to support pole in swampy locations. Where the exposure to high winds is not great and where the earth is never extremely soft, a platform fixture without piling will generally be sufficient.

Code.

Article 60. Signal Systems.

6001. General.

a. The provisions of this article shall apply to telephone, telegraph (except radio), district messenger and call-bell circuits, fire and burglar alarms, and similar systems.

Such protective measures as are essential to safeguard these systems under the various conditions to which they are subjected are outlined in these rules.

6002. Outside Wires.

a. Outside wires shall be placed in underground ducts or strung on poles. They shall not be run across or attached to roofs except by permission of the authority enforcing this code.

b. Underground wires shall not be placed in a duct, handhole, or manhole containing electric light or power wires. Where a handhole or a manhole is divided into sections by means of partitions of brick, concrete or tile, each compartment shall be considered as a separate handhole or manhole.

c. Overhead wires shall not be attached to a crossarm carrying electric light or power wires, nor shall they, when on the exterior walls of buildings, be brought closer than four inches to electric light or power wires, unless one system is in conduit or is permanently separated from the other system by a continuous and firmly fixed non-conductor, additional to the insulation on the wires.

d. The metal sheath of aerial cables which are liable to contact with electric light or power wires shall be interrupted close to the entrance to a building by an insulating joint or equivalent device.

e. The distance between the two inside pins of any crossarm of a pole carrying signal and electric light and power wires shall be not less than 24 inches.

It is recommended that signal wires, being smaller and more liable to break and fall, be placed on the lower crossarms.

f. Aerial cables of the metal-sheathed type may have paper or other suitable insulation. If the metal sheath is omitted each wire shall have 1/32 inch rubber insulation and the bunched wires shall be covered with a substantial braid.

g. Wires from the last outdoor support to the protector, and wires attached to buildings shall have 1/32 inch rubber insulation on each wire, and in addition the wires, either individually or bunched, shall be covered with a substantial braid. Where such wires are entirely within a block the insulation on each wire may be less than 1/32 inch, but not less than 1/40 inch in thickness. Where not in conduit, such wires shall be separated from woodwork and supported on glass or porcelain insulators.

h. Wires shall enter buildings either through non-combustible non-absorptive, insulating bushings, or through approved rigid conduit. Conduit or bushings shall slope upward from the outside, or, where this cannot be done, drip loops shall be formed in the wires immediately outside the point of entrance. The conduit shall be equipped with an approved service head. More than one wire may enter through one conduit or bushing.

i. The preceding paragraphs *g* and *h* shall not apply where the wires enter a building in the form of a cable such as is described in paragraph *f*, of this section, nor where the entire street circuit is run underground, and the circuit within the block is so placed as to be free from chance of accidental contact with electric light or power wires of over 250 volts.

6003. In Buildings, Generally.

a. Wires beyond the protector, or wires inside buildings where no protector is employed, shall be neatly arranged and secured in place in a convenient, workmanlike manner. They shall not approach nearer than two inches to any electric light or power wire unless one

Code.—Continued.

system is in conduit or the two systems are permanently separated by a continuous and firmly-fixed non-conductor, additional to the insulation on the wires.

The wires would ordinarily be insulated, but the kind of insulation is not specified, as reliance is placed on the protector to stop all dangerous currents. Porcelain tubes or approved flexible tubing are considered suitable non-conductors.

b. Wires bunched together in a vertical run shall have a fire-resisting covering sufficient to prevent the carrying of fire from floor to floor. This requirement shall not apply if the wires are encased in non-combustible tubing, or are located in a fireproof shaft having fire stops at each floor.

c. Signal wires and electric light and power wires may be run in the same shaft, if the two systems are separated at least two inches, or if either system is incased in non-combustible tubing.

d. Signal wires shall not be placed in a tube or compartment containing electric light or power wires, nor in the same outlet box, junction box or similar fitting or compartment unless separated from said electric light and power wires by a suitable partition, except where the power wires are introduced solely for power supply to signaling equipment or for connection to remote control equipment.

e. Transformers or other devices supplying current to signal systems from electric light or power circuits shall be of a type expressly approved for such service. The secondary wiring shall conform to the requirements of this article and the primary or the charging circuit wiring to the requirements of articles 1 to 19, inclusive, of this code. This transforming device shall be permitted only when the primary thereof is properly grounded as required in article 9 of this code.

TEST QUESTIONS

1. *What should be done before starting an erecting job?*
2. *How should poles be ordered?*
3. *Where should pole storage yards be provided?*
4. *When poles are obtained locally, where should they be delivered?*
5. *Name four methods of unloading poles from cars.*
6. *Describe the unloading of poles by cutting the stakes.*
7. *What may be said with respect to the storage of poles?*
8. *Describe the method of unloading poles by dragging them off the end of car.*
9. *How are poles unloaded by derrick and by ropes?*
10. *How should poles be placed on highways?*

11. *What should be avoided in placing poles?*
12. *How should pole corners be located?*
13. *How should corner poles be set?*
14. *What may be said with respect to grading the line?*
15. *What is the difference between a rounded and a flat grade?*
16. *Explain the method of sighting for grading.*
17. *What is understood by "framing poles"?*
18. *Where should framing be done if possible?*
19. *How are creosoted poles delivered?*
20. *Name the five operations of framing, and describe each.*
21. *What should be provided on poles which require frequent climbing?*
22. *How high should the lowest step be placed from the ground?*
23. *Describe in great detail the various methods of erecting poles from the digging of the hole to completion.*

CHAPTER 124

Transmission Towers

With the ever increasing tendency to concentrate power house units by making fewer and larger installations, spaced farther apart, it has become necessary to transmit electrical energy over greater distances.

This involves much higher working voltages in order to reduce the transmission loss to a minimum. The use of high voltage makes necessary more efficient supports and also better insulation. Moreover, it is necessary to allow more clearance between the ground and the lowest conductor. So long as the wires were kept only a short distance above the ground, the wood poles made an ideal support for them under ordinary conditions; but when higher supports had to be considered, transmission line engineers began looking about for other supporting structures which would lend themselves more readily to all the varying conditions of service. The steel structure was immediately suggested as the proper support to take the place of the wood poles, and many arguments were advanced in its favor. However, these supports when built of steel were more expensive than the wood poles had been, and in order to keep the total cost of the line equipment down to a minimum, and to make such an installation compare favorably with a similar line using the wood poles, it became necessary to space the steel supports farther apart, so as to use fewer of them to cover the same length of line.

The structures used for supporting high tension conductors may be classed as:

1. Flexible frames;
2. Rigid towers.

Flexible Frames.—These are heavier structures than latticed poles because they are intended to take care of longer spans. Like the poles, their chief function is to take care primarily of transverse loads with a small margin of safety so that under unusual conditions of service they could also provide a little resistance in the direction of the line.

Example. — Distribute a load coming in this direction over a number of supporting structures, and transfer such a load to the still heavier structures placed at regular intervals along the line; or the flexible frames may transfer all loads coming on them in the direction of the line to a point where they will be resisted, by a frame of similar construction and strength, but which is made secure against the action of such loads by being anchored in this direction with guy lines.

Flexible frames are almost always rectangular in plan. Generally, the parallel faces in both directions will get smaller as the top is approached, but often the two faces parallel with the direction of the line will be of the same width from the bottom to the top.

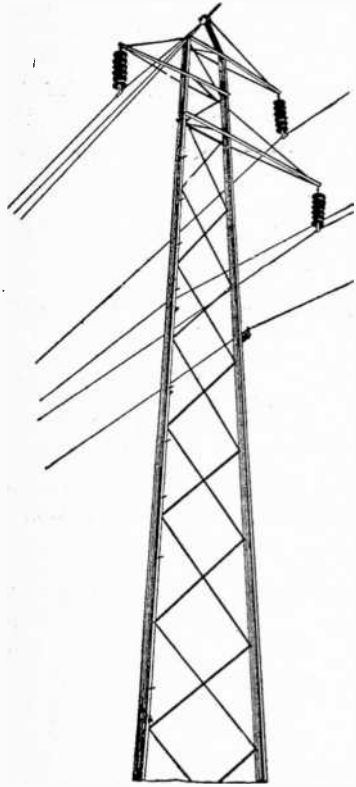


FIG. 5,868.—Flexible A frame for single circuit, 66,000 volt line.

The general appearance of a flexible frame is shown in fig. 5,868.

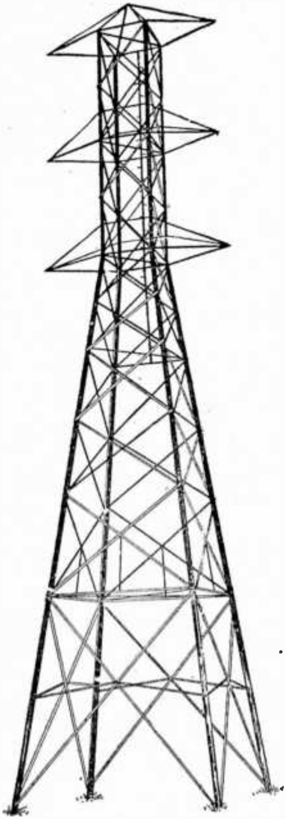


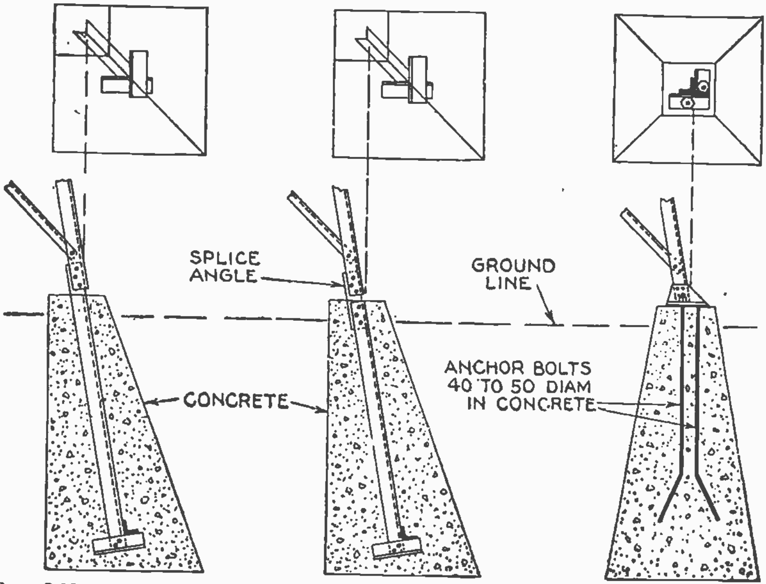
FIG. 5,869.—Blaw-Knox standard type transmission tower.

Rigid Towers.—Towers of this type commonly called transmission towers are the largest and heaviest structures made for transmission line supports, and as would be implied by the designation given them, they are intended to have strength to carry loads coming upon them, either in the direction of the line or at right angles to this direction. They are usually designed to take a combination of loads in both directions.

These towers are built in triangular, rectangular, and square types, depending upon the particular conditions under which the structure is to be used.

NOTE.—*The value of flexible frames* comes from their low cost as compared with the cost of rigid towers and the flexible feature is of value in case of isolated stresses created by storms, falling trees, etc. Where the pin type of insulator is used, the overhead ground wire is sometimes advisable, although not always essential where the flexible structures have sufficient stability to safely stand during the construction period, after which the stability of the conductors places the line in working condition.

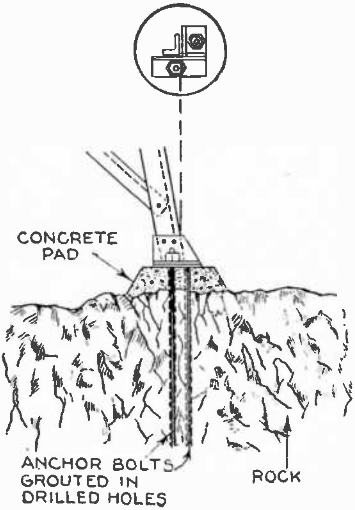
When a plan of the tower at the ground line is square in outline, each side of the square will be very much larger than in the case of either poles or flexible frames. The width of one side of a rigid tower, measured at the ground line, will vary somewhere between about one-seventh and one-third of the total height of the structure. This dimension is usually determined by the construction which will give the most economical design, especially when there are a large number of the towers required; but it often happens that the outline of one or more of the structures will be determined by local conditions which are entirely foreign to the matter of economy of design. Moreover, the conditions of loading may be such as to make a special outline the most economical design. A standard type tower is shown in fig. 5,869.

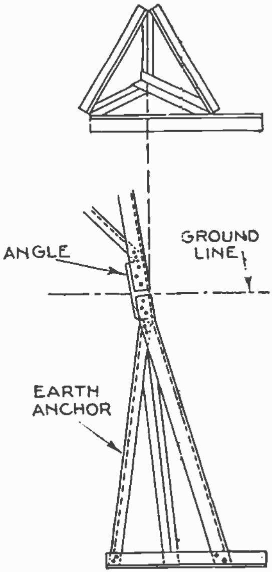


FIGS. 5,870 to 5,875.—Various concrete anchors.

NOTE.—*Transmission towers and structural poles.* A tower is generally assumed to be a large 4 legged structure, sometimes capable of being a dead end structure in itself, although usually a tower is designed more with the idea of taking care of broken wire conditions better than would an ordinary latticed pole. The types of bracing usually are different, the bracing on the latticed pole usually being made up of flats, where the bracing on a tower usually is made up of light angles or members more capable of taking compressive loads. This latter type of design in the tower is more economical construction.

Tower Anchors.—Concrete makes the best footing. The weight of the concrete itself reacts against the tendency of the post to pull away from the base because of the tension in the post on one side of the tower. It also offers more bearing surface against the earth around the footings and introduces the



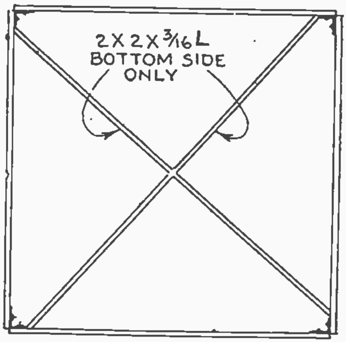


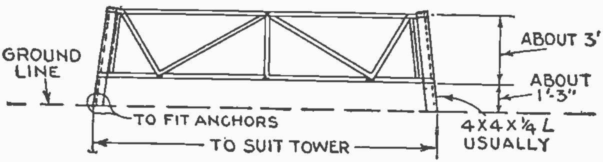
FIGS. 5,876 and 5,877.—Rock anchor.
FIGS. 5,878 and 5,879.—Earth anchor.

passive resistance of a larger volume of earth against the uplifting tendency of the post on the tension side of the tower.

When concrete footings are used, the posts are connected to them in one of two ways:

In the first method, extensions of the post sections, which are called anchor stubs, may be built in these footings with just sufficient length extending above the concrete so that the lower post sections of the tower may be connected directly to them. These anchor stubs may extend almost to the bottom of the footing or they may extend into the footings only far enough so that the adhesion of the concrete to them will develop their full strength, in which case it will be necessary to add steel reinforcing bars from this point to the bottom of the concrete. This is necessary because provision must be made to bind the concrete together so that it will not break apart under the uplifting force in the post, and thus defeat its purpose.





FIGS. 5,880 and 5,881.—Setting template for anchor stubs. Almost all towers are built smaller at the top than at the ground line, and the tower leg inclines from the vertical as determined by the outline of the structure, fig. 5,881. The anchor stub generally follows the direction of the main tower leg, but when it is put in this position and suspended from a template it has a tendency to swing to the vertical position. To obviate this condition the setting template should be trussed as here shown.

The second method consists in having a base at the lower end of the post section which will bear directly on the mass of concrete in the footing, and which will at the same time be connected directly to this concrete by means of long bolts or rods extending well into the mass of concrete. These rods, in this case, would be brought into action only when the post is under tension. If these rods be straight for their full length, and fairly large, they should be imbedded in the concrete for a length equal to fifty times

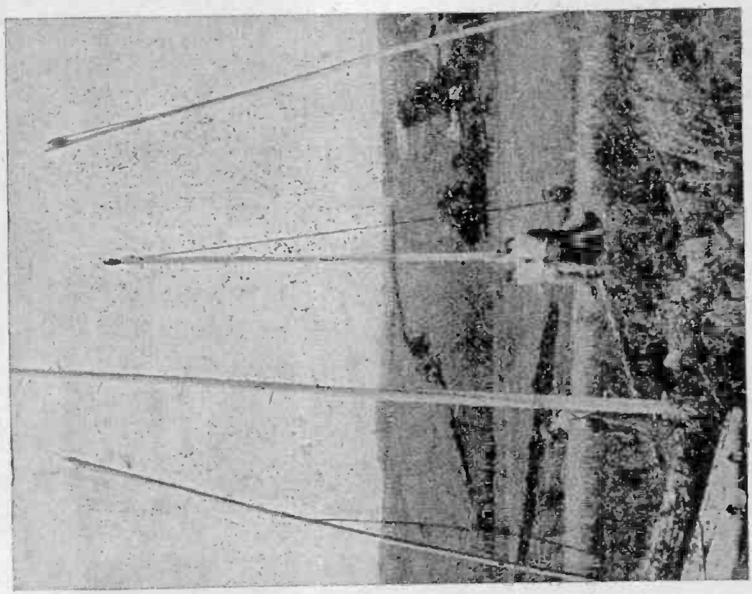


FIG. 5,883.—*Tower erection, second operation.*

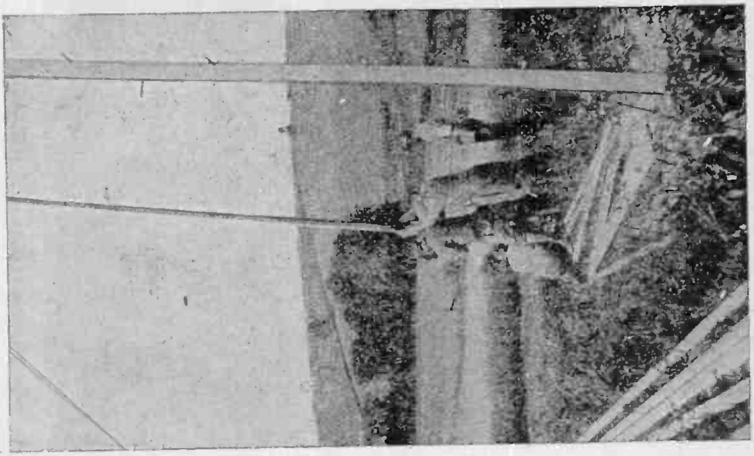


FIG. 5,882.—*Tower erection, first operation.*

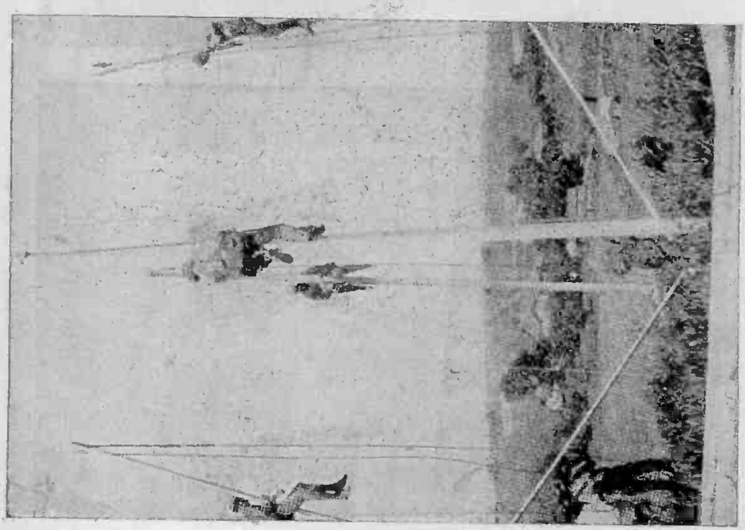


FIG. 5,884.—*Tower erection, third operation.*

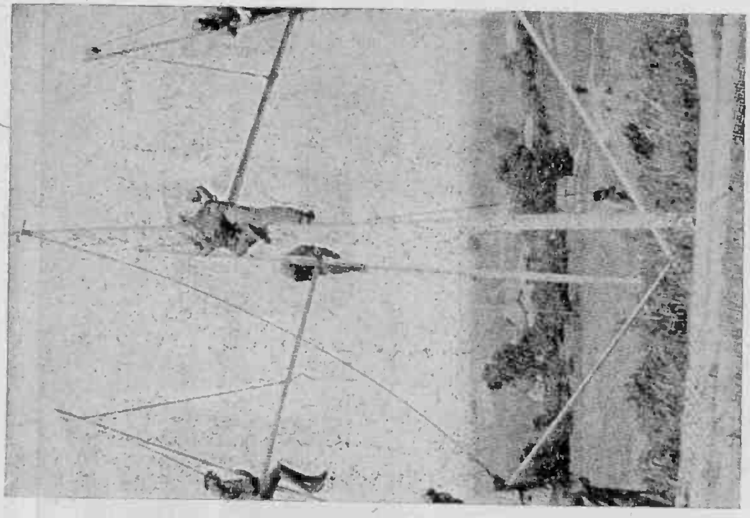


FIG. 5,885.—*Tower erection, fourth operation.*

their diameter, in order to develop their full breaking strength. However, if these rods be bent a little near their lower ends, their breaking strength will be developed by imbedding them in the concrete for a length equal to forty times their diameter.

Provision for binding together the concrete in the footing must be made when anchor rods are employed, just the same as when anchor stubs are used.

Figs. 5,870 to 5,879 show various concrete, rock and earth anchors.

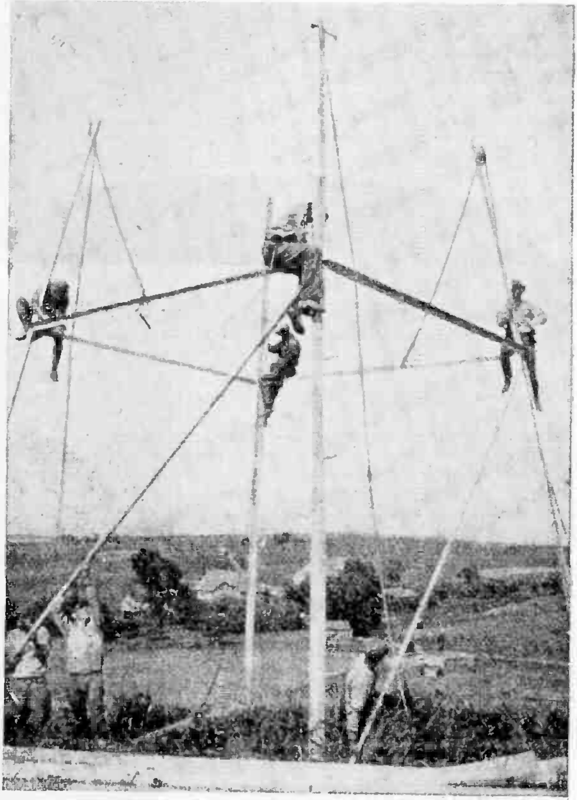


FIG. 5,886.—*Tower erection, fifth operation.*

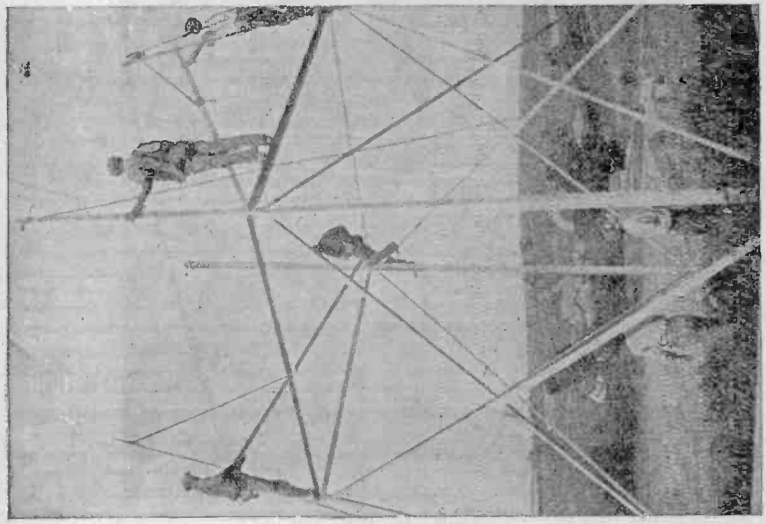


FIG. 5,887.—*Tower erection, sixth operation.*

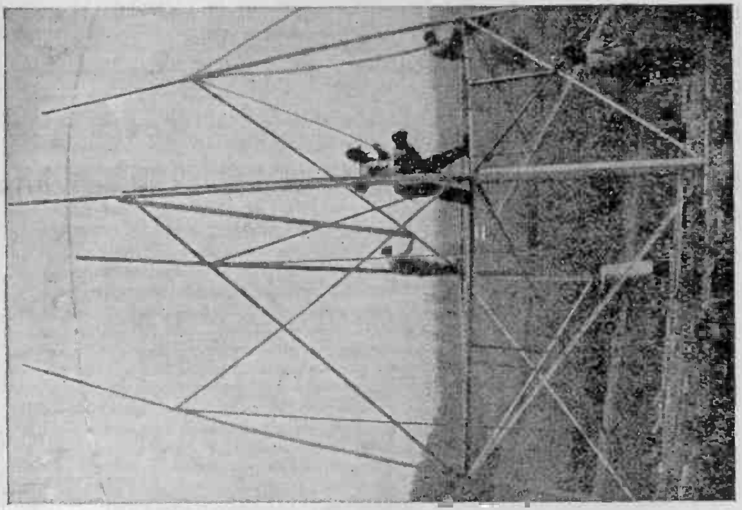


FIG. 5,888.—*Tower erection, seventh operation.*

Erection of Transmission Towers.—There are two methods by which towers may be erected:

1. Assembling in permanent position;
2. Assembling on ground.

First Method.

When a tower is assembled by the first method, that is vertically, there will generally be required a crew of eight men, including one foreman. The following equipment will generally suffice:

One light gin pole, about 25 ft. long.

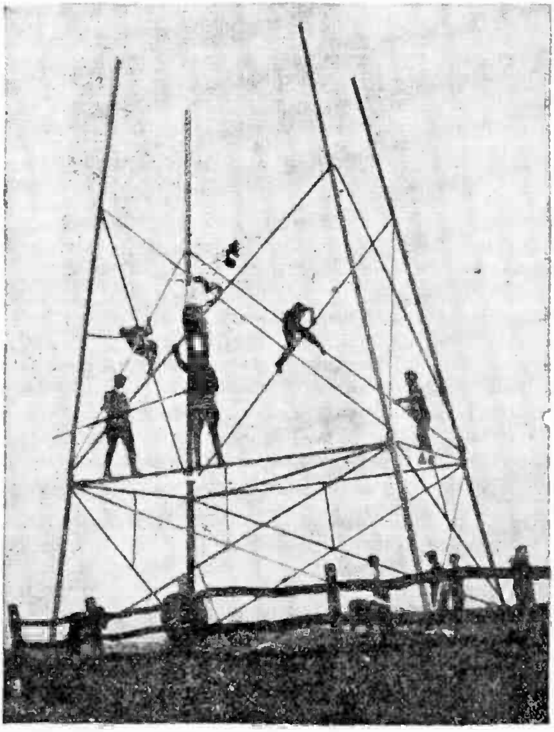


FIG. 5,889.—*Tower erection, eighth operation.*

One set of two-sheave and three-sheave blocks for ¾ in. diameter rope.

About 300 feet of ¾ in. diameter rope; four hand lines, each about 150 ft. long; four small gate blocks for the hand lines.

The post members are erected with the gin pole and tackle, but all the other members are pulled up from the ground with the hand lines. The time required will be about the same whether the tower be light or heavy. The time required will, however, depend upon both the accuracy of the fabrication of the material and the accuracy of the alignment of the anchor stubs.

Second Method.

When the tower is put together on the ground, the actual work of raising it does not consume more than ten or fifteen minutes after all the preparations have been made. These preparations and the erection consist of three distinct operations:

1. Leveling the ground where required for the erection equipment, and blocking up the tower on rough ground and for side hill extensions. A crew of seven or nine men including a foreman is required.

2. Rigging up erection equipment, and bolting erection shoes and struts in place, etc. A crew of about twelve men including a foreman is required.

3. The actual raising of the tower. Sometimes horses are used for this operation, but it is often found to be more satisfactory to use a caterpillar tractor, especially for raising the heavier towers. One team of horses will generally suffice for this work, but it often requires four and sometimes six horses, especially in rough country and for raising towers that are unusually heavy. The tractor gives a much steadier pull, and will permit of holding the load at any desired point more satisfactorily than when horses are used. A substantial A-frame usually built up of steel pipes is generally employed for raising the tower from the prone to the upright position. A steel cable should also be used in preference to a manila rope for this purpose in the case of the heavier towers.

When concrete footings are used, and this method of erection is employed, there is an advantage in having the anchor stubs set and concreted in position in advance of the assembling of the tower. When this is done, the tower can be assembled close to the anchor stub and can be

NOTE.—***When installing a line of flexible frames*** with an overhead ground wire, the builder may use dead end towers, one about every mile, or may use guyed structures, one about every half mile. When a line is guyed in this manner, the head and back guys are usually designed to carry the longitudinal tension of one or more of the conductors broken. The use of guyed poles and structures, as compared with self supporting structures, is economical, and for this reason they are in general use raised about hinges fastened to the tops of the anchor stubs; but when the tower is assembled before the concrete is placed around the anchor stubs, it is necessary to assemble the tower a few feet away from the stubs, and then to skid the tower into the position from which it is to be raised. This process of skidding the tower is costly, and is also likely to injure the tower members.

TEST QUESTIONS

1. *What are the conditions that require the use of transmission towers?*
2. *Name two classes of transmission tower.*
3. *What is a flexible frame?*
4. *Give the construction of a flexible frame.*
5. *What is the chief feature of flexible frames?*
6. *Describe the construction of a transmission tower.*
7. *Give the proportions of transmission towers.*
8. *What makes the best footing for a transmission tower?*
9. *Describe two ways of connecting a post when concrete footings are used.*
10. *Describe the operation of setting a template for anchor stubs.*
11. *Name two methods of erecting transmission towers.*
12. *How is a transmission tower erected by assembling in permanent position?*
13. *How is a transmission tower erected by assembling on the ground?*
14. *How much of a crew is required for the first method?*
15. *What equipment is used for the first method?*
16. *Does it require more time to erect a large tower than a small tower by the first method?*

17. *Name three distinct operations to be performed in the second method.*
18. *How many horses are necessary for raising a tower?*
19. *Is a tractor better than horses?*
20. *What kind of a frame is employed for raising a tower?*
21. *When the tower is assembled on the ground and concrete footings are used, what advantage is offered?*
22. *What is the objection to skidding a tower?*
23. *What are dead end towers?*

CHAPTER 125

Stringing the Wires

There are several methods of stringing the wires depending on the size of the installation, equipment available, conditions under which the work must be done, etc.

On the average job, the conditions are frequently such that the selection in advance of specific points for setting up the reels is inadvisable on account of the difficulty of predetermining the length of wire that can be strung in one pull. Also, pole lines are often so located that the reels may be set up practically anywhere along the line. In such cases, the stringing of the wire is usually started at the beginning of the line and the wire pulled out as far as practicable; then a new set-up is made.

The order in which the operations of stringing the wires as usually performed on the average job is shown in fig. 5,890. They are briefly:

1. Set up the reels at a starting point A;

2. Pull the wires out through the first section, the length of which is determined by the conditions;

3. Dead end the wires at the starting point A, and where necessary place a temporary guy on pole at end of the first section B;

4. Pull the wires to the proper tension and sag, in the first section, locating the apparatus for pulling at the end of the section B, and snub the wires at B.

5. Tie in the wires after they have been pulled up to the proper tension and snubbed.

6. Continue the operation in the succeeding sections in the same manner, except that the wires should be spliced to the wires of the preceding section instead of dead ending them as at the starting point.

7. Remove temporary head guys as the job progresses.

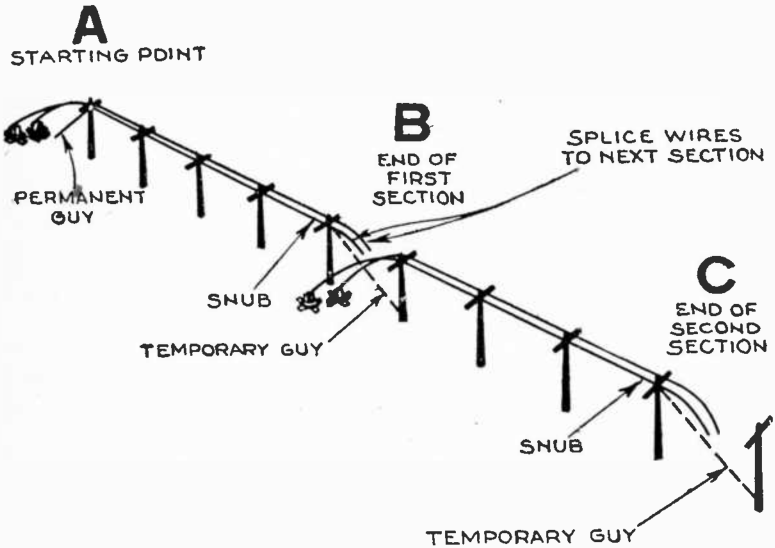


Fig. 5,890.—Diagram to illustrate method of stringing wires on the average job.

Where the conditions are such that only specific points are available for setting up the reels and it is practicable to select points from which the wire can be run out in both directions, the operations of stringing wire are usually performed as shown in fig. 5,890.

Reel Set-ups.—These will depend on various items such as,

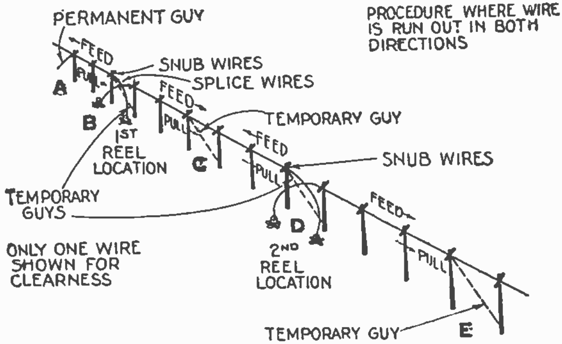


FIG. 5,891.—Diagram to illustrate method of stringing wires where the reels can be set up only at certain points. *Proceed thus:* 1, select first reel location, B, near enough to the starting point A, to permit pulling the wire back to the starting point, and at a point which will permit pulling out the wire in both directions; 2, set up the reels at first reel location B; 3, pull wires out from B, toward A, and dead end the wires at A; 4, where necessary place temporary guy at B; 5, pull wires in section AB, to proper tension from B, and snub the wires at B; 6, pull wires out from B, to C. Tie in section AB, while doing this work; 7, splice wires at B; 8, where necessary place temporary guy at C: 9, pull wires in section BC, to proper tension from point C, and snub wires at C.

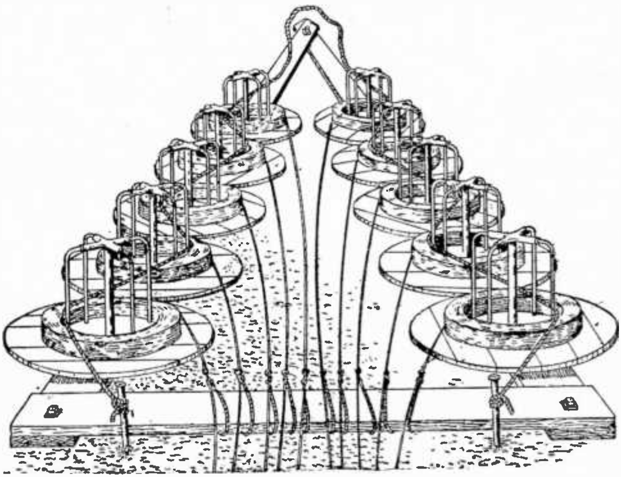


FIG. 5,892.—Multi-reel holder and brake. Use ¾ inch rope to brake the reels.

total length of wire to be strung; maximum length of wire that can be handled in one pull, etc. The arrangement of the reels depends upon the space available, method of setting up the reels and the number of wires to be pulled. Where practicable, set the reels as in fig. 5,892 and locate them far enough from the pole to permit the wires to pay out smoothly.

Pulling the Line.—Equip with a snap fastener each of the

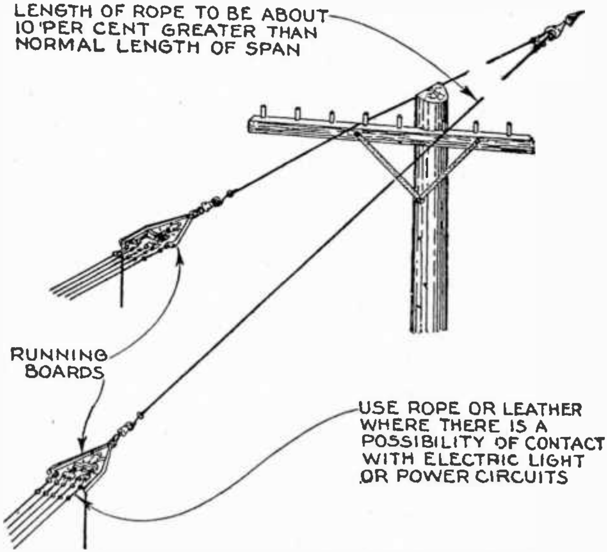


FIG. 5,893.—Apparatus for pulling the line. Where the wires being strung are near electric circuits the snap fasteners should be insulated from the wires with a piece of leather or rope. Where the circuits being strung are located on pins on opposite sides of the pole, as shown, or on different arms, the wires should be attached to two running boards, except where only one wire of a circuit is located on the opposite side of the pole. The second running board should be attached to the pulling line by a rope, each end equipped with a snap fastener. The second running board should trail the first board by a distance of about 5 ft. The use of a rope of this length on the second board permits the lineman on the advance pole to pass the second line to the other side of the pole or to the other cross arm while the lineman at the running board is fanning out the wires. The rope hanging from the running board assists in preventing the running board turning and can be used in guiding the wires from the ground.

SAG FOR 080 COPPER OR 083 GALV. STEEL (OR B.B.) WIRE

Length of span in feet	100°	90°	80°	70°	60°	50°	40°	30°	20°	10°	0°	-10°
	Minimum sag in inches											
80	7	6	5½	5	4½	4	3½	3	3	2½	2½	2
90	8½	8	7	6½	6	5	4½	4	3½	3	3	2½
100	10½	9½	8½	8	7	6	5½	5	4½	4	3½	3½
110	13	12	10½	9½	8½	7½	6½	6	5½	5	4½	4
120	15½	14	12½	11	10	9	8	7	6½	5½	5	5
130	18	16½	14½	13	12	10½	9	8	7½	6½	6	5½
140	21	19	17	15	14	12	10½	9½	8½	8	7	6½
150	24½	22	19½	17½	16	14	12	11	10	9	8	7½
160	27½	25	22	20	18	16	14	12½	11	10	9½	8½
170	31	28	25	22½	20½	18	15½	14	12½	11½	10½	9½
180	35	31½	28	25	23	20	17½	15½	14	13	12	11
190	39	35	31	28	25½	22½	19½	17½	15½	14½	13	12
200	43	39	34½	31	28½	25	21½	19½	17½	16	14½	13½
210	47½	43	38	34	31½	27½	24	21½	19½	17½	16	14½
220	52	47	41½	37½	34½	30	25½	23½	21	19½	17½	16
230	57	51½	45½	41	37½	33	28½	25½	23	21	19½	17½
240	62	56	49½	44½	41	35½	31	28	25	23	21	19½
250	67½	60½	53½	48½	44½	38½	33½	30½	27	24½	23	21

SAG FOR 165 OR 104 COPPER WIRE AND 165 OR 109 GALV. STEEL (OR B.B.) WIRE OR LARGER

Length of span in feet	100°	90°	80°	70°	60°	50°	40°	30°	20°	10°	0°	-10°
	Minimum sag in inches											
80	6	5½	5	4½	4	3½	3	2½	2½	2½	2	2
90	7½	7	6	5½	5	4½	4	3½	3	3	2½	2½
100	9½	8½	7½	6½	6	5½	5	4½	4	3½	3½	3
110	11½	10	9	8	7	6½	6	5	5	4½	4	3½
120	13½	12	10½	9½	8½	7½	7	6	5½	5	4½	4½
130	16	14	12½	11½	10	9	8	7	6½	6	5½	5
140	18½	16½	14½	13	11½	10½	9½	8½	7½	7	6½	6
150	21½	19	17	15	13½	12	11	9½	9	8	7½	7
160	24	21½	19	17	15	13½	12½	11	10	9	8½	8
170	27½	24	21½	19½	17	15	14	12½	11½	10½	9½	9
180	30½	27	24	22	19	17	15½	14	12½	11½	10½	10
190	34	30	27	24½	21½	19	17½	15½	14	13	12	11
200	38	33½	30	27	23½	21	19	17	15½	14½	13	12½
210	41½	37	33	30	26	23½	21	19	17½	16	14½	13½
220	46	40½	36	32½	28½	25½	23	20½	19	17½	16	15
230	50	44	39½	35½	31½	28	25½	22½	21	19	17	16
240	54½	48	43	39	34	30½	27½	24½	22½	21	19	17½
250	59	52	46½	42	37	33	30	26½	24½	22½	20½	19
275	71½	63	56½	51	44½	40	36	32	30	27	24½	23
300	85	75	67	60½	53	47½	43	38½	35½	32½	29½	27½

*NOTE.—*In running out wires along the ground,* the reels may be placed on a truck, allowing the wires to pay out while the truck or wagon is moving ahead, or the wires may be pulled out along the ground with the reels at a fixed location.

wires to be pulled. The wires shall be fastened to a running board as shown in fig. 5,893 so that the wires can be transposed readily. Equip end of pulling line with a snap fastener.

The wire may be run out, either

1. Over the cross arms, or
2. Along the ground.

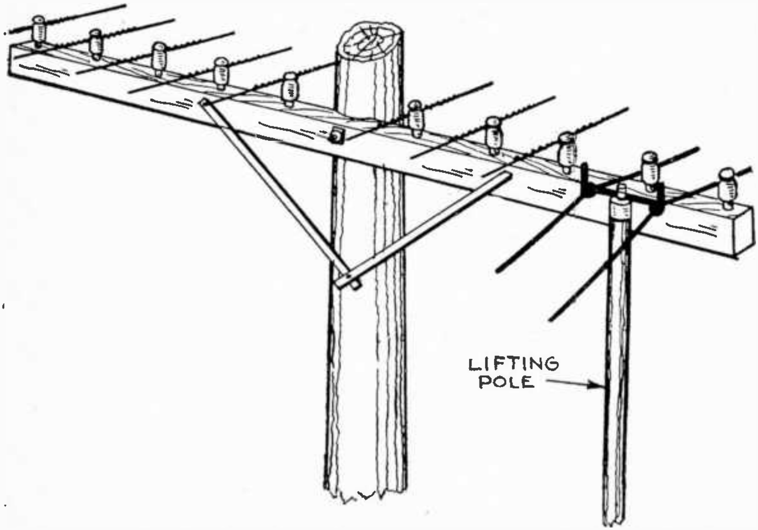


FIG. 5'894.—Lifting pole for raising wires to cross arm.

Where the poles are short and only a few circuits are to be strung and it is practicable to run the wires out along the ground, a wire raising tool may be used, as shown in fig. 5,894.

When pulling the wires use pulling blocks, strain equalizing blocks and tackle as shown in fig. 5,895. Do not pull wires of different sizes with the apparatus shown.

Snubs.—The word *snub* as here used means *to hold fast.*

When it is desired to hold the strain on wire that has just been pulled so that it may be tied in, or to hold the strain on wire while it is being spliced, the wire should be snubbed as shown in fig. 5,896. Where an unbalanced strain would exist on the pole, a temporary guy should be placed before pulling up the wire.

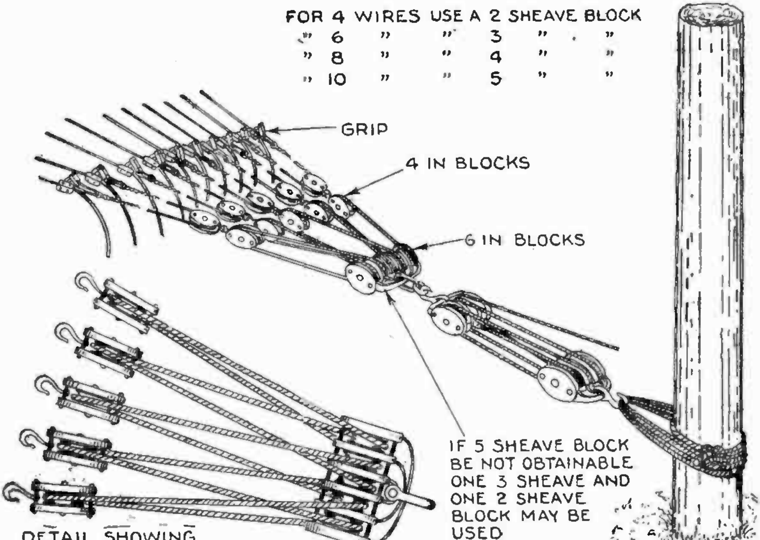


FIG. 5,895.—Pulling apparatus for pulling a number of wires of the same size.

Sag.—By definition sag is *the extent to which a wire dips by its own weight at the middle of the span between two points of support.* In pole line wiring the point at which the sag is measured depends upon whether the ground be level or sloping as indicated in figs. 5,897 and 5,898.

The tables on page 3,527 give the sag for the different sizes of wire.

