CLUB BUILDING FOR THE PEORIA COUNTRY CLUB, PEORIA, ILL.
Herbert Edmund Hewitt, Architect, Peoria, Ill. For plan, see next succeeding plate.

Cyclopedia
of
Architecture, Carpentry, and Building

A General Reference Work

ON ARCHITECTURE, CARPENTRY, BUILDING, SUPERINTENDENCE, CONTRACTS, SPECIFICATIONS, BUILDING LAW, STAIR-BUILDING, ESTIMATING, MASONRY, REINFORCED CONCRETE, STRUCTURAL ENGINEERING, ARCHITECTURAL DRAWING, SHEET METAL WORK, HEATING, VENTILATING, ETC.

Prepared by a Staff of

ARCHITECTS, BUILDERS, ENGINEERS, AND EXPERTS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Three Thousand Engravings

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost architects, engineers, and builders in making these volumes thoroughly representative of the very best and latest practice in the design and construction of buildings; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

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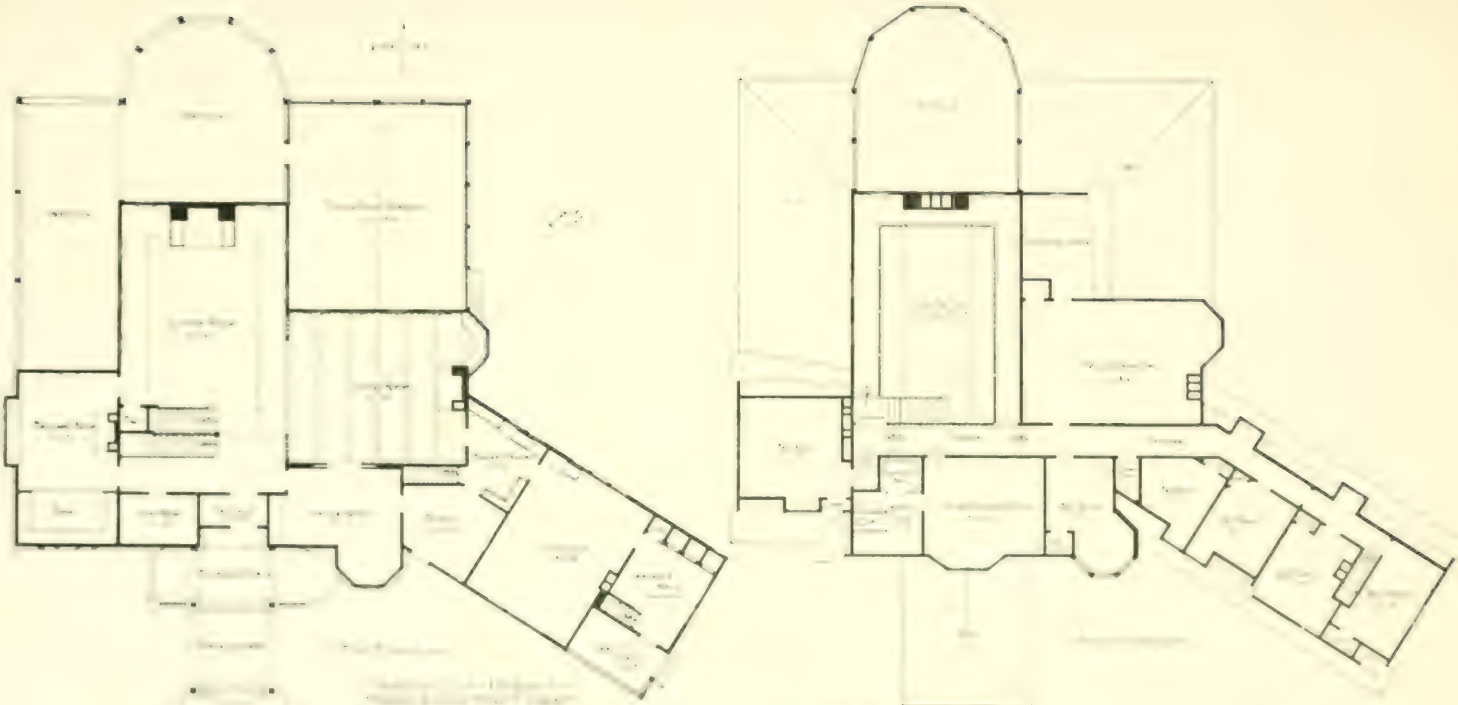


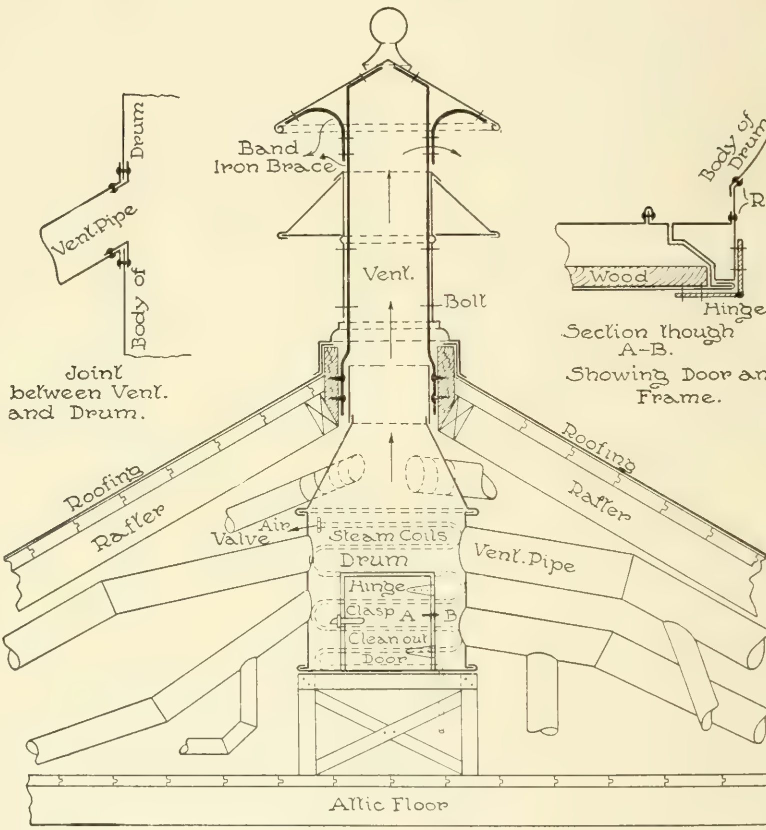
PLANS OF THE PEORIA COUNTRY CLUB, PEORIA, ILL

Herbert Edmund Hewitt, Architect, Peoria, Ill.

For Exterior View, Reproduced in Color, See Frontispiece to this Volume

CONSTRUCTION DRAWING
SHOWING

SHEET METAL DRUM AND VENTILATOR IN VENTILATION WORK



Sectional view showing ventilation pipes connected to drum in attic also steam coils in drum to create suction.

Foreword

THE rapid evolution of constructive methods in recent years, as illustrated in the use of steel and concrete, and the increased size and complexity of buildings, has created the necessity for an authority which shall embody accumulated experience and approved practice along a variety of correlated lines. The Cyclopedia of Architecture, Carpentry, and Building is designed to fill this acknowledged need.

¶ There is no industry that compares with Building in the close interdependence of its subsidiary trades. The Architect, for example, who knows nothing of Steel or Concrete construction is today as much out of place on important work as the Contractor who cannot make intelligent estimates, or who understands nothing of his legal rights and responsibilities. A carpenter must now know something of Masonry, Electric Wiring, and, in fact, all other trades employed in the erection of a building; and the same is true of all the craftsmen whose handiwork will enter into the completed structure.

¶ Neither pains nor expense have been spared to make the present work the most comprehensive and authoritative on the subject of Building and its allied industries. The aim has been, not merely to create a work which will appeal to the trained expert, but one that will commend itself also to the beginner and the self-taught, practical man by giving him a working knowledge of the principles and methods, not only of his own particular trade, but of all other branches of the Building Industry as well. The various sections have been prepared especially for home study, each written by an acknowledged authority on the subject. The arrangement of matter is such as to carry the student forward by easy stages. Series of review questions are inserted in each volume, enabling the reader to test his knowledge and make it a permanent possession. The illustrations have been selected with unusual care to elucidate the text.

¶ The work will be found to cover many important topics on which little information has heretofore been available. This is especially apparent in such sections as those on Steel, Concrete, and Reinforced Concrete Construction; Building Superintendence; Estimating; Contracts and Specifications, including the principles and methods of awarding and executing Government contracts; and Building Law.

¶ The Cyclopedia is a compilation of many of the most valuable Instruction Papers of the American School of Correspondence, and the method adopted in its preparation is that which this School has developed and employed so successfully for many years. This method is not an experiment, but has stood the severest of all tests—that of practical use—which has demonstrated it to be the best yet devised for the education of the busy working man.

¶ In conclusion, grateful acknowledgment is due the staff of authors and collaborators, without whose hearty co-operation this work would have been impossible.

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VOLUME IX

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† [illegible] front of volume.

ELECTRICAL KITCHEN IN EDISON BUILDING, CHICAGO

ELECTRIC WIRING

METHODS OF WIRING

The different methods of wiring which are now approved by the National Board of Fire Underwriters, may be classified under four general heads, as follows:

1. Wires Run Concealed in Conduits.
2. Wires Run in Moldings.
3. Concealed Knob and Tube Wiring.
4. Wires Run Exposed on Insulators.

WIRES RUN CONCEALED IN CONDUITS

Under this general head, will be included the following:

(*a*) Wires run in rigid conduits.
(*b*) Wires run in flexible metal conduits.
(*c*) Armored cable.

Wires Run in Rigid Conduit. The form of rigid metal conduit now used almost exclusively, consists of plain iron gas-pipe the interior surface of which has been prepared by removing the scale and by removing the irregularities, and which is then coated with flexible enamel. The outside of the pipe is given a thin coat of enamel in some cases, and, in other cases, is galvanized. Fig. 1 shows one make of enameled (unlined) conduit.

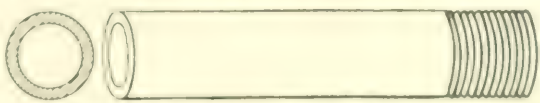


Fig. 1. Rigid Enameled Conduit, Unlined.
Courtesy of American Conduit Mfg. Co., Pittsburg, Pa.

Another form of rigid conduit is that known as the *armored conduit*, which consists of iron pipe with an interior lining of paper impregnated with asphaltum or similar compound. This latter form of conduit is now rapidly going out of use, owing to the unlined pipe being cheaper and easier to install, and owing also to improved methods of protecting the iron pipe from corrosion, and to the introduction of additional braid on the conductors, which partly compensates for the pipe being unlined. The introduction of improved devices—such as outlet insulators, for protecting the conductors from the sharp edges of the pipe, at outlets, cut-out cabinets, etc.—also decreases the necessity of the additional protection afforded by the interior paper lining.

Rigid conduits are made in gaspipe sizes, from one-half inch to three inches in diameter. The following table gives the various data relating to rigid, enameled (unlined) conduit:

TABLE I
Rigid, Enameled Conduit—Sizes, Dimensions, Etc.

Standard Pipe Size	Thickness	Nominal Weight per 100 Feet	Number of Threads per Inch of Screw	Actual Outside Diameter. Inches	Nominal Inside Diameter. Inches
½	.109	84	14	.84	.62
¾	.113	112	14	1.05	.82
1	.134	167	11½	1.31	1.04
1¼	.140	224	11½	1.66	1.38
1½	.145	268	11½	1.90	1.61
2	.154	361	11½	2.37	2.06
2½	.204	574	8	2.87	2.46
3	.217	754	8	3.50	3.06

Tables II, III, and IV give the various sizes of conductors that may be installed in these conduits. Caution must be exercised in

TABLE II
Single Wire in Conduit

Size Wire, B. & S. G.	Loricated Conduit, Unlined; D. B. Wire
No. 14-4	½ inch
" 2	¾ "
" 1	¾ "
" 0	¾ inch or 1 "
" 00	1 "
" 000	1 "
" 0000	1 "
250,000 C. M.	1¼ "
300,000 C. M.	1¼ "
350,000 C. M.	1¼ "
400,000 C. M.	1¼ " or 1½ "
450.000 C. M.	1½ "
500,000 C. M.	1½ "
600,000 C. M.	1½ " or 2 "
700,000 C. M.	2 "
800,000 C. M.	2 "
900,000 C. M.	2 "
1,000,000 C. M.	2 " or 2½ "
1,500,000 C. M.	2½ "
1,700,000 C. M.	3 "
2,000,000 C. M.	3 "

TABLE III

Two Wires in One Conduit

Size Wire, B & S G	[illegible] Conduit [illegible] D. B. Wire
No. 14	[illegible] inch
" 12	½ [illegible] or [illegible]
" 10	[illegible] "
" 8	1 "
" 6	1 "
" 5	1 " or 1¼ "
" 4	1¼
" 3	1¼
" 2	1¼ " or 1½
" 1	1½
" 0	1½
" 00	1½ " or 2
" 000	2
" 0000	2
250,000 C. M.	2 " or 2½ "
300,000 C. M.	2½ "
350,000 C. M.	2½ "
400,000 C. M.	2½ " or 3
450,000 C. M.	3
500,000 C. M.	3
600,000 C. M.	3 "
700,000 C. M.	3 "

TABLE IV

Three Wires in One Conduit

Size Wire, B. & S. G.		[illegible] D. B. Wire
Outside	Center	
No. 14	No. 12	¾ inch
" 12	10	¾ "
" 10	" 8	1 "
" 8	" 6	1 "
" 6	" 4	1¼ "
" 5	" 2	1¼ "
" 4	" 1	1¼ inch or 1½ "
" 3	" 0	1½ "
" 2	" 2/0	1½ " or 2 "
" 1	" 3/0	2 "
" 0	" 4/0	2 "
" 2/0	250 M.	2 or 2½ "
" 3/0	300 M.	2½ "
" 4/0	400 M.	2½ "
250 M.	450 M.	2½ or 3 "
250 M.	500 M.	3 "
300 M.	600 M.	3 "
350 M.	700 M.	3 "
400 M.	800 M.	3 "
450 M.	900 M.	[illegible]

using these tables, for the reason that the sizes of conductors which may be safely installed in any run of conduit depend, of course, upon the length of and the number of bends in the run. The tables are based on average conditions where the run does not exceed 90 to 100 feet, without more than three or four bends, in the case of the smaller sizes of wires for a given size of conduit; and where the run does not exceed 40 to 50 feet, with not more than one or two bends, in the case of the larger sizes of wires, for the same sizes of conduit.

Unlined conduit can be bent without injury to the conduit, if the conduit is properly made and if proper means are used in making the bends. Care should be exercised to avoid flattening the tube as a result of making the bend over a sharp curve or angle.

In installing iron conduits, the conduits should cross sleepers or beams at right angles, so as to reduce the amount of cutting of the beams or sleepers to a minimum.

Where a number of conduits originate at a center of distribution, they should be run at right angles for a distance of two or three feet from the cut-out box, in order to obtain a symmetrical and workmanlike arrangement of the conduits, and so as to have them enter the cabinet in a neat manner. While it is usual to use red or white lead at the joints of conduits in order to make them water-tight, this is frequently unnecessary in the case of enameled conduit, as there is often sufficient enamel on the thread to make a water-tight joint.

When iron conduits are installed in ash concrete, in Keene cement, or, in general, where they are subject in any way to corrosive action, they should be coated with asphaltum or other similar protective paint to prevent such action.

While the cost of circuit work run in iron conduits is usually greater than any other method of wiring, it is the most permanent and durable, and is strongly recommended where the first cost is not the sole consideration. This method of wiring should always be used in fireproof buildings, and also in the better class of frame buildings. It is also to be recommended for exposed work where the work is liable to disturbance or mechanical damage.

Wires Run in Flexible Metal Conduit. This form of conduit, shown in Fig. 2, is described by the manufacturers as a conduit composed of "concave and convex metal strips wound spirally upon each other in such a manner as to interlock several concave surfaces and present their convex surfaces, both exterior and interior, thereby securing a smooth and comparatively frictionless surface inside and out."

The field for the use of this form of conduit is rapidly increasing. Owing to its flexibility, conduit of this type can be used in numerous cases where the rigid conduit could not possibly be employed. Its use is to be recommended above all the other forms of wiring, except that installed in rigid conduits. For new fireproof buildings, it is not so durable as the rigid conduit, because not so water-tight; and it is very difficult, if not impossible, to obtain as workmanlike a conduit system with the flexible as with the rigid type of conduit. For completed or old frame buildings, however, the use of the flexible conduit is superior to all other forms of wiring.

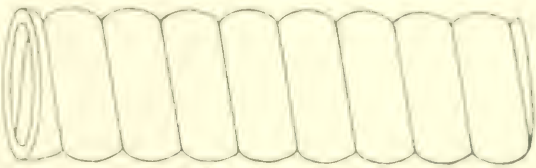


Fig. [illegible]. Flexible Steel Conduit
Courtesy of [illegible] Electric Co., New York, N. Y.

Table V gives the inside diameter of various sizes of flexible conduit, and the lengths of standard coils. The inside diameter of this conduit is the same as that of the rigid conduit; and the table given for the maximum sizes of conductors which may be installed in the various sizes of conduits, may be used also for flexible steel conduits, except that a little more margin should be allowed for flexible steel conduits than for the rigid conduits, as the stiffness of the latter makes it possible to pull in slightly larger sized conductors.

TABLE V

Greenfield Flexible Steel Conduit

Inside Diameter	Approximate Feet in Coil
[illegible] inch	300
[illegible] "	200
[illegible] "	100
[illegible] "	50
1 "	[illegible]
1¼ inches	50
1½ "	50
2 "	Random Lengths
2½ "	
3 "	

This conduit should, of course, be first installed without the conductors, in the same manner as the rigid conduit. Owing to the flexibility of this conduit, however, it is absolutely essential to fasten it securely at all elbows, bends, or offsets; for, if this is not done, considerable difficulty will be experienced in drawing the conductors in the conduit.

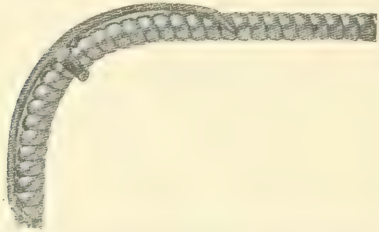


Fig. 3. Use of Elbow Clamp for Fastening Flexible Conduit in Place.

The rules governing the installation of this conduit are the same as those covering rigid conduits. Double-braided conductors are required, and the conduit should be grounded as required by the *Code Rules.* As already stated, the conduit should be securely fastened (in not less than three places) at all elbows; or else the special elbow clamp made for this purpose, shown in Fig. 3, should be used.

In order to cut flexible steel conduit properly, a fine hack saw should be employed. Outlet-boxes are required at all outlets, as well as bushing and wires to rigid conduit. Fig. 4 shows a coil of flexible steel conduit. Figs. 5, 6, and 7 show, respectively, an outlet box and cover, outlet plate, and bushing used for this conduit.

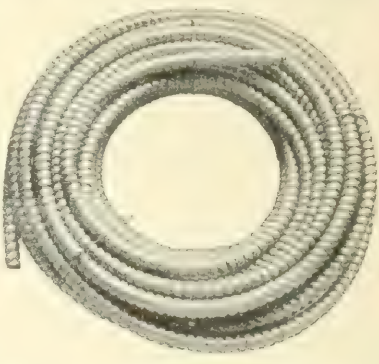


Fig. 4. A 100-Foot Coil of Flexible Steel Conduit.
Courtesy of Sprague Electric Co., New York, N. Y.

Armored Cable. There are many cases where it is impossible to install a conduit system. In such cases, probably the next best results may be obtained by the use of *steel armored cable.* The rules governing the installation of armored cable are given in the *National Electric Code,* under Section 24-A, and Section 48; also in 24–S. This cable is shown in Fig. 8.

Steel armored cable is made by winding formed steel strips over the insulated conductors. The steel strips are similar to those used for the steel conduit. Care is taken in forming the cable, to avoid crushing or abrading the insulation on the conductors as the steel

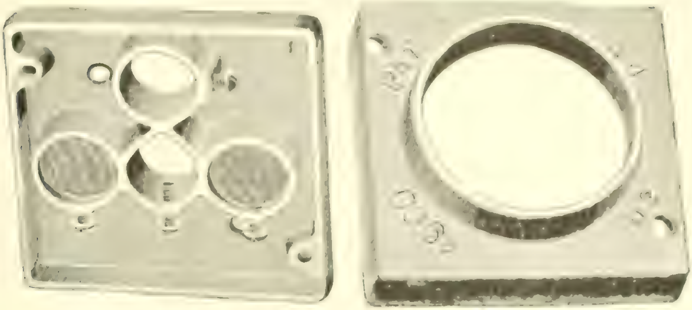


Fig. 5. Outlet Box for Flexible Steel Conduit.

strips are fed and formed over the same. In the process of manufacture, the spools of steel ribbon are of irregular length, and when a

Fig. 6. Outlet Plate for Flexible Steel Conduit.

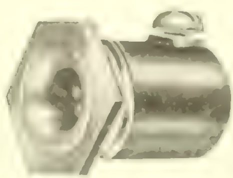


Fig. 7. Outlet Bushing.
Courtesy of Sprague Electric Co., New York, N. Y.

spool is empty, the machine is stopped, and the ribbon is started on the next spool, the process being continued. There is no reason why

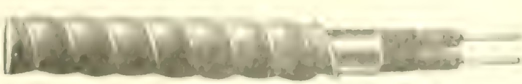


Fig. 8. Flexible Armored Cable. Twin Conductor.
Courtesy of Sprague Electric Co., New York, N. Y.

the conduit cables could not be made of any length; but their actual lengths as made are determined by convenience in handling. Armored cable is made in *single conductors* from No. 1 to No. 10 B. & S. G.; in *twin conductors,* from No. 6 to No. 14 B. & S. G.; and *three-conductor* cable, from No. 10 to No. 14 B. & S. G. Table VI gives various data relating to armored conductors:

TABLE VI

Armored Conductors—Types, Dimensions, Etc.

Size B. & S Gauge	Type and Number of Conductors	Outside Diameter (Inches)
No. 14	BX twin conductor	.63
" 12	" " "	.685
" 10	" " "	.725
" 8	" " "	.875
" 6	" " "	1.3125
" 14	BM twin conductor (for marine work—ship wiring)	.725
" 12	" " "	.725
" 10	" " "	.73
" 14	BX3 three conductor	.71
" 12	" " "	.725
" 10	" " "	.73
" 14	BXL twin conductor, leaded	.725
" 12	" " " "	.725
" 10	" " " "	.87
" 14	BXL3 three conductor, leaded	.90
" 12	" " " "	.90
" 10	" " " "	.94
" 10	Type D single conductor, stranded	.550
" 8	" " " " "	.550
" 6	" " " " "	.575
" 4	" " " " "	.700
" 2	" " " " "	.900
" 1	" " " " "	.965
" 10	Type DL single conductor, stranded, leaded	.625
" 8	" " " " " "	.710
" 6	" " " " " "	.700
" 4	" " " " " "	.760
" 2	" " " " " "	.920
" 1	" " " " " "	.910
	Steel Armored Flexible Cord	
" 18	Type E twin conductor	.40
" 16	" " " "	.40
" 14	" " " "	.47
" 18	Type EM twin conductor, re-inforced	.575
" 16	" " " " "	.585
" 14	" " " " "	.595

In Table VI, Types D (single), BX (twin), and BX3 (3 conductors) are armored cable adapted for ordinary indoor work. Type BM (twin conductors) is adapted for marine wiring. Types BL (single), BXL (twin), and BXL 3 (3 conductors) have the conductors lead-encased, with the steel armor outside, and are especially adapted for damp places, such as breweries, stables, and similar places.

Type E is used for flexible-cord pendants, and is suitable for factories, mills, show windows, and other similar places. Type EM is the same as Type E; but the flexible cord is reinforced, and is suitable for marine work, for use in damp places, and in all cases where it will be subject to very rough handling.

While this form of wiring has not the advantage of the conduit system—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 flexible steel conduit, and it has some additional advantages of its own. For example, 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 conductors should be continuous from outlet to outlet, without being spliced and installed on the loop system. Outlet boxes should be installed at all outlets, although, where this is impossible, outlet plates may be used under certain conditions. Clamps should be provided at all outlets, switch-boxes, junction-boxes, etc., to hold the cable in place, and also to serve as a means of grounding the steel sheathing.

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.

WIRES RUN IN MOULDING

Moulding is very extensively used for electric circuit work, in extending circuits in buildings which have already been wired, and also in wiring buildings which were not provided with electric circuit work at the time of their erection. The reason for the popularity of moulding is that it furnishes a convenient and fairly good-looking runway for the wires, and protects them from mechanical injury.

It seems almost unwise to place conductors carrying electric current, in wood casing; but this method is still permitted by the *National Electric Code*, although it is not allowed in damp places or in places where there is liability to dampness, such as on brick walls, in cellars, etc.

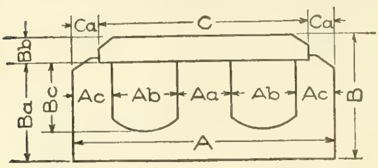


Fig. 9. Two-Wire Wood Moulding.

The dangers from the use of moulding are that if the wood becomes soaked with water, there will be a liability to leakage of current between the conductors run in the grooves of the moulding, and to fire being thereby started, which may not be immediately discovered. Furthermore, if the conductors are overloaded, and consequently overheated, the wood is likely to become charred and finally ignited. Moreover, the moulding itself is always a temptation as affording a good "round strip" in which to drive nails, hooks, etc. However, the convenience and popularity of moulding cannot be denied; and until some better substitute is found, or until its use is forbidden by the *Rules*, it will continue to be used to a very great extent for running circuits outside of the walls and on the ceilings of existing buildings. Figs. 9, 10, 11, and 12 show two- and three-wire moulding respectively; and Table VII gives complete data as to sizes of the moulding required for various sizes of conductors.

While the *Rules* recommend the use of hardwood moulding, as a matter of fact probably 90 per cent of the moulding used is of whitewood or other similar cheap, soft wood. Georgia pine or oak ordinarily

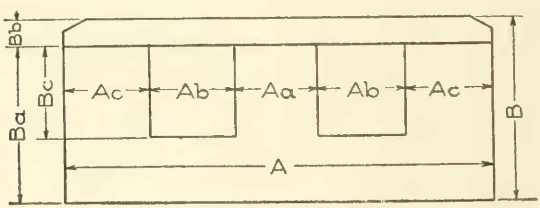


Fig. 10. Two-Wire Wood Moulding.

costs about twice as much as the soft wood. In designing moulding work, if appearance is of importance, the moulding circuits should be laid out so as to afford a symmetrical and complete design. For example, if an outlet is to be located in the center of the ceiling, the moulding should be continued from wall to wall, the portion beyond the outlet, of course, having no conductors inside of the moulding. If four outlets are to be placed on the ceiling, the rectangle of moulding should be completed on the fourth side, although, of course, no conductors need be placed in this portion of the moulding. Doing this increases the cost but little and adds greatly to the appearance.

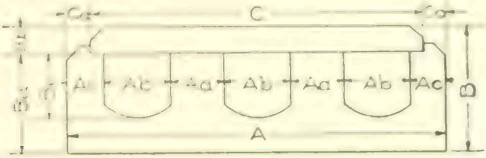


Fig. 11. Three-Wire Wood Moulding.

Moulding is frequently used in combination with other methods of wiring, including armored cable, flexible steel tubing, and fibrous tubing. In many instances, it is possible to fish tubing between beams or studs running in a certain direction; but when the conductors are to run in another direction or at right angles to the beams or studs, exposed work is necessary. In such cases, a junction-box or outlet-box must be placed at the point of connection between the moulding and the armored cable or steel tubing.

Where circuits are run in moulding, and pass through the floor, additional protection must be provided, as required by the *Code Rules*, to protect the moulding. As a rule, it is better to use conduit for all portions of moulding within six feet of the floor, so as to avoid the possibility of injury to the circuits. Where a combination of iron conduit or flexible steel tubing is used with moulding, it is well to use double-braided conductors throughout, because, although only single-

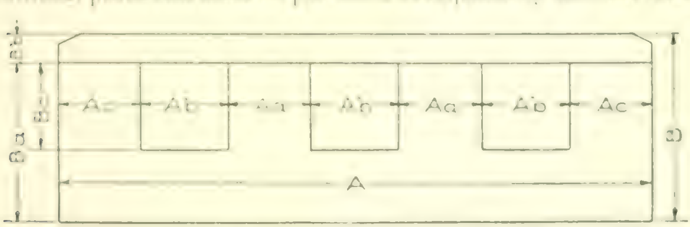


Fig. 12. Three-Wire Wire Moulding.

TABLE VII

Sizes of Mouldings Required for Various Sizes of Conductors

Fig. No.	Type of Moulding	Number of Wires	Maximum Size of Wire B and S. Gauge		Dimensions in Inches									
			Solid	Stranded	A	Aa	Ab	Ac	B	Ba	Bb	Bc	C	Ca
9	A-2	2	12	14	1 1/2	1/2	1/4	1/4	27/32	5/8	7/32	1/4	1 1/8	3/16
9	A-4	2	8	10	1 11/16	1/2	5/16	9/32	29/32	11/16	7/32	5/16	1 5/16	3/16
9	A-6	2	4	5	2	1/2	7/16	5/16	1 1/16	13/16	1/4	7/16	1 9/16	7/32
9	A-8	2	1	2	2 3/8	1/2	9/16	3/8	1 3/16	15/16	1/4	9/16	1 13/16	9/32
9	A-9	2	–	3/0	3	5/8	3/4	7/16	1 13/32	1 1/8	9/32	3/4	2 7/16	9/32
10	A-10	2	–	250,000 C.M.	3 15/16	11/16	7/8	3/4	1 11/16	1 3/8	5/16	7/8	—	—
10	A-11	2	–	400,000 C.M.	4 7/8	15/16	1	31/32	2 3/16	1 7/8	5/16	1	—	—
11	B-2	3	12	14	2 3/16	7/16	1/4	9/32	27/32	5/8	7/32	1/4	1 13/16	3/16
11	B-4	3	8	10	2 1/2	15/32	5/16	5/16	29/32	11/16	7/32	5/16	2 1/8	3/16
11	B-6	3	4	5	2 7/8	13/32	7/16	3/8	1 1/16	13/16	1/4	7/16	2 3/8	1/4
11	B-8	3	1	2	3 5/8	19/32	9/16	3/8	1 3/16	15/16	1/4	9/16	3 1/16	9/32
11	B-9	3	–	3/0	4 5/16	9/16	3/4	15/32	1 13/32	1 1/8	9/32	3/4	3 3/4	9/32
12	B-10	3	–	250,000 C.M.	5 1/2	23/32	7/8	23/32	1 11/16	1 3/8	5/16	7/8	—	—
12	B-11	3	–	400,000 C.M.	6 3/4	15/16	1	15/16	2 3/16	1 7/8	5/16	1	—	—

braided conductors are required with moulding, double-braided conductors are required with unlined conduit, and if double-braided conductors were not used throughout, it would be necessary to make a joint at the outlet-box where the moulding stopped and the conduit work commenced. Where the conductors pass through floors, in moulding work, and where iron conduit is used, the inspection authorities, in order to protect the wire, usually require that a fibrous tubing be used as additional protection for the conductors inside of the iron pipe, although, if double-braided wire is used, this will not usually be required. Fig. 13 shows a fuseless cord rosette for use with moulding work. Fig. 14 shows a device for making a *tap* in moulding wiring.

Moulding work, under ordinary conditions, costs about one-half as much as circuit run in rigid conduit, and about 75 per cent, under ordinary conditions, of the cost of armored cable. Where the latter method of wiring or the conduit system can be employed, one or the other of these two methods should be used in preference to moulding,

Fig. 10. [illegible]

Fig. 11. [illegible] Molding.
Courtesy of [illegible], Philadelphia, Pa.

as the work is not only more substantial, but also safer. Various forms of metal moulding have been introduced, but up to the present time have not met with the success which they deserve.

CONCEALED KNOB AND TUBE WIRING

This method of wiring is still allowed by the *National Electric Code*, although many vigorous attempts have been made to have it abolished. Each of these attempts has met with the strongest opposition from contractors and central stations, particularly in small towns and villages, the argument for this method being, that it is the cheapest method of wiring, and that if it were forbidden, many places which are wired according to this method would not be wired at all, and the use of electricity would therefore be much restricted, if not entirely done away with, in such communities. This argument, however, is only a temporary makeshift obstruction in the way of inevitable progress, and in a few years, undoubtedly, the concealed knob and tube method will be forbidden by the *National Electric Code*.

The cost of wiring according to this method is about one-third of the cost of circuits run in rigid conduit, and about one-half of the cost of circuits run in armored cable. The latter method of wiring is rapidly replacing knob and tube wiring, and justly so, wherever the additional price for the latter method of wiring can be obtained. As the name indicates, this method of wiring employs *porcelain knobs*

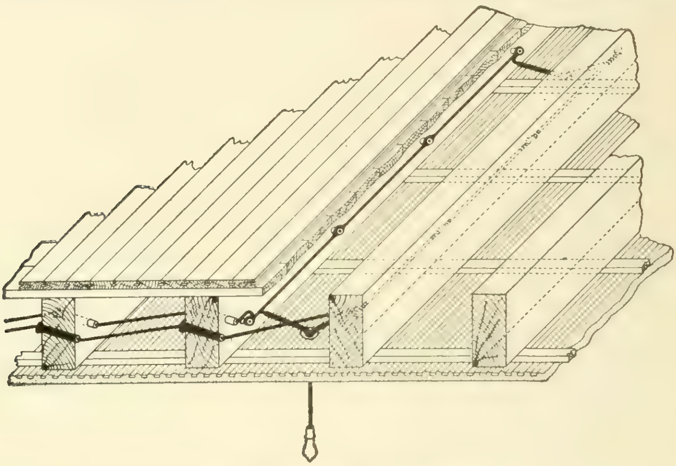


Fig. 15. Knob and Tube Wiring.

and tubes, the circuit work being run *concealed* between the floor beams and studs of a frame building. The knobs are used when the circuits run parallel to the floor beams; and the porcelain tubes are used when the circuits are run at right angles to the floor beams.

Fig. 15 shows an example of knob and tube wiring. In concealed knob and tube wiring, the wires must be separated at least ten inches from one another, and at least one inch from the surface wired over, that is, from the beams, flooring, etc., to which the insulator is fastened. Fig. 16 shows a good type of porcelain knob for this class of wiring. For knob and tube wiring, it will be noted that, owing to the fact that the wiring is concealed, the conductors

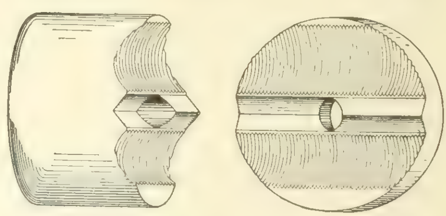


Fig. 16. Porcelain Knob.

must be kept further apart than in the case of exposed or open wiring on insulators, where, except in damp places, the wires may be run on cleats or on insulators only one-half inch from the surface wired over.

Fibrous Tubing. Fibrous tubing is frequently used with knob and tube wiring, and the regulations governing its use are given in Rule 24, Section 8, of the *National Electric Code*. This tubing, as stated in this *Rule*, may be used where it is impossible and impracticable to employ knobs and tubes, provided the difference in potential between the wires is not over 300 volts, and if the wires are not subject to moisture. The cost of wiring in flexible fibrous tubing is approximately about the same as the cost of knob and tube wiring. Duplex conductors, or two wires together are not allowed in fibrous tubing.

Fig. 17. Flexible Tubing. Circular Type.
Courtesy of [illegible], Pittsburg, Pa.

Fibrous tubing is required at all outlets where conduit or armored cable is not used (as in knob and tube wiring); and, as required by the *Rules*, it must extend back from the last porcelain support to one inch beyond the outlet. Fig. 17 shows one make of fibrous tubing.

Table VIII gives the maximum sizes of conductors (double-braided) which may be installed in fibrous conduit.

TABLE VIII

Sizes of Conductors in Fibrous Conduit

Outside Diameter	Inside Diameter	One Wire in Tube
[illegible] inch	[illegible] inch	No. 12
[illegible] "	[illegible] "	" 8
[illegible] "	[illegible] "	" 6
[illegible] "	[illegible] "	" 4
1 [illegible] "	[illegible] "	" 2 or 0
1 [illegible] "	1 "	250,000 C. M.
1 [illegible] "	1 [illegible] "	400,000 C. M.
1 [illegible] "	1 [illegible] "	750,000 C. M.
2 [illegible] "	1 [illegible] "	1,000,000 C. M.
2 [illegible] "	2 "	1,500,000 C. M.
2 [illegible] "	[illegible] "	2,000,000 C. M.

WIRES RUN EXPOSED ON INSULATORS

This method of wiring has the advantages of cheapness, durability, and accessibility.

Cheapness. The relative cost of this method of wiring as compared with that of the concealed conduit system, is about fifty per cent of the latter if rubber-covered conductors are used, and about forty per cent of the latter if weatherproof slow-burning conductors are used. As the *Rules* of the Fire Underwriters allow the use of weatherproof slow-burning conductors in dry places, considerable saving may be effected by this method of wiring, provided there is no objection to it

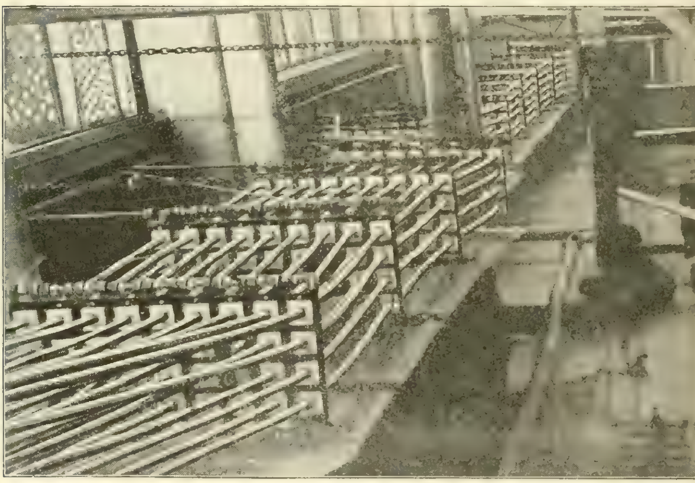


Fig. 18. Large Feeders Run Exposed on Insulators.

from the standpoint of appearance, and also provided that it is not liable to mechanical injury or disarrangement.

Durability. It is a well-known fact that rubber insulation has a relatively short life. Inasmuch as in this method of wiring, the insulation does not depend upon the insulation of the conductors, but on the insulators themselves, which are of glass or porcelain, this system is much more desirable than any of the other methods. Of course, if the conductors are mechanically injured, or the insulators broken, the insulation of the system is reduced; but there is no gradual deterioration as there is in the case of other methods of wiring, where

Dodge Street Substation.

[illegible] Street Substation.

SUBSTATIONS OF THE CLEVELAND ELECTRIC ILLUMINATING COMPANY, CLEVELAND, OHIO

[illegible] & [illegible], Architects, Cleveland, Ohio.

rubber is depended upon for insulation. This is especially true in hot places, particularly where the temperature is 120° F. or above. For such cases the weatherproof slow-burning conductors on porcelain or glass insulators are especially recommended.

Accessibility. The conductors being all exposed, they may be readily repaired or removed, or connections may be made to the same. This method of wiring is especially recommended for mills, factories, and for large or long feeder conductors. Fig. 18 shows examples of exposed large feeder conductors, installed in the New York Life Insurance Building, New York City. For small conductors, up to say No. 6 B. & S. Gauge each, porcelain cleats may be used to support one, two, or three conductors, provided the distance between the conductors is at least 2½ inches in a two-wire system, and 2½ inches between the two outside conductors in a three-wire system where the potential between the outside conductors is not over 300 volts. The cleat must hold the wire at least one-half inch from the surface to which the cleat is fastened; and in damp places the wire must be held at least one inch from the surface wired over. For larger conductors,

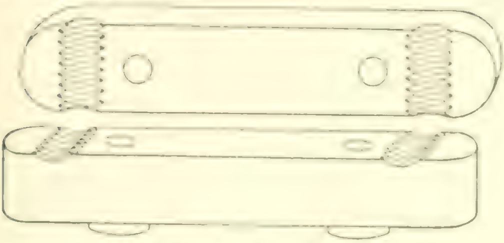


Fig. 17. Two-Wire Cleat.

Fig. 19. One-Wire Cleat.

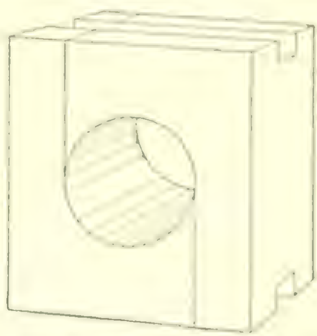


Fig. 20. Porcelain Insulator for Large Conductors.

from No. 6 to No. 4 / 0 B. & S. Gauge, it is usual to use single porcelain cleats or knobs. Figs. 19 and 20 show a good form of two-wire

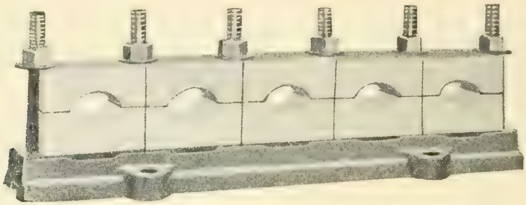


Fig. 22. Iron Rack and Insulators for Large Conductors.
Courtesy of General Electric Co., Schenectady, N. Y.

cleat and single-wire cleat, respectively.

For large feeder or main conductors from No. 4 / 0 B. & S. Gauge upward, a more substantial form of porcelain insulator should be used, such as shown in Fig. 21. These insulators are held in iron racks or angle-iron frames, of which two forms are shown in Figs. 22 and 23. The latter form of rack is particularly desirable for heavy conductors and where a number of conductors are run together. In this form of rack, any length of conductor can be removed without disturbing the other conductors.

As a rule, the porcelain insulators should be placed not more than $4\frac{1}{2}$ feet apart; and if the wires are liable to be disturbed, the distance between supports should be shortened, particularly for small conductors. If the beams are so far apart that supports cannot be obtained every $4\frac{1}{2}$ feet, it is necessary to provide a running board as shown in Fig. 24, to which the porcelain cleats and knobs can be fastened. Figs. 25 and 26 show two methods of supporting small conductors. For conductors of No. 8 B. & S.

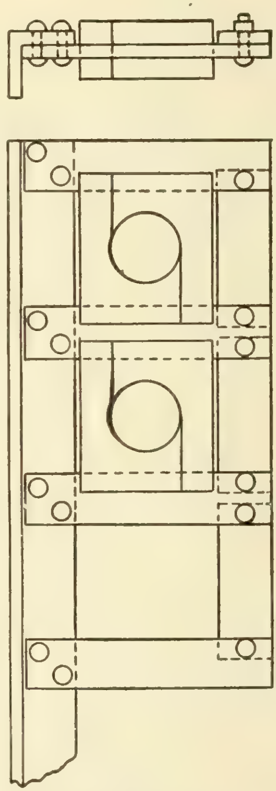
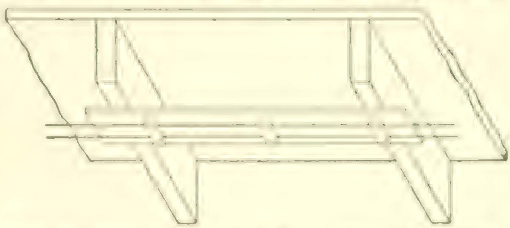


Fig. 23. Elevation and Plan of Insulators Held in Angle-Iron Frames.

Gauge, or over, it is not necessary to break around the beams, provided they are not liable to be disturbed; but the supports may be placed on each beam.

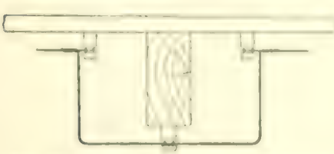
Where the distance between the supports, however, is greater than 4½ feet, it is usually necessary to provide intermediate supports, as shown in Fig. 27, or else to provide a running-board. Another method which may be used, where beams are further than 4½ feet apart, is to run a main along the wall at right angles to the beams, and to have the individual circuits run between and parallel to the beams.



[illegible]

[illegible]

Fig. 27. [illegible]



[illegible]

[illegible]

In low-ceiling rooms, where the conductors are liable to injury, it is usually required that a wooden guard-strip be placed on each side of the conductors, as shown in Fig. 28.

Where the conductors pass through partitions or walls, they must be protected by porcelain tubes, or, if the conductors be of rubber, by means of fibrous tubing placed inside of iron conduits.

All conductors on the walls for a height of not less than six feet from the ground, either should be boxed in, or, if they be rubber-covered, should (preferably) be run in iron conduits; and in conductors having single braid only, additional protection should be provided by means of flexible tubing placed inside of the iron conduit.

Where conductors cross each other, or where they cross iron pipes, they should be protected by means of porcelain tubes fastened with tape or in some other substantial manner that will prevent the tubes from slipping out of place.

TWO-WIRE AND THREE-WIRE SYSTEMS

As both the two-wire and the three-wire system are extensively used in electric wiring, it will be well to give some consideration to the advantages and disadvantages of each system, and to explain them somewhat in detail.

Relative Advantages. The choice of either a two-wire or a three-wire system depends largely upon the source of supply. If, for example, the source of supply will always probably be a 120-volt, two-wire system, there would be no object in installing a three-wire system for the wiring. If, on the other hand, the source of supply is a 120-240-volt system, the wiring should, of course, be made three-wire. Furthermore, if at the outset the supply were two-wire, but with a possibility of a three-wire system being provided later, it would be well to adapt the electric wiring for the three-wire system, making the neutral conductor twice as large as either of the outside conductors, and combining the two outside conductors to make a single conductor until such time as the three-wire service is installed. Of course, there would be no saving of copper in this last-mentioned three-wire system, and in fact it would be slightly more expensive than a two-wire system, as will be shortly explained.

The object of the three-wire system is to reduce the amount of copper—and consequently the cost of wiring—necessary to transmit a given amount of electric power. As a rule, the proposition is usually one of lighting and not of power, for the reason that by means of the three-wire system we are able to increase the potential at which the current is transmitted, and at the same time to take advantage of the greater efficiency of the lower voltage lamps. If current for power (motors, etc.) only were to be transmitted, it would be a simple matter to wind the motors, etc., for a higher voltage, and thereby reduce the weight of copper. If, however, we increase the voltage of lamps, we find that they are not so efficient, nor is their life so long. With the standard carbon lamp, it has been found that the 240-volt lamp, with the same life, requires about 10 to 12 per cent more current than the corresponding 120-volt lamp. Furthermore, in the case of the more efficient lamps recently introduced (such as the Tantalum lamp, Tungsten lamp, etc.), it has been found impracticable, if not impossible, to make them for pressures above 125 volts. For this reason the three-wire system is employed, for by this method we can use 240 volts across the outside conductors, and by the use of a neutral conductor obtain 120 volts between the neutral and the outside conductor, and thereby be enabled to use 120-volt lamps. Furthermore, if a 240-volt lamp should ever be placed on the market that was as economical as the lower voltage lamp, the result would be that the 240-480-volt system would be introduced, and 240-volt lamps used. As a matter of fact, this has been tried in several cities—and particularly in Providence, Rhode Island. As a rule, however, the 120-volt lamp has been found so much more satisfactory as regards life, efficiency, etc., that it is nearly always employed.

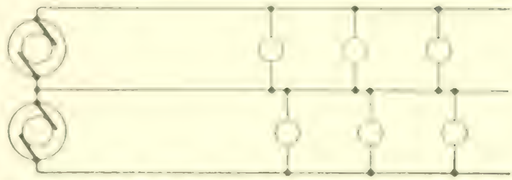


Fig. 29. Three-Wire System, with Neutral Conductor [illegible]

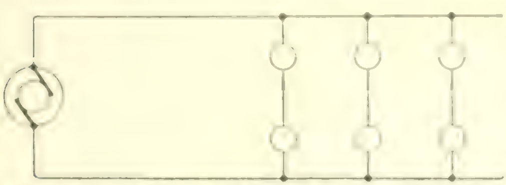


Fig. 30. Lamps Arranged in Pairs in Series, Dispensing with Necessity for Third or Neutral Conductor.

The two-wire system is so extremely simple that no explanation whatever is required concerning it.

The three-wire system, however, is somewhat confusing, and will now be considered.

Details of Three-Wire System. The three-wire system may be considered as a two-wire system with a third or neutral conductor placed between the two outside conductors, as shown in Fig. 29. This neutral conductor would not be required if we could always have the lamps arranged in pairs, as shown in Fig. 30. In this case, the two lamps would burn in series, and we could transmit the current at double the usual voltage, and thereby supply twice the number of lamps with one-quarter the weight of copper, allowing the same loss in pressure in the lamps. The reason for this is, that, having the lamps arranged in series of pairs, we reduce the current to one-half, and, as the pressure at which the current is transmitted is doubled, we can again reduce the copper one-half without increasing the loss in lamps. We therefore see that we have a double saving, as the current is reduced one-half, which reduces the weight of copper one-half, and we can again reduce the copper one-half by doubling the loss in volts without increasing the percentage loss. For example, if in one case we had a straight two-wire system transmitting current to 100 lamps at a potential of 100 volts, and this system were replaced by one in which the lamps were placed in series of pairs, as shown in Fig. 30, and the potential increased to 200 volts—100 lamps still being used—we should find, in the latter case, that we were carrying current really for only 50 lamps, as we would require only the same amount of current for two lamps now that we required for one lamp before. Furthermore, as the potential would now be 200 instead of 100 volts, we could allow twice as much loss as in the first case, because the loss would now be figured as a percentage of 200 volts instead of a percentage of 100 volts. From this, it will readily be seen that in the second case mentioned, we would require only one-quarter the weight of copper that would be required in the first case.

It will readily be seen, however, that a system such as that outlined in the second scheme having two lamps, would be impracticable for ordinary purposes, for the reason that it would always require the lamps to be burned in pairs. Now, it is for this very reason that the third or neutral conductor is required; and, if this conductor be added, it will no longer be necessary to burn the lamps in pairs. This, then, is the object of the three-wire system—to enable us to reduce the amount of copper required for transmitting current, without increasing the electric pressure employed for the lamps.

With regard to the size of the neutral conductor, one important point must be borne in mind; and that is, that the *Rules of the National Electric Code* require the neutral conductor in all interior wiring to be made at least as large as either of the two outside conductors. The reasons for this from a fire standpoint are obvious, because, if for any reason either of the outside conductors became disconnected, the neutral wire might be required to carry the same current as the outside conductors, and therefore it should be of the same capacity. Of course, the chances of such an event happening are slight; but, as the fire hazard is all-important, this rule must be complied with for interior wiring or in all cases where there would be a probability of fire. For outside or underground work, however, where the fire hazard would be relatively unimportant, the neutral conductor might be reduced in size; and, as a matter of fact, it is made smaller than the outside conductors.

The three-wire system is sometimes installed where it is desired to use the system as a two-wire, 125-volt system, or to have it arranged so that it may be used at any time also as a three-wire, 125-250-volt system. Of course, in order to do this, it is necessary to make the neutral conductor equal to the combined capacity of the outside conductors, the latter being then connected together to form one conductor, the neutral being the return conductor. This system is not recommended except in such instances, for example, as where an isolated plant of 125 volts is installed, and where there is a possibility of changing over at some future time to the three-wire, 125-250-volt system. In such a case as this, however, it would be better, where possible, to design the isolated plant for a three-wire, 125-250-volt system originally, and then to make the neutral conductor the same size as each of the two outside conductors.

The weight of copper required in a three-wire system where the neutral conductor is the same size as either of the two outside conductors, is $\frac{3}{8}$ of that required for a corresponding two-wire system using the same voltage of lamps.* It is obvious that this is true, because,

*NOTE.—If, in the two-wire system, we represent the weight of each of the two conductors by 1, the weight of each of the outside conductors in a three-wire system would be represented by $\frac{1}{4}$; and if we had three conductors of the same size we would have $\frac{1}{4} + \frac{1}{4} + \frac{1}{4} = \frac{3}{4}$ of the weight of copper required in a three-wire system, which would be required in a corresponding two-wire system having the same percentage of loss and using the same voltage of lamps.

If the neutral conductor were made $\frac{1}{2}$ of the size of each of the outside conductors, as is sometimes done in underground work, the total weight of copper required would be $\frac{1}{4} + \frac{1}{4} + \frac{1}{8} = \frac{5}{8} \div 2 = \frac{5}{16}$ of that required in the corresponding two-wire system.

as the discussion proved concerning the arrangement shown in Fig. 30, where the lamps were placed in series of pairs, we found that the weight of copper for the two conductors was one-quarter the weight of the regular two-wire system. It is then of course true, that, if we had another conductor of the same size as each of the outside conductors, we increase theweight of copper one-half, or one-quarter plus one-half of one-quarter—that is, three-eighths.

In the three-wire system frequently used in isolated plants in which the two outside conductors are joined together and the neutral conductor made equal to their combined capacity, there is no saving of copper, for the reason that the same voltage of transmission is used, and, consequently, we have neither reduced the current nor increased the potential. Furthermore, though the weight of copper is the same, it is now divided into three conductors, instead of two, and naturally it costs relatively more to insulate and manufacture three conductors than to insulate and manufacture two conductors having the same total weight of copper. As a matter of fact, the three-wire system, having the neutral conductor equal to the combined capacity of the two outside ones, the latter being joined together, is about 8 to 10 per cent more expensive than the corresponding straight two-wire system.

In interior wiring, as a rule, where the three-wire system is used for the mains and feeders, the two-wire system is nearly always employed for the branch circuits. Of course, the two-wire branch circuits are then balanced on each side of the three-wire system, so as to obtain as far as possible at all times an equal balance on the two sides of the system. This is done so as to have the neutral conductor carry as little current as possible. From what has already been said, it is obvious that in case there is a perfect balance, the lamps are virtually in series of pairs, and the neutral conductor does not carry any current. Where there is an unbalanced condition, the neutral conductor carries the difference between the current on one side and the current on the other side of the system. For example, if we had five lamps on one side of the system and ten lamps on the other, the neutral conductor would carry the current corresponding to five lamps.

In calculating the three-wire system, the neutral conductor is disregarded, the outer wires being treated as a two-wire circuit, and the calculation is for one-half the total number of lamps, the percentage of loss being based on the potential across the two outside conductors.

The three-wire system is very generally employed in alternating-current secondary wiring, as nearly all transformers are built with three-wire connections.

While unbalancing will not affect the total loss in the outside conductors, yet it does affect the loss in the lamps, for the reason that the system is usually calculated on the basis of a perfect balance, and the loss is divided equally between the two lamps (the latter being considered in series of pairs). If, however, there is unbalancing to a great degree, the loss in lamps will be increased; and if the entire load is thrown over on one side, the loss in the lamps will be doubled on the remaining side, because the total loss in voltage will now occur in these lamps, whereas, in the case of perfect balance, it would be equally divided between the two groups of lamps.

CALCULATION OF SIZES OF CONDUCTORS

The formula for calculating the sizes of conductors for direct currents, where the length, load, and loss in volts are given, is as follows:

The size of conductor (in circular mils) is equal to the current multiplied by the distance (one way), multiplied by 21.6, divided by the loss in volts; or,

$$CM = \frac{C \times D \times 21.6}{V} \qquad (1)$$

in which C = Current, in amperes;

D = Distance = length of the circuit (one way), in feet;

V = Loss in volts between the beginning and end of the circuit.

The constant (21.6) of this formula is derived from the resistance of a mil foot of wire of 98 per cent conductivity at 25° Centigrade or 77° Fahrenheit. The resistance of a conductor of one mil diameter and one foot long, is 10.8 at the temperature and conductivity named. We multiply this figure (10.8) by 2, as the length of a circuit is usually given as the distance one way, and in order to obtain the resistance of both conductors in a two-wire circuit, we must multiply by 2. The formula as above given, therefore, is for a two-wire circuit; and in calculating the size of conductors in a three-wire system, the calculation should be made on a two-wire basis, as explained hereinafter.

Formula **1** can be transformed so as to obtain the loss in a given circuit, or the current which may be carried a given distance with a stated loss, or to obtain the distance when the other factors are given, in the following manner:

Formula for Calculating Loss in Circuit when Size, Current, and Distance are Given

$$V = \frac{C \times D \times 21.6}{CM} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Formula for Calculating Current which may be Carried by a Given Circuit of Specified Length, and with a Specified Loss

$$C = \frac{CM \times V}{D \times 21.6} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Formula for Calculating Length of Circuit when Size, Loss, and Current to be Carried are Given

$$D = \frac{CM \times V}{C \times 21.6} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Formulæ are frequently given for calculating sizes of conductors, etc., where the load, instead of being given in amperes, is stated in lamps or in horse-power. It is usually advisable, however, to reduce the load to amperes, as the efficiency of lamps and motors is a variable quantity, and the current varies correspondingly.

It is sometimes convenient, however, to make the calculation in terms of watts. It will readily be seen that we can obtain a formula expressed in watts from Formula **1**. To do this, it is advisable to express the loss in volts in percentage, instead of actual volts lost. It must be remembered that, in the above formulæ, V represents the volts lost in the circuit, or, in other words, the difference in potential between the beginning and the end of the circuit, and is not the applied E. M. F. The loss in percentage, in any circuit, is equal to the actual loss expressed in volts, *divided by* the line voltage, *multiplied by* 100; or,

$$P = \frac{V}{E} \times 100.$$

From this equation, we have:

$$V = \frac{P\,E}{100}\,.$$

If, for example, the calculation is to be made on a loss of 5 per cent, with an applied voltage of 250, using this last equation, we would have:

$$V = \frac{5 \times 250}{100} = 12.5 \text{ volts.}$$

Substituting the equation $V = \frac{P\,E}{100}$ in Formula **1**, we have:

$$C\,M = \frac{C \times D \times 21.6}{\frac{P\,E}{100}}$$

$$= \frac{C \times D \times 21.6 \times 100}{P\,E}$$

$$= \frac{C \times D \times 2{,}160}{P\,E}$$

This equation, it should be remembered, is expressed in terms of applied voltage. Now, since the power in watts is equal to the applied voltage *multiplied by* the current ($W = E\,C$), it follows that

$$C = \frac{W}{E}.$$

By substituting this value of C in the equation given above $\left(C\,M = \frac{C \times D \times 2{,}160}{P\,E}\right)$, the formula is expressed in terms of watts instead of current, thus:

$$C\,M = \frac{W \times D \times 2{,}160}{E\,P\,E} \qquad (5)$$

in which W = Power in watts transmitted;
D = Length of the circuit (one way), i.e., the length of one conductor;
P = Figure representing the percentage loss;
E* = Applied voltage.

All the above formulæ are for calculations of two-wire circuits. In making calculations for three-wire circuits, it is usual to make the calculation on the basis of the two outside conductors, and in three-wire calculations, the above formulæ can be used with a slight modification, as will be shown.

In a three-wire circuit, it is usually assumed in making the calculation, that the load is equally balanced on the two sides of the neutral conductor; and, as the potential across the outside conductors is double that of the corresponding potential across a two-wire circuit, it is evident that for the same size of conductor the total loss in volts could be doubled without increasing the percentage of loss in lamps. Furthermore, as the load on one side of the neutral conductor, when the system is balanced, is virtually in series with the load on the third side, the current in amperes is usually one-half the sum of the current required by all the lamps. If C is still taken as the total

*Note.—Remember that [illegible] in Formula 5 represents the applied voltage.

current in amperes (that is, the sum of the current required by all of the lamps) in Formula 1, we shall have to divide this current by 2, to use the formula for calculating the two outside conductors for a three-wire system. Furthermore, we shall have to multiply the voltage lost in the lamps by 2, to obtain the voltage lost in the two outside conductors, for the reason that the potential of the outside conductors is double the potential required by the lamps themselves. In other words, Formula 1 will become:

$$CM = \frac{C \times D \times 21.6}{2 \times V \times 2}$$

$$= \frac{C \times D \times 21.6}{4V} \quad , \ldots\ldots\ldots\ldots\ldots \textbf{(6)}$$

in which C = Sum of current required by all of the lamps on both sides of the neutral conductor;

D = Length of circuit—that is, of any one of the three conductors;

V = Loss allowed in the lamps, i. e., one-half the total loss in the two outside conductors.

In the same manner, all of the other formulæ may be adapted for making calculations for three-wire systems. Of course the calculation of a three-wire system could be made as if it were a two-wire system, by taking one-half the total number of lamps supplied, at one-half the voltage between the outside conductors.

It is understood, of course, that the size of the conductor in Formula 6 is the size of each of the two outside ones; but, inasmuch as the *Rules of the National Electric Code* require that for interior wiring the neutral conductor shall be at least equal in size to the outside conductors, it is not necessary to calculate the size of the neutral conductor. It must be remembered, however, that, in a three-wire system where the neutral conductor is made equal in capacity to the combined size of the two outside conductors, and where the two outside conductors are joined together, we have virtually a two-wire system arranged so that it can be converted into a three-wire system later. In this case the calculation is exactly the same as in the case of the two-wire circuits, except that one of the two conductors is split into two smaller wires of the same capacity. This is frequently done where isolated plants are installed, and where the generators are wound for 125 volts and it may be desired at times to take current from an outside three-wire 125-250-volt system.

METHOD OF PLANNING A WIRING INSTALLATION

The first step in planning a wiring installation, is to gather all the data which will affect either directly or indirectly the system of wiring and the manner in which the conductors are to be installed. These data will include: Kind of building; construction of building; space available for conductors; source and system of electric-current supply; and all details which will determine the method of wiring to be employed. These last items materially affect the cost of the work, and are usually determined by the character of the building and by commercial considerations.

Method of Wiring. In a modern fireproof building, the only system of wiring to be recommended is that in which the conductors are installed in rigid conduits; although, even in such cases, it may be desirable, and economy may be effected thereby, to install the larger feeder and main conductors exposed on insulators using weatherproof slow-burning wire. This latter method should be used, however, only where there is a convenient runway for the conductors, so that they will not be crowded and will not cross pipes, ducts, etc., and also will not have too many bends. Also, the local inspection authorities should be consulted before using this method.

For mills, factories, etc., wires exposed on cleats or insulators are usually to be recommended, although rigid conduit, flexible conduit, or armored cable may be desirable.

In finished buildings, and for extensions of existing outlets, where the wiring could not readily or conveniently be concealed, moulding is generally used, particularly where cleat wiring or other exposed methods of wiring would be objectionable. However, as has already been said, moulding should not be employed where there is any liability to dampness.

In finished buildings, particularly where they are of frame construction, flexible steel conduits or armored cable are to be recommended.

While in new buildings of frame construction, knob and tube wiring are frequently employed, this method should be used only where the question of first cost is of prime importance. While armored cable will cost approximately 50 to 100 per cent more than knob and tube wiring, the former method is so much more permanent and is so much safer that it is strongly recommended.

Systems of Wiring. The system of wiring—that is, whether the two-wire or the three-wire system shall be used—is usually determined by the source of supply. If the source of supply is an isolated plant, with simple two-wire generators, and with little possibility of current being taken from the outside at some future time, the wiring in the building should be laid out on the two-wire system. If, on the other hand, the isolated plant is three-wire (having three-wire generators, or two-wire generators with balancer sets), or if the current is taken from an outside source, the wiring in the building should be laid out on a three-wire system.