Properties of Wires

BARE COPPER WIRE

SIZE	STANDARD COIL				FEET OF WIRE PER LB.	APPROX. WEIGHT PER MILE IN LBS.
	MAXIMUM LENGTH IN FEET	MAXIMUM WEIGHT IN LBS.	MINIMUM LENGTH IN FEET	MINIMUM WEIGHT IN LBS		
080 COPPER WIRE	4400	85	2750	53	51.8	102
104 COPPER WIRE	7950	260	2960	97	30 5	173
165 COPPER WIRE	3160	260	1850	152	12.1	435

BARE IRON WIRE

SIZE	STANDARD COIL		FEET OF WIRE PER LB.	APPROXIMATE WEIGHT PER MILE IN LBS.
	APPROXIMATE LENGTH IN FEET	APPROXIMATE WEIGHT IN LBS.		
083 GALV B.B.WIRE	2640	50	53.3	99
109 GALV.B.B.WIRE	2640	85	31	170

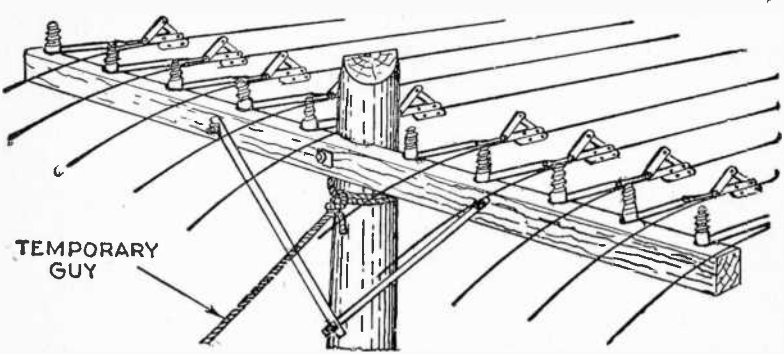
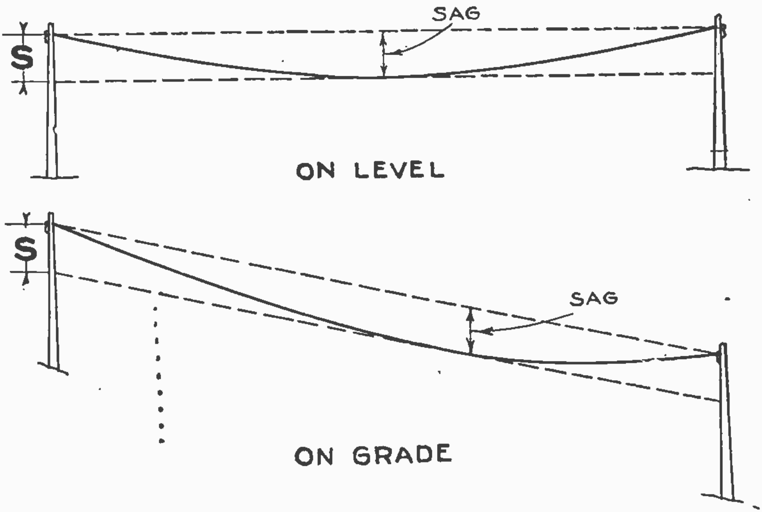


FIG. 5,896.—Method of snubbing wires with "come alongs." The tension is taken by the loop straps which are placed over the insulator pins.

The amount of sag is a direct indication of the tension in the wire. A simple and accurate method of measuring sag is by the use of targets placed on the poles below the cross arm as shown in fig. 5,899. The lineman sights from one target to the other. The tension of the wire is then increased or decreased until the lowest point on the wire coincides with the line of sight.



FIGS. 5,897 and 5,898.—Sag on level and on grade.

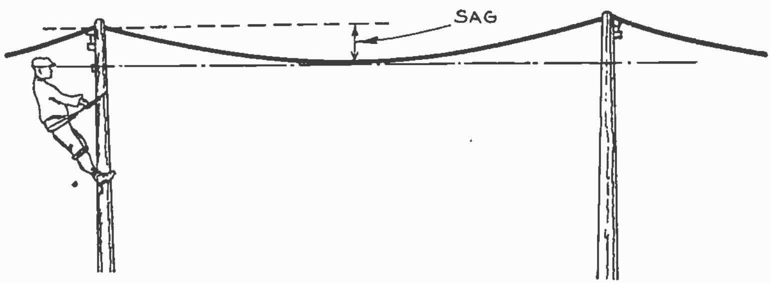


FIG. 5,899.—Target method of measuring sag.

Location of Circuits.—As far as possible, wires and circuits should be kept in the same position on the poles in order to facilitate the tracing of circuits, and to prevent accidents due to misunderstanding as to the service the various wires on the pole supply.

A rule often followed in stringing power lines, to identify the phases of a three phase circuit is as follows:

When the lineman standing under a circuit has his back to the source of power (sub-station or generating station) phase A, should be the left hand conductor, phase B, the middle conductor, and phase C, the right hand conductor. The circuit thus runs ABC, from left to right.

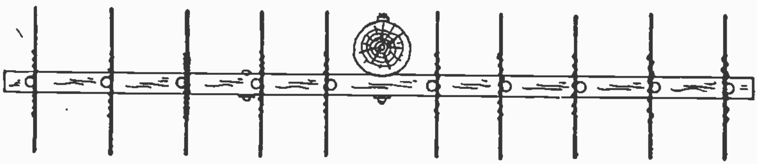


FIG. 5,900.—*Position of wires on insulators.* 1. Straight lines.

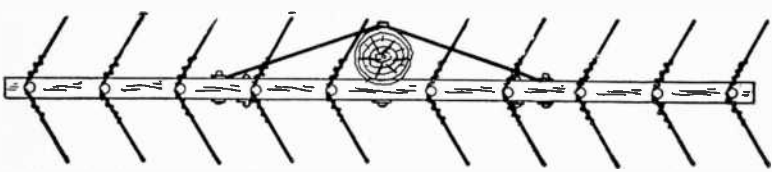
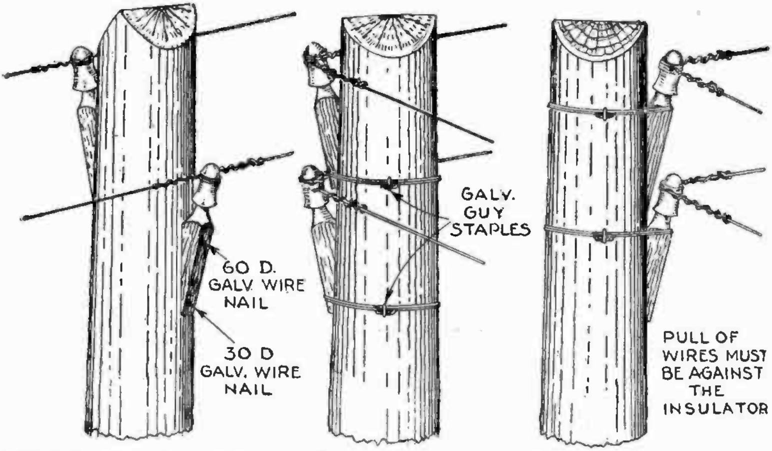


FIG. 5,901.—*Position of wires on insulators.* 2. Curves or corners.

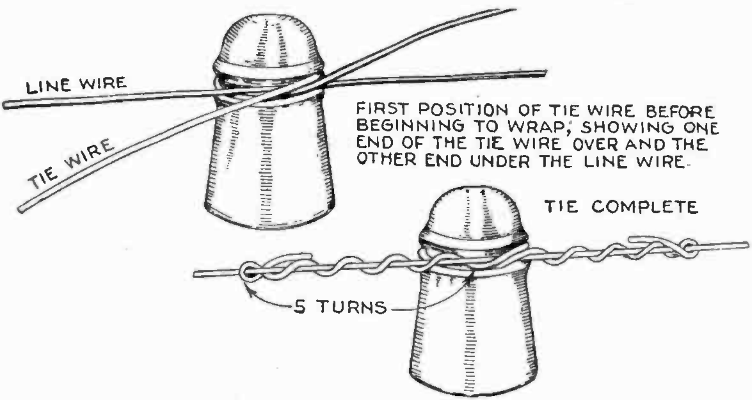
Furthermore, the conductors of a given circuit should be grouped together. In case of a three wire secondary circuit on cross arms, the neutral wire should be located in the middle of the other two wires.

In case of a three phase four wire feeder, the neutral wire should be placed next to the pole. One line wire should be placed on the same side as the neutral and other two line wires on the other side of the pole. On alley or side arms, the high voltage circuits should be placed on the ends of the arms and the low voltage circuits near the pole. In this way the danger of accidents is greatly reduced.

Position of Wires on Insulators.—On straight sections tie the wires to the insulator in the position shown in fig. 5,900, except where wires are displaced due to transposition or shifting of pins.



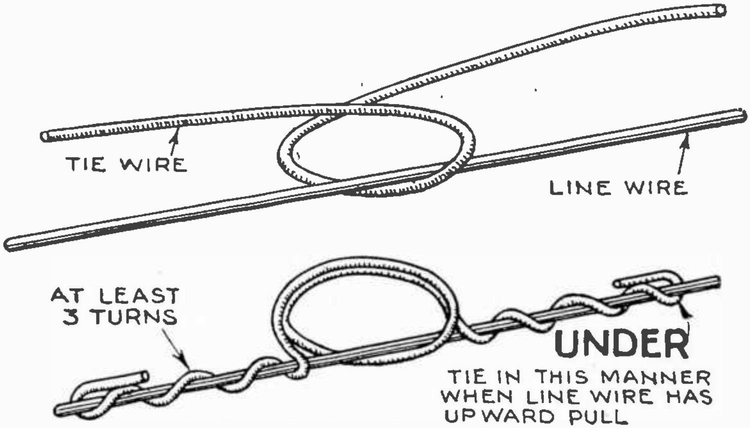
FIGS. 5,902 to 5,904.—***Position of wires on insulators.*** 3. On bracket lines.



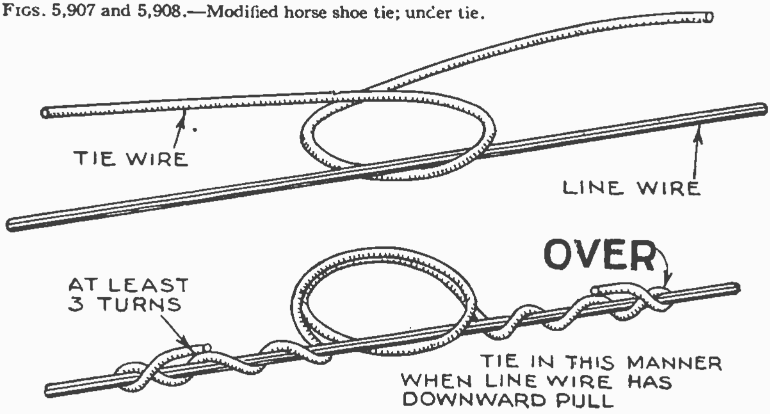
FIGS. 5,905 and 5,906.—Standard tie for copper wire. Fig. 5,905, first position; fig. 5,906, tie completed.

In these latter cases, tie the wires so that they will pull against the insulators. On curves and corners tie the wires to the insulators so that the pull of the wires will be against the insulators, as in fig. 5,901. Where necessary, shift pole pins to prevent wires bearing against pole.

All wires at transposition poles and at poles adjacent to



FIGS. 5,907 and 5,908.—Modified horse shoe tie; under tie.

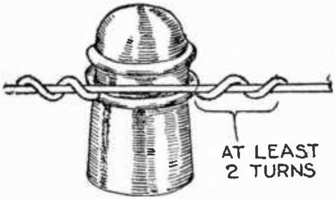


FIGS. 5,909 and 5,910.—Modified horse shoe tie; over tie.

transposition poles should be tied so as to pull against the insulator.

On bracket lines tie the wires on the side of the insulators toward the pole, except where the insulators are on the outside of corner pole. In the latter case, tie the wires so that they will pull against the insulators.

Tying.—Copper line wire must be tied to the insulator with copper tie wire as shown in figs. 5,907 to 5,910. Fig. 5,911 shows method of tying galvanized iron and steel wires.



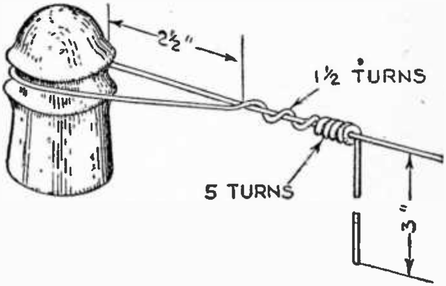


Fig. 5,911.—Standard tie for galvanized iron or steel wires.

Fig. 5,912.—Dead end for iron wire.

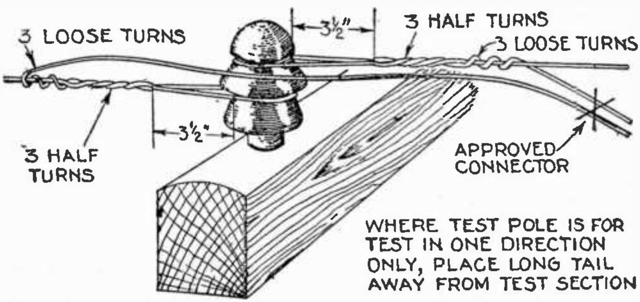


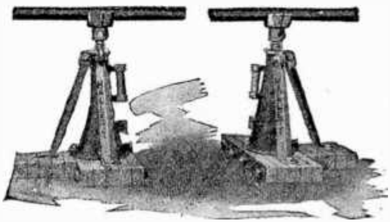
Fig. 5,913.—Dead ends at test points of transposition insulator.

Size of Tie Wire.—The following table gives the proper size of tie wire to be used with conductors of various sizes:

Size of Wires

Size of Line Conductor (B. & S. Gauge)	Size of Tie Wire (B. & S. Gauge)
No. 4 and smaller	No. 6
No. 1 to No. 4	No. 4
No. 0 and larger	No. 2

NOTE.—*The tie wire,* in general, should be of the same kind of wire as the line wire. If the line wire be a bare conductor, the tie wire should be bare also, and if the line conductor be insulated, the tie wire should also be insulated. Copper tie wires should be used with copper line conductors, and aluminum tie wires with aluminum line conductors. The tie wires, however, should always be made of soft annealed wire as hard drawn tie wire would be too brittle and could not be wrapped snugly. A hard tie wire might also injure the line conductor



FIGS. 5,914 and 5,915.—Hallett cable reel jacks. They are fitted with socket heads to make the reel bar give a substantial support to cable reels while running off cable.

Code.

Article 3. Outside Supply Conductors.

The requirements of this article apply to overhead supply conductors run between buildings, upon building walls, or as line conductors which connect with interior wiring systems, or which may come in contact with such wires.

It is fully understood that it is impracticable to include in this Code rules which will cover in detail all conceivable cases that may arise in overhead line work of such an extended and varied nature, and it is recommended that the inspection department be freely consulted as to the specific methods to be followed in any case of doubt, and that the rules of the National Electrical Safety Code, part 2, be followed.

Code.—Continued.

301. General.

Accidental crosses between different conductors on the same or different pole lines may allow the higher-voltage currents concerned to enter buildings over the lower-voltage conductors over a large section of adjoining territory.

Overhead conductors, if carried too close to buildings, tend to hamper the work of firemen in case of fire in the buildings if the raising of ladders is a part of the fire-fighting methods employed. With the higher-voltage lines this hampering effect is greater.

a. In arranging routes for overhead conductors every reasonable precaution shall be taken to secure locations likely to be permanently useful for the circuits concerned and for necessary developments, including the limitation of present and future proximity to other electrical circuits or other pole lines and the appropriate strength, clearances and separations for the proximity concerned.

b. When separate pole lines are carried in nearer proximity than a distance equal to the height of the taller pole line, or where joint poles are used, the appropriate precautions to limit liability of contact shall include the use of wires, cross-arms, pins, insulators, conductor fastenings and poles of appropriate strength. In each such case the minimum clearances and strength shall be those required by the construction rules of the National Electrical Safety Code, Part 2.

302. Joint Lines.

a. The same cross-arm shall not be used for supporting both electric light or power wires and telephone, telegraph or other signal wires which enter any building. An exception is made for signal wires used for operating purposes by an operating utility and entering buildings used for such purposes.

b. When both electric light or power wires and telephone, telegraph or other signal wires are placed on the same pole, the distance between the two inside pins of each crossarm shall be not less than 24 inches for circuits operating at a potential to ground not exceeding 300 volts, and shall be not less than 30 inches for higher potentials.

303. Clearances.

a. Conductors shall be at least eight feet above the nearest point of buildings over which they pass, and if attached to roofs the roof structures shall be substantially constructed. Wherever feasible, wires crossing over buildings shall be supported on structures which are independent of the buildings.

b. Open wires of less than 7,500 volts between conductors shall be at least three feet horizontally from buildings unless 8 feet higher than the roof. Open wires 7,500 volts or more between conductors shall not be installed over buildings other than central stations, substations and transformer vaults. Open wires of voltages between 7,500 and 15,000 volts between conductors shall be kept at least 8 feet horizontally, and open wires of more than 15,000 volts between conductors shall be kept at least 10 feet horizontally, from all buildings except those which they serve or central stations, substations and transformer vaults.

c. Where buildings exceed three stories, or 50 feet in height, overhead lines shall be arranged where practicable so that a clear space (or zone) at least 6 feet wide will be left either adjacent to the buildings or beginning not over 8 feet from them, to facilitate the raising of ladders when necessary for fire fighting.

304. Insulation.

a. Conductors shall be so placed that moisture is not liable to form a cross connection between them. They shall not be in contact with anything but their supports. They shall be

Code.—Continued.

not less than one foot apart except when in conduit or multiple-conductor cable or on approved racks or brackets.

305. Grounding Cable Sheaths.

a. Metallic sheaths of cables shall be grounded in conformity with the requirements of Article 9.

306. Yard Wiring.

For wiring and lamps on series circuits of constant-current systems, see section 5001.

a. All wiring on exterior of building walls shall comply with the requirements for services in section 403. For circuits exceeding 600 volts, it shall be in rigid conduit or metal-sheathed cable.

b. Conduit work on the exterior of buildings shall be waterproof and shall comply with the requirements of Article 5 for interior conduit work.

c. Open wires on exterior of building walls shall be kept at least 6 inches from conductors of other supply or signal circuits not in conduit.

d. Wires strung above alleys, driveways and other open spaces shall have a clearance above ground of not less than 18 feet and if of more than 600 volts, 20 feet.

307. Festoon Lighting.

a. Supply shall be taken only from such points on the wiring system so that correct fusing can be provided for. Conductors shall be protected by fuses not larger than the values given in Column C of Table I, section 612.

b. The conductors of festoon streamers shall not be smaller than No. 14, and shall have an approved rubber covering. When the span of any string of lamps exceeds 40 feet, the string shall be supported by a suitable messenger wire substantially fastened at each end.

c. Festoon lighting strings or messengers shall not be attached to any fire escape or downspout. They shall be supported by secure attachments to buildings, poles or other adequate supports by means of approved strain insulators.

d. Sockets and receptacles shall be of approved moulded composition weatherproof type, and when they are attached as pendants shall have the connections to the circuit wires staggered. All joints shall be made mechanically secure, soldered, covered with both rubber and friction tape, and painted with an insulating paint.

308. Trolley Wires.

a. Trolley wires shall be doubly insulated from the ground, wooden poles being considered as one insulation.

b. Trolley wires and feeders shall be provided with switches which will either disconnect them from the power station, or will so sectionalize them that they may be rendered dead in case of fire along the route.

TEST QUESTIONS

1. *Is there more than one method of stringing the wires?*
2. *What are the conditions met with on the average job?*
3. *What is the order in which the operations of stringing the wires are usually performed?*
4. *Upon what does the reel set ups depend?*
5. *Draw a diagram illustrating method of stringing wires where the reels can be set up only at certain points.*
6. *Describe an apparatus for pulling the line.*
7. *What is a snap fastener?*
8. *How should wires be run out along the ground?*
9. *What should be used in pulling wires?*
10. *What is a snub?*
11. *Define the term sag.*
12. *Describe the method of snubbing wires used with come alongs.*
13. *What does the amount of sag signify?*
14. *Give a simple and accurate method of measuring sag.*
15. *What may be said with respect to the location of circuits?*
16. *Give a rule often followed in stringing power lines.*
17. *Describe the position of wires on insulators.*
18. *How are transpositions made?*
19. *How should wires be tied to insulators?*
20. *How are ties made on bracket lines?*

21. *Give the method of making a dead end.*
22. *What size tie wires should be used?*
23. *Should the tie wire be of the same material as the line wire?*

CHAPTER 126

Catenary Construction

The catenary system derives its name from the curve formed by a flexible cable suspended between two supports and in its

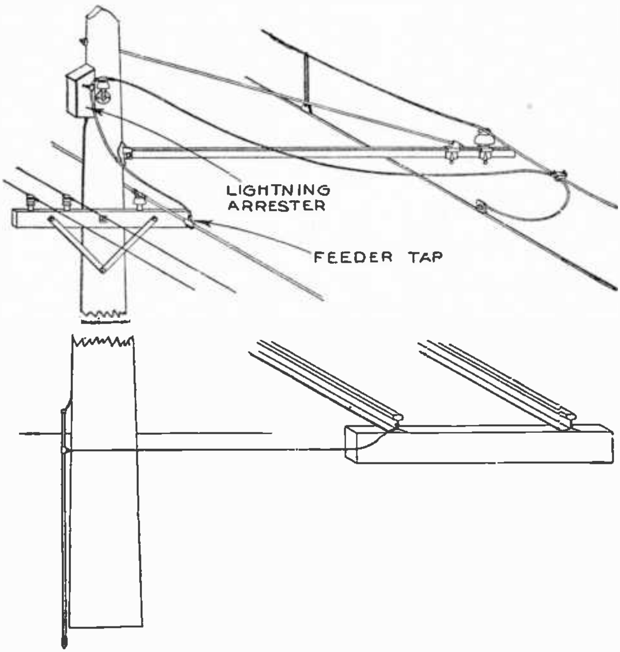


FIG. 5,916.—*Catenary construction 1.* Bracket construction, lightning arrester and feeder tap.

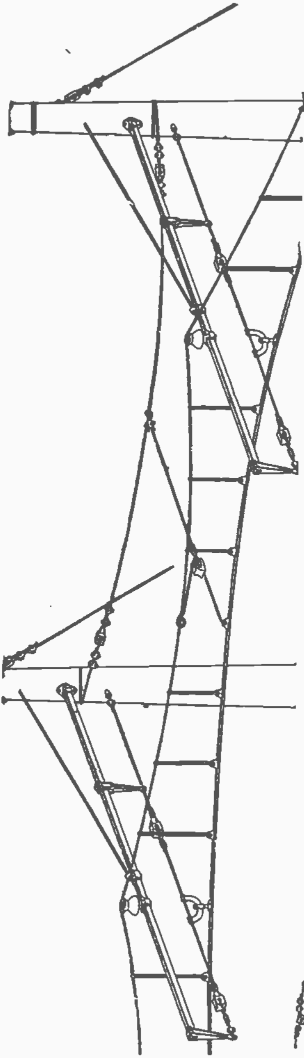
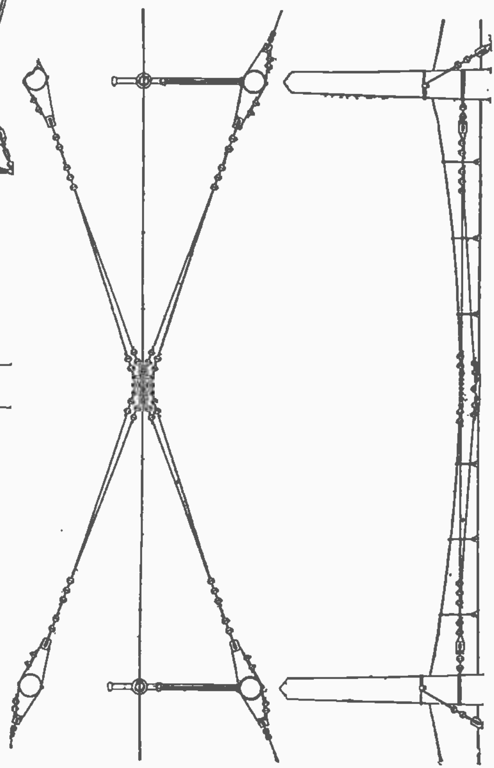


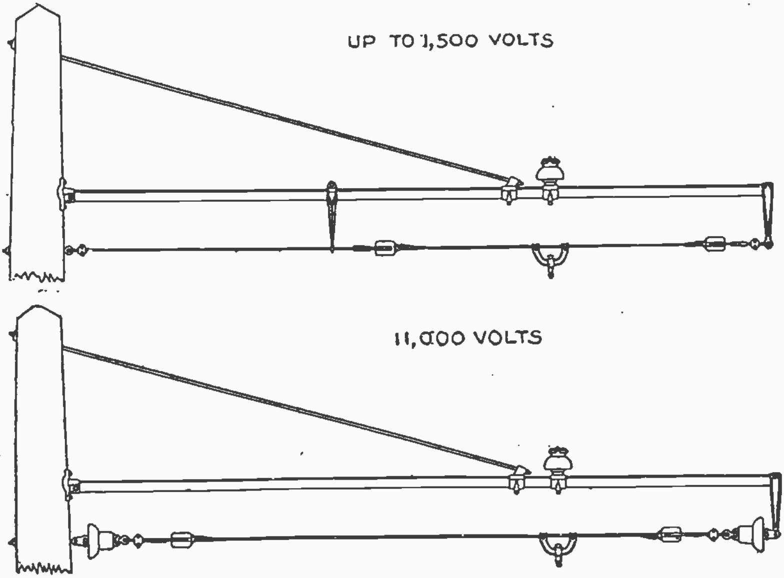
FIG. 5,917.—*Catenary construction 2.* Single track bracket construction on curves showing pull off wires between poles.



FIGS. 5,918 and 5,919.—*Catenary construction 3.* Method of anchoring with strain plates.

simple form consists of a steel messenger cable supported on insulators and thus forming a catenary curve.

The catenary system of line construction, although developed for high voltage roads, possesses so many desirable characteristics from the operating standpoint that it has wide application for all types of electric traction.



FIGS. 5,920 and 5,921.—*Catenary construction 4.* Steady construction for tangent or curves. Fig. 5,920, up to 1,500 volts; fig. 5,921, 11,000 volts.

Catenary construction is well adapted for the efficient insulation of voltages much in excess of present practice; it affords the best current collection for all types of wheel or slipper collectors at any speed and lends itself to the mechanical requirements of long spans and multiple track and yard layout. When well installed it has long life and gives efficient service with low maintenance.

A catenary construction consisting primarily of a single steel messenger cable and a copper contact wire supported by brackets or cross spans spaced 150 feet apart on tangent tracks, with contact wire supported from the messenger wire every 30 feet is the simplest and most economical form of construction for the modern interurban line using wheel collectors and having car speeds of 40 miles per hour or higher.

Modifications of this simple construction, to meet the requirements of

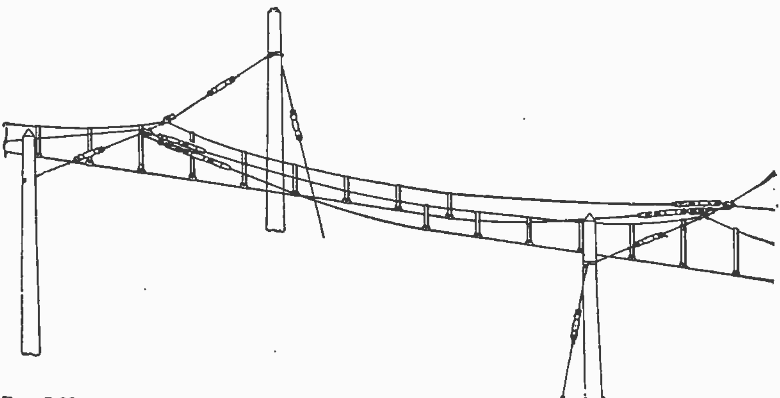
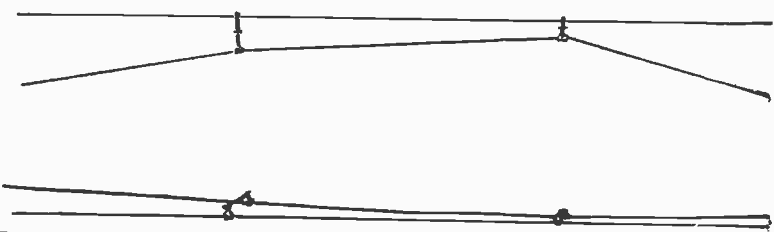


FIG. 5,922.—*Catenary construction 5.* Span anchor construction for pantograph collector showing a method of sectionalizing and anchoring a span line for pantograph collectors only.



FIGS. 5,923 and 5,924.—*Catenary construction 6.* Connecting links for turn outs and crossings. The rigid and adjustable pull off links are for use in holding the trolley wire in position at turn out and crossing points on the line, providing a smooth transition of the pantograph collector from one wire to the other. The rigid links are 8 inches long and several may be used to parallel the wires if the divergence angle be small. By using various lengths of pipe, the adjustable links are made up to span the decreasing distance between the wires approaching the point of crossing or turn out.

higher speeds and pantograph collectors used in heavy interurban and trunk line service, are made by shortening the distances between the contact wire supports to 15 feet, which will result in a perfectly level runway for the pantograph collector.

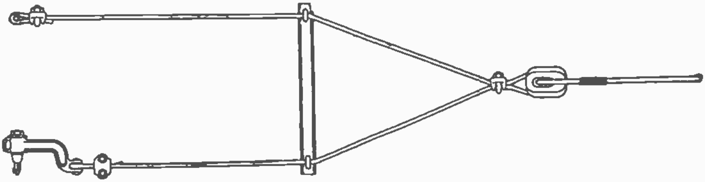


FIG. 5,925.—*Catenary construction 7.* Pull off spreader with pull over yoke for trolley wheel.

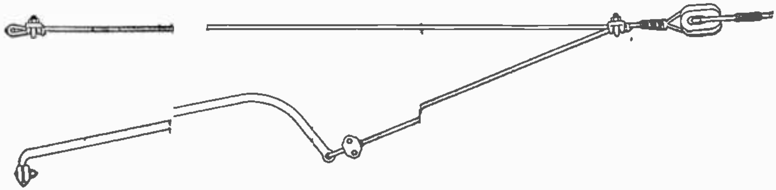
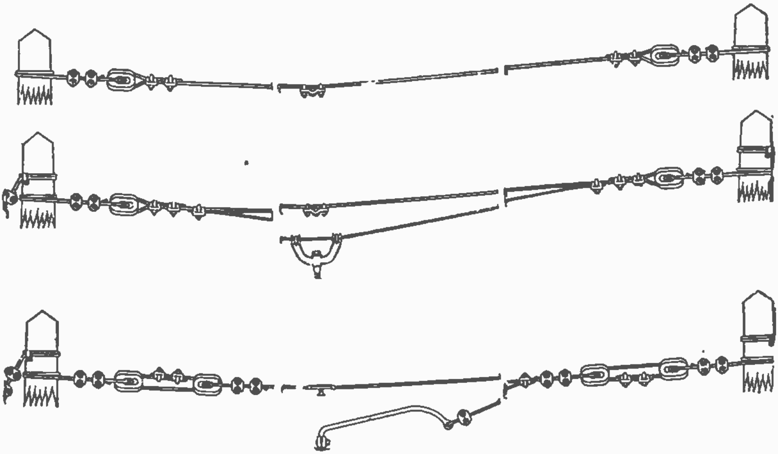


FIG. 5,926.—*Catenary construction 8.* Flexible pull over for pantograph.



FIGS. 5,927 to 5,929.—*Catenary construction 9.* Catenary cross spans for single track. Fig. 5,927, for tangent track single insulation; fig. 5,928, for tangent or curve steady construction; fig. 5,929, for curve pull off, double insulation.

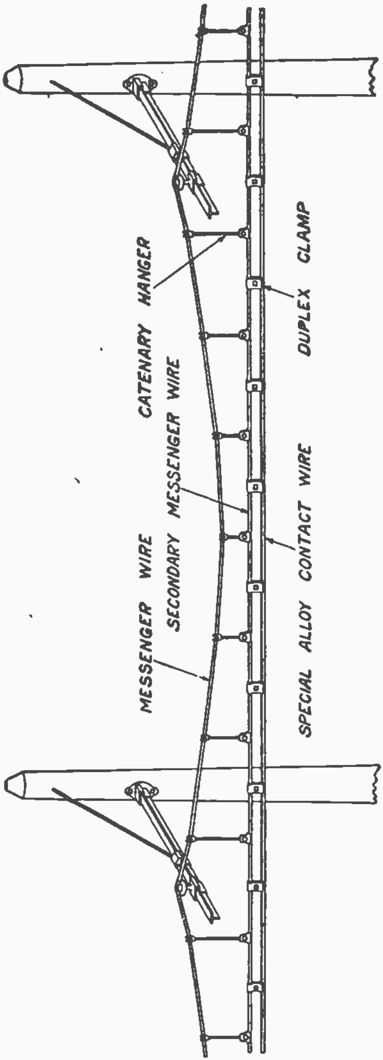


FIG. 5,930.—*Catenary construction 10.* Duplex catenary with names of parts.

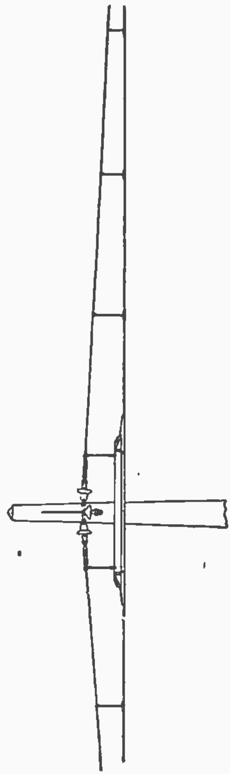
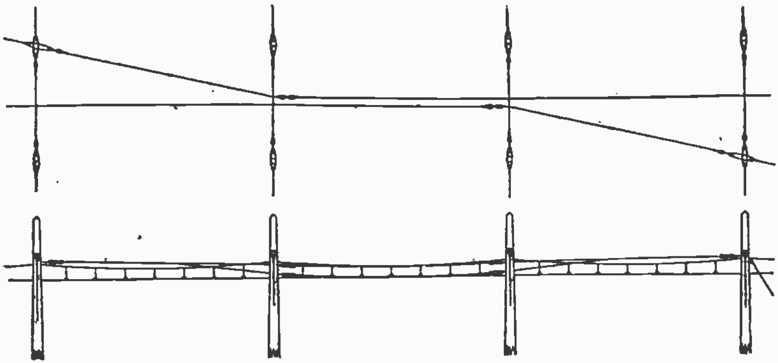


FIG. 5,931.—*Catenary construction 11.* Method of installing catenary section insulators.

Further modifications are in service, such as the use of a copper messenger wire which acts as a feeder wire, as well as steel or bronze contact wires which give increased strength and wearing qualities to the contact wires.

In the catenary system the trolley or slipper wire is suspended below the steel messenger cable by hangers at short intervals and of such lengths that the trolley wire is a straight line without sag.

There are various modifications of the simple construction such as the



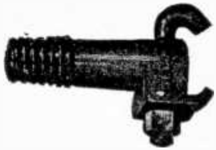
FIGS. 5,932 and 5,933.—*Catenary construction 12.* Method of sectionalizing line showing air break anchor construction.

use of a copper or aluminum feeder for the messenger or a steel or alloy slipper wire hung from the copper trolley wire to take the wear and introduce a small degree of flexibility where rigid hangers are used.

Compound catenary consists of a track messenger strand supported by insulators which are suspended from a main grounded messenger supported on bridges.

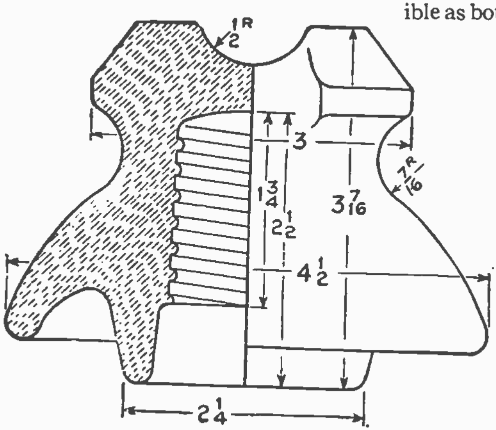
There are other combinations which have been developed to meet certain conditions but the best practice ordinarily is to keep the construction as simple as possible.

In flexible construction, the hanger which suspends the trolley from the



messenger is gripped to the trolley wire and loosely looped over the messenger to permit a free movement of the trolley vertically.

In rigid construction, the hangers are rigidly attached to both the messenger and the trolley. As such construction tends to produce "hard spots" in the trolley at hanger points it is customary to suspend a slipper wire below the trolley at points intermediate of the hangers thus giving just enough flexibility to remove the "hard spots." Both constructions are in successful use and both have points of merit; in designing a new line care should be used not to have it too rigid or too flexible as both extremes lead to trouble.



For the heaviest construction, the introduction of a second or auxiliary messenger wire permits an increase in the distances between the line supports, which may be steel bridges from 240 to 300 feet apart.

Figs. 5,934 to 5,936.—*Catenary materials 1.* General Electric insulator pin and insulator. The pin shown in fig. 5,934, is for "T" iron brackets; it can be adjusted along the bracket arm longitudinally. The diameter at the top is 1¼ inch and is suitable for cementing in insulators having 1⅜ inch diameter pin hole. The messenger or pin type insulator figs. 5,935 and 5,936, is adapted for use on voltages up to and including 3,000 volts. It is recommended that insulators be generally purchased assembled on the pins so that purchasers may have the benefit of the high voltage shop test after assembling. When assembling the insulators in the field, the cementing should be done with a good grade of neat Portland cement.

Catenary construction is well adapted to any voltage, but special consideration should be paid to the design of all insulation in anchorage and strains for the higher voltages.

Because of the importance of maintaining the wires in correct location, the tensions in both messenger and trolley are carried higher than in direct suspension systems with the result that all anchorages and strains are under high loading.

For single track lines, wood poles with steel brackets may be used, on double track, cross spans from wood poles with the poles carefully guyed.

For heavy service, the steel bridge or steel poles with cross

FIGS. 5,937 and 5,938.—*Catenary materials 2.* General Electric span wire messenger supports. They are used for the attachment of the messenger cable to the cross span and are used throughout tangent and curves in cross span construction, except when replaced at anchorages by anchor clamps. The supports are arranged for adjustment to any angle between the messenger and span wires. Fig. 5,937, shows the support which is intended for use in ordinary line construction, and fig. 5,938 a support which is especially adapted for use in yards where many tracks are spanned, the regular cross span wire being picked up at the messenger supports and attached to another cross span wire located above. Both supports are arranged for ⅜ inch span wire and ⅜ inch to ½ inch messenger wire.

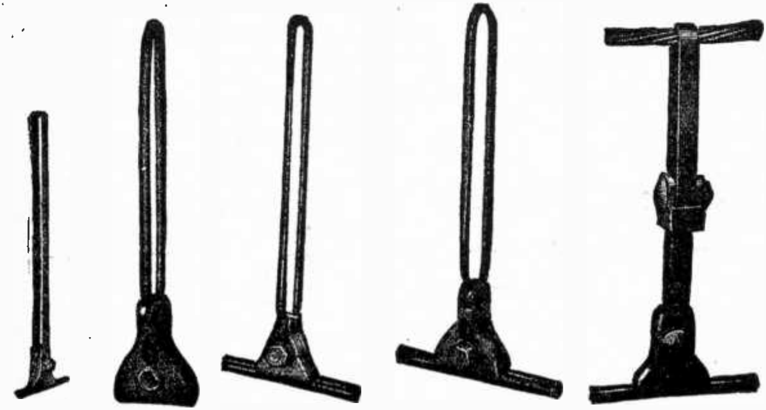
spans make a more substantial construction and reduce the amount of guying that is found necessary with wood pole construction.

With wood pole bracket construction, the messenger must be free to move longitudinally at the insulated support so as to maintain a uniform tension and thus relieve the bracket of strain.

With steel bridge construction, this movement between the insulator and messenger may be prevented and each span designed to take care of its own changes in tension.

Temperature, wind and ice change the tension and sag and must be carefully considered in the design.

The construction must be such that the tension in all wires is below their elastic limit when they are subjected to their maximum wind and ice loading and minimum temperature. It is also important that the stringing of the wires be done in accordance with a temperature tension sag chart, shown in fig. 5,971.



FIGS. 5,939 to 5,943.—*Catenary materials 3.* Various General Electric tangent hangers. The straight line hangers for supporting the trolley wire from the messenger cable are provided with various forms of loops or flexible connections for attaching to the messenger cable, and different forms of mechanical clamping ears for fastening to the trolley wire. The flexible connection or loop hanger for use between messenger and trolley wire permits of a free vertical movement of the trolley wire and hanger from the upward pressure of the collecting device, thus eliminating any pounding or hammer blow directly underneath the hanger and thereby materially increasing the life of the trolley wire itself.

As one of the advantages of catenary construction is the straight trolley without sag, the distance between hangers is important.

Hanger spacings vary from 10 to 50 feet, but it has become common practice to use a nominal spacing of 15 feet for a pantograph or sliding

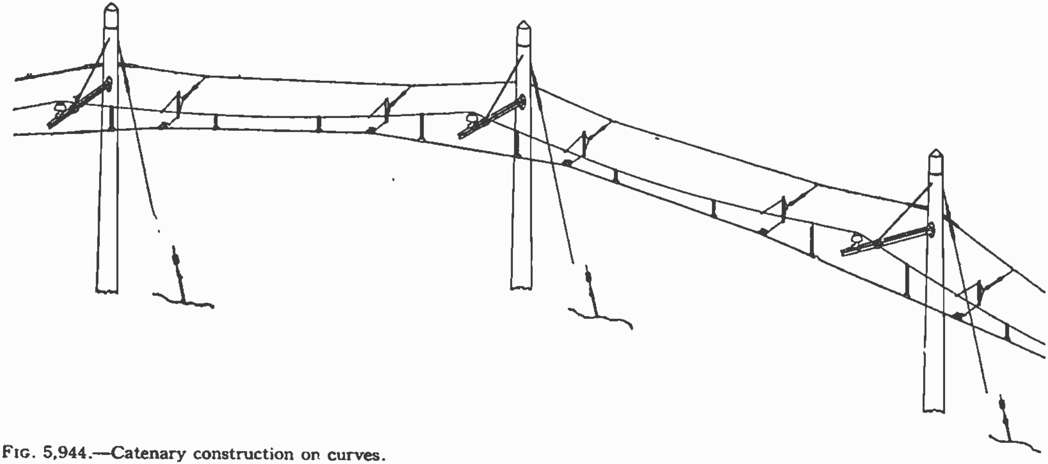


FIG. 5,944.—Catenary construction on curves.

collector and 30 feet for a pole and wheel collector. Especially on electrifications in cities it is often impossible to maintain a standard pole or bridge spacing, in which cases the hanger spacings may only approximate the standard. In a catenary line everything depends upon the messenger, which must never fail. For this reason ordinary steel strand is not recommended.

Siemens-Martin steel is the lowest grade that can be depended upon for the messenger or important anchorages and where loading is high it is better to use high strength or extra high strength.

For ordinary wood pole construction $^7/_{16}$ inch extra galvanized strand is generally used, but on long span bridge construction strand as large as ⅝ inch may be used for the messenger. The correct size to use should be determined by calculation and not assumed from similar practice. For light pull offs and steady strains ½ inch strand is strong enough and is easily worked.

Pole Spacings.—With wood poles, pole spacings as high as 180 feet may be used but 150 feet is common practice for tangents. For steel bridge construction spacings as great as 300 feet, on tangent, are in use.

Curves.—The construction of curves is one that requires considerable study as there are a number of points which must not be overlooked. The trolley is located with respect to the degree of curvature and curve elevation of the track.

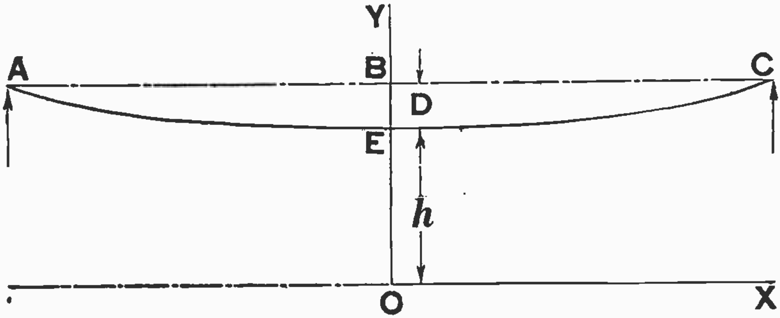


FIG. 5,945.—Catenary curve diagram.

This must be corrected for the side swing of the pantograph or collector and the magnitude of this side swing depends upon the height of the trolley wire and the spring action of the trucks. The transition at the ends of the curve introduces another correction that requires careful treatment. There are curve constructions that can be laid out to produce an ideal condition, but if the construction be not capable of easy adjustment to accommodate track realignment or changes in supporting structures it will develop troubles in operation and high maintenance.

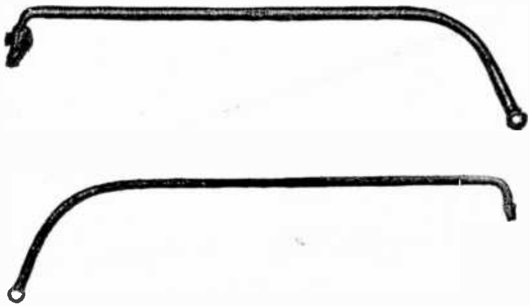
A good curve construction must hold the line in place, but be capable of being easily tuned up and must provide, at all times, a smooth underrun for the collector.

Where pantographs are used, care must be taken to keep all pull-offs clear of the swing of the collector pan or roller. The general practice is to have a clearance of 6 inches above the trolley wire at a distance of 3 feet on each side.

Where poles are located on the outside of curves having large radii (1 degree or less), a single line steady or pull off, located underneath the bracket, may be used, thus avoiding the expense of erecting a "back bone" construction.

The standard construction for wheel operation consists of an ear, yoke, strain insulator and eye bolt.

Where poles for wheel operation are located on the inside of curves of 1



Figs. 5,946 and 5,947.—*Catenary materials 4.* General Electric pipe pull offs. In figs. 5,946 the pull off is made of pipe, the ends of which are formed into eyes. One eye is used to attach the pull off wire and the other to bolt on the ear. The distance between the pull off eye and the ear is 3 ft. which provides a clearance of 6 inches for the collectors. The diameter of the eye is ⅝ inch. All parts are sherardized. It is suitable for slider or roller collectors only. The pull off arm, shown in fig. 5,947, is made of pipe, one end of which is formed into an eye and the other into a button head. The eye is used to attach the pull off wire, and a pair of Form L, clamping jaws are attached to the button head for holding the trolley wire. This pull off is 36 ins. long between the center of the eye and trolley wire, and can be used in connection with either slider or wheel collectors. All parts are sherardized. This pull off is generally preferred on account of its light weight.

degree or less, a longer bracket supporting an outer end drop casting should be used together with an ear, yoke, and strain insulator. A 10 ft. arm readily provides clearance and flexibility for this construction on 150 ft. pole spacing on 1 degree curves. On all curves above 2 degrees, the back bone method of construction is recommended for wheel operation. One or more pull offs per span may be used, depending on the radius of the curve. The flexible pull off construction, fig. 5,944, readily permits operating around curves at the maximum speed permissible for the curve. This construction is preferred where possible.

For wheel operation where poles must be located on the inside of track on curves of more than 1 degree, the back bone method of construction may be supported by outer end drop castings as shown in the illustration. This construction should be limited to 6 degree curves as a maximum, because above this the pole spacing required is necessarily so short that cross span is more economical. The bracket arm should be at least 12 feet long, and some conditions require a 14-foot arm

On long stretches of tangent track, it is often advisable to install line steadiers to prevent a swaying motion which may be set up by the passing collector.

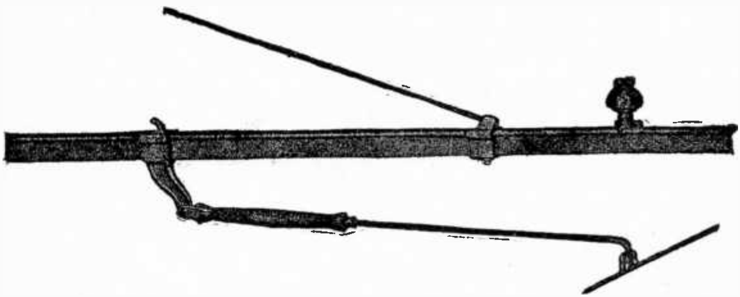


FIG. 5,948.—*Catenary materials 5.* General Electric steady braces. The steady brace for 600 and 1,500 volt lines consists of a malleable iron bracket casting, a wooden body, goose neck rod, and clamping ear. Lateral adjustment is obtained by moving the bracket casting along the bracket arm. It is held in position by a ⅝ in. cup set screw. The brace here shown is suitable for standard sizes of T iron.

For wheel operation, an outer end drop casting supporting an ear, double curve yoke, and strain insulators installed every 600 or 1,000 feet will effectively overcome any tendency in the line to sway.

Catenary Formulæ.—On curves, the distance between messenger supports (pole spacing) is reduced to prevent too great a deflection at the center of the span.

The deflection at the center of the span or at the center between pull-offs can be found from the formula:

$$D = 12\left[R - \sqrt{R^2 - \frac{S^2}{4}}\right]$$

Where

D = Deflection (middle ordinate) at center of span or between pull-offs in *inches*.

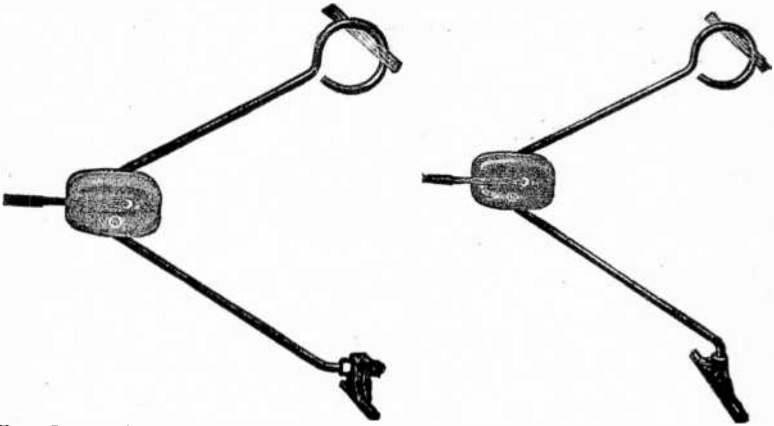
R = Radius of curve in *feet*.

S = Length of span or distance between pull-offs in *feet*.

It is good practice to keep this deflection between pull-offs under 6 inches and the deflection angle for wheel operation under 6°.

In fig. 5,945, the general equation of the catenary AEC, with the origin O, at a distance h, below the curve E, is

FIG. 5,949.—*Catenary materials 6.* General Electric butt end trolley wire jointing sleeves



FIGS. 5,950 and 5,951 —*Catenary materials 7.* Ohio Brass Co. pull off hangers. Used in curve construction where it is necessary to pull messenger and trolley into position. Consists of a ½ in. steel rod shaped as shown. The upper end is formed into a loop which gives a flexible connection with the messenger and the lower end is equipped with a malleable iron clamp which will fit 2-0 to 4-0 grooved trolley wire or an extruded ear which fits 4-0 grooved wire. Rod can be installed in a porcelain strain insulator as shown, before clamp is installed.

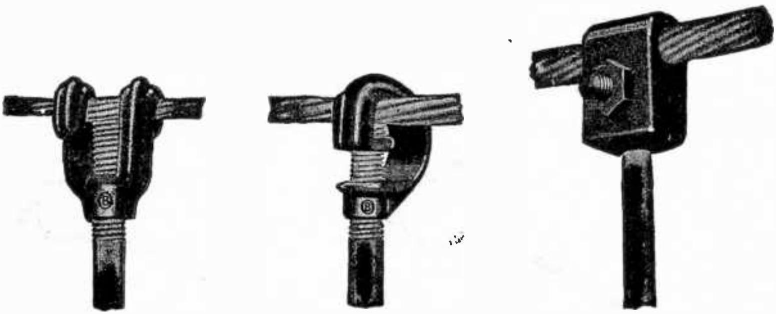
$$y = \frac{h}{2}\left(e^{\frac{x}{h}} + e^{-\frac{x}{h}}\right) \qquad (1)$$

where "e" is the base of the Naperian (hyperbolic) system of logarithms (e=2.7183). Where the sag is small in proportion to the length ot span, which is usually the case on railway catenary or transmission construction, the curves of a parabola will fill all the conditions of the catenary within practical limits of measurement.

Substituting the parabola formula,

$$y = h + \frac{x^2}{2h} \qquad (2)$$

T = Total tension in wire in *pounds.*



FIGS. 5,952 to 5,954.—*Catenary materials 8.* Various Ohio Brass Co. messenger clips. They are installed by hooking clip over messenger wire, turning rod until upper end grips messenger tightly. Used with any ½ or ⅝ in. rod. The clip shown in fig. 5,954 has a concealed nut for threading on to ½ in. rod. Tightened onto messenger wire with bolt.

W = Load in *pounds* per *linear foot* of span (including weight of wire).

S = Length of span in *feet* = ABC.

D = Deflection or sag at center of span in *inches* = BE.

L = Actual length of wire in *feet* = AEC.

$$h = \frac{T}{W} \qquad (3)$$

From (2) and (3) the following useful formulæ are derived:

$$\text{(Pounds)}\ T = \frac{3}{2}\frac{S^2W}{D} \qquad (4)$$

$$\text{(Inches)}\quad D = \frac{3}{2}\,\frac{S^2W}{T} \quad \ldots\ldots (5)$$

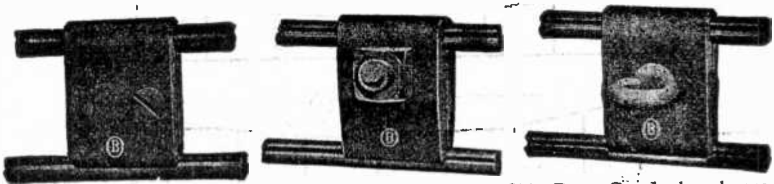
The length of the wire in the span is

$$\text{(Feet)}\quad L = S + \frac{D^2}{54S} \quad \ldots\ldots (6)$$

$$\text{(Inches)}\quad D = \sqrt{54S(L-S)} \quad \ldots\ldots (7)$$

The length of hangers is $y-h+6$. Where 6 is the distance in inches the trolley wire hangs below the lowest point of the messenger, E. Six inches is the generally accepted standard but may be changed if desired.

$$\text{Hanger length in inches} = \frac{6x^2W}{T} + 6 \quad \ldots\ldots (8)$$

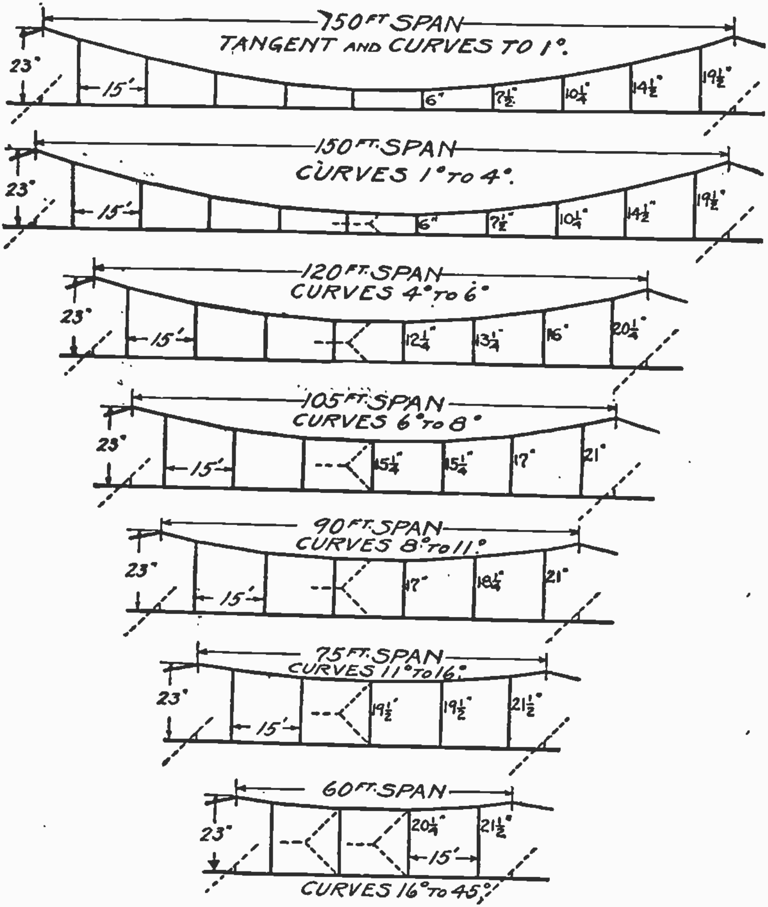


FIGS. 5,955 to 5,957.—*Catenary materials 9.* Various Ohio Brass Co. duplex clamps. They are used where it is desired to install two trolley wires—a steel contact wire because of its wearing qualities and a copper wire for feeder, the latter being supported from a messenger in the same manner as when single catenary construction is used. Installed midway between regular catenary hangers, thus providing greater flexibility. Clamps completely encircle upper wire but allow longitudinal movement.

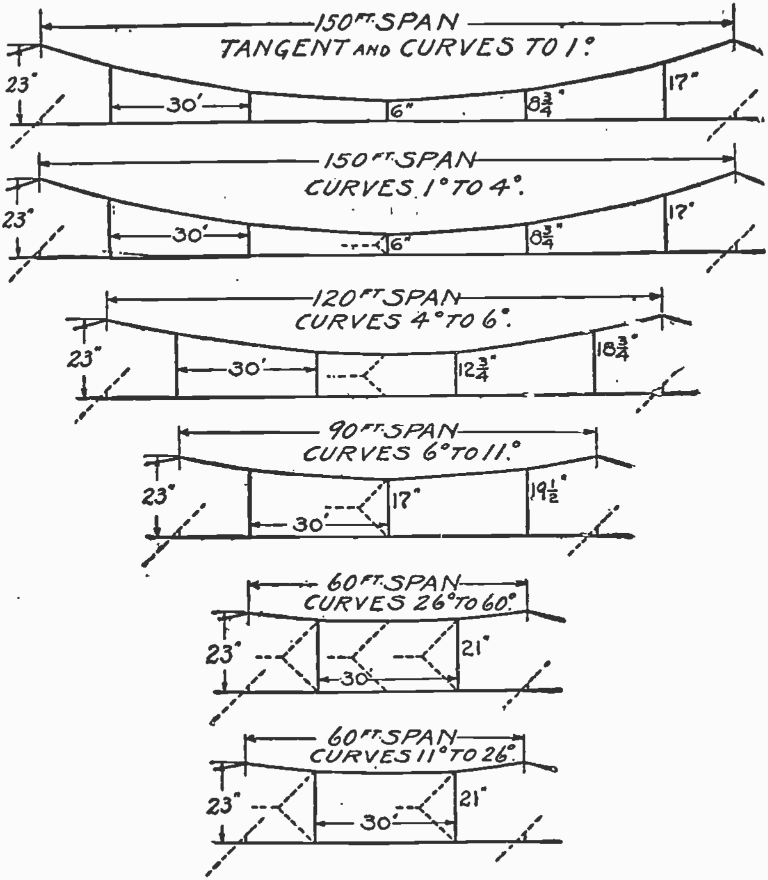
where x. is the distance (feet) from the center of the span to the hanger in question. Hanger length is measured from center of messenger to center of trolley wire.

Sag in Spans.—The curves fig. 5,971 show the relation of tension to sag for the spans shown in figs. 5,958 to 5,970 and also show the effect of temperature changes. These sag curves are plotted from the formula

$$T = \frac{3}{2}\,\frac{S^2W}{D}$$



FIGS. 5,958 to 5,964.—Hanger lengths for 150 ft. pole spacing on tangents and proper shorter spacings and pull off locations for curves. Hangers spaced 15 ft. for pantograph or wheel collector. The curves figs. 5,971 and 5,972 are calculated for these spans.



FIGS. 5,965 to 5,970.—Hanger lengths for 150 ft. pole spacing on tangents and proper shorter spacings and pull off locations for curves. Hangers spaced 30 ft. for wheel collector. The curves figs. 5,971 and 5,972 are calculated for these spans.

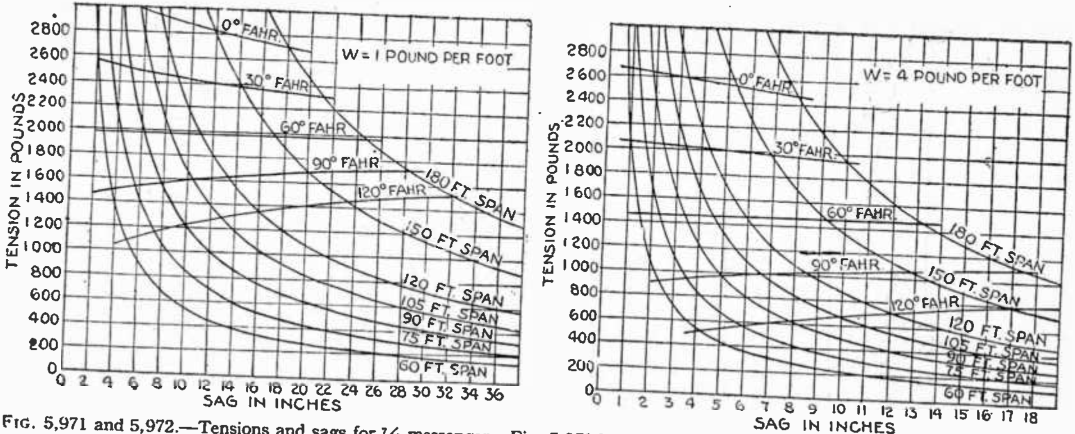


FIG. 5,971 and 5,972.—Tensions and sags for 7/16 messenger. Fig. 5,971 loaded messenger; fig. 5,972 unloaded messenger.

W, is taken at 1 pound per foot and the temperature curves are calculated for a 7/16 inch steel messenger having a cross section of .1188 sq. in. and a modulus of elasticity of 22,000,000. For other conditions it is necessary to plot other curves.

The curves in fig. 5,971 are all calculated for the same tension at 60° which gives the sags and hanger lengths as shown in figs. 5,958 to 5,970. It is obvious that all the spans in a given line must have the same tension when at the same temperature; otherwise each span would have to be anchored.

The temperature curves show that if the trolley wire be a straight line at 60° it will be curved upward when the temperature falls and sag down when the temperature rises. The changed tensions and sags are shown at the intersections of the temperature and sag curves. These curves are calculated from constants and in practice the results will vary from the calculated quantities.

Messenger strand should always be pulled up to the approximate working tension and be permitted to take its initial set before anchoring it for the required sag. Variations in tension and sag due to temperature changes may not be as

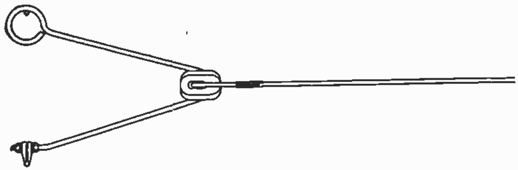


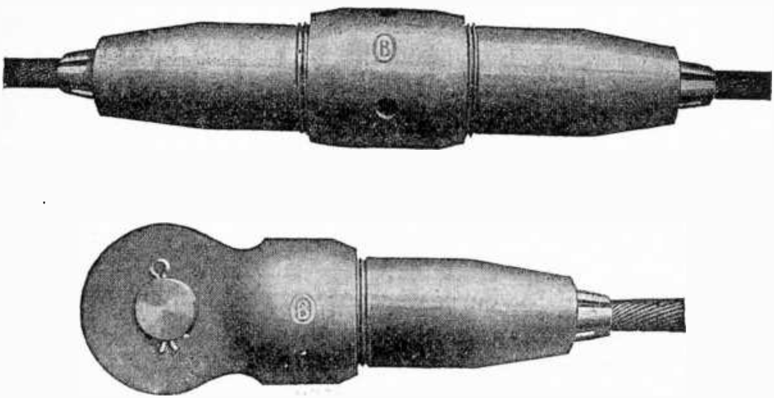
FIG. 5,973.—Ohio Brass pull off hanger for wheel or pantograph.

great as shown in the curves because of the flexibility of poles and anchorages, but when poles and anchorages are rigid the changes shown will take place.

The curves in fig. 5,972 show the sags and temperature changes for the same 7/16 in. steel messenger and spans as in fig. 5,971, except that the messenger is unloaded. Fig. 5,972 is useful in erecting the line as it shows the tension and sag to pull the messenger to before suspending the trolley wire and hangers. After the trolley wire is suspended the conditions are as shown in fig. 5,971.

Ice and Wind Loads.—In figuring ice and wind loads it is customary to assume an ice coating ½ inch in thickness and a wind pressure on the ice coated wire of 8 pounds per sq. ft. of projected surface. The weight of ice is figured at .033 lbs. per cu. in

For districts not affected with sleet formation a maximum wind pressure of 30 lbs. per sq. ft. of projected surface is frequently used as the limiting condition. In all cases find minimum and maximum temperature from the Weather Bureau. The Bureau of Standards issues publications dealing with the loading of wires.



FIGS. 5,974 and 5,975.—Ohio Brass catenary messenger splicer and dead end. FIG. 5,974, cable splicer; fig. 5,975, dead end.

FIG. 5,976.—Ohio brass catenary messenger cable dead end or strain insulator.

TEST QUESTIONS

1. *From what does the catenary system derive its name?*
2. *Describe a simple catenary system.*
3. *For what conditions is the catenary system well adapted?*
4. *Draw a sketch showing span anchor construction for pantograph collector.*
5. *How are connecting links installed for turnouts and crossings?*
6. *What is a pull off spreader?*
7. *Describe a flexible pull over for pantograph.*
8. *Draw a sketch of catenary cross bands for single track.*
9. *What is a duplex catenary?*
10. *Draw a sketch showing method of installing catenary section insulators.*
11. *Describe the method of supporting the trolley or slipper wire.*
12. *What is a compound catenary?*
13. *Is catenary construction well adapted to any voltage?*
14. *What kind of poles may be used for single track lines?*
15. *What kind of supporting structure should be used for heavy service?*
16. *Why is the distance between hangers important?*
17. *What spacing should be given to poles?*
18. *Describe the catenary construction on curves.*
19. *What is the requirement for a good curve construction?*
20. *What precaution must be taken where pantographs are used?*

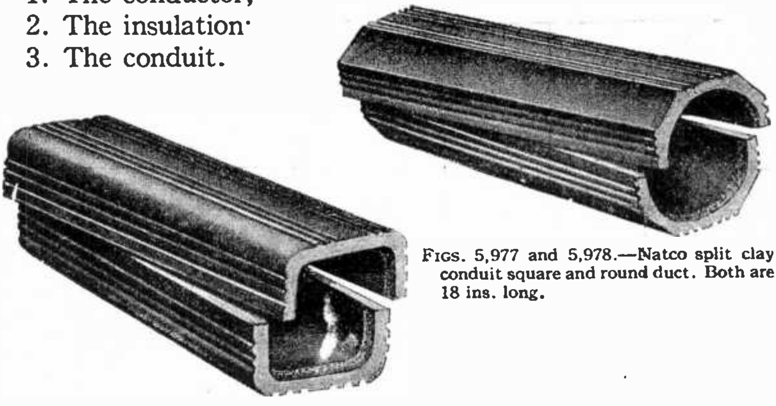
21. *What should be provided on long stretches of tangent track?*
22. *Describe the construction of steady braces.*
23. *Give the various formulæ used in the design of catenary systems.*

CHAPTER 127

Wiring Underground

An underground system of electrical conductors is composed of three essential elements:

1. The conductor;
2. The insulation·
3. The conduit.



FIGS. 5,977 and 5,978.—Natco split clay conduit square and round duct. Both are 18 ins. long.

The various underground systems may be divided into three classes:

1. Lead encased cables laid directly in the ground;
2. Solid or built in systems;
3. Drawing in systems.

Where cables are laid directly in the ground, the metallic covering, consisting usually of a lead tube which is placed over the insulation is depended upon for mechanical protection.

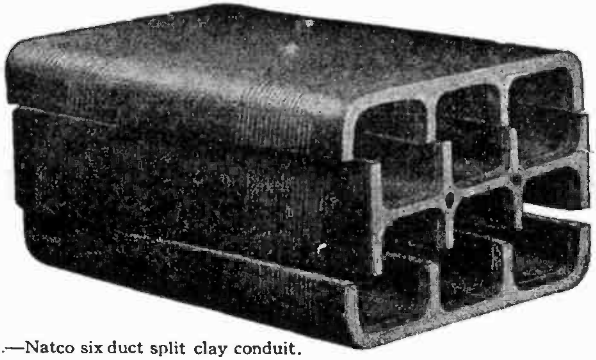
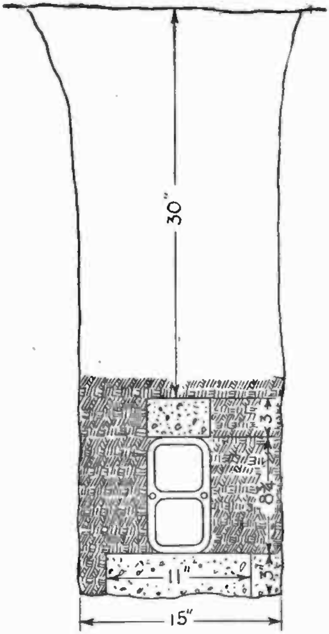
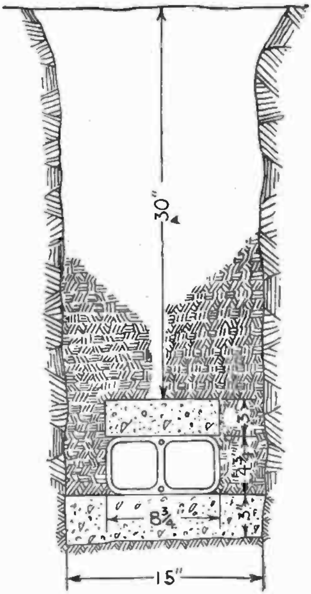
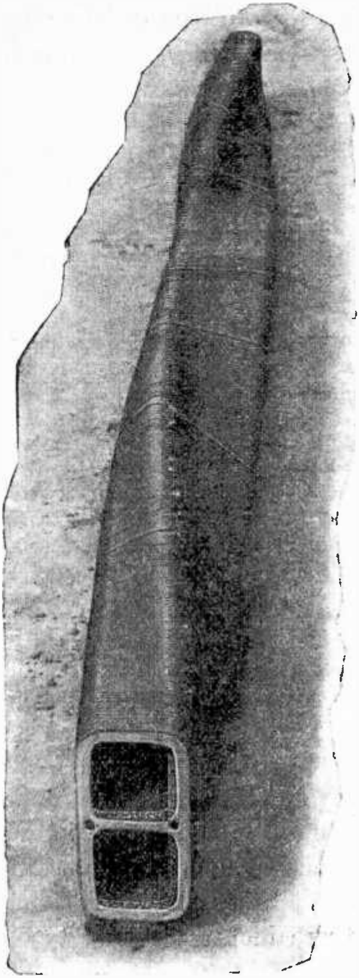


FIG. 5,979.—Natco six duct split clay conduit.





FIGS. 5,980 and 5,981.—Typical bank formations Natco multiple duct clay conduit. Fig. 5,980, 2 ducts, 3¼ in. bore, 1 wide formation; fig. 5,981, 2 ducts, 3¼ in. bore, 2 wide formation.



Such cables are largely used for short private lines and the first cost is less than that of the others, but in case of repairs they have to be dug up.

The conduit of the solid or built in systems consists of steel pipe or concrete trenches, and that of the drawing in system consists of various forms of pipe or troughs of iron, earthenware, concrete, wood or fibre, etc.

Conduits.—There are numerous kinds of conduits, and they may be classified with respect to material, as

1. Vitrified clay;
2. Wood;
3. Fibre;
4. Metallic.

Vitrified Clay Conduit. — By definition, *vitrified clay* is a *clay which has been subjected to intense heat so as to receive a glassy surface which renders it proof against chemical action.*

FIG. 5,982.—Natco 2 duct transposition conduit; typical assembly. 90° combination *l.h* and *r.h* assembly. Total length 16 ft. Another use of this shape is to provide a 180° assembly either *r.h.* or *l.h.* in a distance of 16 ft. for the purpose of reversing the position of top and bottom cables.

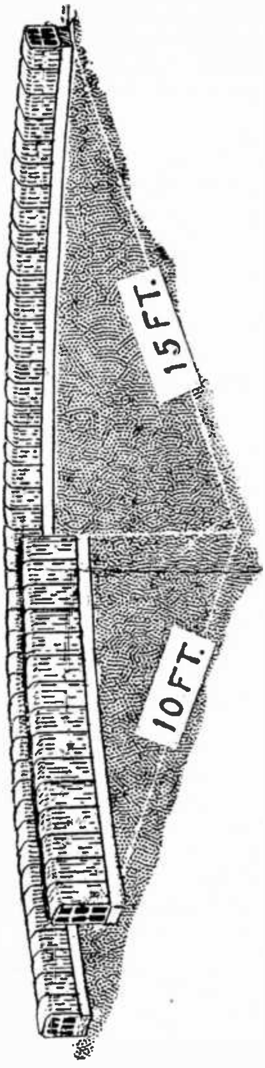


FIG. 5,983.—Assembly of Natco slant (or mitered) conduit for building curves. The illustration shows: 6 way edge position 45°, 10 ft. radius; also, 6 way flat position 90°, 15 ft. radius.

It has very high insulating properties which make it very valuable for conduits in underground wiring, being at the same time inexpensive and easily laid.

The conduits are made in both single and multiple duct, the single type being about 3½ inches in diameter, or 3½ inches square, and 18 inches long. Multiple conduit is made in two, three, four, six and nine sections, ranging from 2 to 3 feet in length.

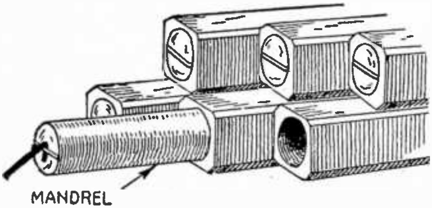
Single conduit is best suited where there is great crowding of gas, water and other pipes, as the conduit can be divided into several layers so as to cross over or under such pipes.

The multi-duct conduit can be laid somewhat cheaper, especially in lines of about two to four ducts; it is best suited to districts free from subsurface obstructions.

Laying Vitrified Clay Pipe Conduit.—In laying the conduit a trench is dug, usually sufficiently wide to allow the placing of three inches of concrete on each side of the ducts, and sufficiently deep to hold at least thirty inches of concrete on top of the upper layer of concrete forming the conduit, and to allow for three inches of concrete in the bottom.

The trench is graded from some point near the middle of the block to the manhole at each intersection, or from one manhole to the next manhole, at a gradient not less than 2 inches to 100 feet.

The tiles of the several ducts are placed close together, and the joints plastered and filled with cement mortar consisting of one part of Portland cement to one part of sand. When the conduit is being laid, a wooden mandrel about four or five feet long, three inches in diameter, and carrying at one end a leather or rubber washer from three to eight inches larger



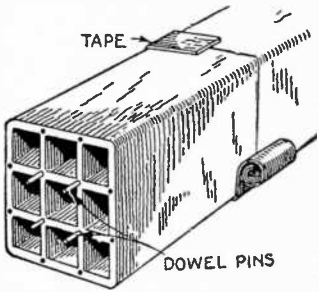


FIG. 5,984.—Method of laying single duct vitrified clay conduit. The tiles of the several ducts are placed close together as shown in the figure, and the joints plastered and filled with cement mortar consisting of one part Portland cement and one part sand.

FIG. 5,985.—Method of laying multiple duct vitrified clay conduit. The sections are centered by the dowel pins shown in the cut.

is drawn through each duct so as to draw out any particles of foreign matter or cement which may have become lodged in the joints, and also to insure good alignment of the tiles.

Single duct conduits are usually laid by bricklayers. This fact accounts for the somewhat greater cost of the single over the multiple conduit which is usually laid by ordinary laborers. One good brick layer and helper, however, will lay from 200 to 300 feet of single duct conduit per hour.

Vitrified Clay Trough Conduit.—It consists of troughs either simple or with partitions as shown in fig. 5,986.

They are usually made in tiles 3 or 4 inches square for each compartment, with walls about one inch thick. The length of the tiles ranges from two to four feet. Each of the two foot form duct troughs weighs about 85 pounds. When laid complete, the top trough is covered with a sheet of mild steel, about No. 22 gauge, made to fit over the sides so as to hold it in position, and then covered over with concrete.

Laying Trough Conduit.—In laying multiple duct earthenware conduit, the ducts or sections are centered by means of dowel pins inserted in the holes at each joint, which is then wrapped with a six inch strip of asphalted burlap, or damp cheese cloth, and coated with cement mortar as shown in fig.

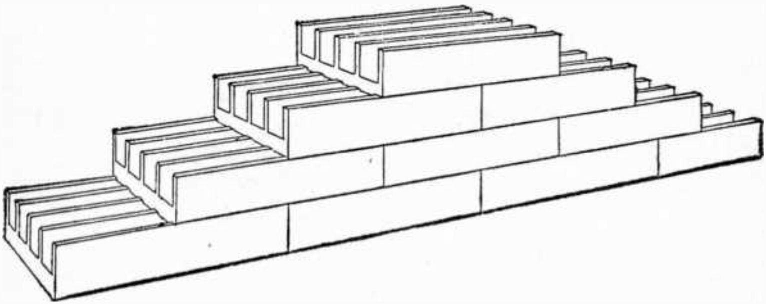


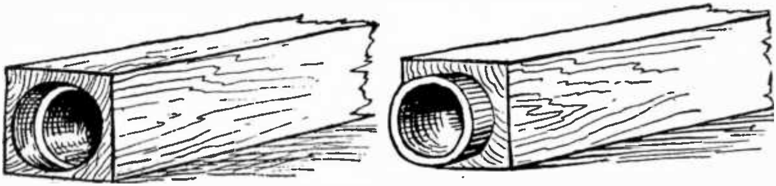
FIG. 5,986.—Vitrified clay or earthenware trough conduit; this type of conduit consists of troughs either simple or with partitions, the latter type being shown in the figure.

5,985. Economy of space and labor constitutes the principal advantages derived from the use of multiple duct conduit.

Concrete Conduits.—These are usually constructed by placing collapsible mandrels of wood or metal in a trench where the ducts are desired and then filling the trench with concrete.

After the concrete has solidified, the mandrels are taken out in pieces, leaving continuous longitudinal holes which serve as ducts. Some builders produce a similar result by placing tubes of sheet iron or zinc in the concrete as it is being filled into the trench. These tubes have just enough strength to withstand the pressure to which they are subjected, and are, therefore, very thin and liable to be quickly destroyed by corrosion, but the ducts formed by them will always remain unimpaired in the hardened mass of concrete.

Wooden Conduits.—In this type of conduit, the ducts are formed of wooden pipe, troughing or boxes, and constitute the simplest and cheapest form of conduit.



FIGS. 5,987 and 5,988.—Wooden pipe type of conduit showing female and male ends.

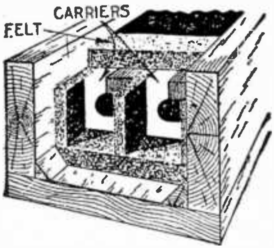


FIG. 5,989.—Perspective view of wooden built-in conduit. *It consists of* an outer rectangular casing of wood which is lined inside with impregnated felt. *In construction,* a wooden trough is laid in a trench about 18 inches deep. Porcelain carriers are placed in the trough at intervals of 4 to 5 feet, to act as bridgework for supporting the conductors. This bridgework is placed on and is surrounded by impregnated felt or similar material, and the spaces between the carriers, after the conductors have been placed in position on them, is filled with voltax, which hardens rapidly and forms a solid insulating material throughout the conduit.

A pipe conduit consists of pieces of wood about 4½ inches square, and three to six feet long, with a round hole about three inches in diameter bored through them longitudinally. As shown by fig. 5,988 a cylindrical projection is turned on one end of each section, which, when the conduit is laid fits into a corresponding recess in one end of the next section. The sections are usually laid in tiers, those of one tier breaking joint with those of the tiers above or below.

The trough conduit consists of ducts about 3 inches square made of horizontal boards and vertical partitions, usually of yellow pine about one inch in thickness. This form of conduit can be laid in lengths of 10 and 12 ft., or it can be built along continuously. The life of wooden conduit may be increased by the application of sterilizing processes.

Wrought Iron or Steel Conduits.—These are formed of

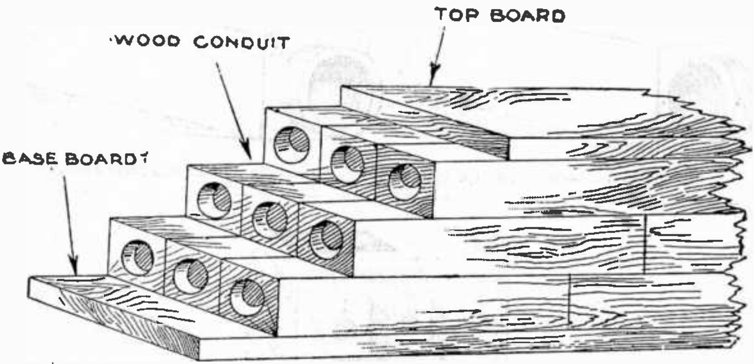


FIG. 5,990.—Wyckoff multi-duct creosoted wooden conduit showing top and base board, Each piece registers with the adjoining piece, by means of the mortise and tenon joint without the use of mandrels, or other means to make the alignment of adjacent pieces perfect.

pipes similar to gas or steam pipes, with screw or other connections.

They are laid either simply in the earth, or in hydraulic cement, and are the strongest and one of the most satisfactory forms of underground conduit. In construction, a trench, the width of which will depend upon the number of pipes to be laid, is first dug in the ground, and after its bottom has been carefully leveled, is braced with side planking and filled to the depth of two to four inches with a layer of good concrete, consisting of two parts of Rosendale cement, three parts of sand, and five parts of broken stone capable of passing through a one and one-half inch mesh.

This concrete is well secured in place and forms the bed for the lowermost layer or tier of pipes.

Ordinary wrought steel or preferably wrought iron pipe is employed, in 20 foot lengths about three to four inches in diameter, depending upon the size and number of cables they are intended to carry. After the last tier of pipes has been put in place, and a layer of concrete from two to four inches placed over it, a layer of two inch yellow pine planking is laid over the whole.

The principal object of the top covering is to protect the conduit against the tools of workmen making later excavations.

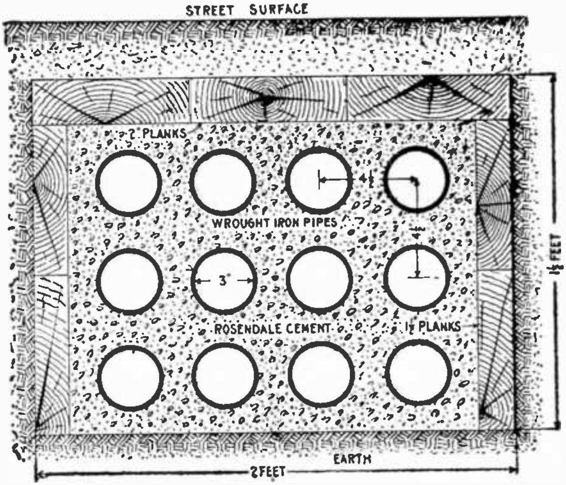


Fig. 5,991.—Cross section of wrought iron pipe conduit laid in hydraulic cement.

Practical experience shows that workmen will dig through concrete without stopping to investigate as to the character of the obstruction, but under similar circumstances, will invariably turn away from wood.

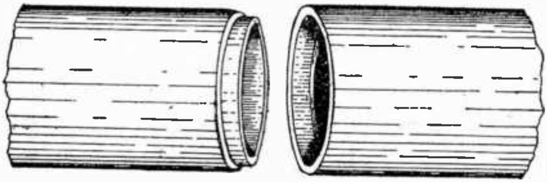
In best construction the pipes are lined with a layer of cement ⅝ in. thick and containing no sand.

Cast Iron Conduit.—Cast iron pipe for underground conduits is similar to ordinary wrought iron pipe, except that it is thicker.

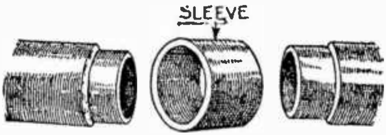
The additional thickness is necessary to make the strength equal to that of wrought iron; it is therefore heavier to handle and more expensive.

The trough conduit consists of shallow troughs of cast iron in six foot lengths, laid directly in the earth so as to form a system of continuous troughing in which the conductors are placed and then covered over by cast iron covers which are bolted to the trough.

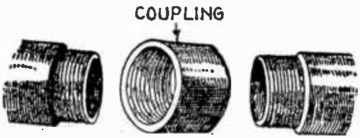
The advantages are that the cables can be laid directly in place, thus eliminating any chance of injury during the process of drawing in, and second, the cables are easily accessible at any point by simply removing one or two of the sectional cast iron covers, thus permitting of their being readily inspected and repaired.



FIGS. 5,992 and 5,993.—Fibre conduit socket joint. The joint is cut to a slight taper, uniform in size and reamed so that there is no appreciable offset on the inside of the pipe at the joints. Since these joints are machine cut, they form a connection that is perfect in fit and alignment. The socket joint, while not offering all the advantages of the tapered sleeve, gives satisfactory results for underground conduit systems when laid in concrete.



FIGS. 5,994 to 5,996.—Sleeve joint type of fibre conduit. Both the socket type and the sleeve type here shown are easily aligned without the use of a mandrel.



FIGS. 5,997 to 5,999.—Screw joint type of fibre conduit. This method of connection will form a tight line and is suitable for running under the lawns of private houses and parks, under the streets of towns and villages, and in other places where the cost of building electric subways is prohibitive.

Fibre Conduits.—This form of conduit consists of pipes made of wood pulp impregnated with a bituminous preservative and insulating compound.

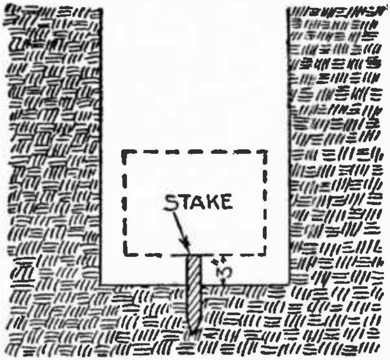
Three types of joint are available for connecting lengths of fibre conduit.

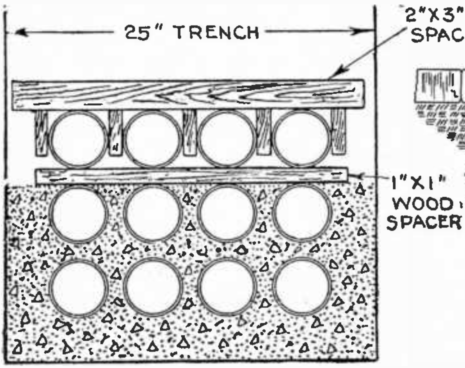
1. Socket joint;
2. Tapered sleeve joint;
3. Screw joint.

These various types of joints are shown in figs. 5,992 to 5,999.

Installation of Fibre Conduit.—There are two methods of installing fibre conduit.

1. Tier by tier method;
2. Built up method.





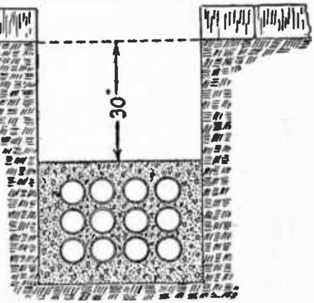
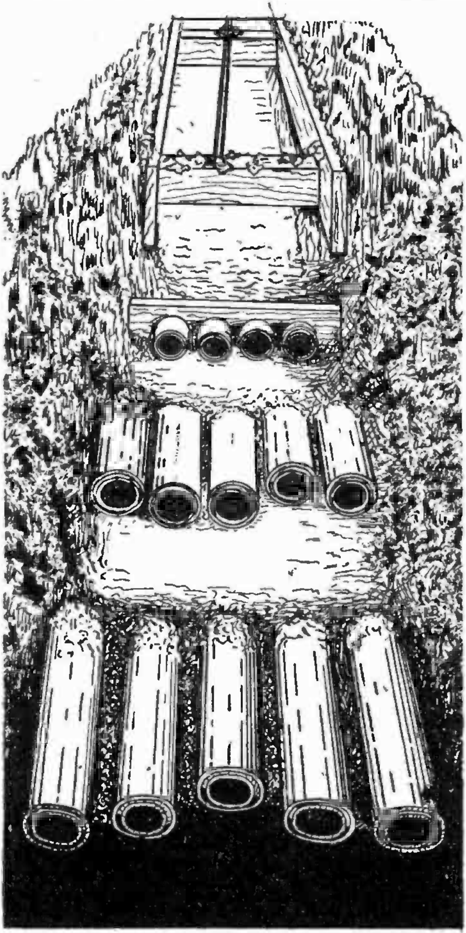


FIG. 6,000.—Conduit excavation showing grade stake.

FIG. 6,001.—Installation of fibre conduit showing spacers which are removed when tiers are partly concreted.

FIG. 6,002.—Conduit installation ready for backfill.

Tier by Tier Method.—This consists of placing on the bed of the trench a foundation of concrete, laying thereon the lowest tier of ducts, holding them at the desired horizontal separation, filling the spaces between the ducts with the concrete and spreading concrete over them until the desired vertical separation has been obtained. The operation is repeated tier by tier until the required number of ducts has been laid.



The concrete base for the conduit should be laid only on firm dirt carefully tamped. This base is usually made 3 ins. thick, the proper depth being insured by stakes driven at intervals into the bottom of the trench and extending 3 ins. above the grade. A space 3 ins. wide between the duct rows and each side of the trench is also filled with concrete and the top tier finally likewise covered.

FIG. 6,003.—Tier by tier method of laying fibre conduit showing installation of 14 single duct conduits.

The several tiers are separated vertically and horizontally by concrete varying from 1 in. to 3 ins. according to voltage to be carried, amount of ventilation in the ducts and the personal conviction of the engineers.

Upon the concrete foundation the first row of conduits is laid, these being properly spaced by means of wooden or concrete combs, as shown in fig. 6,001, placed at approximately 3 ft. intervals. Concrete is

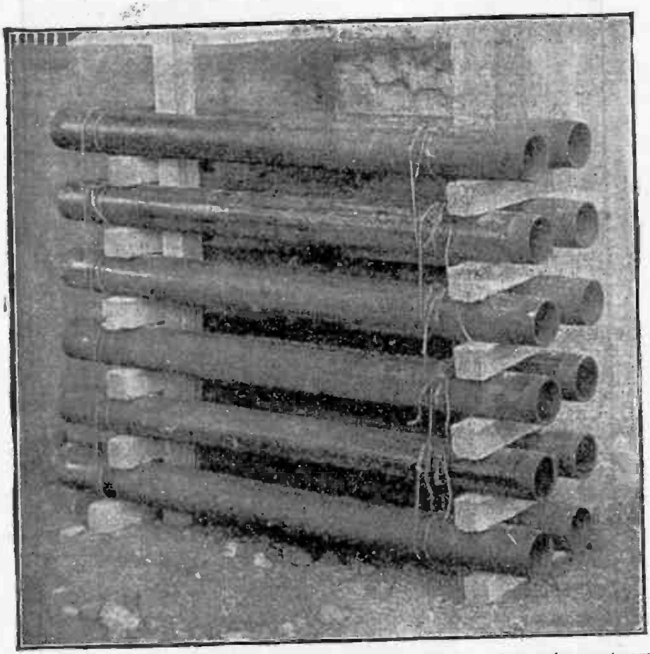


FIG. 6.004.—Orangeburg fibre conduit showing method of tying when using rectangular separators previous to installing by the built up method.

then poured until the tier of ducts is covered to the desired depth and tamped level, a spacing comb at the unfinished end of the line being left in place to indicate accurately the thickness of the concrete. If of wood, the comb is then removed. The desired duct section is thus formed in successive tiers.

Good engineering practice calls for staggering the joints in adjacent pipes and for making all joints perfectly tight to prevent concrete entering and blocking the ducts. Generally a 1-3-5 mixture is used consisting of one part of cement, three parts of sand and five parts of stone broken fine enough to pass a ¾ in. mesh sieve. The amount of water should be carefully watched so the concrete is just thin enough to be easily tamped around the

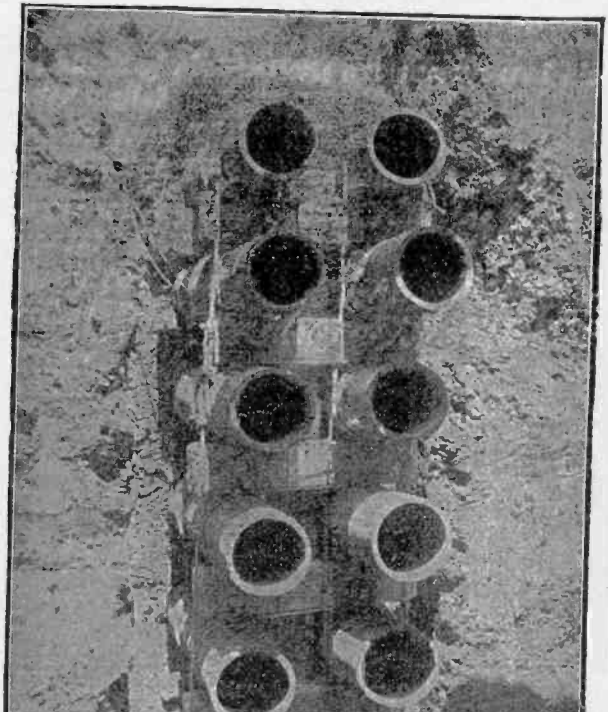


FIG. 6,005.—Built up installation of Orangeburg conduit using rectangular separators.

ducts with no superfluous moisture. The advantages claimed for this method by many engineers is the certainty that the separations between the several tiers of duct will be perfect.

As only a few inches thickness of concrete is spread at any one time, thorough tamping around each duct is readily accomplished and the possibility of voids eliminated.