It very seldom happens that current supply from a central station is arranged with other than the three-wire system inside of buildings, because, if the outside supply is alternating current, the transformers are usually adapted for a three-wire system. For small buildings, on the other hand, where there are only a few lights and where there would be only one feeder, the two-wire system is used. As a rule, however, when the current is taken from an outside source, it is best to consult the engineer of the central station supplying the current, and to conform with his wishes. As a matter of fact, this should be done in any event, in order to ascertain the proper voltage for the lamps and for the motors, and also to ascertain whether the central station will supply transformers, meters, and lamps—for, if these are not thus supplied, they should be included in the contract for the wiring.

Location of Outlets. It is not within the scope of this treatise to discuss the matter of *illumination*, but it is desirable, at this point, to outline briefly the method of procedure.

A set of plans, including elevation and details, if any, and showing decorative treatment of the various rooms, should be obtained from the Architect. A careful study should then be made by the Architect, the Owner, and the Engineer, or some other person qualified to make recommendations as to illumination. The location of the outlets will depend: *First*, upon the decorative treatment of the room, which determines the æsthetic and architectural effects; *second*, upon the type and general form of fixtures to be used, which should be previously decided on; *third*, upon the tastes of the owners or occupants in regard to illumination in general, as it is found that tastes vary widely in regard to amount and kind of illumination.

The location of the outlets, and the number of lights required at each, having been determined, the outlets should be marked on the plans.

The Architect should then be consulted as to the location of the centers of distribution, the available points for the risers or feeders, and the available space for the branch circuit conductors.

In regard to the *rising points for the feeders and mains*, the following precautions should be used in selecting chases:

1. The space should be amply large to accommodate all the feeders and mains likely to rise at that given point. This seems trite and unnecessary, but it is the most usual trouble with chases for risers. Formerly architects and builders paid little attention to the requirements for chases for electrical work; but in these later days of 2-inch and 2½-inch conduit, they realize that these pipes are not so invisible and mysterious as the force they serve to distribute, particularly when twenty or more such conduits must be stowed away in a building where no special provision has been made for them.

2. If possible, the space should be devoted solely to electric wiring. Steam pipes are objectionable on account of their temperature; and these and all other pipes are objectionable in the same space occupied by the electrical conduits, for if the space proves too small, the electric conduits are the first to be crowded out.

The chase, if possible, should be continuous from the cellar to the roof, or as far as needed. This is necessary in order to avoid unnecessary bends or elbows, which are objectionable for many reasons.

In similar manner, the location of *cut-out cabinets or distributing centers* should fulfil the following requirements:

1. They should be accessible at all times.

2. They should be placed sufficiently close together to prevent the circuits from being too long.

3. Do not place them in too prominent a position, as that is objectionable from the Architect's point of view.

4. They should be placed as near as possible to the rising chases, in order to shorten the feeders and mains supplying them.

Having determined the system and method of wiring, the location of outlets and distributing centers, the next step is to lay out the *branch circuits* supplying the various outlets.

Before starting to lay out the branch circuits, a drawing showing the floor construction, and showing the space between the top of the beams and girders and the flooring, should be obtained from the Architect. In f proof buildings of iron or steel construction, it is almost the invariable practice, where the work is to be concealed, to run the conduits over the beams, under the rough flooring, carrying them between the sleepers when running parallel to the sleepers, and notching the latter when the conduits run across them (see Fig. 31). In wooden frame buildings, the conduits run parallel to the beams and to the furring (see Fig. 32); they are also sometimes run below the

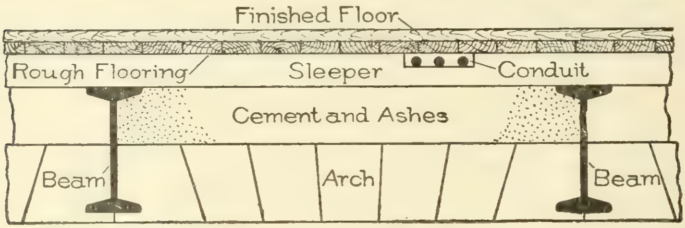


Fig. 31. Running Conductors Concealed under Floor in Fireproof Building.

beams. In the latter case the beams have to be notched, and this is allowable only in certain places, usually near the points where the beams are supported. The Architect's drawing is therefore necessary in order that the location and course of the conduits may be indicated on the plans.

The first consideration in laying out the branch circuit is the *number of outlets* and *number of lights* to be wired on any one branch circuit. The *Rules of the National Electric Code* (Rule 21-D) require that "no set of incandescent lamps requiring more than 660 watts, whether grouped on one fixture or on several fixtures or pendants, will be dependent on one cut-out." While it would be possible to have branch circuits supplying more than 660 watts, by placing various cut-outs at different points along the route of the branch circuit, so as to subdivide it into small sections to comply with the rule, this method is not recommended, except in certain cases, for exposed wiring in factories or mills. As a rule, the proper method is to have the cut-outs located at the center of distribution, and to limit each branch circuit to 660 watts, which corresponds to twelve or thirteen 50-watt lamps, twelve being the usual limit. Attention is called to the fact that the inspectors usually allow 50 watts for each socket connected to a branch circuit; and although 8-candle-power lamps may be placed at some of the outlets, the inspectors hold that the standard lamp is approximately 50 watts, and for that reason there is always the likelihood of a lamp of that capacity being used, and their inspec-

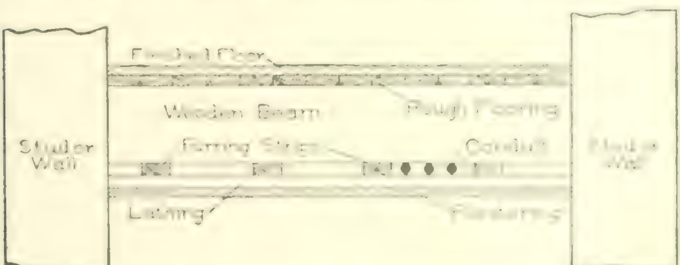
RESIDENCE OF B. J. ALLAN, BEVERLY, MASS.
Guy Lowell, Architect, Boston, Mass.

tion is based on that assumption. Therefore, to comply with the requirements, an allowance of not more than twelve lamps per branch circuit should be made.

In ordinary practice, however, it is best to reduce this number still further, so as to make allowance for future extensions or to increase the number of lamps that may be placed at any outlet. For this reason, it is wise to keep the number of the outlets on a circuit at the lowest point consistent with economical wiring. It has been proven by actual practice, that the best results are obtained by limiting the number to five or six outlets on a branch circuit. Of course, where all the outlets have a single light each, it is frequently necessary, for reasons of economy, to increase this number to eight, ten, and, in some cases, twelve outlets.

We have already referred to the location of the wires or conduits. This question is generally settled by the peculiarities of the construction of the building. It is necessary to know this, however, before laying out the circuit work, as it frequently determines the course of a circuit.

Now, as to the course of the circuit work, little need be said, as it is largely influenced by the relative position of the outlets, cut-



[illegible]

outs, switches, etc. Between the cut-out box and the first outlet, and between the outlets, it will have to be decided, however, whether the circuits shall run at right angles to the walls of the building or room, or whether they shall run direct from one point to another, irrespective of the angle they make to the sleepers or beams. Of course, in the latter case, the advantages are that the cost is somewhat less and the number of elbows and bends is reduced. If the tubes are bent, however, instead of using elbows, the difference in cost is usually very slight, and probably does not compensate for the disadvantages that would result from running the tubes diagonally. As to the number of bends, if branch circuit work is properly laid out and installed, and a proper size of tube used, it rarely happens that there is any difference in "pulling" the branch circuit wires. It may happen, in the event of a very long run or one having a large number of bends, that it might be advisable to adopt a short and most direct route.

Up to this time, the location of the distribution centers has been made solely with reference to architectural considerations; but they must now be considered in conjunction with the branch circuit work.

It frequently happens that, after running the branch circuits on the plans, we find, in certain cases, that the position of centers of distribution may be changed to advantage, or sometimes certain groups may be dispensed with entirely and the circuits run to other points. We now see the wisdom of ascertaining from the Architect where cut-out groups may be located, rather than selecting particular points for their location.

As a rule, wherever possible, it is wise to limit the length of each branch circuit to 100 feet; and the number and location of the distributing centers should be determined accordingly.

It may be found that it is sometimes necessary and even desirable to increase the limit of length. One instance of this may be found in hall or corridor lights in large buildings. It is generally desirable, in such cases, to control the hall lights from one point; and, as the number of lights at each outlet is generally small, it would not be economical to run mains for sub-centers of distribution. Hence, in instances of this character, the length of runs will frequently exceed the limit named. In the great majority of cases, however, the best results are obtained by limiting the runs to 90 or 100 feet.

There are several good reasons for placing such a limit on the length of a branch circuit. To begin with, assuming that we are going to place a limit on the loss in voltage (drop) from the switchboard to the lamp, it may be easily proven that up to a certain reasonable limit it is more economical to have a larger number of distributing centers and shorter branch circuits, than to have fewer centers and longer circuits. It is usual, in the better class of work, to limit the loss in voltage in any branch circuit to approximately one volt. Assuming this limit (one volt loss), it can readily be calculated that the number of lights at one outlet which may be connected on a branch circuit 100 feet long (using No. 14 B. & S. wire), is *four*; or in the case of outlets having a single light each, *five* outlets may be connected on the circuit, the first being 60 feet from the cut-out, the others being 10 feet apart.

These examples are selected simply to show that if the branch circuits are much longer than 100 feet, the loss must be increased to more than one volt, or else the number of lights that may be connected to one circuit must be reduced to a very small quantity, provided, of course, the size of the wire remains the same.

Either of these alternatives is objectionable—the first, on the score of regulation; and the second, from an economical standpoint. If, for instance, the loss in a branch circuit with all the lights turned on is four volts (assuming an extreme case), the voltage at which a lamp on that circuit burns will vary from four volts, depending on the number of lights burning at a time. This, of course, will cause the lamp to burn below candle-power when all the lamps are turned on, or else to diminish its life by burning above the proper voltage when it is the only lamp burning on the circuit. Then, too, if the drop in the branch circuits is increased, the sizes of the feeders and the mains must be correspondingly increased (if the total loss remains the same), thereby increasing their cost.

If the number of lights on the circuit is decreased, we do not use to good advantage the available carrying capacity of the wire.

Of course, one solution of the problem would be to increase the size of the wire for the branch circuits, thus reducing the drop. This, however, would not be desirable, except in certain cases where there were a few long circuits, such as for corridor lights or other special control circuits. In such instances as these, it would be better to increase the sizes of the branch circuit to No. 12 or even No. 10 B. & S. Gauge conductors, than to increase the number of centers of distribution for the sake of a few circuits only, in order to reduce the number of lamps (or loss) within the limit.

The method of calculating the loss in conductors has been given elsewhere; but it must be borne in mind, in calculating the loss of a branch circuit supplying more than one outlet, that separate calculations must be made for each portion of the circuit. That is, a calculation must be made for the loss to the first outlet, the length in this case being the distance from the center of distribution to the first outlet, and the load being the total number of lamps supplied by the circuit. The next step would be to obtain the loss between the first and second outlet, the length being the distance between the two outlets, and the load, in this case, being the total number of lamps supplied by the circuit, *minus* the number supplied by the first outlet; and so on. The loss for the total circuit would be the sum of these losses for the various portions of the circuit.

Feeders and Mains. If the building is more than one story, an elevation should be made showing the height and number of stories. On this elevation, the various distributing centers should be shown diagrammatically; and the current in amperes supplied through each center of distribution, should be indicated at each center. The next step is to lay out a tentative system of feeders and mains, and to ascertain the load in amperes supplied by each feeder and main. The estimated length of each feeder and main should then be determined, and calculation made for the loss from the switchboard to each center of distribution. It may be found that in some cases it will be necessary to change the arrangement of feeders or mains, or even the centers of distribution, in order to keep the total loss from the switchboard to the lamps within the limits previously determined. As a matter of fact, in important work, it is always best to lay out the entire work tentatively in a more or less crude fashion, according to the "cut and dried" method, in order to obtain the best results, because the entire layout may be modified after the first preliminary layout has been made. Of course, as one becomes more experienced and skilled in these matters, the final layout is often almost identical with the first preliminary arrangement.

TESTING

Where possible, two tests of the electric wiring equipment should be made, one after the wiring itself is entirely completed, and switches, cut-out panels, etc., are connected; and the second one after the fixtures have all been installed. The reason for this is that if a ground or short circuit is discovered before the fixtures are installed, it is more easily remedied; and secondly, because there is no division of the responsibility, as there might be if the first test were made only after the fixtures were installed. If the test shows no grounds or short circuits before the fixtures are installed, and one does develop after they are installed, the trouble, of course, is that the short circuit or ground is one or more of the fixtures. As a matter of fact, it is a wise plan always to make a separate test of each fixture after it is delivered at the building and before it is installed.

While a *magneto* is largely used for the purpose of testing, it is at best a crude and unreliable method. In the first place, it does not give an indication, even approximately, of the total insulation resistance, but merely indicates whether there is a ground or short circuit, or not. In some instances, moreover, a magneto test has led to serious errors, for reasons that will be explained. If, as is nearly always the case, the magneto is an alternating-current instrument, it may sometimes happen—particularly in long cables, and especially where there is a lead sheathing on the cable—that the magneto will ring, indicating to the uninitiated that there is a ground or short circuit on the cable. This may be, and usually is, far from being the case; and the cause of the ringing of the magneto is not a ground or short circuit, but is due to the capacity of the cable, which acts as a condenser under certain conditions, since the magneto producing an alternating current repeatedly charges and discharges the cable in opposite directions, this changing of the current causing the magneto to ring. Of course, this defect in a magneto could be remedied by using a commutator and changing it to a direct-current machine, but as the method is faulty in itself, it is hardly worth while to do this.

A portable *galvanometer* with a resistance box and Wheatstone bridge, is sometimes employed; but this method is objectionable because it requires a special instrument which cannot be used for many other purposes. Furthermore, it requires more skill and time to use than the *voltmeter* method, which will now be described.

The advantage of the voltmeter method is that it requires merely a direct-current voltmeter, which can be used for many other purposes, and which all engineers or contractors should possess, together with a box of cells having a potential of preferably over 30 volts. The voltmeter should have a scale of not over 150 volts, for the reason that if the scale on which the battery is used covers too wide a range (say 1,000 volts) the readings might be so small as to make the test unrecurate. A good arrangement would be to have a voltmeter having two scales—say, one of 60 and one of 600—which would make the voltmeter available for all practical potentials that are likely to be used inside of a building. If desired, a voltmeter could be obtained with three connections having three scales, the lowest scale of which would be used for testing insulation resistances.

Before starting a test, all of the fuses should be inserted and switches turned on, so that the complete test of the entire installation can be made. When this has been done, the voltmeter and battery should be connected, so as to obtain on the lowest scale of the voltmeter the electromotive force of the entire group of cells. This connection is shown in Fig. 33. Immediately after this has been done, the insulation resistance to be tested is placed in circuit, whether the insulation to be tested is a switchboard, slate panel-board, or the entire wiring installation; and the connections are made as shown in Fig. 34. A reading should then again be taken of the voltmeter; and the leakage is in proportion to the difference between the first and second readings of the voltmeter. The explanation given below will show how this resistance may be calculated: It is evident that the resistance in the first case was merely the resistance of the voltmeter and the internal resistance of the battery. As a rule, the internal resistance of the battery is so small in comparison with the resistance of the voltmeter and the external resistance, that it may be entirely neglected, and this will be done in the following calculation. In the second case, however, the total resistance in circuits is the resistance of the voltmeter and the battery, *plus* the entire insulation resistance on all the wires, etc., connected in circuit.

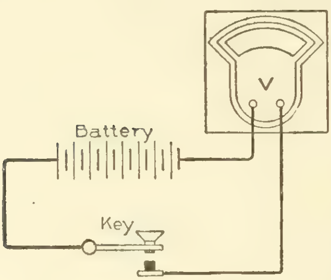


Fig. 33. Connections of Voltmeter and Battery for Testing Insulation Resistance.

To put this in mathematical form, the voltage of the cells may be indicated by the letter E; and the reading of the voltmeter when the insulation resistance is connected by the circuit, by the letter E'. Let R represent the resistance of the voltmeter and R_x represent the insulation resistance of the installation which we wish to measure.

It is a fact which the reader undoubtedly knows, that the E. M. F. as indicated by the voltmeter in Fig. 34 is inversely proportional to the resistance: that is, the greater the resistance, the lower will be the reading on the voltmeter, as this reading indicates the leakage of current passing through the resistance. Putting this in the shape of a formula, we have from the theory of proportion:

$$E : E' = R + R_x : R.$$

or,

$$E' R + E' R_x = E R.$$

Transposing,

$$E' R_x = E R - E' R = R (E - E'),$$

and

$$R_x = \frac{R (E - E')}{E'}.$$

Or, expressed in words, the insulation resistance is equal to the resistance of the voltmeter *multiplied by* the difference between the first reading (or the voltage in the cells) and the second reading (or the reading of the voltmeter with the insulation resistance in series with the voltmeter), *divided by* this last reading of the voltmeter.

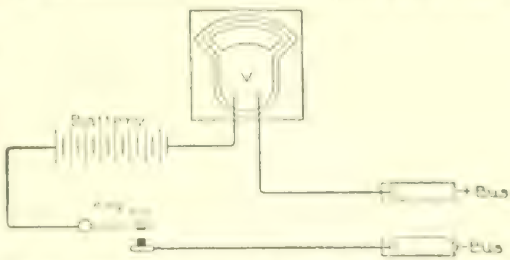


Fig. 35. Insulation Resistance Placed in Circuit Ready for Testing

Example. Assume a resistance of a voltmeter (R) of 20,000 ohms, and a voltage of the cells (E) of 30 volts; and suppose that the insulation resistance test of a wiring installation, including switchboard, feeders, branch circuits, panelboards, etc., is to be made, the insulation resistance being represented by the letter R_x. By substituting in the formula

$$R_x = \frac{R (E - E')}{E'},$$

and assuming that the reading of the voltmeter with the insulation resistance connected is 5, we have:

$$R_x = \frac{20{,}000 \times (30 - 5)}{5} = 100{,}000 \text{ ohms}.$$

If the test shows an excessive amount of leakage, or a ground or short circuit, the location of the trouble may be determined by the process of elimination—that is, by cutting out the various feeders until the ground or leakage disappears, and, when the feeder on which the trouble exists has been located, by following the same process with the branch circuits.

Of course, the larger the installation and the longer and more numerous the circuits, the greater the leakage will be; and the lower will be the insulation resistance, as there is a greater surface exposed for leakage. The *Rules of the National Electric Code* give a sliding scale for the requirements as to insulation resistance, depending upon the amount of current carried by the various feeders, branch circuits, etc. The rule of the *National Electric Code* (No. 66) covering this point, is as follows:

"The wiring in any building must test free from grounds; *i. e.*, the complete installation must have an insulation between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.) not less than that given in the following table:

Up to	5	amperes	4,000,000 ohms
"	10	"	2,000,000 "
"	25	"	800,000 "
"	50	"	400,000 "
"	100	"	200,000 "
"	200	"	100,000 "
"	400	"	50,000 "
"	800	"	25,000 "
"	1,600	"	12,500 "

"The test must be made with all cut-outs and safety devices in place. If the lamp sockets, receptacles, electroliers, etc., are also connected, only one-half of the resistances specified in the table will be required."

ALTERNATING-CURRENT CIRCUITS

It is not within the province of this chapter to treat the various alternating-current phenomena, but simply to outline the modifications which should be made in designing and calculating electric light wiring, in order to make proper allowance for these phenomena.

The most marked difference between alternating and direct current, so far as wiring is concerned, is the effect produced by self-induction, which is characteristic of all alternating-current circuits. This self-induction varies greatly with conditions depending upon the arrangement of the circuit, the medium surrounding the circuit, the devices or apparatus supplied by or connected in the circuit, etc.

For example, if a coil having a resistance of 100 ohms is included in the circuit, a current of one ampere can be passed through the coil with an electric pressure of 100 volts, if direct current is used; while it might require a potential of several hundred volts to pass a current of one ampere if alternating-current were used, depending upon the number of turns in the coil, whether it is wound on iron or some other non-magnetic material, etc.

It will be seen from this example, that greater allowance should be made for self-induction in laying out and calculating alternating-current wiring, if the conditions are such that the self-induction will be appreciable.

On account of self-induction, the two wires of an alternating-current circuit must never be installed in separate iron or steel conduits, for the reason that such a circuit would be virtually a choke coil consisting of a single turn of wire wound on an iron core, and the self-induction would not only reduce the current passing through the circuit, but also might produce heating of the iron pipe. It is for this reason that the *National Electric Code* requires conductors constituting a given circuit to be placed in the same conduit, if that conduit is iron or steel, whenever the said circuit is intended to carry, or is liable to carry at some future time, an alternating current. This does not mean, in the case of a two-phase circuit, that all four conductors need be placed in the same conduit, but that the two conductors of a given phase must be placed in the same conduit. If, however, the three-wire system be used for a two-phase system, all three conductors should be placed in the same conduit, as should also be the case in a three-wire three-phase system. Of course, in a single-phase two- or three-wire system, the conductors should all be placed in the same conduit.

In calculating circuits carrying alternating current, no allowance usually should be made for self-induction when the conductors of the same circuit are placed close together in an iron conduit. When, however, the conductors are run exposed, or are separated from each other, calculation should be made to determine if the effects of self-induction are great enough to cause an appreciable inductive drop. There are several methods of calculating this drop due to self-induction—one by formula, and one by a mathematical method which will be described.

Skin Effect. Skin effect in alternating-current circuits is caused by an incorrect distribution of the current in the wire, the current tending to flow through the outer portion of the wire, it being a well-known fact that in alternating currents, the current density decreases toward the center of the conductor, and that in large wires, the current density at the center of the conductor is relatively quite small.

The skin effect increases in proportion to the square of the diameter, and also in direct ratio to the frequency of the alternating current.

For conductors of No. 0000 B. & S. Gauge, and smaller, and for frequencies of 60 cycles per second, or less, the skin effect is negligible and is less than one-half of one per cent.

For very large cables and for frequencies above 60 cycles per second, the skin effect may be appreciable; and in certain cases, allowance for it should be made in making the calculation. In ordinary practice, however, it may be neglected. Table IX, taken from *Alternating-Current Wiring and Distribution,* by W. R. Emmet, gives the data necessary for calculating the skin effect. The figures given in the first and third columns are obtained by multiplying the size of the conductor (in circular mils) by the frequency (number of cycles per second); and the figures in the second and fourth columns show the factor to be used in multiplying the ohmic resistance, in order to obtain the combined resistance and skin effect.

TABLE IX

Data for Calculating Skin Effect

Product of Circular Mils × Cycles per Sec.	Factor	Product of Circular Mils × Cycles per Sec.	Factor
10,000,000	1.00	70,000,000	1.13
20,000,000	1.01	80,000,000	1.17
30,000,000	1.03	90,000,000	1.20
40,000,000	1.05	100,000,000	1.25
50,000,000	1.08	125,000,000	1.34
60,000,000	1.10	150,000,000	1.43

The factors given in this table, *multiplied by* the resistance to direct currents, will give the resistance to alternating currents for copper conductors of circular cross-section.

Mutual Induction. When two or more circuits are run in the same vicinity, there is a possibility of one circuit inducing an electromotive force in the conductors of an adjoining circuit. This effect may result in raising or lowering the E. M. F. in the circuit in which a mutual induction takes place. The amount of this induced E. M. F. set up in one circuit by a parallel current, is dependent upon the current, the frequency, the lengths of the circuits running parallel to each other, and the relative positions of the conductors constituting the said circuits.

Under ordinary conditions, and except for long circuits carrying high potentials, the effect of mutual induction is so slight as to be negligible, unless the conductors are improperly arranged. In order to prevent mutual induction, the conductors constituting a given circuit should be grouped together. Figs. 35 to 39, inclusive, show

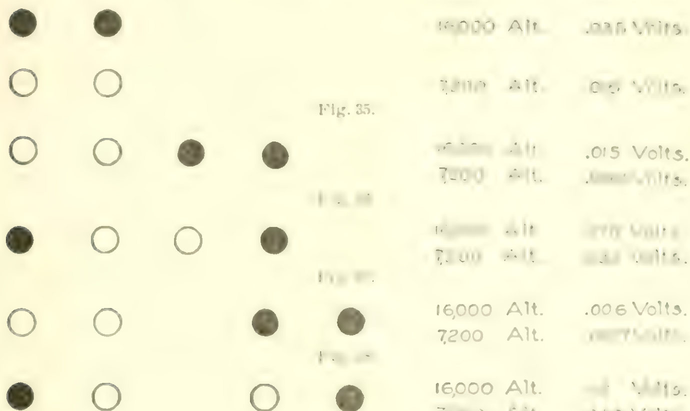


Fig. 35. Fig. 36. Fig. 37. Fig. 38. Fig. 39.

Various Groupings of Conductors in Two Two-Wire Circuits, Giving Corresponding Effects of Induction.

five arrangements of two two-wire circuits; and show how relatively small the effect of first induction is when the conductors are properly arranged, as in Fig. 38, and how relatively large it may be when improperly arranged, as in Fig. 39. These diagrams are taken from a publication of Mr. Charles F. Scott entitled *Polyphase Transmission*, issued by the Westinghouse Electric & Manufacturing Company.

Line Capacity. The effect of capacity is usually negligible, except in long transmission lines where high potentials are used; no calculations or allowance need be made for capacity, for ordinary circuits.

Calculation of Alternating-Current Circuits. In the instruction paper on "Power Stations and Transmission," a method is given for calculating alternating-current lines by means of formulæ, and data are given regarding power factor and the calculation of both single-phase and polyphase circuits. For short lines, secondary wiring, etc., however, it is probably more convenient to use the chart method devised by Mr. Ralph D. Mershon, described in the *American Electrician* of June, 1897, and partially reproduced as follows:

DROP IN ALTERNATING-CURRENT LINES

When alternating currents first came into use, when transmission distances were short and the only loads carried were lamps, the question of *drop* or *loss of voltage* in the transmitting line was a simple one, and the same methods as for direct current could without serious error be employed in dealing with it. The conditions existing in alternating practice to-day—longer distances, polyphase circuits, and loads made up partly or wholly of induction motors—render this question less simple; and direct-current methods applied to it do not lead to satisfactory results. Any treatment of this or of any engineering subject, if it is to benefit the majority of engineers, must not involve groping through long equations or complex diagrams in search of practical results. The results, if any, must be in available and convenient form. In what follows, the endeavor has been made to so treat the subject of drop in alternating-current lines that if the reader be grounded in the theory the brief space devoted to it will suffice; but if he do not comprehend or care to follow the simple theory involved, he may nevertheless turn the results to his practical advantage.

Calculation of Drop. Most of the matter heretofore published on the subject of drop treats only of the inter-relation of the E. M. F.'s involved, and, so far as the writer knows, there have not appeared in convenient form the data necessary for accurately calculating this quantity. Table X (page 47) and the chart (page 46) include, in a form suitable for the engineer's pocketbook, everything necessary for calculating the drop of alternating-current lines.

The chart is simply an extension of the vector diagram (Fig. 40), giving the relations of the E. M. F.'s of line, load and generator. In

Fig. 40, E is the generator E. M. F.; e the E. M. F. impressed upon the load; c, that component of E which overcomes the back E. M. F. due to the impedance of the line. The component c is made up of two components at right angles to each other. One is a, the component overcoming the IR or back E. M. F. due to resistance of the line. The other is b, the component overcoming the reactance E. M. F. or back E. M. F. due to the alternating field set up around the wire by the current in the wire. The drop is the difference between E and e. It is d, the radial distance between two circular arcs, one of which is drawn with a radius e, and the other with a radius E.

The chart is made by striking a succession of circular arcs with O as a center. The radius of the smallest circle corresponds to e, the E. M. F. of the load, which is taken as 100 per cent. The radii of the succeeding circles increase by 1 per cent of that of the smallest circle; and, as the radius of the last or largest circle is 140 per cent of that of the smallest, the chart answers for drops up to 40 per cent of the E. M. F. delivered.

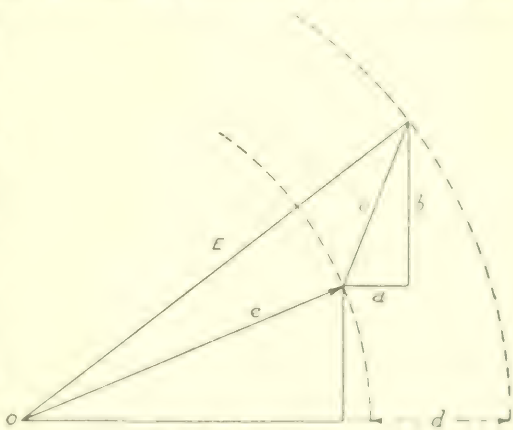


Fig. 40. Vector Diagram.

The terms *resistance volts*, *resistance E. M. F.*, *reactance volts*, and *reactance E. M. F.*, refer, of course, to the voltages for overcoming the back E. M. F.'s due to resistance and reactance respectively. The figures given in the table under the heading "Resistance-Volts for One Ampere, etc." are simply the resistances of 2,000 feet of the various sizes of wire. The values given under the heading "Reactance-Volts, etc.," are, a part of them, calculated from tables published some time ago by Messrs. Houston and Kennelly. The remainder were obtained by using Maxwell's formula.

The explanation given in the table accompanying the chart

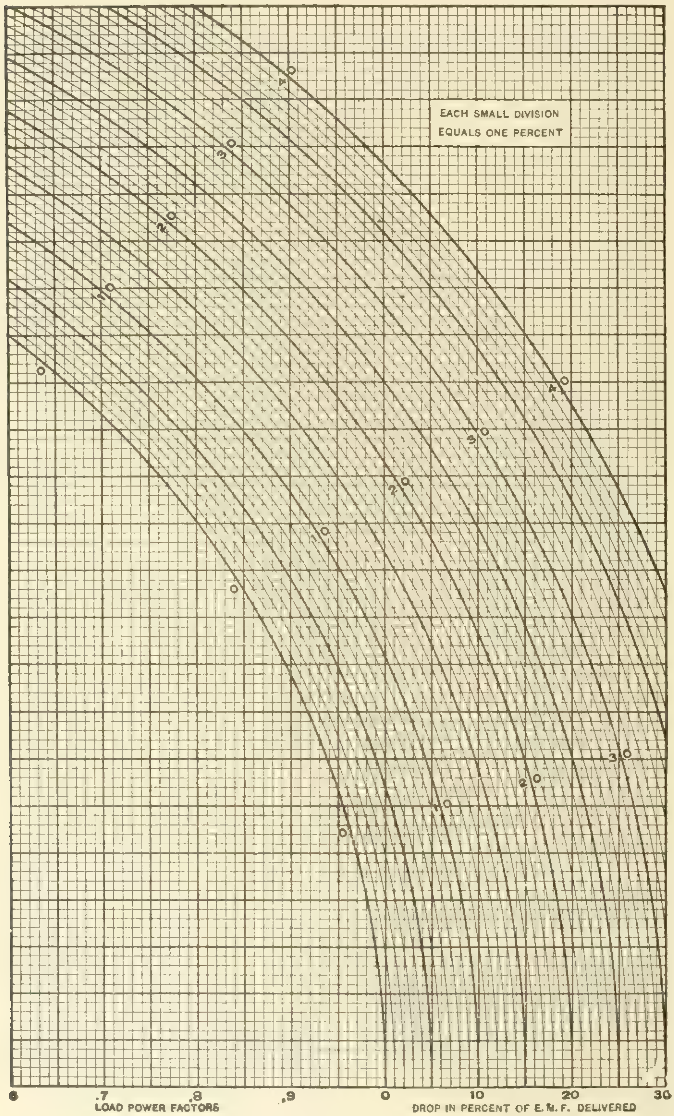


Chart for Calculating Drop in Alternating-Current Lines.

TABLE X

Data for Calculating Drop in Alternating-Current Lines

[illegible]

[illegible]

Throughout the table the lower figures in the squares give values for ONE MILE of line corresponding to those of the upper figures for 1,000 feet of line.

Upper figures are REACTANCE-VOLTS in 1,000 ft. of Line (= 2,000 ft. of Wire) for One Ampere at 7,200 Alternations per Minute (60 Cycles per Second) for the distance given between Centers of Conductors.

[illegible]	[illegible]	[illegible]	[illegible]	1"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18"	24"	30"	[illegible]
0000	639 [illegible]	.098 518	.046 243	.079 [illegible]	.111 .586	.130 .687	.161 .850	.180 .951	.193 [illegible]	.212 [illegible]	.225 1.19	.235 [illegible]	.244 [illegible]
000	507 [illegible]	.124 [illegible]	.052 .275	[illegible] [illegible]	.116 .613	.135 .713	.167 .882	[illegible] [illegible]	.199 1.05	.217 1.15	.230 [illegible]	.241 [illegible]	.249 [illegible]
00	[illegible] [illegible]	.156 .824	.057 .301	.090 [illegible]	.121 [illegible]	.140 .739	.172 [illegible]	.190 1.00	.204 1.08	.222 [illegible]	.236 [illegible]	.246 [illegible]	.254 [illegible]
0	319 [illegible]	.197 [illegible]	[illegible] .332	[illegible] .502	.127 .671	.145 [illegible]	.177 .935	.196 1.04	.209 1.10	.228 1.20	.241 [illegible]	.251 [illegible]	.259 1.37
1	253 [illegible]	[illegible] [illegible]	[illegible] [illegible]	.101 [illegible]	[illegible] [illegible]	.151 .797	.183 [illegible]	.201 1.06	.214 1.13	.233 [illegible]	.246 [illegible]	.256 1.35	.265 [illegible]
2	201 [illegible]	.313 1.65	[illegible] [illegible]	[illegible] .560	[illegible] [illegible]	.156 .824	.188 [illegible]	.206 [illegible]	.220 1.16	[illegible] 1.26	.252 [illegible]	.262 [illegible]	.270 [illegible]
3	159 [illegible]	[illegible] [illegible]	[illegible] .417	.112 [illegible]	.143 [illegible]	.162 [illegible]	.193 [illegible]	.212 [illegible]	.225 1.19	.244 [illegible]	.257 [illegible]	.267 1.41	.275 [illegible]
4	126 [illegible]	[illegible] [illegible]	[illegible] .449	.117 [illegible]	[illegible] [illegible]	[illegible] [illegible]	.199 [illegible]	.217 [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
[illegible]	[illegible] [illegible]	.627 [illegible]	.090 [illegible]	.121 [illegible]	.154 [illegible]	.172 [illegible]	.204 [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
[illegible]	[illegible] [illegible]	.791 [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	.178 [illegible]	[illegible] 1.10	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
7	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
8	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	.188 [illegible]	[illegible] [illegible]	[illegible] [illegible]	.252 [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]

(Table X) is thought to be a sufficient guide to its use, but a few examples may be of value.

Problem. Power to be delivered, 250 K.W.; E. M. F. to be delivered, 2,000 volts; distance of transmission, 10,000 feet; size of wire, No. 0; distance between wires, 18 inches; power factor of load, .8; frequency, 7,200 alternations per minute. Find the line loss and drop.

Remembering that the power factor is that fraction by which the apparent power of volt-amperes must be multiplied to give the true power, the apparent power to be delivered is

$$\frac{250\text{ K.W.}}{.8} = 312.5 \text{ apparent K.W.}$$

The current, therefore, at 2,000 volts will be

$$\frac{312{,}500}{2{,}000} = 156.25 \text{ amperes.}$$

From the table of reactances under the heading "18 inches," and corresponding to No. 0 wire, is obtained the constant .228. Bearing the instructions of the table in mind, the reactance-volts of this line are, 156.25 (amperes) $\times$ 10 (thousands of feet) $\times$ .228 = 356.3 volts, which is 17.8 per cent of the 2,000 volts to be delivered.

From the column headed "Resistance-Volts" and corresponding to No. 0 wire, is obtained the constant .197. The resistance-volts of the line are, therefore, 156.25 (amperes) $\times$ 10 (thousands of feet) $\times$ .197 = 307.8 volts, which is 15.4 per cent of the 2,000 volts to be delivered.

Starting, in accordance with the instructions of the table, from the point where the vertical line (which at the bottom of the chart is marked "Load Power Factor" .8) intersects the inner or smallest circle, lay off horizontally and to the right the resistance-E. M. F. in per cent (15.4); and *from the point thus obtained,* lay off vertically the reactance-E. M. F. in per cent (17.8). The last point falls at about 23 per cent, as given by the circular arcs. This, then, is the drop, in per cent, of *the E. M. F. delivered.* The drop, in per cent, of the *generator* E. M. F. is, of course,

$$\frac{23}{100+23} = 18.7 \text{ per cent.}$$

The percentage *loss of power* in the line has not, as with direct current, the same value as the percentage drop. This is due to the fact that the line has reactance, and also that the apparent power

LIVING ROOM IN DWELLING FOR MR. W. W. WILLITS, HIGHLAND PARK, ILL.

Frank Lloyd Wright, Architect, Oak Park, Ill.

[illegible]

delivered to the load is not identical with the true power; that is, the load power factor is less than unity. The loss must be obtained by calculating $I^2 R$ for the line, or, what amounts to the same thing, by multiplying the resistance-volts by the current.

The resistance-volts in this case are 307.8, and the current 156.25 amperes. The loss = 307.8 × 156.25 = 48.1 K. W. The percentage *loss* is

$$\frac{48.1}{250 + 48.1} = 16.1 \text{ per cent.}$$

Therefore, for the problem taken, the *drop* is 18.7 per cent, and the *loss* is 16.1 per cent. If the problem be to find the size wire for a given drop, it must be solved by trial. Assume a size of wire and calculate the drop; the result in connection with the table will show the direction and extent of the change necessary in the size of wire to give the required drop.

The effect of the line reactance in increasing the drop should be noted. If there were no reactance, the drop in the above example would be given by the point obtained in laying off on the chart the resistance-E. M. F. (15.4) only. This point falls at 12.4 per cent, and the drop in terms of the generator E. M. F. would be

$$\frac{12.4}{112.4} = 11 \text{ per cent, instead of 18.7 per cent.}$$

Anything therefore which will reduce reactance is desirable.

Reactance can be reduced in two ways. One of these is to diminish the distance between wires. The extent to which this can be carried is limited, in the case of a pole line, to the least distance at which the wires are safe from swinging together in the middle of the span; in inside wiring, by the danger from fire. The other way of reducing reactance is to split the copper up into a greater number of circuits, and arrange these circuits so that there is no inductive interaction. For instance, suppose that in the example worked out above, two No. 3 wires were used instead of one No. 0 wire. The resistance-volts would be practically the same, but the reactance-volts would be less in the ratio [illegible] × $\frac{.244}{.228}$, since each circuit would carry but half the current the No. 0 circuit does, and the constant for No. 3 wire is .244, instead of .228, that for No. 0. The effect of subdividing the copper is also shown if in the example given it is desired to reduce the drop to, say, one-half. Increasing the copper from No. 0 to No. 0000 will not produce the required result, for, although the resistance-volts will be reduced one-half, the reactance-volts will be reduced only in the ratio $\frac{.212}{.228}$. If, however, *two* inductively independent circuits of No. 0 wire be used, the resistance- and reactance-volts will both be reduced one-half, and the drop will therefore be diminished the required amount.

The component of drop due to reactance is best diminished by subdividing the copper or by bringing the conductors closer together. It is little affected by change in size of conductors.

An idea of the manner in which changes of power factor affect drop is best gotten by an example. Assume distance of transmission, distance between conductors E. M. F., and frequency, the same as in the previous example. Assume the *apparent* power delivered the same as before, and let it be constant, but let the power factor be given several different values; the true power will therefore be a variable depending upon the value of the power factor. Let the size of wire be No. 0000. As the apparent power, and hence the current, is the same as before, and the line resistance is one-half, the resistance-E. M. F. will in this case be

$$\frac{15.4}{2}, \text{ or } 7.7 \text{ per cent of the E. M. F. delivered.}$$

Also, the reactance-E. M. F. will be

$$\frac{.212 \times 17.8}{.228} = 16.5 \text{ per cent.}$$

Combining these on the chart for a power factor of .4, and deducing the drop, in per cent, of the generator E. M. F., the value obtained is 15.3 per cent; with a power factor of .8, the drop is 14 per cent; with a power factor of unity, it is 8 per cent. If in this example the *true* power, instead of the *apparent* power, had been taken as constant, it is evident that the values of drop would have differed more widely, since the current, and hence the resistance- and reactance-volts, would have increased as the power factor diminished. The condition taken more nearly represents that of practice.

If the line had resistance and no reactance, the several values of drop, instead of 15.3, 14, and 8, would be 3.2, 5.7, and 7.2 per cent respectively, showing that for a load of lamps the drop will not be much increased by reactance, but that with a load, such as induction motors, whose power factor is less than unity, care should be taken to keep the reactance as low as practicable. In all cases it is advisable to place conductors as close together as good practice will permit.

When there is a transformer in circuit, and it is desired to obtain the combined drop of transformer and line, it is necessary to know the resistance- and reactance-volts of the transformer. The resistance-volts of the combination of line and transformer are the sum of the resistance-volts of the line and the resistance-volts of the transformer. Similarly, the reactance-volts of the line and transformer are the sum of their respective reactance-volts. The resistance- and reactance-E. M. F.'s of transformers may usually be obtained from the makers, and are ordinarily given in per cent.* These percentages express the values of the resistance- and reactance-E. M. F.'s when the transformer delivers its normal *full-load* current; and they express these values in terms of the normal *no-load* E. M. F. of the transformer.

Consider a transformer built for transformation between 1,000 and 100 volts. Suppose the resistance- and reactance-E. M. F.'s given are 2 per cent and 7 per cent respectively. Then the corresponding voltages when the transformer delivers full-load current, are 2 and 7 volts or 20 and 70 volts according as the line whose drop is required is connected to the low-voltage or high-voltage terminals. These values, 2—7 and 20—70, hold, no matter at what voltage the trans-

*[illegible]

former is operated, since they depend only upon the strength of current, providing it is of the normal frequency. If any other than the full-load current is drawn from the transformer, the reactance- and resistance-volts will be such a proportion of the values given above as the current flowing is of the full-load current. It may be noted, in passing, that when the resistance- and reactance-volts of a transformer are known, its regulation may be determined by making use of the chart in the same way as for a line having resistance and reactance.

As an illustration of the method of calculating the drop in a line and transformer, and also of the use of table and chart in calculating low-voltage mains, the following example is given:

Problem. A single-phase induction motor is to be supplied with 20 amperes at 200 volts; alternations, 7,200 per minute; power factor, .78. The distance from transformer to motor is 150 feet, and the line is No. 5 wire, 6 inches between centers of conductors. The transformer reduces in the ratio $\frac{2,000}{200}$, has a capacity of 25 amperes at 200 volts, and, when delivering this current and voltage, its resistance-E. M. F. is 2.5 per cent, its reactance-E. M. F. 5 per cent. Find the drop.

The reactance of 1,000 feet of circuit consisting of two No. 5 wires, 6 inches apart, is .204. The reactance-volts therefore are

$$.204 \times \frac{150}{1,000} \times 20 = .61 \text{ volts.}$$

The resistance-volts are

$$.627 \times \frac{150}{1,000} \times 20 = 1.88 \text{ volts.}$$

At 25 amperes, the resistance-volts of the transformer are 2.5 per cent of 200, or 5 volts. At 20 amperes, they are $\frac{20}{25}$ of this, or 4 volts. Similarly, the transformer reactance-volts at 25 amperes are 10, and at 20 amperes are 8 volts. The combined reactance-volts of transformer and line are $8 + .61 = 8.61$, which is 4.3 per cent of the 200 volts to be delivered. The combined resistance-volts are 1.88 +4, or 5.88, which is 2.94 per cent of the E. M. F. to be delivered. Combining these quantities on the chart with a power factor of .78, the drop is 5 per cent of the delivered E. M. F.,

$$\text{or } \frac{5}{105} = 4.8 \text{ per cent}$$

of the impressed E. M. F. The transformer must be supplied with

$$\frac{2,000}{.952} = 2,100 \text{ volts}.$$

in order that 2,000 volts shall be delivered to the motor.

Table X (page 47) is made out for 7,200 alternations, but will answer for any other number if the values for reactance be changed in direct proportion to the change in alternations. For instance, for 10,000 alternations, multiply the reactances given by $\frac{10,000}{7,200}$. For other distances between centers of conductors, interpolate the values given in the table. As the reactance values for different sizes of wire change by a constant amount, the table can, if desired, be readily extended for larger or smaller conductors.

The table is based on the assumption of sine currents and E. M. F.'s. The best practice of to-day produces machines which so closely approximate this condition that results obtained by the above methods are well within the limits of practical requirements.

Polyphase Circuits. So far, single-phase circuits only have been dealt with. A simple extension of the methods given above adapts them to the calculation of polyphase circuits. A four-wire *quarter-phase* (two-phase) transmission may, so far as loss and regulation are concerned, be replaced by two single-phase circuits identical (as to size of wire, distance between wires, current, and E. M. F.) with the two circuits of the quarter-phase transmission, provided that in both cases there is no inductive interaction between circuits. Therefore, to calculate a four-wire, quarter-phase transmission, compute the single-phase circuit required to transmit one-half the power at the same voltage. The quarter-phase transmission will require two such circuits.

A three-wire, *three-phase* transmission, of which the conductors are symmetrically related, may, so far as loss and regulation are concerned, be replaced by two single-phase circuits having no inductive interaction, and identical with the three-phase line as to size, wire, and distance between wires. Therefore, to calculate a three-phase transmission, calculate a single-phase circuit to carry one-half the load at the same voltage. The three-phase transmission will require three wires of the size and distance between centers as obtained for the single-phase.

A three-wire, two-phase transmission may be calculated *exactly* as regards loss, and *approximately* as regards drop, in the same way as for three-phase. It is possible to exactly calculate the drop, but this involves a more complicated method than the approximate one. The error by this approximate method is generally small. It is possible, also, to get a somewhat less drop and loss with the same copper by proportioning the cross-section of the middle and outside wires of a three-wire, quarter-phase circuit to the currents they carry, instead of using three wires of the same size. The advantage, of course, is not great, and it will not be considered here.

WIRING AN OFFICE BUILDING

The building selected as a typical sample of a wiring installation is that of an office building located in Washington, D. C. The figures shown are reproductions of the plans actually used in installing the work.

The building consists of a basement and ten stories. It is of fireproof construction, having steel beams with terra-cotta flat arches. The main walls are of brick and the partition walls of terra-cotta blocks, finished with plaster. There is a space of approximately five inches between the top of the iron beams and the top of the finished floor, of which space about three inches was available for running the electric conduits. The flooring is of wood in the offices, but of concrete, mosaic, or tile in the basement, halls, toilet-rooms, etc.

The electric current supply is derived from the mains of the local illuminating company, the mains being brought into the front of the building and extending to a switchboard located near the center of the basement.

As the building is a very substantial fireproof structure, the only method of wiring considered was that in which the circuits would be installed in iron conduits.

Electric Current Supply. The electric current supply is direct current, two-wire for power, and three-wire for lighting, having a potential of 236 volts between the outside conductors, and 118 volts between the neutral and either outside conductor.

Switchboard. On the switchboard in the basement are mounted wattmeters, provided by the local electric company, and the various switches required for the control and operation of the lighting and power feeders. There are a total of ten triple-pole switches for lighting, and eighteen for power. An indicating voltmeter and ampere meter are also placed in the switchboard. A voltmeter is provided with a double-throw switch, and so arranged as to measure the potential across the two outside conductors, or between the neutral conductor and either of the outside conductors. The ampere meter is arranged with two shunts, one being placed in each outside leg; the shunts are connected with a double-pole, double-throw switch, so that the ampere meter can be connected to either shunt and thus measure the current supplied on each side of the system.

Character of Load. The building is occupied partly as a newspaper office, and there are several large presses in addition to the usual linotype machines, trimmers, shavers, cutters, saws, etc. There are also electrically-driven exhaust fans, house pumps, air-compressors, etc. The upper portion of the building is almost entirely devoted to offices rented to outside parties. The total number of motors supplied was 55; and the total number of outlets, 1,100, supplying 2,400 incandescent lamps and 4 arc lamps.

Feeders and Mains. The arrangement of the various feeders and mains, the cut-out centers, mains, etc., which they supply, are shown diagrammatically in Fig. 41, which also gives in schedule the sizes of feeders, mains, and motor circuits, and the data relating to the cut-out panels.

Although the current supply was to be taken from an outside source, yet, inasmuch as there was a probability of a plant being installed in the building itself at some future time, the three-wire system of feeders and mains was designed, with a neutral conductor equal to the combined capacity of the two outside conductors, so that 120-volt two-wire generators could be utilized without any change in the feeders.

Basement. The plan of the basement, Fig. 42, shows the branch circuit wiring for the outlets in the basement, and the location of the main switchboard. It also shows the trunk cables for the interconnection system serving to provide the necessary wires for telephones.

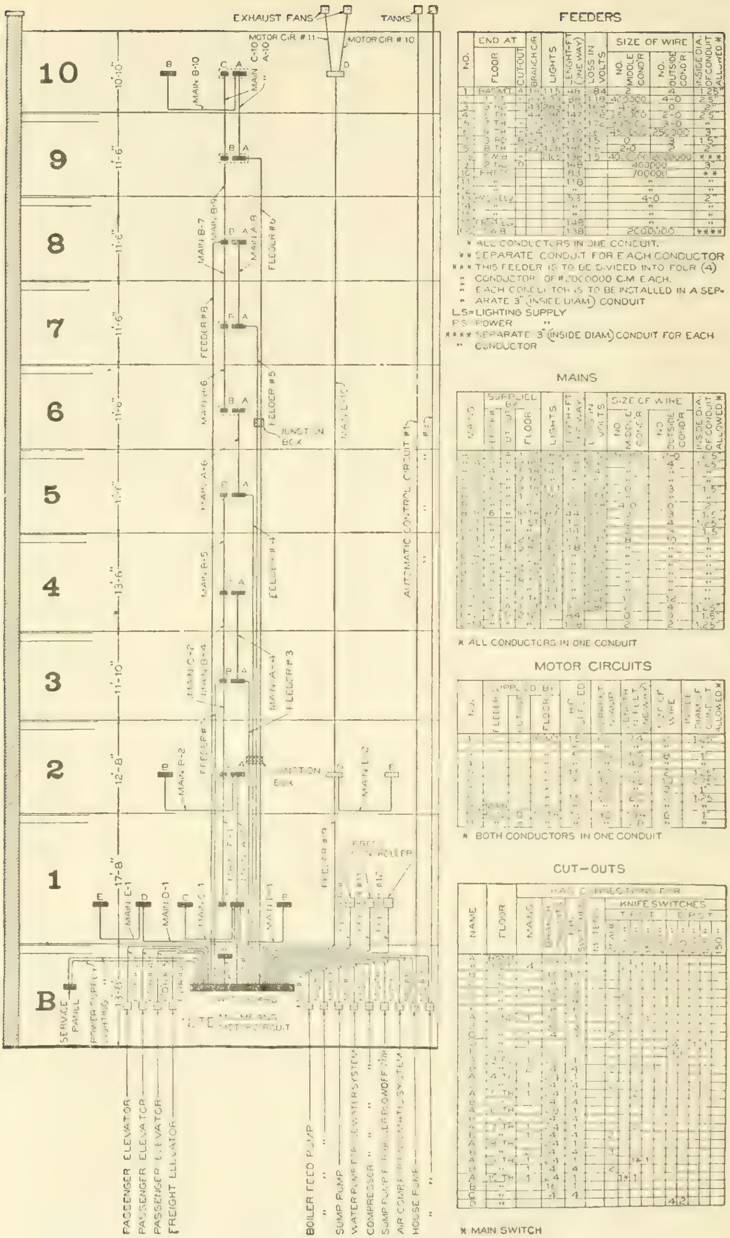
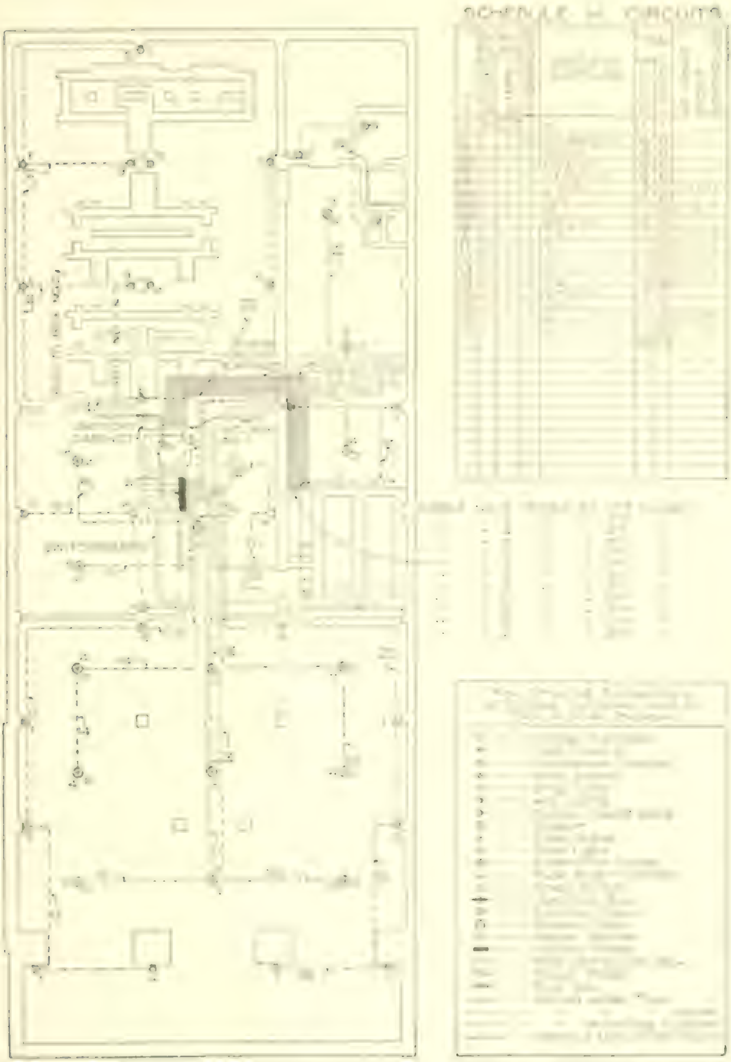


Fig. 41. Wiring of an Office Building. Diagram Showing Arrangement of Feeders and Mains, Cut-Out Centers, etc.


SCHEDULE … CIRCUITS

tickers, messenger calls, etc., in all the rooms throughout the building, as will be described later.

To avoid confusion, the feeders were not shown on the basement plan, but were described in detail in the specification, and installed in accordance with directions issued at the time of installation. The electric current supply enters the building at the front, and a service switch and cut-out are placed on the front wall. From this point, a two-wire feeder for power and a three-wire feeder for lighting, are run to the main switchboard located near the center of the basement. Owing to the size of the conduits required for these supply feeders, as well as the main feeders extending to the upper floors of the building, the said conduits are run exposed on substantial hangers suspended from the basement ceiling.

First Floor. The rear portion of the building from the basement through the first floor, Fig. 43, and including the mezzanine floor, between the first and second floors, at the rear portion of the building only, is utilized as a press room for several large and heavy, modern newspaper presses. The motors and controllers for these presses are located on the first floor. A separate feeder for each of these press motors is run directly from the main switchboard to the motor controller in each case. Empty conduits were provided, extending from the controllers to the motor in each case, intended for the various control wires installed by the contractor for the press equipments.

One-half of the front portion of the first floor is utilized as a newspaper office; the remaining half, as a bank.

Second Floor. The rear portion of the second floor, Fig. 44, is occupied as a composing and linotype room, and is illuminated chiefly by means of drop-cords from outlets located over the linotype machines and over the compositors' cases. Separate $\frac{1}{8}$-horse-power motors are provided for each linotype machine, the circuits for the same being run underneath the floor.

Upper Floors. A typical plan (Fig. 45) is shown of the upper floors, as they are similar in all respects with the exception of certain changes in partitions, which are not material for the purpose of illustration or for practical example. The circuit work is sufficiently intelligible from the plan to require no further explanation.

Interconnection System. Fig. 46 is a diagram of the interconnection system, showing the main interconnection box located in the

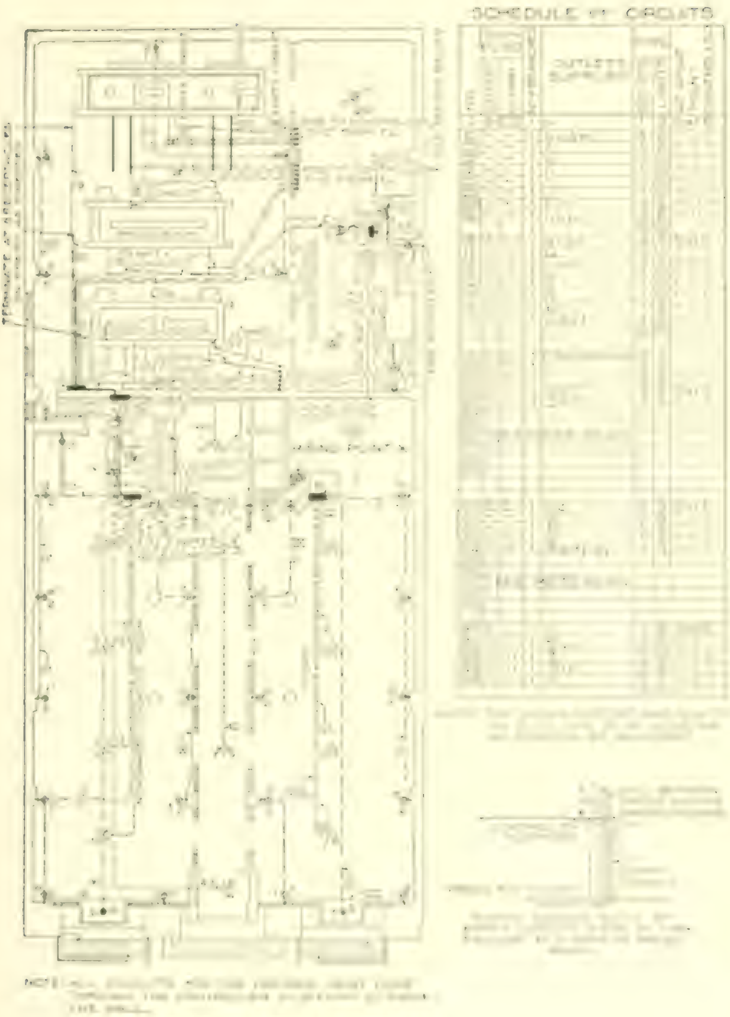
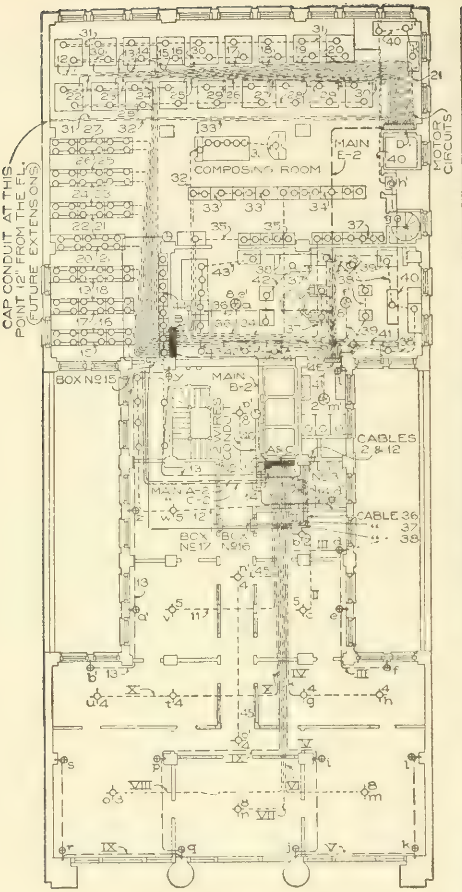


Fig. [illegible]. Wiring of an Office Building

[illegible]



SCHEDULE OF CIRCUITS

NO.	SUPPLIED by CUTOUT	SUPPLIED by MAIN	No. of BRANCHES	OUTLETS SUPPLIED	TOTAL OUTLETS	TOTAL LIGHTS	AT WHAT POINT CONTROLLED
I	A	A-2	1	a	1	2	S at A
II	"	"	1	b c	2	7	
III	"	"	1	d e f	3	3	
IV	"	"	1	g h	2	8	
V	"	"	1	i j k l	4	4	
VI	"	"	1	m	1	3	
VII	"	"	1	n	"	"	
VIII	"	"	1	o	"	"	
IX	"	"	1	p q r s	4	4	
X	"	"	1	t u	2	8	
11	"	"	1	v	1	5	
12	"	"	1	w x & 6 Drop Cds	7	11	
13	"	"	1	y z a' b'	4	4	
14	"	"	1	c' d'	2	2	
					37	78	
15	B	B-2	1	Drop Cords	6	6	
16	"	"	1	" "	"	"	
17	"	"	1	" "	"	"	
18	"	"	1	" "	"	"	
19	"	"	1	" "	"	"	
20	"	"	1	" "	"	"	
21	"	"	1	" "	10	10	
22	"	"	1	" "	6	6	
23	"	"	1	" "	"	"	
24	"	"	1	" "	"	"	
25	"	"	1	" "	"	"	
26	"	"	1	" "	"	"	
27	"	"	1	" "	"	"	
28	"	"	1	" "	9	9	
29	"	"	1	" "	"	"	
30	"	"	1	" "	"	"	
31	"	"	1	" "	"	"	
32	"	"	1	" "	7	7	
33	"	"	1	" "	6	6	
34	"	"	1	" "	7	7	
35	"	"	1	" "	6	6	
36	"	"	1	e'	1	8	S at B
37	"	"	1	Drop Cords	7	7	
38	"	"	1	" "	9	9	
39	"	"	1	f'	1	8	S at B
40	"	"	1	g' h' i' j' k'	5	5	
41	"	"	1	l' m'	2	3	S at B
42	"	"	1	Drop Cords	7	7	
43	"	"	1	" "	7	7	
44	"	"	1	" "	8	8	
45	C	C-2	1	n' o'	2	8	S at C
46	"	"	1	p'	1	5	" " "

TERMINATE ALL MOTOR CIRCUITS AT MOTOR CONTROLLER AS DIRECTED

MOTOR CIRCUITS

NO.	SUPPLIED BY FEEDER No	SUPPLIED BY CUT-OUT	SUPPLIED BY FLOOR	H.P. SUPPLIED	CURRENT IN AMPERES	LENGTH IN FT. (ONE WAY)	SIZE OF WIRE	INSIDE DIA OF CONDUIT ALLOWED *
12	9	D	2ND	* *		98	10	5/8"
13	"	"	"	"		90	"	"
14	"	"	"	"		82	"	"
15	"	"	"	"		76	"	"
16	"	"	"	"		68	"	"
17	"	"	"	"		60	"	"
18	"	"	"	"		52	"	"
19	"	"	"	"		46	"	"
20	"	"	"	"		38	"	"
21	"	"	"	"		28	"	"
22	"	"	"	"		34	"	"
23	"	"	"	"		86	"	"
24	"	"	"	"		78	"	"
25	"	"	"	"		70	"	"
26	"	"	"	"		62	"	"
27	"	"	"	"		54	"	"
28	"	"	"	"		46	"	"
29	"	"	"	"		38	"	"
30	"	"	"	"		30	"	"
31	"	"	"	"		90	"	"
32	"	"	"	"		"	"	"
33	"	"	"	$\frac{1}{2}$		82	"	"
34	"	E	"	3		28	"	"
35	"	"	"	"		32	"	"
36	"	"	"	"		52	"	"
37	"	"	"	"		34	"	"
38	"	"	"	1		48	12	"
39	"	"	"	2		46	10	"
40	"	"	"	3		30	"	"
41	"	"	"	2		28	"	"
42	"	"	"	3		18	"	"

* BOTH CONDUCTORS IN ONE CONDUIT

** $\frac{1}{2}$ H.P. REDUCED TO $\frac{1}{4}$ H.P.

Fig. 44. Wiring of an Office Building. Plan of Second Floor. Rear Portion Occupied as a Composing and Linotype Room.