Built up Method.—With this method the several tiers of duct are all placed in position one above the other before any concrete is poured. The

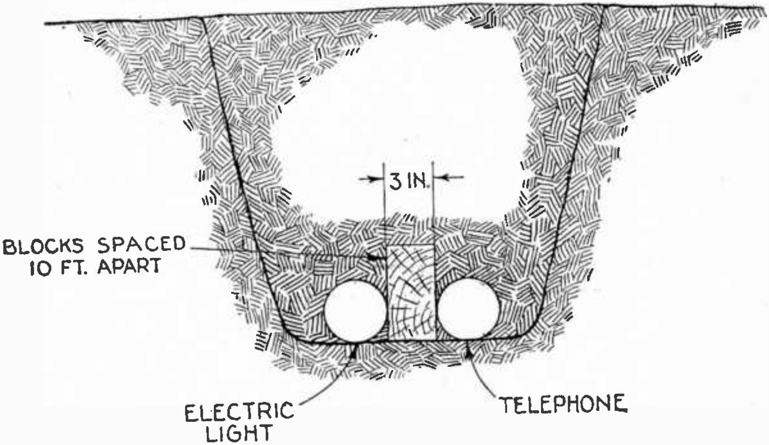


FIG. 6,006.—Telephone and electric light in same trench. Where the duct provided for electric service will be occupied by secondary circuits only which are connected to transformers not exceeding 25 *kw.* capacity, the clearance between telephone and electric light ducts must be not less than 3 ins. provided that stakes, spacers, bricks or paving blocks are placed every 10 ft. to make certain that this separation is maintained.

ducts are held in proper position by concrete separators which later become permanently inbedded in the concrete mass. These separators are of different design. Some engineers use rectangular forms of proper width placing them both vertically and horizontally at sufficient intervals to support the ducts rigidly.

To prevent all possibility of the ducts floating when the concrete is poured they are also bound together by tying them in groups of four with hemp twine. This must be done carefully in order to have the conduit runs perfectly in alignment when the work is completed.

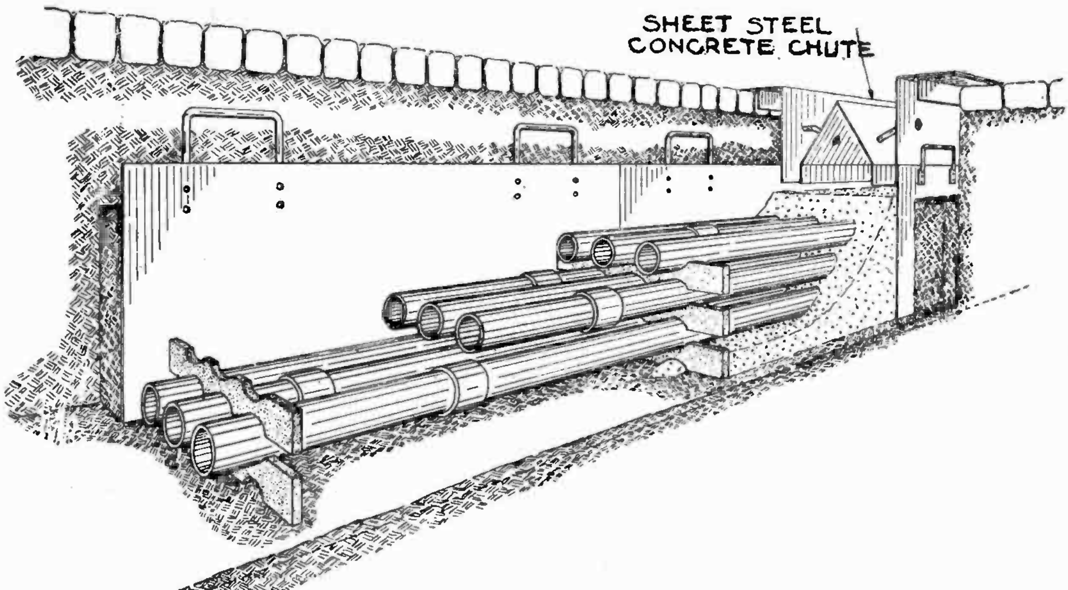
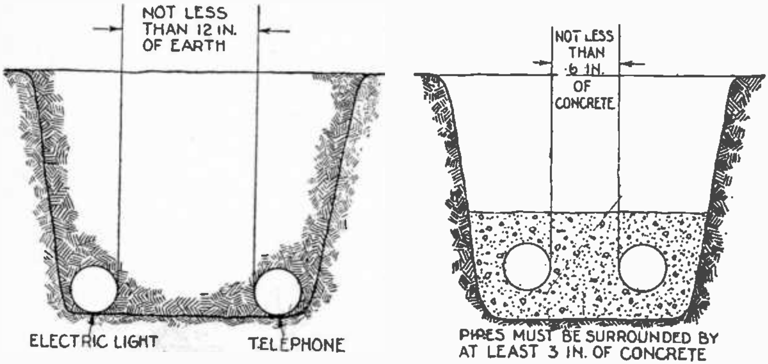


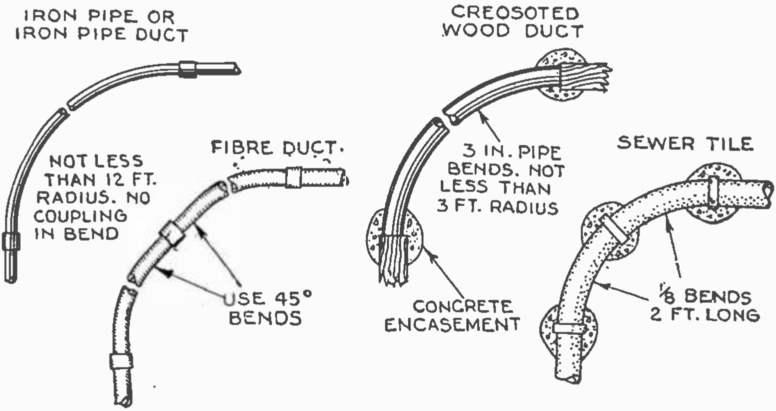
FIG. 6,007.—Built up method of installing fibre conduit using grooved separators.

Other engineers use concrete forms as shown in fig. 6,007. The outline of these is made to follow the curve of the fibre which is laid in the upper curved grooves of the separators and held in place by the lower grooves of the one on top. Sand bags or bars of iron are then placed on top of the upper tier of ducts to prevent any movement of the conduit when the concrete is poured. All the joints in the several duct runs should be staggered.

When all the tiers are in position, concrete is poured or shovelled into the trench, care being taken to see that it is dropped slowly enough to pre-vent damage to the ducts. In a deep trench such damage is obviated by



Figs. 6,008 and 6,009.—Separation of telephone and electric light conduits where the duct provided for electric service is, or may be occupied by secondary circuits connected to transformers of over 25 *kw.* capacity or by primary circuits of any capacity. These clearances apply likewise at crossings of one service over the other.



Figs. 6,010 to 6,013.—Bends in run of various types of conduit.

pouring upon a board laid over the ducts. The concrete is then shovelled from this board in small lots and tamped in final position under and alongside the various tiers. On long runs where conditions warrant it, better results are obtained by the use of a deflecting trough of steel, the concrete flowing from each side of the trench toward the middle, and if of the proper consistency entirely filling all voids under and around the ducts.

A 1-3-5 concrete mixture is used, as in the tier by tier method. Many engineers prefer this method since by pouring the concrete as a whole a monolithic form of duct separation is obtained, making it impossible for horizontal joints to exist between different layers of concrete.

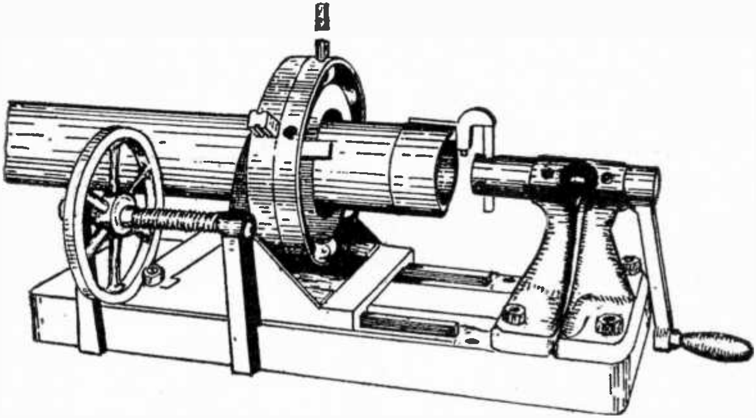


FIG. 6,014.—Johns-Manville portable machine for cutting joints. Where large quantities of conduit are used, short lengths are frequently necessary and are obtained in the field by cutting down regular sections, with a machine such as here illustrated. The use of these lathes prevents loss of conduit by providing a quick and accurate means of re-tooling such ends as may have become broken in handling.

Conduit Boxes or Manholes.—*By definition a manhole is a vault or box-like structure built under the street, having a circular opening at the street surface covered by a cast iron cover, and large enough to conveniently admit a man, so that access may be had to the conduit ducts and the cables.*

Manholes should be provided about every 300 feet, in order to facilitate the installation of the conductors in the duct.

The exact distance between manholes should be determined by conditions; in some cases they should be placed even closer together than the figure given, while in other cases their distance apart might be slightly greater. Manholes are built of concrete or brick, and provided with a cast-iron frame or cover. The manholes may be of square, round, rectangular, or oval section, the last mentioned form of manhole being probably the best, as it avoids the liability to sharp bends or kinks being made in the cable.

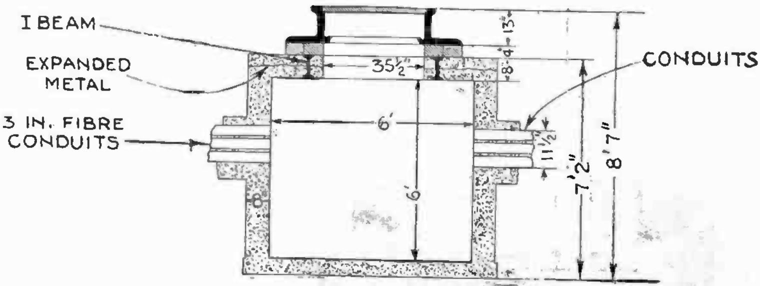
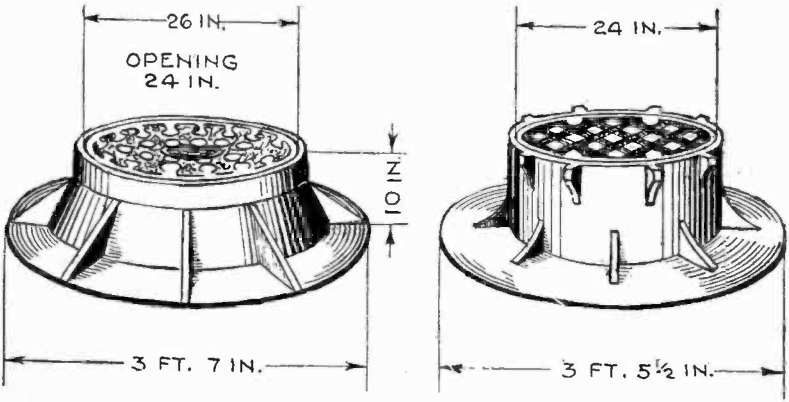


FIG. 6,015.—Standard form of manhole used in New York City.



FIGS. 6,016 and 6,017.—Telephone and sewer types of manhole frame and cover. Either type may be used.

The manhole cover may be of the same form as the manhole itself, or it may be of different form; but round or square covers are usually used.

Fig. 6,015 shows a standard form of manhole used in New York City. This manhole is substantially built, and adapted for heavy traffic passing over the cover. For suburban or country work, manholes may be made of lighter construction. In all cases the cover should be readily removable.

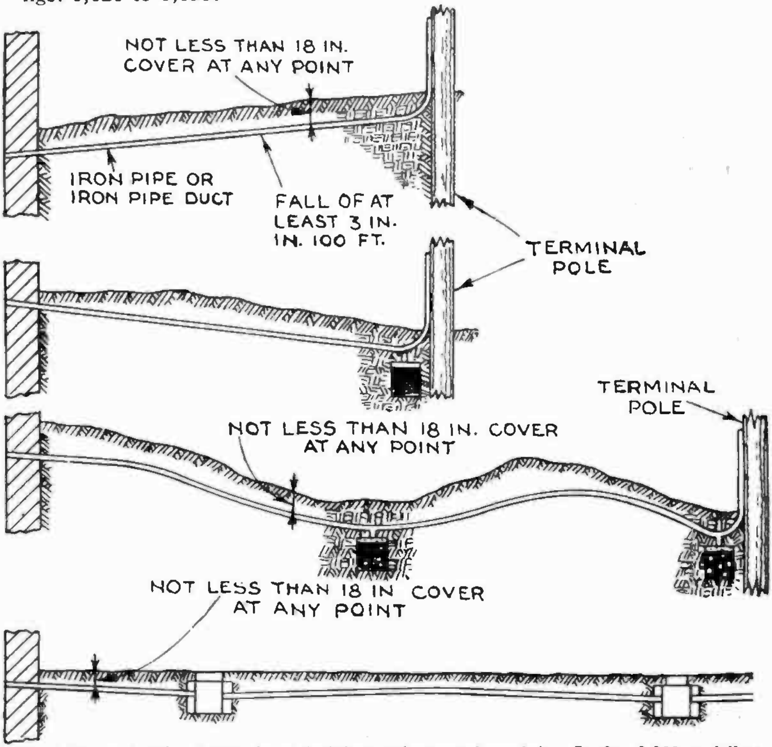
The floor of the conduit boxes must be of earth to allow drainage. If paving be desired, the floor should be made of brick or cobble stones laid loosely on the earth without mortar joints.

Electric light or power wires and telephone wires must not occupy the same conduit box. Separate conduit boxes may be built with one wall common to both, but each conduit box should have a separate entrance and there must be no opening between the two boxes.

FIGS. 6,018 and 6,019.—D & D manhole cover. The cover does not rest on top of the lugs, but on the 45° angle side of the lugs and is held in place by the 85° side. The cover is opened by using two short bars which can be operated by one man by simply prying first on one bar and then reversely on the other until the cover leaves its seat and can then be carried off without any trouble. Another method is to insert a large cold chisel in the keyhole of the cover, and strike it a few heavy blows with a hammer which will loosen the cover in a few minutes even in below zero weather.

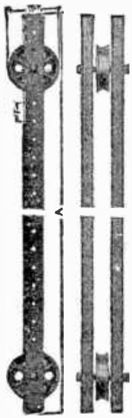
Drainage.—Water will gradually accumulate in the conduit unless good drainage be provided. If drainage be not provided, and water accumulates in the duct, the water may freeze in winter in territories subject to low temperatures and damage the cable to such an extent that a complete failure of the cable will result. In addition to loss of service the replacing of the cable may be expensive because of the difficulty of thawing the pipe in order to remove the damaged cable and place the new one.

It may be found necessary to place a conduit box or a drainage pocket at a point where, either on account of the nature of the soil or because of the contour of the ground, water accumulating in the conduit box or pocket will not drain easily. Drainage pockets are unnecessary in districts where freezing at conduit depth will not occur. Methods of drainage are shown in figs. 6,020 to 6,023.



FIGS. 6,020 to 6,023.—Methods of draining underground conduit. In fig. 6,020, a fall toward the house should be provided only where iron pipe or iron pipe duct is used and no conduit box is built in the run. Otherwise, the fall should be toward the pole or conduit box. In fig. 6,021, where fall is toward the pole a drainage pocket must be provided. In fig. 6,022, where it is impracticable to grade trench so that it makes a continuous fall, a drainage pocket must be provided at lowest point in the dip. Fig. 6,023 shows fall of 3 ins. in 100 ft. toward conduit box. The fall must not be toward house where conduit runs to conduit box. Fall of 3 ins. in 100 ft. toward one conduit box or both. A continuous fall toward one conduit box is preferable where the slope of the ground permits.

Pulling in the Cables.—In this operation special precaution should be taken to avoid sharp bending of the cable and thus prevent injury to the lead sheathing. If the cable be light and of small diameter, the distance not over 300 feet, and the run fairly straight, the cable can usually be pulled in by hand; but often other means must be provided so as to secure sufficient power.



FIGS. 6,024 and 6,025.—Hallett manhole skids and sheaves. *These are for* leading the pulling line from the mouth of duct out through the manhole to the capstan or winch. The skids have pinholes every 4 ins. from top to bottom so that sheaves can be placed at desired height to correspond to height of duct and top of manhole. They are made of channel iron, and are suitable for pulling in the heaviest cables. Standard length, 9 ft.

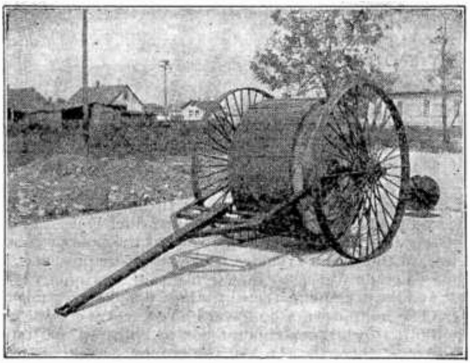


FIG. 6,026.—Hallett cable reel wheels. This outfit is used on cable reels of whatever weight specified and is manipulated by hand or used as a trailer. It consists of steel wheels, shaft 6 ft. by 2½ in. diameter adjustable tongue and reel guides.

Precautions should be taken, however, to avoid placing too great a strain on the cables, as it is liable to injure them, and the injuries may not show up immediately but may cause trouble later. The remedy is to avoid placing the manholes too far apart, and to have the runs as straight as possible; also to properly test the conduits for continuity and smoothness before starting to install the cables. Enough slack should be left in each manhole to allow the cables to pass close to the side walls of the manhole, and to have the centers free and accessible for a man to enter the manhole.

Where there are a great number of cables in a manhole, shelves or other supports should be provided for holding the cables apart and in position. Where two or more conductors are placed in the same duct, they should always be pulled in at the same time, for otherwise the cables last pulled in are apt to injure those already installed.

TEST QUESTIONS

1. *What are the three essential elements of an underground system?*
2. *Give three general classes of underground systems.*
3. *When cables are laid directly in the ground, what is depended upon for mechanical protection?*
4. *Name two general classes of clay conduit.*
5. *Describe a conduit transposition unit.*
6. *What kind of conduit unit is used on curves?*
7. *Describe the method of laying single duct vitrified clay conduit, also for laying multi-duct conduit.*
8. *What is trough conduit and how is it laid?*
9. *How are concrete conduits usually constructed?*
10. *How are the ducts formed in wooden conduits?*
11. *Name two types of wooden conduit, and describe them.*

12. *In what lengths can the trough type of wooden conduit be laid.*
13. *How are wrought iron or steel conduits made?*
14. *Describe two methods of laying steel conduits.*
15. *Is steel or wrought iron preferable?*
16. *What may be said with respect to cast iron conduit?*
17. *Of what does a fibre conduit consist?*
18. *Name three types of joint available for connecting the lengths of fibre conduit.*
19. *Describe the tier by tier method of laying fibre conduit.*
20. *How is conduit laid by the built-up method?*
21. *Describe the construction of manholes.*
22. *Give methods of draining underground conduit.*
23. *Describe in detail the pulling in of the cables.*

CHAPTER 128

Marine Wiring Practice

The regulations for electrical installation on merchant vessels are promulgated by the *Maritime Commission, Department of Commerce, Bureau of Marine Inspection and Navigation, Federal Communications Commission* and the *American Bureau of Shipping*, and are designed in accordance with the *Marine Standard* of the *American Institute of Electrical Engineers*, the practices on which this chapter is based. It is recommended, therefore, that reference always be made to their latest specifications and requirements.

The *Bureau of Marine Inspection and Navigation* has divided vessels into the following groups:

Group No. 1

Ocean-going vessels which navigate on any ocean or the Gulf of Mexico more than 20 miles off-shore.

Group No. 2

Ocean-going vessels which navigate on any ocean or the Gulf of Mexico but less than 20 miles off-shore.

Group No. 3

Vessels navigating Great Lakes only.

Group No. 4

Vessels navigating bays, sounds and lakes other than the Great Lakes.

Group No. 5

Vessels navigating rivers only.

Plans.—Every vessel should be provided with plans giving complete and detailed information as to circuits, wire sizes, loads, etc., for the light, power and interior communication systems. A symbol list giving the manufacturer's name, size, type, rating, catalog number or similar identification for all the equipment on the vessel should also be provided for the vessel's operating personnel.

Type of Current Used.—Distribution of electrical energy may be made either by direct or alternating current, but in present practice for electric auxiliaries direct current is usually employed. On this account, the main body of these recommendations covering auxiliaries relates to direct current installations.

Nature of Supply Source.—The following systems of distribution are recognized as standard:

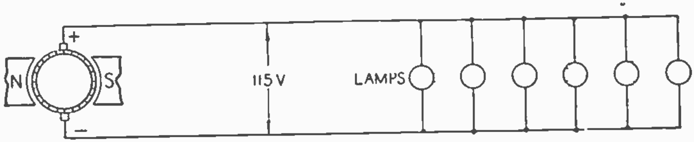
1. Two wire with direct or single phase alternating current.
2. Three wire with direct current or single phase alternating current.
3. Three phase three wire, alternating current.

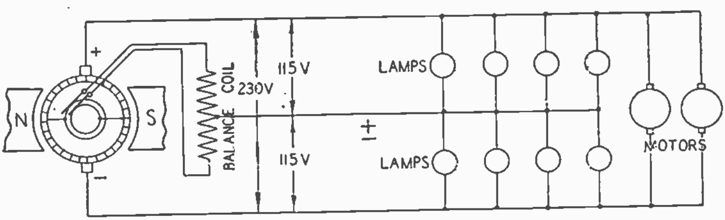
Standard Voltages.—The following voltages are recognized as standard:

	Direct Current	*Alternating Current*
Lighting....................	115 Volts	115 Volts
Power.....................	115 and 230	115–220–440
Generators..................	120 and 240	120–230–450

Standard Frequency.—A frequency of 60 cycles per second is recognized as a standard for all alternating-current lighting and power systems.

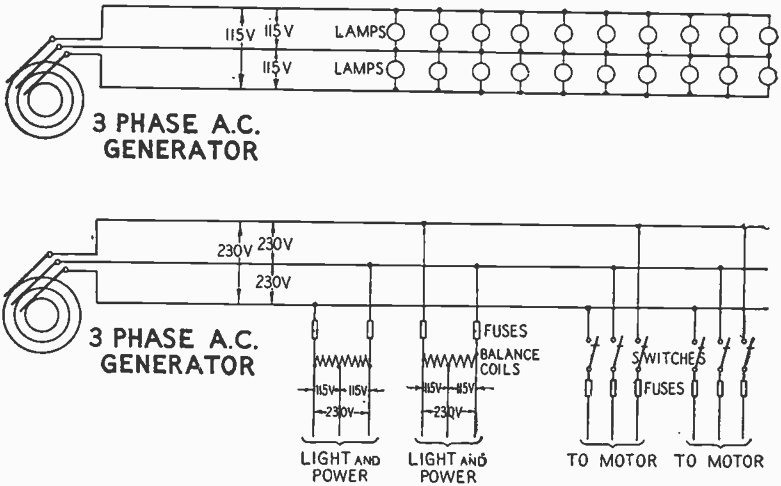
Selection of Voltage and Distribution System—D.C.—For vessels having little power apparatus, 120 volt generators are recommended with 115 volt light and power distribution systems. Where an appreciable amount of power apparatus is provided, 240 volt generators and 230 volt power distribution system with 115 volt lighting distribution system should be selected.





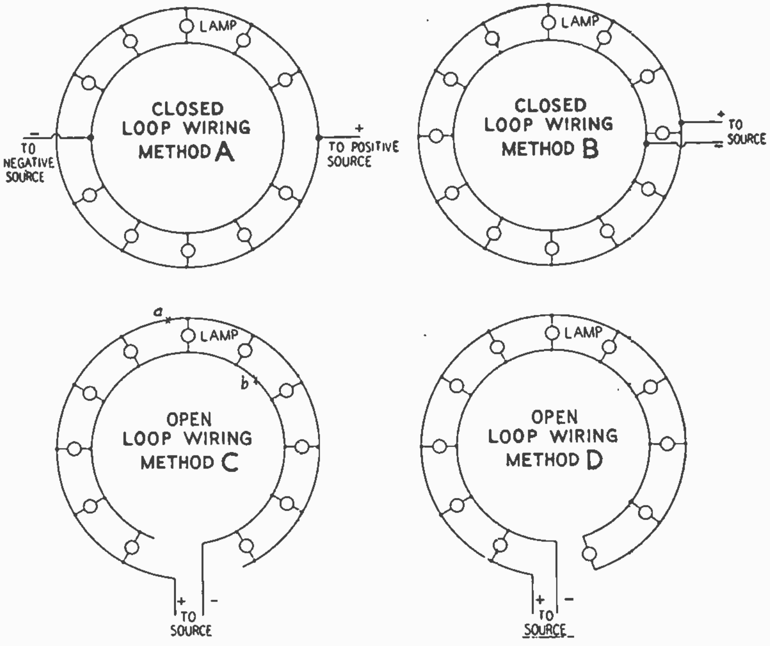
Figs. 1 and 2.—Direct current distribution systems. In the two-wire system the lamps are connected in parallel between the positive and the negative wires. The generator may be either shunt or compound wound. In fig. 2 the distribution is accomplished by means of a three wire direct current generator (Dobrowolsky system). The third wire (some times misleadingly called *neutral*) is obtained as follows: To any ordinary generator designed to give a terminal voltage equal to that between the two main wires, are added two slip rings as shown. From these slip rings two leads are brought out and connected to armature points located 180 electrical degrees apart. Collectors from the slip rings are connected to the two ends of the balance coil wound on an iron core and the middle point of this coil is finally connected to the third wire. It should be observed that in a system of this kind, it is necessary to balance the load between the two main wires and the wire leading from the balance coil as closely as possible, and the amount of unbalance should not exceed the manufacturer's specification, usually of from 10% to 15% of the total current.

Selection of Voltage and Distribution System—A.C.—For small vessels having little power, three phase, 120 volt generators may be used with the 115 volt lighting and power distribution system. For vessels requiring considerable power apparatus, three-phase, 230 volt generators are suggested with three-phase 220 volt distribution for the power system and 115 volt single phase two wire or 115/230 volt single phase three wire



Figs. 3 and 4.—Typical alternating current distribution systems. When it is desired to utilize 115 volts for light supply, balance coils are installed and connected as indicated. In a system of this kind, however, it is necessary that the lighting load be reasonably well balanced among the phases.

or 115 volt three phase three wire as obtained through transformers for distribution to the lighting system. Each of the three single phases should have about the same load so that currents will be about equal in each phase wire at the point where the three single phase systems are joined into one three phase system. For very large vessels with a large amount of power, the use of 450 volt three phase generators with 440 volts or 220 volts for power distribution and 115 volts for the lighting system as described for the 230 volt generator system may be considered.



Figs. 5A to 5D.—Showing various methods of loop-wiring. In order that all lamps in a circuit shall burn with equal brilliance at all times, it is necessary that the resistance of the circuit from the supply source to any lamp shall have a constant value, and be equal to the resistance through any other lamp. This is best accomplished in the *loop system* in which the mains are run in the form of a *closed loop*. With reference to figs. 5A and 5B, a break in either leg of the circuit will cause no break in the continuity of the circuit and all lamps will burn. It would require two breaks in any one leg to extinguish a lamp. If the loop be connected as shown in fig. 5C an analysis reveals that if a break occur at *a*, in the positive main all the lights toward the right of the open would be extinguished. Similarly a break in the negative main at *b*, would extinguish all lights to the left of the fracture.

Balancer Sets.—Balancer sets are not recommended for obtaining 120 volts from the 240 volt, two-wire direct current generators.

Rules Governing Direct Current Equipment and Installations

Installation and Location of Generator Sets.—Generating sets should be located in a well ventilated place as dry as possible. They should not be installed in the immediate proximity to water and steam piping, etc., and should be protected from dripping water, oil, etc.

Generating sets should always be installed with the shaft in the fore and aft position. There should be at least 18 inches between the set and surrounding objects to provide accessibility, and sufficient room should be provided to permit removal of the armature.

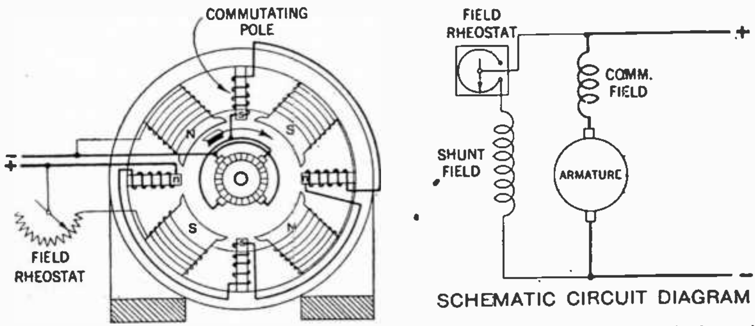
When diesel engine driven generating sets are located in deck houses, the enclosing structure should be steel or other approved fireproof material.

Generating Sets for Ship's Service—Number and Size.—In determining the capacities and number of generating sets to be provided for a vessel, careful consideration should be given to the *normal* and *maximum demands* as well as for the safe and efficient operation of the vessel when at sea and in port. The combined normal capacity of the operating generating sets should be at least equal to the *maximum peak load*, and in addition one *spare unit* should be provided. If the peak load and its duration be within the limits of the specified overload capacity of the generating sets, it is not necessary to have the combined normal capacity equal to the maximum peak load.

Generating Sets—Emergency.—In addition to the foregoing, the *Department of Commerce, Bureau of Marine Inspection and Navigation* requires the installation of a *diesel engine* driven generating set and (or) *storage batteries* located above the bulkhead deck for operating the emergency lighting and power systems.

Gasoline and semi-diesel engines are not recommended for the operation of emergency generators.

Generator Windings.—In the case of installations where the load does not fluctuate appreciably, *shunt-wound generators* without voltage regulators or the special type *compound-wound* generators may be used in lieu of *compound-wound generators*.

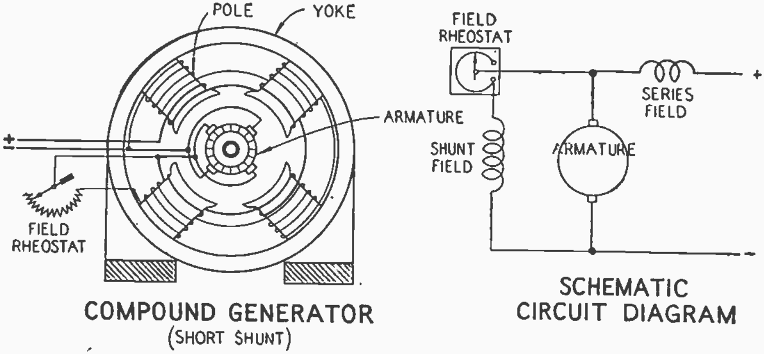


Figs. 6 and 7.—Connections of a shunt-wound generator with commutating poles and schematic diagram.

In the case of installations where the load is apt to fluctuate appreciably, *shunt-wound generators* with *voltage regulators*, or *compound-wound generators* should be used in the interest of substantially constant voltage.

Unless otherwise specified, all three-wire direct current generators should be designed for 25% unbalanced current.

In order to promote uniformity of practice for two-wire compound-wound generators, it is recommended that the series field terminal be negative.



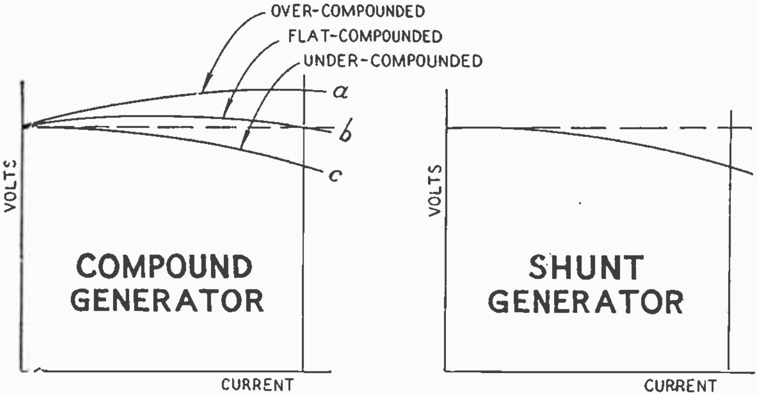
FIGS. 8 and 9.—Connection of a compound wound generator with schematic circuit diagram.

Voltage Regulation and Compounding.—When the lighting load is *not* supplied by the *main generator*, the main generator should be shunt-wound and should have an inherent voltage regulation as follows:

Shunt-wound generating sets of 150 *k.w.* and above should be designed as to speed regulation and governing of the prime mover and inherent regulation of the generator so that at full-load operating temperature there will be a rise in voltage of not over 8% when the load is gradually reduced from 100% load to 20% load, and so that there will be a drop in voltage of not more than 12% when the load is gradually increased from 20% load to 100% load, based on 3.5 per cent speed regulation (drop in speed from no load to full load) of the prime mover. For each condition the field rheostat should be set for normal rated voltage at the beginning of each test.

Compound-wound generators should be designed as to governing of prime mover, compounding and regulation of the generator, so that with the generator at full-load operating temperature, and starting at 20% load with voltage within 1% of rated voltage, it should give at full load a voltage within 1½% of rated voltage. The average of the ascending and descending voltage regulation curves between 20% load and full load should not vary more than 3% from rated voltage, except for diesel engine driven generators, in which case it should not vary more than 4%.

The voltage regulation of a three-wire generator should be such that when operating at rated current on the heavier loaded side (i.e., positive or negative lead) with rated voltage between the positive and negative leads and a current of 25% of the generator current rating in the neutral wire, the resulting difference in voltage between the positive and neutral leads and negative and neutral leads should not exceed 2% of the rated voltage between the positive and negative leads.



FIGS. 10 and 11.—Voltage drop characteristics of a compound and shunt-wound generator respectively. The compound generator may be designed to produce an almost constant voltage or even a rise in voltage as the load increases by placing on the field poles a few turns which may be connected in series with either the load or the armature. When the series ampere-turns on the field coils are adjusted so that the terminal voltage of the generator is greater at full load than at no-load the machine is said to be *over-compounded*. When the coils are adjusted to cause the generator to deliver the same terminal voltage at both full and no-load the machine is *flat-compounded*. When the adjustment is such that it causes the generator to deliver less voltage at full-load than at no-load the machine is *under-compounded*. See curves a, b, and c, fig. 10, respectively.

In the foregoing, the speed regulation curve of the prime mover should not vary more than 1% from a straight line drawn between the speeds at 20% load and 100% load.

The voltage regulation and compounding tests should be made at the works of the electrical manufacturer in accordance with his standard testing practice, using an approximately straight line speed regulation from 20% to 100% in amount as specified by the prime mover builder.

Parallel Operation.—Successful parallel operation is attained if the load on any generator does not differ more than plus or minus 15% of its rated kilowatt load from its proportionate

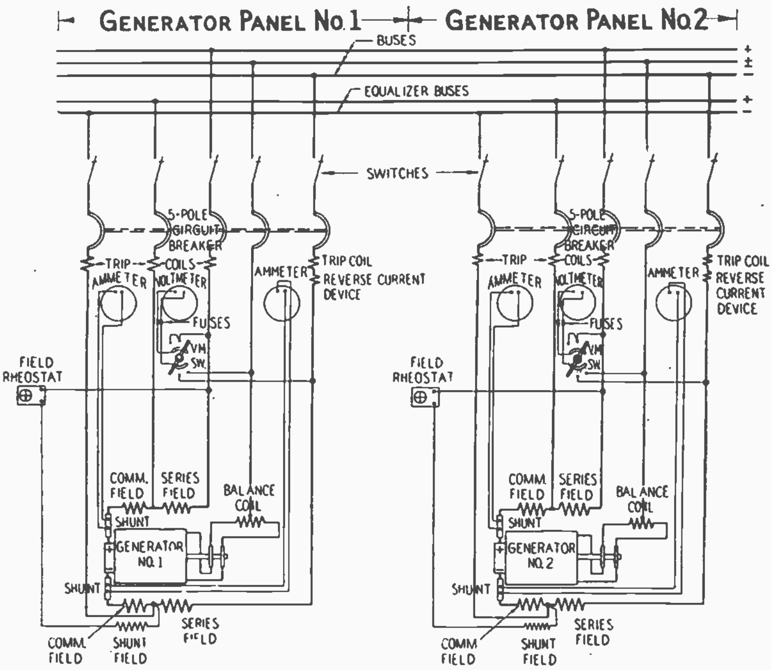


FIG. 12.—Connection diagram of two 120/240 volt three-wire compound-wound d.c. generators. The generators are arranged for parallel operation and require therefore a set of equalizer buses. With reference to diagram each generator has leading from the brushes a commutating and a series field on each leg of the circuit. Between these two fields on each leg is an equalizer connection. Since each generator has a positive, negative and neutral lead, in addition to a positive and a negative equalizer, the total number of outgoing main connectors are five in number. Each of these leads is connected through air circuit breaker and switches to their respective buses usually located in the rear of the generator panels. To prevent motoring of either unit one pole of each circuit breaker is equipped with a reverse current relay, in addition to the over-load trip feature. One voltmeter is provided with each generator, and permits the operator by means of the voltmeter switch to read the voltage between the positive and negative and also voltage positive and negative to neutral. By placing one ammeter in each outgoing leg it is possible to note the amount of unbalance in current at all times by a simple subtraction of readings.

share, based on the generator ratings, of the combined load, for any change in the combined load between 20% and 100% of the sum of the rated loads of all the generators. For this test the speed of the generators shall be constant or slightly decreasing, with the change in speed approximately proportional to the load. For *compound-wound machines*, series field equalizer connections are required, which, between any two machines, shall not have more than 20% of the resistance of the series field with resistors, if any, of the smaller machine.

Prime Movers.—Generating sets may be driven by *steam engines* either of the turbine or reciprocating type, or by *diesel engines*. Each prime mover should be fitted with an efficient speed regulating governor as well as an *automatic overspeed trip*. The automatic overspeed trip should function to shut down the unit automatically when the speed exceeds the designed maximum service speed by more than 15%. Each prime mover should, in addition, be under the control of an efficient *operating governor* capable of limiting the speed, when full load is suddenly removed, to at least 5% less than that of the overspeed trip setting. The overspeed trip should also be equipped with a means for manual tripping. Where a turbine prime mover is also fitted to utilize auxiliary exhaust, it should be provided with a properly arranged automatic shutoff, and where provision is made for extraction of steam, positive means should be provided for preventing a reversal of flow to the turbine.

All sets of 100 *k.w.* capacity and above should be provided with a coupling fitted to the armature shaft.

Mountings.—The generator and its driving unit should be mounted on a *common support* to *insure proper alignment*. Care should be exercised to secure a rigid foundation. Where a bedplate is used, each unit comprising the set should be provided with ample supporting feet secured to the bedplate.

Accessibility.—The design of generating sets should provide for accessibility to all parts requiring inspection during operation or dis-assembling for repairs.

Insulation of Windings.—All assembled armatures and also the armature coils for open slot construction should be immersed in insulating varnish and baked. All field coils should be treated with varnish or other insulating compound while being wound, or impregnated by the vacuum and pressure method. The finished winding should be water and oil resistant.

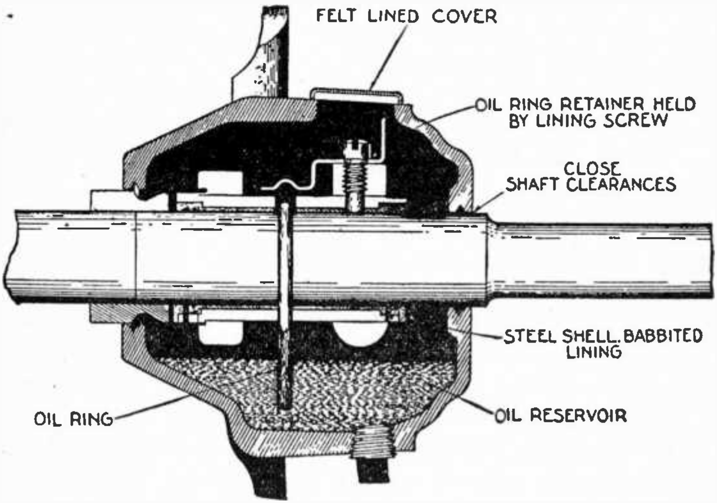


FIG. 13.—Sectional view of a typical self-oiling bearing. As shown the pedestal or bearing standard is cored out to form a reservoir for the oil. The rings are in rolling contact with the shaft, and dip at their lower part into the oil. *In operation*, oil is brought up by the rings which revolve because of the frictional contacts with the shaft. The oil is in this way brought up to the top of the bearing and distributed along the shaft gradually descending by gravity to the reservoir, being thus used over and over. A drain cock is provided in the base so that the oil may be periodically removed from the reservoir and strained to remove the accumulation of foreign matter. This should be frequently done to minimize the wear of the bearing.

Lubrication.—All generating sets should be located with their shafts in a *fore* and *aft direction* on the vessel and they should lubricate and operate satisfactorily when permanently inclined to an angle of 15° athwartship and 5° fore and aft, and arranged so that they will not spill oil under a vessel roll of 30° each side of the vertical. Turbine driven generating sets depending on forced lubrication should be arranged to shut down *automatically on loss of oil pressure.*

Corrosion-Resistant Parts.—To prevent deterioration and corrosion of interior bolts, nuts, pins, screws, terminals, brush-holder studs, springs, etc., and such other small parts as would be seriously damaged and rendered ineffective by corrosion, these should be made of corrosion-resistant material or steel suitably protected against corrosion. Steel springs should be treated to resist moisture in such a manner as not to impair their spring quality.

Terminal Arrangements.—

(1) *Generators* 50 *k.w. and above*

(a) *Side location*

Generators should be provided with an insulating terminal board having secured terminals to which the lugs of the incoming cables can be readily fastened. The terminal board should be enclosed in a drip-proof terminal box so constructed that the incoming cables can be led individually through an insulating cover screwed or bolted to the bottom or through a metal strip at least ¼ in. thick. If the cables enter through the bottom, ordinary clearance holes are recommended. If the cables enter through the top, individual terminal tubes should be used.

(b) *Top location*

Generators should be provided with an insulating terminal board as recommended in (a) enclosed in a drip-proof box having top and side sections at least ¼ in. thickness through which the individual cables can be entered through terminal tubes.

(c) *Bottom location*

Generators should be provided with strap terminals, secured to an insulating block, to which the connections (or straps) of the incoming cables can be fastened. The terminal board should be suitably protected.

(2) *Generators below* 50 *k.w.*

Generators should be provided with a side located, drip-proof conduit box with removable cover plate. The generator cables should be secured inside the conduit box. The arrangement should be such as to permit ready connection of the incoming cables.

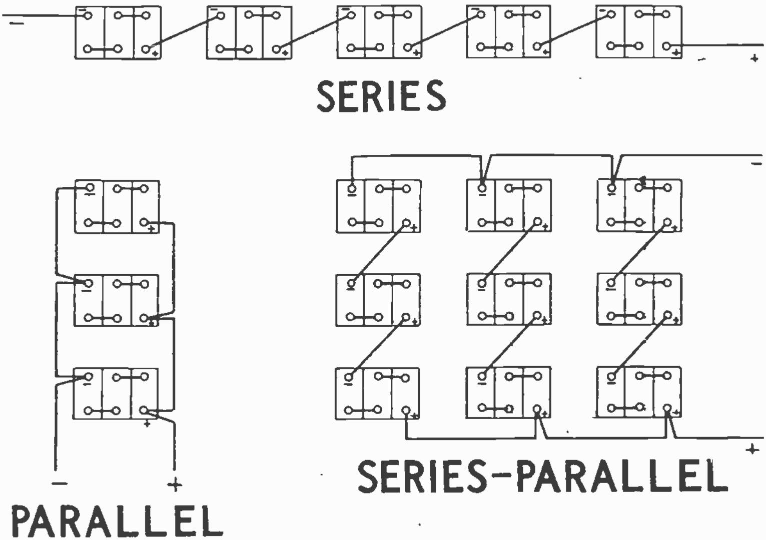
Storage Batteries

Installation and Location.—Storage batteries of either the *lead-acid* or *nickel-alkaline* type should be installed in a well ventilated room, but if no room be available, they may be installed in special deck boxes. The battery room should be large enough to provide adequate access for inspecting, testing and watering the battery.

For a *lead-acid* battery, the exposed metal in the battery room, including the battery and its connections, should be printed with corrosion-resistant paint. The floor of the battery room should be lined with 8 pound sheet lead, carried about 6 inches up the sides of the room and secured thereto or the batteries should be installed in lead-lined shelves with the lead carried up not less than 3 inches at the front, back and end of shelves. All joints in the lead lining should be lead burned watertight. A two inch space should be provided in back of the battery shelves to prevent pocketing of gases.

For a *nickel-alkaline* battery, the exposed metal in the battery room should be painted with corrosion-resistant paint. When the decks are made of ferrous metal, a steel pan should be provided with side walls 6 inches high and made liquid tight. Battery trays can be arranged in tiers, but each tier should be fitted with a pan to take the battery tray.

Where the decks are made of wood or non-ferrous metal, a steel pan of satisfactory thickness with side walls 6 inches high and made liquid tight should be provided. Where the battery rack is located in close proximity to a wooden or non-ferrous bulkhead, the size of the steel pan should be carried up the bulkhead to a point at least 1½ inches above the filler caps of the battery.



Figs. 14 to 16.—Three principal methods of connecting batteries. For best results it is necessary that all inter-connected batteries be of an equivalent type, that is, their terminal voltage and internal resistance be equal.

The ventilating system for battery rooms should be carefully arranged to prevent the accumulation of pockets of *inflammable gases*. If the battery room be located in a deck house, natural ventilation may be used with adequate openings overhead, and near the deck. If the battery room be below deck, a motor driven exhaust fan, capable of changing the air every two minutes, should be provided for use when charging the battery. The fan should draw from top of room and openings for air inlet should be provided near the base of the room. The interior of the fan and ducts, if used, should be painted with corrosion-resisant paint.

If batteries are installed in engine rooms and machinery spaces, the ventilating systems of these spaces should be of a capacity to properly carry off all gases during the charging period and prevent the accumulation of pockets of *inflammable gases*. When *lead-acid* batteries are installed in special deck boxes, they should be lined with 4 pound sheet lead to a height of 10 inches. Ventilation should be provided by means of an inlet and outlet. The inlet should be turned down and the outlet should extend at least 4 feet above the battery box; both should be suitably protected against spray and painted with corrosion-resistant paint.