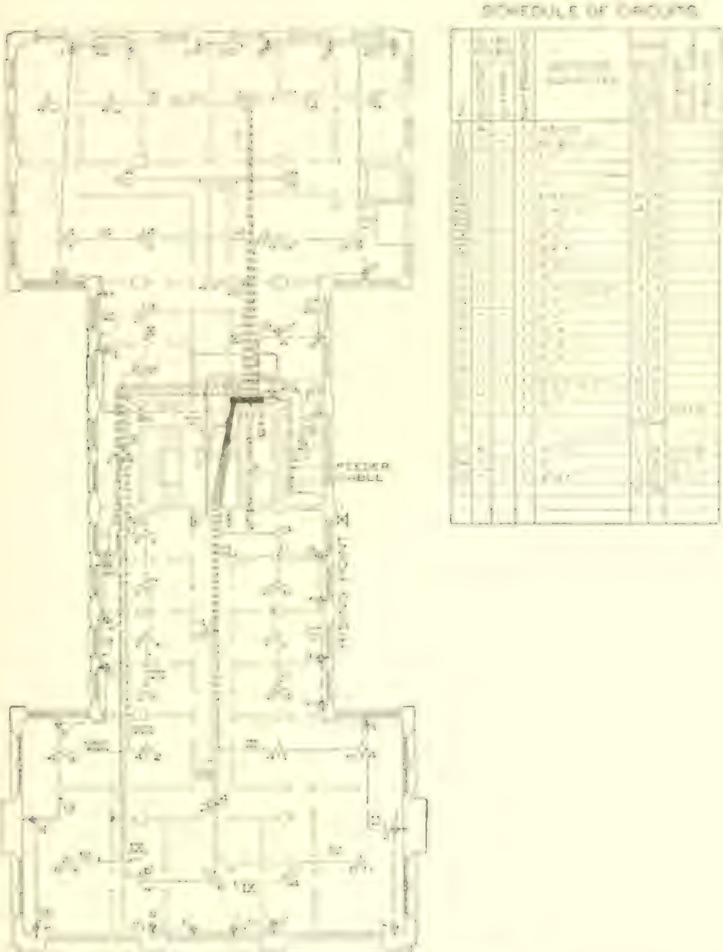
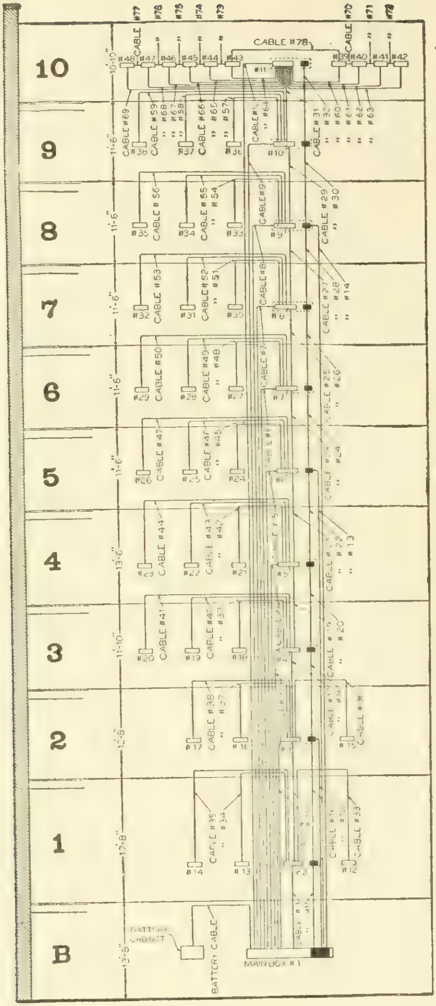


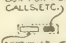
Fig. 46. Wiring of an Office Building.

[illegible]



— FIXTURES. —

LOCATION	BATTERIES	BATTERY CABINET	CLOCKS	MASTER CLOCK								
BASEMENT	[illegible]	1										
1 ST FL.			4									
2 ND "			2									
3 RD "			1									
4 TH "			1									
5 TH "			1									
6 TH "			1									
7 TH "			1									
8 TH "			1									
9 TH "			1									
10 TH "			3	1								
				1								
TOTALS	28	1	16	1								



— CABLES. —

NO.	START AT BOX NO.	START AT FLOOR	END AT BOX NO.	END AT FLOOR	NO. OF WIRES	LENGTH IN FEET	INSIDE DIA. OF CONDUIT ALLOWED
1	1	BASMT	2	1 ST	50	122	1½"
2	"	"	3	2 ND	"	116	"
3	"	"	4	3 RD	"	128	"
4	"	"	5	4 TH	"	139	"
5	"	"	6	5 TH	"	154	"
6	"	"	7	6 TH	"	165	"
7	"	"	8	7 TH	"	176	"
8	"	"	9	8 TH	"	187	"
9	"	"	10	9 TH	"	208	"
10	"	"	11	10 TH	"	219	"
11	"	"	2	1 ST	10	122	¾
12	"	"	3	2 ND	"	116	"
13	"	"	6	5 TH	"	154	"
14	"	"	9	8 TH	"	187	"
15	2	1 ST	3	2 ND	"	22	1"
16	"	"	"	"	"	"	1½"
17	3	2 ND	4	3 RD	"	16	1"
18	"	"	"	"	"	"	1½"
19	4	3 RD	5	4 TH	"	15	1"
20	"	"	"	"	"	"	1½"
21	5	4 TH	6	5 TH	"	"	1"
22	"	"	"	"	"	"	1½"
23	6	5 TH	7	6 TH	"	"	1"
24	"	"	"	"	"	"	1½"
25	7	6 TH	8	7 TH	"	"	1"
26	"	"	"	"	"	"	1½"
27	8	7 TH	9	8 TH	"	"	1"
28	"	"	"	"	"	"	1½"
29	9	8 TH	10	9 TH	"	"	1"
30	"	"	"	"	"	"	1½"
31	10	9 TH	11	10 TH	"	"	1"
32	"	"	"	"	"	"	1½"
33	2	1 ST	12	1 ST	"	61	1"
34	"	"	13	"	"	22	"
35	"	"	14	"	"	84	"
36	3	2 ND	15	2 ND	"	55	"
37	"	"	16	"	"	28	"
38	"	"	17	"	"	22	"
39	4	3 RD	18	3 RD	"	25	"
40	"	"	19	"	"	53	"
41	"	"	[illegible]	"	"	51	"
42	5	4 TH	21	4 TH	"	25	"
43	"	"	22	"	"	53	"
44	"	"	24	"	"	51	"
45	6	5 TH	24	5 TH	"	25	"
46	"	"	25	"	25	53	1½"
47	"	"	26	"	10	51	1"
48	7	6 TH	27	6 TH	"	25	"
49	"	"	28	"	"	53	"
50	"	"	29	"	"	51	"
51	8	7 TH	30	7 TH	"	25	"
52	"	"	31	"	"	53	"
53	"	"	32	"	"	51	"
54	9	8 TH	33	8 TH	"	25	"
55	"	"	34	"	"	53	"
56	"	"	35	"	"	51	"
57	10	9 TH	36	9 TH	"	25	"
58	"	"	37	"	"	53	"
59	"	"	38	"	"	51	"
60	11	10 TH	39	10 TH	"	29	"
61	"	"	49	"	"	36	"
62	"	"	41	"	"	31	"
63	"	"	42	"	"	39	"
64	"	"	43	"	"	40	"
65	"	"	44	"	"	58	"
66	"	"	45	"	"	79	"
67	"	"	46	"	"	93	"
68	"	"	47	"	"	75	"
69	"	"	48	"	"	56	"
70	39	"	49	"	*	11	"
71	49	"	41	"	"	18	"
72	41	"	42	"	"	13	"
73	43	"	44	"	"	33	"
74	44	"	45	"	"	22	"
75	45	"	46	"	"	"	"
76	46	"	47	"	"	"	"
77	47	"	48	"	"	"	"
78	39	"	43	"	"	"	"

* EMPTY CONDUIT ONLY

— BOXES. —

NO.	FLOOR	NO. REQUIRED OF VARIOUS SIZES: 60 F	1-4	14-8	16-8	2-4	2-H	3-4				
1	BASMT	1										
2	1 ST			1								
3	2 ND				1							
4	3 RD			1								
5	4 TH			1								
6	5 TH				1							
7	6 TH			1								
8	7 TH			1								
9	8 TH				1							
10	9 TH			1								
11	10 TH					1						
12	1 ST						1					
13	"						1					
14	"						1					
15	2 ND						1					
16	"						1					
17	"						1					
18	3 RD						1					
19	"						1					
20	"						1					
21	4 TH						1					
22	"						1					
23	"						1					
24	5 TH						1					
25	"						1					
26	"						1					
27	6 TH						1					
28	"						1					
29	"						1					
30	7 TH						1					
31	"						1					
32	"						1					
33	8 TH						1					
34	"						1					
35	"						1					
36	9 TH						1					
37	"						1					
38	"						1					
39	10 TH		1									
40	"		1									
41	"		1									
42	"		1									
43	"		1									
44	"		1									
45	"		1									
46	"							1				
47	"		1									
48	"		1									
TOTALS		1	9	6	3	1	27	1				

Fig. 46. Wiring of an Office Building. Diagram of the Interconnection System.

basement; adjoining this main box is located the terminal box of the local telephone company. A separate system of feeders is provided for the ticker system, as these conductors require somewhat heavier insulation, and it was thought inadvisable to place them in the same conduits with the telephone wires, owing to the higher potential of ticker circuits. A separate interconnection cable runs to each floor, for telephone and messenger call purposes; and a central box is placed near the rising point at each floor, from which run subsidiary cables to several points symmetrically located on the various floors. From these subsidiary boxes, wires can be run to the various offices requiring telephone or other service. Small pipes are provided to serve as raceways from office to office, so as to avoid cutting partitions. In this way, wires can be quickly provided for any office in the building without damaging the building in any way whatever; and, as provision is made for a special wooden moulding near the ceiling to accommodate these wires, they can be run around the room without disfiguring the walls. All the main cables and subsidiary wires are connected with special interconnection blocks numbered serially; and a schedule is provided in the main interconnection box in the basement, which enables any wire originating thereat, to be readily and conveniently traced throughout the building. All the main cables and subsidiary cables are run in iron conduits.

OUTLET-BOXES, CUT-OUT PANELS, AND OTHER ACCESSORIES

Outlet-Boxes. Before the introduction of iron conduits, outlet-boxes were considered unnecessary, and with a few exceptions were not used, the conduits being brought to the outlet and cut off after the walls and ceilings were plastered. With the introduction of iron conduits, however, the necessity for outlet-boxes was realized; and the *Rules* of the Fire Underwriters were modified so as to require their use. The *Rules of the National Electric Code* now require outlet-boxes to be used with rigid iron and flexible steel conduits, and with armored cables. A portion of the rule requiring their use is as follows:

All interior conduits and armored cables must be equipped at every outlet with an approved outlet-box or plate.

"Outlet-plates must not be used where it is practicable to install outlet-boxes.

"In buildings already constructed, where the conditions are such that neither outlet-box nor plate can be installed, these appliances may be omitted by special permission of the inspection department having jurisdiction, providing the conduit ends are bushed and secured."

Fig. 47 shows a typical form of outlet-box for bracket or ceiling outlets of the *universal type.* When it is desired to make an opening for the conduits, a blow from a hammer will remove any of the weakened portion of the wall of the outlet-box, as may be required. This form of outlet-box is frequently referred to as the *knock-out type.* Other forms of outlet-boxes are made with the openings cast in the box at the required points, this class being usually stronger and better made than the universal type. The advantages of the universal type of outlet-box are that one form of box will serve for any ordinary conditions, the openings being made according to the number of conduits and the directions in which they enter the box.

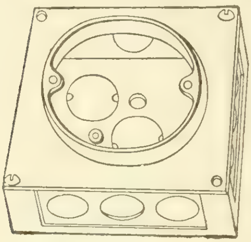


Fig. 47. Universal and Knock-Out Type of Outlet Box.

Fig. 48 shows a waterproof form of outlet-box used out of doors, or in other places where the conditions require the use of a water-tight and waterproof outlet-box.

It will be seen in this case, that the box is threaded for the conduits, and that the cover is screwed on tightly and a flange provided for a rubber gasket.

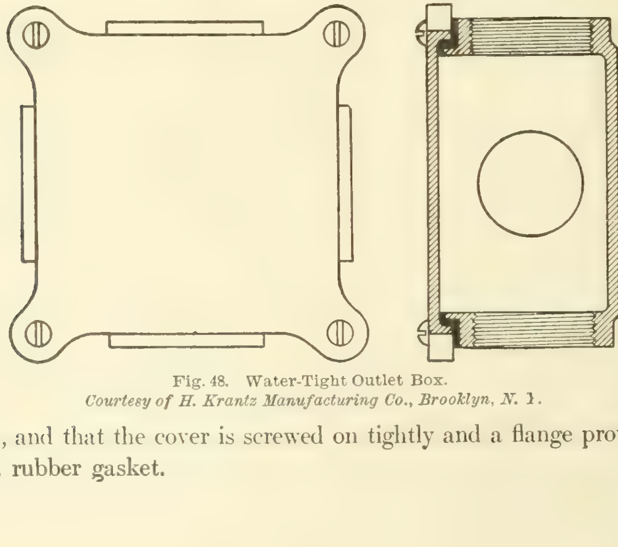
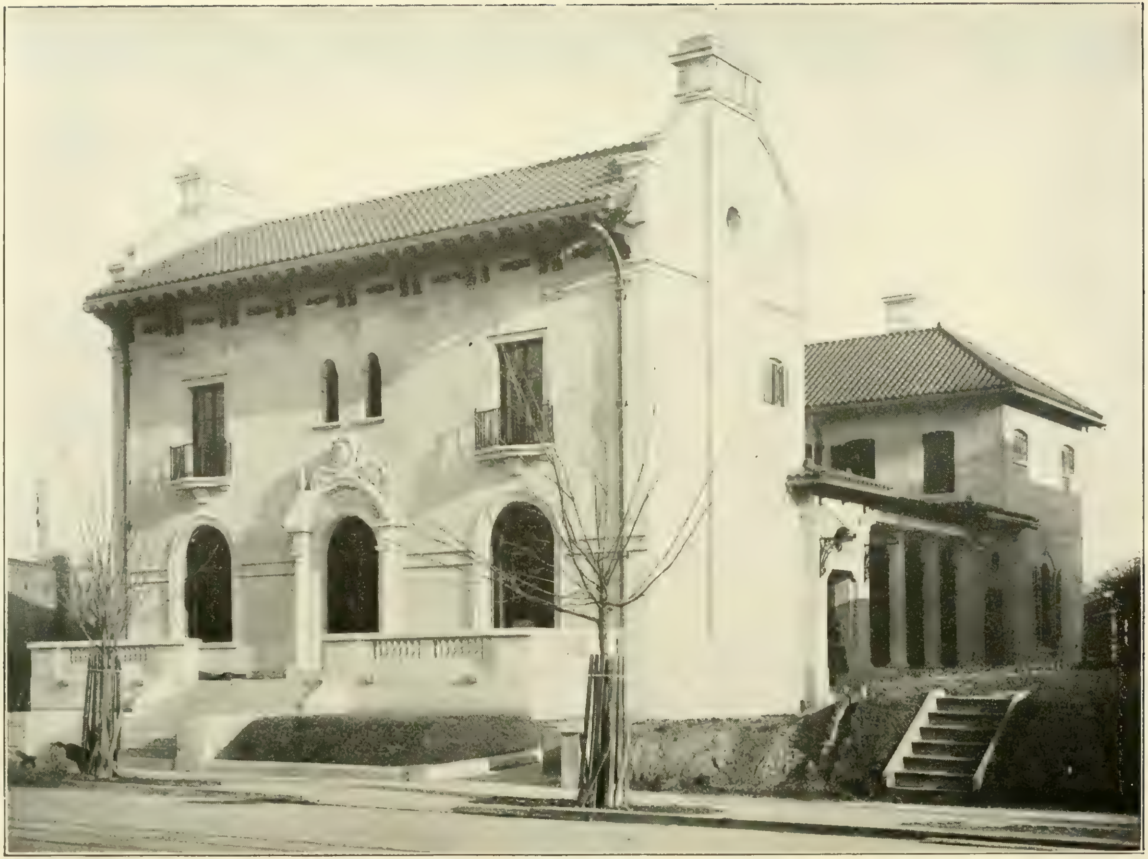


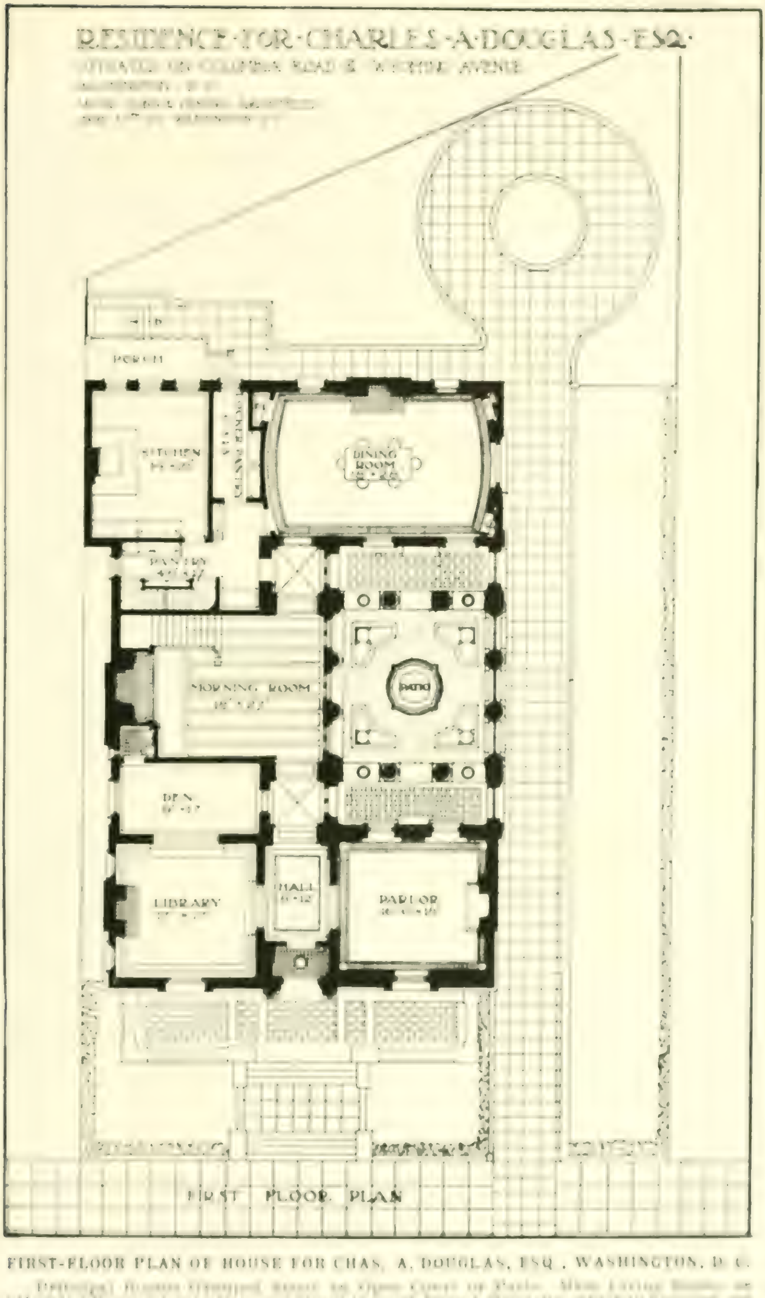
Fig. 48. Water-Tight Outlet Box.
Courtesy of H. Krantz Manufacturing Co., Brooklyn, N. Y.



HOUSE FOR CHAS. A. DOUGLAS, ESQ., WASHINGTON, D. C.

Wood, Donn & Deming, Architects, Washington, D. C.

An Interesting Example of an Open-Court Treatment Applied to a Narrow City Lot. Built of Stucco of White Marble Grit, with Wide, Projecting Eaves and Elaborate Supporting Rafters and Beams Stained a Dark Color.



FIRST-FLOOR PLAN OF HOUSE FOR CHAS. A. DOUGLAS, ESQ., WASHINGTON, D. C.

Principal Rooms Grouped About an Open Court or Patio. [illegible] "Morning Room" [illegible] Thrown Open, Providing Abundant Light and Air. [illegible] on Each Side of Court [illegible] at the Parapet Line of the [illegible] Sketch on Opposite Page.

Figs. 49 and 50 show water-tight floor boxes which are for outlets located in the floor. While the rules do not require that the floor outlet-box shall be water-tight, it is strongly recommended that a water-tight outlet be used in all cases for floor connections. In this case also, the conduit opening is threaded, as well as the stem cover through which the extension is made in the conduit to the desk or table. When the floor outlet connection is not required, the stem cover may be removed and a flat, blank cover be used to replace the same.

A form of outlet-box used for flexible steel cables and steel armored cable, has already been shown (see Fig. 5).

There is hardly any limit to the number and variety of makes of outlet-boxes on the market, adapted for ordinary and for special con-

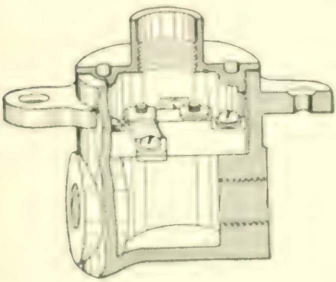


Fig. 49.

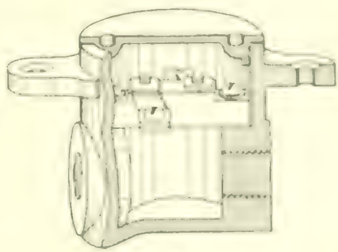


Fig. 50.

Types of Floor Outlet Boxes.

ditions; but the types illustrated in these pages are characteristic and typical forms.

Bushings. The *Rules of the National Electric Code* require that conduits entering junction-boxes, outlet-boxes, or cut-out cabinets shall be provided with approved *bushings*, fitted to protect the wire from abrasion.

Fig. 51 shows a typical form of conduit bushing. This bushing is screwed on the end of the conduit after the latter has been introduced into the outlet-box, cut-out cabinet, etc., thereby forming an insulated orifice to protect the wire at the point where it leaves the conduits, and to prevent abrasion, grounds, short circuits, etc. A lock-nut (Fig. 52) is screwed on the threaded end of the conduit before the conduit is placed in the outlet-box or cut-out cabinet, and this lock-nut and bushing clamp the conduit securely in position. Fig.

53 shows a terminal bushing for panel-boxes used for flexible steel conduit or armored cable.

The *Rules of the National Electric Code* require that the metal of conduits shall be permanently and effectually grounded, so as to insure a positive connection for grounds or leaking currents, and in order to provide a path of least resistance to prevent the current from finding a path through any source which might cause a fire. At outlet-boxes, the conduits and gaspipes must be fastened in such a manner as to insure good electrical connection; and at centers of distribution, the conduits should be joined by suitable bond wires, preferably of copper, the said bond wires being connected to the metal structure of the building, or, in case of a building not having an iron or steel structure, being grounded in a permanent manner to water or gas piping.

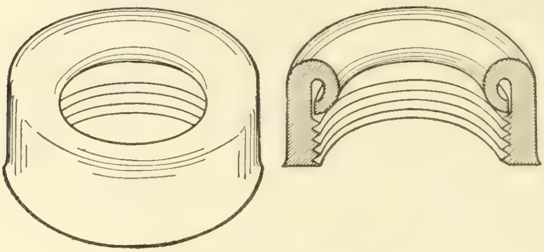


Fig. 51. Conduit Bushing.

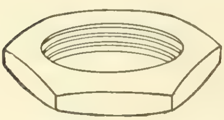


Fig. 52. Lock-Nut.

Fuse-Boxes, Cut-Out Panels, etc. From the very outset, the necessity was apparent of having a protective device in circuit with the conductor to protect it from overload, short circuits, etc. For this purpose, a fusible metal having a low melting point was employed. The form of this fuse has varied greatly. Fig. 54 shows a characteristic form of what is known as the *link fuse* with copper terminals, on which are stamped the capacity of the fuse.

Fig. 53. Panel-Box Terminal Bushing.
Courtesy of Sprague Electric Co., New York, N. Y.

The form of fuse used probably to a greater extent than any other, although it is now being superseded by other more modern forms, is that known as the *Edison fuse-plug*, shown in Fig. 55. A porcelain *cut-out block* used with the Edison fuse is shown in Fig. 56.

Within the last four or five years, a new form of fuse, known as the *enclosed fuse*, has been introduced and used to a considerable

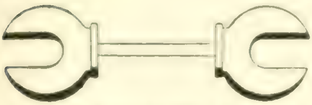


Fig. 54. Copper-Tipped Fuse Link

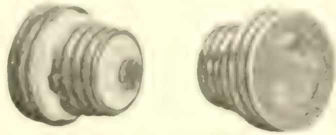


Fig. 55. Edison Fuse-Plug
Courtesy of General Electric Co., Schenectady, N. Y.

extent. A fuse of this type is shown in Fig. 57. Fig. 58 gives a sectional view of this fuse, showing the porous filling surrounding the fuse-strips, and also the device for indicating when the fuse has blown. This form of fuse is made with various kinds of terminals: it can be used with spring clips in small sizes, and with a post screw contact in larger sizes. For ordinary low potentials this fuse is desirable for currents up to 25 amperes; but it is a debatable question whether it is desirable to use an enclosed fuse for heavier currents. Fig. 59 shows a *cut-out box* with Edison plug fuse-blocks used with knob and tube wiring. It will be seen that there is no connection compartment in this fuse-box, as the circuits enter directly opposite the terminals with which they connect.

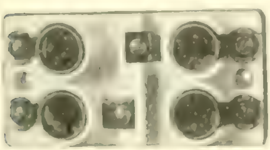


Fig. 56. Porcelain Cut-out Block
Courtesy of General Electric Co., Schenectady, N. Y.

Fig. 60 shows a *cut-out panel* adapted for enclosed fuses, and installed in a cabinet having a connection compartment. As will be seen from the cut, the tablet itself is surrounded on the four sides by slate, which is secured in the corners by angle-irons. The outer box may be of wood lined with sheet iron, or it may be of iron. Fig. 61 shows a door and trim for a cabinet of this type. It will be seen that

Fig. 57. Enclosed Cartridge Fuse

Fig. 58. Section of Enclosed Fuse

the door opens only on the center panel, and that the trim covers and conceals the connection compartment. The inner side of the door should be lined with slate, and the inner side of the trim should be lined with sheet iron. Fig. 62 shows a sectional view of the cabinet and panel. In this type of cabinet, the conduits may enter at any point, the wires being run to the proper connectors in the connection compartment.

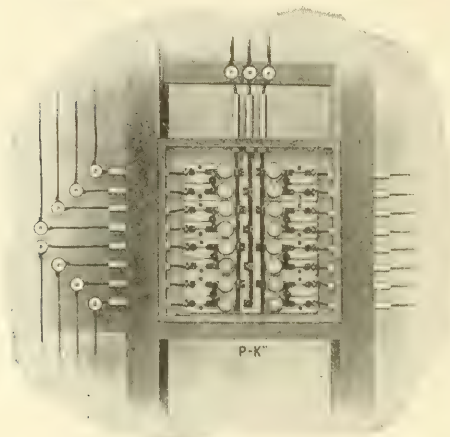


Fig. 59. Porcelain Cut-Outs in Wooden Box.
Courtesy of H. T. Paiste Co., Philadelphia, Pa.

Figs. 63 and 64 illustrate a type of panel-board and cabinet having a push-button switch connected with each branch circuit and so arranged that the cut-out panel itself may be enclosed by locked doors, and access to the switches may be obtained through two separate doors provided with latches only. This type of panel was arranged and designed by the author of this instruction paper.

OVERHEAD LINEWORK

The advantages of overhead linework as compared with underground linework are that it is much less expensive; it is more readily and more quickly installed; and it can be more readily inspected and repaired.

Its principal disadvantages are that it is not so permanent as underground linework; it is more easily deranged; and it is more unsightly.

For large cities, and in congested districts, overhead linework should not be used. However, the question of first cost, the question of permanence, and the municipal regulations, are usually the factors which determine whether overhead or underground linework shall be used.

The principal factors to be considered in overhead linework will be briefly outlined.

Placing of Poles. As a general rule, the poles should be set from 100 to 125 feet apart, which is equivalent to 53 to 42 poles per mile. Under certain conditions, these spacings given will have to be modified; but if the poles are spaced too far apart, there is danger of too great a strain on the poles themselves, and on the cross-arms, pins, and

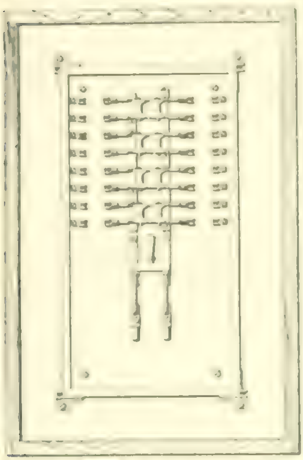


Fig. 60. Plan View, Cover, and [illegible]

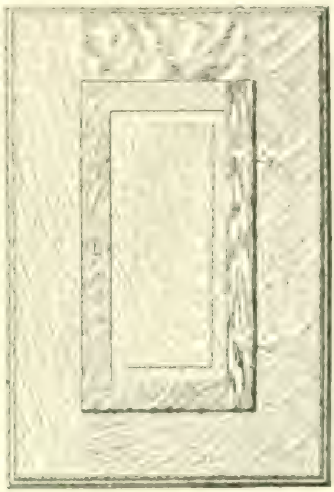


Fig. 61.

Fig. 62.

conductors. If, on the other hand, they are placed too close together, the cost is unnecessarily increased. The size and number of conductors, and the potential of the linework, determine to a great extent the distance between the poles; the smaller the size, the less the number of conductors; and the lower the potential, the greater the distance between the poles may be made. Of course, the exact location of the poles is subject to variation because of trees, buildings, or other obstructions. The usual method employed in locating poles, is first to make a map on a fairly large scale, showing the course of the linework, and then to locate the poles on the ground according to the actual conditions.

Poles. Poles should be of selected quality of chestnut or cedar, and should be sound and free from cracks, knots, or other flaws. Experience has proven that chestnut and cedar poles are the most durable and best fitted for linework. If neither chestnut nor cedar poles can be obtained, northern pine may be used, and even other timber in localities where these poles cannot be obtained; but it is found that the other woods do not last so long as those mentioned,

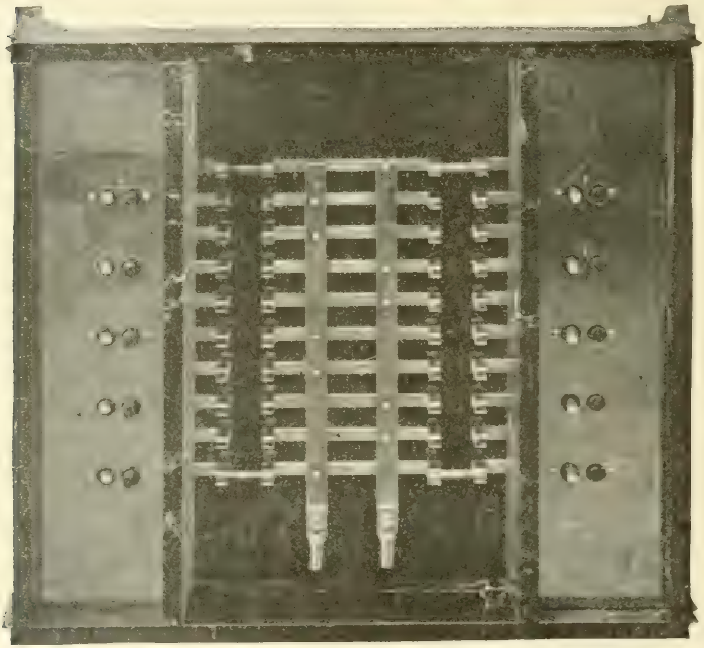


Fig. 63. Cut-Out Panel with Push-Button Switches. Cover Removed.

and some of the other woods are not only less strong initially, but are apt to rot much quicker at the "wind and water line"—that is, just above and below the surface of the ground.

The proper height of pole to be used depends upon conditions. In country and suburban districts, a pole of 25 to 30 feet is usually of sufficient height, unless there are more than two or three cross-arms required. In more densely populated districts and in cities where a great number of cross-arms are required, the poles may have to be

40 to 60 feet, or even longer. Of course, the longer the pole, the greater the possibility of its breaking or bending; and as the length increases, the diameter of the butt end of pole should also increase. Table XI gives the average diameters required for various heights of poles, and the depth the poles should be placed in the ground. These data have been compiled from a number of standard specifications.

TABLE XI

Pole Data

Length of Pole	Diameter 6 Ft. from Butt	Diameter at Top	Depth Placement of Poles in Ground
25 feet	9 to 10 in.	6 to 8 in.	5 feet
30 "	11 "	"	5½ "
35 "	12 "	"	5½ "
40 "	13 "	"	6 "
45 "	14 "	"	6½ "
50 "	15 "	"	7 "
55 "	16 to 17 "	"	7½ "
60 "	18 "	"	7½ "
65 "	19 "	"	8 "
70 "	20 "	"	8 "
75 "	21 "	"	8½ "
80 "	22 "	"	9 "

NOTE: Instead of using diameters, it is sometimes more convenient to measure the circumference of some poles; the circumference may be measured instead. Then, by multiplying the diameters given in the above table, by 3,1416, the measurements may be reduced to the circumference in inches.

The minimum diameter of the pole at the top, which should be allowed, will depend largely on the size of the conductors used, and on the potential carried by the circuits; the larger the conductors and the higher the potentials, the greater should be the diameter at the top of the pole.

Poles should be shaved, housed, and gained, also cleaned and ready for painting, before erection.

Poles should usually be painted, not only for the sake of appearance, but also in order to preserve them from the weather. It is particularly important that they should be protected at their butt end, not only where they are surrounded by the ground, but for a foot or two above the ground, as it is at this point that poles usually deteriorate most rapidly. Painting is not so satisfactory at this point as the use of tar, pitch, or creosote. The life of the pole can be increased considerably by treating it with one or another of these preservatives.

Before any poles are erected, they should be closely inspected for flaws and for crookedness or too great departure from a straight line.

Where appearance is of considerable importance, octagonal poles may be used, although these cost considerably more than round poles. *Gains* or notches for the cross-arms should be cut in the poles before they are erected, and should be cut square with the axis of the pole, and so that the cross-arms will fit snugly and tightly within the space thus provided. These gains should be not less than 4½ inches wide,

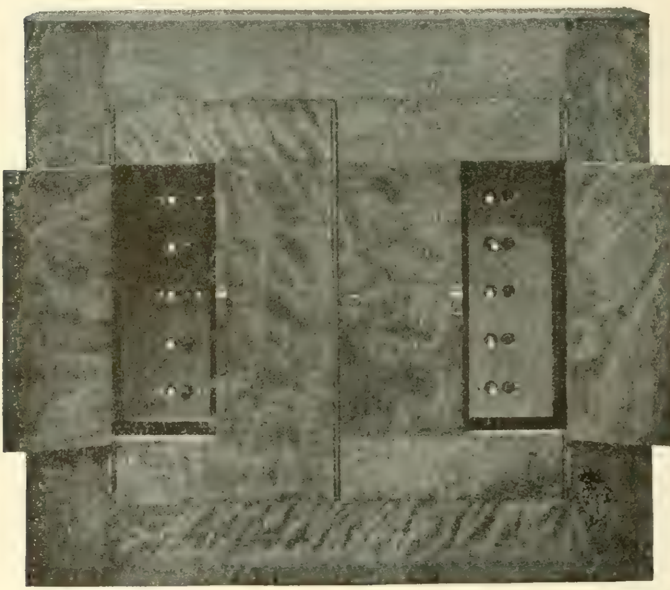


Fig. 64. Cut-Out Panel with Push-Button Switches. With Cover.

nor less than ½ inch deep. Gains should not be placed closer than 24 inches between centers, and the top gains should be at least 9 inches from the apex of the pole.

Pole Guying. Where poles are subject to peculiar strains due to unusual stress of the wires, such as at corners, etc., *guys* should be employed to counteract the strain and to prevent the pole from being bent and finally broken, or from being pulled from its proper position.

ELECTRIC BELL WIRING.

In wiring for electric bells to be operated by batteries, the danger of causing fires from short circuits or poor contacts does not exist as in the case of wiring for light and power, because the current strength is so small. Neither is the bell-fitter responsible to city inspectors or fire underwriters. On this account, bell fitting is too often done in a careless and slovenly manner, causing the apparatus to give unsatisfactory results and to require frequent repairs, so that the expense and inconvenience in the end far more than offset any time saved by doing an inferior grade of work. Hence, at the outset it is well to state that as much care should be taken in the matter of joints and insulation of bell wiring as in wiring for light or power.

If properly installed, the electric bell forms a reliable and yet inexpensive means of signaling, and is far superior to any other. On this account practically every new building is fitted throughout with electric bells.

In addition to the necessity of thoroughness already mentioned, care should be taken to use only reliable apparatus which must be installed in accordance with the fundamental principles on which its satisfactory operation depends.

WIRE.

The common sizes of wire in use for bell work are Nos. 18, 20, and 22. In general, however, No. 20 will be found satisfactory as it is usually sufficiently large, while in many cases No. 22 is not strong enough from a mechanical standpoint.

It is important that the wires should be well insulated to pre-

Fig. 1.

vent accidental contacts with the staples or other wires. First of all the wire should be tinned, as this prevents the copper from being acted upon by the sulphur in the insulation. It also facilitates soldering. The inner coating of insulation should be of india rubber, surrounded by several longitudinal strands of cotton, outside of which are wound several strands of colored cotton laid on spirally. This is next immersed in melted paraffin wax and polished by friction. A short length of approved electric bell wire is shown in Fig. 1.

When ordering wire, it is well to have it furnished in several different colors as this greatly facilitates both the original installation and later repairs, because in this way one line may be distinguished from another, taps from main lines, etc. Moreover, a faulty wire having been found, it is possible to identify it at any desired section of its length.

METHODS OF WIRING.

In running wires, the shortest and most direct route should, of course, be taken between the battery, bells, and bell pushes. There are two cases to be considered. The better method is that in which the wires are run before the building is completed, and the wiring should be done as soon as the roof is on and the walls are up. In this case the wires are usually run in zinc tubes secured to the walls with nails. The tubes should be from $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in diameter, preferably the latter. It is better to place the wires and tubes simultaneously, but the tubes may be put in place first and the wires drawn in afterward, although this latter plan has the objection that the insulation is liable to become abraded when the wires are drawn in. In joining up two lengths of tube, the end of one piece should be opened up with the pliers so that it may receive the end of the other tube, which should also be opened up, but to a less extent, to prevent wear upon the insulation. Specially prepared paper tubes are sometimes substituted for the zinc.

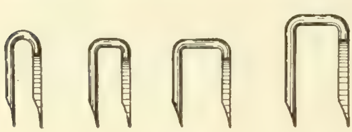


Fig. 2.

If the building is completed before the wiring is done, the concealed method described above cannot be used, and it is necessary to run the wires along the walls supported by staples, where they will be least conspicuous. Fig. 2 shows ordinary double-pointed tacks, Fig. 3 shows an insulating saddle staple which is to be recommended. Two wires should never be secured under the same staple if it can possibly be avoided, owing to the danger of short circuits. With a little care it is usually possible to conceal the wiring behind the picture moulding, along the skirting-board, and beside the door posts; but where it is impossible to conceal it, a light ornamental casing to match the finish of the room, may be used. It is sometimes advisable to use twin wires or two insulated wires run in the same outer covering.

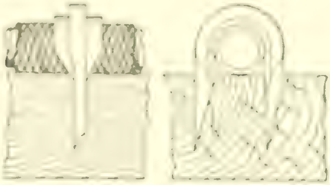


Fig. 3.

In some cases it is well to run the wires under the floor, laying them in notches in the tops of the joists or in holes bored about two inches below the tops of the joists.

JOINTS.

When making a joint, care should be taken to have a firm, clean connection, both mechanically and electrically, and this must always be soldered to prevent corrosion. The insulation should be stripped off the ends of the wires to be joined, for a distance of about 2 inches, and the wires made bright by scraping or sandpa-

Fig. 4.

pering. They should then be twisted tightly and evenly together as shown in Fig. 4.

Next comes the operation of **soldering**, which is absolutely necessary if a permanent joint from an electrical standpoint is to be obtained. A joint made without solder may be electrically sound at first, but its resistance rapidly increases, due to deterioration of the joint. As has already been stated, the wires should be made bright and clean before they are twisted together. Soldering fluids should never be used, because they cause corrosion of the wire. The best flux to use is resin or composite candle. The soldering should always be done with a copper bit rather than with a blowpipe or wireman's torch.

A convenient form of soldering tool consists of a small copper bit having a semicircular notch near the end. This bit should, of course, be well tinned. It is then heated over a spirit lamp, or wireman's torch, and the notch filled with soft solder. Lay the joint, which has previously been treated with the flux, in this notch and turn it so that the solder runs completely around among the spirals of the joint. The loose solder should be shaken off or removed with a bit of rag. When the joint is set, it should be insulated with rubber tape, so that it will be protected as perfectly as the other portions.

It is often possible to save a considerable length of wire and amount of labor by using a ground return, which, if properly arranged, will give very satisfactory results, although a complete metallic circuit is always to be preferred. Where water or gas mains are available, a good ground may be obtained by connecting to them, being sure to have a good connection. This may be secured by scraping a portion of the pipe perfectly bright and clean and then winding this with bare wire; the whole is then well soldered. An end should be left to which the wire from the bell circuit is twisted and soldered. If such mains are not available, a good ground can be obtained by connecting the wire from the bell circuit, as described above, to a pump pipe. In the absence of water and gas mains, and of a pump pipe, a ground may be obtained by burying beneath permanent moisture level a sheet of copper or lead, having at least five square feet of surface, to which the return wire is connected. The ground plate should be covered with coke nearly to the surface; the hole should then be filled in with ordinary soil well rammed.

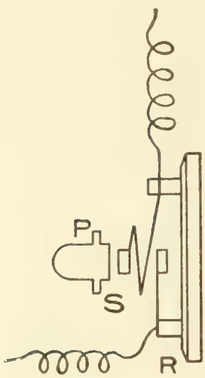


Fig. 5.

OUTFIT.

The three essential parts of the electric bell outfit are the bell push, which furnishes a means of opening and closing the circuit at will, the battery, which furnishes the current for operating the bell, and the bell itself. Before discussing the combination of these pieces of apparatus in the complete circuit, let us take up the individual parts in order.

A bell push is shown diagrammatically in Fig. 5. In this illustration P is the push button; when this is pressed upon it brings the point of the spring S in contact with the metal strip R, thus closing the circuit with which it is connected in series. Normally the springs are separated as shown, and the circuit is accordingly open.

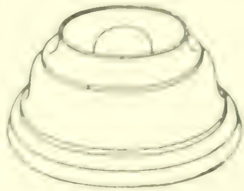


Fig. 6.

Bell pushes are made in various designs and styles, from the simple wooden push shown in Fig. 6 to very elaborate and expensive articles. Fig. 7 shows four cast bronze pushes of neat appearance and moderate price.

Batteries. Electric bells are nearly always operated on the open circuit plan, and hence the battery used is generally of the

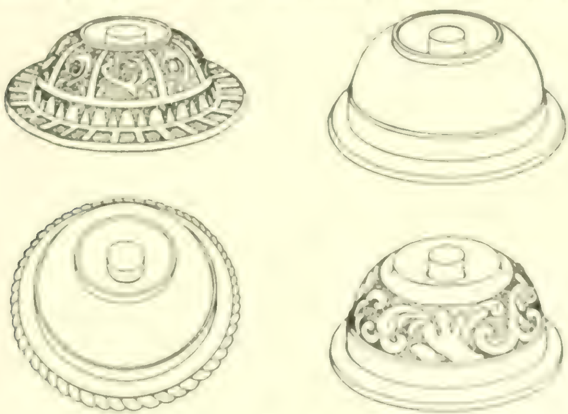


Fig. 7.

open circuit type, such as the Leclanche cell, which is used very largely except for heavy work. This is a zinc-carbon cell in which the excitant is sal ammoniac dissolved in water. Polarization is prevented by peroxide of manganese, which gives up part of its oxygen, combining with the hydrogen set free and forming water.

Dry Batteries are also frequently used for bell work, their principal advantage being cleanliness, as they cannot spill. Dry cells are really a modification of the Leclanche type, as they use zinc and carbon plates and sal-ammoniac as the exciting agent. The Burnley cell, which is one of the principal types of dry cell, has an electrolyte composed of sal-ammoniac, chloride of zinc, plaster, flour, and water. This compound when mixed is a semi-liquid mass which quickly stiffens after being poured into the cup. The depolarizing agent is peroxide of manganese, the same as is used in the Leclanche cell, this being packed around the carbon cylinder. The top of the cell is sealed with bitumen or some similar substance.

For very heavy work the Edison-Lalande and the Fuller types of cell are best suited, while for closed circuit work the gravity cell is most satisfactory.

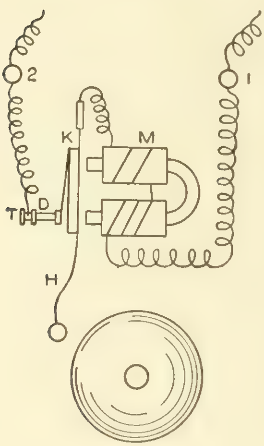


Fig. 8.

Bell. It is a well-known fact that if a current of electricity flows through a coil of wire wound on an iron core, the core becomes magnetized and is capable of attracting any magnetic substances to itself. The operation of the electric bell, like that of so many other pieces of electrical apparatus, depends upon this fact. A diagrammatic representation of an electric bell is shown in Fig. 8, in which M is an electromagnet composed of soft-iron cores on which are wound coils of insulated wire. The armature is mounted upon a spring K, and carries a hammer H at its end for striking the gong. On the back of the armature is a spring which makes contact at D with the back stop T. The action of the bell is as follows: When the circuit is closed through the bell a current flows from terminal 1, around the coils of the magnet, through the spring K and contact point D, through the back stop T, to terminal 2. In flowing around the electromagnet the current magnetizes its core, which consequently attracts the armature. This causes the hammer H to strike the gong. While in this position the contact at D is broken, the current ceases to flow around the electromagnet and the cores consequently lose their attractive force. The armature is thus carried back to its original position by the spring K, making contact at D, and the process is repeated. The hammer will thus vibrate and the bell continue to ring as long as the circuit is closed.

The type of bell described above is the one most commonly used. Such bells are made in a great variety of shapes and styles, the prices varying accordingly. It is important that platinum tips be furnished at the contact point D, Fig. 8, to prevent cor-

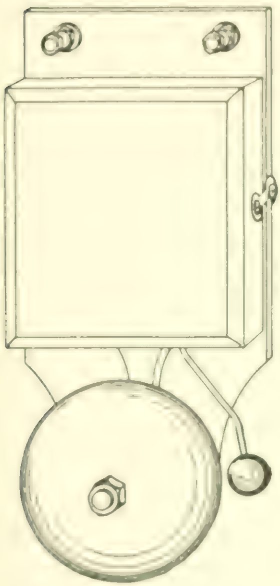


Fig. 9.

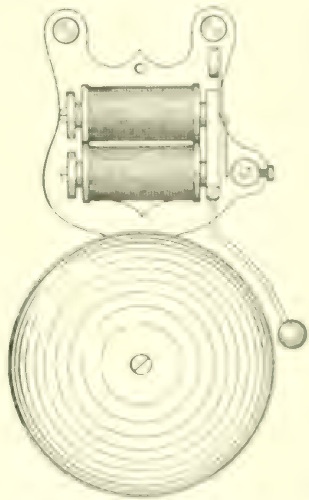


Fig. 10.

rosion. The bells on the market today are of two classes, the iron box bell and the wooden box bell. A bell of the wooden box type is shown in Fig. 9, and a higher grade bell of the iron frame skeleton type is shown in Fig. 10. Bells without covers should never be used, as dust will settle on the contacts and interfere with their action.

CIRCUITS.

The possible combinations of the various parts into complete circuits are so varied that it would be impossible to describe them all; in fact, almost every one is to a certain extent a special problem. It is, however, possible to give typical circuits the underlying principles of which can be applied successfully to any particular case.

Fig. 11 shows a bell circuit in its simplest form, in which P represents the push, B the bell, and C the battery; all connected in series. The circuit is normally open at P, and hence no current flows to exhaust the batteries. When P is pressed, the circuit, otherwise complete, is closed and current passes through the bell causing it to ring, as already explained. For instance, the push might be located beside the front door, the bell in the kitchen and the battery in the cellar; the location depending on the results desired and conditions to be met. The wire between P and C may, if necessary, be dispensed with and connection made to ground at G and G, as shown by the dotted lines.

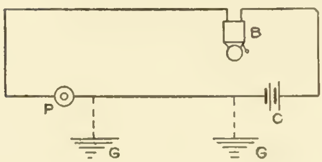


Fig. 11.

Fig. 12 shows an arrangement by means of which one bell B

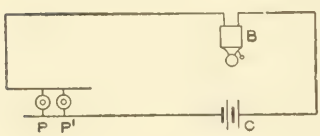


Fig. 12.

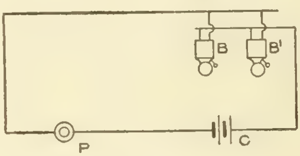
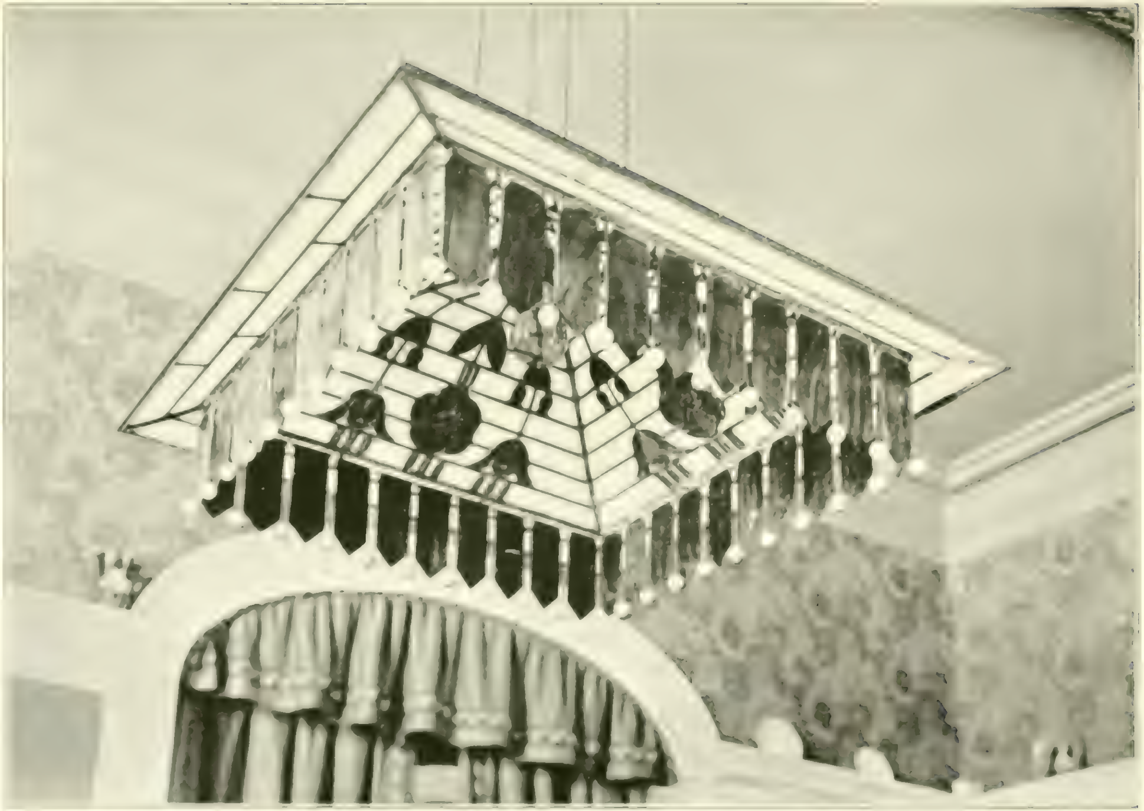


Fig. 13.

may be controlled by either of the pushes P or P′. This system may be extended to any number of pushes similarly connected.

A method for ringing two bells simultaneously from one push is shown in Fig. 13, where both bells B and B′ will ring from push P. Bells, if connected in this manner, should have as nearly as possible the same resistance, otherwise the bell of lower resistance will take so much current that there will not be a sufficient amount left for the other. Also, the batteries must be of greater current capacity as the amount of current taken is, of course, doubled. This system can be extended to any number of bells connected in this way, up to the limit of capacity of the battery to ring them. Figs.

SIMPLE COMBINATION GAS AND ELECTRIC FIXTURE IN A DINING ROOM



DETAIL OF DINING-ROOM TABLE LANTERN IN HOUSE AT WAUKEGAN, ILL.

R. C. Spencer, Jr., Architect, Chicago, Ill.

12 and 13 may be combined so that two or more bells may be rung from any one of two or more places.

In Fig. 14 is shown a scheme for ringing either bell, B or B', from one push and one battery by means of the two-point switch

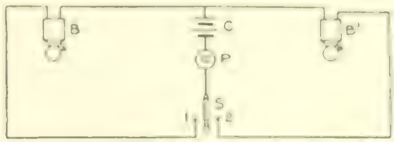


Fig. 14

S. When the arm of the switch is on contact 1, the push will ring bell B, and when on contact 2 it will ring bell B'.

In Fig. 15 is shown a method of connecting bells in series so that B and B' may be rung from P. If all the bells so connected were of the vibrating type, they would not work satisfactorily, as it would be impossible to time them so that the vibrations would keep step, hence only one bell should be of the vibrating type, and the others should have the circuit breakers short-circuited, the vibrating bell serving as interrupter for the whole series. Obviously this system requires a higher volt-

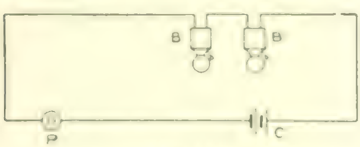


Fig. 15

age than parallel connection, and the cells must be of sufficient E.M.F. to ring the bells satisfactorily. Several bells may be connected in this way, if desired, up to the limit of voltage of the battery.

Fig. 16

Oftentimes a bell is to be rung from several different places. For instance, the bell in an elevator may be rung from any one of several floors, or the bell in the office of a hotel may be rung from any one of several different rooms. In this case it is necessary to have some device to indicate from which push the bell was rung. The annunciator furnishes this information very well. A three-station annunciator is shown in Fig. 16. The connections for an annunciator are shown in Fig. 17 where A represents the annunciator, B the bell, C the battery, and P^1, P^2, and P^3 the pushes. For instance, when P^1 is pressed, the current passes through the electromagnet controlling point 1 on the annunciator which causes

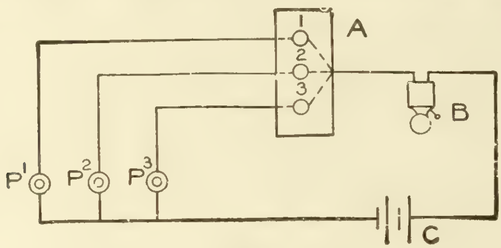


Fig. 17.

the arrow to be turned and at the same time the bell rings. After the attendant has noted the signal, the arrow is restored to its normal position by pressing a lever on the bottom of the annunciator box.

The electric burglar alarm furnishes a very efficient protection and is an application of the principles already described. The circuit, instead of being completed by a push, is completed by contacts placed on the doors or windows so that the opening of either will cause the bell to ring. The same device may be used on money-drawers, safes, etc.

In the case of the electric fire alarm, the signal may be given either automatically when the temperature reaches a certain degree, or pushes may be placed in convenient locations to be operated manually. The pushes should be protected by glass so that they will not be tampered with, it being necessary to break the glass to give the alarm.

HOLOPHANE EXHIBIT.

World's Fair St Louis

LIVING ROOM IN RESIDENCE OF J. R. CRAVATH, CHICAGO. ILL.
A good Arrangement for Reading and General Lighting in a Small Room.

ELECTRIC LIGHTING

HISTORY AND DEVELOPMENT

The history of electric lighting as a commercial proposition begins with the invention of the Gramme dynamo, by Z. T. Gramme, in 1870, together with the introduction of the Jablochkoff candle or light, which was first announced to the public in 1876, and which formed a feature of the International Exposition at Paris in 1878. Up to this time, the electric light was known to but few investigators, one of the earliest being Sir Humphry Davy who, in 1810, produced the first arc of any great magnitude. It was then called the *voltaic arc*, and resulted from the use of two wood charcoal pencils as electrodes and a powerful battery of voltaic cells as a source of current.

From 1840 to 1859, many patents were taken out on arc lamps, most of them operated by clockwork, but these were not successful, due chiefly to the lack of a suitable source of current, since all depended on primary cells for their power. The interest in this form of light died down about 1859, and nothing further was attempted until the advent of the Gramme dynamo.

The incandescent lamp was but a piece of laboratory apparatus up to 1878, at which time Edison produced a lamp using a platinum spiral in a vacuum, as a source of light, the platinum being rendered incandescent by the passage of an electric current through it. The first successful carbon filament was made in 1879, this filament being formed from strips of bamboo. The names of Edison and Swan are intimately connected with these early experiments.

From this time on, the development of electric lighting has been very rapid, and the consumption of incandescent lamps alone has reached several millions each year. When we compare the small amount of lighting done by means of electricity twenty-five years ago with the enormous extent of lighting systems and the numerous applications of electric illumination as they are to-day, the growth and development of the art is seen to be very great, and the value of a study of this subject may be readily appreciated. While no extencases electricity is not the cheapest source of power for illumination, its admirable qualities and convenience of operation make it by far the most desirable.

CLASSIFICATION

The subject of electric lighting may be classified as follows:

1. The type of lamps used.
2. The methods of distributing power to the lamps.
3. The use made of the light, or its application.
4. Photometry and lamp testing.

The types of lamps used may be subdivided into:

1. Incandescent lamps: Carbon, metallic filament, Nernst.
2. Special lamps: Exhausted bulb without filament, such as the Cooper-Hewitt lamp and Moore tube lamp.
3. Arc lamps: Ordinary carbon, flaming arc.

INCANDESCENT LAMPS

The *incandescent lamp* is by far the most common type of lamp used, and the principle of its operation is as follows:

If a current I is sent through a conductor whose resistance is R, for a time t, the conductor is heated, and the heat generated = $I^2R\ t$, $I^2R\ t$ representing joules or watt-seconds.

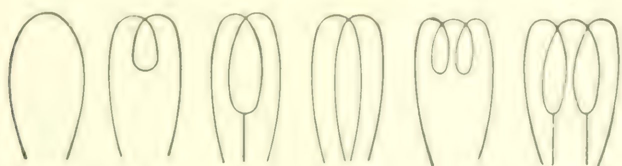
If the current, material, and conditions are so chosen that the substance may be heated in this way until it gives out light, becomes incandescent, and does not deteriorate too rapidly, we have an incandescent lamp. Carbon was the first successful material to be chosen for this conductor and for ordinary lamps it is formed into a small thread or filament. Very recently metallic filament lamps have been introduced commercially with great success but the carbon incandescent lamp will continue to be used for some time, especially in the low candle-power units operated at commercial voltages. Carbon is a successful material for two reasons:

1. The material must be capable of standing a very high temperature, 1,280° to 1,330° C., or even higher.

2. It must be a conductor of electricity with a fairly high resistance.

Platinum was used in an early stage of the development, but, as we shall see, its temperature cannot be maintained at a value high enough to make the lamp as efficient as when carbon or a metal having a melting point higher than that of platinum, is used. Nearly all attempts to substitute another substance in place of carbon have failed until recently, and the few lamps which are entirely or partially successful will be treated later. The nature of the carbon employed in incandescent lamps has, however, been much improved over the first forms, and owing to the still very great importance of this lamp, the method of manufacture will be considered.

Manufacture of Carbon Incandescent Lamps. *Preparation of the Filament.* Cellulose, a chemical compound rich in carbon, is prepared by treating absorbent cotton with zinc chloride in proper proportions to form a uniform, gelatine-like mass. It is customary to stir this under a partial vacuum in order to remove bubbles of air which might be contained in it and destroy its uniformity. This material is then forced, "squirted," through steel dies into alcohol, the



alcohol serving to harden the soft, transparent threads. These threads are then thoroughly washed to remove all trace of the zinc chloride, dried, cut to the desired lengths, wound on forms, and carbonized by heating to a high temperature away from air. During carbonization, the cellulose is transformed into pure carbon, the volatile matter being driven off by the high temperature to which the filaments are subjected. The material becomes hard and stiff, assuming a permanent form, shrinking in both length and diameter—the form being specially constructed so as to allow for this shrinkage. The forms are made of carbon blocks which are placed in plumbago crucibles and packed with powdered carbon. The crucibles, which are covered with loosely fitting carbon covers, are gradually brought to a white heat, at which temperature the cellulose is changed to carbon, and then allowed to cool. After cooling, the filaments are removed, measured, and inspected, and the few defective ones discarded.

In the early days, these filaments were made of cardboard or bamboo, and later, of thread treated with sulphuric acid.

A few of the shapes of filaments now in use are shown in Fig. 1, the different shapes giving a slightly different distribution of light. As here shown they are designated as follows: A, U-shaped; B, single-curl; C, single-curl anchored; D, double-loop; E, double-curl; F, double-curl anchored.

Mounting the Filament. After carbonization, the filaments are mounted or joined to wires leading into the globe or bulb. These wires are made of platinum—platinum being the only substance, so far as known, that expands and contracts the same as glass, with change in temperature and which, at the same time, will not be melted by the heat developed in the carbon. Since the bulb must remain air-tight, a substance expanding at a different rate from the glass cannot be used. Several methods of fastening the filament to the *leading in* wires have been used, such as forming a socket in the end of the wire, inserting the filament, and then squeezing the socket tightly against the carbon; and the use of tiny bolts when cardboard filaments were used; but the pasted joint is now used almost exclusively. Finely powdered carbon is mixed with some adhesive compound, such as molasses, and this mixture is used as a paste for fastening the carbon to the platinum. Later, when current is sent through the joint, the volatile matter is driven off and only the carbon remains. This makes a cheap and, at the same time, a very efficient joint.