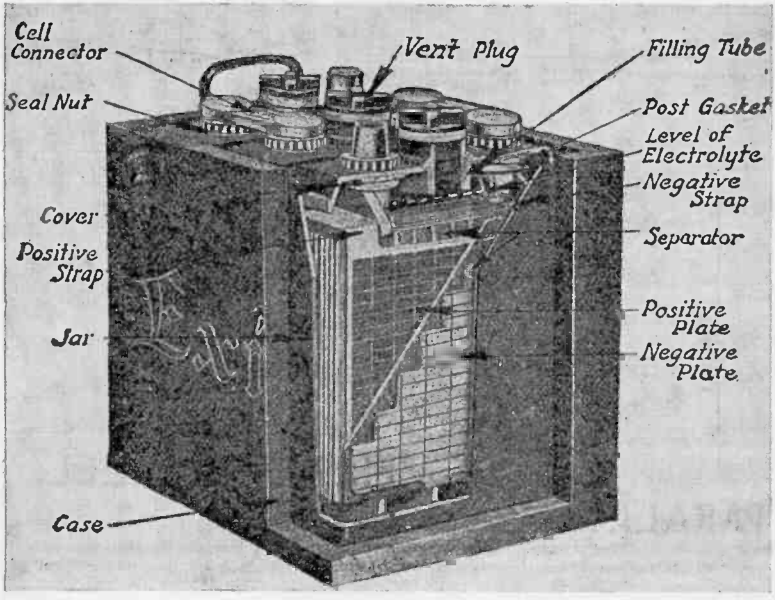


FIG. 17.—Sectional view of Exide battery showing construction. The active material is lead peroxide on the *positive* plate and finely divided or sponge lead on the *negative* plate. The plates are immersed in a solution of sulphuric acid and water called electrolyte. On discharge of the battery, both these active materials are quantitatively converted into lead sulphate at the expense of the acid radical of the electrolyte and the formation of water. Precisely the reverse action takes place upon the charge of the battery.

When *nickel-alkaline* batteries are installed in special deck boxes, the box should be lined with sheet steel of satisfactory thickness to a maximum height of 10 inches. The floor of the deck box shall be covered with removable wood strips of at least ½ in. thickness. In addition, the battery shall be securely blocked in place by means of wooden strips of ¾ in. x 1½ in. cross section permanently attached to the inner sides of the box and placed at least 1½ in. apart in such a way that all trays are held at least ¾ in. from the inner lining. A reasonable amount of ventilation should be provided by locating holes as high as possible on opposite sides or ends. Openings on one side or end are not enough to insure positive ventilation. All wooden lining bases and exposed steel surfaces should be covered with corrosion-resistant paint.

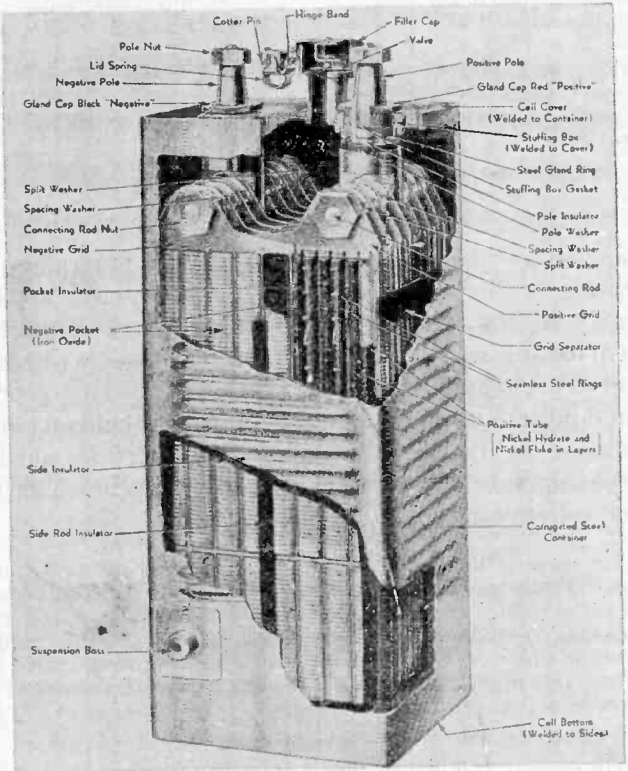


FIG. 18.—Sectional view of Edison Nickel-Iron Alkaline battery. The *positive* or nickel plate consists of a number of perforated steel tubes heavily nickel plated and filled with alternate layers of nickel and hydroxide and pure metallic nickel in thin flakes. The *negative* or iron plate consists of a grid of nickel plated cold rolled steel that holds a number of rectangular pockets filled with powdered iron oxide.

When *radio*, *emergency radio* and *auto-alarm* batteries of the *lead-acid* type are installed in boxes, the boxes should be lined with 4 pound sheet lead to a height of 3 inches.

When *radio*, *emergency radio* and *auto-alarm* batteries of the *nickel-alkaline* type are installed in boxes, the interior of the boxes should be fitted with steel pans having a height of 4 inches.

The location of the battery should be carefully considered at the time of installation, and should be such as to protect the battery from damage in case of accident, so far as this is possible. Batteries used for emergency lighting or to operate radio equipment sets, should be located as high as possible, and never below the bulkhead deck level. In selecting the location, exposure to extreme heat or cold, vibration, steam or salt water should be avoided.

Storage batteries of either the *lead-acid* or *nickel-alkaline* type should not be installed in sleeping quarters.

Capacity.—When only a storage battery is required for the operation of the emergency lighting and power system, the capacity of the battery should be sufficient to operate the system for at least 12 hours. For passenger vessels where storage batteries are required for the operation of the emergency lighting and power system in conjunction with the diesel emergency generating set(s), the capacity of the battery should be sufficient to operate the portions of the emergency lighting and power system for at least 1½ hours.

The *capacity* of the *emergency lighting* and *power storage* battery should be such that when connected to the line for the purpose of supplying power, the initial voltage should not exceed the normal rated generator voltage by more than 5% and the final battery voltage at the end of full-rate discharge, should not be more than 12½ per cent below the normal rated generator voltage. The initial capacity of a lead plate type battery should be based on a specific gravity of electrolyte when fully charged between 1.210 and 1.220 at a temperature of 25°C.

The *capacity* of a battery that is normally floated on the power bus, so as to take care of load peaks, should be determined for each particular installation. The *generators* which must operate in parallel with the battery should have voltage characteristics suitable for the type and capacity of the battery, to insure stable operation. Automatic voltage regulators should be provided to protect the distribution circuits which will not function properly if operated above their designed voltage.

The *capacity* of batteries when provided as the only power supply for *signalling, communication* or *alarm systems*, should be sufficient to operate the equipment connected thereto under normal conditions for at least one week without charge. It is recommended that a standby battery be provided for such systems to permit operation from alternate sets.

It is recognized, however, that in special cases there may be some unimportant equipment where a capacity sufficient to operate the equipment for 72 hours may be adequate, when a spare set is provided and the ampere hour capacity is not less than sixty.

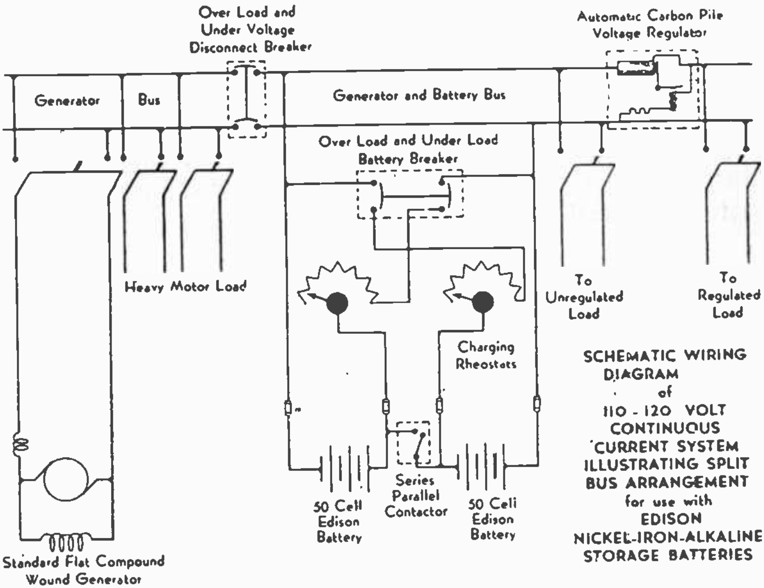


Fig. 19.—110-120 volt battery-generator circuit. An economical arrangement is obtained by means of a disconnect circuit breaker so located in the control circuit that it divides the heavy motor loads from the emergency and lighting loads. This circuit breaker accomplishes two purposes: it relieves the generator of any overload condition and because of the close limits over which the voltage relay operates it provides the emergency and lighting circuits with a continuous source of current through instantaneous transfer of these circuits from generator to battery. This transfer is made upon loss of the generator voltage from overload or any other cause. The generator is then forced to carry the heavy motor loads which are connected ahead of the disconnect circuit breaker.

Batteries for starting *marine diesel engines* and other service, shall have a fully charged specific gravity of not less than 1.275 to 1.285 at 25°C. Batteries shall have sufficient capacity for the necessary breakaway current voltage, and to crank the engine for not less than two minutes at a speed sufficient to insure starting the engine at the lowest temperature anticipated.

Batteries used for starting duty only may be furnished in thin positive plate construction (.100 to .150 thick); however, when auxiliary duties are to be performed from the battery, heavier positive plate construction shall be considered (.150 to .250 thick). *Exception*—Starting batteries which will be continuously exposed to tropical temperatures shall have a fully charged specific gravity of 1.210 to 1.220 at 25°C.

Batteries should develop at least 90% of their rated capacity within the first three cycles after assembly.

Accessibility.—The battery should be arranged so that the trays are readily accessible for care, inspection and removal. Lifting eyes or equipment should be provided over all large batteries to facilitate removal.

Voltage.— The emergency lighting and power batteries should supply a voltage equal to that of the vessel's supply.

Charging Equipment.—Where the voltage of the battery is the same as ship's supply, the battery may be split for the purpose of charging. The capacity of the charging equipment should allow the entire battery to be charged at once. Emergency lighting and power batteries should be charged at their normal charging rate, and time for complete recharge should not exceed 18 hours, based on the 1½ hour discharge rate. The battery and charging equipment should be protected against overload and reversal of current by means of efficient circuit interrupting devices.

The *charging panel* should include an ammeter and voltmeter of suitable range, provided when desired, with switches to read different circuits. A fixed resistor should be provided for each battery. The charging circuit of the battery should include an overload and underload, or overload and reverse-current circuit breaker. The use of an automatic charging panel is recommended.

Switches and other electrical fittings which are liable to cause an arc are not to be located in the battery room. Each conductor is to be fitted with a protective device which may be located in the battery room if it is enclosed in an explosion-proof casing; otherwise a protective device is to be fitted in each conductor immediately outside the room. Fuses on the *battery charging switchboard*, when in adjoining compartments, will meet this requirement. Fuses may be used for the protection of emergency lighting storage batteries instead of circuit breakers, up to and including 600 ampere rating.

Where conductors enter the battery room, the holes are to be substantially and tightly bushed as required for watertight bulkheads.

All connections within acid battery rooms should be lead covered cables, sealed tightly to resist the entrance of electrolyte by spray or creepage.

Switchboards

Installation and Location.—Switchboards should be installed in the same compartment with generating sets, in a dry place away from the vicinity of steam, water and oil pipes. The switchboards should be so located as to be accessible from front, rear and one end. The space in rear of switchboard should be ample to permit maintenance and should, in general, be not less than 18 inches in the clear. Ample clearance should be given for current carrying parts to ground. Asbestos barriers should be installed above the secondary contacts of air circuit breakers if less than 12 inches from ship's structure. If the space in the rear of the switchboard is accessible to unauthorized personnel, the space should be completely enclosed with metal grill provided with either sliding or hinged doors equipped with a lock.

An insulating grating should be provided on the deck in front and rear of switchboard, and grating should extend the entire length and be of sufficient width to provide adequate operating space. A non-conducting horizontal hand rail should be provided in front of the switchboard. When current carrying parts are located close to the deck, a guard should be provided to prevent accidental contact with live parts. Wood should not be used in the construction or protection of switchboards except for hand rails. For bulk oil carriers and vessels carrying oil having a flash point of less than 150°F., switchboards should not be located in spaces where vapor or gas is liable to accumulate.

Construction

1. **Panels.**—These should be of non-combustible, non-absorbent, insulating material, free from metallic veins, spots, etc., such as impregnated ebony asbestos lumber, or similar material. Impregnated material should be impregnated all the way through and properly buffed and finished a dull black on all surfaces to prevent accumulation of dust and moisture. Each panel should have a bevel on the front edge. The thickness of panels should be not less than one inch and generally not over two inches, depending upon the equipment installed and the size of the panel. Small panels are preferable.

2. **Framework.**—The supporting framework should consist of metal angle, channel or other shapes with a cross member or sill of liberal dimensions under the panels and rigid tie rods to the bulkhead or flexible ties to the deck above to allow for deflection of the deck without injury to the switchboard. A continuous strip of ⅛ in. rubber should be used between all non-metal panels and the vertical supports and a double strip between the bottom of panels and the horizontal member under them. Any other members necessary to make a rigid construction should be provided. Where self-supporting switchboards with complete box framing are used, the rods or braces to the ship structure should not be required.

3. **Dead Front Switchboards.**—It is recognized that this type of switchboard protects against accident or shock, and the use of such switchboards is desirable in certain installations. Metal panels may be used, providing all current carrying parts are properly insulated.

Equipment for Generator Switchboards.—The following should be supplied for a two-wire system:

Each generator of 25 *k.w.* and above should be protected by an independent arm or trip-free-from-handle circuit breaker with a separate pole for each power cable. These should be arranged to open at a predetermined overload and should be provided with a suitable *overload time-limiting* device. Generators of less than 25 *k.w.* may have fused knife switches or circuit breaker type switches. Compound-wound ordinary type generators arranged for parallel operations should be provided with equalizer switches and circuit breakers having overload and reverse current trip attachments.

An unfused generator switch which will completely disconnect the generator and the circuit breaker from the bus.

An ammeter for each generator.

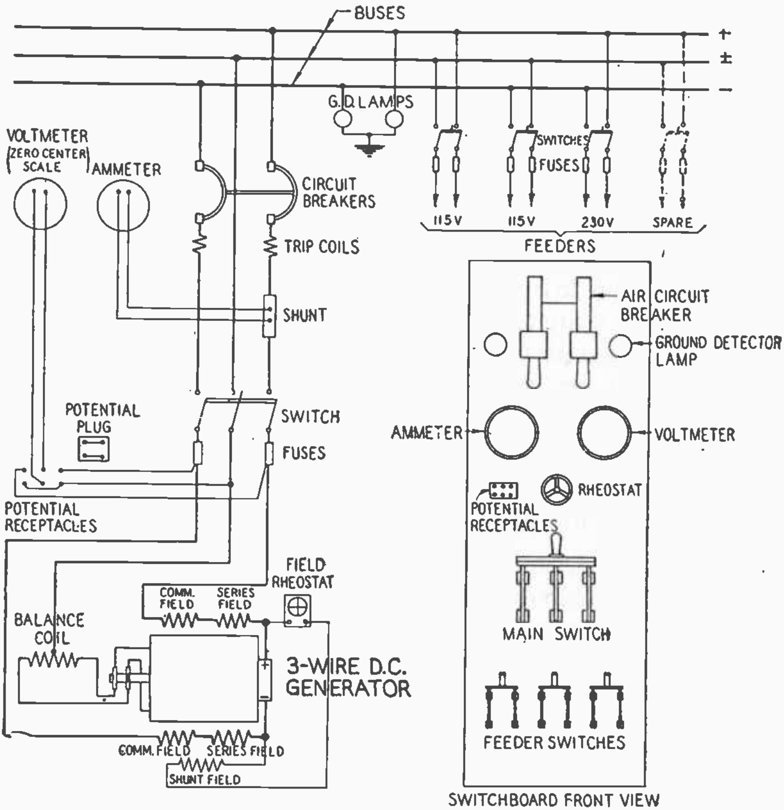
A voltmeter with selector switch for one generator and at least two voltmeters and selector switches for two or more generators.

A field rheostat for each generator.

A pilot lamp for each generator connected permanently between generator and circuit breaker which, in event of the tripping of the circuit breaker, will provide light for restoration of service.

For *ungrounded* systems, ground detector lamps and voltmeter connection or equivalent.

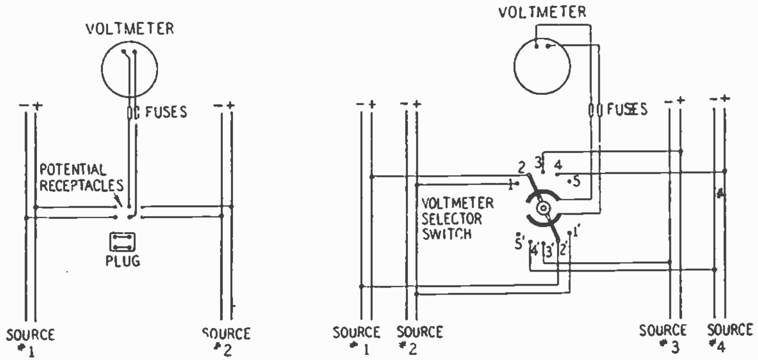
For generators of 500 *k.w.* rating and above, a single-pole field switch with discharge clips and resistor and a watt-hour meter are recommended.



FIGS. 20 and 21.—Typical wiring diagram and switchboard arrangement for a three-wire direct current generator. It is customary when using a supply system of this kind for operation of power and light, to connect the motors between the outside wires and the lights equally distributed between the positive and neutral and negative and neutral.

For a *three-wire* system the above recommendations should be followed except: Circuit breaker and disconnecting switches should be arranged in one of the following ways: (The first arrangement is recommended.)

1. A three pole circuit breaker and a five pole disconnect switch with one pole of the circuit breaker and disconnect switch in the neutral lead. The machine side of one breaker pole is connected to the positive armature lead. The other side of this breaker pole is connected through a pole of the disconnect switch to the positive equalizer bus and through half of the series

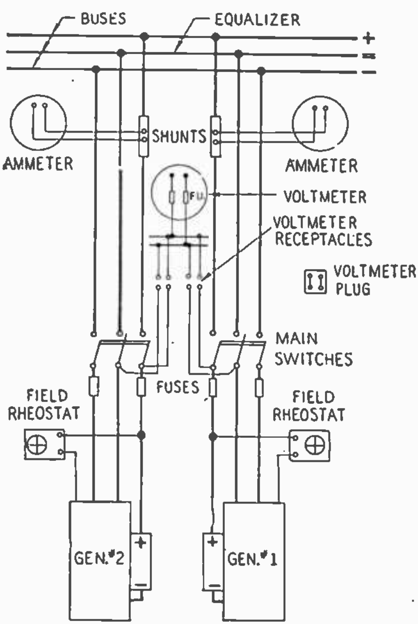


FIGS. 22 and 23.—Methods of measuring voltage from two or more sources of power. In fig. 22 the voltage to be measured is transferred to the meter by the insertion of plug as shown. In the arrangement fig. 23 the voltages across the various sources are measured by means of a selector switch, the operation of which is accomplished by a rotative movement, thus paralleling the meter with the source whose voltage is to be determined.

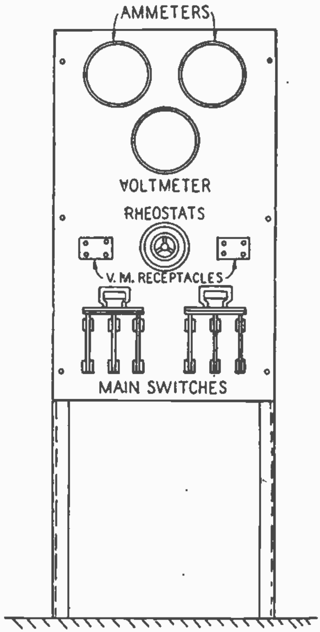
field and a pole of the disconnect switch to the positive bus. The machine side of the other breaker pole is connected to the negative armature lead. The other side of this breaker pole is connected through a pole of the disconnect switch to the negative equalizer and through the other half of the series field and a pole of the disconnect switch to the negative bus. This arrangement requires seven main leads from the generator to the switchboard. *Ammeter shunts* should be located on the switchboards.

2. A five pole algebraic sum circuit breaker with a pole in each armature lead, a pole in each equalizer lead and a pole in the neutral lead; and a five

pole disconnect switch with a pole in each lead. This arrangement requires three main and two equalizer leads from the generator to the switchboard. Ammeter shunts should carry the armature current which requires that they be located at the generator.



COMPOUND GENERATORS



SWITCHBOARD FRONT VIEW

Figs. 24 and 25.—Typical wiring diagram and switchboard arrangements for parallel operation of two compound generators. When two over-compounded generators are to be operated in parallel, it is necessary for a satisfactory division of loads, to parallel their respective series field. This is accomplished by connecting their negatives together and this common connector is usually referred to as the *equalizer*. The instruments and switches shown are connected in the usual manner, which are similar to those used for connection of shunt generators in parallel, the only addition being the equalizer and connections thereto. It should, however, be noted, that the ammeter for each machine should be connected in the lead from the armature to the main bus, and not in the lead from the series field, because if the ammeter be placed in the latter it will read the series field current which may be quite different from the current supplied by the generator to the load connected to the buses.

3. With either of these two arrangements an overload device may be used instead of a circuit breaker pole in the neutral lead, arranged to trip the circuit breaker. The circuit breaker should protect against a short circuit on the equalizer bus. An ammeter should be provided for positive and negative leads for each generator.

Grounding Three-Wire Dual Voltage Systems.—The neutral connection of three wire 230/115 volt direct current systems should be solidly grounded at the main switchboard with a center zero ammeter in the ground connection. The center zero ammeter should be equipped with a shunt, having a full scale reading of 150% of the neutral current rating of the largest generator and marked "plus" and "minus" to indicate the polarity of grounds.

The emergency lighting and power system is to be arranged so that when operating from a dual voltage emergency generator or storage battery, the neutral will be grounded but the ground connection at the emergency generator or storage battery should not be in parallel with the ground connection at the main generator. The ground connection should not prevent checking the insulation of the emergency generator to ground before the generator is connected to the bus.

Equipment for Distribution Switchboards.—Fuses in excess of 200 ampere rating should not be used for any circuits except for emergency system batteries. Circuits not protected by fuses should have each ungrounded conductor protected by an overload operated circuit breaker or circuit breaker type switch of the independent arm or *trip-free* type. The grounded neutral conductors of a *three-wire* feeder should be provided with a means for disconnecting and arranged so that the grounded conductor cannot be opened without simultaneously opening the ungrounded conductors. *Overload* protection is not necessary in the grounded neutral conductor. Circuit breaker type switches should provide overload and short-circuit protection.

Feeder circuits of 200 amperes or less may be provided with multiple lever type fused switches with one pole for each conductor instead of circuit breakers, except that for three-wire 230/115 volt feeders, no fuse is to be provided in the neutral. All fuses other than instrument fuses should be mounted on the front of the switchboard, except in the case of dead front switchboards. Arc searchlight circuits should be provided with a double-pole independent arm or a *trip-free*-from-handle type circuit breaker and an ammeter.

Two feeders should be provided from the main switchboard to the steering gear room. The overload protection for each steering gear feeder should be an instantaneous circuit breaker set at not less than 300% of the rating of the steering gear motor. The opening of the main switchboard steering gear circuit breaker should operate an audible alarm located adjacent to the principal propulsion control station.

Arrangement of Switchboard Equipment.—When facing front of switchboard, *left hand* contacts should be *negative* and *right hand* contacts *positive*. If, in special cases, it should appear necessary to use horizontal switches, the top contacts should be positive. If the buses are arranged horizontally, the positive bus should be nearest the panels; if arranged vertically, the positive bus should be at the top. Generator circuit breakers should be located at the top of the panels. Below the circuit breakers should be located the meters and if the general switchboard illumination is not sufficient for the scales of these meters other means of illumination should be provided. Below the meters should be located the ground detector and voltmeter switches and the rheostat handwheel, and below these the generator switch should be mounted. For small switchboards there may be room at the bottom of the generator panel for feeder switches.

On the feeder panels where circuit breakers are mounted above each other there should be adequate spacing for the arcing or otherwise protective barriers installed. Switches on feeder panels should be located with the largest ones at the bottom. Sufficient space should be allowed vertically between switches to avoid injury to the hand in operation. No part of any equipment should project beyond the edge of the panel. Metal framework and instrument cases should be grounded.

Arrangement of distribution boards when separate from the generator boards, should be the same as for generator switchboards as far as practicable.

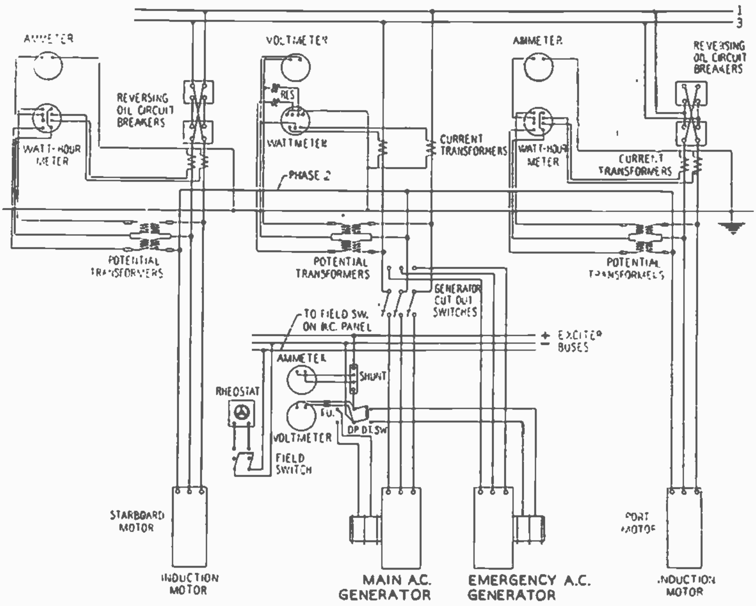


FIG. 26.—Typical wiring diagram of a twin screw turbo-electric propulsion drive with induction motors. The propelling machinery consists of one 5,500 *k.w.* turbo-generator, two induction motors, two water cooled rheostats, one main switchboard and one auxiliary propelling turbo-generator of 450 *k.w.* The machinery is all contained in one engine room. The main turbo-generator is mounted on its bed plate on the center line of the ship. The auxiliary generator is mounted on a platform above the main generator on the port side of the engine room. The two induction motors are connected directly to the two propeller shafts. The ship's 3–35 *k.w.* generators one of which may be used for excitation are located on a platform in the aft end of the engine room on the starboard side. At 15 knots the turbine makes 2,130 *r.p.m.* and the motors run 117 *r.p.m.*, the reduction being approximately 18 to 1. The electrical apparatus except those used for excitation, are of the three phase A.C. type. To reverse the direction of rotation of the propelling motors, it is only necessary to transpose two of the phases. This is easily accomplished by reversing oil circuit breakers operated by means of control levers situated on the control panels.

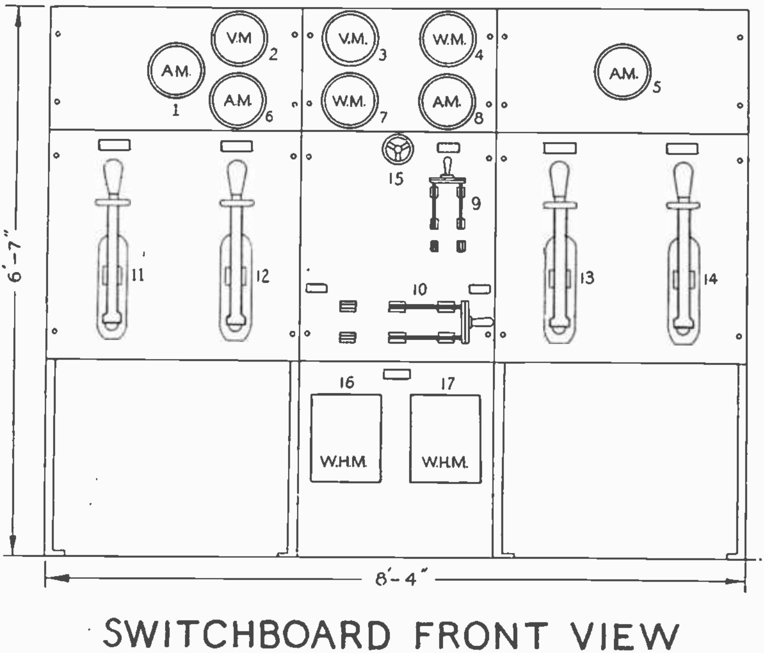


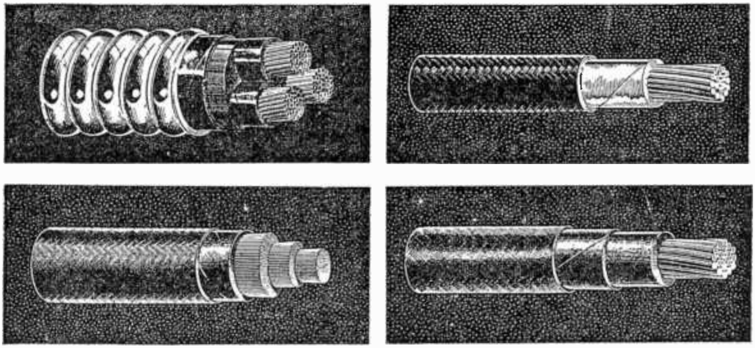
FIG. 27.—Front view of turbo-electric drive switchboard, connected as shown in fig. 26. The instrument and apparatus are: 1, ammeter; 2, volt-meter; 3, volt-meter; 4, watt-meter; 5, ammeter; 6, ammeter; 7, watt-meter; 8, field ammeter; 9, field switch; 10, D.P.-D.T. lever switch; 11 to 14, oil circuit breaker reversing switches; 15, field rheostat; 16 and 17, watt-hour meters.

Cables—Applications

Leaded and Armored Varnished Cambric Insulated.—Varnished cambric insulated cable may be used for all cable runs, and should be used for auxiliary power and lighting cables where the ambient temperature is in excess of 50°C. Where varnished cambric is used, the wire size should not be smaller than No. 12 AWG. (This necessitates the use of No. 12 wire for lighting branch circuits instead of No. 14.)

Leaded and Armored Rubber Insulated.—It is recommended that rubber insulated cable be used in all spaces where the ambient temperature does not exceed 50°C.

Steel, Bronze or Aluminum Armor.—Bronze or aluminum armor should be used for all cables exposed to weather. Steel, bronze or aluminum armor may be used for all other spaces.



FIGS. 28 to 31.—Various cables used in electrical installations. Fig. 28 illustrates varnished cambric-insulated cable with interlocked steel armor; fig. 29 glyptal cloth-insulated cable for hot and oily locations; figs. 30 and 31 varnished-cambric-insulated extra flexible apparatus leads and asbestos-varnished-cambric insulated cable respectively.

Armored Cable, Varnished Cambric and Rubber Insulated.—Rubber or varnished cambric insulated armored cables may be used only in quarters for officers and crew and passenger accommodations. Varnished cambric should not be used for wires having cross sectional areas less than No. 12 AWG.

Where lighting fixtures or sockets are not vented or designed to prevent the connecting wires from reaching an excessive temperature, rubber insulated wires should not be used where the conductor temperature will exceed 75°C.

Braided Cable.—Rubber insulated may be used in lighting fixtures except as noted in the previous paragraph. In multiple lamp fixtures 2,580 circular mils stranded, rubber and cotton braid insulated wire may be used for the individual lamps and may be spliced in the lighting fixtures.

Interior Communication Wires and Cables.—For call bell circuits of less than 25 volts, within passenger and crew accommodations, single-conductor bell wire may be used, if properly installed in protected raceways.

For interior communication apparatus, such as *fire alarms, telegraphs, telemotors, signalling circuits, control circuits*, etc., requiring two or more wires, interior communication cable should be used and should be either leaded and armored or armored, in accordance with the locations described in the preceding paragraph, except that twin conductor light and power cable may be substituted for twin conductor interior communication cable.

All telephones and telephone systems except those installed for the convenience of passengers and not essential for the operation of the vessel should be wired with either armored, or leaded and armored telephone cable as previously described.

Inter-cabin telephone cable of either the armored or leaded and armored type as described, may be used for the passenger non-essential telephone system.

The American Tel. & Tel. Specification Double-Silk Impregnated Lead Sheath Cable without armor may be used for telephone circuits where a large number of ship's service telephones are installed in passengers' and/or crew's quarters. Bridle wire in accordance with American Tel. & Tel. specifications may also be used for local wiring for ship's service telephones provided it is rigidly held in place, protected from mechanical injury and not exposed to moisture.

Portable Conductors

1. **Rubber-sheathed.**—Conductors for portable cargo fixtures, tools, watertight and non-watertight portables, signalling lights and all portable or semi-portable fixtures outside living quarters should be two-conductor portable rubber-sheathed.

2. **Armored.**—Armored portable conductor cable may be used for the foregoing applications and should be used where the cable is continuously in contact with oil.

3. **Braided.**—Conductors for portable or semi-portable apparatus such as desk lights, flat irons and curling irons used in living quarters may be two-conductor portable braided. However, the parallel conductor rubber-sheathed type portable cable is recommended.

Cable Installation

Cable Continuity and Grounding.—All cables should be continuous between outlet boxes, connection boxes, switchboards, panel boards, switch outlets, receptacle outlets, terminal equipment, etc. For any cable provided with a metallic sheath or armor, the sheath should be continuous from outlet to outlet and should be grounded at each end except that for final subcircuits the sheath may be grounded at the supply end only. Where sheathed or armored cable enters any box or wiring device the sheath should enter the box and should be secured by a clamp or connector to assure good electrical connection between the cable sheath or armor and the box.

Cable Locations.—Feeders of every description should be located with a view to avoiding spaces where excessive heat and gases may be encountered such as galleys, fire rooms, pump rooms and oil tanks; also spaces where exposed to damage such as cargo spaces and exposed sides of deck houses.

Cables should not be located behind or embedded in structural heat insulation and where they pass through such insulation each should be protected by a continuous pipe, preferably fitted with a watertight stuffing tube at each end.

Generator cables should not be located in bilges unless no other run is practicable.

Cable Protection.—All cables in bunkers and where particularly liable to damage such as locations in way of cargo ports, hatches and tank tops should be specially protected by metal coverings, angle irons or other equivalent means. Horizontal pipes or equivalent used for cable protection should have ¼ in. diameter holes for drainage every five feet.

Cable Support.—Cables where installed in groups should preferably be supported in metal hangers arranged as far as practicable to permit painting all around without undue disturbance of the installation. Cables grouped in a single hanger should preferably be limited to double banking.

Clips or straps used for cable support should each be secured by two screws except that clips for supporting one cable, No. 10 AWG twin or smaller, may be of the one-screw type. Cables supported by clips or straps on under side of beams should be run on backing plates or the equivalent. Cable supports should be spaced not more than 18 in. where vertical and 14 in. where horizontal.

Metal supports should be designed to secure cables without damage to armor or insulation and should be so arranged that the cable will bear for a length of at least ½ in.

Cables—Radius of Bends.—Leaded and armored cables should not be bent to a radius of less than 8 cable diameters. Other cables may be bent to a radius of 6 diameters.

Cables Through Bulkheads, Decks, Beams, Etc.—Where cables pass through watertight decks or bulkheads, a watertight stuffing tube capable of taking packing should be employed. Where cables pass through non-watertight bulkheads, beams, etc., a suitable bushing should be used of such a type as will permit drawing of the cable without damage. When the thickness of the bulkhead or web is ¼ in. or more the bushing may be omitted but the edges of the holes should be rounded.

Cable—Pulling in Force.—No cable should be drawn into wireways where the required pull exceeds twenty times the weight of the cable within the wireway and no appliance should be used which will damage the braid or armor.

Cables.—(Rat Proofing). During the installation of cables due consideration should be given to the feasibility of rat proofing as required by the *Public Health Service.*

Installation of Low Voltage Bell Wiring.—Wires serving low voltage circuits such as call bells for staterooms, public spaces, etc., should be neatly grouped and run together and distributed as required. These wires should be protected by molding, split fibre tubing or equivalent wrapping. The battery and branch leads may be tapped off by splicing. It is recommended that protected accessible connection blocks be used wherever possible instead of splicing within wireway enclosures. Low voltage circuits should be run entirely separate from other systems except when contained in interior communication cable.

Where the public spaces, passages, staterooms, etc., are ceiled, the call bell wiring should be run and secured above or behind the ceiling. Molding may be used in similar locations where there is no ceiling. Call bell wiring leading through crew's quarters and other living spaces where they may be subject to mechanical injury should be protected.

Holes for Cables.—The size of holes required for the installation of the cables for various systems should be such that they will not affect the structural strength of the various members through which they pass.

Distribution—D.C.

Distribution—General.—In general the methods of distribution are as follows: (the number and size of the sub-divisions depending on the size of the vessel and electric plant)—From the distribution section of the main or emergency generator switchboards to:—

1. A branch circuit for an individual controller and motor.
2. A power panel-board then to a branch circuit for an individual controller and motor.
3. A lighting branch circuit.
4. A panel-board then to lighting branch circuit.
5. More than one panel-board, each panel-board serving to subdivide the feeder to a sub-feeder supplying another panel-board or a branch circuit.
6. Another switchboard, then by any individual or combinations of (1) to (5) above, as desired.

Except in the case of small vessels and small electric plants, it is recommended that the lighting distribution system and the power distribution system be maintained as a separate distribution system from the main generator and emergency generator switchboards.

Location and Type of Panel-boards.—All panel-boards should be located so that they are readily accessible at all times to qualified personnel. They should not be located in bunkers, cargo holds and similar spaces. If the method of operation demands the operation of the switches by unqualified persons, the panel-board should be of the safety type. This type panel-board should be used for the distribution to all lighting branch circuits. Panel-boards located on weather decks or other spaces exposed to the weather or other severe moisture conditions should be watertight, elsewhere they may be of drip-proof construction.

Metallic Circuits.—All circuits should be completely metallic, and no ground return circuits should be employed except for aerial or submarine transmission.

Grounding of Portable Equipment.—Portable equipment such as portable motor units for life-boat hoisting or any other portable equipment fitted with portable cables and attaching devices and which operate on either two or three-wire circuits of 220 volts or more should have their frames grounded.

This should be accomplished by an additional conductor in the portable cable and grounding device in the attachment plug and receptacle.

Demand Factor and Voltage Drop for Generator and Bus.—Conductors from each generator to the generator switchboard should be *calculated for the rating*, including the *two-hour overload rating* (if provided) of each generator.

Conductors between generator switchboards of different generating stations should be *calculated on the basis of* 75% of the station having the *greatest generating capacity*. The drop in voltage from each generator to its adjacent generator switchboard *should not exceed one per cent.*

Conductors from storage batteries to the point of distribution should be calculated for a maximum charge, or discharge rate of the storage batteries, and the drop in voltage from the storage batteries to the point of distribution *should not exceed one per cent.*

Conductors from generator switchboard to outlet for receiving shore power should be calculated on the basis of the load required for this condition, or as specified, and the drop in voltage from the outlet to the generator switchboard *should not exceed two per cent.* Conductors should be *continuous* throughout their length.

Balance of Circuits for Three-Wire Systems.—Since branch lighting circuits are to be of the two-wire type, the three-wire system should not extend beyond the final panel-board. The 115-volt two-wire lighting branch circuits should be so disposed that the load will be *balanced within* 15 *per cent* at the individual panel-boards as well as for the complete lighting system.

Conductor Identification.—The individual conductors of branch circuit cables should have distinguishing colors, and in grounded systems, the grounded conductor should be connected to the shell of all sockets and all single-pole switches should be in the ungrounded conductor. The ungrounded systems, single-pole switches should be connected to similarly colored conductors.

Feeder Connections.—Where a feeder supplies more than one panel-board, the connection should be of a type that does not sever the conductor, and the connection should be within the panel-board or in a feeder junction box which is readily accessible at all times. In restricted spaces the feeder may be severed at the panel-board provided lugs and special bus bars of sufficient capacity for the entire load are provided which will permit through feed in the event it is desired to disconnect the local panel-board.

Distribution for Navigating Lights.—A separate feeder from the emergency switchboard to the pilot house should be installed for the running, and necessary navigating lights in the *pilot house* and on the *navigating bridge;* any other lights or small apparatus connected to this feeder should be on branch circuits fitted with fuses of no greater capacity than three amperes. Masthead, port, starboard, range and stern lights should be provided with duplicate lamps or a single lamp with two filaments. The duplicate lamps may be connected separately, by means of portable cable to two two-wire receptacles or as in the case of the two-filament lamp, by a single three-conductor portable cable to a three-wire receptacle.

Each receptacle should be connected to an *automatic indicator* located in the pilot house which will give an audible and visual signal on the occurrence of an open circuit. Each individual lamp circuit should be fused and provided with selective switches. The indicator should be enclosed in a steel case unless the magnets are properly shielded.

Distribution for Power Equipment.—In general, power feeders for cargo elevators, cargo hoists and cargo winches which are to be disconnected when the vessel is underway should not be used to supply ventilation sets, drainage pump motors or any apparatus required for the ship's operation.

Separate feeders should be run for engine and fire room auxiliaries, motors for cargo handling gear, steering gear, windlass, radio transmitters, searchlights and ventilation sets. Cargo ventilation fans and fans for ventilation of passenger accommodations should not be supplied from the same feeder.

Two feeders should be provided from the main switchboard to the steering gear room. These feeders should be widely separated so as to minimize failure of both feeders by collision, fire or other casualty. Each feeder should have a continuous current carrying capacity of not less than 125% of the rating of the motor or motors simultaneously operated therefrom.

In order to prevent the spread of fire, recent regulations of the *Bureau of Marine Inspection and Navigation* require arrangements to permit stopping all vent fans from a central point.

Distribution for Heating Equipment.—Separate feeders should be provided for air heaters when extensively used to augment or supplant other forms of heating and the aggregate capacity of the heaters in any one compartment exceeds 5 *k.w.* Isolated heaters, the aggregate of which does not exceed 5 *k.w.* may be taken from other power feeders which are normally energized. An isolated heater, not exceeding 1 *k.w.* may be connected by a separate circuit to a panel-board which is connected to a lighting feeder.

Motor Branch Circuits.—A separate branch circuit should be provided for each fixed motor having a full-load current rating of 6 amperes or more, and the conductors should have a carrying capacity of not less than 125 per cent of the motor full-load current rating. No branch circuit should have conductors less than No. 14 wire.

Heating Appliance Branch Circuits.—Fixed heating appliances having an aggregate rating of not more than 6 *amperes* may be grouped on a branch circuit wired with not less than *No.* 14 *wire* and fused not in excess of 10 *amperes*. Fixed heating appliances having an aggregate rating of not more than 15 *amperes* may be grouped on a branch circuit wired with not less than *No.* 12 *wire* and fused not in excess of 15 *amperes*. Fixed heating appliances having an aggregate rating of not more than 20 *amperes* may be grouped on a branch circuit wired with not less than *No.* 10 *wire* and fused not in excess of 20 *amperes*.

In these cases no other outlets or appliance should be connected to the branch circuit except that current-on indicating lights may be considered a part of the heater. Individual heating appliances with a rating of 15 amperes or more should be wired with a separate branch circuit having a current carrying capacity of not less than the full-load rating of the appliance and protected by a fuse of not greater rating or nearest larger size than the heater. Indicating lights within the heater may be considered to be protected by the branch circuit fuse. For range units, bake ovens, griddles, broilers, in which self-contained fuses are provided for each individually controlled heating element only one branch circuit need be provided for each assembled unit.

Motors Larger than One-Quarter H.P.—In general, motors larger than ¼ *h.p.* or apparatus consuming more than 660 *watts*, other than incandescent lamps, should not be connected to lighting circuits.

Receptacles for 230 Volt Portable Equipment.—In cases where it is necessary to use 230 volt portable motors the receptacles for their attachment should be permanently marked indicating the voltage and of a type which will not permit attaching 115 volt equipment.

Lighting Branch Circuits.—Connected Load.—It is recommended that in designing the lighting system, the maximum connected load on any branch circuit should not exceed 880 *watts*.

Lighting Branch Circuits—Wire Size.—All branch circuits should be wired with not less than No. 14 AWG conductors.

Lighting Branch Circuits—Over-current Protection.—Each lighting branch circuit should be protected by an over-current device in each wire of no greater capacity than 10 *amperes*, except branch circuits supplying only sockets or receptacles of the Mogul type and wired with not less than *No.* 12 *AWG wire* may be protected by fuses having a rated capacity not greater than 20 *amperes*.

Wire Connections.—Wire joints or connections should be made by screw connections or approved connectors in flame-proof outlet boxes and wiring appliances. Except for portable cords, bell wires and lighting branch circuits the individual wires should terminate in lugs. For lighting branch circuits, wire lugs may be used or the ends of the stranded wire may be formed into eyes and soldered. The lug should be of sufficient size so that it is unnecessary to reduce the wire cross section to permit proper entry into the lug except where the wire size has been increased to reduce voltage drop. Under this latter condition, strands may be removed at the lug entrance but in no case should the remaining cross sectional area be less than that required to carry the maximum current. This exception may not be applicable with some types of mechanical lugs due to the inability to obtain uniform bearing on the conductor.

Use of Outlet and Connection Boxes.—Outlet and connection boxes should be located in accessible locations and not in back of joiner panels unless the covering panels are hinged to permit ready access to the boxes.

Interior Communication Wire and Feeders.—Conductors for interior communication circuits should be calculated for carrying capacities for the rated current of the apparatus connected.

Interior Communication Circuits—Selection of Voltage.—All interior communication circuits should be designed for operation from a 20 volt or a 120 volt direct current or alternating current supply unless the circuits are simple when 12 or 6 volts should be satisfactory.

Interior Communication Circuits—Voltage Drop.—The maximum allowable drop on any circuit shall not exceed 5 per cent of the supply voltage from the point of supply to the most remote outlet under any operating condition.

Interior Communication Circuits—Over-Current Protection.—Where a common feeder is employed for a number of interior communication circuits, each circuit as well as the feeder should be fused and the feeder size based on the connected load.

Interior Communication Circuits—Wire Connections—Except for low voltage call bell circuits, all connections should be made with approved connector or terminal blocks in *flame-proof boxes*. It is suggested that properly protected and accessible terminal blocks be provided for low voltage call bells to facilitate maintenance.

Interior Communication Circuits—Connection Boxes.—Connection boxes where exposed to moisture or used with leaded and armored cable should be of the water-tight type and all others of the drip-proof type; water-tight boxes may be substituted for drip-proof wherever desired.

Special Requirements for Oil Tankers.—For requirements for tankers consult the *Bureau of Marine Inspection and Navigation*.

Conductors and Apparatus in Vicinity of Standard Compass

General.—It is an established fact that generators, motors and conductors carrying currents and particularly grounded circuits have an effect on *magnetic compasses*. The surroundings of the apparatus and wiring, if in steel houses, may reduce to a considerable extent this effect.

For small cables closely associated, carrying small currents, the effect is very slight and for a single lamp for lighting the compasses the conductor, when twisted, may be led inside the binnacle.

The compasses should be adjusted to meet the average operating conditions and the effect of electric circuits in close proximity should be checked by turning them on and off during adjustment.

Direct Current Motors

General.—All motors should be wound for operation on 230 volts direct current (except in the case of installations having a very limited amount of power apparatus where 1/15 volt motors may be used).

Installation and Location.—Motors for mounting on open deck should be of the waterproof type or enclosed in metal housings giving the same protection as a waterproof motor frame. In the case of tank vessels, only enclosed separately ventilated motors should be installed in compartments which may be subject to inflammable gases. All other types of motors should be strictly prohibited in such locations.

Motors should be installed, as far as practicable, with the armature shafts in the fore and aft direction of the vessel. In case motors for service at sea are to be mounted in an *athwartship position*, the manufacturer should be notified.

Accessibility.—All motors should permit ready removal of the armature and field coils and bearings should be arranged to facilitate lubrication and flushing. Eye bolts should be provided for lifting motors of over 150 lb. in weight. All motors except fractional horse power motors should be provided on the commutator end with openings or removable covers of sufficient size and number to give easy access to brush rigging, etc., and permit direct view of the commutator and/or brushes while in operation.

Insulation of Windings.—All assembled armatures and also the armature coils for open slot construction should be immersed in insulating varnish and baked. All field coils should be treated with varnish or other insulating compound while being wound, or impregnated by the vacuum and pressure method. The finished winding should be water and oil resistant.

Lubrication.—Motors should operate successfully for continuous periods when tilted at an angle of 5° fore and aft, and 15° athwartship, and should not spill oil when the vessel rolls 30° either side of the vertical. (In cases where the shaft will be located athwartship, the manufacturer should be advised.)

Terminal Arrangements.—All motors except those of the waterproof type should be provided with drip proof terminal boxes and have the terminal leads suitably secured to the motor frame. The ends of these leads should be fitted with approved connectors. All connections to interior of motors as well as those to the current supply should be provided with efficient locking devices.

The leads of the waterproof motors should be brought out of the motor through waterproof junction boxes. All leads should be located on the *right-hand side* (facing the commutator) unless otherwise ordered. However, both sides of the motor should be so constructed that the waterproof device can be attached in case a change is desired after installation.

Corrosion-Resistant Parts.—All motor interior bolts, nuts, pins, screws, terminals, brush-holder studs, springs, hand-hole cover bolts, nuts and such other small parts, which would be seriously damaged and rendered ineffective by corrosion should be made of corrosion-resistant material or steel suitably protected against corrosion. Steel springs should be treated to resist moisture in such a manner as not to impair their spring quality.

Heating Equipment

Convector and Radiant Type.—Heaters should be suitable for 115 or 230 volts. The sizes recommended are 550, 660, 1000, 1500, 2000, and 3000 watts. The 550, 660, 1000 and 1500 watt sizes may be designed for single heat. The 2000 watt size and above should be designed for at least two heats. The construction of the heaters should be such as to heat the surrounding air by convection. The heaters should be strong, durable and all parts should be of solid construction, capable of withstanding abuse under service conditions. The framework should be metal of substantial proportion and securely fastened together. They should have *non-inflammable* heat insulating material, or adequate air circulation between the heater and surface, upon which it is mounted or to which it is adjacent. When heaters are of the portable type, a suitable clip or bracket should be fitted holding the heater in a fixed position.

Heaters installed on or adjacent to decks or bulkhead should be protected by a perforated or expanded metal covering or equivalent. The ends, back and top may be of solid material. Heaters with exposed surfaces installed flush with the bulkhead should have such exposed surfaces protected by a screen or guard similar to the other type with the same per cent openings, but the other sides of such heaters should be suitably protected by a solid metal enclosure so designed as to meet the specified temperature limitations. Heaters for mounting on bulkheads should have their top slanted or otherwise designed to prevent hanging towels, etc., on the heater.

The protecting guard should be strong enough to resist being forced against any current carrying part and give full protection from electrical or mechanical injury. The openings should be of small size to prevent the heating elements from being short-circuited or damaged by accident. All metal parts of the heater should be suitably protected against corrosion. The heater element may be of the open or enclosed types and the resistor material should be non-corrodible. If the heating unit is of the enclosed type, the enclosing case or jacket should be permanently corrosion-resistant. If the heating elements are of the open coil type, they should be so designed and supported as to withstand vibrations and prevent short circuit with adjacent elements.

The heating elements should be made up of uniform units easily installed and replaced. The elements should be of a material that will not corrode or oxidize. Alloys containing *zinc* are not recommended for this purpose. No material should be used which is *inflammable*. All connections of the heating elements should be *accessible* and so made that they will not become loose from vibration.

The elements should be wired to a terminal block with connectors and the leads brought out through insulating bushings. All insulated parts should be unaffected by the heat from the heating elements. The external temperature of the enclosing cases of the heaters should not exceed 125°C. except the flush type, in which case the temperature should not exceed 100°C. When the heaters are mounted upon or adjacent to the decks or bulkheads, the construction of the heater should be such that the nearest deck or bulkhead surface will not exceed a temperature of 55°C. For test purposes, an ambient temperature of 25°C. should be used. A suitable regulating switch mounted on an approved insulating base should be provided. Heaters should be equipped with a thermal cut-out of the manual reset type that will prevent overheating of the elements. The heater when hot should withstand 500 volts alternating current, 60 cycles for one minute applied between the frame and current-carrying parts.

Every piece of apparatus should have a name plate attached specifying *"Marine" manufacturer's name, volts, amperes, watts* and designating number.

Luminous heaters of a type approved by the *Underwriter's Laboratory* may be installed if desired by the owners.

Glow heaters of the incandescent lamp type in which the element is enclosed in an exhausted glass bulb, are not recommended, but should be constructed to recommendations previously stated, as regards fire risk, guarding, etc., and in addition the lamps should be supported in sockets of ample current carrying capacity, preferably of a spring or flexible type; an additional spring support should be fitted at two-thirds of height of lamps to prevent breakage from vibration.

Electric Heaters (Theory).—Electric heaters used aboard ships are for the purpose of *cooking* or for *heating* of *water* or *space*.

The heating effect received is due to the current flowing through its resistance coil. The resistance units are usually wound for the full line voltage of the supply. They are classified in accordance with the number of watts required to operate them, and also in accordance with the number of ways in which the units may be connected such as, *single heat*, *double heat*, *triple heat*, etc.

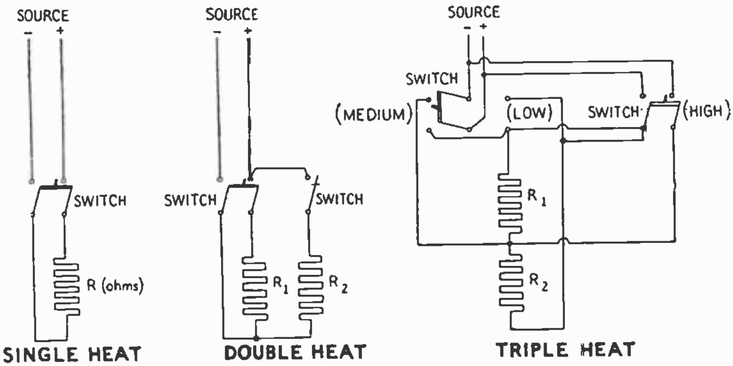
Single Heat Type.—In this type the resistance units are connected permanently in *series*, *parallel* or *series-parallel* and are operated by closing a switch, fig. 32.

Assuming a potential (E) across the heater coil or coils of (R) ohms resistance, then the heat generated is E^2/R joules per seconds.

Double Heat Type.—In the arrangement fig. 33 the heat is controlled by two switches connecting two equal resistance coils to the source. When closing the double pole switch only resistance R_1 is being heated. The amount of heat generated is E^2/R_1 joules per seconds.

If only the single pole switch be closed the heat generated is E^2/R_2 joules, but since R_1 equals R_2 it is evident that the heating will be the same in both cases. On the other hand if both switches be closed the heat generated will be $\left(\frac{R_1+R_2}{R_1R_2}\right)E^2$ joules per second or twice the amount generated with only one switch closed at a time.

Triple Heat Type.—With reference to fig. 34 low heat is obtained when the double throw switch is closed toward the right, connecting R_1 and R_2 in series. If E is the supply voltage, the heat generated is E^2/R_1+R_2 joules per second.



FIGS. 32 to 34.—Various heat control circuits.

When the double throw switch is closed toward the left, medium heat is obtained R_1 is connected across the line and R_2 is cut out. The heat generated is now E^2/R_1 joules per second.

Finally when the double pole switch only is closed, R_1 and R_2 are connected in parallel.

The heat is now $\left(\frac{R_1+R_2}{R_1R_2)}\right)$ E^2 joules per second. If R_1 equals R_2 the ratio of the heat obtained is 1/2R : 1/R : 2/R, that is the medium and high heat are two and four times respectively as high as that of the low heat.

Thermal Units.—The unit of *heat energy is the B.t.u.* (British thermal unit) and is defined as the *amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.* An expression giving the relations between the electrical energy in a circuit and the heat in B.t.u. is:

$$H = 0.057t \frac{E^2}{R}$$

Where H = amount of heat in B.t.u.

E = potential of the source in volts

R = resistance of the circuit in ohms

t = time in minutes.

Example.—An electric heater having a resistance of 12.1 ohms is connected to a potential of 110 volts for one hour. How many *B.t.u.* are obtained?

Solution.—A substitution of values in the above formula gives

$$H = 0.057 \times 60 \times \frac{110^2}{12.1} = 57 \times 60 \text{ or } 3{,}420 \text{ } B.t.u. \quad Ans.$$

Example.—How much current does a 115 volt 1500 watt heater draw from the line? What should its fuse rating be?

Solution.—The current from Ohm's law is:

$$\text{amperes} = \frac{\text{watts}}{\text{volts}}$$

A substitution of values gives

$$\text{amperes} = \frac{1500}{115} = 13.04$$

The fuses should be the next commercial size above 13, say 15 amperes.

Lighting Equipment

Location of Fixtures.—Lamps should be located preferably overhead, except as a decorative feature in specially equipped rooms. The lamps and wiring appliances should have maximum protection and should not be obscured by moving or stationary objects. When located on bulkheads they should be about six feet above the deck.

Lamps and portable outlets in cargo spaces or on the underside of decks, subject to dropping of heavy weights, should not be fastened to decks, but to clips secured to the side of beams and brackets and should be protected in cargo spaces by metal rods or angles on each side of the fixture or portable outlet.

Attention is directed that some types of high wattage lamps are designed to operate only in either "base up" or "base down" position.

A tell-tale light should be installed outside each refrigerated space to indicate when the lights inside are energized.

Illumination Requirements.— Every compartment, stateroom, office, bath or lavatory should have at least the equivalent of a 25 *watt lamp* or portable for connecting same.

Single lamps or fixtures of more than 50 *watts* should not be used unless diffused by colored or ground glass, except for cargo lighting and for machinery spaces if mounted above range of vision.

Lamps.—All lamps should be selected for the voltage on which they will operate, generally 115 volts. Intermediate base with special shapes and sizes should be used only in spaces as a decorative feature. It is recommended except for instrument lighting that lamp bases not smaller than the intermediate type be used for decorative lighting purposes.

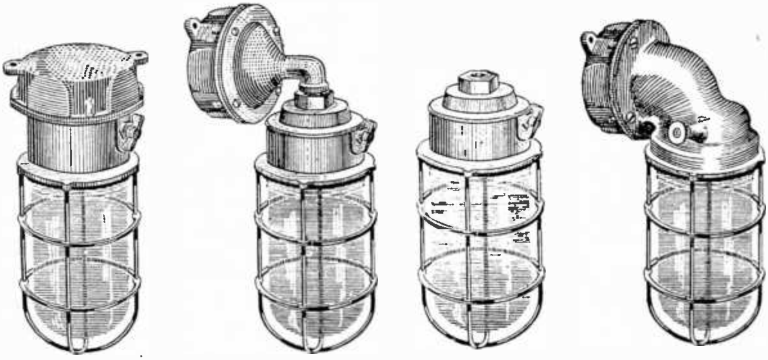
Arc Lamps.—Arc lamps should not be used except for searchlights or moving picture projectors.

Outlets for Portable Lighting Equipment.—Portable outlets of watertight type should be provided for chain lockers, windlass, deck machinery, steering gear, boiler man-holes, boiler rooms, bunkers, engine room, shaft alleys, refrigerating machinery pump rooms and wherever exposed to moisture.

Non-watertight outlets may be used in baggage rooms, mail rooms, deck lockers, store room, passenger and crew accommodations, deck fan rooms and similar places. All portable lights should be guarded, except when used for semi-decorative purposes in passenger and crew staterooms. Portable lights should not be used for built-in berths. Lights on beds or other furniture connected by portable cable should have the cable secured to the furniture to reduce the amount of loose cable to a minimum. Cords for bed lamps, floor lamps, table lamps and desk lamps for new installations should in general not exceed five feet in length.

Lighting for Cargo Handling.—Lighting of cargo spaces, hatches and cargo handling gear by large units should only be used when the lighting units are out of range of vision of the persons employed. Outside lighting for lighters, wharves, gangways, decks and hatches should be from overhead. In cargo spaces, lights should be so placed as to protect the light on the cargo ports and hatches.

Permanent Watertight Fixtures.—For outside use, forecastle, poop deck houses and mess spaces (not used as living quarters) cargo spaces, engine room, fire rooms, steering gear, windlass and pump room fixtures should be made of corrosion-resistant material and should be made watertight. The globe should be protected by a substantial guard.

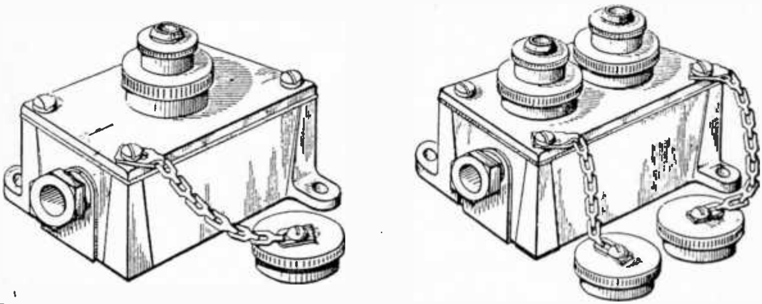


FIGS. 35 to 38.—Represent various types of permanent water-tight fixtures for outside use.

These fixtures should be so proportioned and constructed that when operating continuously with rated size lamp, the temperature will not exceed 35°C. above the surrounding air. Watertight globes should be flanged or of threaded type. Screw threads should conform to the following dimensions:

	Inside diameter of globe	Outside diameter across top of thread	Inside diameter across bottom of thread
Globes for 100 watt lamps	$4\frac{13}{32}$ in.	4.859 in. max. 4.844 in. min.	4.734 in. max. 4.719 in. min.
Globes for 50 watt lamps	$2\frac{27}{32}$ in.	3.297 in. max. 3.282 in. min.	3.1719 in. max. 3.1569 in. min.

4 rh threads per inch with a minimum threaded distance of one inch. The radius of the thread should be ⅛ inch and the center of the first thread should be ¼ inch from the edge of globe with threads spaced on ¼ inch centers. The inside diameter of globe may have a variation of 1/32 inch. The base of the fixture should have no less than 2½ threads for the reception of the globe and should be provided with external threads for the reception of the guard.



FIGS. 39 and 40.—Water-tight receptacle and plugs for one and two outlets respectively.

Portable Watertight Fixtures.—Watertight portables should be similar in construction to the permanent watertight fixtures. The guard should be provided with a hook or ring; also a handle with a stuffing tube for the cable and means to prevent strain on the connections. Portables with bodies of molded insulating material may be used. The use of brass shell sockets is not recommended.

FIGS. 41 and 42.—Portable water-tight fixtures.

Portable Non-Watertight Fixtures.—These need not have a globe or stuffing tube, but should be equipped with guard except for semi-decorative desk lights, floor lamps, table lamps, etc., in living quarters and should preferably be composed of insulating material as far as possible. They should be provided with means to prevent strain on the connections.

FIGS. 43 to 45.—Cabin, stateroom and promenade deck fixtures respectively.

Interior Fixtures.—Fixtures for passenger accommodations and living quarters of crews should be substantially constructed and provided with sockets or receptacles which cannot become loose or disassembled through shock or vibration.

Dome fixtures should be ventilated and designed so that none of the adjoining woodwork is directly exposed to the heat of the lamps. Fire resisting material may be provided as a heat insulator. All fixtures should also be adequately vented to prevent excessive temperature from reaching the supply wires.

Emergency Light and Power System

General.—General requirements for this system will be found in *Department of Commerce, Bureau of Marine Inspection and Navigation Rules and Regulations*, and all details of this system are subject to the approval of the *Bureau of Marine Inspection and Navigation*. In general, the following recommendations, though somewhat more detailed, are in accordance with the

Bureau requirements but the latest requirements of the *Bureau* should be used as the authority for each vessel.

Every vessel equipped with an electric lighting plant should be provided with an independent emergency source of power installed above the bulkhead deck, as described in the following sections: *All emergency lights should bear a distinguishing mark for ready identification.* Emergency lights should form a part of the regular lighting system to insure readiness of burning.

Cargo Vessels.—For all vessels of 1600 gross tons and over the emergency source should consist of storage batteries or diesel generating set having sufficient capacity for continuous operation over a period of at least 12 hours when supplying the navigating light circuits, telegraphs, binnacles, and the emergency lighting for machinery spaces, steering gear room, radio room, emergency power stations, passageways, exits from crew's quarters and other spaces and equipment necessary for the operation of the vessel in an emergency. The emergency system should comprise independent circuits from the emergency panel, and be normally energized from the main power source.

Cargo Vessels Less Than 1600 Gross Tons.—Approved safety lanterns may be used for emergency lighting for vessels less than 1600 gross tons.

Passenger Vessels of 1600 Gross Tons or Over.—The emergency source for all vessels of 1600 gross tons and over should consist of one or more diesel engine driven generator sets having sufficient capacity and fuel supply to carry the full emergency load continuously for a period of at least 36 hours, and such final emergency source should be supplemented by a temporary emergency source of power for lighting, consisting of storage batteries having sufficient capacity for continuous operation over a period of at least 1½ hours.

The capacity of the temporary and final emergency sources should be determined by the maximum operating loads of the following groups of circuits. The temporary emergency circuits should provide continuous emergency lighting and power for essential communication circuits during the interval between the failure of main source and starting of the emergency generator.

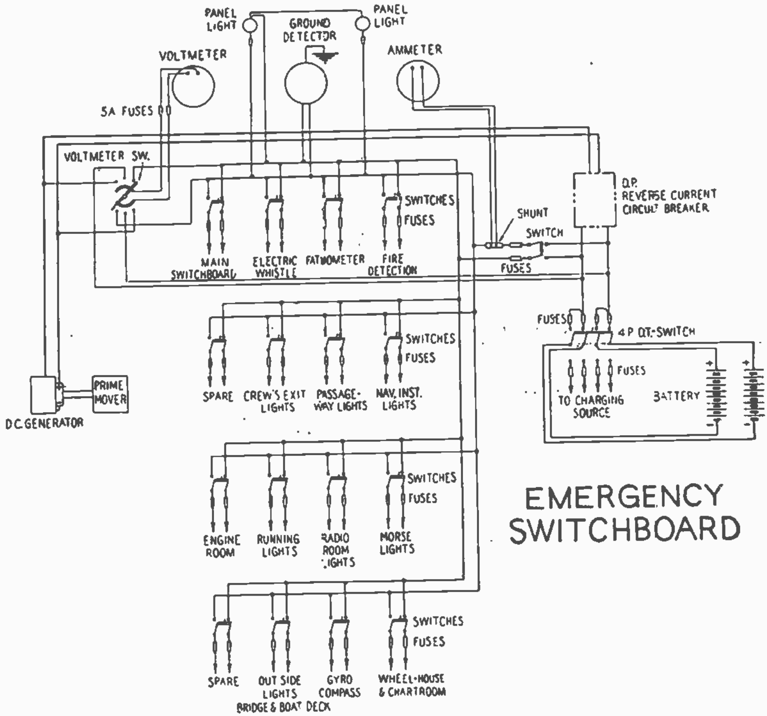


Fig. 46.—Typical emergency control switchboard. This switchboard is usually located on the boat deck and adjacent to the emergency generator set. Power is supplied to the emergency switchboard from the main board on normal operation, and from the diesel driven emergency generator or storage batteries on emergency operation.

The circuits recommended for connection to the temporary emergency lighting storage batteries are as follows:

1. *Temporary Emergency Lighting, Communication and Power Circuits.*

(a) Navigating lights

(b) Machinery space lighting

(c) Radio room lighting

(d) Passenger and crew exits and passageways (including public spaces) adequately to permit passengers and crew to readily find their way to the boat deck. Lights should be located at least at each end of each section of all fore and aft and athwartship passageways and at each stairway and exit on each deck. In no case should the distance between lights exceed 75 feet.

(e) At least one light on each berthing compartment accommodating 20 or more persons.

(f) One or more lights in the galley, pantry, steering gear room, emergency power station, generator space lighting, chart room, pilot house, public spaces, and at all other locations, gauge boards, gauge glasses, etc., essential for emergency operation of the vessel.

(g) Boat deck lighting.

(h) Power for essential communication circuits between bridge, engine room, steering station including telegraphs, if electric.

(i) Watertight door operating gear (if electric) and indicating system.

(j) General or emergency alarm and fire alarm system.

(k) Emergency loud speaker system.

2. Final Emergency Lighting, Communication and Power Circuits to be connected to the emergency generator:

(a) All items enumerated in No. 1.

(b) Life-boat flood lights. The lighting in the vicinity of the life boats and the boat handling equipment, including the flood lighting of water at the sides of the vessel, should be sufficient to permit the complete operation of loading, lowering and releasing of the life boats.

(c) Emergency bilge pump, one fire pump, and one sprinkler pump (if provided).

(d) Other interior communication systems essential for the emergency operation of the vessel.

(e) Radio equipment. (This is in addition to the separate storage battery source required by the Federal Communications Commission.)

The switchboard for the control of the emergency plant should be designed so that all emergency circuits are normally energized through the emergency switchboard from the main generating plant.

The temporary emergency lighting and communication circuits should be transferred to the storage battery automatically upon failure of the main generator supply. In general, all emergency circuits should be provided as independent circuits from the emergency power distribution source. Wire sizes, voltage drops and all other details should conform to the recommendations as previously given.

Passenger Vessels—100 to 1600 Gross Tons.—For passenger vessels of 100 gross tons and less than 1600 gross tons, the emergency source for lighting and power should consist of a diesel engine driven generating set or a storage battery having sufficient capacity to carry the full emergency load for a period of at least 12 hours.

Passenger Vessels—Less than 100 Gross Tons.—For passenger vessels of less than 100 gross tons the emergency lighting system may be approved safety lanterns.

Signal and Communication Systems

General.—Electrical signal systems forming part of the essential operating systems of the vessels should be as independent and self-sustaining as possible. When dependent on a current supply the source of energy should be capable of maintaining the *operation* of the *systems* for a period of *at least twelve hours* and should be independent of the generating plant or as required by the Bureau of Marine Inspection and Navigation.

Electrically operated signalling and indicating systems are recommended for such applications as engine, steering and docking telegraphs and rudder indicators, in preference to mechanical wire or shaft operated systems where the installation necessitates many turns which may be adversely affected by the varying stresses and strains due to loaded and light condition of the vessel.

Installation and Location of Instruments.—All instruments should be installed with a view to securing the greatest amount of mechanical protection. Lamp type indicating devices should be so located that they do not interfere with the vision of the helmsman for light navigation. Pedestal type instruments should preferably be installed on wood deck blocks and caulked at the deck to prevent water collecting under the pedestal base.

Instruments for bulkhead mounting should be rigidly secured in place and should be mounted at a convenient height for ease in reading. It is recommended that the designation plates and marking for all equipment located on the bridge, essential for the operation of the vessel, be of the luminous type.

Any attachments made to machinery or apparatus for the operation of electrical or mechanical indicators should be such that the derangement of the parts will not interfere with the operation of the machinery or apparatus and the deranged parts can be readily removed.

Instrument Construction.—The construction of the various telegraph instruments should be in accordance with the best standard practice for marine installation, the salient points for consideration being the following:

Instruments should as far as possible, be *water-tight*, fitted with suitable terminal tubes for cable entrance and a connection board with marked terminals for each wire.

The outer case should be of corrosion-resistant material and may be either casting, molding, stamping or fabricated construction. If molded composition be used, it should be flame-proof. All small parts should be of corrosion-resistant material or steel suitably protected against corrosion.

The current carrying parts should be of suitable material for the service, such as brushes, copper connection blocks, etc., and all wearing parts should be of sufficient hardness to prevent excessive wear

All coils should be suitably insulated and impregnated to withstand the conditions of heat, oil or moisture that may be encountered within the instrument by virtue of its own operation or external conditions.

In all electrical instruments (transmitter, indicators, etc.) the transmitting segments, brushes, magnets, motors, etc., should conform to the best general practice as regards construction.

Push Buttons, Bells, Buzzers, Etc.—Construction.—The push buttons, bells and other fittings required in various systems mentioned hereinafter should meet the following general recommendations:

All small parts, including screws, contact elements, etc., should be of *corrosion-resistant material* or steel suitably protected against corrosion.

In all exposed locations, and in boiler rooms, engine rooms, crew's spaces, galleys, working passageways and all similar locations, *water-tight equipment* should be used. The water-tight enclosures for the operating mechanism should be of corrosion-resistant material.

Bells and buzzers should be of rugged construction, suitable for marine service, and not affected by vibration; the appliance to consist of box enclosing the mechanism, cover, and a gong, or vibrator; the mechanism should be readily accessible. The securing of the cover to the box for water-tight appliances should be by means of a coarse screw thread, with a ground joint, or a suitable rubber gasket with four or more securing screws. The box should be provided with at least three lugs for bulkhead mounting, and provide for mounting screws of not less than ¼ in. diameter. Suitable bosses should be provided on the side of the box for tapping for terminal tubes for incoming leads.

There should be at least ¼ inch clearance through air, and ½ inch creepage clearance between all live parts of opposite polarity and between inside of enclosure and any live parts for 115 volts or less.

The exterior surface of the bell box should be painted and gongs should be given a durable finish. The interior of the bell box should be given two coats of suitable insulating paint.

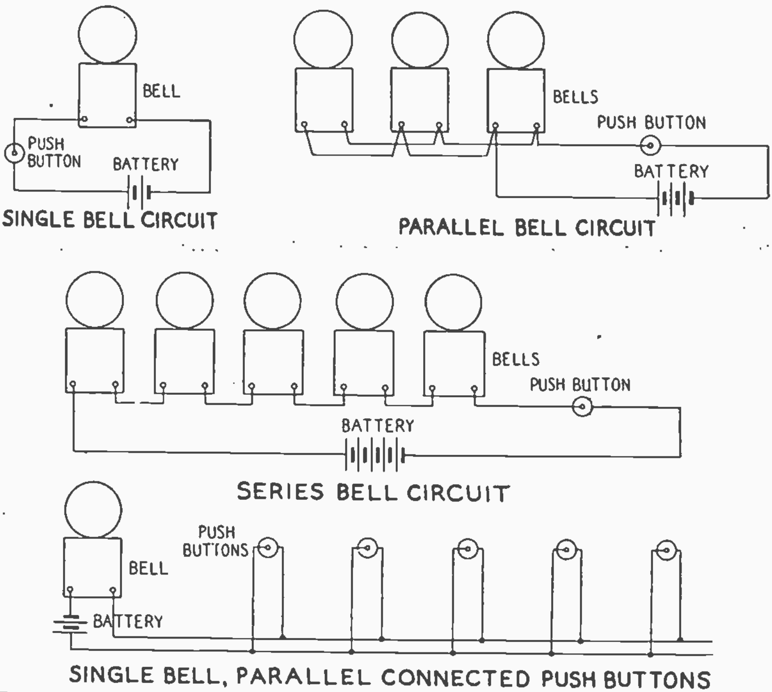
If the design of water-tight bells and buzzers is such that the bell clapper passes through the box, it should be made water-tight. The bell should operate on a 20% reduction in voltage.

Coils should successfully withstand, for a period of 5 seconds, the following high potential test between each electric circuit and ground:

(a) 1500 volts, 60 cylces, for 115 volt coils, or

(b) 200 volts, 60 cycles, for coils of 20 volts or less.

Succeeding the dielectric test the coils should show an insulation resistance of each electric circuit to ground or not less than 1 megohm at 500 volts.



Figs. 47 to 50.—Various bell circuits. The series arrangement, fig. 49, however, is very seldom used. Since the bells are series connected the potential of the battery must be five times larger than that required by one bell. Another disadvantage is that an open connection anywhere in the circuit will put all bells out of service.

The operation of bells and buzzers should be unaffected by range of temperature from 20°C to 70°C and the winding should be such as to not have a rise in temperature above surrounding air of more than 30°C under 30 minute normal operation.

Name Plates.—All current consuming equipment including telegraphs, bells, buzzers, etc., should be equipped with a suitable *name plate*, giving manufacturer's name, voltage and current consumption or rating.

Engine Order Telegraphs.—Every vessel should be equipped with a *repeat-back signal system* from the navigating officer's station to the engine room.

Any system installed should check within ¼ an indication on the transmitter and receiver and the indication should retain this accuracy. This accuracy should be met with the vessel light and loaded and under the most severe weather conditions. There should be an audible signal with every change in the order and reply.

Mechanically operated telegraph transmitters at the forward and after end of large vessels should not be connected to the same engine room indicator.

Deck mounted transmitters should be mounted with the dials in a fore and aft position, and the movements of the operator's handle should be in the direction of the desired movement of the vessel. The dials should contain at least the following indications or their equivalent:

For Port Dial

Ahead—Full Half Slow

Standby Stop Finished with engines

Astern—Slow Half Full

and should be so constructed that they are plainly visible 10 feet distant and the bridges or deck transmitters should be illuminated from behind the dial for visibility at night. Indicators in the engine room should be mounted as near the operating gear as possible, and equipped with solid brass engraved or the equivalent dials.

Fireroom Order Telegraphs.—Telegraph systems for transmitting orders from engine room to boiler rooms should be of similar construction, installation and operation as engine telegraph system; the transmitters need not be illuminated. The markings should be suitable for the system of air, fuel and feed employed or as required.

Docking Order Telegraphs.—Telegraph systems for transmitting docking orders between the navigating positions and the after bridge, should be of the same construction, installation and operation as the engine telegraph systems. *Transmitters* and *indicators* should be *illuminated*.

Steering Order Telegraphs.—Telegraphs for transmitting steering orders should have a transmitter at the bridge, connected to an indicator at the after steering station and steering gear room. The after steering station and steering gear room indicator is to be fitted with a repeat back signal to the bridge, unless a rudder indicator is installed on the bridge.

Rudder Angle Indicator.—On passenger ships and other large ships as required, an electric rudder angle indicator system should be supplied. The transmitter should be located at the rudder head and actuated by the movement of the rudder, the angular movements being indicated in the pilot house. The *angle* of the *rudder* should be *indicated automatically* at the pilot house station and if the indicator does not move synchronously with the rudder but operates step by step, the minimum indications should be by degrees to ten, then 12½ degrees, 15 degrees and by 5's to 35 degrees. Wherever possible, synchronous type indicating equipment is recommended. The indicator located on the bridge and at the after steering station should be illuminated.

Mechanical Telegraph Installations.—For mechanical telegraph systems all wires, pulleys, chains, sheaves, turnbuckles, springs and wearing parts should be *corrosion-resistant metal.* Pulleys should be of at least 3¾ in. diameter and provided with suitable holes for oiling. All wire should be of brass, at least No. 10 AWG thoroughly stretched before installation. No splices in wire should be used. Chains in pulleys should be used at all turns; bell cranks should not be used. Wires should be turned and wrapped at gongs and pulls. At chains, they should be turned and provided with sleeves. Where necessary, systems should be provided with springs to take up slack wire in the system.

Mechanical telegraph systems operated by wires should be as direct and have as few turns as possible, and should be so installed as to be accessible at all times.

Wires should not be run behind *insulation* for *refrigerator spaces, through coal bunkers or cargo spaces*, except when *unavoidable* and then should be run through tubes for each wire; the tubes terminating so that wire may be *removed* and *renewed* with the bunkers and cargo spaces filled. Wires should not run *behind paneling of rooms* unless made readily accessible by suitable removable covers. Wire should be supported every three feet or when run through members of the ship's structures should be through holes having a diameter not less than two diameters of the wire and should be so installed that they do not bind on the supports or edge of the holes when in motion.

Wires should be protected by suitable covers throughout their length, except as provided for above and for risers in engine room and between decks, where all wires for a single system, not exceeding four, may be run in one tube and not less than three inch diameter. Wires should be spaced at least ⅝ inch horizontally and ¾ inch minimum vertically between centers throughout system.

Engine Order Bells.—For some groups of vessels, bell pulls instead of telegraphs are permitted by the *Bureau of Marine Inspection and Navigation.* The use of telegraphs is recommended in preference to bell pulls. Bell pull systems employing pulls in pilot house, on bridge and on deck houses operating hammer gongs and jingle bells in engine room should be provided with suitable sounding tube with a receiver embracing one-half the gong in the engine room connected by at least 1½ in. brass tubing to a flaring transmitter at all the pull stations; the transmission of sound should be such that it can be heard anywhere in the enclosure and five feet distant in open spaces. The material, installation and operation should be the same as described for mechanical telegraphs. The system should be provided with a *label plate* at each mechanical pull, gong and sound transmitter, giving the systems used.

For *Great Lakes* and *River Rules* see *Bureau of Marine Inspection and Navigation Latest Rules.*

Alarms for Cold Storage Spaces.—In order to prevent injury to personnel, all refrigerated spaces and ice boxes for the storage of ship's stores and provisions should be provided with *a mechanical or electrical signal*. A pull or push button should be *located inside* and at the *exit* of each storage space, and the signal

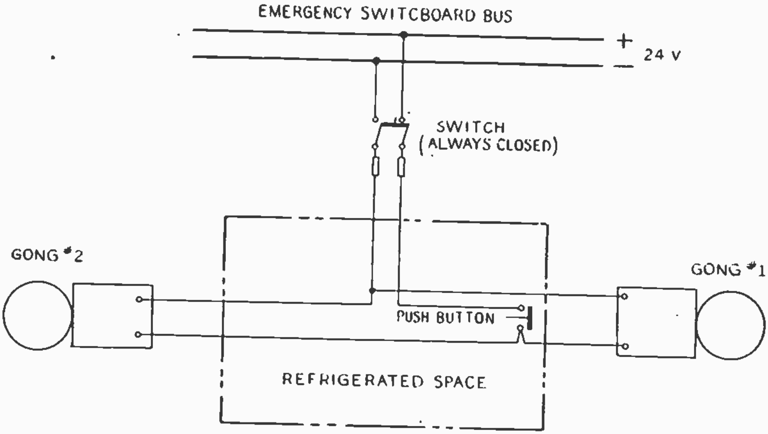


Fig. 51.—Cold storage space alarm wiring. This alarm is designed to protect anyone who may become locked in the cold storage area. The alarm operates from a push button located inside the refrigerated space through gongs or howler located in ship's passageway adjacent to the refrigerated area.

should be located within hearing distance of a location where a person is regularly employed. The signal and pull or push button should be provided with a suitable nameplate to designate its function.

Anchor Windlass Signal.—When the operator of the anchor windlass is out of sight of the man handling the chain, there should be installed between the two positions a bell pull system with a pull on deck and a six-inch gong at the operator's position, or in lieu of this, a 1½ in. voice tube.

General Alarm—(Passenger Ships).—A general alarm system is required by the regulation of the *Bureau of Marine Inspection and Navigation*. General alarm system should be provided on all vessels over 100 gross tons and should consist of not less than *eight inch diameter bells* producing signals of a distinctive type from other bells in the vicinity, and so located that their operation will be heard by all *passengers and crew*. These bells should be controlled by manually operated contact makers from the pilot house, fire control station or stations as determined by *Bureau of Marine Inspection and Navigation*. Each bell should be independently fused and the fuses located above the bulkhead deck. *The system should operate from a source of energy capable of supplying the system for a period of at least eight hours and independent of the main generating plant or as required by the Bureau of Marine Inspection and Navigation.*

Day Passenger Ships.—Same as previous except the bells should be so located that their operation will warn all the crew and the passengers occupying staterooms. *In public spaces and open decks alarm to crew should be visual instead of by bell.* The general alarm system is to comply with the *latest Rules of the Bureau of Marine Inspection and Navigation.*

Cargo Ships.—Same requirements as for Passenger Ships.

Call Bells.—On passenger vessels all staterooms should be equipped with a push button located at the head of the berth to permit a call for assistance, the bell or annunciator being located where there is someone always in attendance. The *voltage* for this system should not *exceed twenty volts*. Annunciators should be of a type requiring the attendant to restore the drop. Annunciator cases should be perfectly tight with holes for entrance of wire only. The wire should be a neat fit

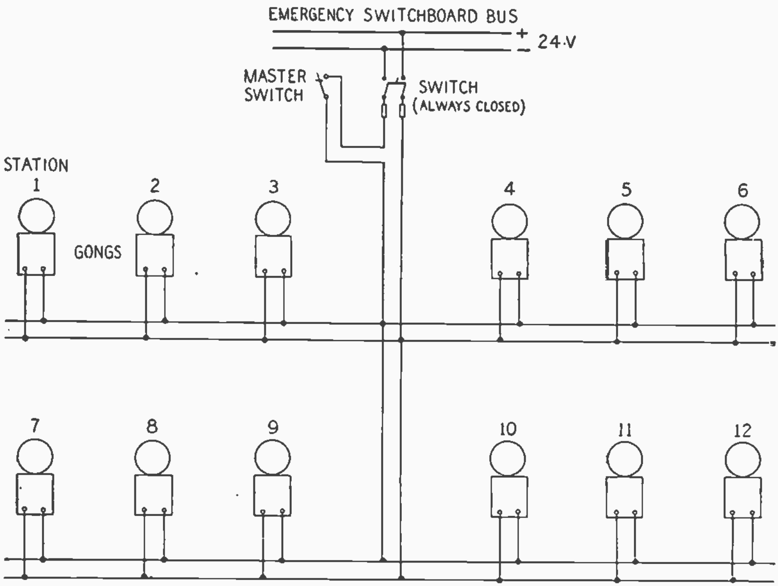
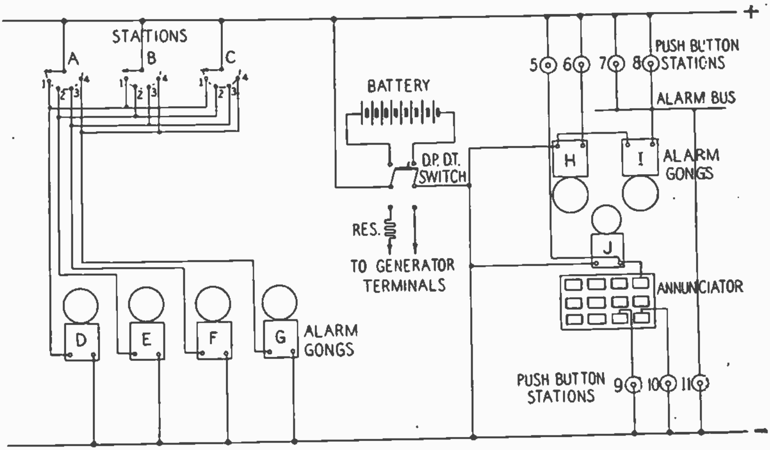


FIG. 52.—Typical arrangement of a general alarm system. The alarm gongs are simultaneously operated from a manual contactor or master switch located in the wheelhouse or at a fire control station. The gongs are spaced throughout the vessel where they may be heard by the crew and passengers at all times.

to exclude vermin. This should, if water-tight, be provided with a gasket between the fixed and movable sections.

If passenger staterooms are equipped with a telephone system that is maintained in operation at all times when at sea, the installation of a call bell system is not considered essential.

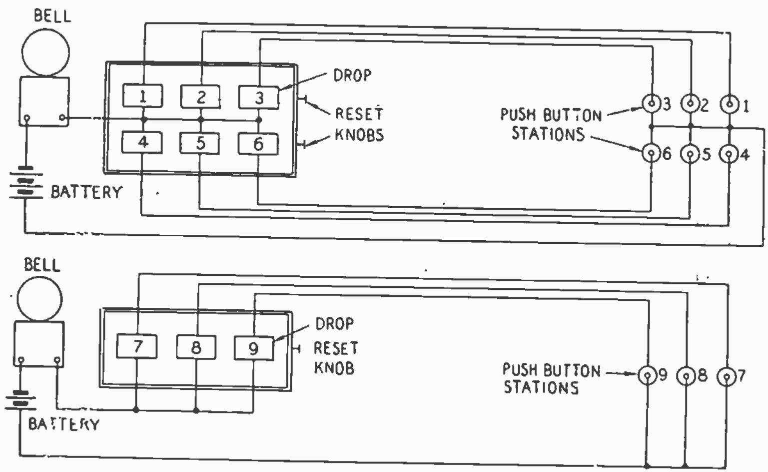
Other call bell systems such as for officers, smoking rooms, or other purposes are to be constructed and installed in accordance with the *Rules* set forth herein.



SHIPBOARD ALARM WIRING

FIG. 53.—Method of alarm wiring. The left part of the diagram illustrates how any one of four alarm gongs may be operated from any one of three alarm stations by moving the selector switch to the contact desired. The current is supplied to the buses through a double-pole double throw switch connected either to a battery or to the generator. The operation of alarm gongs *H*, *I* and *J* is performed by pressing the various push buttons as indicated.

Whistle and Siren Control Systems.—There should be installed *mechanical means* for operating the *ship's whistle and siren* from every *navigating station* regardless of *other systems installed*. The lead should be as direct as possible, amply protected and when suspended for more than 15 feet should be supported from a corrosion-resistant cable with suitable bearers. The systems should be provided with amply corrosion-resistant springs to relieve all weight on the lever and for the proper functioning of the system. All materials should be as described for mechanical telegraph systems.



ANNUNCIATOR CIRCUITS

Figs. 54 and 55.—Typical annunciator circuit. With reference to circuit wiring, it is evident that when any one button is pressed it closes the circuit and energizes a bell at some convenient point and at the same time by a mechanical or electrical device indicates the location of the button.

When *electrically operated whistles and sirens are installed*, all parts should be *independent* of the *mechanical system*. If a motor operated timer is installed, particular attention should be given to its construction or location so that it will be *inaudible* in the *pilot house* and does not affect the *magnetic compass*. The supply for electrically operated signals should be taken from the *emergency system*.

When the electrically operated valve for this system is located more than five feet from the whistle an *automatic drain feature* for the *whistle steam pipe* should be installed.

Morse Telegraph Signalling Lamp.—A signalling lamp is required by the *Bureau of Marine Inspection and Navigation*

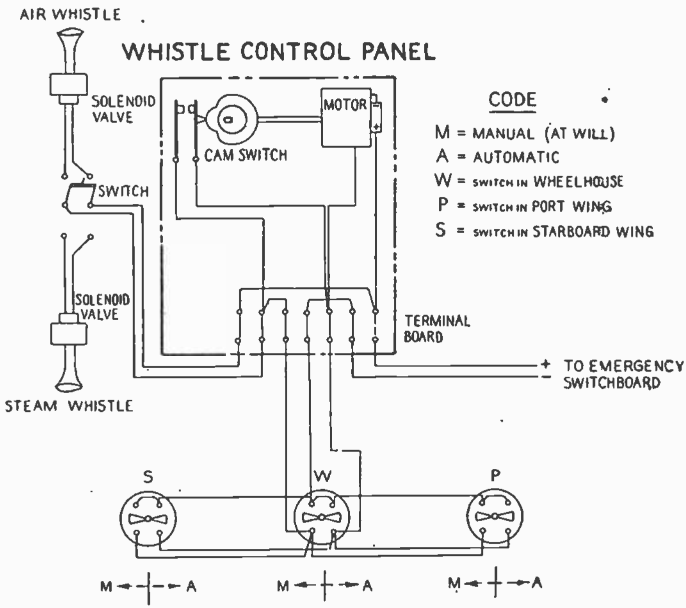


FIG. 56.—Electric whistle control circuit. Recently built ships make use of both electrically operated air and steam whistles. When they are used over a sustained period of time as in the case of fog, etc., an electric timer of the cam operated type is commonly employed. If it be desired to blow the whistle in some particular manner such as three short blasts the switch is pulled to the "*At will*" position three times for a short interval each time.

and should comply with the *latest rules and regulations* of that *Bureau*. The signalling lamp should be of *water-tight* construction, fitted with a clear fresnel lens and a 100 watt high-speed lamp bulb, mounted at a height above the pilot house to show completely around the horizon. A number of small size lamp bulbs may be used in lieu of a single lamp bulb.

The signalling lamp should be operated by a *Morse telegraph key* fitted with a *condenser*. The key may be located in the pilot house, or may be provided with a portable cord of sufficient length to reach either wing of the bridge from a receptacle in the pilot house. The type of enclosure for the key should be weather proof if mounted in the pilot house, or water-tight if permanently mounted on either wing of the bridge.

The supply for the signal lamp should be from the *emergency lighting system*.

Alarm System for Lubricating Oils, Refrigeration and Other Circulating Systems.—Whenever a circulating system is installed, the functioning of which affects permanent operation of the ship or preservation of life such as lubricating oil systems for turbine drive, refrigerating systems for passenger or other ships, an alarm system for them should be installed.

On lubricating oil systems, the alarm system should be such as to indicate *audibly* and *visibly* at some definite location when the oil pressure fails, due to shut down of pump or any other cause. In the refrigerating system, the alarm should be such as to ring a bell at a predetermined point and shut down the refrigerating machine motor when the pressure in the circulating water-line to the machine reaches a predetermined low pressure.

The contact maker should be of rugged construction. If a pressure transmitter be provided which depends on electric current for operation, all of the contact parts, coils, etc., should conform to the general requirements given elsewhere.

If the pressure contact maker is of mechanical type, the construction should be strong and rugged.

In either of the foregoing types of pressure transmitters, the electric contacts and connection posts should be suitably protected from mechanical injury and so constructed as to be easily accessible for necessary adjustment.

Telephone Equipment.—All telephone transmitters and receivers substituted for voice tubes or essential for the operation of the vessel should be of *sound powered type* designed specifically for *marine use*, and should be of a type approved by the *Bureau of Marine Inspection and Navigation*. The manufacturer's name, type and model number should be stamped on each telephone.