Flashing. Filaments, prepared and mounted in the manner just described, are fairly uniform in resistance, but it has been found that their quality may be much improved and their resistance very closely regulated by depositing a layer of carbon on the outside of the filament by the process of *flashing*. By flashing is meant heating the filament to a high temperature when immersed in a hydrocarbon gas, such as gasoline vapor, under partial vacuum. Current is passed through the filament in this process to accomplish the heating. Gas is used, rather than a liquid, to prevent too heavy a deposit of the carbon. Coal gas is not recommended because the carbon, when deposited from this, has a dull black appearance. The effects of flashing are as follows:

1. The diameter of the filament is increased by the deposited carbon and hence its resistance is decreased. The process must be

discontinued when the desired resistance is reached. Any little irregularities in the filament will be eliminated since the smaller sections, having the greater resistance, will become hotter than the remainder of the filament and the carbon is deposited more rapidly at these points.

2. The character of the surface is changed from a dull black and comparatively soft nature to a bright gray coating which is much harder and which increases the life and efficiency of the filament.

Exhausting. After flashing, the filament is sealed in the bulb and the air exhausted through the tube A in Fig. 2, which shows the lamp in different stages of its manufacture. The exhaustion is accomplished by means of mechanical air pumps, supplemented by Sprengle or mercury pumps and chemicals. Since the degree of exhaustion must be high, the bulb should be heated during the process so as to drive off any gas which may cling to the glass. When chemicals are used, as is now almost universally the case, the chemical is placed in the tube A and, when heated, serves to take up much of the remaining gas. Exhaustion is necessary for several reasons:

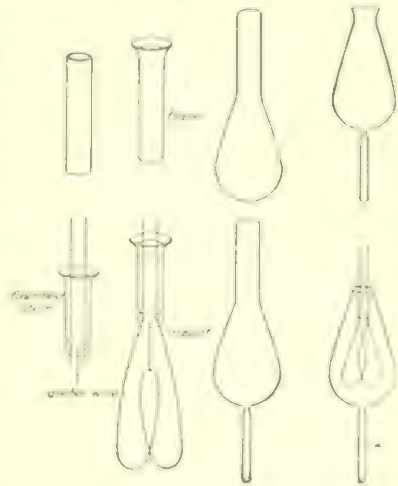


Fig. 2. Different Stages of Lamp Manufacture

1. To avoid oxidation of the filament.
2. To reduce the heat conveyed to the glass.
3. To prevent wear on the filament due to currents of air in the gas.

After exhausting, the tube A is sealed off and the lamp completed for testing by attaching the base by means of plaster of Paris. Fig. 3 shows some of the forms of completed incandescent lamps.

Voltage and Candle-Power. Incandescent lamps of the carbon type vary in size from the miniature battery and candelabra lamps to those of several hundred candle-power, though the latter are very seldom used. The more common values for the candle-power are

8, 16, 25, 32, and 50, the choice of candle-power depending on the use to be made of the lamp.

The voltage will vary depending on the method of distribution of the power. For what is known as *parallel distribution,* 110 or 220 volts are generally used. For the higher values of the voltage, long and slender filaments must be used, if the candle-power is to be low; and lamps of less than 16 candle-power for 220-volt circuits are not practical, owing to difficulty in manufacture. For series distribution, a low voltage and higher current is used, hence the filaments may be quite heavy. Battery lamps operate on from 4 to 24 volts, but the vast majority of lamps for general illumination are operated at or about 110 volts.

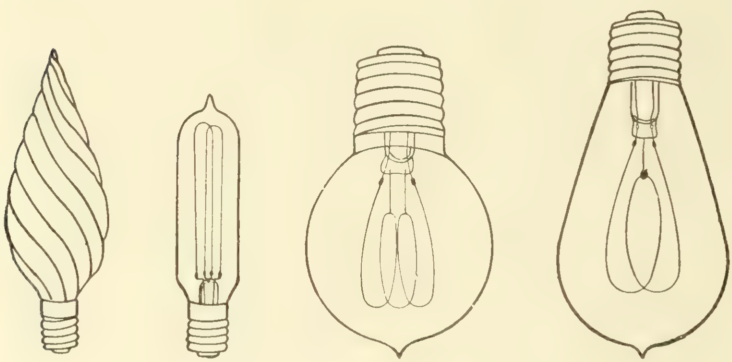


Fig. 3. Several Forms of Completed Lamps.

Efficiency. By the efficiency of an incandescent lamp is meant the power required at the lamp terminals per candle-power of light given. Thus, if a lamp giving an average horizontal candle-power of 16 consumes $\frac{1}{2}$ an ampere at 112 volts, the total number of watts consumed will be $112 \times \frac{1}{2} = 56$, and the watts per candle-power will be $56 \div 16 = 3.5$. The efficiency of such a lamp is said to be 3.5 watts per candle-power, or simply watts per candle. *Watts economy* is sometimes used for *efficiency.*

The efficiency of a lamp depends on the temperature at which the filament is run. In the ordinary lamp this temperature is between 1,280° and 1,330° C, and the curve in Fig. 4 shows the increase of efficiency with the increase of temperature. The temperature attained by a filament depends on the rate at which heat is radiated and the amount of power supplied. The rate of radiation of heat is proportional to the area of the filament, the elevation in temperature, and the emissivity of the surface.

By emissivity is meant the number of heat units emitted from unit surface per degree rise in temperature above that of surrounding bodies. The bright surface of a flashed filament has a lower emissivity than the dull surface of an unheated filament, hence less energy is lost in heat radiation and the efficiency of the filament is increased.

As soon as incandescence is reached, the illumination increases much more rapidly than the emission of heat, hence the increase in

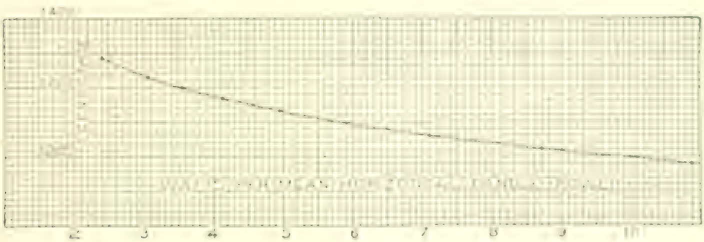


Fig. 4. Efficiency Curve for Incandescent Lamps.

efficiency shown in Fig. 4. Were it not for the rapid disintegration of the carbon at high temperature, an efficiency higher than 3.1 watts could be obtained.

By a special treatment of the carbon filaments, the nature of the carbon is so changed that the filaments may be run at a higher temperature and the lamps still have a life comparable to that of the 3.1-watt lamp. Lamps using these special carbon filaments are known as *gem metallized filament lamps*, or merely as *gem lamps*, and they will be described more fully later.

Relation of Life to Efficiency. *Ordinary Carbon Lamp.* By the useful life of a lamp is meant the length of time a lamp will burn before its candle-power has decreased to such a value that it would be more economical to replace the lamp with a new one than to continue to use it at its decreased value. A decrease to 80% of the initial candle-power of carbon lamps is now taken as the point at which a lamp should be replaced, and the normal life of a lamp is in the neighborhood of 800 hours. To obtain the most economical results, such lamps should always be replaced at the end of their useful life.

In Table I are given values of efficiency and life of a 3.5-watt, 110-volt carbon lamp for various voltages impressed on the lamp. These values are plotted in Fig. 5. The curves show that a 3% increase of voltage on the lamp reduces the life by one-half, while an increase of 6% causes the useful life to fall to one-third its normal value. The effect is even greater when 3.1-watt lamps are used, but not so great with 4-watt lamps. From this we see that the regulation of the voltage used on the system must be very good if high efficiency lamps are to be used, and this regulation will determine the efficiency of the lamp to be installed.

Selection of Lamps. *Ordinary Carbon Type.* Lamps taking 3.1 watts per candle-power will give satisfaction only when the regulation of voltage is the best—practically a constant voltage maintained at the normal voltage of the lamp.

TABLE I

Effects of Change in Voltage

Standard 3.5-Watt Lamp

Voltage Per Cent. of Normal	Candle-Power Per Cent. of Normal	Watts Per Candle-Power	Life Per Cent. of Normal	Deterioration Per Cent. of Normal
90	53	5.36		
91	56	5.09		
92	61	4.85		
93	65	4.63		
94	69	4.44	394	25
95	73	4.26	310	32
96	78	4.09	247	41
97	83	3.93	195	51
98	88	3.78	153	65
99	94	3.64	126	79
100	100	3.5	100	100
101	106	3.38	84	118
102	111	3.27	68	146
103	116	3.16	58	173
104	123	3.05	47	211
105	129	2.95	39	253
106	137	2.85	31	316
107	143	2.76	26	380
108	152	2.68	21	474
109	159	2.60	17	575
110	167	2.53	16	637

Lamps of 3.5 watts per candle-power should be used when the regulation is fair, say with a maximum variation of 2% from the normal voltage.

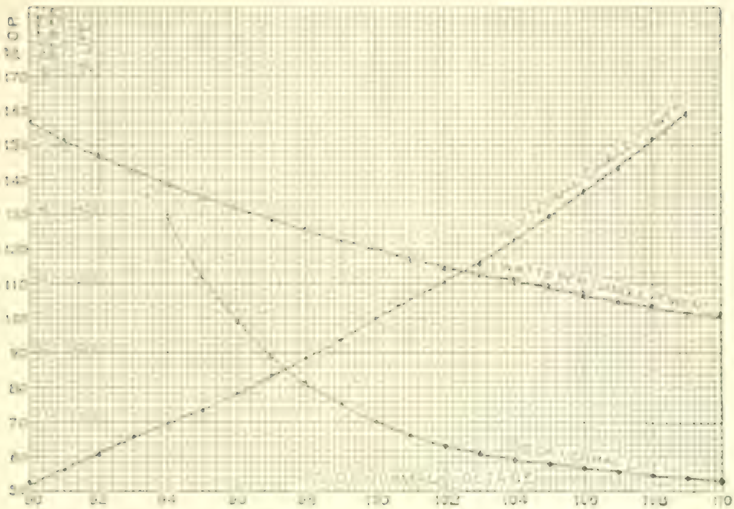


Fig. 5. Curves of Efficiency and Life of Carbon-Filament Lamps

Lamps of 4 watts per candle-power should be installed when the regulation is poor. These values are for 110-volt lamps. A 220-volt lamp should have a lower efficiency to give a long life. This is on

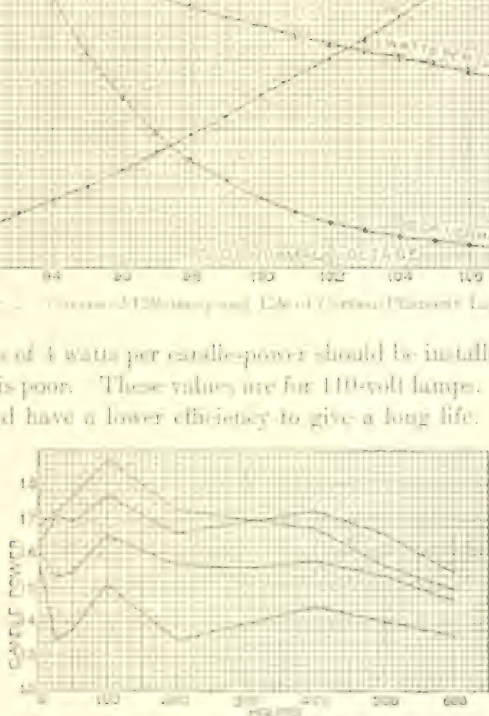


Fig. 6. Life Curves of Incandescent Lamps

account of the fact that, for the same candle-power, the 220-volt lamp must be constructed with a filament which is long and slender compared to that of the 110-volt lamp, and if such a filament is run at a high temperature its life is short. The 220-volt lamp is used to some considerable extent abroad but it is not employed extensively in the United States. It is customary to operate such lamps at an efficiency of about 4 watts per candle-power.

Lamps should always be renewed at the end of their useful life, this point being termed the *smashing-point*, as it is cheaper to replace the lamp than to run it at the reduced candle-power. Some recommend running these lamps at a higher voltage, but that means at a reduced life, and it is not good practice to do this.

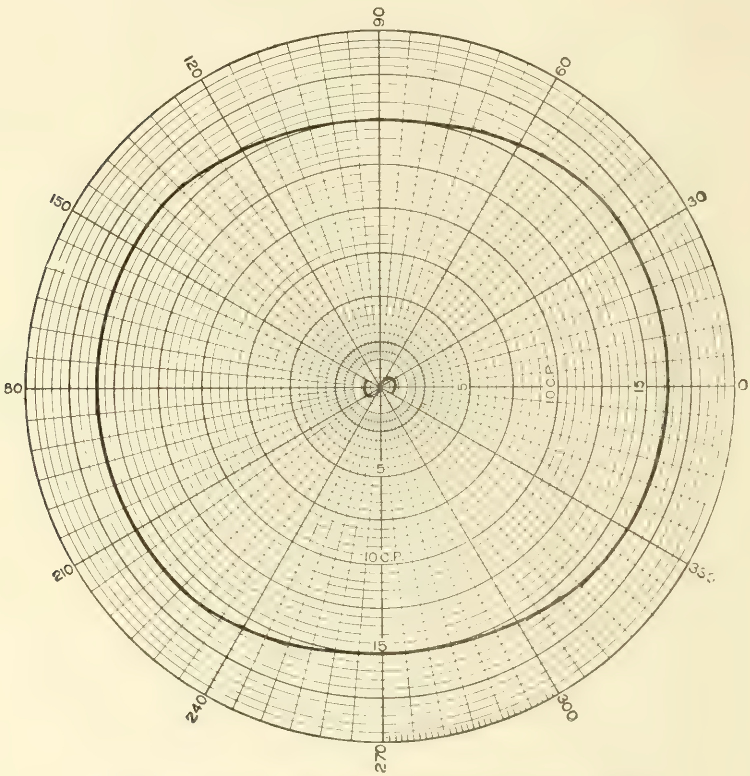


Fig. 7. Horizontal Distribution Curve for Single-Loop Filament.

Fig. 6 shows the life curves of a series of incandescent lamps. These curves show that there is an increase in the candle-power of some of the lamps during the first 100 hours, followed by a period during which the value is fairly constant, after which the light given by the lamp is gradually reduced to about 80% of the initial candle-power.

Distribution of Light. In Fig. 1 are shown various forms of filaments used in incandescent lamps, and Figs. 7 and 8 show the distribution of light from a single-loop filament of cylindrical cross-section. Fig. 7 shows the distribution of light in a horizontal plane, the lamp being mounted in a vertical position, and Fig. 8 shows the distribution in a vertical plane. By changing the shape of the filament the light distribution is varied. A mean of the readings taken in the horizontal plane forms the mean *horizontal candle-power*, and this candle-power rating is the one generally assumed for the ordinary incandescent lamp. A mean of the readings taken in a vertical plane gives us the mean vertical candle-power, but this value is of little use.

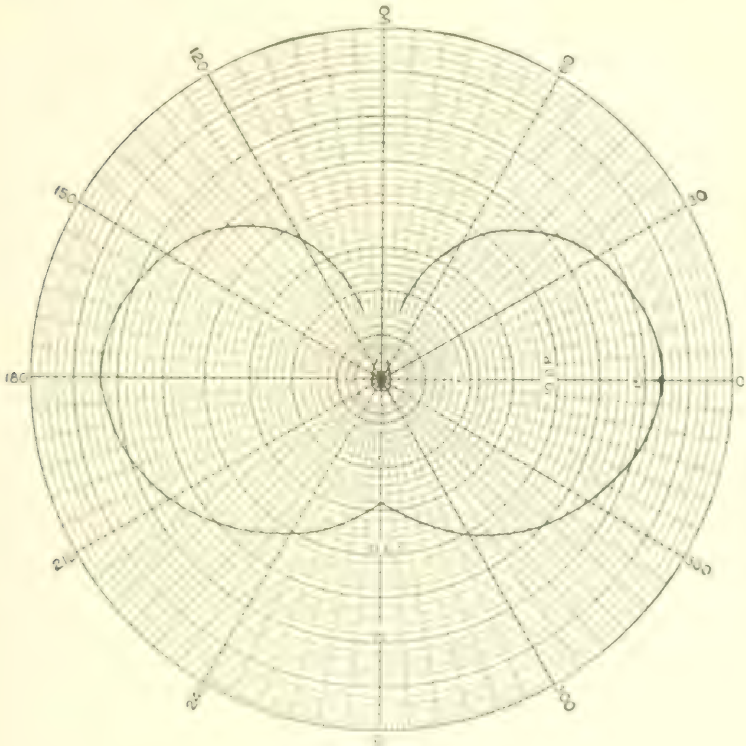


Fig. 8. Vertical Distribution Curve for Single-Loop Filament

Mean Spherical Candle-Power. When comparing lamps which give an entirely different light distribution, the mean horizontal candle-power does not form a proper basis for such comparison, and the mean spherical or the mean hemispherical candle-power is used instead. By *mean spherical candle-power* is meant a mean value of the light taken in all directions. The methods for determining this will be taken up under *photometry*. The mean hemispherical candle-power has reference, usually, to the light given out below the horizontal plane.

The Gem Metallized Filament Lamp. When the incandescent lamp was first well established commercially, the useful life of a unit, when operated at 3.1 watts per candle, was about 200 hours. The improvements in the process of manufacture have been continuous from that time until now, and the useful life of a lamp operated at that efficiency to-day is in the neighborhood of 500 hours. Experiments in the treatment of the carbon filament have led to the introduction of the *gem metallized filament lamp*. This lamp should not be confused with the metallic filament lamps, to be described later, because the material used is carbon, not a metal. As a result of special treatment the carbon filament assumes many of the characteristics of a metallic conductor, hence the term *metallized filament*. The word *graphitized* has been proposed in place of metallized.

TABLE II

*** Data on the Gem Metallized Filament Lamp**

Watts	Horizontal C. P.	Watts per Candle	†Spherical Reduction Factor	§ Useful Life
40	16	2.5	.816	450 hrs.
50	20	2.5	.825	450 "
80	32	2.5	.816	450 "
100	40	2.5	‡	460 "
125	50	2.5	‡	450 "
187.5	75	2.5	‡	450 "
250	100	2.5	‡	450 "

* These lamps are normally rated at three voltages, 114, 112, and 110 volts, but data referring to the highest voltage only are given.

† By spherical reduction factor is meant the factor by which the horizontal candle-power must be multiplied to obtain the mean spherical candle-power.

‡ The larger units are almost invariably used with reflectors, hence no spherical reduction factor is given.

§ The life of the lamps when operated at the lower voltage is increased to about 950 hours, and the efficiency is changed to 2.83 watts per candle.

DINING ROOM IN HOUSE FOR MR. W. F. DUMMER AT CORONADO BEACH, CAL.
Pond & Pond, Architects, Chicago, Ill.
Curly California Redwood Wainscoting.

LIVING ROOM IN HOUSE FOR MR. W. F. DUMMER, AT CORONADO BEACH, CAL.

Pond & Pond, Architects, Chicago, Ill.

[illegible] Cypress [illegible] Woodwork [illegible] Fireplace, Hard Burned Variegated Brick. For Plans and Exterior See Vol. I, Pages [illegible] and [illegible]

When a filament, as treated in the ordinary manner, is run at a high temperature in a lamp there is no improvement of the filament, but it was discovered that if the treated filaments were subjected to the extremely high temperature of the electric resistance furnace—3,000 to 3,700 degrees C.—at atmospheric pressure, the physical nature of the carbon was changed and the resulting filament could be operated at a higher temperature in the lamp and a higher efficiency,

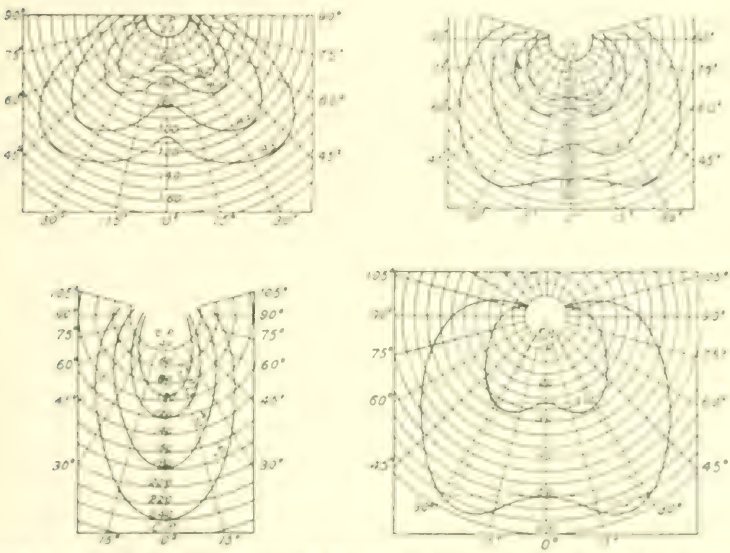


Fig. 9.—Typical Distribution Curves of Gem Lamps with Different Types of Reflectors

and still maintain a life comparable to that of a 3.1-watt lamp. This special heating of the filament, which is applied to the base filament before it is flashed, as well as to the treated filament, causes the cold resistance of the carbon to be very materially decreased and the filament, as used in the lamp, has a positive temperature coefficient—rise in resistance with rise in temperature—a desirable feature from the standpoint of voltage regulation of the circuit from which the lamps are operated. The high temperature also results in the driving off of considerable of the material which, in the ordinary lamp, causes the globe to blacken after the lamp has been in use for some time. The blackening of the bulb is responsible to a considerable degree for the decrease in candle-power of the incandescent lamp. The metallized filament lamp is operated at an efficiency of 2.5 watts per candle with a useful life of about 500 hours. The change in candle-power with change in voltage is less than in the ordinary lamp on account of the positive temperature coefficient of the filament. These lamps are not manufactured for very low candle-powers, owing to the difficulty of treating very slender filaments, but they are made in sizes consuming from 40 to 250 watts. Table II gives some useful information in connection with metallized filament lamps. The filaments are made in a variety of shapes and the distribution curves are usually modified in practice by the use of shades and reflectors. The general appearance of the lamp does not differ from that of the ordinary carbon lamp. Fig. 9 shows typical distribution curves of the metallized filament lamp as it is installed in practice.

Fig. 10. Round Bulb Tantalum Lamp.

Metallic Filament Lamps. *The Tantalum Lamp.* The first of the metallic filament lamps to be introduced to any considerable extent commercially was the tantalum lamp. Dr. Bolton of the Siemens & Halske Company first discovered the methods of obtaining the pure metal tantalum. This metal is rendered ductile and drawn into slender filaments for incandescent lamps. Tantalum has a high tensile strength and high melting point, and tantalum filaments are operated at temperatures much higher than those used with the carbon filament lamp. On account of the comparatively low specific resistance of this material the filaments for 110-volt lamps must be long and slender, and this necessitates a special form of support. Figs. 10, 11, and 12 show some interesting views of the tantalum lamp and the filament. This lamp is operated at the efficiency of 2 watts per

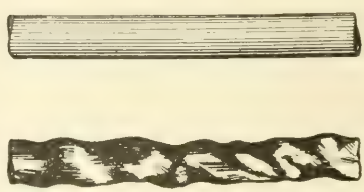


Fig. 11. Tantalum Filament Before and After 1,000 Hours' Use.

candle-power, with a life comparable to that of the ordinary lamp. By special treatment it is possible to increase the resistance of the filaments so that they may be shorter and heavier than those used in

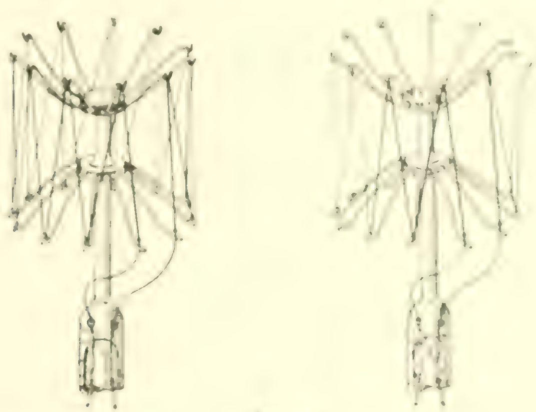


Fig. 12

Appearance of Filament After Having Been Used — [illegible]

the first of the tantalum lamps. It should be noted that the life of this type of lamp on alternating-current circuits is somewhat uncertain; it is much more satisfactory for operation on direct-current circuits. Tables III and IV give some general data on the tantalum lamp, and Figs. 13 and 14 show typical distribution curves for the units as installed at present.

TABLE III

Data on Tantalum Lamp

[illegible]

[illegible]		Diameter of Bulb in Inches	[illegible]	
[illegible]	[illegible]		[illegible]	[illegible]
40 watt		[illegible]	[illegible]	[illegible]
50 "		[illegible]	[illegible]	[illegible]
80 "		[illegible]	[illegible]	[illegible]
	40 watt	[illegible]	[illegible]	[illegible]
	80 "	[illegible]	[illegible]	[illegible]

TABLE IV

Data on the Life of a 25-C. P. Unit

No. of Hours Burned	Candle-Power	Watts per Candle
0	19.8	2.17
25	23.6	1.865
50	23.1	1.90
125	22.3	1.98
225	22.4	1.96
350	22.3	1.97
450	22.2	1.98
550	21.2	2.05
650	19.6	2.20

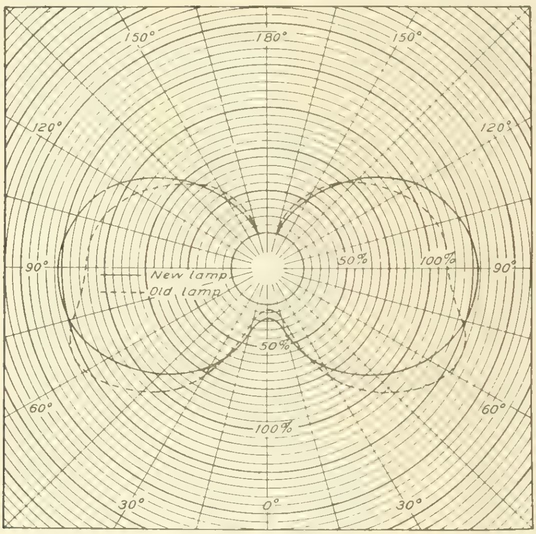


Fig. 13. Vertical Distribution Curve Without Reflector.

The Tungsten Lamp. Following closely upon the development of the tantalum lamp came the tungsten lamp. Tungsten possesses a very high melting point and an indirect method is employed in forming filaments for incandescent lamps. There are several of these methods in use. In one method a fine carbon filament is flashed in an atmosphere of tungsten oxychloride mixed with just the proper proportion of hydrogen, in which case the filament gradually changes to one of tungsten. A second method consists of the use of powdered tungsten and some binding material, sometimes organic and in other cases metallic. The powdered tungsten is mixed with the binding material, the paste squirted into filaments, and the binding material is then expelled, usually by the aid of heat. Another method of manufacture consists of securing tungsten in colloidal form, squirting it

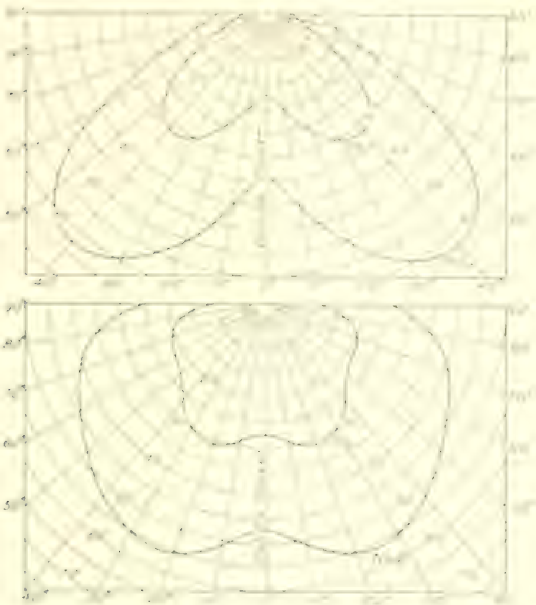


Fig. [illegible] Distribution Curves for Tungsten Lamp. [illegible]

into filaments, and then changing them to the metallic form by passing electric current through the filaments.

The tungsten lamp has the highest efficiency of any of the commercial forms of metallic filament lamps now in use, about 1.25 watts per candle-power when operated so as to give a normal life, and lamps for 100-volt service and consuming [illegible] watts have recently been put on the market. A 25-watt lamp for this same voltage appears to be a possibility. The units mentioned are those of high candle-power because of the difficulty of manufacturing the slender filaments required for the low candle-power lamps.

The advantages of these metals, tantalum and tungsten, for incandescent lamps are in the improved efficiency of the lamps and the good quality of the light, white or nearly white in both cases. In either case the change in candle-power with change in voltage is less than the corresponding change in an ordinary carbon lamp. The disadvantage lies in the fact that the filaments must be made long and slender, and hence are fragile, for low candle-power units to be used

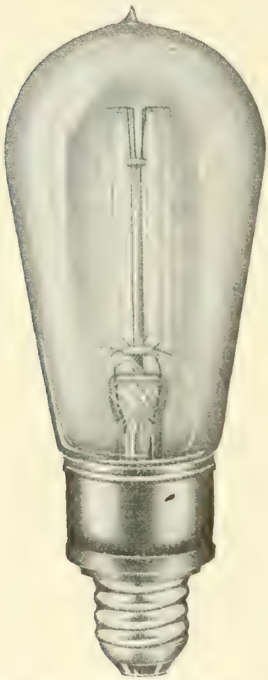


Fig. 15. Multiple Tungsten Lamp.

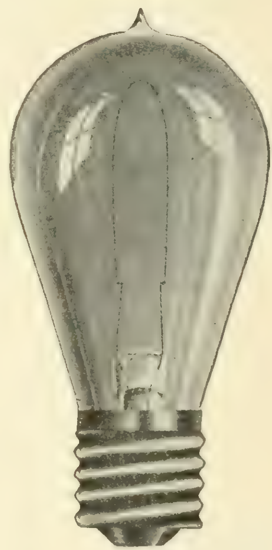


Fig. 16. Series Tungsten Lamp.

on commercial voltages. In some cases tungsten lamps are constructed for lower voltages and are used on commercial circuits through the agency of small step-down transformers. Improvements in the process of manufacture of filaments and of the method of their support have resulted in the construction of 110-volt lamps for candle-powers lower than was once thought possible. Figs. 15 and 16 show the appearance of the tungsten lamp, and Figs. 17 and 18 give some typical distribution curves. Tables V and VI give data on this lamp as it is manufactured at present. One very considerable application

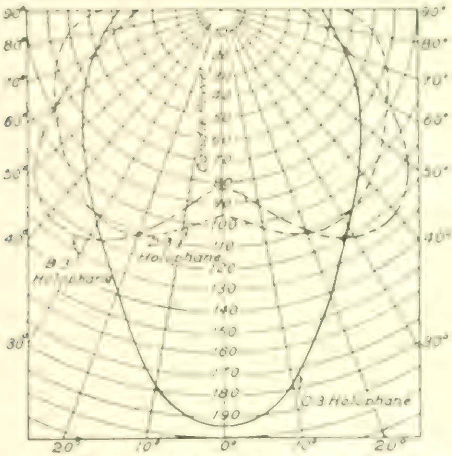


Fig. 17.—C. P. Distribution Curves of [illegible] Tungsten Incandescent Units with [illegible] Holophanes.

of the tungsten lamp is to incandescent street lighting on series circuits, in which case the lamp may be made for a low voltage across its terminals and the filament may be made comparatively short and

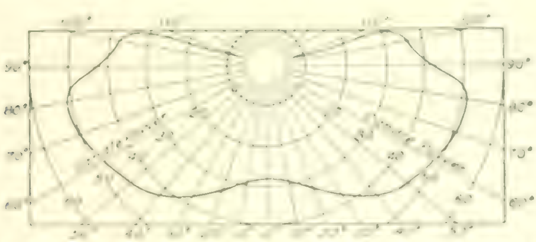


Fig. 18.—Candle-Power Distribution Curve with [illegible] Tungsten Street Lamp and [illegible] Wavy Reflector.

heavy. The tungsten lamp is also being introduced as a low voltage battery lamp.

The Just lamp, the Z lamp, the Osram lamp, the Zircon-Wolfram lamp, the Osmin lamp, etc., are all tungsten lamps, the filaments being prepared by some of the general methods already described or modifications of them.

TABLE V

Tungsten Lamps

MULTIPLE

Watts	Volts	Candle-Power	Watts per C. P.	Tip Candle-Power	Spherical Reduction Factor
40	100	32	1.25	5	76.3
60	125	40	1.25	5.6	76.3

TABLE VI

Tungsten Lamps

SERIES

Amperes	Volts	Candle-Power	Watts per C. P.
4	13.5	40	1.35
	20.25	60	
5.5	9.8	40	1.35
	14.7	60	
6.6	8.2	40	1.35
	12.3	60	
7.5	7.2	40	1.35
	10.8	60	

The Osmium Lamp. Very efficient incandescent lamps have been constructed using osmium for the filament. An indirect method is resorted to in the formation of these filaments. Osmium lamps have not been successful for commercial voltages because the filament is too fragile if it is made to have a high resistance, so these lamps must be operated in series or through the agency of reducing transformers if they are to be applied to 110-volt circuits. At 25 volts, lamps are constructed giving an efficiency of about 1.5 watts per candle-power with a life comparable to that of a 3.5-watt carbon lamp. Owing to the introduction of the tungsten lamp, the osmium lamp will probably never be used to any great extent.

Other Metallic Filament Lamps. Table VII gives the melting points of several metals which are highly refractory and those already mentioned are not the only ones which have been successfully used in incandescent lamps. Titanium, zirconium, iridium, etc., have been successfully employed, but the tantalum and tungsten lamps are the only ones which are used to any extent in the United States.

TABLE VII

Melting Point of Some Metals

Metal	Approximate Melting Point in Degrees C.
Tungsten	3000-3200
Titanium	2800
Tantalum	[illegible]
Osmium	2500
Platinum	[illegible]
Zirconium	[illegible]
Silicon	1500
Carbon (not a metal)	[illegible]

The Helion Lamp. The helion lamp, which gives considerable promise of commercial development, is a compromise between the carbon lamp and the metallic filament lamp. A slender filament of carbon is flashed in a compound of silicon (gaseous state) and a filament composed of a carbon core more or less impregnated with silicon and coated with a metallic layer is formed. The emissivity of such a filament is high, the light is white in color, and the filament is strong. The efficiency of the helion filament as far as it has been developed is higher than that of a carbon filament when operated at the same temperature. At 1,500 degrees C. the efficiency of the helion filament is 2.15 watts per candle-power, while for a carbon filament it is about 3.5 watts per candle-power. Filaments of this type have been made which may be heated to incandescence in open air without immediate destruction. This lamp is not yet on the market.

Fig. 19. Westinghouse-Nernst Single-Glower Lamp.

The Nernst Lamp. The Nernst lamp is still another form of incandescent lamp, several types of which are shown in Figs. 19, 20, 21, and 22. This lamp uses for the incandescent material certain oxides of the rare earths, the oxides being mixed in the form of a paste, then squirted through a die into a string which is subjected to a roasting process forming the filament or *glower* material of the lamp as represented by the lower white line in Fig. 23. The more recent glowers are made hollow instead of solid. The glowers are cut to the desired length and platinum terminals attached. The attachment of these terminals to the glowers is an important process in the manufacture of the lamp. The recent discovery of additional oxides has led to the construction of glowers which show a considerable gain in efficiency over those previously used. The glowers are heated to incandescence in open air, a vacuum not being required.

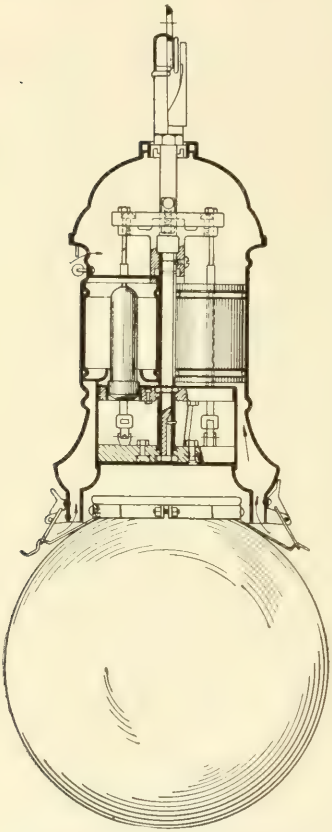


Fig. 20. Sectional View of Multiple-Glower Westinghouse Nernst Lamp.

As the glower is a non-conductor when cold, some form of *heater* is necessary to bring it up to a temperature at which it will conduct. Two forms of heater have been used. One of them consists of a porcelain tube shown just above the glower, Fig. 23, about which a fine platinum wire is wound; the wire is in turn coated with a cement. Two or more of these tubes are mounted directly over the glower, or glowers, and serve as a reflector as well as a heater. The second form of heater consists of a slender rod of refractory material about which a platinum wire is wound, the wire again being covered with a cement. This rod is then formed into a spiral which surrounds the glower in the vertical glower type, or is formed into the *wafer heater*, Fig. 24, now universally employed in the Westinghouse Nernst lamp with horizontal glowers. The wafer heater is bent so that it can be mounted with several sections parallel to the glower or glowers.

The heating device is connected across the circuit when the lamp is first turned on, and it must be cut out of circuit after the glowers become conductors in order to save the energy consumed by the

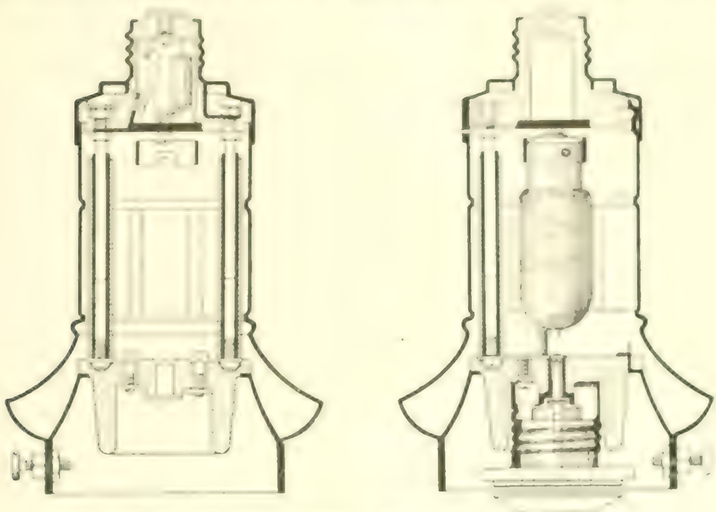


Fig. [illegible] Sectional Views of [illegible] Westinghouse Nernst Lamp

heater and to prolong the life of the heater. The automatic cut-out is operated by means of an electromagnet so arranged that current flows through this magnet as soon as the glower becomes a conductor, and contacts in the heater circuit are opened by this magnet. The contacts in the heater circuit are kept normally closed, usually by the force of gravity.

The conductivity of the glower increases with the increase of temperature—the material has a negative temperature coefficient—hence if it were used on a constant potential circuit directly, the current and temperature would continue to rise until the glower was destroyed. To prevent the current

Fig. [illegible] Westinghouse [illegible] Lamp from increasing beyond the desired value, a *ballast resistance* is used in series with the glower. As is well known, the resistance of iron wire increases quite rapidly with increase in temperature, and the resistance of a fine pure iron wire is so adjusted that the resistance of the combined circuit of the glower and the ballast becomes constant at the desired temperature of the glower. The iron wire must be protected from the air to prevent oxidization and too rapid temperature changes, and, for this reason, it is mounted in a glass bulb filled with hydrogen. Hydrogen has been selected for this purpose because it is an inert gas and conducts the heat from the ballast to the walls of the bulb better than other gases which might be used.

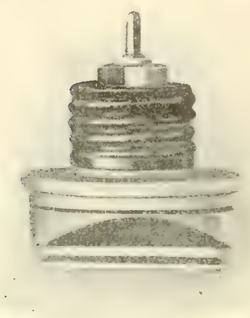


Fig. 23. Westinghouse Nernst Screw Burner with Globe Removed, Showing Glower and Tubular Heater.

All of the parts enumerated, namely, glower, heater, cut-out, and ballast, are mounted in a suitable manner; the smaller lamps have but one glower and are arranged to fit in an incandescent lamp socket, while the larger types are constructed at present with four glowers

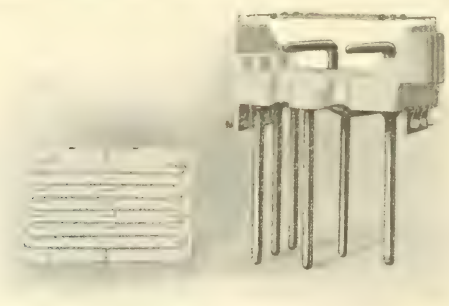


Fig. 24. Wafer Heater and Mounting.

and are arranged to be supported in special fixtures, or the same as small arc lamps. All parts are mechanically arranged so that renewals may be easily made when necessary and it is not possible to insert a part belonging to one type of lamp into a lamp of a different type.

The advantages claimed for the Nernst lamp are: High efficiency; a good color of light; a good distribution of light without the use of reflectors; a long life with low cost of maintenance; and a complete series of sizes of units, thus allowing its adaptation to practically all classes of illumination.

Fig. 25. Converter Coil

The lamp is constructed for both direct- and alternating-current service and for 110 and 220 volts. When the alternating-current lamp is used on a 110-volt circuit a small transformer, commonly called a *converter coil*, Fig. 25, is utilized to raise the voltage at the lamp terminals to about 220 volts.

Data on the Nernst lamp in its present form are given in Table VIII, and Figs. 26 and 27 show the form of distribution curves.

TABLE VIII

General Data on the Nernst Lamp

Lamp Rating in Watts	Voltage	Current in Amperes	Max. Candle-Power	Mean Hemispherical C. P.	Watts per M.H.C.P.	[illegible]	
66	110	.6	73	60	1.08	1 Glower	A.C. or D.C.
88	220	.4	105	77	1.2		
110	110 / 220	1.0 / .5	151	96.4	1.2		
132	110 / 220	1.2 / .6	166	114	1.2		
264	220	1.2	345	[illegible]	1.2	2 Glower	A.C. or D.C.
396	220	1.8	[illegible]	369	1.1	3 Glower	
528	220	2.4	[illegible]	504	1.05	4 Glower	

Comparison of the Different Types of Incandescent Lamps. A direct comparison of the different types of incandescent lamps cannot be made but it is desirable at this time to note the following points: The lamps which are considered commercial in the United States at the present time are the carbon, gem, tantalum, tungsten, and Nernst lamp. The efficiencies ordinarily accepted run in the order given, approximately 3.1, 2.5, 2, 1.25, and 1.2 watts per candle respectively. The figure of 1.2 watts per candle for the Nernst lamp is based upon the mean hemispherical candle-power and it should not be compared directly with the other efficiencies. The color of the light in all of the above cases is suitable for the majority of classes of illumination, the light from the higher efficiency units being somewhat whiter than that from the carbon lamp. All of these lamps are constructed for commercial voltages and for either direct or alternating current. The use of the tantalum lamp on alternating current is not

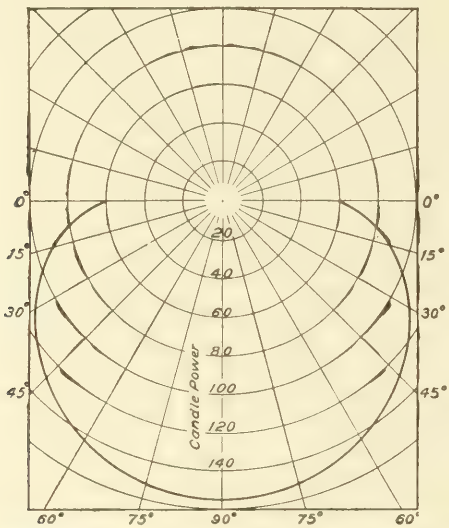


Fig. 26. Distribution Curve of 132-Watt Type Westinghouse Nernst Lamp. Single Glower.

always to be recommended as the service is unsatisfactory in some cases. The minimum size of units for 110 volts is about 4 candle-power for the carbon lamp, 20 candle-power for the metallic filament lamp, and 50 candle-power (mean hemispherical) for the Nernst lamp. Some of the metallic filament lamps are constructed for a consumption of as high as 250 watts, while the largest size of the Nernst lamp uses 528 watts. The light distribution of any of the units is subject to considerable variation through the agency of reflectors, but the Nernst lamp is ordinarily installed without a reflector. Practically all of the other units of high candle-power use reflectors and only a few of the typical curves of light distribution curves with reflectors have been shown in connection with the description of the lamps. The life of all of the commercial lamps described is considered as satisfactory. The minimum life is seldom less than 500 hours and the useful life is generally between 500 and 1,000 hours. On account of the slender filaments employed in the metallic filament

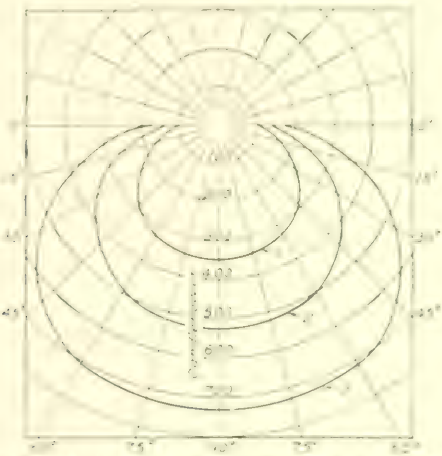


Fig. [illegible]. Distribution of Light from Multiple-Glower Westinghouse Nernst Lamps with 8" Clear Globes. No. 1, 2 Glowers; No. 2, 3 Glowers; No. 3, 4 Glowers.

lamps they are not made for low candle-powers at commercial voltages. The introduction of transformers for the purpose of changing the circuit voltage to one suitable for low candle-power units has not become at all general as yet in this country.

SPECIAL LAMPS

The Mercury Vapor Lamp. The mercury vapor lamp in this country is put on the market by the Cooper-Hewitt Electric Company and it is being used to a considerable extent for industrial illumination. In this lamp mercury vapor, rendered incandescent by the passage of an electric current through it, is the source of light. In its standard form this lamp consists of a long glass tube from which the air has been carefully exhausted, and which contains a small amount of metallic mercury. The mercury is held in a large bulb at one end of the tube and forms the negative electrode in the direct-current lamp. The other electrode is formed by an iron cup and the connections between the lamp terminals and the electrodes are of platinum where this connection passes through the glass. Fig. 28 gives the general appearance of a standard lamp having the following specifications:

Total watts (110 volts, 3.5 amperes) = 385
Candle-power (M. H. with reflector) = 700
Watts per candle = 0.55
Length of tube, total = 55 in.
Length of light-giving section = 45 in.
Diameter of tube = 1 in.
Height from lowest point of lamp to ceiling plate = 22 in.
For 220-volt service two lamps are connected in series.

The mercury vapor, at the start may be formed in two ways: First, the lamp may be tipped so that a stream of mercury makes contact between the two electrodes and mercury is vaporized when the stream breaks. Second, by means of a high inductance and a quick break switch, a very high voltage sufficient to pass a current from one electrode to the other through the vacuum, is induced and the conducting vapor is formed. The tilting method of starting is preferred and this tilting is brought about automatically in the more recent types of lamp. Fig. 29 shows the connections for automatically starting two lamps in series. A steadying resistance and reactance are connected as shown in this figure.

Fig. 28. Cooper-Hewitt Mercury Vapor Lamp.

The mercury vapor lamp is constructed in rather large units, the 55-volt, 3.5-ampere lamp being the smallest standard size. The color of the light emitted is objectionable for some purposes as there is an entire absence of red rays and the light is practically *monochromatic*. The illumination from this type of lamp is excellent where sharp contrast or minute detail is to be brought out, and this fact has led to its introduction for such classes of lighting as silk mills and cotton mills. On account of its color the application of this lamp is limited to the lighting of shops, offices, and drafting rooms, or to dis-

GOOD METHOD OF LIGHTING UP A DRESSER.

LIBERTY ENLIGHTENING THE WORLD

[illegible]

play windows where the goods shown will not be changed in appearance by the color of the light. It is used to a considerable extent in photographic work on account of the actinic properties of the light. Special reactances must be provided for a mercury arc lamp operating on single-phase, alternating-current circuits.

The Moore Tube Light. The Moore light makes use of the familiar Geissler tube discharge—discharge of electricity through a vacuum tube—as a source of illumination. The practical application of this discharge to a system of lighting has involved a large amount

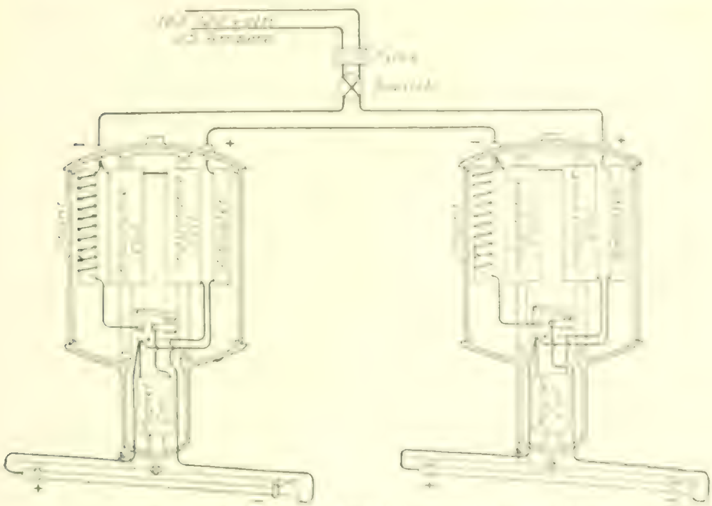


Fig. [illegible] Wiring Diagram. [illegible]

of consistent research on the part of the inventor and it has now been brought to such a stage that several installations have been made. The system has many interesting features.

In the normal method of installation, a glass tube $1\frac{3}{4}$ inches in diameter is made up by connecting standard lengths of glass tubing together until the total desired length is reached, and this continuous tube, which forms the source of light when in operation, is mounted in the desired position with respect to the plane of illumination. In many cases the tube forms a large rectangle mounted just beneath the ceiling of the room to be lighted. The tube may be of any reasonable length, actual values running from 40 to 220 feet. In order to provide an electrical discharge through this tube it is customary to lead both ends of the tube to the high tension terminals of a transformer, the low tension side of which may be connected to the alternating-current lighting mains. This transformer is constructed so that the high tension terminals are not exposed and the current is led into the tube by means of platinum wires attached to carbon electrodes. The electrodes are about eight inches in length. The ends of the tube and the high tension terminals are enclosed in a steel casing so as to effectually prevent anything from coming in contact with the high potential of the system. As stated, the low tension side of the transformer is connected to the usual 60-cycle lighting mains. If direct current is used for distribution, a motor-generator set for furnishing alternating current to the primary of the transformer is required. Any frequency from 60 cycles up is suitable for the operation of these tubes. At lower frequencies there is some appreciable variation of the light emitted. One other device is necessary for the suitable operation of this form of light and this is known as the *regulator*. In order to maintain a constant pressure inside the tube, and such a constant pressure is necessary for its satisfactory operation, there must be some automatic device which will allow a small amount of gas to enter the tube at intervals while it is in operation. The regulator accomplishes this purpose. Fig. 30 shows a diagram of the very simple connections of the system and gives the relative positions occupied by the transformer, tube, and regulator. Fig. 31 gives an enlarged view of the regulator, a description of which and its method of operation is given as follows:

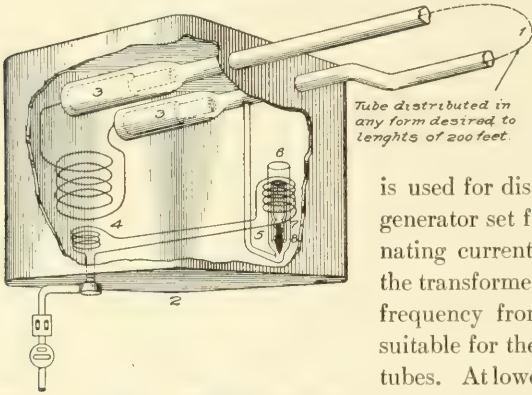
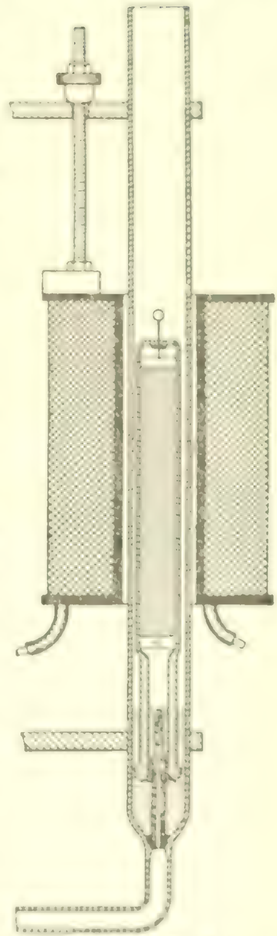


Fig. 30. Diagram Showing Essential Features of the Moore Light. 1. Lighting Tube; 2. Transformer Case; 3. Lamp Terminals; 4. Transformer; 5, 6, 7, 8, Regulators.

A piece of $\frac{7}{8}$-inch glass tubing is supported vertically and its bottom end is contracted into a $\frac{3}{8}$-inch glass tube which extends to the main lighting tube.

At the point of juncture at the bottom of the small tube there is sealed by means of cement a small carbon plug, the porosity of which is not great enough to allow mercury to permeate through it but which will permit gases easily to pass due to the high vacuum of the lighting tube connected to the lower end of the plug and approximately atmospheric pressure above it. This carbon plug is normally completely covered with what would correspond to a thimbleful of mercury which simply seals the pores of the carbon plug, and therefore has nothing whatever to do with the conducting properties of the gas in the main tube which produces the light. Partly immersed in the mercury and concentric with the carbon plug, is another smaller and movable glass tube, the upper end of which is filled with soft iron wire, which acts as the core of a small solenoid connected in series with the transformer. The action of the solenoid is to lift the concentric glass tube partly out of the mercury, the surface of which falls and thereby causes the minute tip of the conical shaped carbon plug to be slightly exposed for a second or two.



This exposure is sufficient to allow a small amount of gas to enter the tube, the current decreases slightly, and the carbon plug is again sealed. The process above described takes place at intervals of about one minute when the tube is in operation.

The color of the light emitted by the tube depends upon the gas used in it. The regulator is fitted with some chemical arrangement whereby the proper gas is admitted to it when the tube is in operation. Nitrogen is employed when the tube gives the highest efficiency and the light emitted when this gas is used is yellowish in color. Air gives a pink appearance to the tube and carbon dioxide is employed when a white light is desired.

Table IX gives general data on the Moore tube light. The advantages claimed for this light are: High efficiency, good color, and low intrinsic brilliancy.

TABLE IX

Data on the Moore Tube Light

Length of Tube	Transformer Capacity	Power Factor of Circuit	Voltage at Lamp Terminals
40–70 ft.	2 kw.	65–84%	3,146 for 40-ft. tube, at 12 hefners per ft.
80–125 "	2.75 "		
130–180 "	3.5 "		
190–220 "	4.5 "		12,441 for 220-ft. tube, at 12 hefners per ft.

Pressure in tube, about $\frac{1}{10}$ m.m.
Watts per hefner, 3.2 for 20-foot tube including transformer.
Watts per hefner, 1.4 for 180-foot tube including transformer.
Hefner per foot, normal, 12.
Note that one hefner equals 0.88 candle-power.

ARC LAMPS

The Electric Arc. Suppose two carbon rods are connected in an electric circuit, and the circuit closed by touching the tips of these rods together; on separating the carbons again the circuit will not be broken, provided the space between the carbons be not too great, but will be maintained through the arc formed at these points. This phenomenon, which is the basis of the arc light, was first observed on a large scale by Sir Humphrey Davy, who used a battery of 2,000 cells and produced an arc between charcoal points four inches apart.

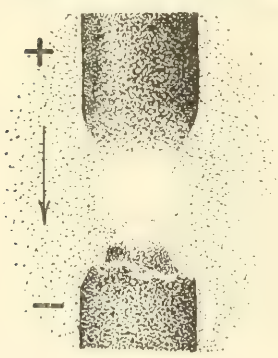


Fig. 32. The Electric Arc between Carbon Terminals.

As the incandescence of the carbons across which an arc is maintained, together with the arc itself, forms the source of light for a large portion of arc lamps, it will be well to study the nature of the arc. Fig. 32 shows the general appearance of an arc between two carbon electrodes when maintained by direct current.

Here the current is assumed as passing from the top carbon to the bottom one as indicated by the arrow and signs. We find, in the direct-current arc, that the most of the light comes from the tip of the positive carbon, or electrode, and this portion is known as the crater of the arc. This crater has a temperature of from 3,000° to 3,500° C., the temperature at which the carbon vaporizes, and gives fully 80 to 85% of the light furnished by the arc. The negative carbon becomes pointed at the same time that the positive one is hollowed out to form the crater, and it is also incandescent but not to as great a degree as the positive carbon. Between the electrodes there is a band of violet light, the *arc proper*, and this is surrounded by a luminous zone of a golden yellow color. The arc proper does not furnish more than 5% of the light emitted when pure carbon electrodes are used.

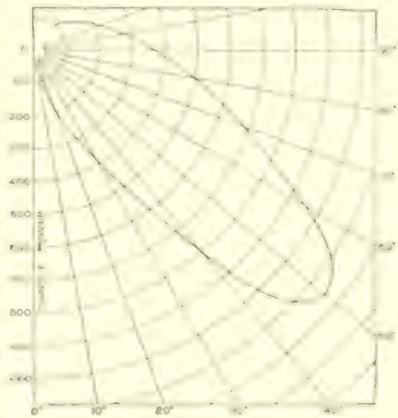


Fig. 33. Distribution Curve for D. C. Arc Lamp; Vertical Plane.

The carbons are worn away or consumed by the passage of the current, the positive carbon being consumed about twice as rapidly as the negative.

The light distribution curve of a *direct-current arc*, taken in a vertical plane, is shown in Fig. 33. Here it is seen that the maximum amount of light is given off at an angle of about 50° from the vertical, the negative carbon shutting off the rays of light that are thrown directly downward from the crater.

If alternating current is used, the upper carbon becomes positive and negative alternately, and there is no chance for a crater to be formed, both carbons giving off the same amount of light and being consumed at about the same rate. The light distribution curve of an *alternating-current arc* is shown in Fig. 34.

Arc Lamp Mechanisms. In a practical lamp we must have not only a pair of carbons for producing the arc, but also means for supporting these carbons, together with suitable arrangements for feeding the current to them and for maintaining them at the proper distance apart. The carbons are kept separated the proper distance by the operating mechanisms which must perform the following functions:

1. The carbons must be in contact, or be brought into contact, to start the arc when the current first flows.

2. They must be separated at the right distance to form a proper arc immediately afterward.

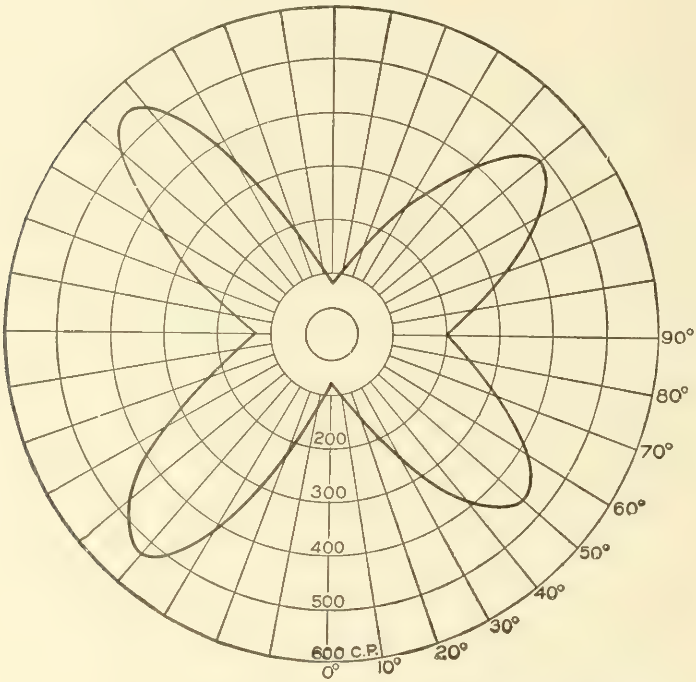


Fig. 34. Distribution Curve for A. C. Arc Lamp (Vertical Plane).

3. The carbons must be fed to the arc as they are consumed.

4. The circuit should be open or closed when the carbons are entirely consumed, depending on the method of power distribution.

The feeding of the carbons may be done by hand, as is the case in some stereopticons using an arc, but for ordinary illumination the striking and maintaining of the arc must be automatic. It is made so in all cases by means of solenoids acting against the force of gravity or against springs. There are an endless number of such mechanisms, but a few only will be described here. They may be roughly divided into three classes:

1. Shunt mechanisms.
2. Series mechanisms.
3. Differential mechanisms.

Shunt Mechanisms. In shunt lamps, the carbons are held apart before the current is turned on, and the circuit is closed through a solenoid connected in across the gap so formed. All of the current must pass through this coil at first, and the plunger of the solenoid is arranged to draw the carbons together, thus starting the arc. The pull of the solenoid and that of the springs are adjusted to maintain the arc at its proper length.

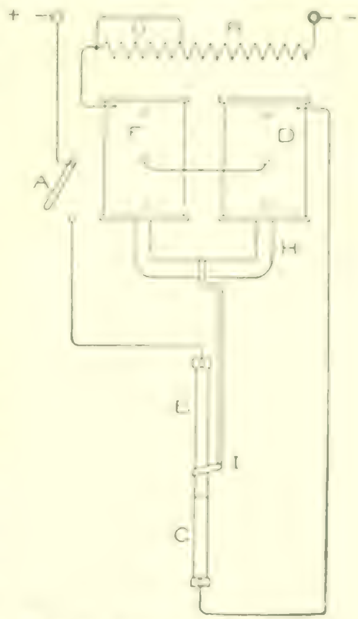


Fig. 15. Series Mechanism for D. C. Arc Lamp.

Such lamps have the disadvantage of a high resistance at the start—150 ohms or more—and are difficult to start on series circuits, due to the high voltage required. They tend to maintain a constant voltage at the arc, but do not aid the dynamo in its regulation, so that the arcs are liable to be a little unsteady.

Series Mechanisms. With the series-lamp mechanism, the carbons are together when the lamp is first started and the current, flowing in the series coil, separates the electrodes, striking the arc. When the arc is too long, the resistance is increased and the current lowered so that the pull of the solenoid is weakened and the carbons feed together. This type of lamp can be used only on constant-potential systems.

Fig. 15 shows a diagram of the connection of such a lamp. This diagram is illustrative of the connection of one of the lamps manufactured by the Western Electric Company, for use on a direct-current, constant-potential system. The symbols + and − refer to the terminals of the lamp, and the lamp must be so connected that the current flows from the top carbon to the bottom one. *R* is a series resistance, adjustable for different voltages by means of the shunt *G*. *F* and *D* are the controlling solenoids connected in series with the arc. *B* and *C* are the positive and negative carbons respectively, while *A* is the switch for turning the current on and off. *H* is the plunger of the solenoids and *I* the carbon clutch, this being what is known as a *carbon-feed lamp.* The carbons are together when *A* is first closed, the current is excessive, and the plunger is drawn up into the solenoids, lifting the carbon *B* until the resistance of the arc lowers the current to such a value that the pull of the solenoid just counterbalances the weight of the plunger and carbon. *G* must be so adjusted that this point is reached when the arc is at its normal length.

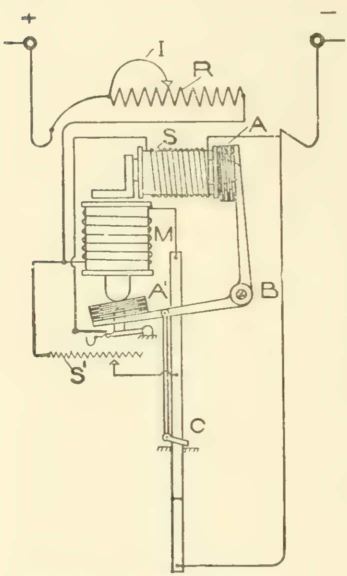


Fig. 36. Differential Mechanism for D. C. Arc Lamp.

Differential Mechanisms. In the differential lamp, the series and shunt mechanisms are combined, the carbons being together at the start, and the series coil arranged so as to separate them while the shunt coil is connected across the arc, as before, to prevent the carbons from being drawn too far apart. This lamp operates only over a low-current range, but it tends to aid the generator in its regulation.

Fig. 36 shows a lamp having a differential control, this also being the diagram of a Western Electric Company arc lamp for a direct-current, constant-potential system. Here *S* represents the shunt coil and *M* the series coil, the armature of the two magnets *A* and *A'* being attached to a bell-crank, pivoted at *B*, and attached to the carbon clutch *C*. The pull of coil *S* tends to lower the carbon while that of *M* raises the carbon, and the two are so adjusted that equilibrium is reached when the arc is of the proper length. All of the lamps are fitted with an air dashpot, or some damping device to prevent too rapid movements of the working parts.

The methods of supporting the carbons and feeding them to the arc may be divided into two classes:

1. Rod-feed mechanism.
2. Carbon-feed mechanism.

Rod-Feed Mechanism. Lamps using a rod feed have the upper carbons supported by a conducting rod, and the regulating mechanism acts on this rod, the current being fed to the rod by means of a sliding contact. Fig. 37 shows the arrangement of this type of feed. The rod is shown at *R*, the sliding contact at *B*, and the carbon is attached to the rod at *C*.

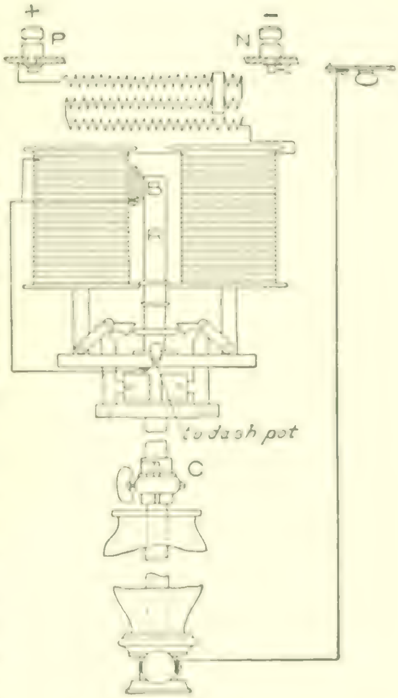


Fig. 37. Rod-Feed Mechanism.

These lamps have the advantage that carbons, which do not have a uniform cross-section or smooth exterior, may be used, but they possess the disadvantage of being very long in order to accommodate the rod. The rod must also be kept clean so as to make a good contact with the brush.

Carbon-Feed Mechanism. In carbon-feed lamps the controlling mechanism acts on the carbons directly through some form of clutch such as is shown at *C* in Fig. 38. This clamp grips the carbon when it is lifted, but allows the carbon to slip through it when the tension is released. For this type of feed the carbon must be straight and have a uniform cross-section as well as a smooth exterior. The current may be led to the carbon by means of a flexible lead and a short carbon holder.

TYPES OF ARC LAMPS

Arc lamps are constructed to operate on *direct-current* or *alternating-current* systems when connected in *series* or in *multiple*. They are also made in both the *open* and the *enclosed* forms.

By an *open arc* is meant an arc lamp in which the arc is exposed to the atmosphere, while in the *enclosed arc* an inner or enclosing

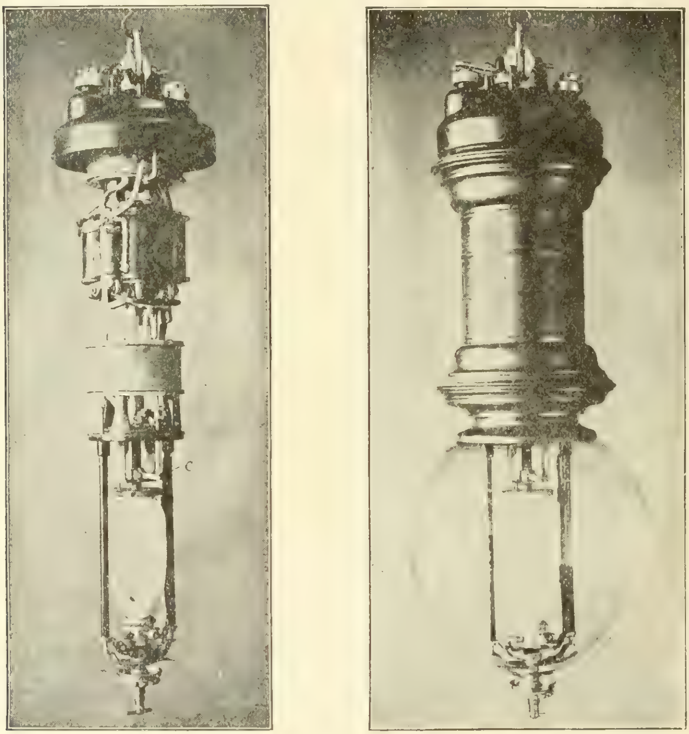


Fig. 38. Enclosed Arc Lamp with Carbon-Feed Mechanism.

globe surrounds the arc, and this globe is covered with a cap which renders it nearly air-tight. Fig. 38 is a good example of an enclosed arc as manufactured by the General Electric Company.

Direct-Current Arcs. *Open Types of Arcs* for direct-current systems were the first to be used to any great extent. When used they are always connected in series, and are run from some form of special arc machine, a description of which may be found in "Types of Dynamo Electric Machinery."

Each lamp requires in the neighborhood of 50 volts for its operation, and, since the lamps are connected in series, the voltage of the system will depend on the number of lamps; therefore, the number of lamps that may be connected to one machine is limited by the maximum allowable voltage on that machine. By special construction as many as 125 lamps are run from one machine, but even this size of generator is not so efficient as one of greater capacity. Such generators are usually wound for 6.6 or 9.6 amperes. Since the carbons are exposed to the air at the arc, they are rapidly consumed, requiring that they be renewed daily for this type of lamp.

Double-carbon arcs. In order to increase the life of the early form of arc lamp without using too long a carbon, the double-carbon type was introduced. This type uses two sets of carbons, both sets being fed by one mechanism so arranged that when one pair of the electrodes is consumed the other is put into service. At present nearly all forms of the open arc lamp have disappeared on account of the better service rendered by the enclosed arc.

Enclosed arcs for series systems are constructed much the same as the open lamp, and are controlled by either shunt or differential mechanism. They require a voltage from 68 to 75 at the arc, and are usually constructed for from 5 to 6.8 amperes. They also require a constant-current generator or a rectifier outfit if used on alternating-current circuits.

Constant-potential arcs must have some resistance connected in series with them to keep the voltage at the arc at its proper value. This resistance is made adjustable so that the lamps may be used on any circuit. Its location is clearly shown in Fig. 38, one coil being located above, the other below the operating solenoids.

Alternating-Current Arcs. These do not differ greatly in construction from the direct-current arcs. When iron or other metal parts are used in the controlling mechanism, they must be laminated or so constructed as to keep down induced or eddy currents which might be set up in them. For this reason the metal spools, on which the solenoids are wound, are slotted at some point to prevent them from forming a closed secondary to the primary formed by the solenoid winding. On constant-potential circuits a reactive coil is used in place of a part of the resistance for cutting down the voltage at the arc.

Interchangeable Arc. Interchangeable arcs are manufactured which may be readily adjusted so as to operate on either direct or alternating current, and on voltages from 110 to 220. Two lamps may be run in series on 220-volt circuits.

The distribution of light, and the resulting illumination for the different lamps just considered, will be taken up later. Aside from the distribution and quality of light, the enclosed arc has the advantage that the carbons are not consumed so rapidly as in the open lamp because the oxygen is soon exhausted from the inner globe and the combustion of the carbon is greatly decreased. They will burn from 80 to 100 hours without retrimming.

TABLE X

Rating of Enclosed Arcs

D. C. Lamp	Current	Watts Consumed: In Lamp	Watts Consumed: In Arc	Watts Consumed: Mechanism	Mean Intensity in H. U.: Spherical: Opal Outer	Mean Intensity in H. U.: Spherical: Clear Outer	Mean Intensity in H. U.: Lower Hemi-spherical: Clear Outer	Mean Watts: Spherical H. U.: Opal Outer	Mean Watts: Spherical H. U.: Clear Outer	Mean Watts: Lower Hemi-spherical: Clear Outer
						235	332		2.37	1.66
1	5.01	551	401	150	172	256*	362*	3.10	2.18*	1.52*
3	5.08	559	406	252	195	216	282	2.85	2.60	1.99
4	4.76	524	381	143	127	139	208	4.12	3.76	2.52
5	4.16†	458	333	125	154	174	221	2.96	2.63	2.07
7	4.76	524	381	143	203	333	317	2.63	2.20	1.65
9	4.84	532	387	145	182	226	281	2.83	2.38	1.89
10	4.99	549	399	150	202	242	309	2.74	2.24	1.77
12	4.87	536	390	146	178	195	230	3.05	2.66	2.33
Mean	4.9	529	384	144	176	207	272	3.03	2.60	1.98

A. C. Lamp	Current	In Lamp	Power Factor Lamp	In Arc	Power Factor Arc	Mechanism	Spherical: Opal Outer	Spherical: Clear Outer	Lower Hemi-spherical: Clear Outer	Mean Watts: Opal Outer	Mean Watts: Clear Outer	Mean Watts: Lower Hemi-spherical: Clear Outer
101	6.40	448	.63	340	.82	108	127	141	206	3.52	3.17	2.17
								203	236		2.26	1.94
102	6.79	459	.61	375	.73	84	146	176†	226†	3.31	2.60†	1.72†
103	5.89	424	.65	344	.75	80	116	130	147	3.66	3.15	2.88
105	6.20	414	.61	382	.80	32	128	187	219	3.24	2.20	1.89
								153	169		2.56	2.23
106	6.12	378	.56	298	.70	80	132	182†	284	2.82	2.19†	1.48†
108	6.48	457	.64	383	.80	74.5	133	175	211	3.20	2.61	2.16
110	6.18	339	.49	276	.72	63	140*	126	143	2.41*	2.68	2.37
Mean	6.29	417	.60	342	.76	74.5	130	159	190	3.31	2.66	2.23

*Condition of no outer globe. †Condition with shade on lamp. H.U. Hefner Units.

Rating of Arc Lamps. Open arcs have been classified as follows:

Full Arc, 2,000 candle-power taking 9.5 to 10 amps. or 450–480 watts.
Half Arc, 1,200 candle-power taking 6.5 to 7 amps. or 325–350 watts.

These candle-power ratings are much too high, and run more nearly 1,200 and 700, respectively, for the point of maximum intensity and less than this if the mean spherical candle-power be taken. For this reason, the ampere or watt rating is now used to indicate the power of the lamp. It is now recommended that specifications for street lighting should be based upon the illumination produced. This point is considered later under the topic of street lighting. Enclosed arcs use from 3 to 6.5 amperes, but the voltage at the arc is higher than for the open lamp. Table X gives some data on enclosed arcs on constant-potential circuits.

Efficiency. The efficiency of arc lamps is given as follows:

Direct-Current Arc (enclosed) 2.9 watts per candle-power.
Alternating-Current Arc (enclosed) 2.95 watts per candle-power.
Direct-Current Arc (open) .6–1.25 watts per candle-power.

Carbons for Arc Lamps. Carbons are either moulded or forced from a product known as *petroleum coke* or from similar materials such as *lampblack*. The material is thoroughly dried by heating to a high temperature, then ground to a find powder, and combined with some substance such as pitch which binds the fine particles of carbon together. After this mixture is again ground it is ready for moulding. The powder is put in steel moulds and heated until it takes the form of a paste, when the necessary pressure is applied to the mould. For the forced carbons, the powder is formed into cylinders which are placed in machines which force the material through a die so arranged as to give the desired diameter. The forced carbons are often made with a core of some special material, this core being added after the carbon proper has been finished. The carbons, whether moulded or forced, must be carefully baked to drive off all volatile matter. The forced carbon is always more uniform in quality and cross-section, and is the type of carbon which must be used in the carbon-feed lamp. The adding of a core of a different material seems to change the quality of light, and being more readily volatilized, keeps the arc from wandering.

Plating of carbons with copper is sometimes resorted to for moulded forms for the purpose of increasing the conductivity, and, by protecting the carbon near the arc, prolonging the life.

The Flaming Arc. In the carbon arc the arc proper gives out but a small percentage of the total amount of light emitted. In order to obtain a light in which more of the source of luminosity is in the arc itself, experiments have been made with the use of electrodes impregnated with certain salts, as well as with electrodes of a material different than carbon. The result of these experiments has been to place upon the market the flaming arc lamps and the luminous arc lamps—lamps of high candle-power, good efficiency, and giving various colors of light. These lamps may be put in two classes: One class uses carbon electrodes, these electrodes being impregnated with certain salts which add luminosity to the arc, or else fitted with cores which contain the required material; the other class covering lamps which do not employ carbon, the most notable example being the magnetite arc which uses a copper segment as one electrode and a magnetite stick as the other electrode.

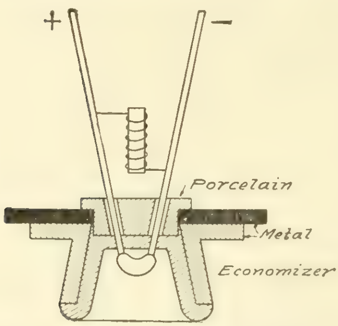


Fig. 39. Diagram of Bremer Flaming Arc.

Flaming arcs of the first class are made in two general types: One in which the electrodes are placed at an angle, and the other in which the carbons are placed one above the other as in the ordinary arc lamp. The term luminous arc is usually applied to arcs of the flaming type in which the electrodes are placed one above the other. The minor modifications as introduced by the various manufacturers are numerous and include such features as a magazine supply of electrodes by which a new pair may be automatically introduced when one pair is consumed; feed and control mechanisms; etc. The flaming arc presents a special problem since the vapors given off by the lamp may condense on the glassware and form a partially opaque coating, or they may interfere with the control mechanism.

Bremer Arc. The Bremer flaming arc lamp was introduced commercially in 1899, and since some of its principles are incorporated in many of the lamps on the market to-day, it will be briefly described here. The diagram shown in Fig. 39 illustrates the main features of this lamp. The electrodes are mounted at an angle and an electromagnet is placed above the arc for the purpose of keeping the arc from creeping up and injuring the economizer, and also for the purpose of spreading the arc out and increasing its surface. The vapor from the arc is condensed on the economizer and this coating acts as a reflector, throwing the light downward. The economizer serves to limit the air supplied to the arc and thus increases the life of the electrodes. The inclined position of the carbons was suggested by the fact that in the impregnated carbons a slag was formed which gave trouble when the electrodes were mounted in the usual manner. By using the electrodes in this position there is little if any obstruction to the light which passes directly downward from the arc.

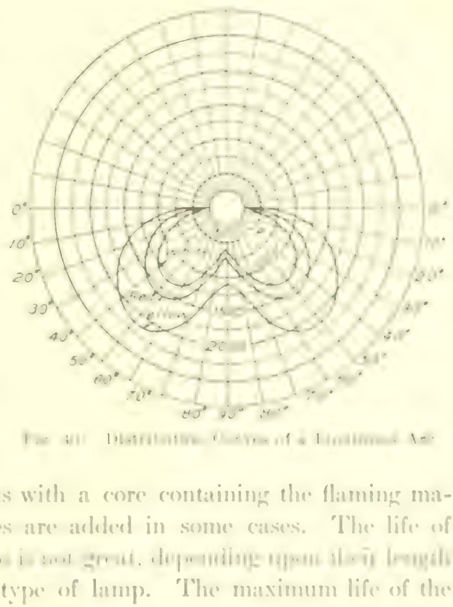


Fig. [illegible]. Distribution Curves of a Flaming Arc

Bremer's original electrodes contained compounds of calcium, strontium, magnesium, etc., as well as boracic acid. Electrodes as employed in the various lamps to-day differ greatly in their make-up. Some use impregnated carbons, others use carbons with a core containing the flaming materials, and metallic wires are added in some cases. The life of electrodes for flaming lamps is not great, depending upon their length and somewhat upon the type of lamp. The maximum life of the treated carbons is in the neighborhood of 20 hours.

The color of the light from the flaming arc is yellow when calcium salts are used as the main impregnating compound, and the majority of the lamps installed use electrodes giving a yellow light. By employing more strontium, a red or pink light is produced, while if a white light is wanted, barium salts are used. Calcium gives the most efficient service and strontium comes between this and barium. The distribution curves in Fig. 40 illustrate the relative economies of the different materials. Modern electrodes contain not more than 15% of added material and it is customary to find the salts applied as a core to the pure carbon sticks. The electrodes are made of a small diameter in order to maintain a steady light and this partially accounts for their short life.

The feeding mechanisms employed differ greatly. They may be classified as: Clock, gravity-feed, clutch, motor, and hot-wire mechanisms. Fig. 41 illustrates a clock mechanism. This is a differential mechanism in which the shunt coils act to release a detent *f* which allows the electrodes to feed down and when they come in contact the series coils separate them to the proper extent for maintaining a suitable arc. In the gravity feed an electromagnet is used to operate one carbon in springing the arc and the other carbon is fed by gravity, it being prevented from dropping too far by means of a special rib formed on the electrode which comes in contact with a part of the lamp structure. Gravity feed is also employed in the clutch mechanism but here the carbons are held in one position by an electrically operated clutch which releases them only when the current is sufficiently reduced by the lengthening of the arc. In the hot-wire lamp, the wire is usually in series with the arc; the contraction and expansion of this wire is balanced against a spring and the arc is regulated by such contraction or expansion of the wire. Such a lamp is suitable for either direct or alternating current. In the motor mechanism, as applied to alternating-current lamps, a metallic disk is actuated by differential magnets and its motion is transmitted to the electrodes to lengthen or shorten the arc accordingly as the force exerted by the series or shunt coils predominates.

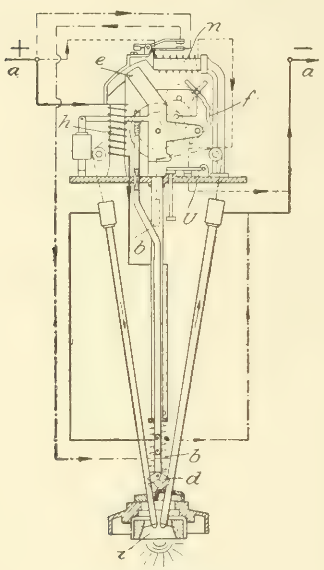


Fig. 41. Clock Feeding Mechanism for Luminous Arc Lamp.

Magnetite Arc. The magnetite arc employs a copper disk as

LIVING ROOM IN ALPHA DELTA PHI CHAPTER-HOUSE AT CORNELL UNIVERSITY, ITHACA, N. Y.

Dean & Dean, Architects, Chicago, Ill.

Oak Stained a Gray Green and Waxed; Furniture to Match; Plaster Stained and Waxed. For Plans and Exterior, See Vol. III, Pages 282 and 298; for other Interiors, see Page 154 in this Volume.

GAS AND ELECTRIC FIXTURE IN LIVING ROOM OF ALPHA DELTA PHI CHAPTER-HOUSE
AT CORNELL UNIVERSITY, ITHACA, N. Y.

Dean & Dean, Architects, Chicago, Ill.

Corrugated Mirror in the Iron Frame, Iron Brackets and Leaded Glass Screen.

one electrode, and a magnetite stick—formed by forcing magnetite, to which titanium salts are usually added, into a thin sheet steel tube—is used as the other electrode. This lamp gives a luminous arc of good efficiency and the magnetite electrode is not consumed as rapidly as the treated carbons with the result that magnetite lamps do not require trimming as frequently. The life of the magnetite electrode as at present manufactured is from 170 to 200 hours. A diagram of the connections of this lamp as manufactured by the General Electric

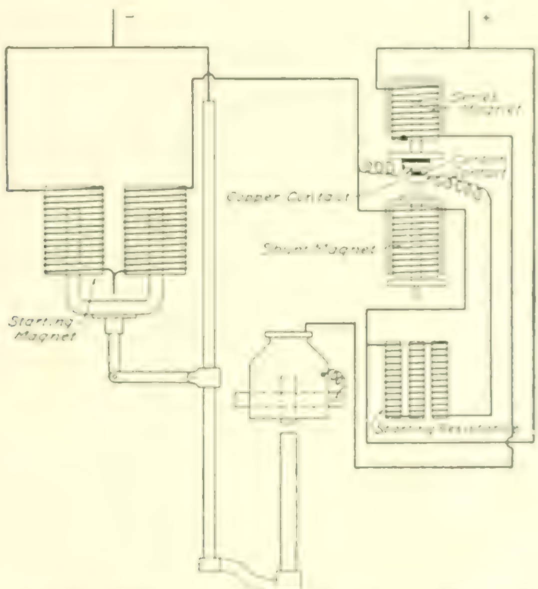


Fig. 42.—Diagram of Connections for Magnetite Arc Lamp.

Company is shown in Fig. 42. The magnetite electrode is placed below. The copper electrode has just the proper dimensions to prevent its being destroyed by the arc and yet it is not large enough to cause undue condensation of the arc vapor. Direct current must be used with this lamp, the current passing from the copper to the magnetite.

Table XI gives some general data on the flaming arc, while Figs. 43 and 44 give typical distribution curves. The advantages of the flaming arc over lamps using pure carbon electrodes are: High efficiency; better light distribution, and better color of light for some purposes. A greater amount of light can be obtained from a single unit than is practical with the carbon arc. The disadvantages lie in the frequent trimming required and the expense of electrodes. Flaming arcs have been introduced abroad, especially in Germany, to a much greater extent than in the United States.

TABLE XI

General Data on Flaming Arcs

Volts	Amperes	Watts	Mean Spherical Candle-Power	Watts per Mean Spherical C. P.
55	6	330	480	.68
	8	440	800	.55
	10	550	1100	.5
	12	660	1300	.5
	15	825	1700	.49
	20	1100	2250	.48

POWER DISTRIBUTION

The question of power distribution for electric lamps and other appliances is taken up fully in the section on that subject, therefore it will be treated very briefly here. The systems may be divided into:

1. Series distribution systems.
2. Multiple-series or series-multiple systems.
3. Multiple or parallel systems.

They apply to both alternating and direct current.

The Series System. This is the most simple of the three; the lamps, as the name indicates, are connected in series as shown in Fig. 45. A constant load is necessary if a constant potential is to be used. If the load is variable, a constant-current generator, or a special regulating device is necessary. Such devices are constant-current transformers and constant-current regulators as applied to alternating-current circuits.

The series system is used mostly for arc and incandescent lamps when applied to street illumination. Its advantages are simplicity and saving of copper. Its disadvantages are high voltage, fixed by the number of lamps in series; the size of the machines is limited since they cannot be insulated for voltage above about 6,000; a single open circuit shuts down the whole system.

Alternating-current series distribution systems are being used to a very large extent. By the aid of special transformers, or regulators, any number of circuits can be run from one machine or set of bus bars, and apparatus can be built for any voltage and of any size. It is not customary, however, to build transformers of this type having a capacity greater than one hundred 6.6-ampere lamps because of the high voltage which would have to be induced in the secondary for a larger number of lamps.

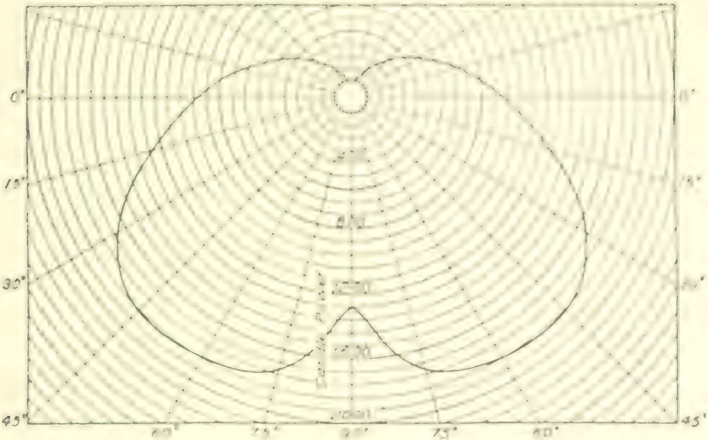


Fig. 43. Distribution Curve for Flaming Arc Lamps

Fig. 45 gives a diagram of the connection of a single-coil transformer in service. The constant-current transformer most in use for lighting purposes is the one manufactured by the General Electric Company and commonly known as a *tub transformer*. Fig. 46 shows such a transformer (double-coil type) when removed from the case.

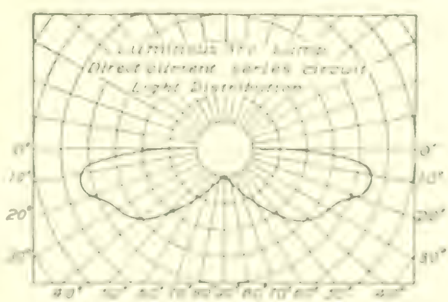


Fig. 44. Distribution Curve for 6.6-Ampere, 75-Volt, Magnetite Luminous Arc Lamp

Referring to Fig. 46, the fixed coils *A* form the primaries which are connected across the line; the movable coils *B* are the secondaries connected to the lamps. There is a repulsion of the coils B by the coils A when the current flows in both circuits and this force is balanced by means of the weights at W, so that the coils B take a position such that the normal current will flow in the secondary. On light loads, a low voltage is sufficient, hence the secondary coils are close together near the middle of the machine and there is a heavy magnetic leakage. When all of the lamps are on, the coils take the position shown when the leakage is a minimum and the voltage a maximum. When first starting up, the transformer is short-circuited and the secondary coils brought close together. The short circuit is then removed and the coils take a position corresponding to the load on the line.

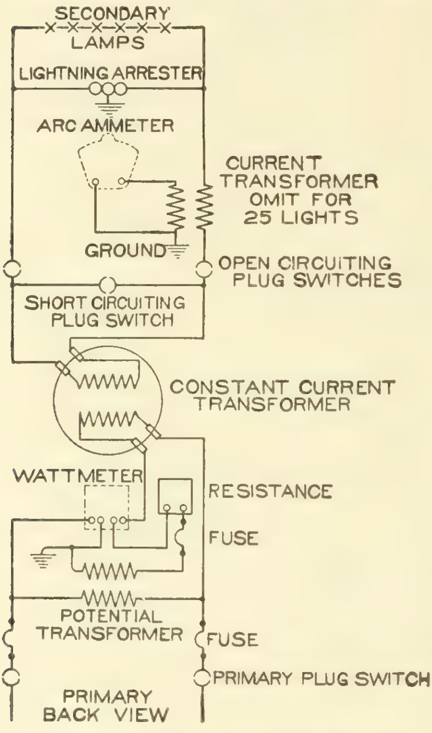
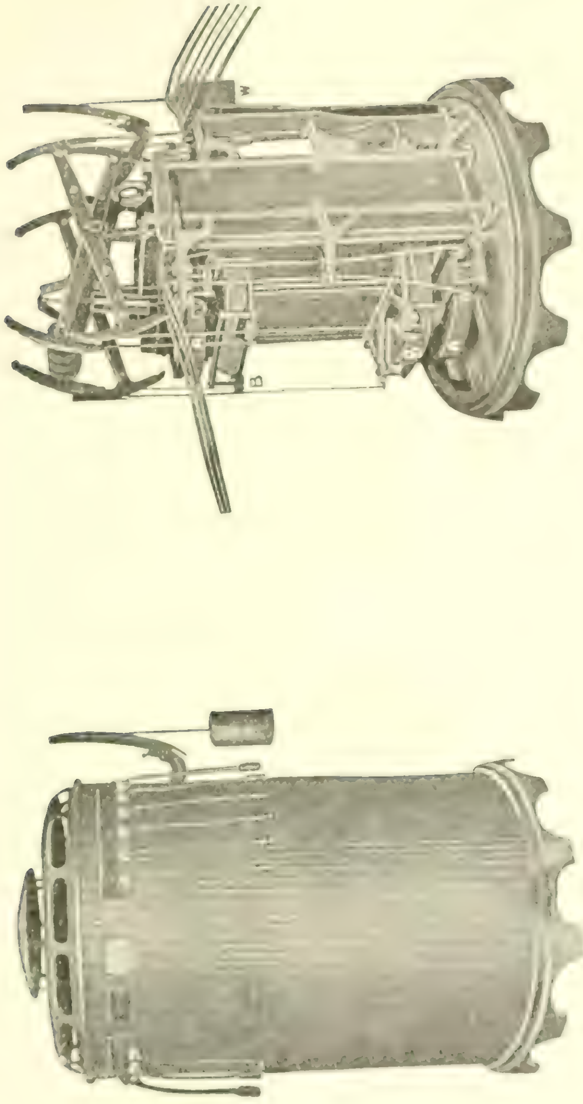


Fig. 45. Wiring Diagram for Single-Coil Transformer.

These transformers regulate from full load to $\frac{1}{3}$ rated load within $\frac{1}{10}$ ampere of normal current, and can be run on short circuit for several hours without overheating. The efficiency is given as 96% for 100-light transformers and 94.6% for 50-light transformers at full load. The power factor of the system is from 76 to 78% on full load, and, owing to the great amount of magnetic leakage at less than full load—the effect of leakage being the same as the effect of an inductance in the primary—the power factor is greatly reduced, falling to 62% at $\frac{3}{4}$ load, 44% at $\frac{1}{2}$ load, and 24% at $\frac{1}{4}$ load.

Standard sizes are for capacities of 25-, 35-, 50-, 75-, and 100-6.6 ampere enclosed arcs, and they are also made for lower currents in


B

the neighborhood of 3.3 amperes for incandescent lamps. The low power factor of such a system on light loads shows that a transformer should be selected of such a capacity that it will be fully or nearly fully loaded at all times. The primary winding can be constructed for any voltage and the open circuit voltages of the secondaries are as follows:

25 light	transformer,	2,300 volts.		75 light	transformer,	6,900 volts.	
35	"	"	3,200 "	100	"	"	9,200 "
50	"	"	4,600 "				

The 50-, 75-, and 100-light transformers are arranged for multiple circuit operation, two circuits used in series, and the voltages at full load reach 4,100 for each circuit on the 100-light machine.

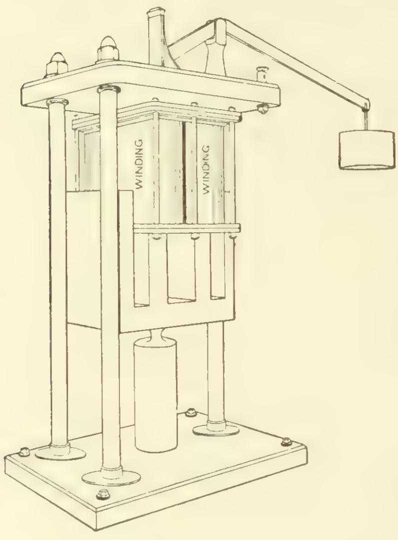


Fig. 47. Current Regulator for A. C. Series Distribution Systems.

The second system, used for series distribution on alternating-current circuits consists of a constant-potential transformer, stepping down the line voltage to that required for the total number of lamps on the system, allowing 83 volts for each lamp, and in series with the lamps is a reactive coil, the reactance of which is automatically regulated, as the load is increased or decreased, in order to keep the current in the line constant. Fig. 47 shows such a regulator and Fig. 48 shows this regulator connected in circuit. The inductance is varied by the movement of the coil so as to include more or less iron in the magnetic circuit. Since the inductance in series with the lamps is high on light loads, the power factor is greatly reduced as in the constant-current transformer; and the circuits should, preferably, be run fully loaded. 60 to 65 lamps on a circuit is the usual maximum limit.

While used primarily for arc-light circuits, the same systems, designed for lower currents, are very readily applied to series incandescent systems.

The introduction of certain flaming or luminous arcs requiring direct current for their operation has led to the use of the *mercury arc rectifier* in connection with series circuits on alternating-current systems. A constant-current transformer is used to regulate for the proper constant current in its secondary winding, and this secondary current is rectified by means of the mercury arc rectifier for the lamp circuit. In the recent outfits the rectifier tubes are immersed in oil for cooling. While this rectifier was first introduced for the operation of luminous arc lamps, there is no reason why it should not be used with any series lamp requiring direct current, provided the system is designed for the current taken by such lamps. With this system any commercial frequency may be used. Sets are constructed for 25-, 50-, and 75-light circuits. They have a combined efficiency, transformer and rectifier tube, of 85% to 90%, and operate at a power factor of from 65% to 70%. Fig. 49 gives a diagram of the circuit and rectifier connections used with a single-tube outfit.

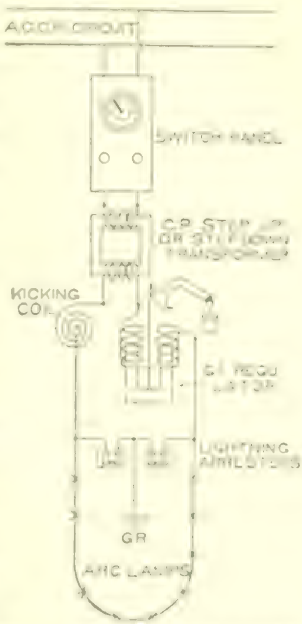


Fig. 49. [illegible]

Multiple-Series or Series-Multiple Systems. These combine several lamps in series, and these series groups in multiple, or several lamps in multiple and these multiple groups in series, respectively. They have but a limited application.

Multiple or Parallel Systems of Distribution. By far the largest number of lamps in service are connected to parallel systems of distribution. In this system, the units are connected across the lines leading to the bus bars at the station, or to the secondaries of constant-potential transformers. Fig. 50 shows a diagram of ten lamps connected in parallel. The current delivered by the machine dispends directly on the number of lamps connected in service, the voltage of the system being kept constant.

Inasmuch as the flow of current in a conductor is always accompanied by a fall of potential equal to the product of the current flowing into the resistance of the conductor, the lamps at the end of the system shown will not have as high a voltage impressed upon them as those nearer the machine. This drop in potential is the most serious obstacle that we have to overcome in multiple systems, and various schemes have been adopted to aid in this regulation. The systems may be classified as:

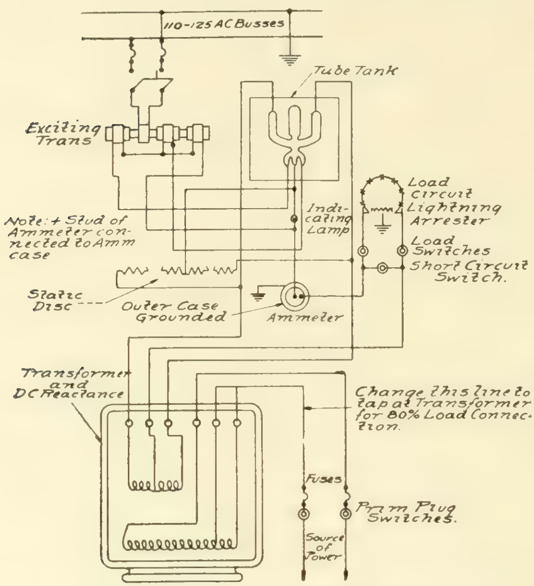


Fig. 49. Wiring Diagram for A. C. System Showing Introduction of Mercury Arc Rectifier.

1. Cylindrical conductors, parallel feeding.
2. Conical " " "
3. Cylindrical " anti-parallel feeding.
4. Conical " " "

In the cylindrical conductor, parallel-feeding system, the conductors, *A*, *B*, *C*, *D*, Fig. 50, are of the same size throughout and are fed at the same end by the generator. The voltage is a minimum at the lamps *E* and a maximum at the lamps *F;* the value of the voltage at any lamp being readily calculated.

By a *conical* or *tapering conductor* is meant a conductor whose diameter is so proportioned throughout its length that the current, divided by the cross-section, or the current density, is a constant quantity. Such a conductor is approximated in practice by using smaller sizes of wire as the current in the lines becomes less.

In an anti-parallel system the current is fed to the lamps from opposite ends of the system, as shown in Fig. 51.

Multiple-Wire Systems. In order to take advantage of a higher voltage for distribution of power to the lighting circuits, three- and five-wire systems have been introduced, the three-wire system being used to a very large extent. In this system, three conductors are used, the voltage from each outside conductor to the middle neutral conductor being the same as for a simple parallel system. Fig. 52 gives a diagram of this. By this system the amount of copper required for a given number of lamps is from five-sixteenths to three-eighths of the amount required for a two-wire distribution, depending on the size of the neutral conductor. The saving of copper together with the disadvantages of the system is more fully treated in the paper on "Power Transmission."

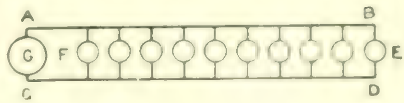


Fig. 50. Parallel Feeding System

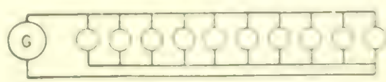


Fig. 51. Anti-parallel Feeding System

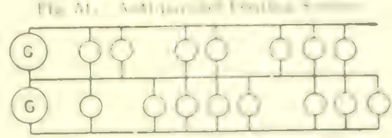


Fig. 52. Three-wire System

ILLUMINATION

Illumination may be defined as the quality and quantity of light which aids in the discrimination of outline and the perception of color. Not only the quantity, but the quality of the light, as well as the arrangement of the units, must be considered in a complete study of the subject of illumination.

Unit of Illumination. The unit of illumination is the *foot-candle* and its value is the amount of light falling on a surface at a distance of one foot from a source of light one candle-power in value. The law of inverse squares—namely, that the illumination from a given source varies inversely as the square of the distance from the source—shows that the illumination at a distance of two feet from a single candle-power unit is .25 foot-candles. For further consideration of the law of inverse squares, see "Photometry."

Illumination may be classified as *useful*—when used for the ordinary purposes of furnishing light for carrying on work, taking the place of daylight; and *scenic*—when used for decorative lighting such as stage lighting, etc. The two divisions are not, as a rule, distinct, but the one is combined with the other.

Intrinsic Brightness. By intrinsic brightness is meant the amount of light emitted per unit surface of the light source. Table XII gives the intrinsic brightness of several light sources.

TABLE XII

Intrinsic Brilliancies in Candle-Power per Square Inch

Source	Brilliancy	Notes
Sun in zenith	600,000	
Sun at 30 degrees elv.	500,000	Rough equivalent values, taking account of absorption
Sun on horizon	2,000	
Arc light	10,000 to 100,000	Maximum about 200,000 in crater
Calcium light	5,000	
Nernst "glower"	1,000	Unshaded
Incandescent lamp	200–300	Depending on efficiency
Enclosed arc	75–100	Opalescent inner globe
Acetylene flame	75–100	
Welsbach light	20 to 25	
Kerosene light	4 to 8	Variable
Candle	3 to 4	
Gas flame	3 to 8	Variable
Incandescent (frosted)	2 to 5	
Opal shaded lamps, etc.	0.5 to 2	

Regular Reflection. Regular reflection is the term applied to reflection of light when the reflected rays are parallel. It is of such a nature that the image of the light source is seen in the reflection. The reflection from a plane mirror is an example of this. It is useful in lighting in that the direction of light may be changed without complicating calculations aside from deductions necessary to compensate for the small amount of light absorbed.

Irregular Reflection. Irregular reflection, or diffusion, consists of reflection in which the reflected rays of light are not parallel but take various directions, thus destroying the image of the light source. Rough, unpolished surfaces give such reflection. Smooth, unpolished surfaces generally give a combination of two kinds of reflection.

Diffused reflection is very important in the study of illumination inasmuch as diffused light plays an important part in the lighting of interiors. This form of reflection is seen in many phenomena of nature. Light is also diffused when passing through semi-transparent shades or screens.

In considering reflected light, we find that, if the surface on which the light falls is colored, the reflected light may be changed in its nature by the absorption of some of the colors. Since, as has been said, in interior lighting the reflected light forms a large part of the source of illumination, this illumination will depend upon the nature and the color of the reflecting surfaces.

Whenever light is reflected from a surface, either by direct or diffused reflection, a certain amount of light is absorbed by the surface. Table XIII gives the amount of white light reflected from different materials.

TABLE XIII

Relative Reflecting Power

Material	[illegible]
White blotting paper..	82
White cartridge paper.	80
Chrome yellow paper..	62
Orange paper	50
Yellow wall paper	40
Light pink paper	36
Yellow cardboard	30
Light blue cardboard..	25
Emerald green paper..	18
Dark brown paper..	13
Vermilion paper	12
Blue-green paper..	12
Black paper	5
Black cloth	1.2
Black velvet	.4

From this table it is seen that the light-colored papers reflect the light well, but of the darker colors only yellow has a comparatively high coefficient of reflection. Black velvet has the lowest value, but this only holds when the material is free from dust. Rooms with dark walls require a greater amount of illuminating power, as will be seen later.

Useful illumination may be considered under the following heads:

1. Residence Lighting.
2. Lighting of Public Halls, Offices, Drafting Rooms, Shops, etc.
3. Street Lighting.

RESIDENCE LIGHTING

Type of Lamps. The lamps used for this class of lighting are limited to the less powerful units—namely, incandescent or Nernst lamps varying in candle-power from 8 to 50 per unit. These should always be shaded so as to keep the intrinsic brightness low. The intrinsic brilliancy should seldom exceed 2 to 3 candle-power per square inch, and its reduction is usually accomplished by appropriate shading. Arc lights are so powerful as to be uneconomical for small rooms, while the color of the mercury-vapor light is an additional objection to its use.

Plan of Illumination. Lamps may be selected and so located as to give a brilliant and fairly uniform illumination in a room; but this is an uneconomical scheme, and the one more commonly employed is to furnish a uniform, though comparatively weak, ground illumination, and to reinforce this at points where it is necessary or desirable. The latter plan is satisfactory in almost all cases and the more economical of the two.

While the use of units of different power is to be recommended, where desirable, lights differing in color should not be used for lighting the same room. As an exaggerated case, the use of arc with incandescent lamps might be mentioned. The arcs being so much whiter than the incandescent lamps, the latter appear distinctly yellow when the two are viewed at the same time.

Calculation of Illumination. In determining the value of illumination, not only the candle-power of the units, but the amount of reflected light must be considered for the given location of the lamps. Following is a formula based on the coefficient of reflection of the walls of the room, which serves for preliminary calculations:

$$I = \frac{c.p.}{d^2} \cdot \frac{1}{1 - k}$$

I = Illumination in foot-candles.
c.p. = Candle-power of the unit.
k = Coefficient of reflection of the walls.
d = distance from the unit in feet.

Where several units of the same candle-power are used the formula becomes

$$I = c.p. \left(\frac{1}{d^2} + \frac{1}{d_1^2} + \frac{1}{d_2^2} + \cdots \right) \frac{1}{1-k}$$

or,

$$c.p. = \frac{I}{\left(\frac{1}{d^2} + \frac{1}{d_1^2} + \frac{1}{d_2^2} + \cdots \right) \frac{1}{1-k}}$$

where d, d_1, d_2, etc., equal the distances from the point considered to the various light sources. If the lamps are of different candle-power, the illumination may be determined by combining the illumination from each source as calculated separately. An example of calculation is given under "Arrangement of Lamps."

The above method is not strictly accurate because it does not take account of the angle at which the light from each one of the sources strikes the assumed plane of illumination. If the ray of light is perpendicular to the plane, the formula $I = \frac{c.p.}{d^2}$ gives correct values. If a is the angle which the ray of light makes with a line drawn from the light source perpendicular to the assumed plane, then the formula becomes $I = \frac{c.p. \times \text{cosine } a}{d^2}$. Therefore, by multiplying the candle-power value of each light source in the direction of the illuminated point by the cosine of each angle a, a more accurate result will be obtained.

It is readily seen that the effect of reflected light from the ceilings is of more importance than that from the floor of a room. The value of k, in the above formula, will vary from 60% to 10%, but for rooms with a fairly light finish 50% may be taken as a good average value.

The amount of illumination will depend on the use to be made of the room. One foot-candle gives sufficient illumination for easy reading, when measured normal to the page, and probably an illumination of .5 foot-candle on a plane 3 feet from the floor forms a sufficient ground illumination. The illumination from sunlight reflected from white clouds is from 20 foot-candles up, while that due to moonlight is in the neighborhood of [illegible] foot-candle. It is not possible to produce artificially a light equivalent to daylight on account of the great amount of energy that would be required and the difficulty of obtaining proper diffusion.

The method of calculating the illumination of a room that has just been described is known as the *point-by-point* method and it gives very accurate results if account is taken of the angle at which the light from each source strikes the plane of illumination and if the light distribution curves of the units, and the value of k, have been carefully determined. Under these conditions the calculations become extended and complicated and methods only approximate, but simpler in their application, are being introduced. One method, which gives good results when applied to fairly large interiors, makes the flux of light from the light sources the basis of calculation of the average illumination.

Flux of light is measured in lumens and a *lumen* may be defined as the amount of light which must fall on one square foot of surface in order to produce a uniform illumination of an intensity of one foot-candle. A source of light giving one candle-power in every direction and placed at the center of a sphere of one foot radius would give an illumination of one foot-candle at every point in the surface of the sphere and the total flux of light would be 4π, or 12.57, lumens since the area of the sphere would be 4π, or 12.57, sq. ft. A lamp giving one mean spherical candle-power gives a flux of 12.57 lumens and the total flux of light from any source is obtained by multiplying its mean spherical candle-power by 12.57. In calculating illumination it is customary to determine the illumination on a plane about 30 inches from the floor for desk work, and about 42 inches from the floor for the display of goods on counters. If we determine the total number of lumens falling on this plane and divide this number by the area of the plane, we obtain the average illumination in foot-candles. This of course tells us nothing about the maximum or minimum value of the illumination and such values must be obtained by other methods if they are desired. Reflected light, other than that covered by the distribution curve of the light unit including its reflector, is usually neglected in this method of calculation.

We may assume that in large rooms the light coming from the lamp within an angle of 75 degrees from the vertical reaches the plane of illumination. In smaller rooms this angle should be reduced to about 60 degrees. In order to determine the flux of light within this angle a Rousseau diagram, which is described later, should be drawn. By the means of this diagram the average candle-power of the light source within the angle assumed may be readily determined and this mean value, multiplied by 12.57, will give the flux of light in lumens. This method of calculation, together with some guides for its rapid application, is described by Messrs. Cravath and Lansingh in the "Transactions of the Illuminating Engineering Society, 1908." The same authorities give the following useful data:

To determine the watts required per square foot of floor area, multiply the intensity of illumination desired by the constants given as follows:

INTENSITY CONSTANTS FOR INCANDESCENT LAMPS

Tungsten lamps rated at 1.25 watts per horizontal candle-power; clear prismatic reflectors, either bowl or concentrating; large room; light ceiling; dark walls; lamps pendant; height from 8 to 15 feet	.25
Same with very light walls	.20
Tungsten lamps rated at 1.25 watts per horizontal candle-power; prismatic bowl reflectors enameled; large room; light ceiling; dark walls; lamps pendant, height from 8 to 15 feet	.29
Same with very light walls	.23
Gem lamps rated at 2.5 watts per horizontal candle-power; clear prismatic reflectors either concentrating or bowl; large room; light ceiling; dark walls; lamps pendant; height from 8 to 15 feet	55
Same with very light walls	[illegible]
Carbon filament lamps rated at 3.1 watts per horizontal candle-power; clear prismatic reflectors either bowl or concentrating; light ceiling; dark walls; large room; lamps pendant; height from 8 to 15 feet	.65
Same with very light walls	55
Bare carbon filament lamps rated at 3.1 watts per horizontal candle-power; no reflectors; large room; very light ceiling and walls; height from 10 to 14 feet	.75 to 1.5
Same; small room; medium walls	1.25 to 2.0
Carbon filament lamps rated at 3.1 watts per horizontal candle-power; opal dome or opal cone reflectors; light ceiling; dark walls; large room; lamps pendant; height from 8 to 12 feet	[illegible]
Same with light walls	[illegible]

INTENSITY CONSTANTS FOR ARC LAMPS

[illegible] enclosed, direct-current arc on 110-volt circuit; [illegible] opal outer globes; no reflectors; large room; light ceiling; medium walls; height from 9 to 14 feet	[illegible]

Arrangement of Lamps. An arrangement of lamps giving a uniform illumination cannot be well applied to residences on account of the number of units required, and the inartistic effect. We are limited to chandeliers, side lights, or ceiling lights, in the majority of cases, with table or reading lamps for special illumination.

When ceiling lamps are used and the ceilings are high, some form of reflector or reflector lamp is to be recommended. In any case where the coefficient of reflection of the ceilings is less than 40%, it is more economical to use reflectors. When lamps are mounted on chandeliers, the illumination is far from uniform, being a maximum in the neighborhood of the chandelier and a minimum at the corners of the room. By combining chandeliers with side lights it is generally possible to get a satisfactory arrangement of lighting for small or medium-sized rooms.

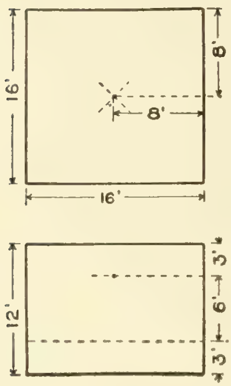


Fig. 53. Diagram Showing Method of Calculating Room Illumination.

As a check on the candle-power in lamps required, we have the following:

For brilliant illumination allow one candle-power per two square feet of floor space. In some particular cases, such as ball rooms, this may be increased to one candle-power per square foot.

For general illumination allow one candle-power for four square feet of floor space, and strengthen this illumination with the aid of special lamps as required. The location of lamps and the height of ceilings will modify these figures to some extent.

As an example of the calculation of the illumination of a room with different arrangements of the units of light, assume a room 16 feet square, 12 feet high, and with walls having a coefficient of reflection of 50%. Consider first the illumination on a plane 3 feet above the floor when lighted by a single group of lights mounted at the center of the room 3 feet below the ceiling. If a minimum value of .5 foot-candle is required at the corner of the room, we have the equation (first method outlined):

$$.5 = c.\,p.\,\frac{1}{12.8^2} \times \frac{1}{1 - .5}$$

Since $d = \sqrt{8^2 + 8^2 + 6^2} = 12.8$ (see Fig. 53)

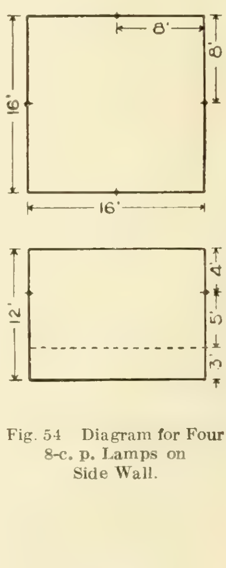


Fig. 54 Diagram for Four 8-c. p. Lamps on Side Wall.

DINING ROOM IN ALPHA DELTA PHI CHAPTER-HOUSE AT CORNELL UNIVERSITY, ITHACA, N. Y.

Dean & Dean, Architects, Chicago, Ill.

Oak Woodwork Stained a Dark Venetian Red; Mantel, Akron Roman Brick. Furniture Designed by Architects: Stained to Match the Woodwork.

LIBRARY IN ALPHA DELTA PHI CHAPTER-HOUSE AT CORNELL UNIVERSITY, ITHACA, N. Y.

Solving the above for the value of $x\,p$ we have:

$$x\,p = \frac{.5}{\frac{1}{16.4} - \frac{1}{6}} = 3 \times 8 = 41$$

Three 16-candle-power lamps would serve the purpose very well.

Determining the illumination directly under the lamps, we have:

$$I = 48 \times \frac{1}{6^2} \times \frac{1}{1 - .5} = \frac{48}{36} \times 2 =$$

2.7 foot-candles, or five times the value of the illumination at the corners of the room.

Next consider four 8-candle-power lamps located on the side walls 8 feet above the floor, as shown in Fig. 54. Calculating the illumination at the center of the room on a plane three feet above the floor, we have:

$$I = 8\left(\frac{1}{89} + \frac{1}{89} + \frac{1}{89} + \frac{1}{89}\right)\frac{1}{1 - .5}$$

$$d^2 = 8^2 + 5^2 = 64 + 25 = 89$$

$$I = 8 \times \frac{4}{89} \times 2 = .72 \text{ foot-candles}$$

The illumination at the corner of the room would be:

$$I = 8\left(\frac{1}{89} + \frac{1}{89} + \frac{1}{345} + \frac{1}{345}\right)\frac{1}{1 - .5}$$

$$= 8\left(\frac{2}{89} + \frac{2}{345}\right) \times 2 = .45 \text{ foot-candles.}$$

In a similar manner the illumination may be calculated for any point in the room, or a series of points may be taken and curves plotted showing the distribution of the light, as well as the areas having the same illumination. Where refined calculations are desired, the distribution curve of the lamp must be used for determining the candle-power in different directions. Fig. 55 shows illumination curves for the Meridian lamp as manufactured by the General Electric Company. This is a form of reflector lamp made in two sizes, 25 or 50 candle-power. Fig. 56 gives the distribution curves for the 50-candle-power unit. Similar incandescent lamps are now being manufactured by other companies.

Table XIV gives desirable data in connection with the use of the Meridian lamp.

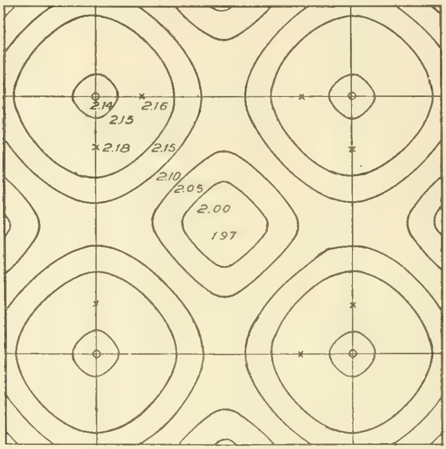


Fig. 55. Illumination Curves for a G. E. Meridian Lamp.

TABLE XIV
Illuminating Data for Meridian Lamps

Class Service	Light Intensity in Foot-candles	No. 1 Lamp (60 Watts)		No. 2 Lamp (120 Watts)		Watts per Sq. Ft. of Area Lighted with either Lamp
		Height of Lamp and Diameter of Uniformly Lighted Area	Distance between Lamps when Two or more are Used	Height of Lamp and Diameter of Uniformly Lighted Area	Distance between Lamps when Two or more are Used	
Desk or Reading Table	3	2.9 feet	4.9 feet	4 feet	7 feet	2.50
	2	3.5 "	6 "	5 "	8.5 "	1.66
	1½	4 "	7 "	5.75 "	9.8 "	1.25
General Lighting	1	5 "	8.5 "	7 "	12 "	0.83
	¾	5.75 "	9.8 "	8.2 "	13.9 "	0.62
	½	7 "	12 "	10 "	11 "	0.41

By means of the Weber, or some other form of portable photometer, curves as plotted from calculations may be readily checked after the lamps are installed. When lamps are to be permanently located, the question of illumination becomes an important one, and it may be desirable to determine, by calculation, the illumination curves for each room before installing the lamps. This applies to the lighting of large interiors more particularly than to residence lighting. The point-by-point method of calculation is used for very accurate work when the system of illumination admits of this method. Other methods are often simpler and sufficiently accurate for practical work.

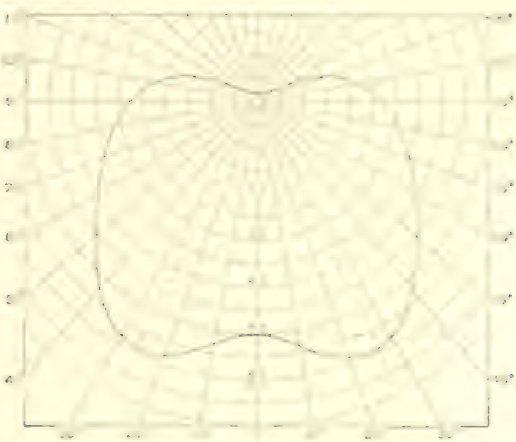


Fig. [illegible]. Distribution curve for [illegible] Meridian lamp.

Dr. Louis Bell gives the following in connection with residence lighting:

TABLE XV

Residence Lighting Data

Room	8 C.P.	16 C.P.	32 C.P.	Sq. Ft. [illegible]	Remarks
Hall, 15' × 20'	8			4.7	
Library, 20' × 20'	12		1	3.1	8 c.p. reflector lamps
Reception room, 15' × 15'	[illegible]			7.0	
Music room, 20' × 20'	12		2	[illegible]	
Dining room, 15' × 20'	14			2.7	8 reflector lamps
Billiard room, 15' × 20'			4	[illegible]	32 c.p. with reflectors
Porch			1		
Bedrooms (6), 12' × 15'		14		[illegible]	
Dressing rooms (2), 10' × 15'		4		4.7	
Servants' rooms (3), 10' × 15'		[illegible]		[illegible]	
Bathrooms (3), 8' × 10'		[illegible]		5.0	
Kitchen, 15' × 15' } Pantry, 10' × 10' }		3			
Halls } Cellar }	10	[illegible]			
Closets (?)	[illegible]				Reflector lamps
Total	[illegible]	[illegible]	[illegible]		

LIGHTING OF PUBLIC HALLS, OFFICES, ETC.

Lighting of public halls and other large interiors differs from the illumination of residences in that there is usually less reflected light, and, again, the distance of the light sources from the plane of illumination is generally greater if an artistic arrangement of the lights is to be brought about. This in turn reduces the direct illumination. The primary object is, however, as in residence lighting, to produce a fairly uniform ground illumination and to superimpose a stronger illumination where necessary. An illumination of .5 foot-candle for the ground illumination may be taken as a minimum.

In the lighting of large rooms it is permissible to use larger light units, such as arc lamps and high candle-power Nernst or incandescent units, while for factory lighting and drafting rooms, where the color of the light is not so essential, the Cooper-Hewitt lamp is being introduced. High candle-power reflector lamps, such as the tungsten lamp, are being used to a large extent for offices and drafting rooms.

The choice of the type of lamp depends on the nature of the work. Where the light must be steady, incandescent or Nernst lamps are to be preferred to the arc or vapor lamps, though the latter are often the more efficient. When arcs are used, they must be carefully shaded so as to diffuse the light, doing away with the strong shadows due to portions of the lamp mechanism, and to reduce the intrinsic brightness. Such shading will be taken up under the heading "Shades and Reflectors." Arcs are sometimes preferable to incandescent lamps when colored objects are to be illuminated, as in stores and display windows.

In locating lamps for this class of lighting, much depends on the nature of the building and on the degree of economy to be observed. For preliminary determination of the location of groups, or the illumination when certain arrangement of the units is assumed, the principles outlined under "Residence Lighting" may be applied. It has been found that actual measurements show results approximating closely such calculated values.

When arcs are used they should be placed fairly high, twenty to twenty-five feet when used for general illumination and the ceilings are high. They should be supplied with reflectors so as to utilize the light ordinarily thrown upwards. When used for drafting-room work, they should be suspended from twelve to fifteen feet above the floor, and special care must be taken to diffuse the light.

Incandescent lamps may be arranged in groups, either as wall lights or mounted on chandeliers, or they may be arranged as a frieze running around the room a few feet below the ceiling. The last named arrangement of lights is one that may be made artistic, but it is uneconomical and when used should serve for the ground illumination only. Reflector lights may be used for this style of work and the lights may be entirely concealed from view, the reflecting property of the walls being utilized for distributing the light where needed.

Ceiling lights should preferably be supplied with reflectors, especially when the ceilings are high.

Indirect lighting is employed to some extent. By indirect lighting we mean a system of illumination in which the light sources are concealed and the light from them is reflected to the room by the walls, or ceilings, or other surfaces; or in which the light sources are placed above a diffusing panel. In the latter case the diffusing plate appears to be the source of light. In some cases the walls themselves are shaped and constructed so as to form the reflectors for the lights (as in cove lighting), but in others all of the reflecting surfaces, except the side walls and ceiling, are made portions of the lamp fixtures.

Tables XVI and XVII give data on arc and mercury-vapor lamps for lighting large rooms. Table XVII refers to arc lights as actually installed.