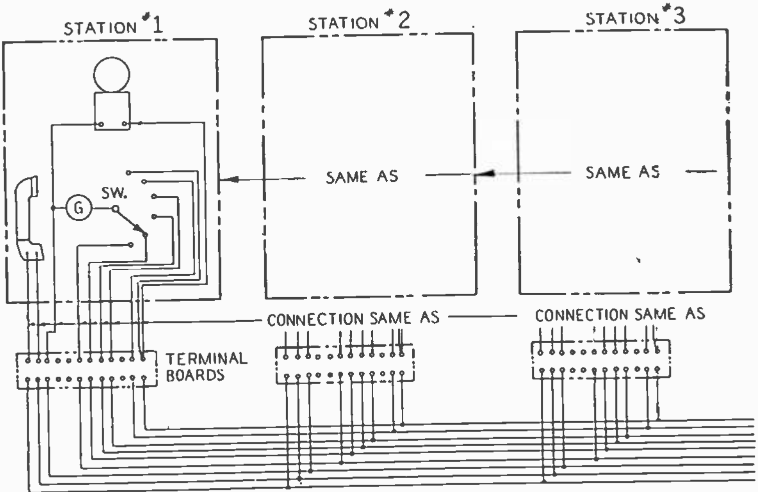


FIG. 57.—Connection diagram of telephone system. The systems now generally in use are of the *self-sufficent* "sound powered telephone" class which derives its power from a permanent magnet and a moving coil. It is sometimes termed a *moving coil microphone* or *dynamic microphone*. This system is used only for short distances, and is therefore limited to ships, buildings, etc. On merchant ships the usual arrangement is to have common talking and selective ringing, using a station selector switch and a hand operated generator.

A call signal and magneto should be provided at each telephone station. This signal may be a bell or other sound device wnich provides a distinctive signal throughout the space where the telephone is installed. On installations which are protected by water-tight boxes, all signals should be of such character as to comply with the foregoing when the box is closed. Ringers, if located outside the box, should be of *water-tight construction*. All bells and push buttons should be constructed in accordance with the requirements contained herein.

At each telephone installation a suitable hanger for the handset should be provided. It should be constructed in such a way as to hold the handset firmly in place and away from the bulkhead. The handset should not be dislodged from the hanger by the motion of the ship or by a severe shock near the mounting.

Telephones installed at external locations exposed to the weather or in locations subject to severe moisture conditions should be enclosed in a *substantial water-tight cast-metal box*. The cover should be hinged at the bottom of the box and when closed should be fastened by a simple substantial mechanism which, when operated, exerts sufficient pressure to make enclosure water-tight. The gasket should be fastened to and inserted in the edge of the box or cover. The signal generator and switches should be of *water-tight construction*. The generator and all switches should be installed inside the box.

At other locations where a *water-tight box* is not recommended, the telephone equipment should be of splash-proof construction and should be so installed as to mininize possibility of damage by external means. In engine rooms or noisy locations, a booth or other suitable auxiliary equipment should be provided if necessary in order that a telephone conversation can be carried on while the vessel is being navigated.

The system should be installed independent of any other systems of communication or of wiring, but may be extended to cover any other locations which are necesssary or desirable. Telephone cable should be of a type as recommended and should be run as close to the fore and aft center-line of the vessel as possible, and protected from external damage. In some cases *Bureau of Marine Inspection and Navigation* requires two sets of cables in parallel. It should be so installed as to minimize ingress of water and dampness.

The *talking circuit* should be *electrical independent* of the *calling circuit*. A short or open circuit or a ground on either side of the calling circuit should not affect the talking circuit in any way.

Emergency Loudspeaker Telephone Systems.—The *Bureau of Marine Inspection and Navigation* requires the installation of a loud speaker system on certain classes of passenger vessels. All materials, devices, equipment and the installation should be in accordance with the *Bureau of Marine Inspection and Navigation Rules*. For exact requirements, see *Bureau's* latest regulations.

Inter-cabin Type Telephone System.—Commercial type of equipment is recommended subject to the construction details to suit marine installations. Telephone sets may be of the wall type, desk type or hand type to best suit the location. Sets in exposed locations should be water-tight. The switchboard should be suitable for marine service and the ship's wiring and appliances should conform with the requirements of these recommendations.

The power supply should be as specified by the manufacturer and conform to other sections of these recommendations.

Other telephone system operating conditions of the larger size vessels may make the installation of one or more separate intercommunication systems or power amplifier systems with or without talk back desirable. All the equipment required for these systems and the installation thereof should be in accordance with the applicable recommendations specified herein.

Fire Alarm Systems

General.—All materials, devices, equipment and the installation thereof for both fire detection and manual fire alarm systems should be suitable for marine use and should be as approved by the *Bureau of Marine Inspection and Navigation.*

Automatic Fire Alarm System.—Passenger ships with berth or stateroom accommodations should be provided with *fire detecting and alarm systems which should automatically indicate audibly and register visually at the fire control station or stations the presence or indication of fire in spaces constructed of or stowed with inflammable material.*

The fire detection system may be electric, pneumatic tube, pneumatic bulb, smoke pipe, or automatic sprinkler, used singly or in combination with other equally effective systems. They may be either the fixed temperature type or the rate of rise type and the signals from the thermostats may be transmitted either pneumatically or electrically.

Classification of Types.—Electrical systems using thermostats or thermostatic wire actuated by heat to produce visual and audible signals. Pneumatic tube system using thermostats composed of copper tubing containing air, the expansion of which produces visual and audible signals, which are transmitted from the thermostat either pneumatically by copper tubing or electrically.

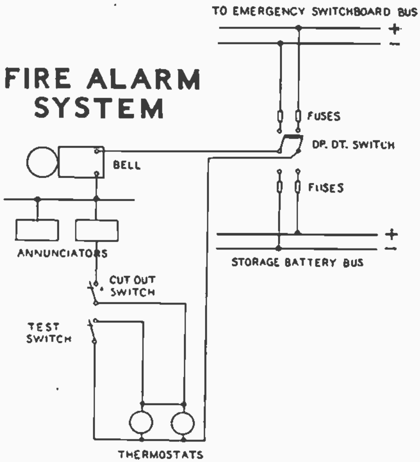


Fig. 58.—Elementary diagram of a fire alarm system. A modern fire alarm system consists of a series of thermostats, located at various points throughout the ship and connected electrically to an automatic, electrically supervised fire alarm circuit panel. The thermostats are arranged so as to make electric contact at some predetermined degree of temperature causing the fire bells to ring and dropping two red flags, one on the master section of the panel, indicating the bell circuit is closed, and one on the line section indicating the location of fire.

Pneumatic bulb system using thermostats composed of copper bulb containing air, the expansion of which produces visual or audible signals which are transmitted from the thermostats either pneumatically by copper tubing or electrically.

Smoke pipe system in which fire is indicated audibly and visually by smoke drawn through pipes, the discharge of which is suitably illuminated.

Wiring.—*Fire Alarm Systems* should not be used for the transmission of other than *fire alarm signals*. In case of smoke detecting systems, the pipes may be used for the introduction of smothering gas.

All electrical systems should be normally free of electrical grounds, except a ground introduced for supervisory purposes.

All conductors should conform to the specifications for lighting, power and interior communication wiring; and the use of leaded and armored cable is recommended throughout the vessel.

The fire alarm annunciator should be so designed that an accidental cross of the fire alarm wiring with the lighting system will not damage or render the fire alarm system inoperable.

Electrical and Pneumatic Systems.—For detail requirements, consult the *Bureau of Marine Inspection and Navigation requirements*.

Location of Detectors—Electrical Systems.—For detail requirements, consult the *Bureau of Marine Inspection and Navigation requirements*.

Pneumatic Systems.—For detail requirements, consult the *Bureau of Marine Inspection and Navigation* requirements.

Zoning.—For detail requirements, consult the *Bureau of Marine Inspection and Navigation* requirements.

Manual Fire Alarm System (Passenger Ships).—*Manual fire alarm system should be provided on all ships and should consist of at least one manually operated fire alarm box, having a red finish,* for each detection zone (except cargo spaces, inaccessible during voyage) located in stairway enclosures, corridors and public rooms, readily accessible to passengers and crew.

The system should register visually for each detection zone in the fire control station or stations and should automatically ring gongs of a distinctive sound from other gongs in the fire control station or stations, the navigating station, the engine room and the quarters of the fire fighting crew.

In vessels fitted with an automatic fire detecting and alarm system in accommodation spaces, the manual system may be a part of the automatic system.

All materials, devices, equipment, etc., and the installation thereof are to be approved by and in accordance with the latest requirements of the *Bureau of Marine Inspection and Navigation.*

Smoke Pipe Systems.—The smoke pipe systems for fire detection consist of individual pipes installed from collectors located in the compartments to be protected to an indicating cabinet located in the pilot house or fire station. A circulation of air is maintained through the pipes by means of a suction fan located adjacent to the indicating cabinet. In case of fire in the compartment, the smoke is drawn through the pipe to the indicator cabinet.

This type of system should be fitted with an audible alarm that will call attention to the receipt of smoke in the indicator cabinet. Suction fans should be provided in duplicate and arranged so that the idle unit is ready for immediate operation in case of failure of the operating unit. All wiring should be in accordance with the recommendations given and all electrical circuits supervised so as to give a warning in case of failure of motor, wiring, main power supply, etc.

Automatic Sprinkler System.—Each system should have an annunciator with lamp or drop for each sprinkler zone. The indicating device should be located in the fire control station, or stations, and should *automatically ring gongs located in the fire control station, or stations, navigating control station, the engine room, and quarters of the fire fighting crew.* The *electrical supply* for this system should be from the *emergency lighting system.*

CHAPTER 129

Cable Jointing

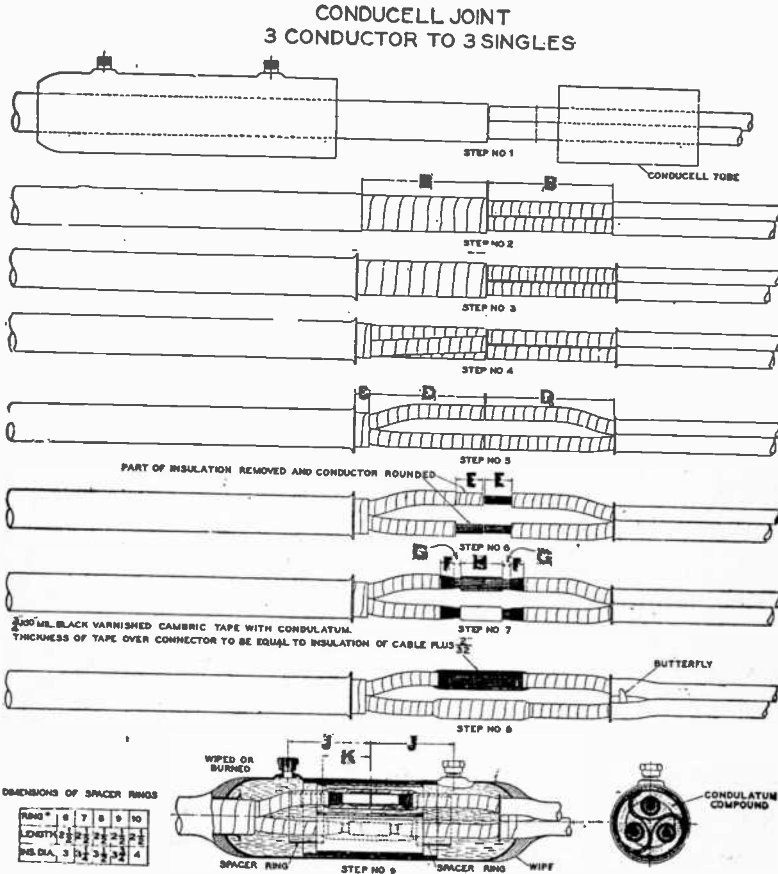
As explained in Chapter 104, the author objects to the generally accepted use of the terms *joints* and *splices*, and accordingly, this Chapter is called Cable Jointing and not Cable Splicing. The student of cable jointing will find that there are numerous types of joint met with in practice. These various joints may be classified.

1. With respect to voltage

   a. 100 to 240
   b. 2,300 to 3,000
   c. 7,800 to 13,800
   d. 27,000
   e. 45,000
   f. 132,000

2. With respect to insulation

   a. Cotton tape
   b. Rubber
   c. Cambric
   d. Paper



DIMENSIONS OF SPACER RINGS

RING	6	7	8	9	10
LENGTH	2½	2½	2½	2½	2½
INS. DIA.	3	3¼	3½	3¾	4

TABLE OF SPACER RING NUMBERS

CABLE SIZE	INSULATION THICKNESS [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
250,000 MCM	6	7	7	8	8
350,000 MCM	7	7	8	8	9
500,000 MCM	8	8	9	10	10

CONDUCELL NUMBER	SLEEVE	B	C	D	E	F	G	H	J	K
282	22x5½	9½	1	9½	1¾	1	½	2½	6	3½
283	28x5½	12½	1	11½	1¾	1	½	2½	9½	6½

FIGS. 6,027 to 6,036.—13,800 to 27,000 volt Conducell joint three conductor to three singles.

3. With respect to conductors

a. Single
b. Duplex
c. Three conductor
d. Four conductor
etc.

Lead work forms an important part of the operations of cable jointing and as a preliminary the student should study soldering in its various branches and joint wiping.

Before attempting to wipe a sleeve joint on a cable, the student should practice wiping a joint on an ordinary lead pipe. In addition to the

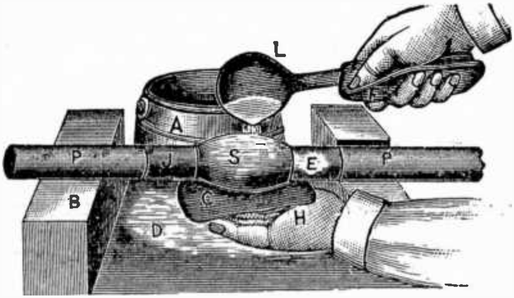


FIG. 6,037.—Method of wiping a horizontal joint. The *cloth* used for wiping is a pad of mole skin or fustian about four inches square made from a piece twelve inches by nine, folded six times, and sewed to keep it from opening; the side next the pipe is saturated with hot tallow when used. If the lead has been brought to the heat of the solder, and the latter properly manipulated and shaped while in a semi-fluid or plastic condition, the joint gradually assumes the finished egg shaped appearance. In making the joint a quantity of solder is taken from the pot by means of the ladle, the solder being previously heated so hot that the hand can be kept within two inches of its surface. The solder is poured lightly on the joint, the ladle being moved backwards and forwards, so that too much solder is not put in one place. The solder is also poured an inch or two on the soiling, to make the pipe of proper temperature. Naturally the further the heat is run or taken along the pipe, the better the chance of making the joint. The operator keeps pouring and with the left hand holds the cloth to catch the solder, and also to cause the same to tin the lower side of the pipe, and to keep the solder fron dropping down. By the process of steady pouring the solder now becomes nice and soft and begins to feel shaped, firm and bulky. When in this shape and in a semi-fluid condition the ladle is put down, and, with the left hand, the operation of wiping, as illustrated, is begun working from the soiling toward the top of the bulb. If the lead cool rapidly, it is reheated to a plastic condition by a torch, or a heated iron. When the joint is completed, it is cooled with a water spray, so that the lead shall not have time to alter its shape.

instructions given in this chapter on lead work, a study of this subject as given in volume No. 1 of the author's Plumbers and Steam Fitters Guides is recommended.

The operations to be performed in wiping the various types of joint are in general very much the same, differing chiefly in the proportions of the joint, kind and quantity of material to be used, etc.

Detailed instructions will now be given for wiping joints on type cables largely used.

Jointing 13,800 Volt, 3 Conductor Cable.—This cable takes a 5½×22 lead sleeve and 350,000 *cm.* connector. The cable is paper insulated; conductors 7×7/32 insulation. Straight joint. The following materials are used:

1	lead sleeve 5½" *i.d.* ⅛" wall 22" long.
1	Conducell No. 253.
3	350,000 *cm.* copper sleeve connectors.
108	yards ¾×10 mils black varnished cambric tape.
6	lbs. wiping solder (40 tin 60 lead).
12½	lbs. Condulatum.
2	oz. waste ends.
1	oz. Stearine flux.
15	ins. Melrose cord.
1	yard ½" white tape.
1	sheet 00 emery cloth.
7	paper pasters.

Instructions will now be given for performing the various operations in jointing.

Training.—The term "training" indicates the shaping of the two cables where they project into the manhole so that they will follow the contour of the walls and come together at the point where they are to be joined, with their ends overlapping.

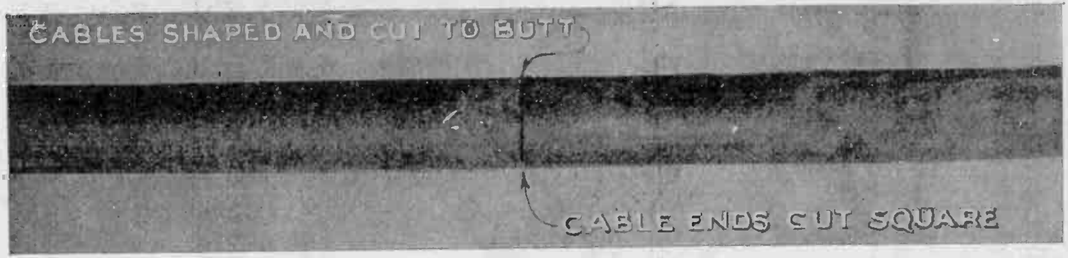


FIG. 6,038.—Appearance of cables after being cut "square" to exact length to butt.

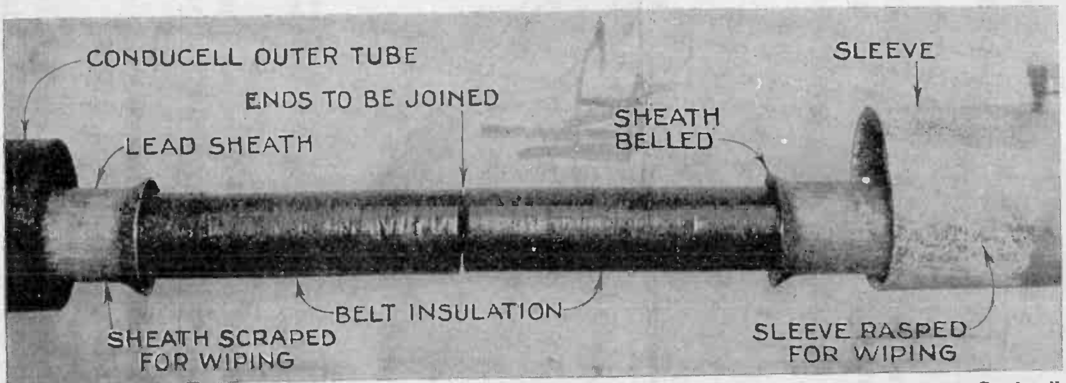


FIG. 6,039.—Appearance of cables in position with lead sheath removed and sheath ends belled. Note sleeve and Conducell outer tube threaded on cables. The sleeve should be scraped back from each end a distance of about 3 ins. as these portions of the sleeve will later be covered with solder in the wiping operation.

In training, care should be taken to handle the cables so as not to give them any sharp bend. The cable should be supported by brackets or hangers.

Cutting Cable Ends.—Mark the two overlapping cables at the point where they are to be joined, and take the precaution to cut

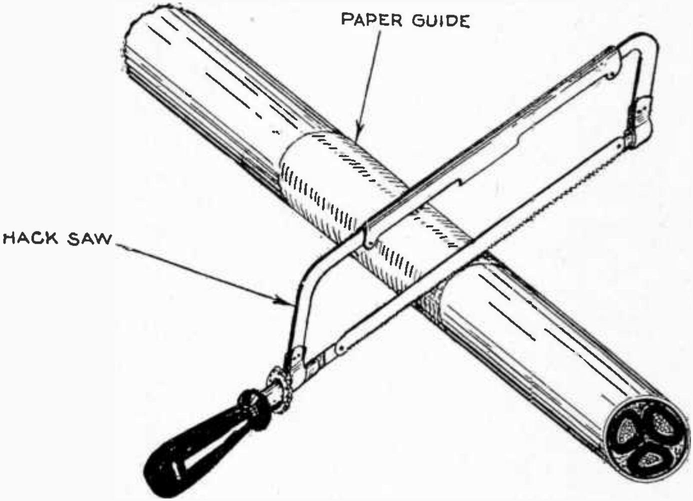


FIG. 6,040.—Paper guide for cutting off cable "square." The beginner should wrap a paper guide around the cable at the point where it is to be cut, as shown, which will serve as a guide for the hack saw

them square with a hack saw. They should be so cut that the ends which are to be joined butt up against each other, that is, no space between as in fig. 6,038.

To facilitate cutting off cable square, wrap paper guide around the cable as in fig. 6,040.

Ringing.—Mark with a knife the point where the lead sheath is to be removed on each cable, this will be 9½ ins. from the

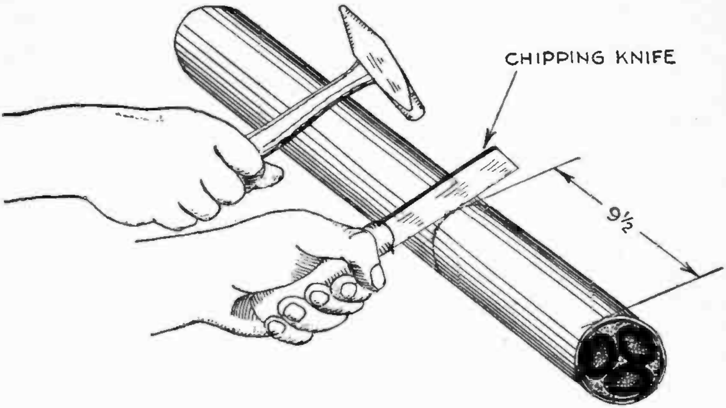


Fig. 6,041.—Ringing operation. After cable has been trained on racks measure back 9½ ins. from cut and ring lead sheath with a chipping knife and hammer as shown.

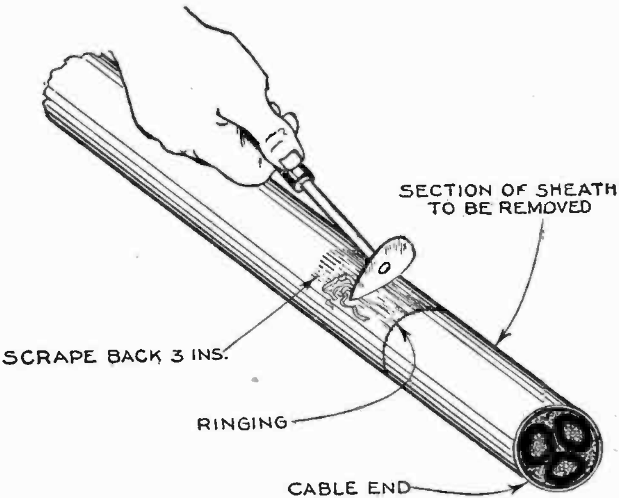


Fig. 6,042.—Scraping operation. The lead sheath should be scraped back 3 ins. from the point of ringing, as shown. After scraping rub the scraped part with Stearine flux.

point where the cable was cut. This 9½ ins. is the length of lead sheath to be removed. Ring each cable sheath along the circumferential marks with a chipping knife, as shown in fig. 6,041. Scrape the lead sheath of each cable three inches back

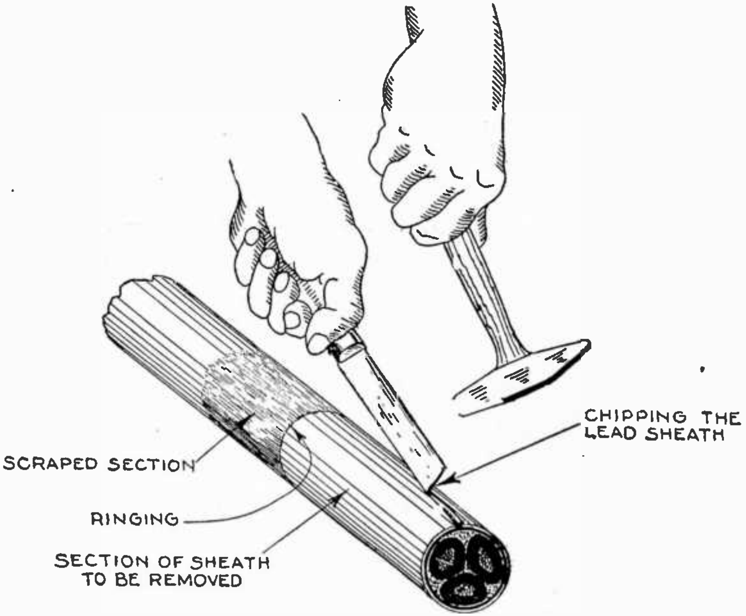
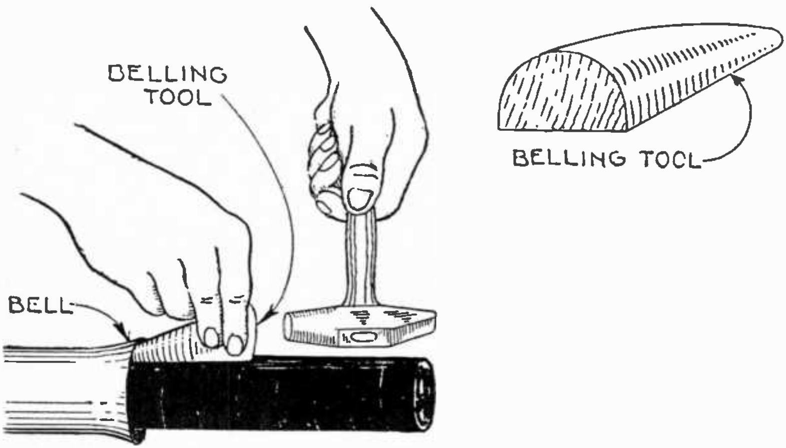


FIG. 6,043.—Splitting operation. The lead sheath must be removed from the end of the cable to the point of ringing. It is first split by chipping with a chipping knife as shown. After the sheath has been split it is easily twisted off with the aid of a pair of pliers.

from the point of ringing, as in fig. 6,042. After scraping, rub the scraped part with flux (Stearine).

Removing the Sheath.—From the end of the cable to the point of ringing, the lead sheath should be split with a chipping knife as shown in fig. 6,043, after which it can be easily removed. Note the angle at which the chipping knife is held in splitting. Be careful not to damage the insulation in clipping.

Belling.—The term "bell" means to flare out. The end of the lead sheath is now belled, as shown in fig. 6,044, using a blunt



FIGS. 6,044 and 6,045.—Belling operation and belling tool. The end of the lead sheath is flared out by using the belling tool, fig. 6,045 as shown in fig. 6,044. Flare out the sheath about ½ in.

nosed tool of hard wood or fibre, such as shown in fig. 6,045. In performing this operation, care should be taken not to cut the insulation.

Removing Insulation and Shaping.—Remove the overall or belt insulation to a point 1 in. from bell, that is, the edge of the lead sheath, as shown in fig. 6,047.

Next, cut the jute fillers at a point close to the end of the belt insulation, as shown in fig. 6,048.

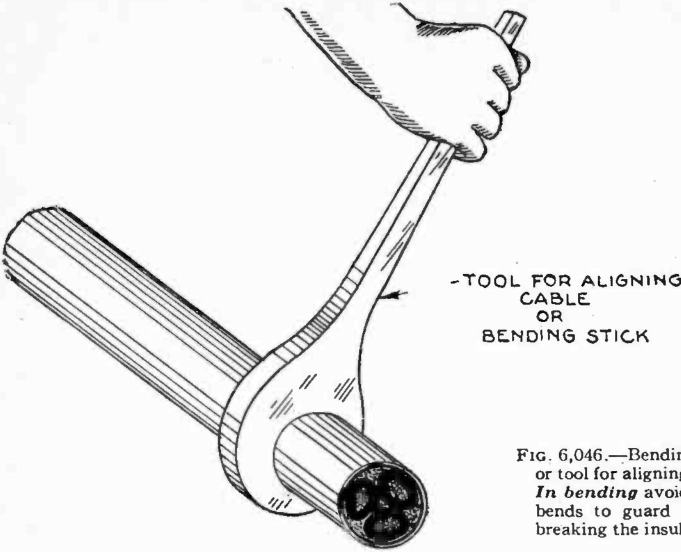


FIG. 6,046.—Bending stick or tool for aligning cable. ***In bending*** avoid sharp bends to guard against breaking the insulation.

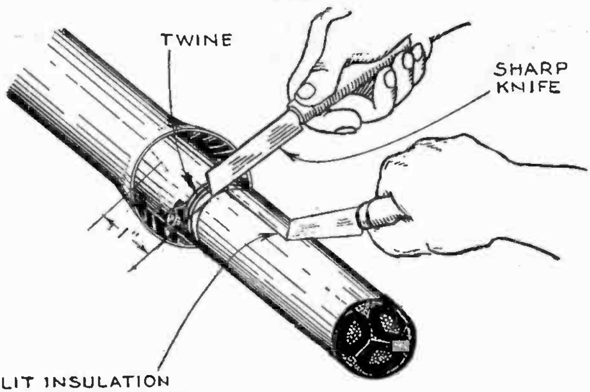


FIG. 6,047.—Removing belt insulation. The belt insulation must be removed from the end of the cable to within a distance of 1 in. from the bell. ***In doing this*** be careful not to injure the insulation over each conductor. In removing the belt insulation first wrap twine around the insulation extending 1 in. from sheath; this is to prevent the insulation unraveling. The illustration shows the various operations.

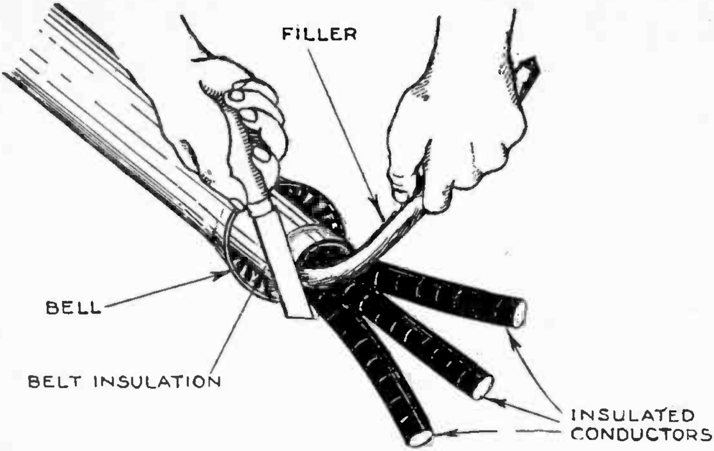


FIG. 6,048.—Cutting the fillers. This cable has four fillers and all of them should be cut close to the end of the inch margin of belt insulation left around the insulated conductors.

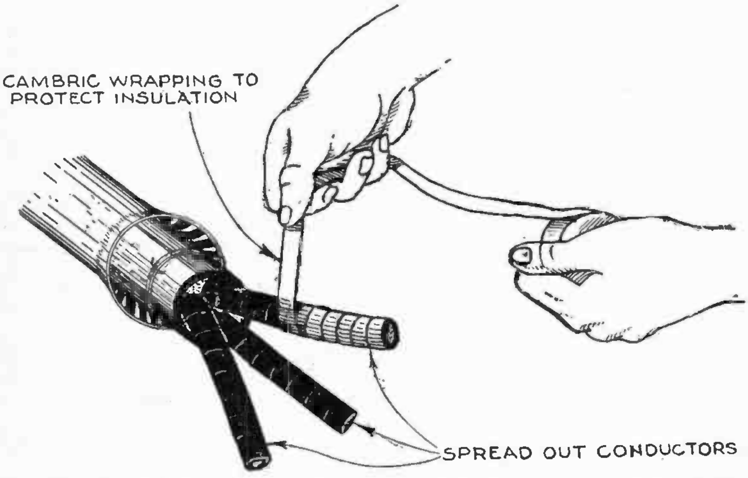
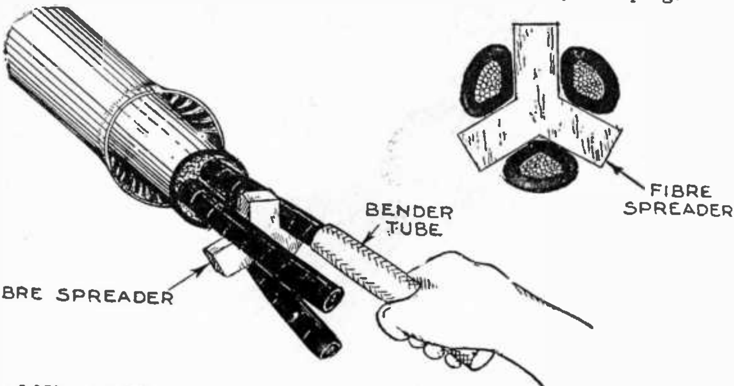


FIG. 6,049.—Spreading operation. Before spreading out the three conductors, wrap each with cambric tape as shown to prevent injuring the insulation. Do not spread out conductors more than necessary, and thus avoid chance of breaking the mill insulation at crutch.

At this stage, the lead sleeve and mica tube of the Conducell should be slipped on the cable so that when the conductors have been joined and insulated, it may be slid into place over the joint preparatory to wiping.



FIGS. 6,050 and 6,051.—Insertion of spreader and shaping. *After* the conductors have been spread out to the desired extent, they are held apart by means of a spreader or fibre block, as shown in detail in fig. 6,051. After inserting the spreader, the conductors are shaped or slightly bent inward by means of the bender tube, as shown.

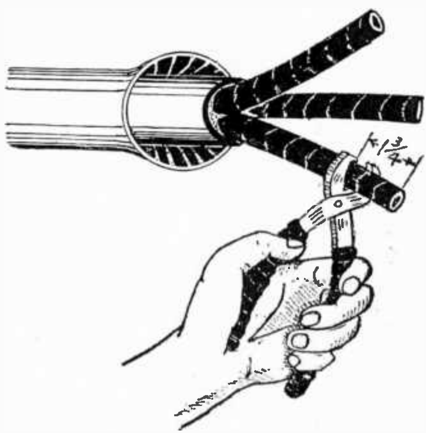


FIG. 6,052.—Removing half of insulation from conductors with insulation cutter. Measure back 1¾ ins. from end of conductor and cut off half of the insulation. The reason for removing only half of the insulation is explained in fig. 6,053.

Before slipping on the lead sleeve, rasp both ends to give a clean bright surface and candle. The conductors should now be shaped and retained so by the use of a spreader or separator as shown in figs. 6,050, 6,051 and 6,054, the insulation being protected by wrapping each conductor as in fig. 6,049.

Since the conductors with insulation are pretty stiff, they are conveniently bent in the desired position by the use of a fibre tube, shown in fig. 6,050, previously inserting spaces and wrapping conductors with protective tape.

Some of the accompanying illustrations show only one conductor; this is to bring out more clearly some of the operations preparatory to sweating.

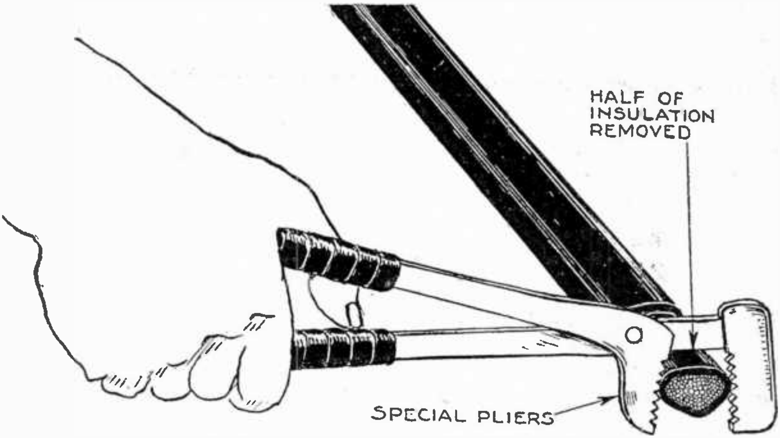


Fig. 6,053.—Rounding or shaping conductor strands. It will be noticed that the conductor stranding is of sector form, and this must be brought to circular form so that the connector can later be properly put on. The operation is easily done by means of the special claw plier tool here shown, although ordinary gas pliers are generally used. The belt of insulation left over the conductor protects the strands from the teeth of the pliers. After shaping, this insulation is removed exposing the conductor.

Rounding.—Measure off 1¾ ins. from end of conductors and cut off half of the insulation with an insulation cutter, as shown in fig. 6,052. The conductor strands should be shaped to the form of a circle, that is *rounded*, by the use of gas pliers, or the special wrench shown in fig. 6,053.

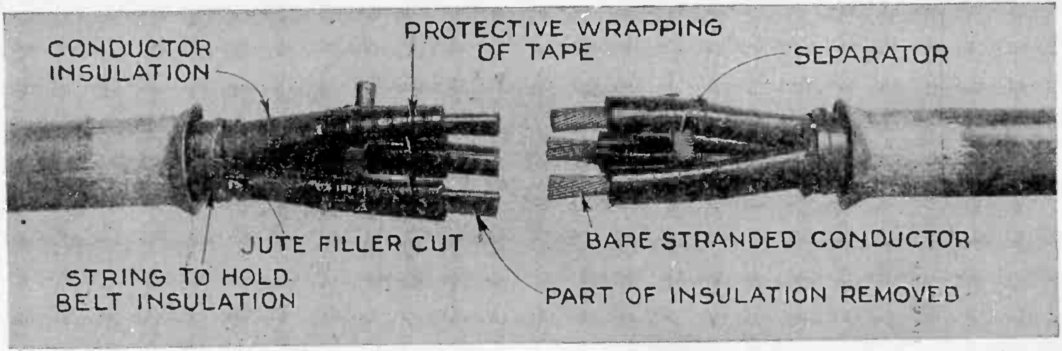


FIG. 6,054.—Appearance of cables in position with lead sheath removed and sheath ends belled. Note treatment of conductors to be joined.

The remaining half of the insulation which was left at the end of the conductor was for the purpose of preventing injury to the strands during the rounding operation just described. This half of the insulation is now removed; that is, the remaining half of the insulation is removed back $1\frac{3}{4}$ ins.

Placing Connectors and Sweating.—Put the conductors in alignment and place over each butting pair a split connector. Squeeze up connector with gas pliers, using paper or other protecting layer between pliers and connector, as shown in fig. 6,055 (for one conductor).

During this operation one or more of the strands may be squeezed out of the connector; if so, they are easily bedded by the use of the special pliers shown in fig. 6,056.

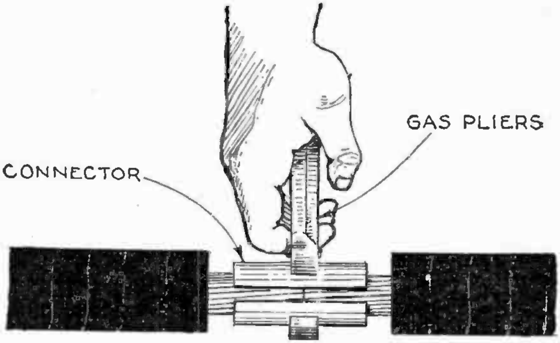


Fig. 6,055.—Placing connector over conductors. Put each pair of butting conductors in line. Open up the connector so it can be placed around the conductors and then squeeze up with pliers so that it tightly grips the conductors. It should be so placed that the conductors come together at the middle point of the connector. In using the pliers on the connector, wrap some cloth around the connector to protect it from the teeth of the pliers.

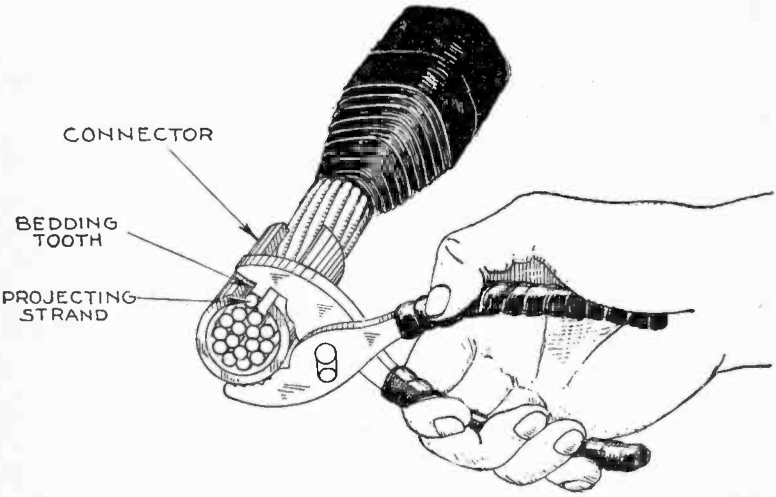


Fig. 6,056.—Special "bedding" pliers. This convenient tool is easily made from ordinary pliers by filing the jaw to the shape shown. ***In attaching*** the connector, sometimes one or more strands may be pushed up so that the connector cannot be squeezed together. Any strand is easily embedded by means of the pliers, as shown.

The edge of the insulation on conductors should be wrapped tightly with cotton tape as shown in fig. 6,057 and tied in place to protect the insulation from charring during the sweating operation, and to prevent the solder running under the insulation. Remove tape after sweating.

Flux the joints to be sweated with Stearine or a solution of rosin and alcohol.

In sweating the joint, thoroughly saturate by repeated pourings of the hot solder as in fig. 6,058, using fresh solder from the

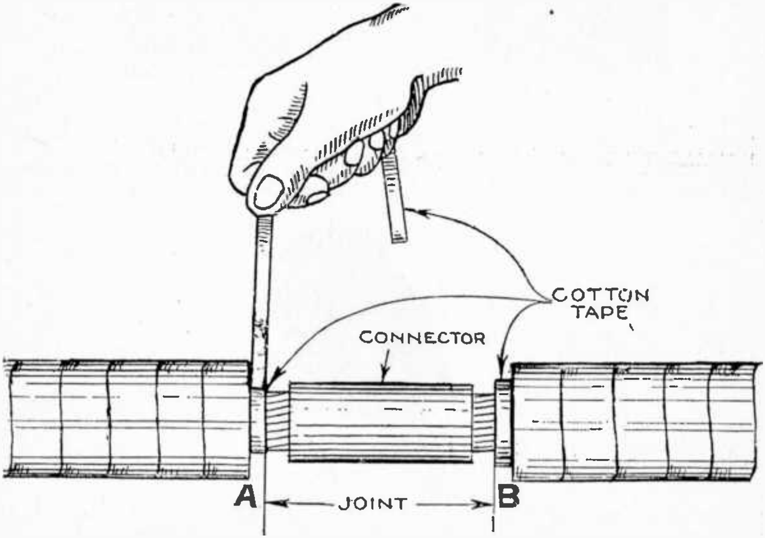


FIG. 6,057.—Preparing a joint for sweating. Wrap cotton tape around conductors at **A** and **B**, to prevent solder running beyond these points during the sweating operation. This tape thus defines the limit of the joint proper, that is to say, the soldered portion. ***It should be noticed that in this and several other illustrations only one conductor is shown, in order to show the parts larger and more plainly.***

pot for each pouring. To "build up" pour the same solder, from ladle to ladle, two or three times until the temperature is sufficiently lowered for the solder to become plastic. After the joint has been properly built up, smooth the surface by wiping

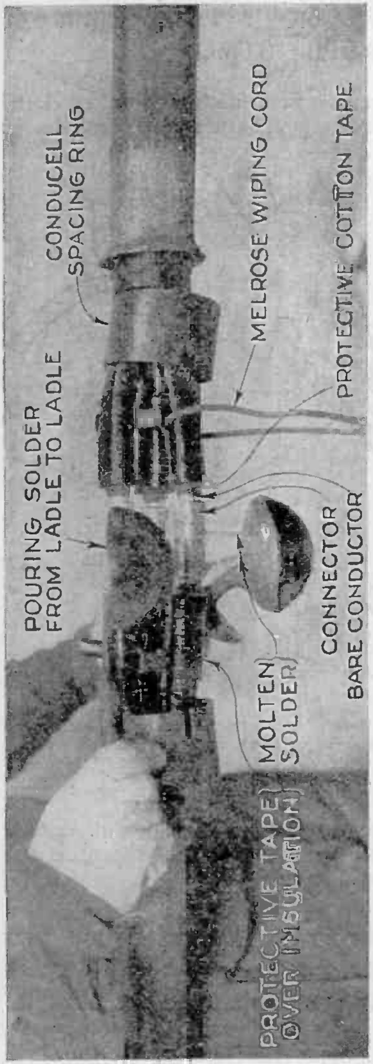


FIG. 6,058.—Method of sweating the connectors by pouring the hot solder from ladle to ladle. Note Melrose cord reading for wiping.

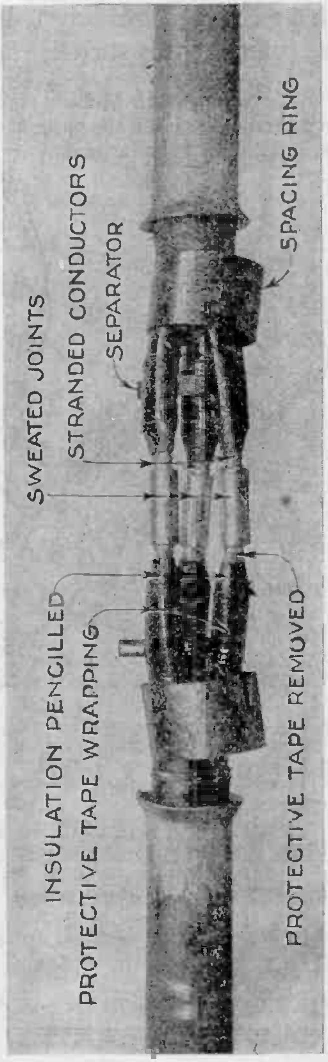


FIG. 6,059.—Appearance of joints after they have been sweated and wiped with a piece of Melrose cord, and the insulation penciled. Note separators, and spacing rings of the Conducell.

with a piece of melrose cord, as in fig. 6,060. The appearance of these joints at this stage is shown in fig. 6,059.

After wiping with Melrose cord, make a final finish with emery cloth, and thoroughly clean the parts of emery dust. The other two joints should be sweated in a similar manner.

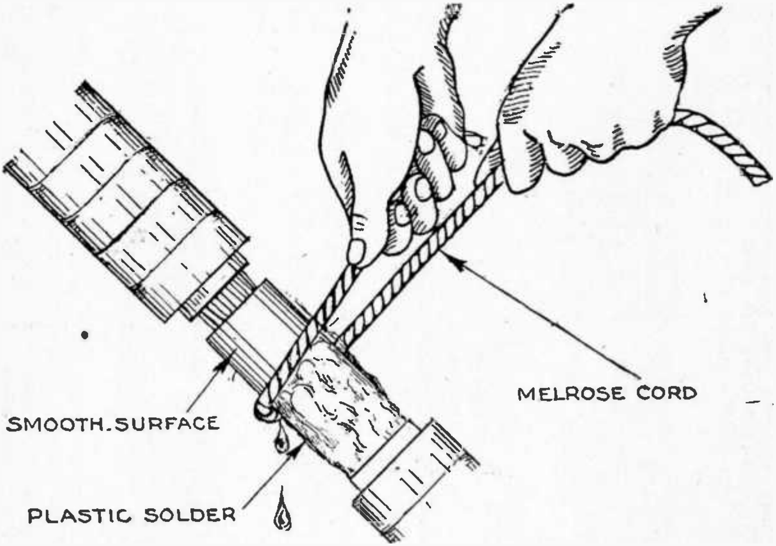


FIG. 6,060.—Use of Melrose cord in cleaning off sweat. Owing to the proximity of the other conductors, a joint cannot be sweated with the ordinary cloth, and accordingly a piece of Melrose cord is used instead, as shown. Fig. 6,058 clearly shows the difficulty in using a cloth in sweating on account of the nearness of the other conductors.