TABLE XVI

Cooper Hewitt Lamps

Service	Height of Lamp	C. P. per Unit	Sq. Area per Lamp in Square Feet
Foundry	10-15 ft.	300	900
	20-25 "	700	[illegible]
Machine shop	10-16 "	300	[illegible]
Printing shop	20-30 "	700	[illegible]
Drafting room	16 "	300	[illegible]
	20 "	700	[illegible]
Offices	10-15 "	300	[illegible]
	20-25 "	700	[illegible]
Ordinary labor	10-15 "	300	1100
	20-25 "	700	2750

TABLE XVII

Lighting Data for Arc Lamps

Place Lighted	Clothing Store	Weave Room	Erecting Room	Machine Shop	Drafting Room	Drafting Room	Ship Shed	Cataloging Dept.	Jewelry Store
No. of sq. ft. place lighted	4000	14400	281600	42250	6275	5690	69000	4136	4000
No. lamps used	12	50	200	42	27	24	50	17	6
Circuit	A. C. Mult	D. C. Mult.	D. C. Mult.	D. C. Mult.	A. C Series	D. C. Mult.	D. C. Mult.	D. C. Mult.	D. C. Mult.
Cycles	60	.....	......	......	60	....	.....	.....	......
Volts line	104	110	120	120	....	120	220	110	110
Amperes	6	3¾	6.2	6.2	7.5	4	6	4½	5
Volts at arc	72	75	80	80	72	80	80	80	80
Power factor of lamp	.69	.....	.....	.....	.86	....	......	......	......
Watts per lamp	430	357	744	744	490	480	660	495	550
Watts per sq. ft. (term.)	1.29	1.24	.53	.74	2.11	2.02	.478	2.03	.825
Kw. at term. (whole installation)	5.16	17.8	148.8	31.25	13.22	11.52	33	8.42	3.3
Kw. at arc (whole installation)	4.62	12.28	99.2	20.8	12.42	7.68	24	6.12	2.4
Sq. ft. lighted per lamp	333	288	1408	1006	232	237	1380	243	667
Sq. ft. lighted per amp.	55.6	88.6	227	162	31	59.2	230	54.1	133.5
Enclosing globe	Opal.		Opal.	Opal.	Opal.	Opal.		Opal.	Opal.
Height and style of ceiling	12′ white steel	Saw Toothed	Trussed	Trussed	12′ White	Trussed	160′ Trussed	13′ 9″ Maroon	16′ 10′ White
Reflector system used	Concentric Diffuser	Adjust. Diffuser	9″ Mirror	9″ Mirror	Concentric Diffuser	16 Adj.Dif 8 Con.Dif	12″ Mirror	Concentric Diffuser	Concentric Diffuser
Height of arc from floor	9′ 6″	12′ to 15′	46′	47′	9′	15′	150′	10′ 7″	13′ 2″
Distance between lamps	14′ to 18′	24′	32′ to 38′	30′ 9″	15′	12′ to 25′	17′ to 20′	14′ to 18′	16′ to 25′

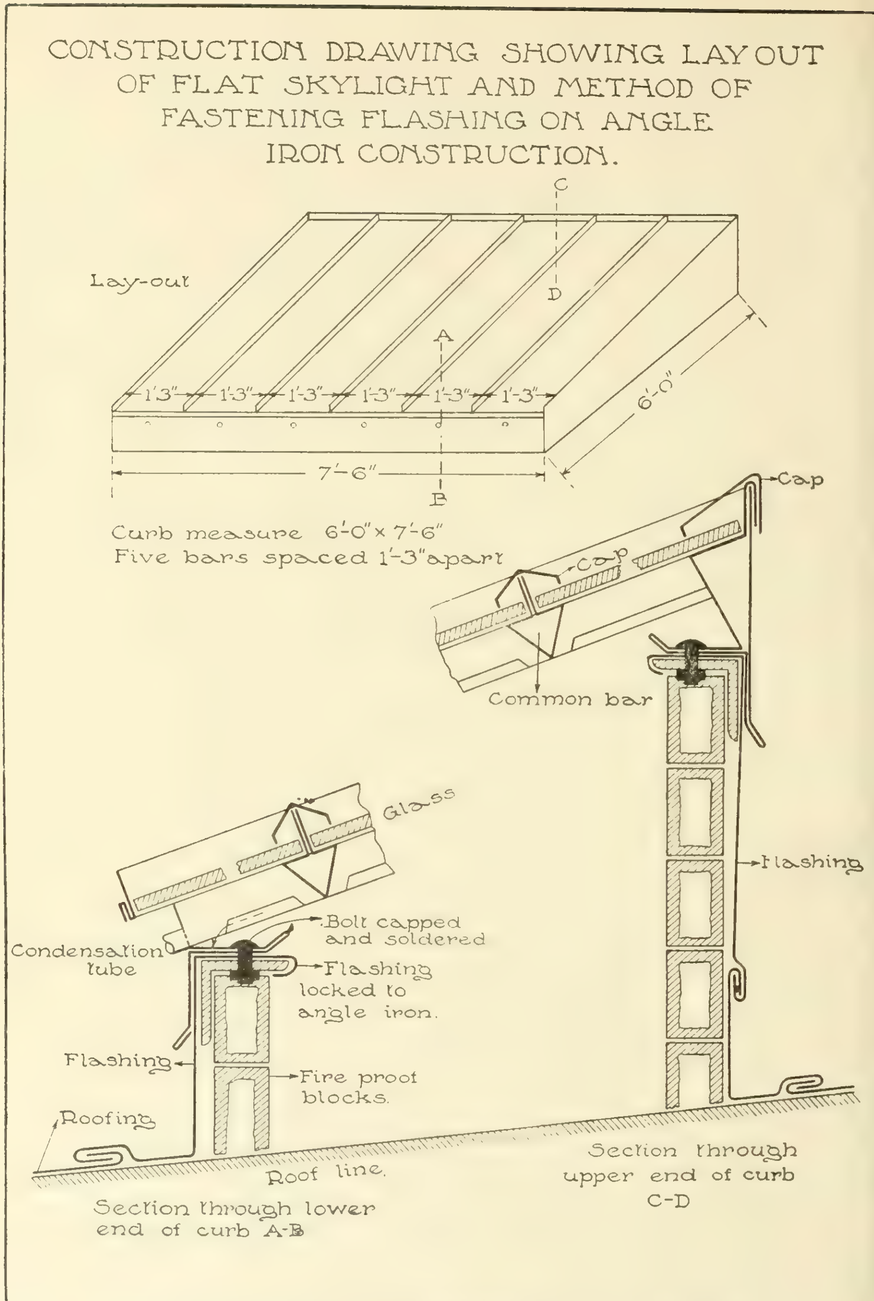
SKYLIGHT WORK *

The [illegible] 6′ 0″ on a horizontal line. Five bars are required, making the glass 15 inches wide A working section through AB and CD is shown below.

It will be noticed in the section through AB that the flashing is locked to the roofing and flanged around the inside of the angle iron construction; over this the curb of the skylight rests, bolted through the angle iron as shown, the bolt being capped and soldered to avoid leakage.

The same construction is used in the section through CD, with the exception, that when the flashing cannot be made in one piece, a cross lock is placed in the manner indicated, over the fireproof blocks.

* [illegible]



FOR EXPLANATION OF THIS PROBLEM SEE BACK OF PAGE

SHEET METAL WORK

PART I

SKYLIGHT WORK

Where formerly skylights were constructed from wrought iron or wood, to-day in all the large cities they are being made of galvanized sheet iron and copper. Sheet metal skylights, having by their peculiar construction lightness and strength, are superior to iron and wooden lights; superior to iron lights, inasmuch as there is hardly any expansion or contraction of the metal to cause leaks or breakage of glass; and superior to wooden lights, because they are fire, water and condensation-proof, and being less clumsy, admit more light.

The small body of metal used in the construction of the bar and curb and the provisions which can be made to carry off the inside condensation, make sheet metal skylights superior to all others constructed from different material.

CONSTRUCTION

The construction of a sheet metal skylight is a very simple matter, if the patterns for the various intersections are properly developed. For example, the bar shown in Fig. 145 consists of a piece of sheet metal having the required stretchout and length, and bent by special machinery, or on the regular cornice brake, into the shape shown, which represents strength and rigidity with the least amount of weight. A A represent the condensation gutters to receive the condensation from the inside when the warm air strikes against the cold surface of the glass, while B B show the rabbets or glass-rest for the glass.

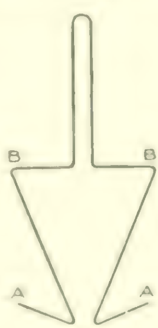


Fig. 145.

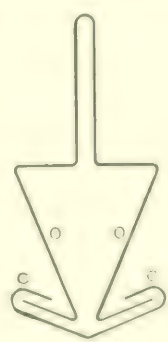


Fig. 146.

In Fig. 146 C C is a reinforcing strip which is used to hold the two walls O O together and impart to it great rigidity. When skylight bars are required to bridge long spans, an internal core is made of sheet metal and placed as shown at A in Fig. 147, which adds to its weight-sustaining power. In this figure B B shows the glass laid on a bed of putty with the metal cap C C C, resting snugly against the glass, fastened in position by the rivet or bolt D D. Where a very large span is to be bridged a bar similar to that shown in Fig. 148 is used. A heavy core plate A made of $\frac{1}{4}$-inch thick metal is used, riveted or bolted to the bar at B and B. In construction, all the various bars terminate at the curb shown at A B C in Fig. 149, which is fastened to the wooden frame D E.

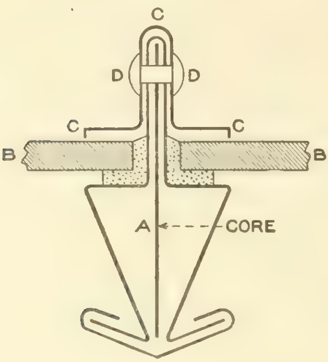


Fig. 147.

The condensation gutters C C in the bar *b*, carry the water into the internal gutter in the curb at *a*, thence to the outside through holes provided for this purpose at F F. In Fig. 150 is shown a sectional view of the construction of a double-pitched skylight. A shows the ridge bar with a core in the center and cap attached over the glass. B shows the cross bar or clip which is used in large skylights where it is impossible to get the glass in one length, and where the glass must be protected and leakage prevented by means of the cross bar, the gutter of which conducts the water into the gutter of the main bar, thence outside the curb as before explained. C is the frame generally made of wood or angle iron and covered by the metal roofer with flashing as shown at F. D shows the skylight bar with core showing the glass and cap in position. E is the metal curb against which the bars terminate, the condensation being let out through the holes shown.

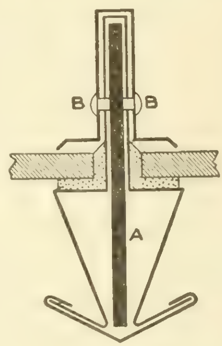


Fig. 148.

In constructing pitched skylights having double pitch, or being hipped, the pitch is usually one-third. In other words it is one-third of the span. If a skylight were 12 feet wide and one-third pitch were required, the rise in the center would be one-third of 12, or 4 feet. When a flat skylight is made the pitch is usually built in the wood or iron frame and a flat skylight laid over it. The glass used in the construction of metallic skylights is usually ¼-inch rough or ribbed glass, but in some cases heavier glass is used.

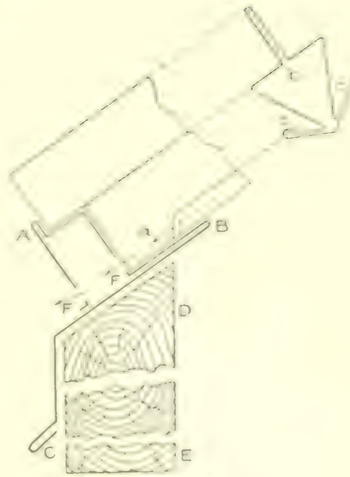


Fig. 148.

If for any reason it is desired to know the weight of the various thickness of glass, the following table will prove valuable.

Weight of Rough Glass Per Square Foot.

Thickness in inches.
⅛. 3/16. ¼. ⅜. ½. ⅝. ¾. 1.
Weight in pounds.
2. 2½. 3½. 5. 7. 8½. 10. 12½.

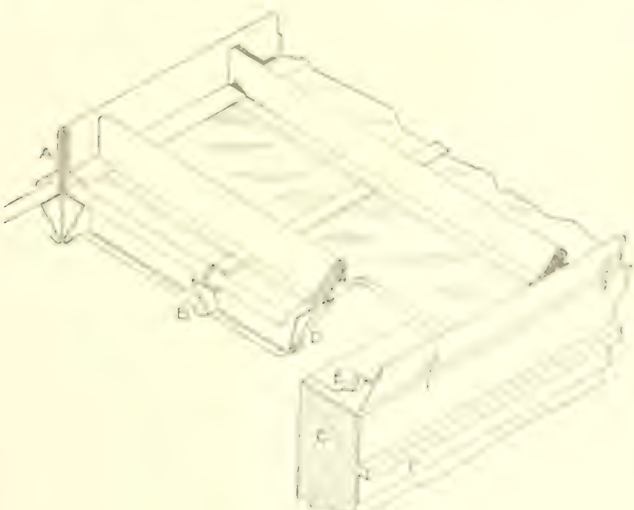


Fig. 149.

SHOP TOOLS

In the smaller shops the bars are cut with the hand shears and formed up on the ordinary cornice brake. In the larger shops, the strips required for the bars or curbs are cut on the large squaring shears, and the miters on the ends of these strips are cut on what is known as a miter cutter. This machine consists of eight foot presses on a single table, each press having a different set of dies for the purpose of cutting the various miters on the various bars. The bars are then formed on what is known as a Drop Press in which the bar can be formed in two operations to the length of 10 feet.

METHOD EMPLOYED IN OBTAINING THE PATTERNS

The method to be employed in developing the patterns for the various skylights is by parallel lines. If, however, a dome, conservatory or circular skylight is required, the blanks for the various curbs, bars, and ventilators, are laid out by the rule given in Sheet Metal Work, Part IV, under "Circular Work".

VARIOUS SHAPES OF BARS

In addition to the shapes of bars shown in Figs. 145 to 148 inclusive, there is shown in Fig. 151 a plain bar without any condensation gutters, the joint being at A. B B represents the glass resting on the rabbets of the bar, while C shows another form of cap which covers

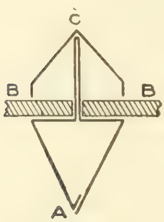


Fig. 151.

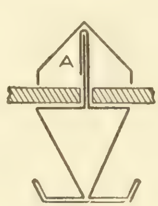


Fig. 152.

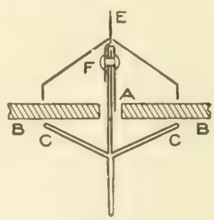


Fig. 153.

the joint between the bar and glass. Fig. 152 gives another form of bar in which the condensation gutters and bar are formed from one piece of metal with a locked hidden seam at A. Fig. 153 shows a bar on which no putty is required when glazing. It will be noticed that it is bent from one piece of metal with the seam at A, the glass B B resting on the combination rabbets and gutters C C. D is the cap which is fastened by means of the cleat E. These cleats are cut about ½-inch wide from soft 14-oz. copper, and riveted to the top of the bar at F; then a slot is cut into the cap D as shown from a to b in Fig. 153, then the cap is pressed firmly onto the glass and the cleat E turned down which holds the cap in position.

When a skylight is constructed in which raising sashes are required, as shown in Fig. 155, half bars are required at the sides A and B, while the bars on each side of the sash to be raised are so constructed that a water-tight joint is obtained when closed. This is shown in Fig. 156, which is an enlarged section through A B in Fig. 155. Thus in Fig. 156, A A represents the two half bars with condensation gutters as shown, the locked seam taking place at B B. C C represent the two half bars for the raising sash with the caps D D attached to same, as shown, so that when the sash C C is closed, the caps

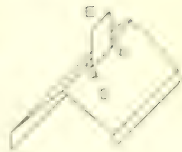


Fig. 154.

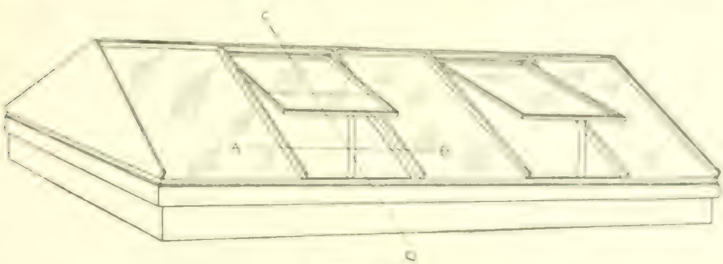


Fig. 155.

D D cover the joint between the glass E E and the stationary half bars. F F are the half caps soldered at a a to the bars C C which protect the joints between the glass H H and the bars C C.

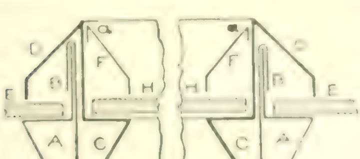


Fig. 156.

VARIOUS SHAPES OF CURBS

In Figs. 157, 158 and 159 are shown a few shapes of curbs which are used in connection with flat skylights. A in Fig. 157 shows the curb for the three sides of a flat skylight, formed in one piece with a joint at B, while C shows the cap, fastened as previously described. "A" shows the height at the lower end of the curb which is made as high as the glass is thick and allows the water to run over. In Fig. 158 A is another form of skylight formed in one piece and riveted at B; *a* shows the height at the lower end. In the previous figures the frame on which the metal curb rests is of wood, while in Fig. 159 the frame is

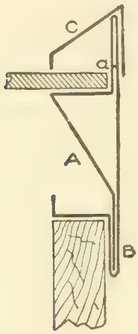


Fig. 157.

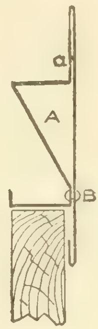


Fig. 158.

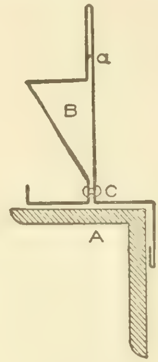


Fig. 159.

of angle iron shown at A. In this case the curb is slightly changed as shown at B; bent in one piece, and riveted at C. In Figs. 160, 161, and 162 are shown various shapes of curbs for pitched skylights in addition to that shown in Fig. 149. A in Fig. 160 shows a curb formed in one piece from *a* to *b* with a condensation hole or tube shown at B.

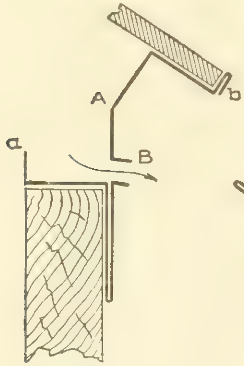


Fig. 160.

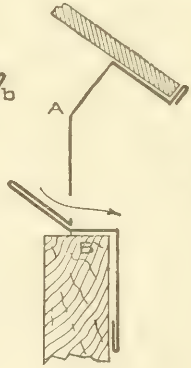


Fig. 161.

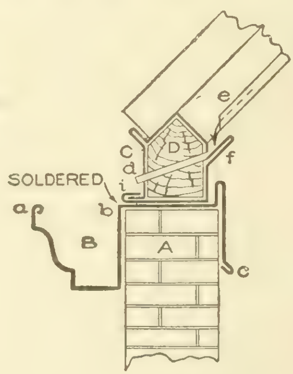


Fig. 162.

In Fig. 161 is shown a slightly modified shape A, with an offset to rest on the curb at B. When a skylight is to be placed over an opening whose walls are brick, a gutter is usually placed around the wall, as shown in Fig. 162, in which A represents a section of the wall on which a gutter, B, is hung, formed from one piece of metal, as shown from a to b to c. On top of this the metal curb C is soldered, which is also formed from one piece with a lock seam at i. To stiffen this curb a wooden one is slipped inside as shown at D. From the inside condensation gutter f a 1¼-in. copper tube runs through the curb, shown at *d*. The condensation from the gutter *e* in the bar, drips into the gutter *f*, out of the tube *d*, into the main gutter B, from which it is conveyed to the outside by a leader.

In Fig. 163 is shown an enlarged section of a raising sash, taken through C D in Fig. 155. A in Fig. 163 shows the ridge bar, B the lower curb and C D the side sections of the bars explained in connection with Fig. 156. E F in Fig. 163 shows the upper frame of the raising sash, fitting onto the half ridge bar A. On each raising sash, at the upper end two hinges H are riveted at E and I, which allow the sash to raise or close by means of a cord, rod, or gearings. J K shows the lower frame of the sash fitting over the curb B. Holes are punched at *a* to allow the condensation to escape into *b*, thence to the outside through C. Over the hinge H a hood or cap is placed which prevents leakage. Fig. 164 shows a section through A B in Fig. 167 and represents a hipped skylight having one-third pitch. By a skylight of one-third pitch is meant a skylight whose altitude or height A B, is equal to one-third of the span C D. If the skylight was to have a pitch of one-fourth or one-fifth, then the altitude A B would equal one-fourth or one-fifth respectively of the span C D.

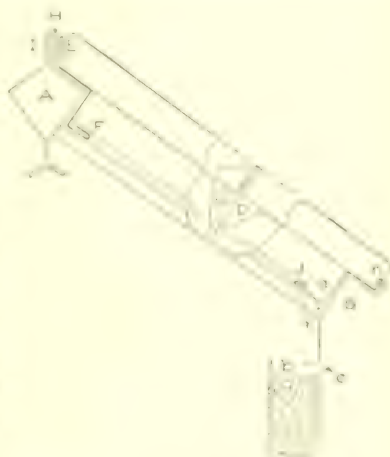


Fig. 163.

The illustration shows the construction of a hipped skylight with ridge ventilator which will be briefly described. C D is the curb; E E the inside ventilator; F F the outside ventilator forming a cap over the glass at *a*. G shows the hood held in position by two cross braces H. J represents a section of the common bar on the rabbets of which the glass K K rests. L shows the condensation gutters on the bar J,

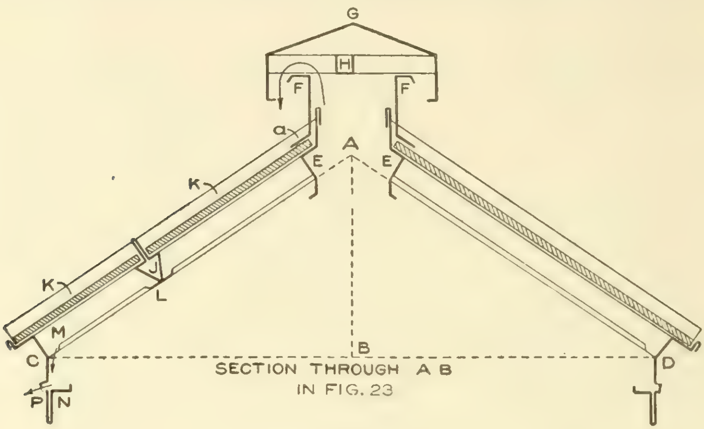


Fig. 164.

which are notched out as shown at M, thus allowing the drip to enter the gutter N and discharge through the tube P. The foul air escapes under the hood G as shown by the arrow.

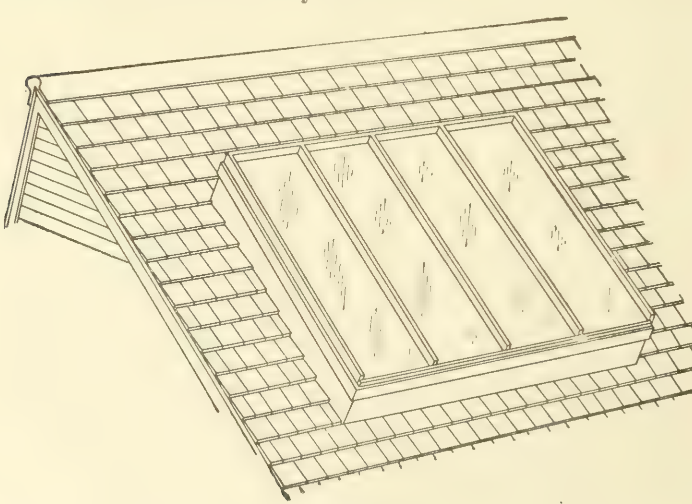
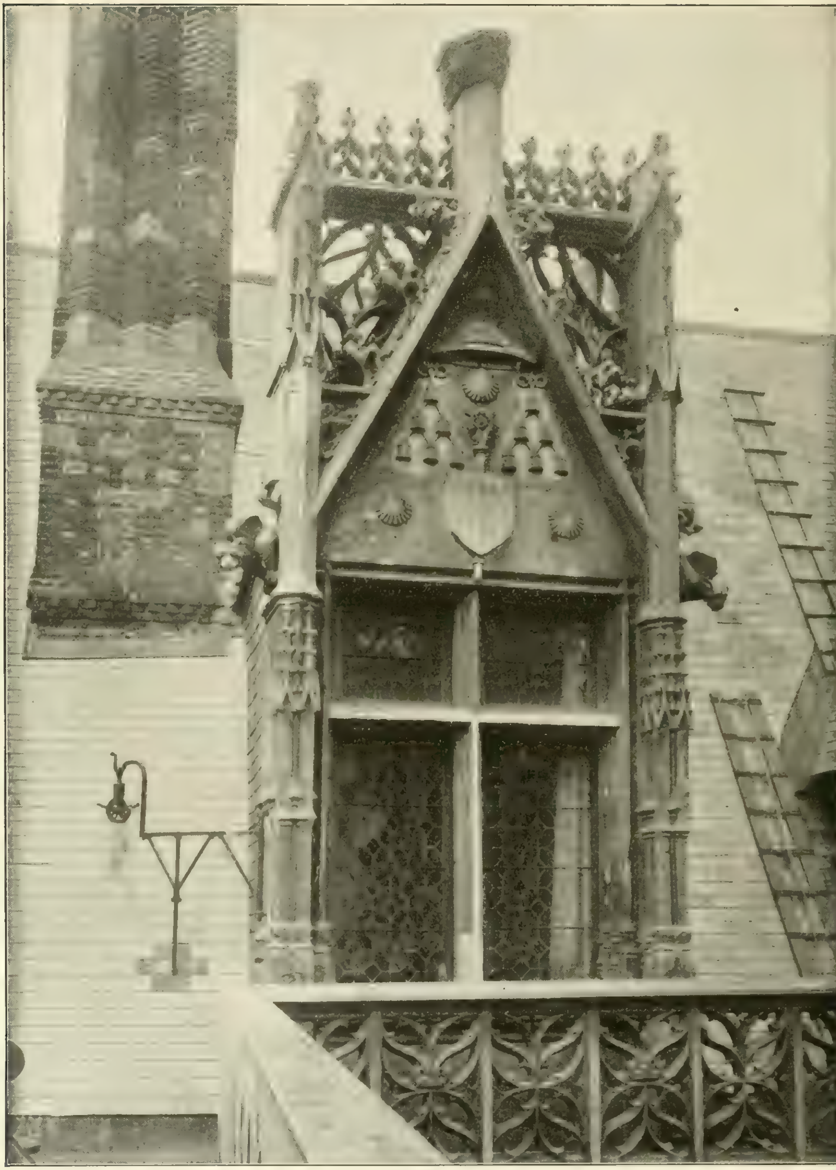


Fig. 165.



DORMER ON MUSÉE DE CLUNY, PARIS, FRANCE

Built in the Fifteenth Century. Note the Figure Sculpture at Sides of Dormer.

MAUTH GEBAUDE, NÜRNBERG, GERMANY

VARIOUS STYLES OF SKYLIGHTS

In Fig. 165 is shown what is known as a single-pitch light, and is placed on a curb made by the carpenter which has the desired pitch.

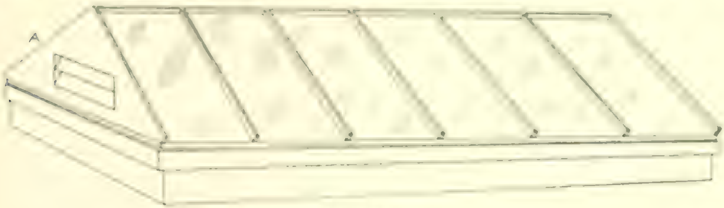


Fig. 166

These skylights are chiefly used on steep roofs as shown in the illustration, and made to set on a wooden curbs pitching the same as the

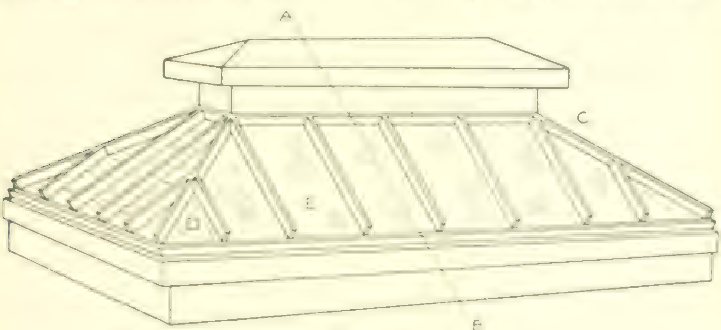


Fig. 167

roof, the curb first being flashed. Ventilation is obtained by raising one or more lights by means of gearings, as shown in Fig. 155.

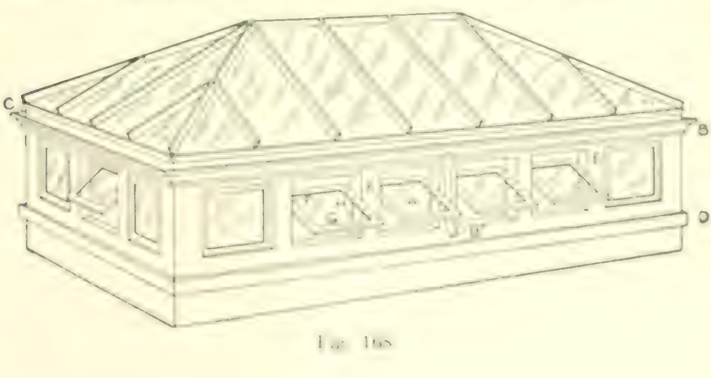


Fig. 168

Fig. 166 shows a double-pitch skylight. Ventilation is obtained by placing louvres at each end as shown at A. Fig. 167 shows a skylight with a ridge ventilator. The corner bar C is called the hip bar; the small bar D, mitering against the corner bar, is called the jack bar, while E is called the common bar. Fig. 168 illustrates a hip monitor skylight with glazed opening sashes for ventilation. These sashes can be opened or closed separately, by means of gearings similar to those shown in Fig. 177 In Fig. 169 is shown the method of raising

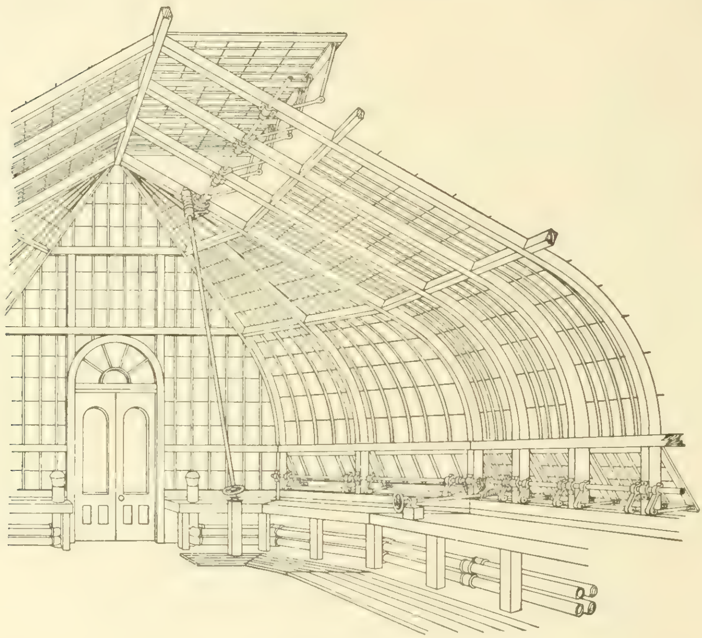


Fig. 169.

sashes in conservatories, greenhouses, etc., the same apparatus being applicable to both metal and wooden sashes. Fig. 170 shows a view of a photographer's skylight; if desired, the vertical sashes can be made to open.

In Fig. 171 is shown a flat extension skylight at the rear of a store or building. The upper side and ends are flashed into the brick work and made water-tight with waterproof cement, while the lower side rests on the rear wall to which it is fastened. In some cases the rear gutter is of cast iron, put up by the iron worker, but it is usually made of No. 22 galvanized iron, or 20-oz. cold-rolled copper. To receive the bottom of the gutter and skylight, the wall should be covered by a wooden plate A, Fig. 172, about two inches thick, and another plank set edgeways flush with the inside of the wall, as shown at B. The two planks are not required when a cast iron gutter is used.

Fig. 173 shows a hipped skylight without a ridge ventilator, set on a metal curb in which louvres have been placed. These louvres may be made stationary or movable. When made movable, they are

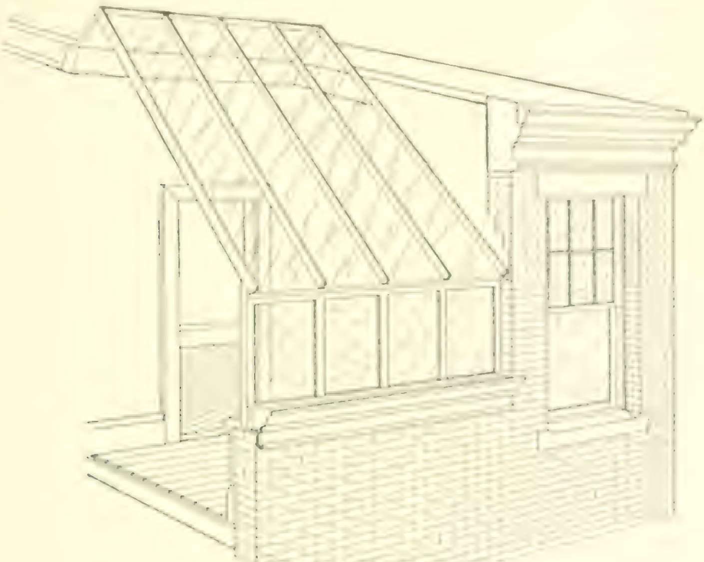


Fig. 173

constructed as shown in Fig. 174, in which A shows a perspective view. B shows them closed, and C open. They are operated by the quadrants attached to the upright bars *a* and *b*, which in turn are pulled up and down by cords or chains worked from below. When a skylight has a very long span, as in Fig. 175, it is constructed as shown in Fig. 176, in which A represents a T-beam which can be trussed if necessary. This construction allows the water to escape from the bottom of the upper light to the outside of the top of the lower skylight, the curb C of the upper light fitting over the curb B of the lower light.

In Fig. 177 is shown the method of applying the gearings A shows the side view of the metal or wooden sash partly opened, B the

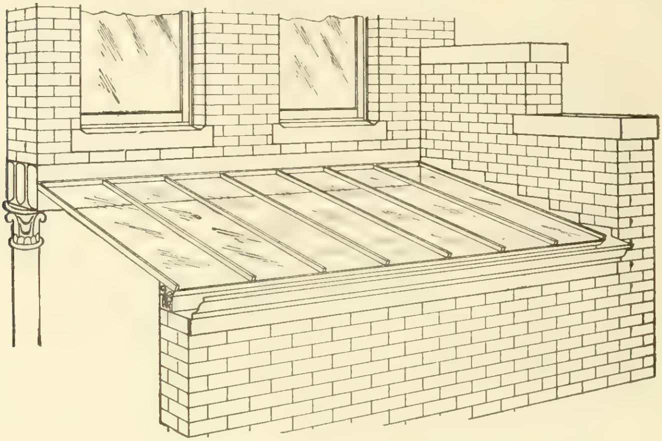


Fig. 171.

end of the main shaft, and C the binder that fastens the main shaft to the upright or rafter. D shows the quadrant wheel attached to main shaft and E is the worm wheel, geared to the quadrant D, communicating motion to the whole shaft. F is a hinged arm fastened to the main shaft B and hinged to the sash. By turning the hand-wheel the sash can be opened at any angle.

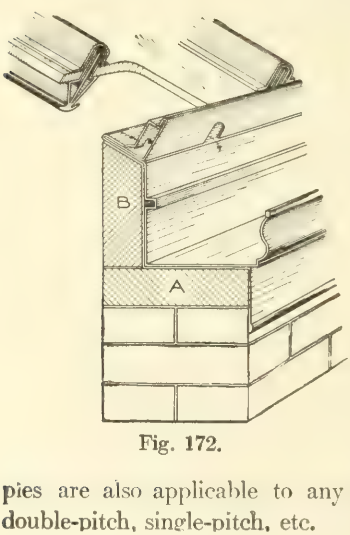


Fig. 172.

DEVELOPMENT OF PATTERNS FOR A HIPPED SKYLIGHT

The following illustrations and text will explain the principles involved in developing the patterns for the ventilator, curb, hip bar, common bar, jack bar, and cross bar or clip, in a hipped skylight. These principles are also applicable to any other form of light, whether flat, double-pitch, single-pitch, etc.

In Fig. 178 is shown a half section, a quarter plan, and a diagonal elevation of a hip bar, including the patterns for the curb, hip, jack, and common bars. The method of making these drawings will be explained in detail, so that the student who pays close attention

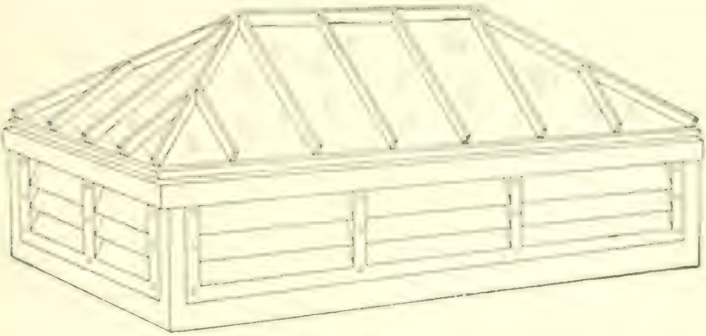


Fig. 176.

will have no difficulty in laying out any patterns no matter what the pitch of the skylight may be, or what angle its plan may have.

First draw any center line as A B, at right angles to which lay off C 4′, equal to 12 inches. Assuming that the light is to have one-third

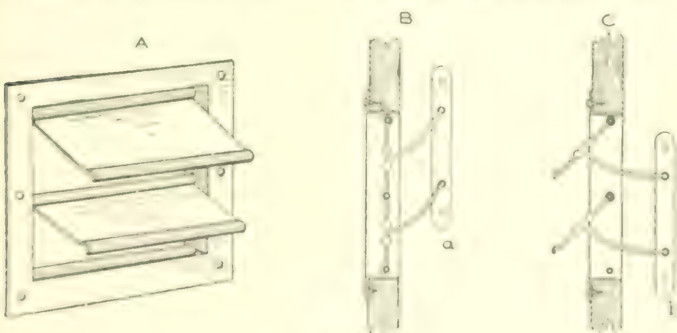


Fig. 177.

pitch, then make the distance C D equal to 8 inches which is one-third of 24 inches, and draw the slant line D 4′. At right angles to D 4′ place a section of the common bar as shown by E, through which draw lines parallel to D 4′, intersecting the curb drawn from a to b at the bottom and the inside section of the ventilator from F to G at the top. At pleasure draw the section of the outside vent shown from *h* to *l* and the hood shown from *m* to *p*. X represents the section of the brace resting on *i j* to uphold the hood resting on it in the corner *o*. The condensa-

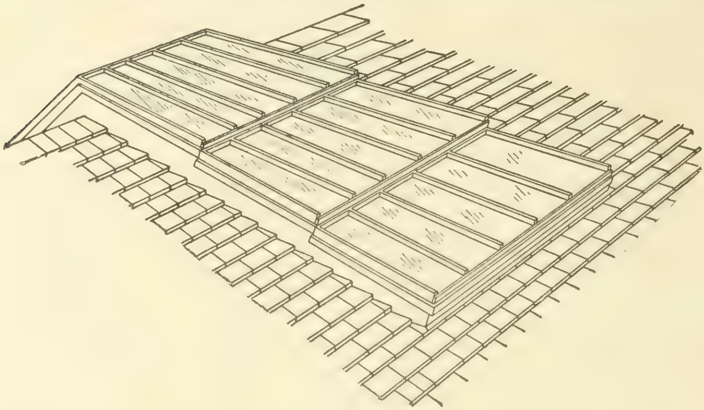


Fig. 175.

tion gutters of the common bar E are cut out at the bottom at 5′ 6′ which allows the drip to go into the gutter *d e f* of the curb and pass out of the opening indicated by the arrow. Number the corners of each half of the common bar section E as shown, from 1 to 6 on each side, through which draw lines parallel to D 4′ until they intersect the curb at the bottom as shown by similar numbers 1′ to 6′, and the inside ventilator at the top by similar figures 1″ to 6″. This completes the one half-section of the skylight. From this section the pattern for the common bar can be obtained without the plan, as follows:

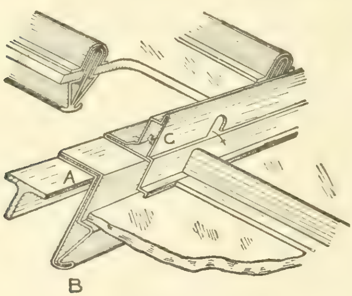


Fig. 176.

At right angles to D 4′ draw the line I J upon which place the stretchout of the section E as shown by similar figures on I J. Through these small figures, and at right angles to I J, draw lines, and intersect them by lines drawn at right angles to D 4′ from similarly numbered intersections 1′ to 6′ on the curb and 1″ to 6″ on the inside ventilator. Trace a line through points thus obtained; then A^1 B^1 C^1 D^1 will be the pattern for the common bar in a hipped skylight. The same method would be employed if a pattern were developed for a flat or a double-pitch light. From this same half section the pattern for the curb is developed by taking the stretchout of the various corners in the curb, *a b* 3′ 4′ *c d e* and *f*, and placing them on the center line A B as shown by similar letters and figures. Through these divisions and at right angles to A B draw lines which intersect with lines drawn at right angles to C 4′ from similar points in the curb section *a f*. Trace a line through points thus obtained; then E′ E *f a* will be the half pattern for the curb shown in the half section. V represents the condensation hole to be punched into the pattern between each light of glass in the skylight. As the portion *c d* turns up on *c* 4′, use *r* as a center, and with

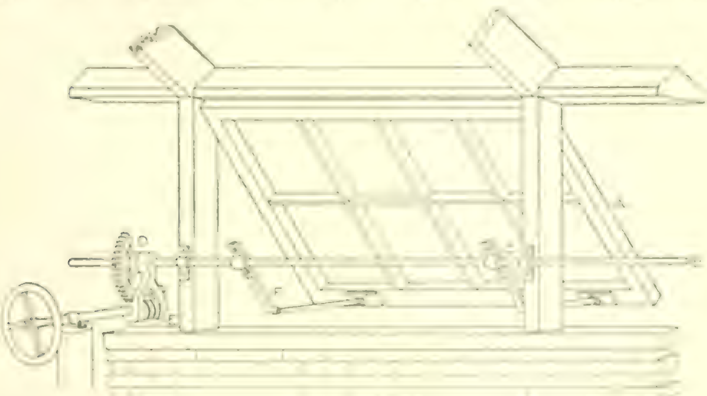


Fig. 177.

the radius *r s* strike the semicircle shown. Above this semicircle punch the hole V.

Before the patterns can be obtained for the hip and jack bars, a quarter plan view must be constructed which will give the points of intersections between the hip bar and curb, between the hip bar and vent, or ridge bar, and between the hip and jack bar. Therefore, from any point on the center line A B as K, draw K L at right angles to A B. As the skylight forms a right angle in plan, draw from K, at an angle of 45°, the hip or diagonal line K 1°. Take a tracing of the common bar section E with the various figures on same, and place it on the hip line K 1° in plan so that the points 1 4 come directly on the hip as shown by E′. Through the various figures draw lines parallel to K 1°

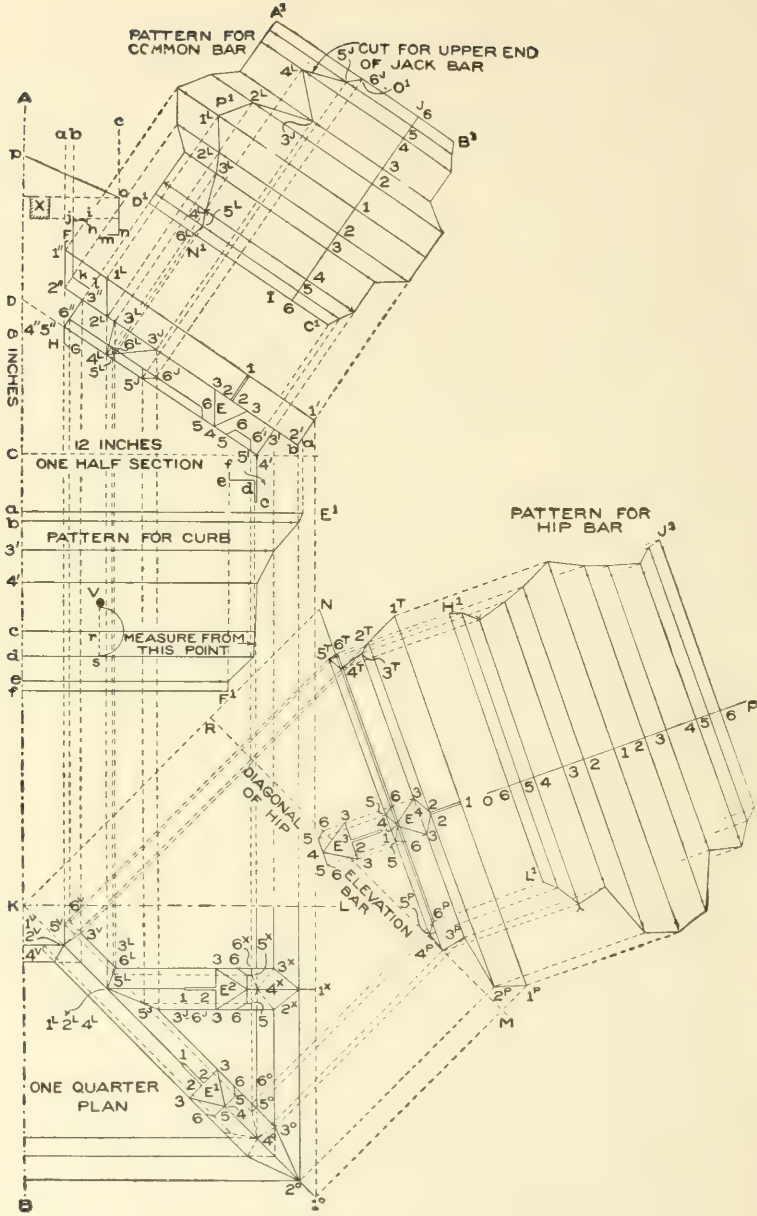

PATTERN FOR COMMON BAR
CUT FOR UPPER END OF JACK BAR
8 INCHES
12 INCHES
ONE HALF SECTION
PATTERN FOR CURB
MEASURE FROM THIS POINT
PATTERN FOR HIP BAR
DIAGONAL OF HIP
ELEVATION BAR
ONE QUARTER PLAN

Fig. 178.

one-half of which are intersected by vertical lines drawn parallel to A B from similar points of intersection $1'$ to $6'$ on the curb, and $1''$ to $6''$ on the ventilator in the half section as shown respectively in plan by intersections 1^a to 6^a and 1^b to 6^b. Below the hip line K 1^a trace the opposite intersection as shown. It should be understood that the section E^3 in plan does not indicate the true profile of the hip bar (which must be obtained later), but is only placed there to give the horizontal distances in plan. In laying out the work in practice to full size, the upper half intersection of the hip bar in plan is all that is required. It will be noticed that the points of intersections in plan and one half section have similar numbers, and if the student will carefully follow each point the method of these projections will become apparent.

Having obtained the true points of intersections in plan the next step is to obtain a diagonal elevation of the hip bar, from which a true section of the hip bar and pattern are obtained. To do this draw any line as R M parallel to K 1^a. This base line R M has the same elevation as the base line C 4′ has in the half section. From the various points 1^a to 6^a and 1^b to 6^b in plan, erect lines at right angles to K 1^a crossing the line R M indefinitely. Now measuring in each and every instance from the line C 4′ in the half section take the various distances to points D $1''$ $2''$ $3''$ $4''$ $5''$ and $6''$ at the top, and to points $1'$ $2'$ $3'$ $4'$ $5'$ and $6'$ at the bottom, and place them in the diagonal elevation measuring in each and every instance from the line R M on the similarly numbered lines drawn from the plan, thus locating respectively the points N 1^t 2^t 3^t 4^t 5^t and 6^t at the top, and 1^r 2^r 3^r 4^r 5^r and 6^r at the bottom. Through the points thus obtained draw the miter line 1^t to 6^t and 1^r to 6^r and connect the various points by lines as shown which completes the diagonal elevation of the hip bar intersecting the curb and vent, or ridge. To obtain the true section of the hip bar, take a tracing of the common bar E or E^1 and place it in the position shown by E^3, being careful to place the points 1 4 at right angles to 1^t 1^r as shown. From the various points in the section E^3 at right angles to 1^t 1^r draw lines intersecting similarly numbered lines in the diagonal elevation as shown from 1 to 6 on either side. Connect these points as shown; then E^4 will be the true profile of the hip bar. Note the difference in the two profiles; the normal E^3 and the modified E^4.

Having obtained the true profile E^4 the pattern for the hip bar is obtained by drawing the stretchout line O P at right angles 1^t 1^r.

Take the stretchout of the profile E^4 and place it on O P as shown by similar figures. Through these small figures and at right angles to O P draw lines which intersect by lines drawn at right angles to 1^T 1^P from similarly numbered points at top and bottom, thus obtaining the points of intersections shown. A line traced through the points thus obtained, as shown by H^1 J^1 K^1 L^1 will be the pattern for the hip bar.

For the pattern for the jack bar, take a tracing of the section of the common bar E and place it in the position in plan as shown by E^2 being careful to have the points 1 and 4 at right angles to the line 1^X 1°. It is immaterial how far the section E^2 is placed from the corner 2° as the intersection with the hip bar remains the same no matter how far the section is placed one way or the other. Through the various corners in the section E^2 draw lines at right angles to the line 1° 1^X intersecting one half of the hip bar on similarly numbered lines as shown by the intersections 1^L 2^L 3^L 4^L 5^L 6^L and 1^L 2^J 3^J 4^L 5^J and 6^J; also intersecting the curb in plan at points 1^X to 6^X. The intersection between the jack bar and curb in plan is not necessary in the development of the pattern as the lower cut in the pattern for the common bar is the same as the lower cut in the pattern for the jack bar. However, the intersection is shown in plan to make a complete drawing. At right angles to the line of the jack bar in plan, and from the various intersections with the hip bar, erect lines intersecting similarly numbered lines in the section as shown. Thus from the various intersections shown from 1^L to 6^L in plan, erect vertical lines intersecting the bar in the half section at points shown from 1^L to 6^L. In similar manner from the various points of intersections 3^J, 5^J, and 6^J in plan, erect lines intersecting the bar in the half section at points shown by 3^J 5^J 6^J. Connect these points in the half section, as shown, which represents the line of joint in the section between the hip and jack bars.

For the pattern for the upper cut of the jack bar, the same stretchout can be used as that used for the common bar. Therefore, at right angles to D 4′ and from the various intersections 1^L 2^L 3^L 4^L 5^L and 6^L draw lines intersecting similar numbered lines in the pattern for the common bar as shown by similar figures. In similar manner from the various intersections 3^J 5^J and 6^J in the one half section, draw lines at right angles to D 4′ intersecting similarly numbered lines in the pattern as shown by 3^J 5^J and 6^J. Trace lines from point to point, then the cut shown from N^a to 1^a will represent the miter for that part shown in plan from 2^a to 6^a, and the cut shown from 1^a to O^a in the pattern will represent the cut for that part shown in plan from 2^a to 6^a. The lower cut of the jack bar remains the same as that shown in the pattern.

The half pattern for the end of the hood is shown in Fig. 179, and is obtained as follows: Draw any vertical line as A B, upon which place the stretchout of the section of the hood *m n o p* in Fig. 178, as shown by similar letters *m n o p* on A B in Fig. 179. At right angles to A B and through the small letters draw lines, making them equal in length, (measuring from the line A B) to points having similar letters in Fig. 178, also measuring from the center line A B. Connect points shown in Fig. 179, which is the half pattern for the end of the hood. For the half pattern for the end of the outside ventilator, take the

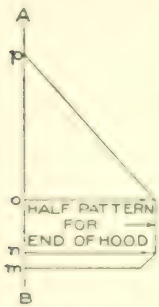


Fig. 179.

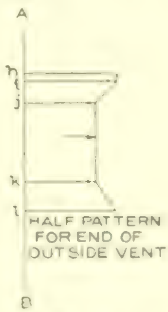


Fig. 180.

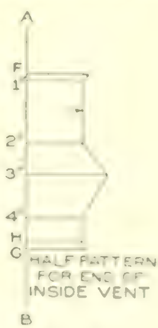


Fig. 181.

stretchout of *h i j k l* in Fig. 178 and place it on the vertical line A B in Fig. 180 as shown by similar letters, through which draw horizontal lines making them in length, measuring from A B, equal to similar letters in Fig. 178, also measuring from the center line A B. Connect the points as shown in Fig. 180 which is the desired half pattern. In Fig. 181 is shown the half pattern for the end of the inside ventilator, the stretchout of which is obtained from F 1^a 2^a 3^a 4^a H G in Fig. 178, the pattern being obtained as explained in connection with Figs. 179 and 180.

When a skylight is to be constructed on which the bars are of such lengths that the glass cannot be obtained in one length, and a cross bar or clip is required as shown by B, in Fig. 150, which miters against the main bar, the pattern for this intersecting cut is obtained as shown in

Fig. 182. Let A represent the section of the main bar, B the elevation of the cross bar, and C its section. Note how this cross bar is bent so that the water follows the direction of the arrow, causing no leaks because the upper glass *a* is bedded in putty, while the lower light *b* is capped by the top flange of the bar C (See Fig. 150). Number all of the corners of the section C as shown, from 1 to 8, from which points draw horizontal lines cutting the main bar A at points 1 to 8 as shown At right angles to the lines in B draw the vertical line D E upon which

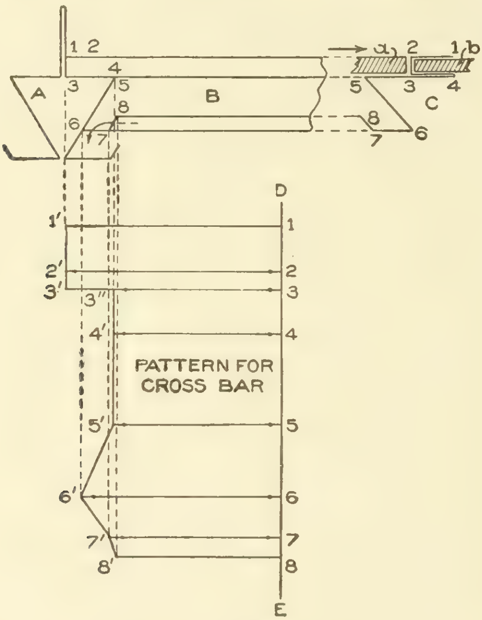


Fig. 182.

place the stretchout of the cross bar C, shown by similar figures, through which draw horizontal lines, intersecting them with lines drawn parallel to D E from similar numbered intersections against the main bar A, thus obtaining the points of intersections 1′ to 8′ in the pattern. Trace a line through points of intersections thus obtained which will be the pattern for the end cut of the cross bar.

In Fig. 183 is shown a carefully drawn working section of the turret sash shown in Fig. 168 at A. These sashes are operated by means of cords, chains or gearing from the inside, the pivot on which they turn being shown by R S in Fig. 183. The method of obtaining the patterns for these sashes will be omitted, as they are only square and butt miters which the student will have no trouble in developing, providing he understands the construction. This will be made clear by the following explanation:

A B represents the upper part of the turret proper with a drip bent on same, as shown at B, against which the sashes close, and a double seam, as shown at A, which makes a tight joint, takes out the twist in bending, and avoids any soldering. This upper part A B is indicated by C in Fig. 168, over which the gutter B is placed as shown by X U Y in Fig. 183. C D represents the lower part of the turret proper or base, which fits over the wooden curb W, and is indicated by D in Fig. 168. E in Fig. 183 represents the mullion made from one piece of metal and double seamed at *a*. This mullion is joined to the top and bottom. The pattern for the top end of the mullion would simply show a square cut, while the pattern for the bottom would represent a butt miter against the slant line *i j*. Before forming up this mullion the holes should be punched in the sides to admit the pivot R S. These mullions are shown in position in Fig. 168 by E E, etc.

Fig. 183

F G in Fig. 183 represents the section of the side of the sash below the pivot T. Notice that this lower half of the side of the sash has a lock attachment which hooks into the flange of the mullion F at I. While the side of the sash is bent in one piece the upper half, above the pivot T, has the lock omitted as shown by J K. Thus when the sash opens, the upper half of the sides turn toward the inside as shown by the arrow at the top, while the lower half swings outward as shown by the arrow at the bottom. When the lower half closes, it locks as shown at F, which makes a water-tight joint; but to obtain a water-tight joint for the upper half, a cap is used, partly shown by L M, into which the upper half of the side of the sash closes as shown at M. This cap is fastened to the upper part of the mullion E with a projecting hood *f* which is placed at the same angle as the sash will have when it is opened as shown by *e e′* and *d d′* or by the dotted lines.

The side of the sash just explained is shown in Fig. 168 at H. The pattern for the side of the sash has a square cut at the top, mitering with H I at the bottom, in Fig. 183, the same as a square miter. H I represents the section of the bottom of the sash. Note where the metal is doubled as at *b*, against which the glass rests in line with the rabbet on the side of the sash. A beaded edge is shown at H which stiffens it. This lower section is shown in Fig. 168 by G and has square cuts on both ends. N O in Fig. 183 shows the section of the top of the sash shown in Fig. 168 by F. The flange N in Fig. 183 is flush with the outside of the glass, thereby allowing the glass to slide into the grooves in the sides of the sash. After the glass is in position the angle P is tacked at *n*. A leader is attached to the gutter Y as shown by B° in Fig. 168. While the method of construction shown in Fig. 183 is generally employed, each shop has different methods; what we have aimed to give is the general construction in use, after knowing which, the student can plan his own construction to suit the conditions which are apt to arise.

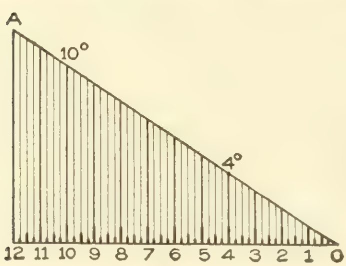


Fig. 184.

In the following illustrations, Figs. 184 to 187, it will be explained how to obtain the true lengths of the ventilator, ridge, hip, jack, and common bars in a hipped skylight, no matter what size the skylight may be. Using this rule only one set of patterns are required, as for example, those developed in connection with Figs. 178, 179, 180, and 181, which in this case has one-third pitch. If, however, a skylight was required whose pitch was different than one-third, a new set of patterns would have to be developed, to which the rule above mentioned would also be applicable for skylights of that particular pitch. Using this rule it should be understood that the size of the curb, or frame, forms the basis for all measurements, and that one of the lines or bends of the bar should meet the line of the curb as shown in Fig. 178, where the bottom of the bar E in the half section meets the line of the curb c 4′ at 4′, and the ridge at the top at 4′. Therefore when laying

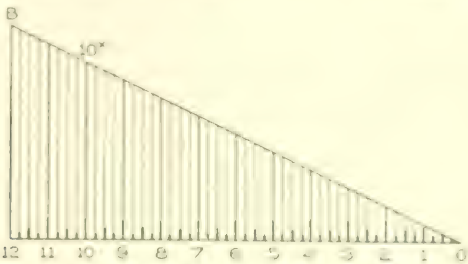


Fig. 185

out the lengths of the bars, they would have to be measured on the line 4 of the bar E from 4′ to 4″ on the patterns, as will be explained as we proceed.

The first step is to prepare the triangles from which the lengths of the common and jack bars are obtained, also the lengths of the hip bars. After the drawings and patterns have been laid out full size according to the principles explained in Fig. 178, take a tracing of the triangle in the half section D C 4′ and place it as shown by A 12 O, in Fig. 184. Divide O 12, which will be 12 inches in full size, into quarter, half-inches, and inches, the same as on a 2-foot rule, as shown by the figures O to 12. From these divisions erect lines until they intersect the pitch A O which completes the triangle for obtaining the true lengths of jack

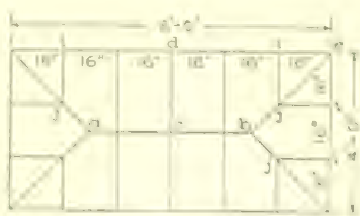


Fig. 186

and common bars for any size skylight. In similar manner take tracing of N R 4″ in the diagonal elevation in Fig. 178 and place it as shown by B 12 O in Fig. 185. The length 12 O then becomes the base of the triangle for the hip bar in a skylight whose base of the triangle for the common and jack bars measures 12 inches as shown in Fig. 184, the heights A 12 in Fig. 184 and B 12 in Fig. 185 being equal. Now divide 12 O in 12 equal spaces which will represent inches when obtaining the measurements for the hip bar. Divide each of the parts into quarter-inches as shown. From these devisions erect lines intersecting the hypothenuse or pitch line B O as shown.

To explain how these triangles are used in practice, Figs. 186 and 187 have been prepared, showing respectively a skylight without and with a ventilator whose curb measures 4 ft. x 8 ft. Three rules are used in connection with the triangles in Figs. 184 and 185, the comprehension of which will make clear all that follows.

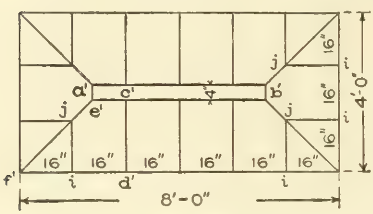


Fig. 187.

Rule 1. To obtain the length of the ridge bar in a skylight without a ventilator, as in Fig. 186, deduct the short side of the frame or curb from the long side.

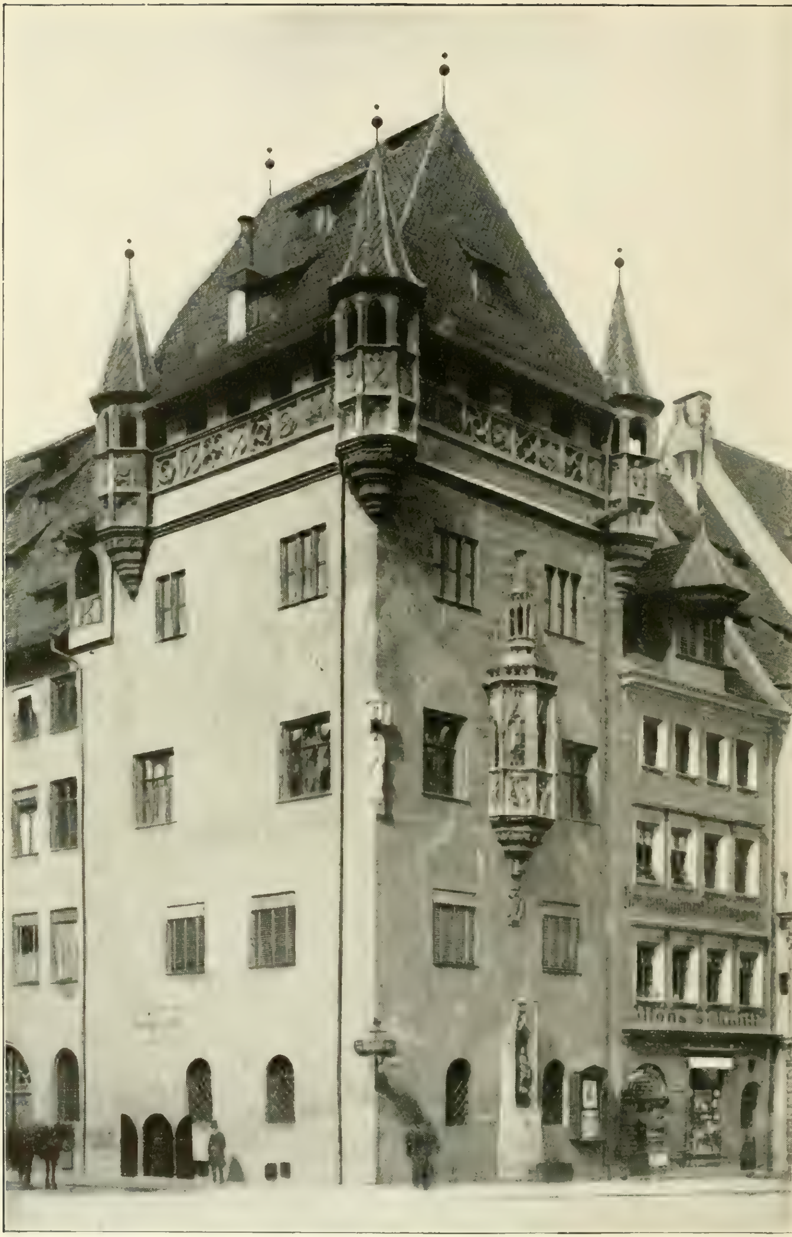
Example: In Fig. 186, take 8 feet (long side of frame) − 4 feet (short side of frame) = 4 feet (length of ridge bar *a b*).

Rule 2. To find the length of the ventilator in a skylight deduct the short side of the frame from the long side and add the width of the desired ventilator (in this case 4 inches, as shown in Fig. 187).

Example: In Figure 187 take 8 feet (long side of frame) − 4 feet (short side of frame) = 4 feet. 4 feet + 4 inches (width of inside ventilator) = 4 feet 4 inches, (length of inside ventilator *a′ b′*). To find the size of the outside ventilator *h l* and hood *m p* in Fig. 178 simply add twice the distance *a b* and *a c* respectively to the above size, 4 inches, and 4 feet 4 inches, which will give the widths and lengths of the outside vent and hood.

Rule 3. To find the lengths of either common or hip bar (in any size skylight) deduct the width of the ventilator, if any, from the length of the shortest side of frame and divide the remainder by two. Apply the length thus obtained on the base line of its respective triangle for common or hip bars and determine the true lengths of the desired bars, from the hypothenuse.

Example: As no ventilator is shown in Fig. 186, there will be nothing to deduct for it, and the operation is as follows: 4 feet (short-



THE "NASSAUER HAUS" IN NÜRNBERG, GERMANY

Built at the End of the Thirteenth Century. Railing of Gallery underneath Red-Tiled Roof is Decorated with Coats of Arms. In the Niche over the Fountain at the Lower Right, is a Statue of King Adolf von Nassau.

TERRACE OF HOUSE AT MONTECITO, CALIFORNIA

Myron Hunt & Elmer Grey, Architects, Los Angeles, Cal.

For Perspective View of Building See Page [illegible]; Basement, First, and Second Floor Plans Shown on Page [illegible]

est side of frame) ÷ 2 = 2 feet. We have now the length with which to proceed to the triangle for common and hip bars. Thus the length of the common bar *c d* will be equal to twice the amount of A O in Fig. 184, while the length of the hip bar *b e* in Fig. 186, will be equal to twice the amount of B O in Fig. 185. Referring to Figs. 186 and 187 the jack bars *i j* are spaced 16 inches, therefore, the length of the jack bar for 12 inches will equal A O in Fig. 184, and 4 inches equal to 4" O, both of which are added together for the full length.

The lengths of the common and hip bars will be shorter in Fig. 187 because a ventilator has been used, while in Fig. 186 a ridge bar was employed. To obtain the lengths of the common and hip bars in Fig. 187 use Rule 3: 48 inches (length of short side) − 4 inches (width of inside ventilator) = 44 inches; and 44 inches ÷ 2 = 22 inches or 1 foot 10 inches. Then the length of the common bar *c′ d′* measured with a rule will be equal to A O in Fig. 184 and 10" O added together, and the length of the hip bar *e′ f′* in Fig. 187 will be equal to B O in Fig. 185 and 10" O added together. Use the same method where fractional parts of an inch occur. In laying out the patterns according to these measurements use the cuts shown in Figs. 178, 179, 180, and 181, being careful to measure from the arrowpoints shown on each pattern.

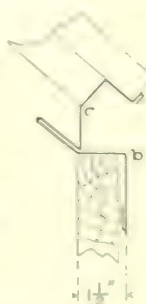


Fig. 188

It will be noticed in Fig. 178 we always measure on line 4 in the patterns for the hip, common, and jack bars. This is done because the line 4 in the profiles E and E[1] come directly on the slant line of the triangles which were traced to Figs. 184 and 185 and from which the true lengths were obtained. Where a curb might be used, as shown in Fig. 188, which would bring the bottom line of the bar $1\frac{1}{2}$ inches toward the inside of the frame *b*, all around, then instead of using the size of 4 x 8 feet as the basis of measurements deduct 3 inches on each side, making the basis of measuremerts 3 ft. 9 inches x 7 ft. 9 inches, and proceed as explained above.

ROOFING

A good metal covering on a roof is as important as a good foundation. There are various materials used for this purpose such as terne plate or what is commonly called roofing tin. The rigid body, or the base of roofing tin, consists of thin sheets of steel (black plates) that are coated with an alloy of tin and lead. Where a first-class job is desired soft and cold rolled copper should be used. The soft copper is generally used for cap flashing and allows itself to be dressed down well after the base flashing is in position. The cold-rolled or hard copper is used for the roof coverings. In some cases galvanized sheet iron or steel is employed. No matter whether tin, galvanized iron, or copper is employed the method of construction is the same, and will be explained as we proceed.

Another form of roofing is known as corrugated iron roofing, which consists of black or galvanized sheets, corrugated so as to secure strength and stiffness. Roofs having less than one-third pitch should be covered by what is known as flat-seam roofing, and should be covered (when tin or copper is used) with sheets 10 x 14 inches in size rather than with sheets 14 x 20 inches, because the larger number of seams stiffens the surface and prevents the rattling of the tin in stormy weather. Steep roofs should be covered by what is known as standing-seam roofing made from 14″ x 20″ tin or from 20″ x 28″. Before any metal is placed on a roof the roofer should see that the sheathing boards are well seasoned, dry and free from knots and nailed close together. Before laying the tin plate a good building paper, free from acid, should be laid on the sheathing, or the tin plate should be painted on the underside before laying. Corrugated iron is used for roofs and sides of buildings. It is usually laid directly upon the purlins in roofs, and held in place by means of clips of hoop iron, which encircle the purlins and are riveted to the corrugated iron about 12 inches apart. The method of constructing flat and double-seam roofing, also corrugated iron coverings, will be explained as we proceed.

TABLES

The following tables will prove useful in figuring the quantity of material required to cover a given number of square feet.

FLAT-SEAM ROOFING

Table showing quantity of 14 x 20 inch tin required to cover a given number of square feet with flat seam tin roofing. A sheet of 14 x 20 inches with [illegible] inch edges measures, when edged or locked, 13 x 19 inches or 247 square inches. In the following all fractional parts of a sheet are counted a full sheet.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	163	[illegible]	[illegible]	[illegible]	[illegible]
112	[illegible]	[illegible]	[illegible]	570	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
136	[illegible]	[illegible]	210	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
150	[illegible]	[illegible]	222	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	463
[illegible]	[illegible]	110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	111	[illegible]	245	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	117	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
210	123	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	910	[illegible]
[illegible]	[illegible]	[illegible]	275	[illegible]	[illegible]	920	[illegible]
250	[illegible]	[illegible]	[illegible]	740	444	[illegible]	[illegible]
[illegible]	152	[illegible]	[illegible]	[illegible]	[illegible]	940	540
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	950	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	710	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	970	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]				

1000 square feet, 583 sheets.

A box of 112 sheets 14 x 20 inches will cover approximately 192 square feet.

Example. How much 14 x 20 inch tin with [illegible]-inch edges is required to cover a roof 20 feet x 84 feet? Take 20 x 84 = 1,680 square feet.

Referring to the table for Flat Seam Roofing, 1000 square feet require 583 sheets and 680 square feet require 397 sheets, making a total of 980 sheets.

It should be understood that this amount is figured on the basis of 247 square inches in an edged sheet, which will be a trifle less when the sheets are laid on the roof.

Example. What quantity of 20 x 28-inch tin will be required to lay a standing seam roof, measuring 37 feet long x 45 feet in width? Take 37 x 45 = 1,665 square feet, or 16 squares and 65 feet. Referring to the table for Standing Seam Roofing, 16 squares require 4 boxes and 48 sheets, and 65 feet require 20 sheets, making a total of 4 boxes and 68 sheets.

STANDING-SEAM ROOFING

Table showing the quantity of 20 × 28-inch tin in boxes, and sheets required to lay any given standing-seam roof.

SQ. FEET	SHEETS	SQUARES	SQ. FEET	BOXES	SHEETS	SQUARES	BOXES	SHEETS
1	1	......	68	......	21	35	9	77
2	1	......	69	......	21	36	9	108
3	1	......	70	......	22	37	10	27
4	2	......	71	......	22	38	10	58
5	2	......	72	......	22	39	10	89
6	2	......	73	......	22	40	11	8
7	3	......	74	......	23	41	11	39
8	3	......	75	......	23	42	11	70
9	3	......	76	......	23	43	11	101
10	4	......	77	......	24	44	12	20
11	4	......	78	......	24	45	12	51
12	4	......	79	......	24	46	12	82
13	4	......	80	......	25	47	13	1
14	5	......	81	......	25	48	13	32
15	5	......	82	......	25	49	13	63
16	5	......	83	......	25	50	13	94
17	6	......	84	......	26	51	14	13
18	6	......	85	......	26	52	14	44
19	6	......	86	......	26	53	14	75
20	7	......	87	......	27	54	14	106
21	7	......	88	......	27	55	15	25
22	7	......	89	......	27	56	15	56
23	7	......	90	......	28	57	15	87
24	8	......	91	......	28	58	16	6
25	8	......	92	......	28	59	16	37
26	8	......	93	......	28	60	16	68
27	9	......	94	......	29	61	16	99
28	9	......	95	......	29	62	17	18
29	9	......	96	......	29	63	17	49
30	10	......	97	......	30	64	17	80
31	10	......	98	......	30	65	17	111
32	10	......	99	......	30	66	18	30
33	10	......	100	......	31	67	18	61
34	11	1	......	......	31	68	18	92
35	11	2	......	......	62	69	19	11
36	11	3	......	......	93	70	19	42
37	12	4	......	1	12	71	19	73
38	12	5	......	1	43	72	19	104
39	12	6	......	1	74	73	20	23
40	13	7	......	1	105	74	20	54
41	13	8	......	2	24	75	20	85
42	13	9	......	2	55	76	21	4
43	13	10	......	2	86	77	21	35
44	14	11	......	3	5	78	21	66
45	14	12	......	3	36	79	21	97
46	14	13	......	3	67	80	22	16
47	15	14	......	3	98	81	22	47
48	15	15	......	4	17	82	22	78
49	15	16	......	4	48	83	22	109
50	16	17	......	4	79	84	23	28
51	16	18	......	4	110	85	23	59
52	16	19	......	5	29	86	23	90
53	16	20	......	5	60	87	24	9
54	17	21	......	5	91	88	24	40
55	17	22	......	6	10	89	24	71
56	17	23	......	6	41	90	24	102
57	18	24	......	6	72	91	25	21
58	18	25	......	6	103	92	25	52
59	18	26	......	7	22	93	25	83
60	19	27	......	7	53	94	26	2
61	19	28	......	7	84	95	26	33
62	19	29	......	8	3	96	26	64
63	19	30	......	8	34	97	26	95
64	20	31	......	8	65	98	27	14
65	20	32	......	8	96	99	27	45
66	20	33	......	9	15	100	27	76
67	21	34	......	9	46			

Size of sheet before working, 20 × 28 inches. Exposed on roof $27 \times 17\frac{3}{4}$ inches.
Square inches per sheet exposed $479\frac{1}{4}$ inches. Sheets per box 112.

NET WEIGHT PER BOX TIN PLATES
Base 14 × 20, 112

Trade term		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Weight per box, lb.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]											
[illegible] x 14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100	107	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14 x 20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20 x 28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x 20	225	[illegible]	121	[illegible]	[illegible]	[illegible]	153	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x [illegible]	225	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	184	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x [illegible]	[illegible]	[illegible]	[illegible]	170	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12 x 12	[illegible]	[illegible]	87	93	[illegible]	[illegible]	110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12 x 24	112	[illegible]	[illegible]	93	[illegible]	103	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13 x 13	[illegible]	[illegible]	[illegible]	[illegible]	115	121	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13 x 26	112	[illegible]	103	109	115	121	[illegible]	154	163	187	211	[illegible]
14 x [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	140	[illegible]	[illegible]	[illegible]	217	245	[illegible]
14 x 28	112	[illegible]	119	126	133	140	[illegible]	[illegible]	[illegible]	217	[illegible]	[illegible]
[illegible] x [illegible]	[illegible]	[illegible]	137	[illegible]	153	[illegible]	172	[illegible]	217	[illegible]	[illegible]	313
[illegible] x [illegible]	225	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	357
[illegible] x 17	[illegible]	[illegible]	[illegible]	186	196	206	[illegible]	[illegible]	[illegible]	[illegible]	361	[illegible]
18 x 18	[illegible]	[illegible]	[illegible]	104	[illegible]	116	124	[illegible]	[illegible]	179	[illegible]	[illegible]
[illegible] x 19	[illegible]	[illegible]	[illegible]	116	[illegible]	129	[illegible]	[illegible]	173	200	[illegible]	[illegible]
[illegible] x 20	112	[illegible]	[illegible]	129	[illegible]	143	153	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x 21	112	[illegible]	134	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x 22	[illegible]	[illegible]	147	[illegible]	[illegible]	172	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x 23	112	[illegible]	[illegible]	170	[illegible]	[illegible]	202	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x 24	112	[illegible]	175	185	195	204	[illegible]	263	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x [illegible]	112	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x [illegible]	112	[illegible]	[illegible]	103	[illegible]	114	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] x 31	[illegible]	[illegible]	132	[illegible]	147	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	271	[illegible]
[illegible] x [illegible]	[illegible]	[illegible]	78	[illegible]	[illegible]	91	[illegible]					
[illegible] x [illegible]	112	[illegible]	71	[illegible]	[illegible]	[illegible]	[illegible]					
[illegible] x [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	91	[illegible]					
[illegible] x [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	94	[illegible]					
[illegible] x [illegible]	112	[illegible]	[illegible]	[illegible]	[illegible]	95	102					
[illegible] x [illegible]	124	[illegible]	[illegible]	[illegible]	98	103	110					
[illegible] x [illegible]	[illegible]	[illegible]	[illegible]	93	98	103	[illegible]					
14 x 21	112	[illegible]	[illegible]	95	100	[illegible]	[illegible]					
14 x 22	[illegible]	[illegible]	[illegible]	99	105	[illegible]	[illegible]					
14 x [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	119					
[illegible] x 21	[illegible]	102	[illegible]	[illegible]	121	[illegible]	[illegible]					

STANDARD WEIGHTS AND GAUGES OF TIN PLATES

Trade term	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Trade term	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	.619	.712	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	lb. [illegible]	lb. [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

OTHER FORMS OF METAL ROOFING

There is another form of roofing known as metal slates and shingles, pressed in various geometrical designs with water-tight lock attachments so that no solder is required in laying the roof. Fig. 189 shows the general shape of these metal shingles which are made from tin, galvanized iron, and copper, the dots *a a a a* representing the holes for nailing to the wood sheathing. In Fig. 190, A represents the side lock, showing the first operation in laying the metal slate or shingle on a roof, *a* representing the nail. B, in the same figure, shows the metal slate or shingle in position covering the nail *b*, the valley *c* of the bottom slate allowing the water, if any, to flow over the next lower slate as in A in Fig. 189.

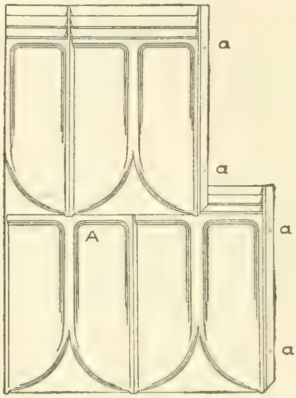


Fig. 189.

In Fig. 191 is shown the bottom slate A covered by the top slate B, the ridges *a a a* keeping the water from backing up. Fig. 192 shows the style of roof on which these shingles are employed, that is, on steep roofs. Note the construction of the ridge roll, A and B in Fig. 192, which is first nailed in position at *a a* etc., after which the shingles B are slipped under the lock *c*. Fig. 193 shows a roll hip covering which is laid from the top downward, the lower end of the hip having a projection piece for nailing at *a*, over which the top end of the next piece is inserted, thus

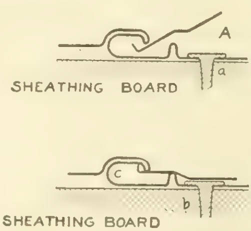


Fig. 190.

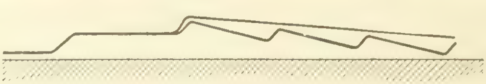


Fig. 191.

covering and concealing the nails. Fig. 194 represents a perspective view of a valley with metal slates, showing how the slates A are locked to the fold in the valley B. There are many other forms of metal shingle but the shapes shown herewith are known as the Cortright patents.

TOOLS REQUIRED

Fig. 195 shows the various hand tools required by the metal roofer; starting at the left we have the soldering copper, mallet, scraper,

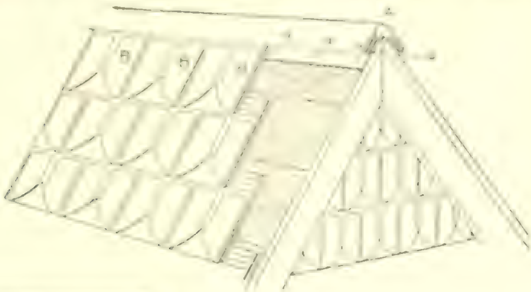


Fig. 192.

stretch-awl, shears, hammer, and dividers. In addition to these hand tools a notching machine is required for cutting off the corners of the

Fig. 193.

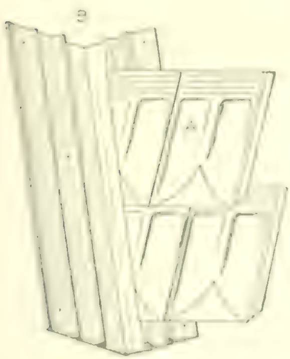


Fig. 194.

sheets, and roofing folders are required for edging the sheets in flat-seam roofing, and hand double seamer and roofing tongs for standing-seam roofing. The roofing double seamer and squeezing tongs can be used for standing-seam roofing (in place of the hand double seamer), which allow the operator to stand in an upright position if the roof is not too steep.

ROOF MENSURATION

While some mechanics understand thoroughly the methods of laying the various kinds of roofing, there are some, however, who do not understand how to figure from architects' or scale drawings the amount of material required to cover a given surface in a flat, irregular shaped, or hipped roof. The modern house with its gables and va-

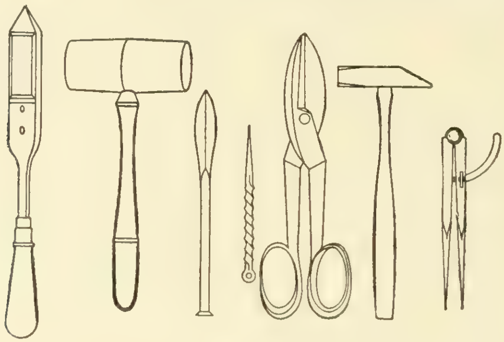


Fig. 195.

rious intersecting roofs, forming hips and valleys, render it necessary to give a short chapter on roof measurement. In Figs. 196 to 198 inclusive are shown respectively the plans with full size measurements for a flat, irregular, and intersected hipped roof, showing how the length of the hips and valleys are obtained direct from the architects' scale drawings.

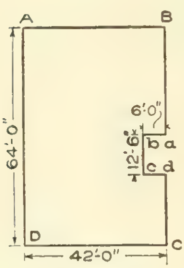


Fig. 196.

The illustrations shown herewith are not drawn to a scale as architects' drawings will be, but the measurements on the diagrams are assumed, which will clearly show the principles which must be applied when figuring from scale drawings. Assuming that the plans from which we are figuring are drawn to a quarter-inch scale, then when measurements are taken, every quarter inch represents one foot. $\frac{1}{8}$ inch = 6 inches, $\frac{1}{16}$ inch = 3 inches, etc. If the drawings were drawn to a half-inch scale, then $\frac{1}{2}$ inch = 12 inches, $\frac{1}{4}$ inch = 6 inches, $\frac{1}{8}$ inch = 3 inches, $\frac{1}{16}$ inch = $1\frac{1}{2}$ inches, etc.

A B C D in Fig. 196 represents a flat roof with a shaft at one side as shown by *a b c d*. In a roof of this kind we will figure it as if there was no air shaft at all. Thus 64 feet × 42 feet = 2,688 square feet. The shaft is 12.5 × 6 feet = 75 square feet; then 2,688 feet − 75 feet =

2,613 square feet of roofing, to which must be added an allowance for the flashing turning up against and into the walls at the sides.

In Fig. 197 is shown a flat roof with a shaft at each side, one shaft being irregular, forming an irregular shaped roof. The rule for obtaining the area is similar to that used for Fig. 196 with the exception that the area of the irregular shaft *x x x x* in Fig. 197 is determined differently to that of the shaft *b c d e*. Thus A B C D = 108 feet × 45 feet = 4,860 square feet. Find the area of *b c d e* which is 9.25 × 39.5 = 365.375 or 365⅜ square feet. To find the area of the irregular shaft, bisect *xx* and *xx* and obtain *a a*, measure the length of *a a* which is 48 feet, and multiply by 9. Thus 48 × 9 = 412, and 412 + 365.375 = 777.375. The entire roof minus the shafts = 4,860 square feet − 777.375 = 4,082.625 square feet of surface in Fig. 197.

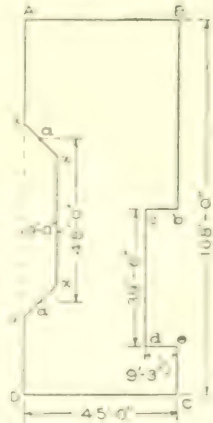


Fig. 197.

In Fig. 198 is shown the plan, front, and side elevations of an intersected hipped roof. A B C D represents the plan of the main building intersected by the wing E F G H. We will first figure the main roof as if there were no wing attached and then deduct the space taken

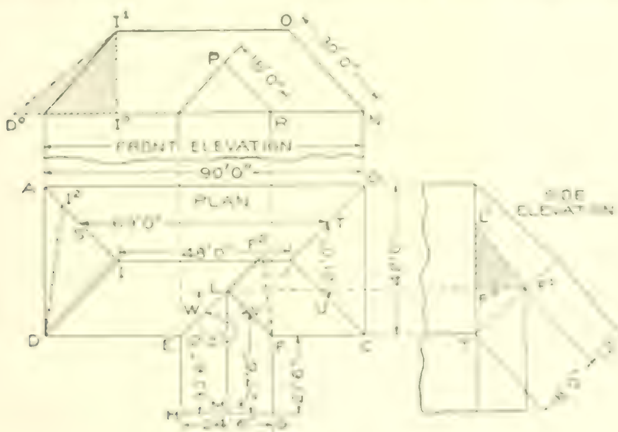


Fig. 198

up by the intersection of the wing. While it may appear difficult to some to figure the quantities in a hipped roof, it is very simple, if the rule is understood. As the pitch of the roof is equal on four sides the length of the rafter shown from O to N in front elevation represents the true length of the pitch on each side. The length of the building at the eave is 90 feet and the length of the ridge 48 feet. Take 90 − 48 = 42, and 42 ÷ 2 = 21. Now either add 21 to the length of the edge or deduct 21 from the length of the eave, which gives 69 feet as shown from S to T. The length of the eave at the end is 42 feet and it runs to an apex at J. Then take 42 feet ÷ 2 = 21, as shown from T to U. If desired the hip lines A I, J B and J C can be bisected, obtaining respectively the points S, T, and U, which when measured will be of similar sizes; 69 feet and 21 feet. As the length of the rafter O N is 30 feet, then multiply as follows: 69 × 30 = 2070. 21 × 30 = 630. Then 630 + 2,070 = 2,700, and multiplying by 2 (for opposite sides) gives 5,400 square feet or 54 squares of roofing for the main building. From this amount deduct the intersection E L F in the plan as follows:

The width of the wing is 24 feet 6 inches and it intersects the main roof as shown at E L F. Bisect E L and L F and obtain points W and V, which when measured will be 12 feet 3 inches or one half of HG, 24 feet 6 inches. The wing intersects the main roof from Y to F^1 in the side elevation, a distance of 18 feet. Then take 18 × 12.25 = 220.5. Deduct 220.5 from 5400 = 5,179.5. The wing measures 33 feet 6 inches at the ridge L M, and 21 feet 6 inches at the eave F G, thus making the distance from V to X = 27 feet 6 inches. The length of the rafter of the wing is shown in front elevation by P R, and is 18 feet. Then 18 × 27.5 = 495, and multiplying by 2 (for opposite side), gives 995 sq. ft. in the wing. We then have a roofing area of 5,179.5 square feet in the main roof and 995 square feet in the wing, making a total of 6,174.5 square feet in the plan shown in Fig. 198.

If it is desired to know the quantity of ridge, hips, and valleys in the roof, the following method is used. The ridge can be taken from the plans by adding 48′ + 33′6″ = 81′ − 6″. For the true length of the hip I D in the plan, drop a vertical line from I^1 in the front elevation until it intersects the eave line 1°. On the eave line extended, place the distance I D in the plan as shown from 1° to D° and draw a line from D° to I^1 which will be the true length of the hip I D in the plan. Multiply this length by 4, which will give the amount of ridge capping required. This length of hip can also be obtained from the plan by taking the vertical height of the roof $F^0 F^1$ in the elevation and placing it at right angles to I D in the plan, as shown, from I to F^2, and draw a line from F^2 to D which is the desired length.

For the length of the valley L F in the plan, drop a vertical line from F^1 in the side elevation until it intersects the eave line at F^0. Take the distance F L in the plan and place it as shown from F^0 to L^0, and draw a line from L^0 to F^1, which is the true length of the valley shown by L F in the plan. Multiply this length by 2, which will give the required number of feet of valley required. This length of valley can also be obtained from the plan by taking the vertical height of the roof of the wing, shown by F^0 F^1 in the side elevation, and placing it at right angles to F L in the plan, from L to F^2, and draw a line from F^2 to F which is the desired length similar to F^1 L^0 in the side elevation.

FLAT-SEAM ROOFING

The first step necessary in preparing the plates for flat seam roofing is to notch or cut off the four corners of the plate as shown in Fig. 199 which shows the plate as it is taken from the box, the shaded corners *a a a a* representing the corners which are notched on the notching machine or with the shears. Care must be taken when cutting off these corners not to cut off too little otherwise the sheets will not edge well, and not to cut off too much, otherwise a hole will show at the corners when the sheets are laid. To find the correct amount to be cut off proceed as follows:

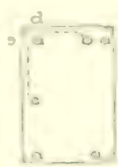


Fig. 199.

Assuming that a ½-inch edge is desired, set the dividers at ½ inch and scribe the lines *b a* and *a c* on the sheet shown in Fig. 199, and, where the lines intersect at *a*, draw the line *d e* at an angle of 45 degrees, which represents the true amount and true angle to be cut off on each corner. After all the sheets have been notched, they are edged as shown in Fig. 200, the long sides of the sheet being bent right and left, as shown at *a*, while the short side is bent as shown at *b*, making the notched corner appear as at *c*. In some cases after the sheets are edged the contract requires that the sheets be painted on the underside before laying. This is usually done with a small brush being careful that the edges of the sheets

Fig. 200.

are not soiled with paint, which would interfere with soldering. Before laying the sheets the roof boards are sometimes covered with an oil or rosin-sized paper to prevent the moisture or fumes from below from rusting the tin on the underside. As before mentioned, the same method used for laying tin roofing would be applicable for laying copper roofing, with the exception that the copper sheets would have to be tinned about 1½ inches around the edges of the sheets after they are notched, and before they are edged.

In Fig. 201 is shown how a tin roof is started and the sheets laid when a gutter is used at the eaves with a fire wall at the side. A represents a galvanized iron gutter with a portion of it lapping on the roof,

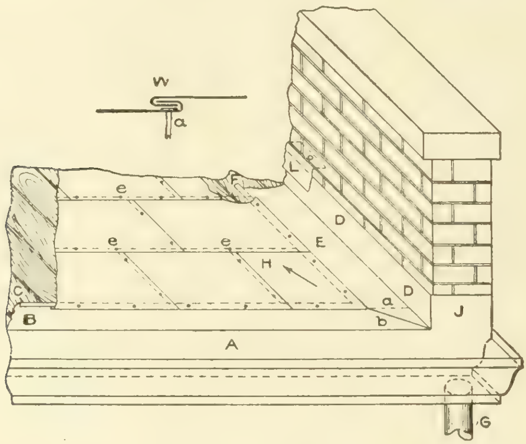


Fig. 201.

with a lock at C. In hanging the gutter it is flashed against the fire wall at J; after which the base flashing D D is put in position, flashing out on the roof at E, with a lock at F. Where the base flashing E miters with the flange of the gutter B it is joined as shown at *b*, allowing the flange E of the base flashing as shown by the dotted line *a*. As the water discharges at G, the sheets are laid in the direction of the arrow H, placing the nails at least 6 inches apart, always starting to nail at the butt *e e*, etc. Care should be taken when nailing that the nail heads are well covered by the edges, as shown in W, by *a*. Over the base flashing D D J the cap flashing L is placed, allowing it to go into the wall as at O.

When putting in base flashings there are two methods employed. In Fig. 202 is shown a side flashing between the roof and parapet wall. A shows the flashing turning out on the roof at B, with a lock C, attached and flashed into the wall four courses of brick above the roof line, as shown at D, where wall hooks and paintskins or roofer's cement are used to make a tight joint. Flashings of this kind should always be painted on the underside, and paper should be placed between the brick work and metal, because the moisture in the wall is apt to rust the tin. This method of putting in flashing is not advisable in new work, because when the building is new, the walls and beams are liable to settle and when this occurs the flange D tears out of the wall, and the result is disagreeable leaks that stain the walls. When a new roof is to be placed on an old building where the walls and copings are in place and the brick work and beams have settled, there is not so much danger of leakage.

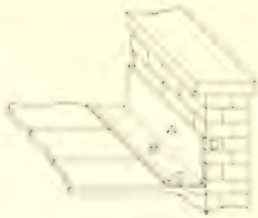


Fig. 202.

The proper method of putting in flashings and one which allows for the expansion and contraction of the metal and the settlement of the building is shown in Fig. 203, in which A shows the cap flashings

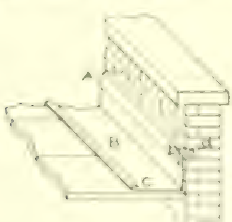


Fig. 203

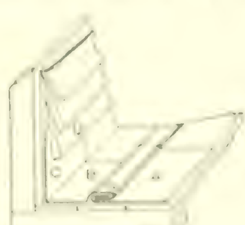


Fig. 204

painted with two coats of paint before using. When the mason has built his wall up to four courses of brick above the roof line the cap flashing A is placed in position and the wall and coping finished; the base flashing B is then slipped under the cap A. In practice the cap flashing is cut 7 inches, then bent at right angles through the center, making each side *a* and *b* 3½ inches. The base flashing B is then slipped under the cap flashing A as shown at C.

Where the cost is not considered and a good job is desired, it is better to use sheet lead cap flashings in place of tin. They last longer, do not rust, and can be dressed down well to lay tight onto the base flashings. Into the lock C the sheets are attached. After the sheets are laid the seams are flattened down well by means of a heavy mallet, with slightly convex faces, after which the roof is ready for soldering. When a base flashing is required on a roof which abuts against a wall composed of clap boards or shingles as shown in Fig. 204, then, after the last course of tin A has been laid, the flashing B with the lock *a* is locked into the course A and extends the required distance under the boards D. The flashing should always be painted and allowed to dry before it is placed in position. In the previous figures it was shown how the sheets are edged, both sides being edged right and left. In

Fig. 205.

Fig. 205 is shown what is known as a valley sheet, where the short sides are edged both one way, as shown at *a a*, and the long sides right and left as shown at *b b*. Sheets of this kind are used when the water runs together from two directions as shown by A in Fig. 206. By having the locks *a* and *a* turned one way the roof is laid in both directions.

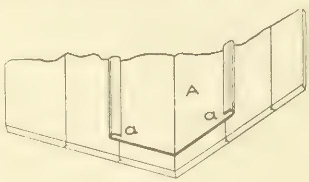


Fig. 206.

Fig. 207 shows a part plan of a roof and chimney A, around which the flashing B C D E is to be placed, and explains how the corners C and D are double seamed, whether on a chimney, bulkhead, or any other object on a roof when the water flows in the direction of the arrow F. The first operation is shown at *a* and the final operation at *b*. Thus it will be seen that the water flows past the seam and not against it. In laying flat seam roofing especially when copper is used, allowance must be made for the expansion and contraction of the sheets.

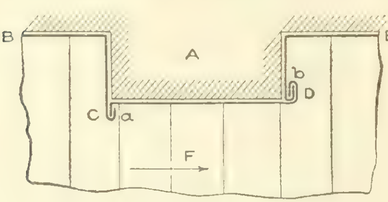


Fig. 207.

Care should be taken not to nail directly through the sheet as is shown in W, Fig. 201. While this method is generally employed in tin roofing, on a good job, as well as on copper roofing, cleats as shown at D in Fig. 208 should be used.

To show how they are used, A and B represent two locked-edged sheets. The lock on the cleat D is locked into the edge of the sheets and nailed into the roof board, as at *a b c* and *d*, or as often as required.

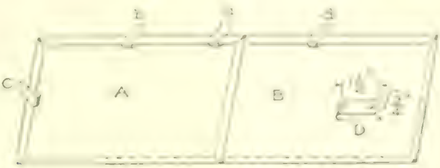


Fig. 208

In this manner the entire roof can be fastened with cleats without having a nail driven into the sheets, thereby allowing for expansion and contraction of the metal. The closer these cleats are placed, the firmer the roof will be and the better the seams will hold. By using fewer cleats, time may be saved in laying the roof, but double this time is lost when soldering the seams, for the heat of the soldering copper

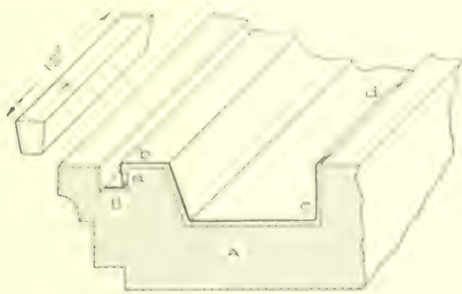


Fig. 209

will raise the seams, causing a succession of buckles, which retard soldering and require 10 per cent more solder. When the seams are nailed or cleated close it lays flat and smooth and the soldering is done with ease and less solder.

When a connection is to be made between metal and stone or terra cotta, the method shown in Fig. 209 is employed. This illustration shows a stone or terra-cotta cornice A. The heavy line *a b c d* represents the gutter lining, which is usually made from 20-oz. cold-rolled copper. If the cornice A is of stone, the stone cutter cuts a raggle into the top of the cornice A as at B, dove-tail in shape, after which the lining *a b c d* is put in position as shown. Then, being careful that there is no water or moisture in the raggle B, molten lead is poured into the raggle and after it is cooled it is dressed down well with the caulking chisel and hammer.

By having the dove-tail cut, the lead is secured firmly in position, holding down the edge of the lining and making a tight joint. Should the cornice be of terra cotta this raggle is cut into the clay before it is baked in the ovens. This method of making connection between

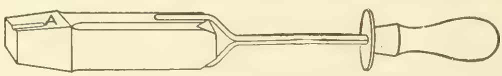


Fig. 210.

metal and stone is the same no matter whether a gutter or upright wall is to be flashed. When a flashing between a stone wall and roof is to be made tight, then instead of using molten lead, cakes of lead are cast in molds made for this purpose, about 12 inches long, and these are driven into the raggle B as shown in Fig. 209 at X.

The most important step in roofing is the soldering. The style of soldering copper employed is shown in Fig. 210 and weighs at least 8 pounds to the pair. When rosin is used as a flux, it is also employed in tinning the coppers, but when acid is used as a flux for soldering zinc or galvanized iron, salammoniac is used for tinning the coppers. It will be noticed that the soldering coppers are forged square at the ends, and have a groove filed in one side as shown at A. When the copper is turned upward the groove should be filed toward the lower side within ¼ inch from the corner, so that when the groove is placed upon the seam, as shown in Fig. 211, it acts as a guide to the copper as the latter is drawn along the seam. The groove *a* being in the position shown, the largest heated surface *b* rests directly on the seam, "soaking" it thoroughly with solder. As the heat draws the solder between the locks, about 6 pounds of ½ and ½ solder are required for 100 square feet of surface using 14 x 20-inch tin The use of acid in soldering seams in a tin roof is to be avoided as acid coming in contact with the

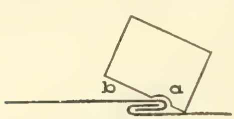
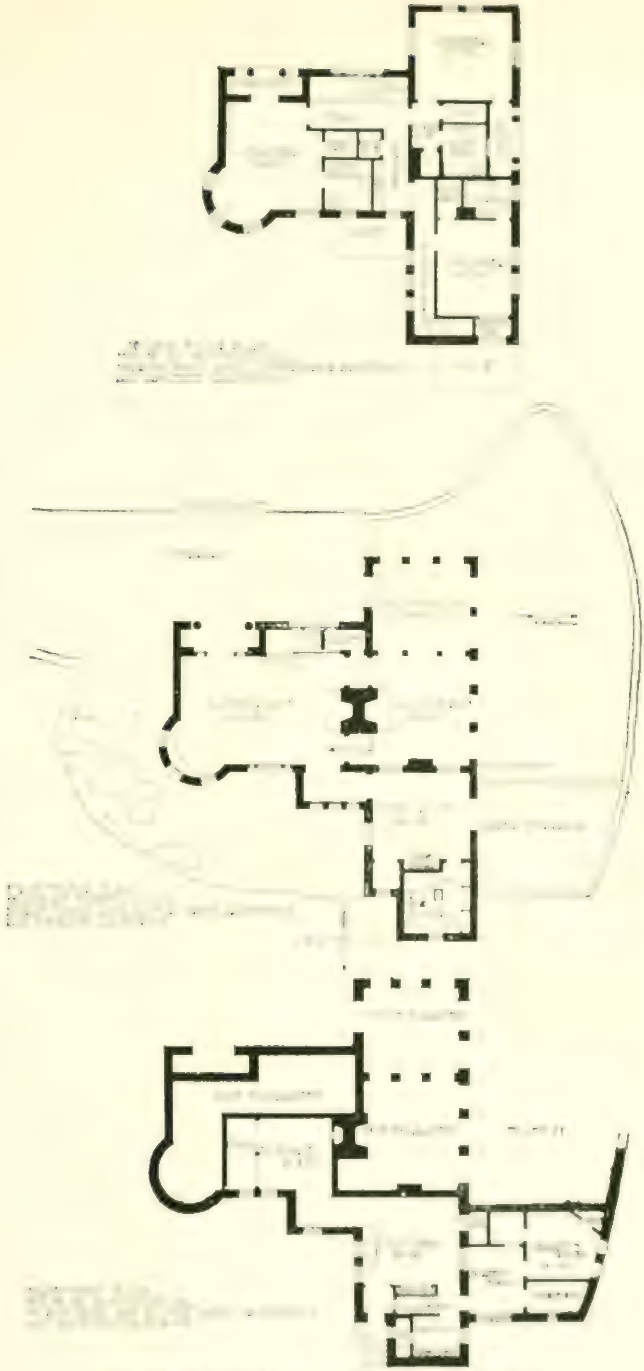


Fig. 211.

HOUSE AT MONTECITO, CALIFORNIA

Myron Hunt & Elmer Grey, Architects, Los Angeles, Cal.

Cost, Approximately, $40,000. Walls of Local Stone. Roofs of Japanese Tile of Metallic Composition Containing Aluminum and other Ingredients which, under Erosion of the Weather, Become Partially Disintegrated, Giving Beautiful Bronze Color Effects. For Plans, See Page 151; for View of Terrace, See Page 186.



PLANS OF HOUSE AT MONTECITO, CALIFORNIA

[illegible] Architects, Los Angeles, Cal.

bare edges and corners, where the sheets are folded and seamed together, will cause rusting. No other soldering flux but good clean rosin should be employed. The same flux (rosin) should be used when soldering copper roofing whose edges have previously been tinned with rosin.

We will now consider the soldering of upright seams. The soldering copper to be employed for this purpose is shaped as shown in Fig. 212. It is forged to a wedge shape about 1 inch wide and ¼ inch

Fig. 212

thick at the end, and is tinned on one side and the end only; if tinned otherwise, the solder, instead of remaining on the tinned side when soldering, would flow downward; by having the soldering copper tinned on one side only, the remaining sides are black and do not tend to draw the solder downward. The soldering copper being thus prepared, the upright seam, shown in Fig. 213, where the sheet B overlaps the sheet A 1", is soldered by first tacking the seam to make it lay close, then thoroughly soaking the seam, and then placing ridges of solder across it to strengthen the same. In using the soldering copper it should be held in the position shown by C, which allows the solder to flow forward and into the seam, while if the copper were held as shown by D, the solder would flow backward and away from the seam. In "soaking" the seam with solder the copper should be placed directly over the lapped part, so that the metal gets thoroughly heated and draws the solder between the joint. It makes no difference where this cross joint occurs; the same methods are used.

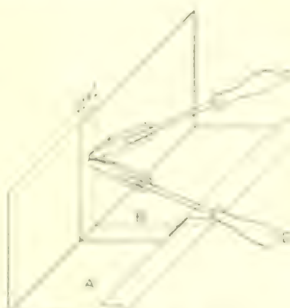


Fig. 213

The roof being completed, the rosin is scraped off the seams and the roof cleaned and painted with good iron oxide and linseed oil paint. Some roofers omit the scraping of rosin and paint directly over it. This is the cause of rusting of seams which sometimes occurs. If the paint is applied to the rosin, the latter, with time, will crack, and the rain will soak under the cracked rosin to the tin surface. Even when the surface of the roof is dry, by raising the cracked rosin, moisture will often be found underneath, which naturally tends to rust the plate more and more with each storm. If the rosin is removed, the entire tin surface is protected by paint.

One of the most difficult jobs in flat-seams roofing is that of covering a conical tower. As the roof in question is round in plan and tapering in elevation, it is necessary to know the method of cutting the various patterns for the sheets. In Fig. 214 A B C shows the elevation of a tower to be covered with flat seam roofing, using 10 × 14-inch tin at the base. Assuming that the tower through B C is 10 feet 6 inches, or 126 inches, in diameter, the circumference is obtained by multiplying 126 by 3.1416 which equals 395.8416, or say 396 inches. As 10 x 14-inch plate is to be used at the base of the tower the nearest width which can be employed, and which will divide the space into equal spaces, is $13\frac{1}{5}$ inches without edges, thus dividing the circumference in 30 equal spaces. This width of $13\frac{1}{5}$ inches together with the length of the rafter A B or B C in elevation, will be the basis from which all the patterns for the various courses will be laid off.

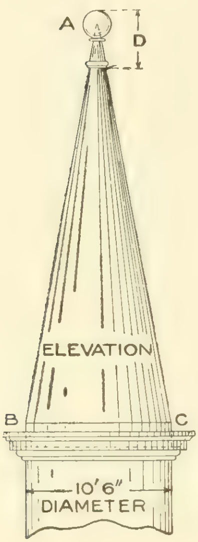


Fig. 214.

At any convenient place in the shop or at the building, stretch a piece of tar felting of the required length, tacking it at the four corners with nails to keep the paper from moving. Upon the center of the felting strike a chalk line as A B in Fig. 215, making it equal to the length of the rafter A B or A C in Fig. 214. At right angles to A B in Fig. 215 at either side, draw the lines B D and B C each equal to $6\frac{3}{5}$ inches, being one half of the $13\frac{1}{5}$ above referred to. From the points C and D draw lines to the apex A (shown broken). As the width of the sheet used is 10 inches and as we assume an edge of $\frac{3}{8}$ inch for each side, thus leaving $9\frac{1}{4}$ inches, measure on the vertical line A B lengths of $9\frac{1}{4}$ inches in succession, until the apex A is reached, leaving the last sheet at the top to come as it may. Through the points thus obtained on A B draw lines parallel to C D intersecting the lines A C and A D as shown. Then the various shapes marked 1 2 3 etc. will be the net patterns for similarly numbered courses. Take the shears and cut out the patterns on the folding and number them as required.

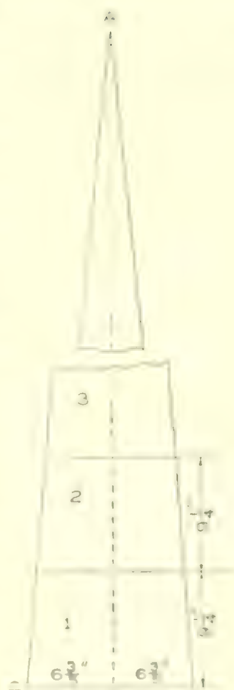


Fig. 215

For example, take the paper pattern No. 1, place it on a sheet of tin as shown in Fig. 216, and allow ¼-inch edges all around, and notch the corners A B C and D. Mark on the tin pattern "No. 1, 29 more", as 30 sheets are required to go around the tower, and cut 29 more for course No. 1. Treat all of the paper patterns from No. 1 to the apex in similar manner. Of course where the patterns become smaller in size at the top, the waste from other patterns can be used.

In Fig. 217 is shown how the sheets should be edged, always being careful to have the narrow side towards the top with the edge toward the outside, the same as in flat seam roofing. Lay the sheets in the usual manner, breaking joints as in general practice. As the seams are not soldered care must be taken to lock the edges well. After the entire roof is laid and before closing the seams with the mallet take a small brush and paint the locks with thick white lead, then close with the mallet. This will make a water-tight job. After the roof is completed the finial D in Fig. 214 is put in position.

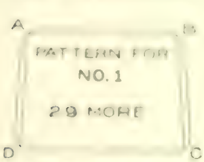


Fig. 216.

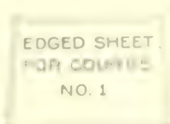


Fig. 217.

As the method used for obtaining the patterns for the various sheets in Fig. 215 is based upon the principle used in obtaining the envelope of a right cone, some students may say that an accurate patterns the line from C to D and all following lines should be curved, as if struck with a radius from the center A, and not straight as shown. To those the writer would say that the curve would be so little on a small pattern, where the radius is so long, that a straight line answers the purpose just as well in all practical work; for it would amount to considerable labor to turn edges on the curved cut of the sheet, and there is certainly no necessity for it.

When different metals are to be connected together, as for instance tin roofing to copper flashing, or copper tubes to galvanized iron gutters, or zinc flashings in connection with copper linings, care must be taken to have the copper sheets thoroughly tinned on both sides where it joins to the galvanized iron, zinc, or other metal, to avoid any electrolysis between the two metals. It is a fact not well known to roofers that if we take a glass jar and fill it with water and place it in separately, two clean strips, one of zinc and the other of copper, and connect the two with a thin copper wire, an electrical action is the result, and if the connection remains for a long time (as the action is very faint) the zinc would be destroyed, because, it may be said, the zinc furnishes the fuel for the electrical action, the same as wood furnishes the fuel for the fire. Therefore, if the copper was not tinned, before locking into the other metal, and the joint became wet with rain, the coating of the metal would be destroyed by the electrical action between the two metals, and the iron would rust through.

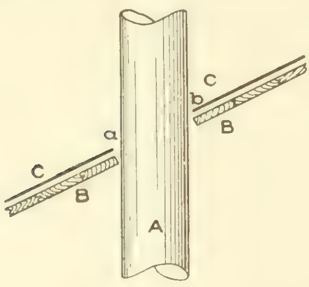


Fig. 218.

While the roofer is seldom called upon to lay out patterns for any roofing work occasion may arise that a roof flashing is required around a pipe passing through a roof of any pitch, as shown in Fig. 218, in which A represents a smoke or vent pipe passing through the roof B B, the metal roof flashing being indicated by C C. If the roof B B were level the opening to be cut into the flashing C C would simply be a true circle the same diameter as the pipe A. But where the roof pitches the opening in the flashing becomes an ellipse, whose minor axis is the same as the diameter of the pipe, and whose major axis is equal to the pitch $a\ b$. In Fig. 219 is shown how this opening is obtained by the use of a few nails, a string, and a pencil, which the roofer will always have handy.

First draw the line A B representing the slant of the roof; and then make the pipe of the desired size passing through this line at its proper angle to the roof line. Next draw the center line R S of the pipe as shown. Call the point where this line intersects the roof line, I, and the points where D E and C F intersect A B, G and H respectively. Through I draw K L at right angles to A B, making K I and I L each equal to the half diameter of the pipe. Having established the minor axis K L and the major axis G H, the ellipse is made by taking I H, or half the major axis, as a radius, and with L as a center strike arcs intersecting the major axis, at points M and N. Drive a small nail in each of these two points and attach a string to the nails as shown by the dotted lines K M N, in such a way that when a pencil point is placed in the string it will reach K. Move the pencil along the string, keeping it taut all the time until the ellipse K H L G is obtained. Note how the position of the string changes when it reaches a, then b, etc.

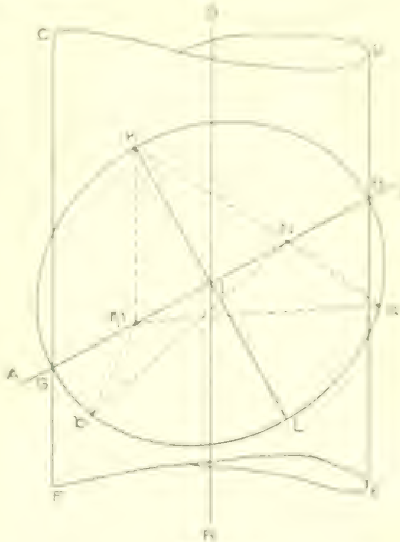


Fig. 219

STANDING-SEAM ROOFING

Another form of metal roofing is that known as standing seam, which is used on steep roofs not less than $\frac{1}{8}$ pitch, or $\frac{1}{8}$ the width of the building. It consists of metal sheets whose cross or horizontal seams are locked as in flat seam roofing, and whose vertical seams are standing locked seams, as will be described in connection with Fig.

220 to 229 inclusive. Assume that 14 x 20-inch sheets are used and the sheets are edged on the 20-inch sides only, as shown by A in Fig. 220, making the sheet 13 x 20 inches. After the required number of sheets have been edged, and assuming that the length of the pitched roof is 30 feet, then as many sheets are locked together as will be required, and the seams are closed with the mallet and soldered. In practice these strips are prepared of the required length in the shop, painted on the underside, and when dry are rolled up and sent to the building. If desired they can be laid out at the building, which avoids the buckling caused by rolling and transportation from the shop to the job.

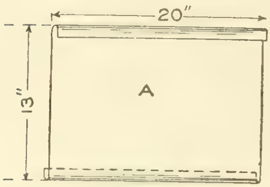


Fig. 220.

After the necessary strips have been prepared they are bent up with the roofing tongs, or, what is better and quicker, the roofing edger for standing-seam roofing. This is a machine into which the strips of tin are fed, being discharged in the required bent form shown at A or B in Fig. 221, bent up 1 inch on one side and $1\frac{1}{4}$ inches on the other side. Or the machine will, if desired, bend up $1\frac{1}{4}$ inches and $1\frac{1}{2}$ inches, giving a $\frac{3}{4}$-inch finished doubled seam in the first case and a 1-inch seam in the second. When laying standing-seam roofing, in no case should any nails be driven into the sheets. This applies to tin, copper or galvanized iron sheets. A cleat should be used, as shown in Fig. 222, which also shows the full size for laying the sheets given in Fig. 221. Thus it will be seen in Fig. 222 that $\frac{1}{4}$ inch has been added over the measurements in Fig. 221, thus allowing edges.

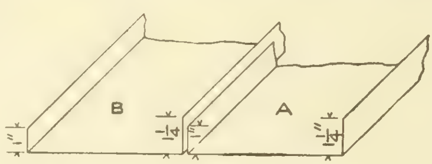


Fig. 221.

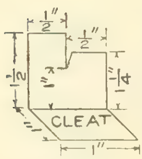


Fig. 222.

These cleats shown in Fig. 222 are made from scrap metal; they allow for the expansion and contraction of the roofing and are used in practice as shown in Fig. 223, which represents the first operation in laying a standing-seam roof, and in which A represents the gutter with a lock attached at B. The gutter being fastened in position by means of cleats under the lock B—the same as in flat seam roofing—the standing seam strips are laid as follows: Take the strip C and lock it well into the lock B of the gutter A as shown, and place the cleat shown in Fig. 222 tightly against the upright bend of the strip C in Fig. 223 as shown at D, and fasten it to the roof by means of a 1-inch roofing nail or

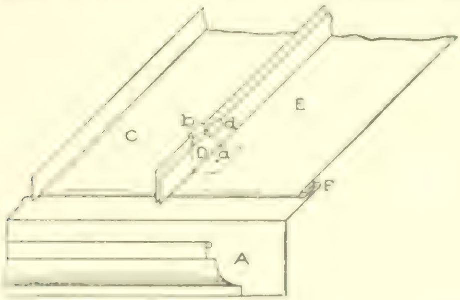


Fig. 223.

Press the strip C firmly onto the roof and turn over edge b of the cleat D. This holds the sheet C in position. Now take the next sheet E, press it down and against the cleat D and turn over the edge d, which holds E in position. These cleats should be placed about 18 inches

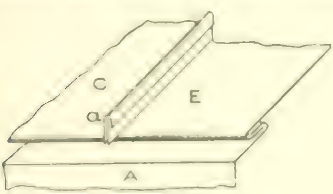


Fig. 224.

Fig. 225.

apart and by using them it will be seen that no nails have been driven through the sheets, the entire roof being held in position by means of the cleats only.

The second operation is shown in Fig. 224. By means of the hand double seamer and mallet or with the roofing double seamers and squeezing tongs, the single seam is made as shown at *a*. The third and last operation is shown in Fig. 225 where by the use of the same tools the doubled seam is obtained. In Fig. 226 is shown how the finish is made with a comb ridge at the top. The sheets A A A have on the one side the single edge as shown, while the opposite side B has a double edge turned over as shown at *a*. Then, standing seams *b b b* are soldered down to *e*.

In Fig. 227 is shown how the side of a wall is flashed and counter

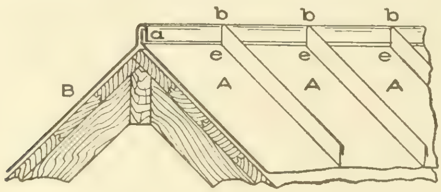


Fig. 226.

flashed. A shows the gutter, B the leader or rain water conductor, and C the lock on the gutter A, fastened to the roof boards by cleats

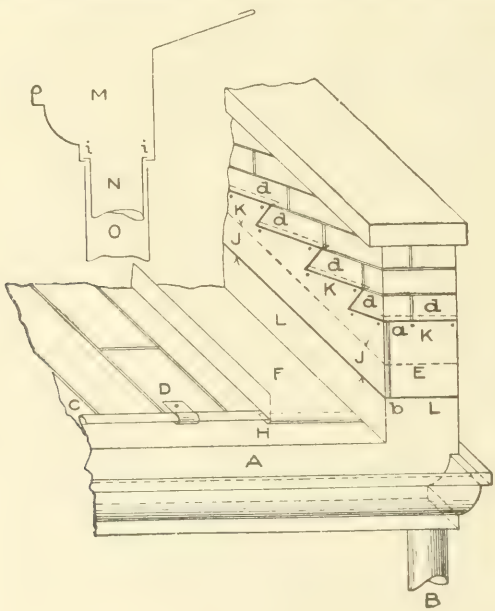


Fig. 227.

as shown at D. The back of the gutter is flashed up against the wall as high as shown by the dotted line E. F represents a standing-seam strip locked into the gutter at H and flashed up against the wall as high as shown by the dotted line I J. As the flashing J J E is not fastened at any part to the wall the beams or wall can settle without disturbing the flashing. The counter or cap flashing K K K is now stepped as shown by the heavy lines, the joints of the brick work being cut out to allow a one-inch flange *d d d* etc. to enter. This is well fastened with flashing hooks, as indicated by the small dots, and then made water-tight with roofer's cement. As will be seen the cap flashing overlaps the base flashing a distance indicated by J J and covers to L L; the corner is double seamed at *a b*. M shows a sectional view through the gutter showing how the tubes and leaders are joined. The tube N is flanged out as shown at *i i*, and soldered to the gutter; the leader O is then slipped over the tube N as shown, and fastened.

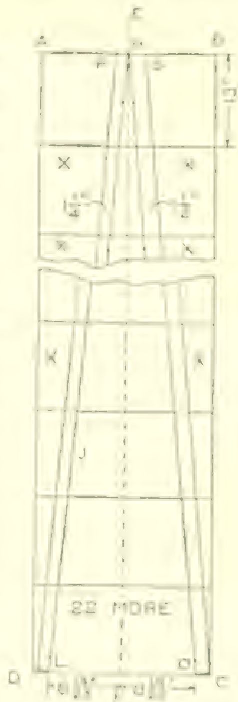


Fig. 228

In the section on Flat-Seam Roofing it was explained how a conical tower, Fig. 214, would be covered. It will be shown now how this tower would be covered with standing-seam roofing. As the circumference of the tower at the base is 396 inches, and assuming that 14 x 20-inch tin plate is to be used at the base of the tower, the nearest width which can be employed and which will divide the base into equal spaces is 17$\frac{5}{23}$ inches, without edges, thus dividing the circumference into 23 equal parts. Then the width of 17$\frac{5}{23}$ inches and the length of the rafter A B or A C in elevation will be the basis from which to construct the pattern for the standing seam strip, for which proceed as follows:

Let A B C D in Fig. 228 represent a 20-inch wide strip locked and soldered to the required length. Through the center of the strip draw the line E F. Now measure the length of the rafter A B or A C in Fig. 214 and place it on the line E F in Fig. 228 as shown from H to F. At right angles to H F on either side draw F O and F L making each equal to 8$\frac{14}{23}$ inches, being one-half of the 17$\frac{5}{23}$ above referred to

From points L and O draw lines to the apex H (shown broken). At right angles to H L and H O draw lines H P equal to 1¼ inches and H S equal to 1½ inches respectively. In similar manner draw L D and O C and connect by lines the points P D and S C. Then will P S C D be the pattern for the standing seam strip, of which 22 more will be required. When the strips are all cut out, use the roofing tongs and bend up the sides, after which they are laid on the tower, fastened with cleats, and double seamed with the hand seamer and mallet in the usual manner.

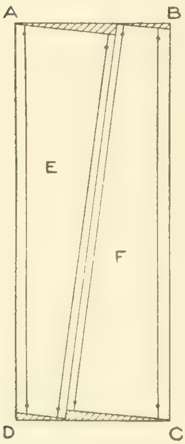


Fig. 229.

If the tower was done in copper or galvanized sheet iron or steel, where 8-foot sheets could be used, as many sheets would be cross-locked together as required; then metal could be saved, and waste avoided, by cutting the sheets as shown in Fig. 229 in which A B C D shows the sheets of metal locked together, and E and F the pattern sheets, the only waste being that shown by the shaded portion. Where the finial D in Fig. 214 sets over the tower, the standing seams are turned over flat as much as is required to receive the finial, or small notches would be cut into the base of the finial, to allow it to slip over the standing seams. Before closing the seams, they are painted with white lead with a tool brush, then closed up tight, which makes a good tight job.

CORRUGATED IRON ROOFING AND SIDING

Corrugated iron is used for roofs and sides of buildings. It is usually laid directly upon the purlins in roofs constructed as shown in Figs. 230 and 231, the former being constructed to receive sidings of corrugated iron, while in the latter figure the side walls of the building are brick. Special care must be taken that the projecting edges of the corrugated iron at the eaves and gable ends of the roof are well secured, otherwise the wind will loosen the sheets and fold them up. The corrugations are made of various sizes such as 5-inch, 2½-inch, 1¼-inch and ¾-inch, the measurements always being from A to B in Fig. 232, and the depth being shown by C. The smaller corrugations give a more pleasing appearance, but the larger corrugations are stiffer and will span a greater distance thereby permitting the purlins to be farther apart.

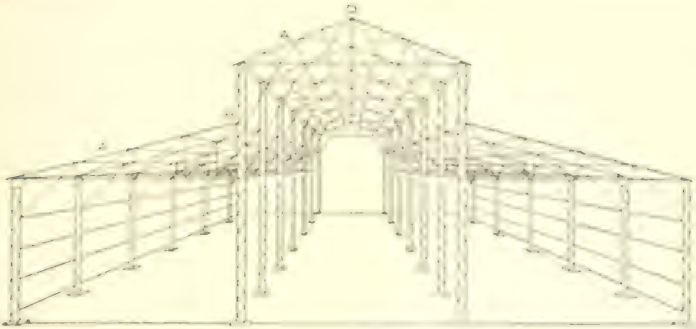


Fig. 230.

The thickness of the metal generally used for roofing and siding varies from No. 24 to No. 16 gauge. By actual trial made by The

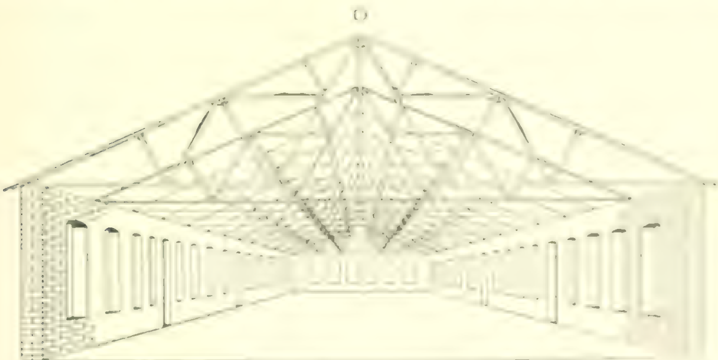


Fig. 231.

Keystone Bridge Company it was found that corrugated iron No. 20, spanning 6 feet, began to give permanent deflection at a load of 30 lb. per square foot, and that it collapsed with a load of 60 lb per square foot. The distance between centers of purlins should, therefore, not exceed 6 feet, and preferably be less than this.

Fig. 232.

TABLES

The following tables will prove of value when desiring any information to which they appertain.

MEASUREMENTS OF CORRUGATED SHEETS

Dimensions of Sheets and Corrugations.

Kind of corrugation	Width of corrugation	Depth of corrugation	No. of corrugations to the sheet	Covering width after lapping one corrugation	Width of sheet after corrugated	Length of the longest sheets furnished
5 inch.	5 inch.	1 inch.	6	24 inch.	27 inch.	10 feet.
$2\frac{1}{2}$ inch.	$2\frac{1}{2}$ inch.	$\frac{1}{2}$ to $\frac{5}{8}$ inch.	10	24 inch.	26 inch.	10 feet.
$1\frac{1}{4}$ inch.	$1\frac{1}{4}$ inch.	[illegible] to $\frac{1}{2}$ inch.	$19\frac{1}{2}$	24 inch.	26 inch	10 feet.
$\frac{3}{4}$ inch.	$\frac{3}{4}$ inch.	$\frac{1}{4}$ inch.	$34\frac{1}{2}$	25 inch.	26 inch.	8 feet.

RESULTS OF TEST

of a corrugated sheet No. 20, 2 feet wide, 6 feet long between supports, loaded uniformly with fire clay.

Load per square foot. lb.	Deflection at center under load. Inches.	Permanent Deflection, load removed.
5	$\frac{1}{32}$	0
10	$\frac{3}{4}$	0
15	1	0
20	$1\frac{1}{4}$	0
25	$1\frac{1}{2}$	0
30	$1\frac{7}{8}$	$\frac{1}{8}$
35	$2\frac{1}{4}$	$\frac{1}{2}$
40	$2\frac{5}{8}$	$\frac{3}{4}$
45	$3\frac{1}{2}$	$1\frac{1}{8}$
50	4	$1\frac{1}{2}$
55	$6\frac{1}{2}$	Not noted.
60	Broke down.	" "

The following table shows the distance apart the supports should be for different gauges of corrugated sheets:

Nos. 16 and 18 .... 6 to 7 feet apart.
Nos. 20 and 22 .... 4 to 5 feet apart.
No. 24 .... 2 to 4 feet apart.
No. 28 .... 2 feet apart.