After the three joints have been sweated and cleaned as just described, remove the cotton tape which was placed over the edge of the insulation and also the protective tape wrapping shown in fig. 6,059.

Penciling.—The insulation around each conductor should be "penciled" back 1 in. This is done much in the same way as sharpening a lead pencil. It is important that the penciling be smooth and even.

Use a very sharp knife or special tool in penciling the insulation, and be careful not to nick the conductors. The operation of penciling is shown in fig. 6,061 and the appearance of the penciled joints in fig. 6,059.

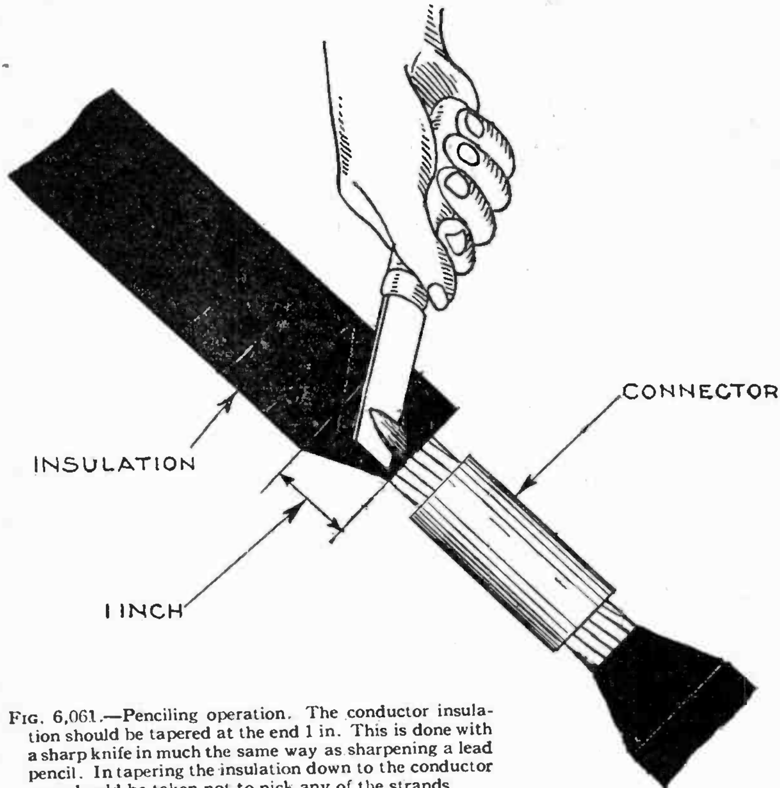


Fig. 6,061.—Penciling operation. The conductor insulation should be tapered at the end 1 in. This is done with a sharp knife in much the same way as sharpening a lead pencil. In tapering the insulation down to the conductor care should be taken not to nick any of the strands.

Boiling Out.—The joints should now be boiled out with hot condulatum 240° Fahr. using a dipper. Condulatum is a by-product of petroleum. After boiling out, paint with hot condulatum.

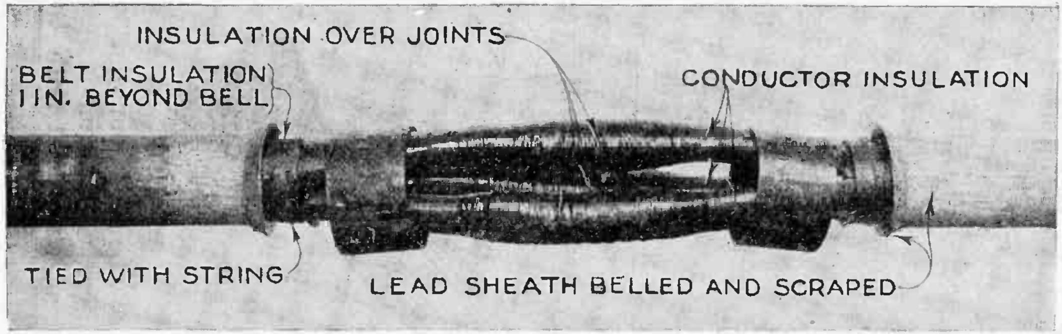


FIG. 6,062.—Appearance of joints after they have been insulated. Note lead sheath ends belled and scraped, also belt insulation projecting 1 in. and secured by a string so that it will not unravel. At this stage the separators are removed.

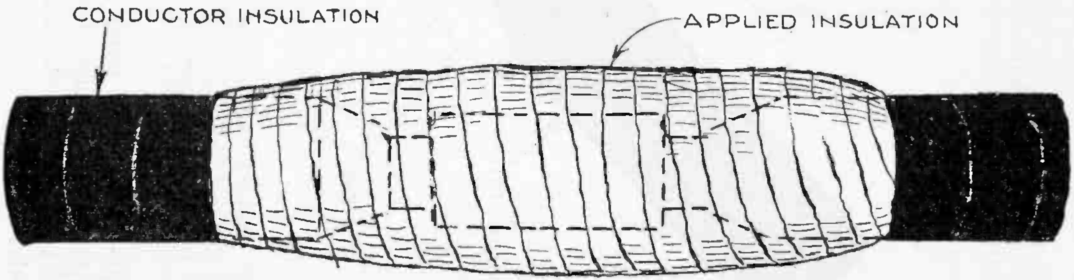
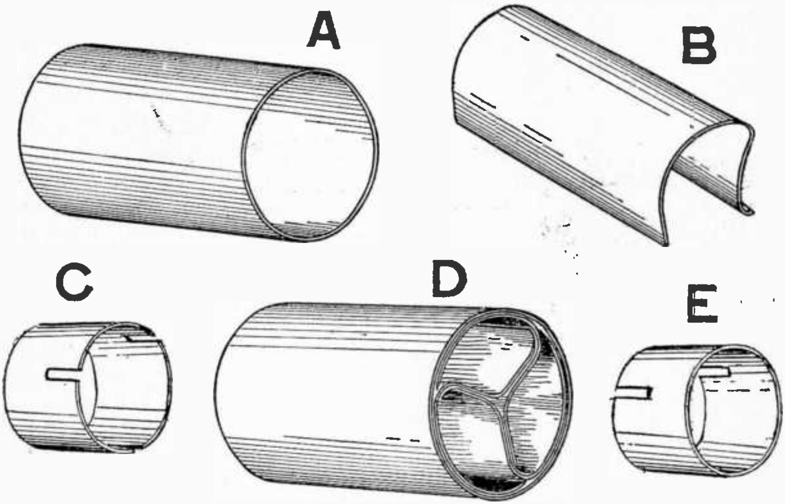


FIG. 6,063.—Insulating conductors. Each conductor should be wrapped with ¾ in. cambric tape. Build up the taping 13/16 in. over the connector. The taping should extend 1 in. back of the penciling. In wrapping the tape let it overlap 50%; this is called half lap. Paint each layer with hot condulatum.

Insulating.—The joints should now be insulated by wrapping them with cambric tape and painting each layer with hot condulatum as shown in figs. 6,062 and 6,063. Build up the taping 13/32 over the connector and extending 1 in. back of the penciling.



Figs. 6,064 to 6,068.—Conducell insulating and spacing unit showing parts and assembly. The unit consists of three inner separating pieces, fig. **B**, held in position by two spacing rings figs. **C** and **E**, and a sleeve, fig. **A**. The assembly is shown in fig. **D**.

Assembling the Conducell.—The Conducell for a three conductor cable consists of an outer seamless tube, as shown in fig. 6,064, three similarly formed curved inner separating pieces, shown in fig. 6,065, and two end spacing rings, shown in figs. 6,066 and 6,068, the assembly being shown in fig. 6,067. This assembly forms three separate cells for the conductors, the parts being interlocked among themselves. The operations of assembling the Conducell over the conductors are shown in figs. 6,069 to 6,071.

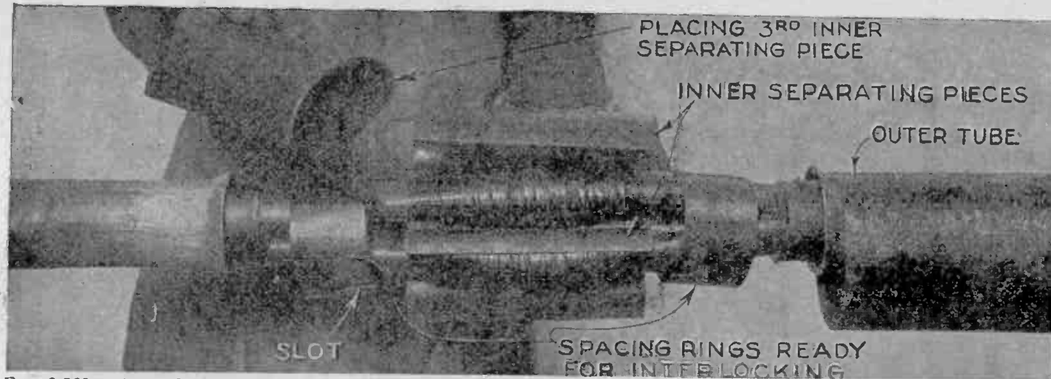


FIG. 6,069.—***Assembling Conducell.*** *First operation:* Placing the inner separating pieces in position. The illustration shows also the two spacing rings ready to be placed in interlocking position, also the outer seamless tube threaded over cables.

FIG. 6,070.—***Assembling Conducell.*** *Second operation:* Placing the outer seamless tube over the inner separating pieces which have previously been placed in position and locked by the spacing rings.

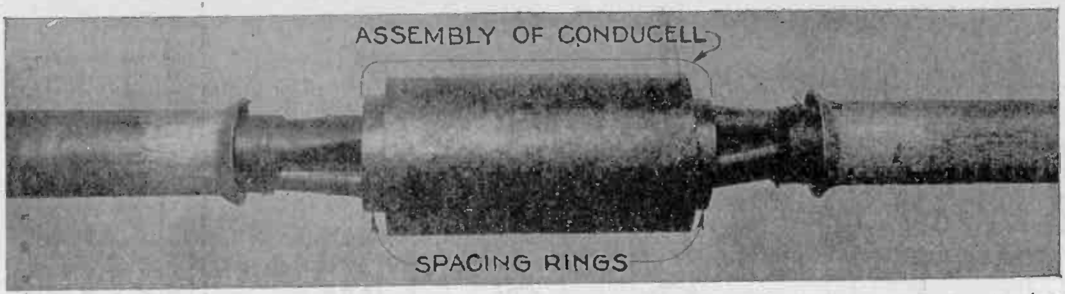


FIG. 6,071.—Appearance of Conducell assembled over the three conductor cable. Note the spacing rings which project beyond the end of the outer seamless tube.

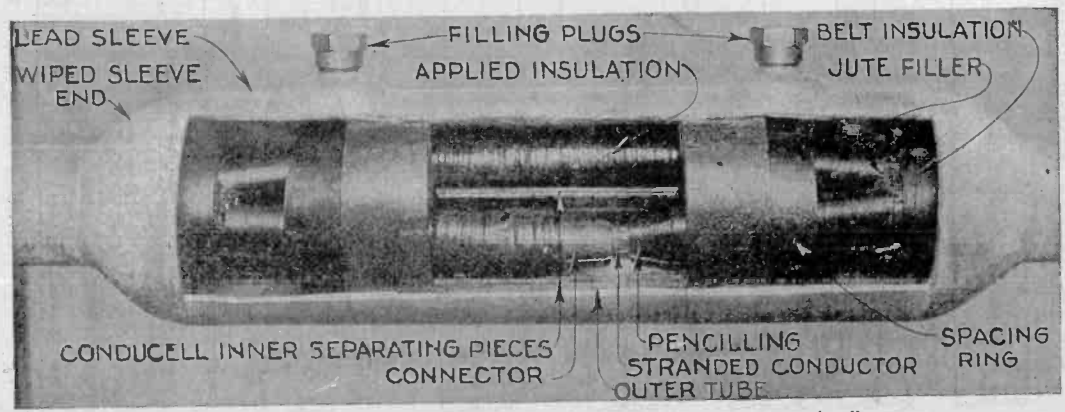
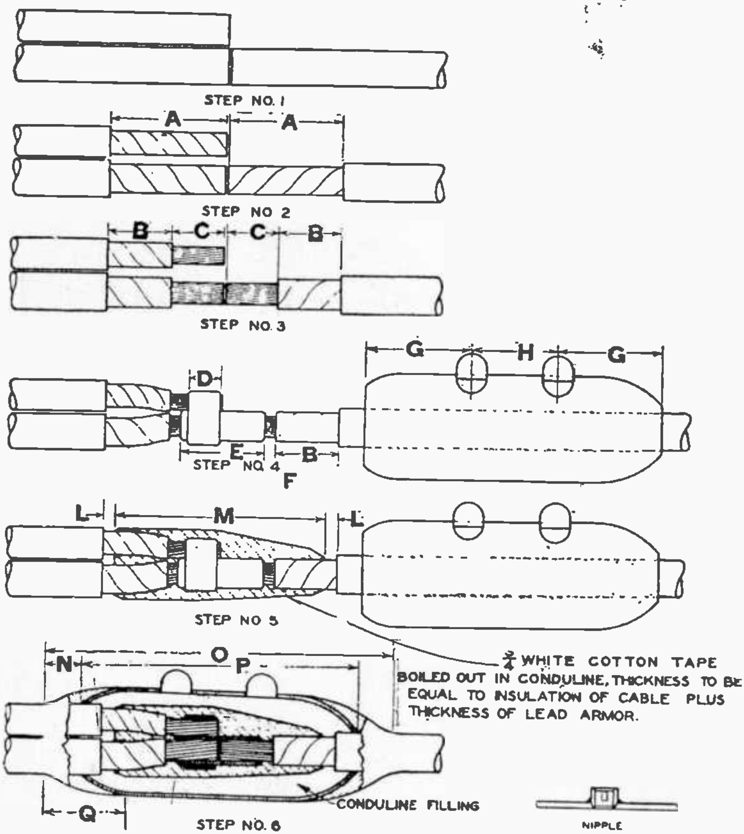


FIG. 6,072.—Cut-away view showing appearance of exterior and interior of three conductor conducell.

SECONDARY HALF DUPLEX JOINTS



CABLE		A	B	C	D	E	F	G	H	SLEEVE	L	M	N	O	P	Q
MAINS	BRANCH															
80 000 CM	80 000 CM	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	2	$\frac{1}{4}$	$2\frac{1}{2}$	2	7 X 2	$\frac{1}{4}$	5	$\frac{3}{4}$	8	$6\frac{1}{2}$	2
200 000 CM	200 000 CM	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	2	$\frac{1}{4}$	$2\frac{1}{2}$	2	7 X $2\frac{1}{2}$	$\frac{1}{4}$	5	$\frac{3}{4}$	8	$6\frac{1}{2}$	$2\frac{1}{4}$
200 000 CM	80 000 CM	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{3}{4}$	2	$\frac{1}{4}$	$2\frac{1}{2}$	2	7 X 2	$\frac{1}{4}$	5	$\frac{3}{4}$	8	$6\frac{1}{2}$	2
40 000 CM	40 000 CM	$2\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{2}$	2	$\frac{1}{4}$	$2\frac{1}{2}$	2	7 x 2	$\frac{1}{4}$	5	$\frac{3}{4}$	8	$6\frac{1}{2}$	2

Figs. 6,073 to 6,079.—Secondary half duplex joint.

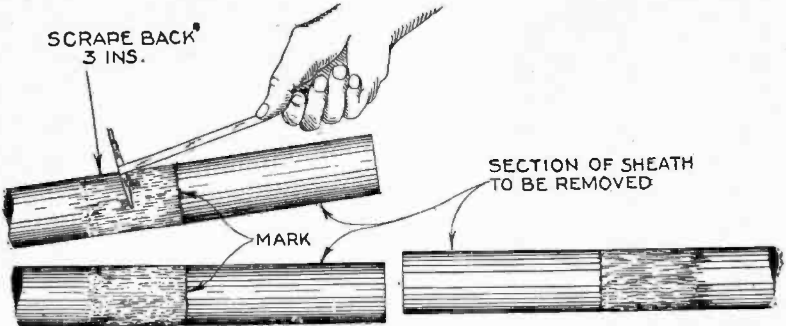
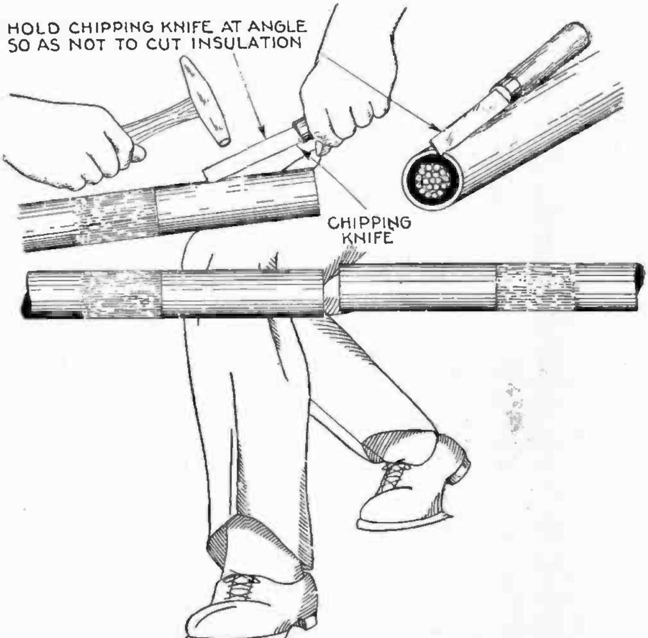


FIG. 6,080.—Scraping lead sheath on cables after they have been cut, aligned and marked.



FIGS. 6,081 and 6,082.—Chipping operation showing method of holding cable on the knee and in detail the proper angle at which to hold the chipping knife (fig. 6,082).

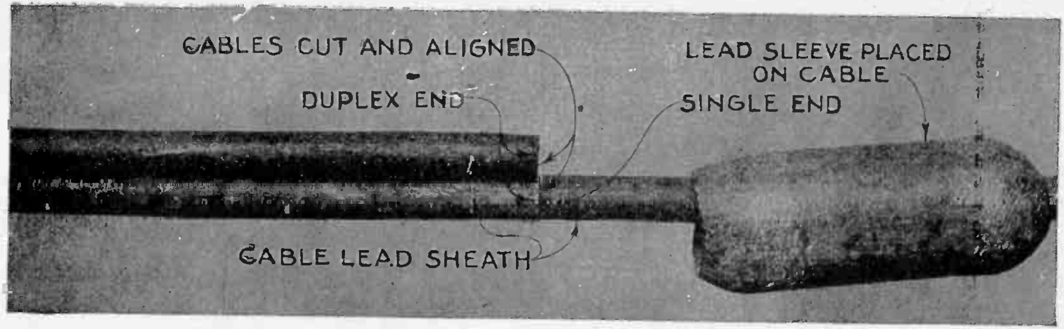


FIG. 6,083.—***Half duplex cable joint 1.*** Appearance of cable with ends cut and in position, also sleeve threaded on cable.

Wiping the Sleeve.—Slip the lead sleeve into position and dress the end down to fit over the cable. Apply gummed paper about 3 ins. wide on cable and on the sleeve, in order to confine the wiping to the proper point. Both ends of the sleeve should be soldered to the lead sheath of the cable with a wiped joint.

The operations of placing the sleeve in the proper position and wiping are explained at length for the half duplex joint, later described. Fig. 6,072 shows appearance of the completed three conductor cable joint being cut away to show how the sleeve fits over the joint.

Testing Joint.—After wiping the sleeve test joint to 15 lbs. air pressure with a tire pump and gauge. Apply soapy water to test for leaks.

Filling Joint with Compound.—After the joint has been completed and tested it should be filled through the filling nipple with compound heated to a temperature of 240° Fahr.

In doing this, tilt the joint so that the filling hole will be slightly above the level of the other hole. The compound to be poured through the filling hole until the joint is filled, and about one gallon of hot compound should

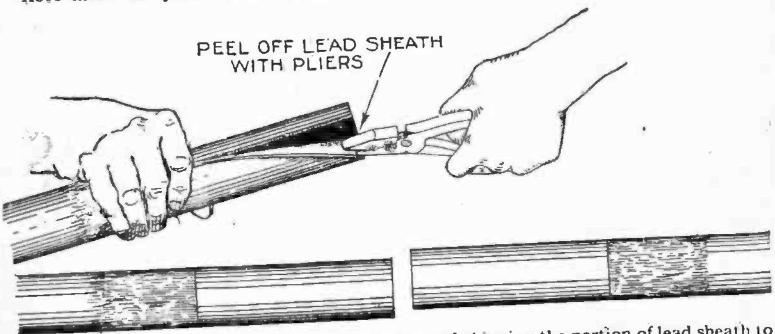


FIG. 6,084.—Removing lead sheath. After ringing and chipping the portion of lead sheath to be removed is easily twisted off with the aid of a pair of pliers.

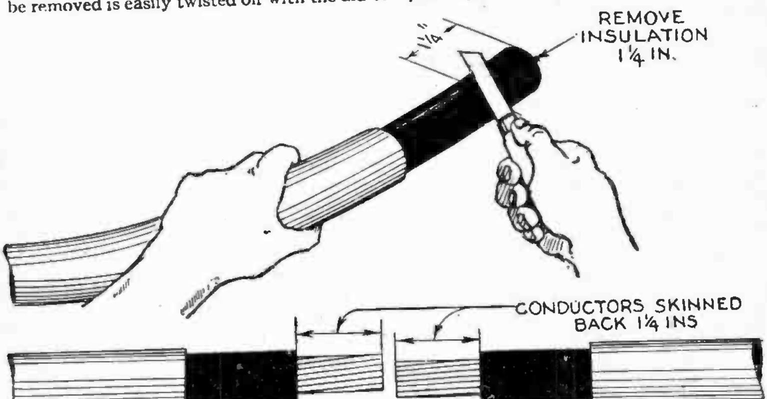


FIG. 6,085.—Removing insulation. If the stranding be of circular cross section, all the insulation is removed at once, but when of the oval form with paper insulation only half should be removed at first so that the shaping operation may be performed without injuring the strands, as fully explained in fig. 6,053.

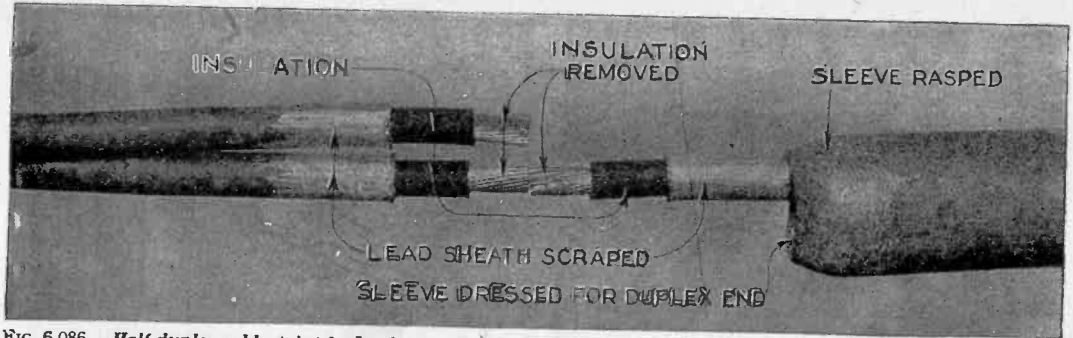


FIG. 6,086.—***Half duplex cable joint 2.*** Lead sleeve threaded on cable, sheaths scraped and insulation removed; cable ends in position for connector.

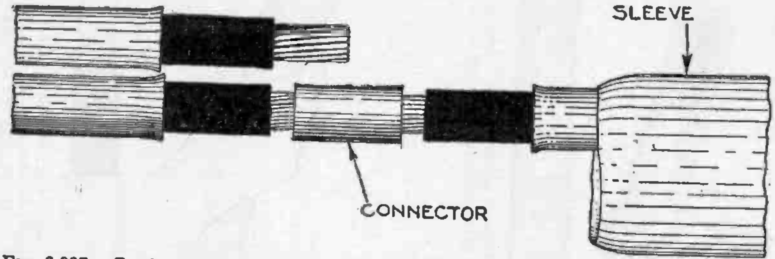


FIG. 6,087.—Conductors in alignment and connector in position over the two abutting conductors.

be allowed to run through the joint in order to boil it out, and remove any moisture which may be present. If there still be frothing of the compound after running the one gallon through the joint, the pouring should be continued until the frothing ceases, as this frothing indicates moisture.

The operation of filling is illustrated for the half duplex cable, fig. 6,100, and differs only in that it is poured through a filling hole instead of a threaded nipple.

After the compound has settled give the joint a final fill, close the filling nipple. Be sure the two holes are tightly closed; clean the gummed paper from the lead and do not disturb the joint after this is done.

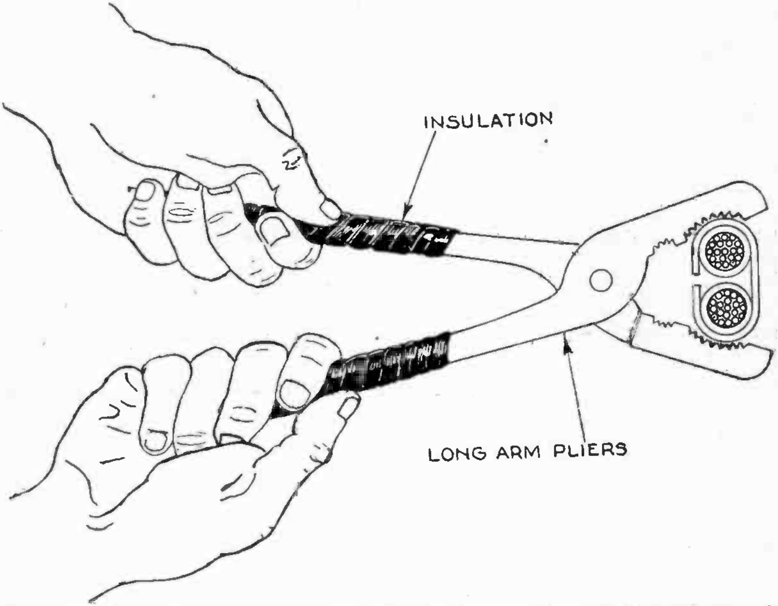


FIG. 6,088.—Method of squeezing on collar with aid of long arm pliers. Note that both hands are used in this operation.

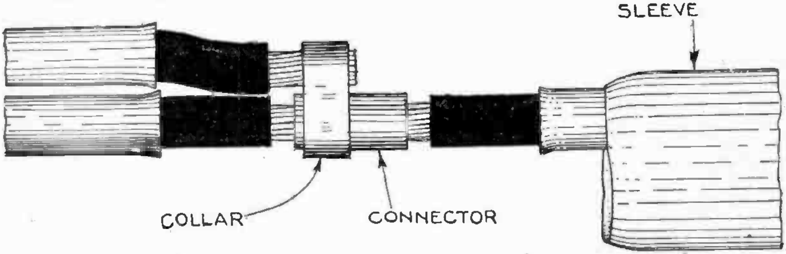


FIG. 6,089.—Collar in position joining the third conductor with the two conductors joined by the connector.

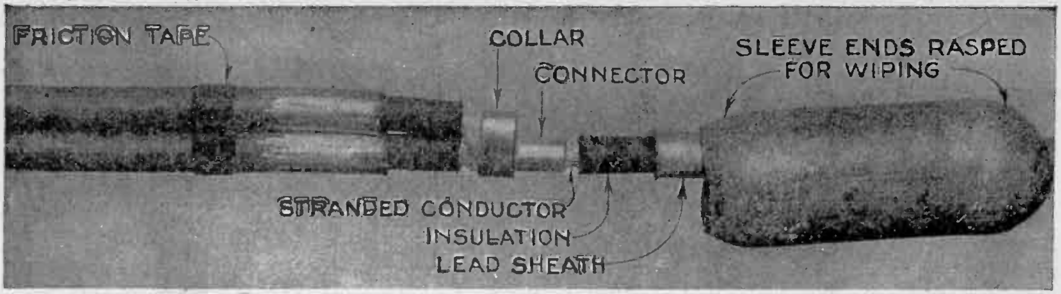


Fig. 6,090.—***Half duplex cable joint 3.*** Appearance of joint after sweating connector and collar. Note the two cables at left held firmly together by friction tape.

Fig. 6,091.—***Half duplex cable joint 4.*** Appearance of joint after insulating.

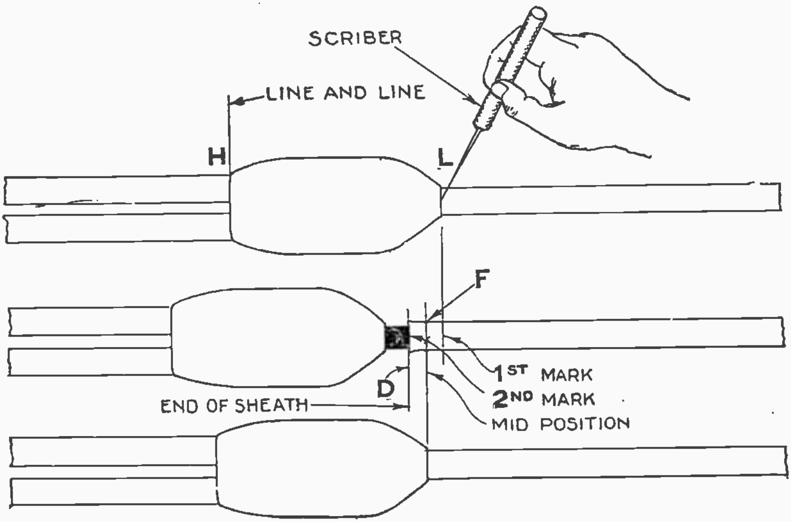
Precautions.—It is important that each operation be made in a neat and workmanlike manner, care being taken that the hands of the jointer are kept dry and that all material used in making the splice is kept in a dry place. No cable should be opened and left exposed to the weather.

110 to 240 Volt Half Duplex Joint.—The cable here used has the following specifications: 200,000 *cm.*; 3/32 rubber and takes a 2½×7 sleeve. Many of the operations performed in making this joint are made in the same way as for the three conductor cable, and accordingly need little or no further explanation.

After training and cutting off the cables, they are marked and scraped as in fig. 6,080.

Next the lead sheath is removed as in figs. 6,081 and 6,082. In fig. 6,082, note that the clipping knife should be held at an acute angle to avoid cutting the insulation.

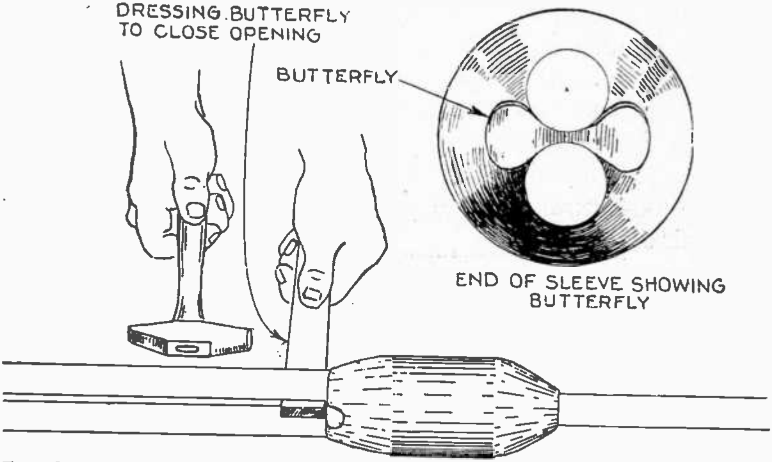
Fig. 6,084 shows the method of twisting off the lead sheath with pair of pliers.



FIGS. 6,092 to 6,094.—Method of centering sleeve over joint. Slide sleeve till its end is *line and line* with the end of the lead sheath as at H, and mark position with scriber as at L, fig. 6,092. Next slide sleeve to left beyond end of sheath and divide the distance between end of sheath (indicated by line D), and position L, in half as indicated by the line F; slide sleeve back to this position. It now overlaps the cables equally at each end, as in fig. 6,094.

Remove conductor insulation back a distance of $1\frac{1}{4}$ in. as in fig. 6,085.

Now in the half duplex cable a connector and also a collar are



FIGS. 6,095 and 6,096.—Fitting butterfly or filler piece to close up opening at sleeve end. The butterfly should be shaped to fit the sleeve using a rectangular dresser and hammer, as in fig. 6,095. The shaping of the other end is easily done with a dresser.

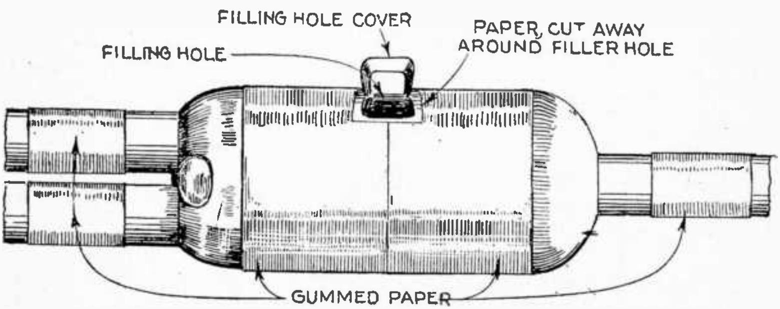


FIG. 6,097.—Application of "paper pasters" to limit the flow of solder in making the wiped joints. These paper pasters are more conveniently applied than the old time "soil" used by plumbers for the same purpose. Any paper with gum on one side will do.

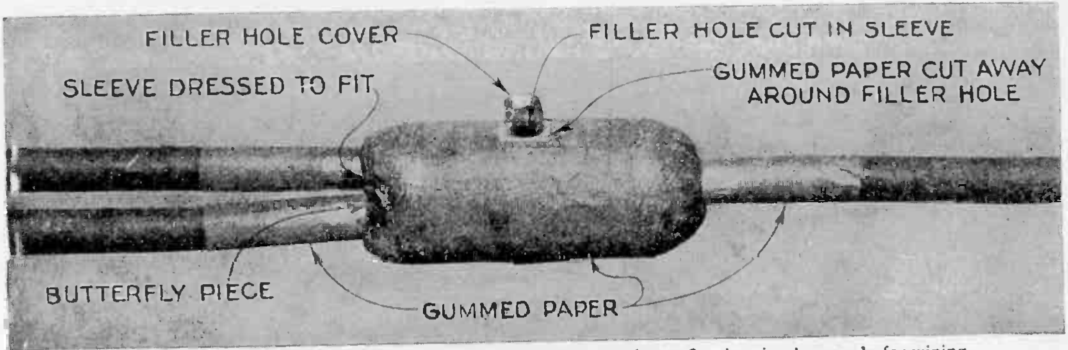


FIG. 6,098.—*Half duplex cable joint 5.* Sleeve in position dressed, and butterfly piece in place ready for wiping.

used. After slipping on the sleeve squeeze the connector around the two butting conductors, as in fig. 6,087. The third conductor being squeezed against the connector by means of the collar, shown in fig. 6,089.

Fig. 6,088 shows the operation of squeezing on the collar with a pair of long arm pliers, using both hands.

The joint is now ready for the sweating operation and this has been thoroughly explained in the instructions for the three conductor cable.

The method of centering the sleeve over the joint with precision is shown in figs. 6,092 to 6,094.

Any opening where the cables come out of the sleeve must be closed up.

At the right side where there is only one cable this is easily done by dressing the sleeve end with a dresser.

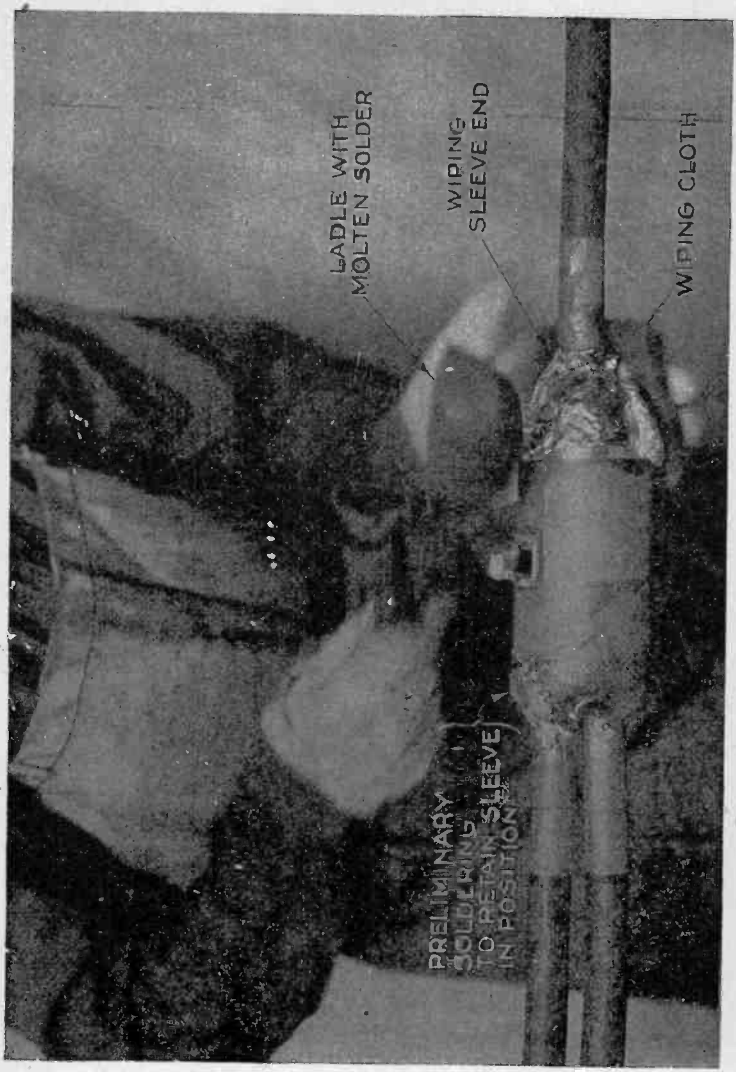


Fig. 6,099.—***Half duplex cable joint 6.*** Operation of pouring the molten solder and wiping sleeve end. Note the patch of solder at the duplex end to hold sleeve rigid while wiping.

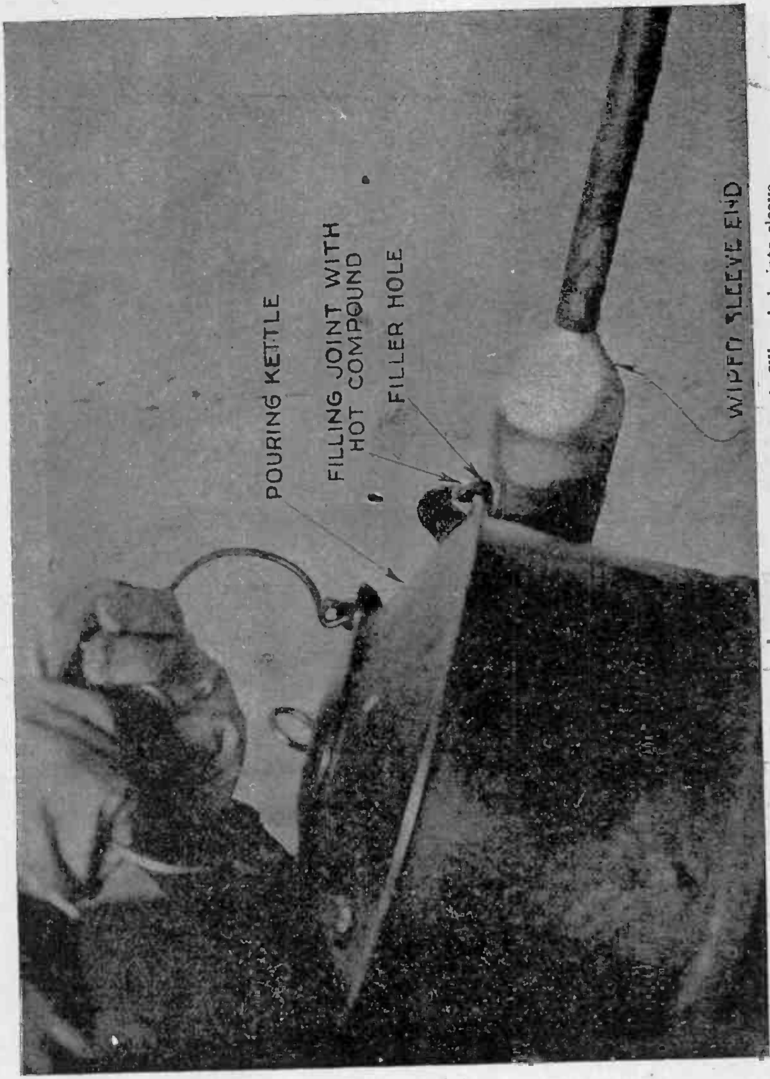


Fig. 6,100.—*Half duplex cable joint 7.* Pouring the hot compound through filling hole into sleeve.

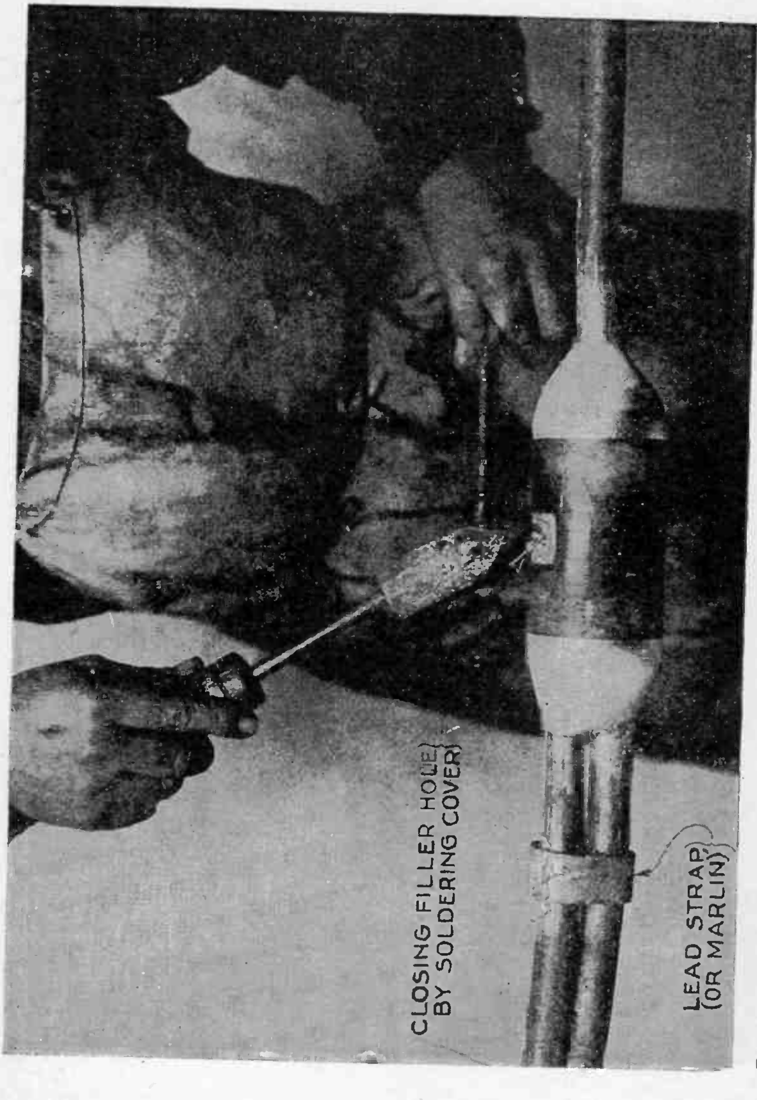


FIG. 6,101.—*Half duplex cable joint 8.* Closing filling hole by soldering cover.

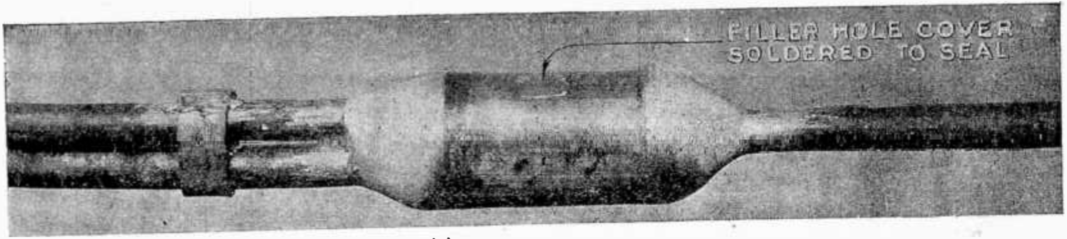


FIG. 6,102.—Appearance of completed half duplex joint.

Now at the other end where the two cables come out there will be an open space between the cables and this is closed with a "butterfly" or filler piece, which is placed at the end of the sleeve and fitted to the opening so as to close the latter. Evidently this is necessary, otherwise in wiping the joint, molten solder would flow into the sleeve.

Mark on the cables and the sleeve the limits of the wiped joints, and paste paper pasters around cables and sleeves so that the edges of the paper register with the marks; as in fig. 6,097 this will limit the flow of solder in wiping up the joints.

After the sleeve has been filled with the compound, as instructed for the three conductor cable, the filler holes are soldered up as in fig. 6,101. Fig. 6,102 shows joint completed.

NOTE.—Jointing for the four wire three phase system, is executed the same as for the three conductor cable explained in this chapter, the fourth or neutral wire being external to the three conductor cable. The system is explained fully in other sections of this series.

TEST QUESTIONS

1. *Give a classification of various cable joints.*
2. *What preliminary knowledge should the student have before taking up cable jointing?*
3. *Explain in great detail the method of jointing a 13,800 volt, 3 conductor cable.*
4. *What precaution should be taken when bending cables?*
5. *Why are the three insulated conductors wrapped with cambric tape?*
6. *What kind of flux is used on a joint to be sweated?*
7. *Why is a Melrose cord used in wiping a joint?*
8. *What precaution should be taken in penciling?*
9. *Explain in great detail the method of jointing a secondary half duplex cable.*
10. *What tool is used in scraping the ends of a sleeve?*
11. *What fitting is used to joint the second cable at the duplex end?*
12. *What is understood by the expression "line and line?"*
13. *What is the object of the butterfly piece fitted to sleeve?*
14. *How is the sleeve sealed after filling?*

The Author is indebted to the United Electric Light and Power Co. of New York for considerable assistance in the preparation of this Chapter.