The following table is calculated for sheets [illegible] inches wide before corrugating.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.41
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1.41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	.022	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	137	[illegible]	[illegible]
[illegible]	.018	.72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LAYING CORRUGATED ROOFING

When laying corrugated iron on wood sheathing use galvanized iron nails and lead washers. The advantage in using lead washers is that they make a tight joint and prevent leaking and rusting of the nail hole; the washer being soft it easily shapes itself to any curve. In Fig. 233 is shown how these washers are used; A shows the full size nail

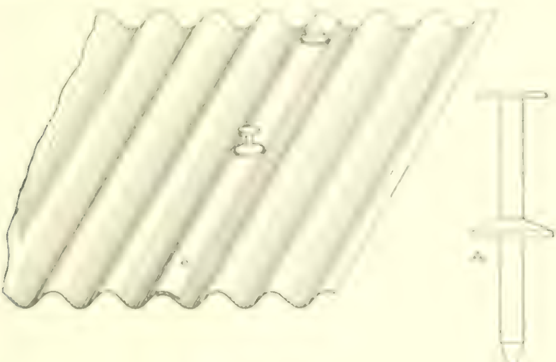


Fig. 233

and washer. When laying, commence at the left hand corner of the eave and end of the building. Continue laying to the ridge by lapping the second sheet over the first 4 inches, the left-hand edge being finished by means of a gable band A, formed as shown in Fig. 234, into which the corrugated sheet B is well bedded in roofer's cement C. When it is not desired to use this gable band the sheet must be well secured at the edge to keep the wind from raising the sheets from the roof in a storm, as at A in Fig. 234.

Should the gable have a fire wall, then let the sheets A butt against the wall and flash with corrugated flashing as shown in Fig. 235, over which the regular cap or counter flashing is placed as explained in connection with Fig. 227. Should the ridge of the roof A butt against a wall, as shown at B in Fig. 230, then an end-wall flashing is used as is shown in Fig. 236 which must also be capped, by either using cap flashing or allowing the corrugated siding to overlap this end-wall flashing as would be the case at B in Fig. 230. Now commence the second course at the eaves, giving one and one half corrugations for side lap, being careful that the side corrugations center each other exactly and nail with washers as shown in Fig. 237. Nail at every other corrugation at end laps, and at about every 6 inches at side laps, nailing through top of corrugation as shown in Fig. 237. Continue laying in this manner until the roof is covered.

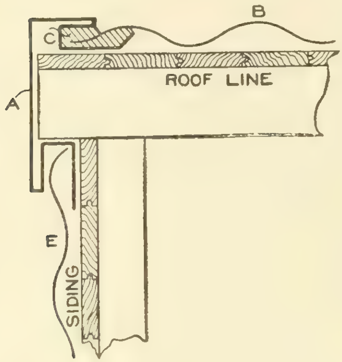


Fig. 234.

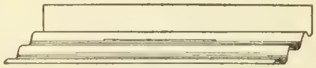


Fig. 235.

Fig. 236.

The same rule is to be observed in regard to laps and flashing if the corrugated iron were to be fastened to iron purlins, and the method of fastening to the iron frames would be accomplished as shown in Figs. 238 to 240 inclusive. Assuming that steel structures are to be covered, as shown in Figs. 230 and 231, then let A in Fig. 238 be the iron rafter, B the cross angles on which the sheets D are laid, then by means of the clip or clamp C, which is made from hoop iron and bent around the angle B, the sheets are riveted in position. In Fig. 239 is shown another form of clamp, which is bent over the bottom of the angle iron.

Fig. 237.

Fig. 240 shows still another method, where the clamp F is riveted to the sheet B at E, then turned around the angle A at D. To avoid having the storm drive in between the corrugated opening at the eaves, corrugated wood filler is used as shown in Fig. 241. This keeps out the

Fig. 238

Fig. 239

snow and sleet. On iron framing this is made of pressed metal. Another form of corrugated iron roofing is shown in Fig. 242. This is put down with cleats in a manner similar to standing-seam roofing.

If there are hips on the roof, the corrugated iron should be carefully cut and the hip covered with sheet lead. This is best done by having a wooden cove or filler placed on the hip, against which the roofing butts. Sheet lead is then formed over this wooden core and into the corrugations, and fastened by means of wood screws through the lead cap into the wooden core. The lead being soft, it can be worked into any desired shape. When a valley occurs in a hipped roof, form from plain sheet iron a valley as shown in Fig. 243, being sure to give it two coats of paint before laying, and make it from 24-inch wide sheets, bending up 12 inches on each side. Fit it in the valley, and cut the corrugated iron to fit the required angle. Then lap the corrugated iron over the valley from 6 to 8 inches.

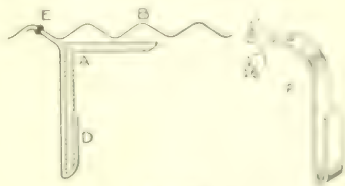


Fig. 240

Fig. 241

When a chimney is to be flashed, as shown in Fig. 244, use plain iron, bending up and flashing into the chimney joints and allowing the flashing to turn up under the corrugated iron at the top about 12 inches and over the corrugated iron at the bottom about the same distance. At the side the flashing should have the shape of the corrugated iron and receive a lap of about 8 inches, the entire flashing

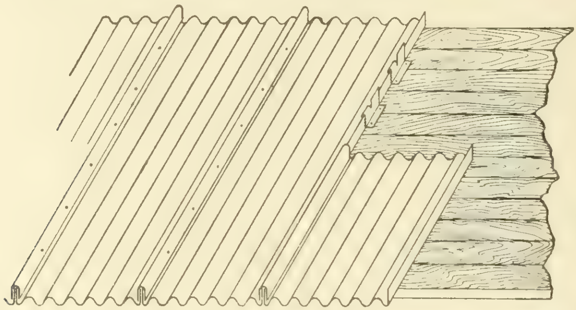


Fig. 242.

being well bedded in roofer's cement. When a water-tight joint is required around a smoke stack, as shown in Fig. 245, the corrugated iron is first cut out as shown, then a flashing built around one half the upper part of the stack to keep the water from entering inside. This is best done by using heavy sheet lead and riveting it to the sheets, using strips of similar corrugated iron as a washer to avoid damaging the lead. Before riveting, the flashing must be well bedded in roofer's cement and then make a beveled angle of cement to make a good joint. After this upright flashing is in position a collar is set over the same and fastened to the stack by means of an iron ring bolted and made tight as shown. Cement is used to make a water-tight joint around the stack. This construction gives room for the stack to sway and allows the heat to escape.

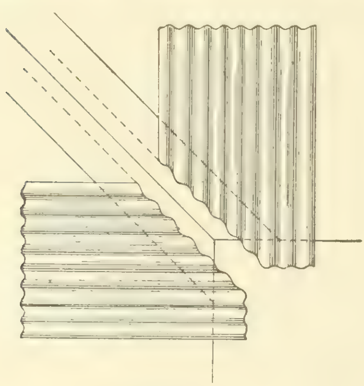


Fig. 243.

Sometimes the end-wall flashing shown in Fig. 236 can be used

FRONT AND REAR VIEWS OF RESIDENCE OF MRS. H. M. COBB, MAGNOLIA DRIVE, CLEVELAND, OHIO

Watterson & Schneider, Architects, Cleveland, Ohio.

FRONT AND REAR VIEWS OF RESIDENCE OF MR. H. T. LOOMIS, MAGNOLIA DRIVE, CLEVELAND, OHIO

[illegible]

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to good advantage in building the upright flashing in Fig. 245. Where the corrugated iron meets at the ridge, as at D and D in Figs. 230 and

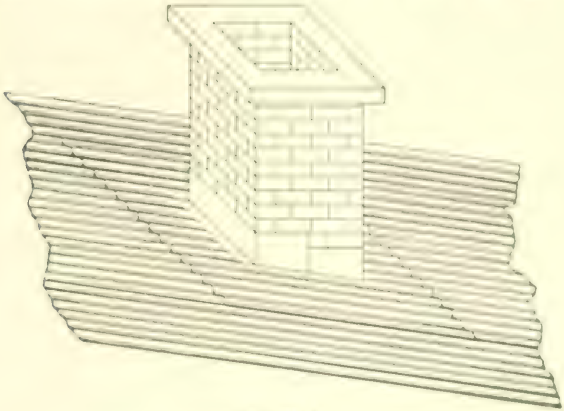

Fig. 244

231, a wooden core is placed in position as explained in connection with the hip ridge, and an angle ridge, pressed by dealers who furnish the

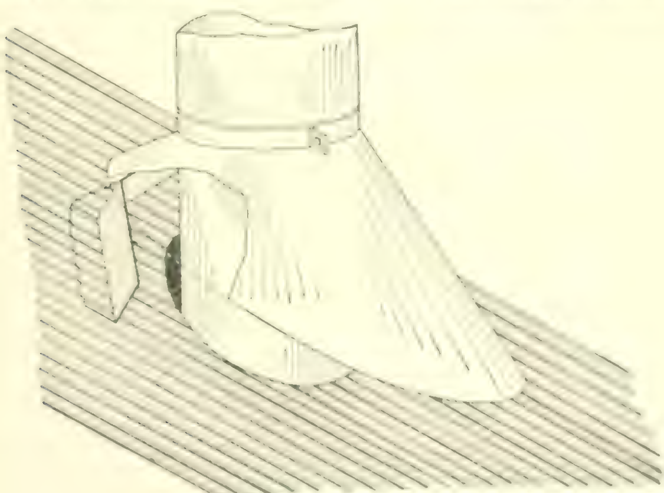

Fig. 245

corrugated iron, is placed over the ridge as shown in Fig. 246. When a ridge roll is required, the shape shown in Fig. 247 is employed.

These ridges are fastened direct to the roof sheets by means of riveting or bolting.

LAYING CORRUGATED SIDING

Before putting on any corrugated siding or clapboarding, as shown in Fig. 248, a finish is usually made at the eaves by means of a

Fig. 246.

hanging gutter or a plain cornice, shown in Fig. 249, which is fastened to the projecting wooden or iron rafters. This method is generally used on elevators, mills, factories, barns, etc., where corrugated iron, crimped iron or clapboards are used for either roofing or siding. This

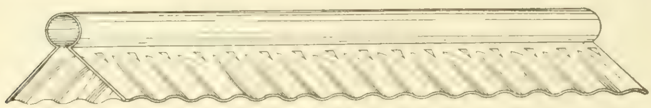

Fig. 247

style of cornice covers the eaves and gable projections, so as to make the building entirely ironclad. When laying the siding commence at the left hand corner, laying the courses from base to cornice, giving the sheets a lap of two inches as the ends and one and one half corruga-

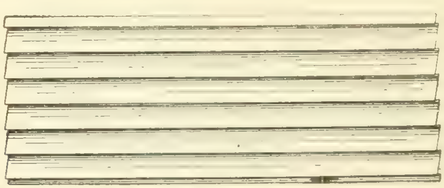

Fig. 248.

tions at the sides. Nail side laps every 6 inches and end laps at every other corrugation, driving the nails as shown in Fig. 250.

Where the sheets must be fastened to iron framing use the same method as explained in connection with Figs. 238, 239 and 240. In this case, instead of nailing the sheets, they would be riveted. If siding is put on the wooden studding care should be taken to space the studding the same distance apart as the laying width of the iron used. In this case pieces of studding should be placed between the uprights at the end of each sheet to nail the laps. When covering grain elevators

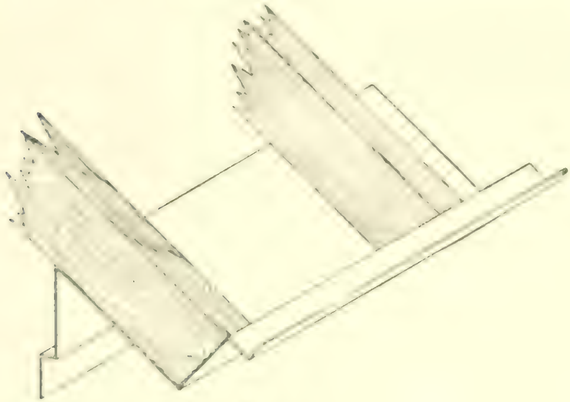

Fig. 249

it is necessary to use swinging scaffolds. Commence at the base and carry up the course to the eave, the length of the scaffold. Commence at the left hand and give the sheets a lap of one corrugation on the side and a two-inch lap at the end. Nail or rivet in every corrugation 3 inches from the lower end of the sheet; this allows for settling of the building.

Fig. 250

When any structure is to be covered on two or more sides, corner casings made of flat iron are employed, of a shape similar to that shown at B, Fig. 251. It will be seen that a rabbet is bent on both sides *a* and *b* to admit the siding. This makes a neat finish on the outside and hides the rough edges of the siding. If a window opening is to have casings a jamb is used as shown at A, Fig. 251, which has a similar rabbet at *a* to receive the siding, and a square bend at *b* to nail against the frame. In Fig. 252 is shown the cap of a window or opening. It is

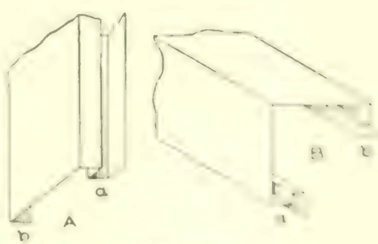

Fig. 251

bent so that *a* is nailed to the window or other frame at the bottom, while *b* forms a flashing over which the siding will set. Fig. 253 shows the sill of a window, which has a rabbet at *a*, in which the siding is

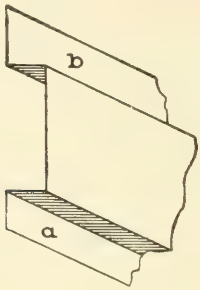

Fig. 252.

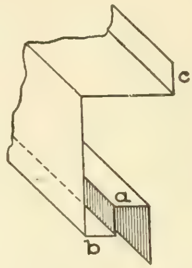

Fig. 253.

slipped; then *b* forms a drip, and any water coming over the sill passes over the siding without danger of leaks; *c* is nailed in white lead to the window frame.

Another use to which corrugated iron is put is to cover sheds and awnings. Sheets laid on wood are nailed in the usual manner, while sheets laid on angle iron construction are fastened as explained in the

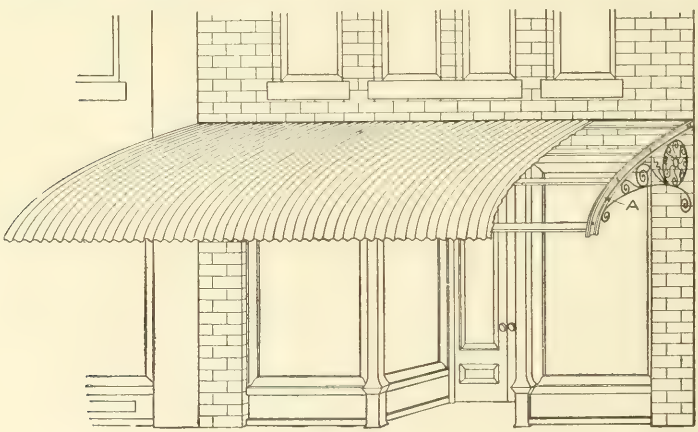

Fig. 254.

preceding sections. In Fig. 254 is shown an awning over a store laid on angle iron supports. In work of this kind, to make a neat appearance, the sheets are curved to conform to the iron bracket A.

CORNICE OVER BRICK BAY *

An elevation and plan of a brick bay are shown in the illustration, the sides of which are 8 inches, 3 feet 2 inches and 5 feet 10 inches wide. Laps or flanges for soldering are to be allowed on the 3 feet 2 inch pieces and no laps on the 8 inch and 5 feet 10 inch pieces. The lookouts or iron braces are indicated in the plan by the heavy dashes making a total of 9 required.

After the detail section is drawn and knowing the angle of the bay in plan, the angle is placed as shown by ABC, being careful to place CB on a line drawn vertically from 3–4 in the section. The miter line is then drawn as shown by BD, the section divided into equal spaces, and vertical lines dropped to the miter line BD as shown. At right angles to BC the girth of the section is drawn as shown by similar figures from 1 to 26, through which points at right angles to 1–26, lines are drawn and intersected by similar numbered lines drawn from the miter line BD at right angles to BC, thus obtaining the upper miter cut shown. Now using this miter cut in practice, make the distance from either points 25 or 24 (which represents the line of the wall) equal to 8 inches, 3 feet 2 inches and 5 feet 10 inches. The 3 feet 2 inches and 5 feet 10 inches have opposite miter cuts as shown.

As will be seen by the plan, two eight inch pieces will be required, one right and one left and two 3 feet 2 inch and one 5 feet 10 inch pieces. Nine iron lookouts will be required formed to the shape shown in the detail section, where holes are punched for bolting as there indicated.

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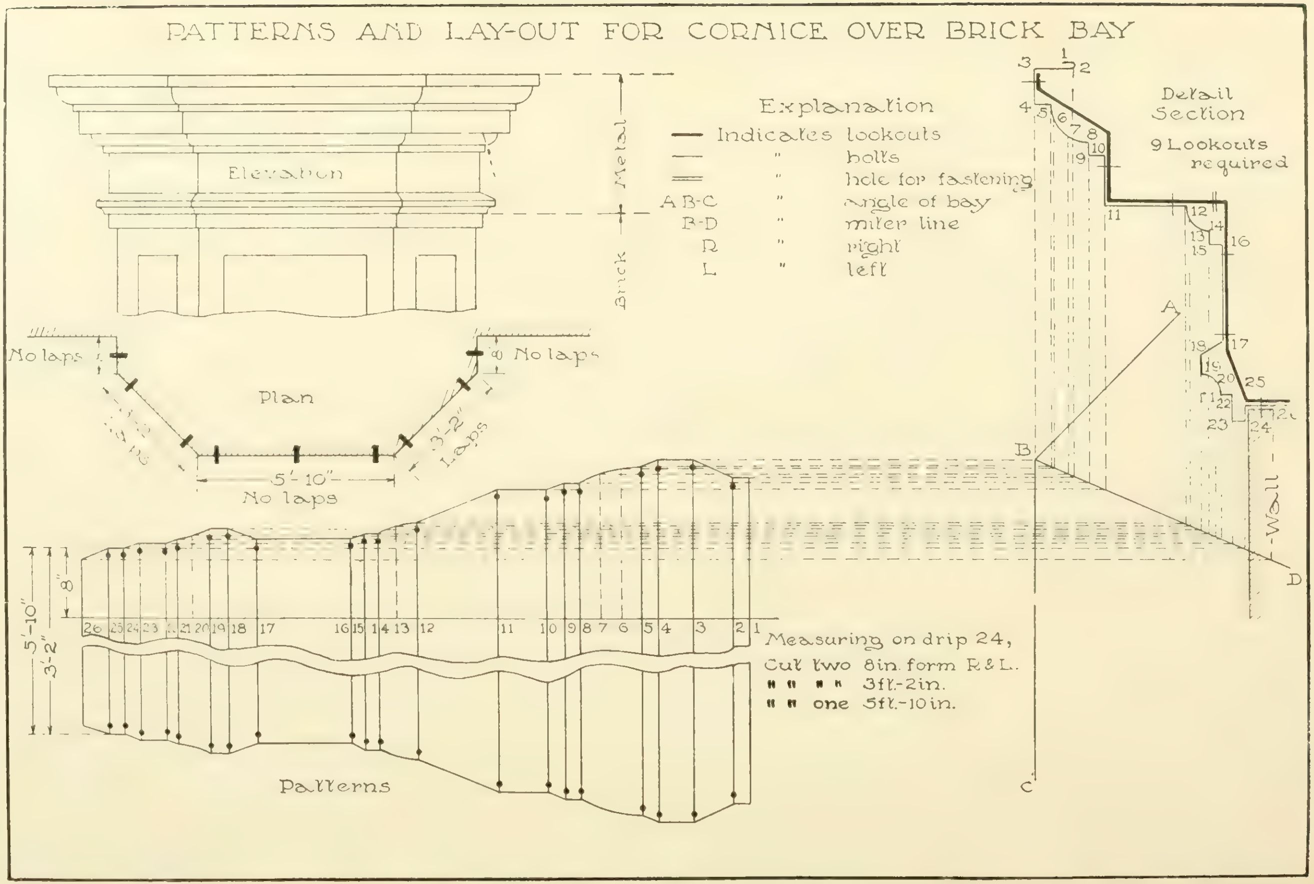
* The illustration referred to will be found on the back of this page.



FOR EXPLANATION OF THIS PROBLEM SEE BACK OF PAGE

SHEET METAL WORK

PART II

CORNICE WORK

There is no trade in the building line to-day which has made more rapid progress than that of Sheet-Metal Cornice, or Architectural Sheet-Metal Work. It is not very long since the general scope of this branch of craftsmanship merely represented a tin-shop business on a large scale. But as things are to-day, this is changed. From an enlarged tin-shop business, sheet-metal cornice work, including under that title every branch of architectural sheet-metal work, has become one of the substantial industries of the country, comparing favorably with almost any other mechanical branch in the building trades. Nor is this work confined to the larger cities. In the smaller towns is shown the progress of architectural sheet-metal work in the erection of entire building fronts constructed from sheet metal.

CONSTRUCTION

Sheet-metal cornices have heretofore, in a great measure, been duplications of the designs commonly employed in wood, which, in turn, with minor modifications, were imitations of stone.

With the marked advancement of this industry, however, this need no longer be the case. A sheet-metal cornice is not now imitative. It possesses a variety and beauty peculiarly its own. No pattern is too complex or too difficult. Designs are satisfactorily executed in sheet metal which are impossible to produce in any other material. By the free and judicious application of pressed metal ornaments, a product is obtained that equals carved work. For boldness of figure, sharp and clean-cut lines, sheet-metal work takes the lead of all competitors.

In order that there may be no mistake or ambiguity as to the various parts considered in what the Architectural worker calls a "Cornice," Fig. 255 has been prepared, which gives the names of all the members in the "entablature"—the architectural name for what in the shop is known as the cornice. The term "entablature" is seldom heard among mechanics, a very general use of the word "cornice" having supplanted it in the common language of business.

An entablature consists of three principal parts—the *cornice*, the *frieze*, and the *architrave*. A glance at the illustration will serve to show the relation that each bears to the others. Among mechanics the shop term for architrave is *foot-moulding*; for frieze, *panel*; and for

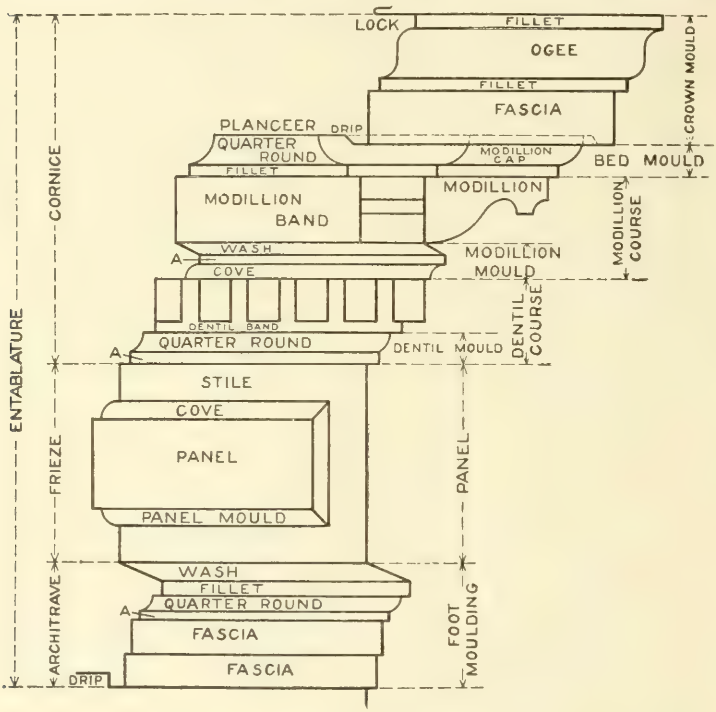


Fig. 255.

the subdivisions of the cornice, *dentil course, modillion course, bed-mould,* and *crown-mould.* In the modillion course, are the *modillion-band* and *modillion-mould*; while in the dentil course are the *dentil-band* and *dentil-mould. Drips* are shown at the bottom of the crown- and foot-mould fascias, and the ceiling under the crown mould is called the *planceer.* The edge at the top of the cornice is called a *lock*, and is used to lock the metal roofing into, when covering the top of the cornice. In the panel, there are the *panel* proper, the *panel-mould* and the *stile*. The side and front of the modillion are also shown.

Fig. 256 shows the side and front view of what is known as a bracket. Large terminal brackets in cornices, which project beyond the mouldings, and against which the mouldings end, are called trusses, a front and a side view of which are shown in Fig. 257. A block placed above a common bracket against which the moulding ends, is called a *stop block*, a front and a side view of which are shown in Fig. 258.

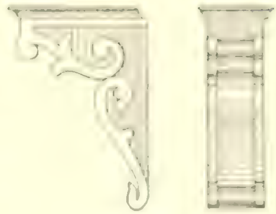


Fig. 256

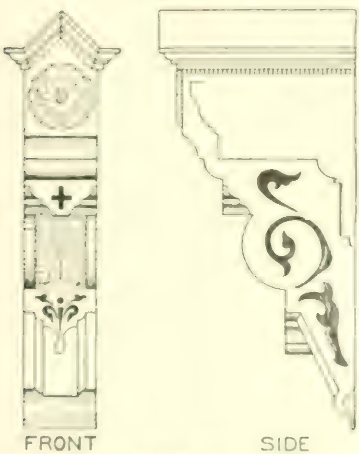


Fig. 257

Fig. 259 is the front elevation of a cornice, in which are shown the truss, the bracket, the modillion, the dentil, and the panel. It is sometimes the case, in the construction of a cornice, that a bracket or modillion is called for, whose front and sides are carved as shown in the front and side views in Fig. 260. In that case, the brackets are obtained from dealers in pressed ornaments, who make a specialty of this kind of work. The same applies to capitals which would be required for pilasters or columns, such as those shown in Figs. 261 and 262. The pilaster or column would be formed up in sheet metal, and the capital purchased and soldered in position. In Fig. 263, A shows an inclined moulding, which, as far as general position is concerned, would be the same as a gable moulding.

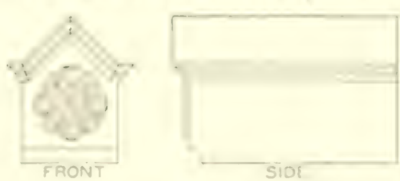
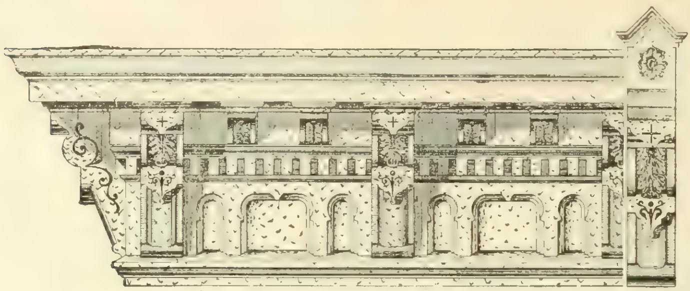


Fig. 258

Raking mouldings are those which are inclined as in a gable or pediment; but, inasmuch as to miter an inclined moulding (as A) into a horizontal moulding (as B and C), under certain conditions, necessitates a change of profile, the term "to rake," among sheet-metal workers, has come to mean "to change profiles" for the accomplishment of



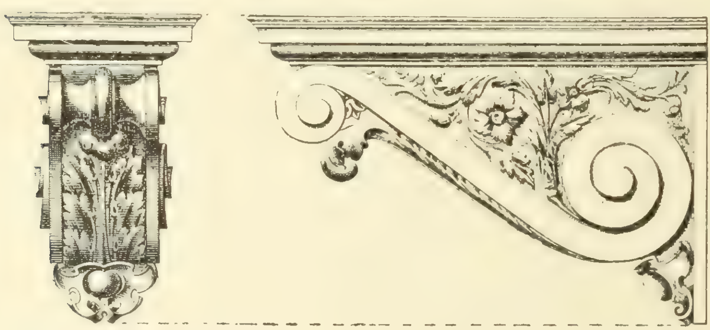
FRONT ELEVATION

Fig. 259

such a miter. Hence the term "raked moulding" means one whose profile has been changed to admit of mitering.

The term *miter*, in common usage, designates a joint in a moulding at any angle.

Drawings form a very important part in sheet-metal architectural



FRONT ELEVATION SIDE ELEVATION

Fig. 260

work. An *elevation* is a geometrical projection of a building or other object, on a plane perpendicular to the horizon—as, for example, Figs. 259 and 263. Elevations are ordinarily drawn to a scale of $\frac{1}{4}$ or

¾ inch to the foot. A *sectional drawing* shows a view of a building or other object as it would appear if cut in two at a given vertical line—as, for example, Fig. 262. *Detail drawings* are ordinarily full size and

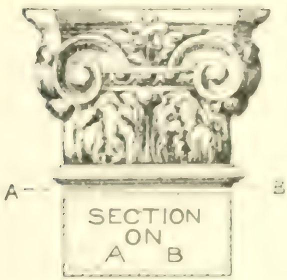


Fig. 261.

Fig. 262.

are often called *working drawings*. *Tracings* are duplicate drawings made by tracing upon transparent cloth or paper placed over the orig-

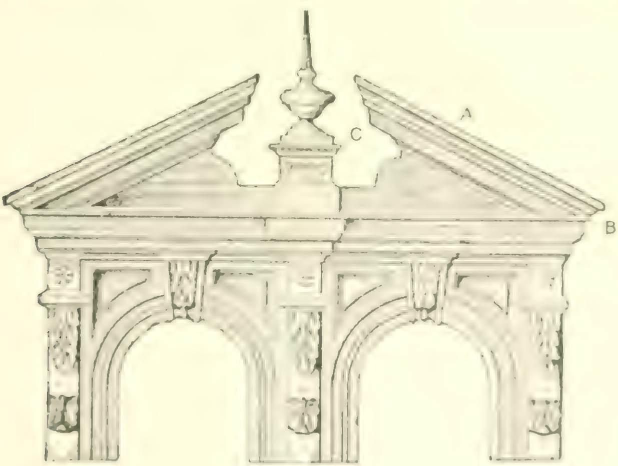


Fig. 263.

inal drawing. Many other terms might be introduced here, but enough, we believe, have been presented to give the student the leading general points.

A few words are necessary on the subject of *fastening the cornice to the wall.*

Sheet-metal cornices are made of such a wide range of sizes, and are required to be placed in so many different locations, that the methods of construction, when wooden lookouts are employed and

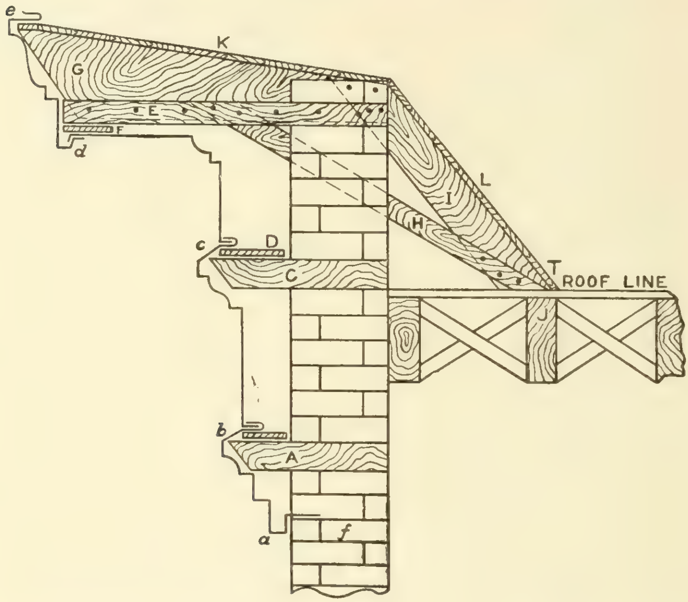


Fig. 264.

when the cornice is put together at the building in parts, are worthy of the most careful study. The general order of procedure in putting up, is as follows:

The foot-moulding or architrave *a b* (Fig. 264) is set upon the wall finished up to *f*, the drip *a* being drawn tight against the wall. The brickwork is then carried up, and the lookout A placed in position, the wall being carried up a few courses higher to hold the lookout in position. A board B is then nailed on top of the lookouts (which should be placed about three feet apart); and on this the flange of the foot-mould *b* is fastened. The frieze or panel *b c* is now placed into the lock B, which is closed and soldered; when the lookout C and the board D are placed in their proper positions, as before described.

The plancer and bed-mould *c d* are now locked and soldered at D, and the lookout E placed in position, with a board F placed under the lookouts the entire length of the cornice; onto this board the plancer is fastened. Having the proper measurements, the framer now constructs his lookouts or brackets G H I E, fastening to the beam at T, when the crown-mould *d e* is fastened to the plancer, through the flange of the drip at *d*, and at the top at *e*. The joints between lengths of mouldings, are made by lapping, riveting, or bolting, care being taken that they are joined so neatly as to hide all indications of a seam when finished and viewed from a short distance.

If brackets or modillions are to be placed in position, they are riveted or bolted in position; or sometimes the back of the cornice is blocked out with wood, and the brackets screwed in position through their flanges.

While a galvanized-iron cornice thus constructed on wooden lookouts will resist fire for a long time, a strictly fireproof cornice is obtained only by the use of metal for supports and fastenings, to the entire exclusion of wood. This fireproof method of construction is shown in Fig. 265. Instead of putting up in parts on the building, the cornice is constructed in one piece in the shop or upon the ground, and hoisted to the top of the wall in long lengths easily handled. A drip *a* is used at the bottom of the foot-mould, and the joints made in the way indicated at *b* and *c*, with a lock at *d*. Band iron supports and braces are used, formed to the general contour of the parts as shown by A B C, and bolted direct to the cornice, as shown, before hoisting.

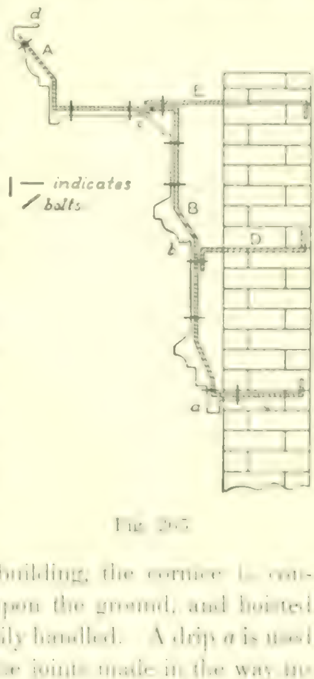


Fig. 265

When the cornice sets on the wall as at C, anchors are fastened to the main brace, as at D and E, with an end bent up or down for fastening. If the cornice sets perfectly plumb the mason carries up his wall, which holds the cornice in a firm position. The top and back are then framed in the usual manner and covered by the metal roofer. In constructing cornices in this manner, the mouldings are run through solid, behind all brackets and modillions. The brackets and modillions are attached by means of riveting through outside flanges.

SHOP TOOLS

One of the most important tools in cornice or architectural sheet-metal working shop is the *brake.* On those operated by hand, sheets are bent up to 8 feet in one continuous length. In the larger shops, power presses or brakes are used, in which sheets are formed up to 10 feet in length, the press being so constructed that they will form ogees, squares, or acute bends in one operation.

Large 8- or 10-feet *squaring shears* also form an important addition to the shop, and are operated by foot or power.

When cornices are constructed where the planceer or frieze is very wide, it is usual to put crimped metal in, to avoid the waves and buckles showing in the flat surface; for this purpose the *crimping machine* is used.

In preparing the iron braces for use in the construction of fireproof cornices, a *punching machine* and *slitting shears* are used for cutting the band iron and punching holes in it to admit the bolts. While braces are sometimes bent in a vise, a small machine known as a ***brace bender*** is of great value in the shop. In large fireproof building constructions, it is necessary that all doors, window frames, and even sashes be covered with metal, and made in so neat a manner that, when painted and grained, no differences will be apparent to indicate whether the material is wood or metal, the smallest bends down to $\frac{1}{8}$ inch being obtained. This, of course, cannot be done on the brakes just mentioned, but is done by means of the *draw-bench*, which is constructed in lengths up to 20 feet and longer, operated by means of an endless chain, and capable of drawing the sheet metal over any shaped wood mould as tightly as if it were cast in one piece. The smaller tools in the shop are similar to those described in the Instruction Papers on Tinsmithing and Sheet Metal Work, Part I.

METHOD EMPLOYED FOR OBTAINING PATTERNS

The principles applied to cylinder developments as explained in the Tinsmithing and Sheet Metal Work courses, under the heading of "Parallel-Line Developments," are also applicable for obtaining the patterns for any moulding where all members run parallel, for it makes no difference what profile is employed, so long as the lines run parallel to one another, the parallel-line method is used. While this method is chiefly employed in cornice work, other problems will arise in which the "Radial-Line" and "Triangulation" methods are employed in practice. [illegible]

The term generally used in the shop for pattern-cutting on cornice work is *miter-cutting*. To illustrate: suppose two pieces of moulding are to be joined together at an angle of 90°, as shown in Fig. 266. The first step necessary would be to bisect the given angle and obtain the *miter-line* and cut each piece so that they would miter together. If a carpenter had to make a joint of this kind, he would place his moulding in the miter-box, and cut one piece right and one piece left at an angle of 45°, and he would be careful to hold the moulding in its proper position before sawing; or else he may, instead of having a return miter as shown, have a face miter as on a picture frame, shown in Fig. 267. The sheet-metal cornice-maker cannot, after his moulding is formed, place it in the miter-box to cut the miter, but must lay it out—or, in other words, develop it—on a flat surface or sheet of metal. He must also be careful to place the profile in its proper position with the miter-line; or else, instead of having a return miter as shown in Fig. 266, he will have a face miter as shown in Fig. 267. If he lays out his work correctly, he can then cut two pieces, form one right and the other left, when a miter will result between the two pieces of moulding and will look as shown in Fig. 266. If, however, a face miter is desired, as shown in Fig. 267, which is used when miters are desired for panels and other purposes, the method of laying them out will be explained as we proceed. The same principles required for developing Figs. 266 and 267 are used, whether the mouldings are mitered at angles of 90°

Fig. 266

Fig. 267

or otherwise. The method of *raking* the mouldings—or, in other words, changing their profile to admit the mitering of some other moulding at various angles—will also be thoroughly explained as we proceed.

VARIOUS SHAPES OF MOULDINGS

The style of mouldings arising in the cornice shop are chiefly Roman, and are obtained by using the arcs of a circle. In some cases, Greek mouldings are used, the outlines of which follow the curves of conic sections; but the majority of shapes are arcs of circles. In

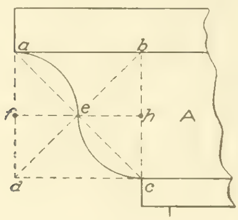


Fig. 268.

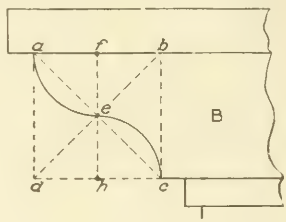


Fig. 269.

Figs. 268 to 272 inclusive, the student is given a few simple lessons on Roman mouldings, which should be carefully followed. As all pattern-cutters are required to draw their full-size details in the shop from small-scale drawings furnished by the architect, it follows that they must understand how to draw the moulds with skill and ease; other-

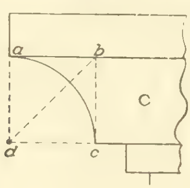


Fig. 270.

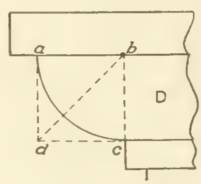


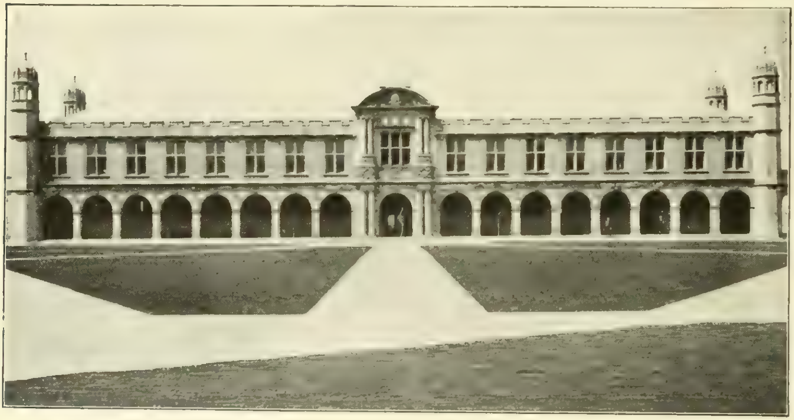
Fig. 271.

wise freehand curves are made, which lack proportion and beauty.

In Fig. 268, A shows the mould known as the *cyma recta,* known in the shop as the *ogee,* which is drawn as follows:

Complete a square *a b c d*; draw the two diagonals *a c* and *b d*, intersecting each other at *e*. Through *e*, draw a horizontal line intersecting *a d* at *f* and *b c* at *h*. Then, with *f* and *h* as centers, draw respectively the two quarter-circles *a e* and *e c*.

Cupples Hall, No. 2. Building is 207 Feet Long, 47 Feet Wide. First Floor Devoted to Mechanical Engineering; Second Floor, to Electrical Engineering.



The Library. The Building is 257 Feet Long, 46 Feet Wide. The Reading Room is 100 Feet by 41 Feet. The Stacks for Books Have Room for Over 400,000 Volumes. Cost of Building, $250,000.

Busch Hall, the Chemical Laboratory. The Building is 290 Feet Long, 60 Feet Wide. Cost $110,000.

THREE FIREPROOF BUILDINGS OF THE UNIVERSITY OF WASHINGTON, ST. LOUIS, MO.

Illustrating the Restful Effect of a Long, Almost Unbroken Roof-Line.

In Fig. 269, B shows the *cyma reversa*, known in the shop as the *ogee, reversed*. Complete a square *a b c d*, and draw the two diagonals *b d* and *a c* intersecting at *e*; through *e*, draw a vertical line intersecting *a b* at *f* and *c d* at *h*, which points are the respective centers for the arcs *e a* and *e c*.

C in Fig. 270 shows the *cavetto*, called the *cove* in the shop, which is drawn by completing a square *a b c d*. Draw the diagonal *b d* at 45°, which proves the square; and, using *d* as a center, draw the quarter-circle *a c*.

In Fig. 271, D represents the *ovolo* or *echinus*, known in the shop as the *quarter-round*, which is constructed similarly to C in Fig. 270, with the exception that *b* in Fig. 271 is used to obtain the curve *a c*.

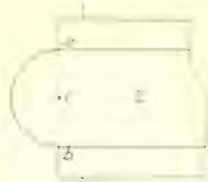


Fig. 272

E in Fig. 272 is known as the *torus*, known in the shop as a *bead-mould*. A given distance *a b* is bisected, thus obtaining *c*, which is the center with which to describe the semicircle *a b*.

All of these profiles should be drawn by the student to any desired scale for practice. In preparing mouldings from sheet metal,

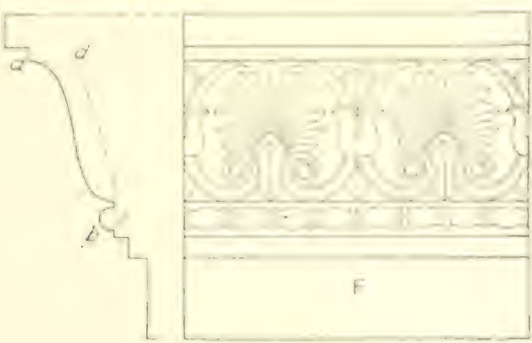


Fig. 273

it is sometimes required that enrichments are added to the ogee, cove and bead. In that case the mould must be bent to receive these enrichments, which are usually obtained from dealers in stamped or pressed sheet-metal work. Thus, in Fig. 273, F represents a front view of a crown mould whose ogee is enriched, the section of the enrichment being indicated by *a b* in the section, in which the dotted line *d c* shows the body of the sheet-metal moulding bent to receive the pressed work. In Fig 274, H represents part of a bed-mould in which

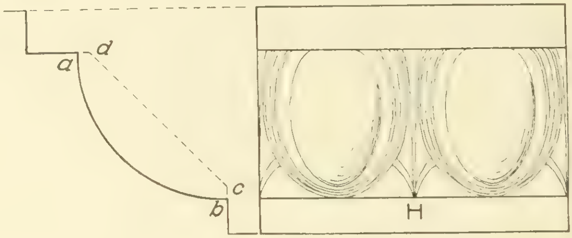


Fig. 274.

egg-and-dart enrichments are placed. In this case the body of the mould is bent as shown by *c d* in the section, after which the egg-and-dart is soldered or riveted in position. J in Fig. 275 represents part

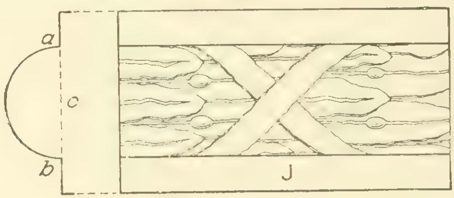


Fig. 275.

of a foot-mould on which an enriched bead is fastened. The body of the mould would be formed as indicated by *c* in the section, and the bead *a b* fastened to it. This same general method is employed, no matter what shape the pressed work has.

PRACTICAL MITER CUTTING

Under this heading come the practical shop problems. The problems which will follow should be drawn to any desired scale by the student, developed, and bent from stiff cardboard to prove the accuracy of the pattern. If the student cannot use the small brake in the shop and test his patterns cut from metal, he can use the dull blade of a table knife, over which the bends can be made, when using cardboard patterns. This at once proves interesting and instructive. Should there be any problem which is not clear, he should write at once for further information; or, should any problem arise on which he desires information, the School will inform him which problems in the Instruction Papers contain similar principles, or will prepare such a problem for him.

The first problem will be to obtain the development of a square return miter, such as would occur when a moulding had to return around the corner of a building, as shown in Fig. 276. In Fig. 277 are shown two methods of obtaining the pattern. The first method which will be described is the "long" method, in which are set forth all the principles applicable to obtaining patterns for mouldings, no matter what angle the plan may have. The second method is the "short"

Fig. 276

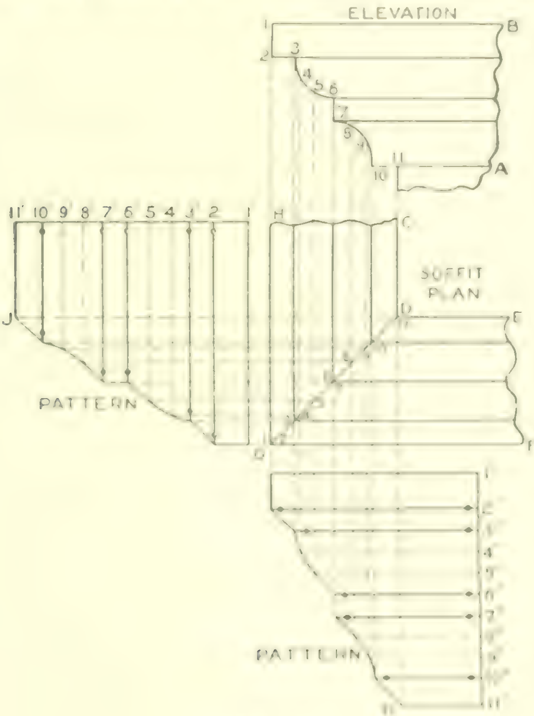


Fig. 277

rule generally employed in the shop, which, however, can be used only when the angle H G F in plan is 90°, or a right angle.

To obtain the pattern by the first method, proceed as follows: First, draw the elevation of the mould as shown by 1, B, A, 11, drawing the coves by the rule previously given. Divide the curves into equal spaces; and number these, including the corners of the fillets as shown by the small figures 1 to 11. In its proper position below the elevation, draw the soffit plan as shown by C D E F G H. Bisect the angle H G F by the line G D, which is drawn at an angle of 45°. From the various intersections in the elevation, drop lines intersecting the miter-line as shown. At right angles to H G, draw the stretchout line 1′ 11′, upon which place the stretchout of the mould 1 11 in elevation, as shown by similar figures on the line 1′ 11′. At right angles to 1′ 11′, and from the numbered points thereon, draw lines, which intersect by lines drawn at right angles to H G from similarly numbered intersections on the miter-line G D. Trace a line through the intersections

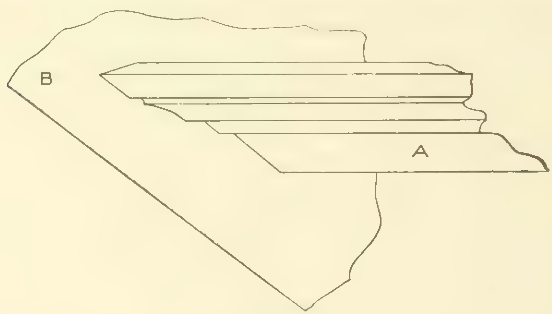


Fig. 278.

thus obtained, as shown by J G. Then will 1′ G J 11′ be the desired pattern. This gives the pattern by using the miter-line in plan.

In developing the pattern by the short method, on the other hand, the plan is not required. At right angles to 1 B in elevation, draw the stretchout line 1″ 11″, upon which place the stretchout of the profile 1 11 in elevation, as shown by similar figures on 1″ 11″, at right angles to which draw lines through the numbered points as shown, which intersect by lines drawn at right angles to 1 B from similarly numbered intersections in the profile in elevation. Trace a line through points thus obtained, as shown by G K. Then will G 1″ 11″ K be similar to J G 1′ 11′ obtained from the plan.

In Fig. 278 is shown a horizontal moulding butting against a plane surface oblique in elevation. A miter cut of this kind would be required when the return moulding of a dormer window would butt against a mansard or other pitched roof. In this case we assume A to be the return butting against the pitched roof B. The method of

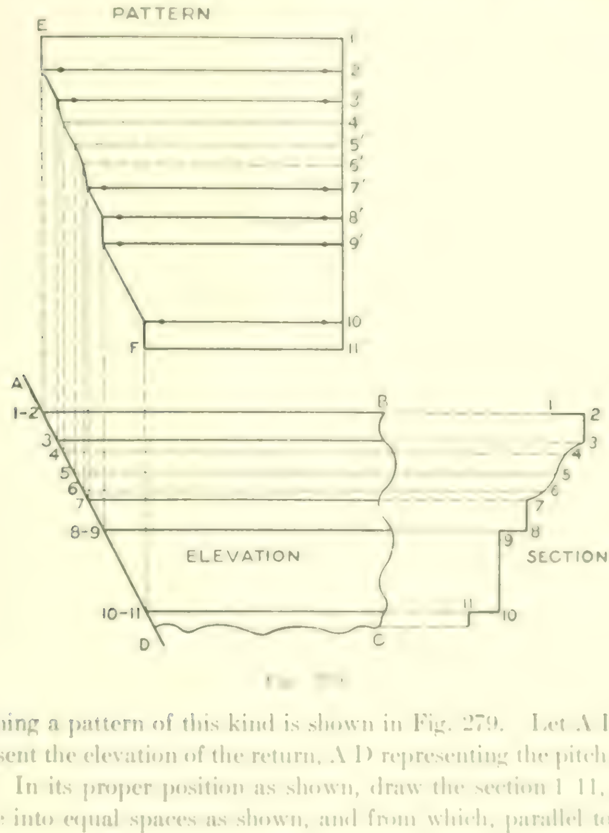


Fig. 279

obtaining a pattern of this kind is shown in Fig. 279. Let A B C D represent the elevation of the return, A D representing the pitch of the roof. In its proper position as shown, draw the section 1 11, which divide into equal spaces as shown, and from which, parallel to A B, draw lines intersecting the slant line A D from 1 to 11, as shown. At right angles to A B erect the stretchout line 1′ 11′, upon which place the stretchout of the section as shown by similar figures on 1′ 11′. At right angles to 1′ 11′, and through the numbered points thereon, draw lines, which intersect by lines drawn at right angles to A B from similarly numbered intersections on the slant line A D. Through the various intersections thus obtained, draw E F. Then will E F 11′ 1′ be the desired pattern.

It is sometimes the case that the roof against which the moulding butts, has a curved surface either concave or convex, as shown by B C in Fig. 280, which surface is convex. Complete the elevation of the moulding, as D E; and in its proper position draw the section 1 9, which divide into equal spaces as shown by the small figures, from which draw horizontal lines until they intersect the curved line B C, which is struck from the center point A. At right angles to the line of the moulding erect the line 1′ 9′, upon which place the stretchout

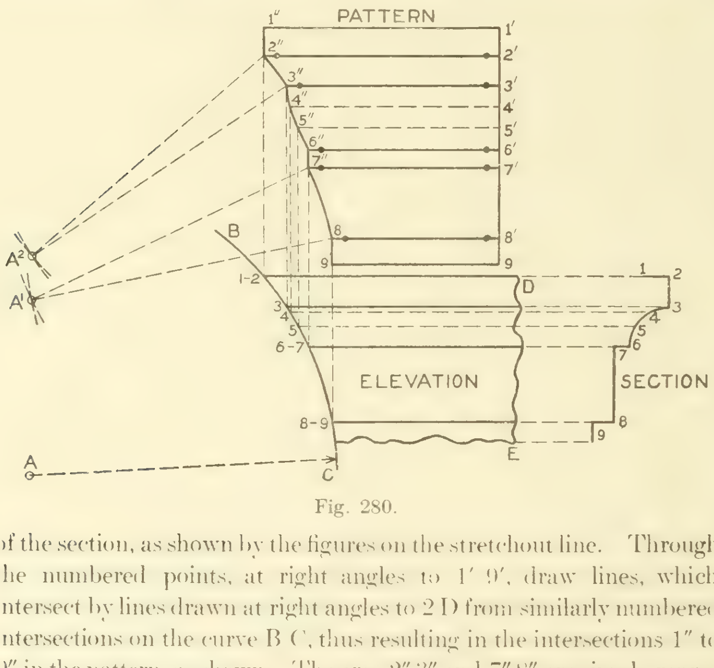


Fig. 280.

of the section, as shown by the figures on the stretchout line. Through the numbered points, at right angles to 1′ 9′, draw lines, which intersect by lines drawn at right angles to 2 D from similarly numbered intersections on the curve B C, thus resulting in the intersections 1″ to 9″ in the pattern, as shown. The arcs 2″ 3″ and 7″ 8″ are simply reproductions of the arcs 2 3 and 7 9 on B C. These arcs can be traced by any convenient method; or, if the radius A C is not too long to make it inconvenient to use, the arcs in the pattern may be obtained as follows: Using A C as radius, and 7″ and 8″ as centers, describe arcs intersecting each other at A^1; in similar manner, using 2″ and 3″ as centers, and with the same radius, describe arcs intersecting each other at A'. With the same radius, and with A' and A' as centers, draw the arcs 8° 7° and 1° 2° respectively. Trace a line through the other various intersections as shown. Then will 1' 1° 8° 8' be the desired pattern.

In Fig. 281 is shown an elevation of an oblong or rectangular panel for which a miter-cut is desired on the line *a b*—known as a "panel" or "face" miter. The rule to apply in obtaining this pattern is shown in Fig. 282. A shows the part elevation of the panel; *a b* and *c d*, the miter-lines drawn at angles of 45°. In its proper position with the lines of the moulding, draw the profile B, the curve or mould of which divide into equal spaces, as shown by the figures 1 to 7, and from the points thus obtained, parallel to 1 *b*, draw lines inter-

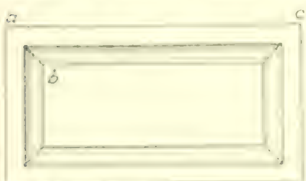


Fig. 281

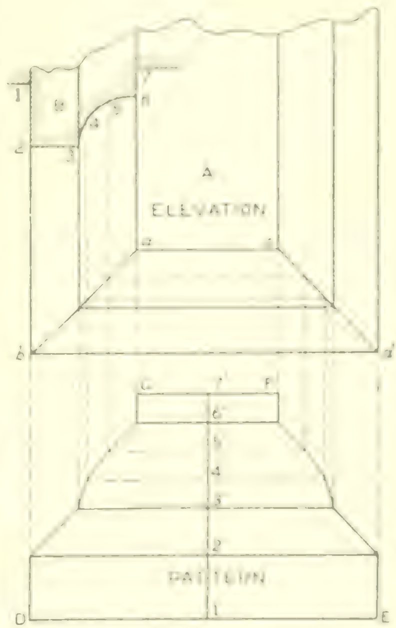


Fig. 282

secting the miter-line *a b* as shown. From these intersections, parallel to *b d*, draw lines intersecting also *c d*. At right angles to *b d* draw the stretchout line 1′ 7′, upon which place the stretchout of the profile B. At right angles to 1′ 7′, and through the numbered points of division, draw lines, which intersect by lines drawn at right angles to *b d* from similarly numbered intersections on the miter-lines *a b* and *c d*. Trace lines through the various points of intersection in the pattern as shown. Then will C D E F be the required cut for the ends of the panel.

The same miter-cuts would be employed for the long side *a c* or

Fig. 281, it being necessary only to make D E in Fig. 282 that length when laying out the patttern on the sheet metal.

Where the miter-cut is required for a panel whose angles are other than right angles, as, for example, a triangular panel as shown in Fig. 283, then proceed as shown in Fig. 284. First draw the elevation of the triangular panel as shown by A B C, the three sides in the case being equal. Bisect each of the angles A, B, and C, thus obtaining the miter-lines A *c*, B *b*, and C *a*. In line with the elevation, place in its proper position the profile E, which divide into equal spaces as shown; and from the numbered division points, parallel to A C, draw lines cutting the miter-line C *a*. From these intersections, parallel to C B, draw lines intersecting the miter-line *b* B. At right angles to C B draw the stretchout line 1′ 7′, upon which place the stretchout of the profile E. Through the numbered points of division and at right angles to 1′ 7′, draw lines as shown, which intersect by lines drawn at right angles to C B from intersections of similar numbers on the miter-lines *a* C and *b* B. Through the points thus obtained, trace the pattern F G H I.

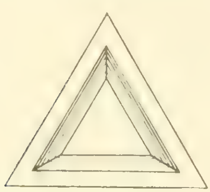


Fig. 283.

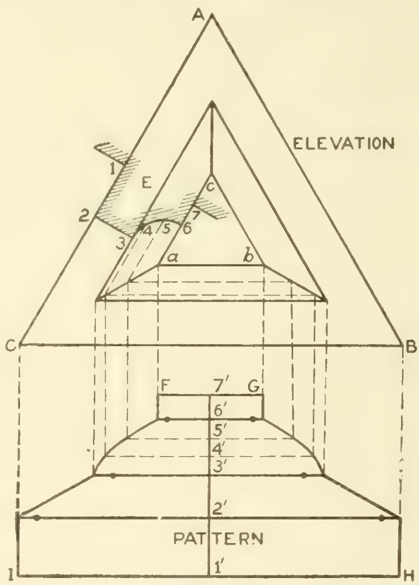


Fig. 284.

It makes no difference what shape or angle the panel may have; the principles above explained are applicable to any case.

In ornamental cornice work, it often happens that tapering moulded panels are used, a plan and elevation of which are shown in Fig. 285.

By referring to the plan, it will be seen that the four parts b a, a b′, b′ a′, and a′ b are symmetrical; therefore, in practice, it is necessary only to draw the one-quarter plan, as shown in Fig. 286, and omit the elevation, since the height d e (Fig. 285) is known. Thus, in Fig. 286 draw the quarter-plan of the panel, no matter what is its shape, as shown

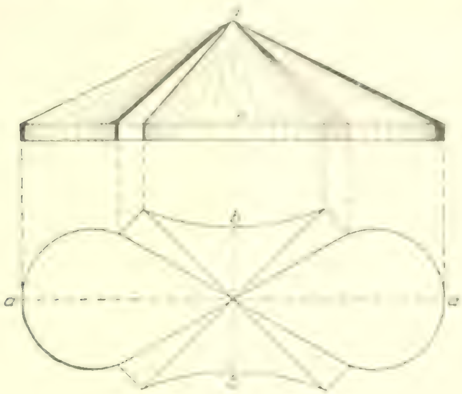


Fig. 285

by a 1 5 6 9. Divide the curves from 1 5 and 6 9 into equal spaces, indicated respectively by 1, 2, 3, 4, and 5, and 6, 7, 8, and 9. From these points, draw lines to the apex a. As the pattern will be developed by triangulation, a set of triangles will be required, as shown in

Fig. 286

Fig. 287, for which proceed as follows: Draw any horizontal line, as a 1; and from a erect the perpendicular a a′ equal to the height the panel is to have. Now take the lengths of the various lines in Fig. 286 from a to 1, a to 2, a to 3, etc., to a to 9, and place them on the line a 1 in Fig. 287, as shown by similar numbers. Then using as radii the various lengths a' 1, a' 2, a' 3, etc., to a' 9, and with any point, as a' in Fig. 288 as center, describe the various arcs shown from 1 to 9. From any point on the arc 1 draw a line to a'. Set the dividers equal to the spaces contained in the curve 1 5 in Fig. 286; and, starting from 1 in Fig. 288 step from one arc to anothe. having similar numbers, as shown from 1 to 5. In similar manner, take the distance from 5 to 6 and the spaces in the curve 6 9 in Fig. 286, and place them on corresponding arcs in Fig. 288, stepping from one arc to the other, resulting in the points 5 to 9. Trace a line through the points thus obtained. Then will a' 1 5 6 9 a' be the quarter-pattern, which can be joined in one-half or whole pattern as desired.

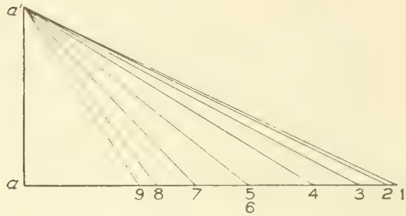


Fig. 287.

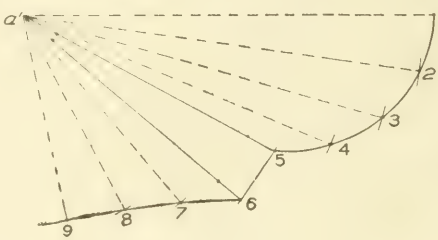


Fig. 288.

In Fig. 289 is shown a perspective of a moulding which miters at an angle other than a right angle. This occurs when a moulding is required for over a bay window or other structure whose angles vary. The rule given in Fig. 290 is applicable to any angle or profile. First draw a section or an elevation of the moulding as shown by A B 14 1. Directly below the moulding, from its extreme point, as 2 3, draw a plan of the desired angle as shown by C 2 D. Bisect this angle by using 2 as center and, with any radius, describing an arc meeting the sides of the angle at C and E. With the same or any other radius, and with C and E as centers, describe arcs intersecting each other in F. From the corner 2, draw a line through F. Then will 2 H be the

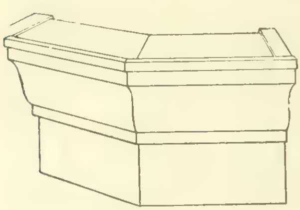


Fig. 289.

miter-line, or the line bisecting the angle C 2 D. Now divide the profile 1 14 into equal spaces as shown by the figures, and from the points thus obtained drop vertical lines intersecting the miter-line 2

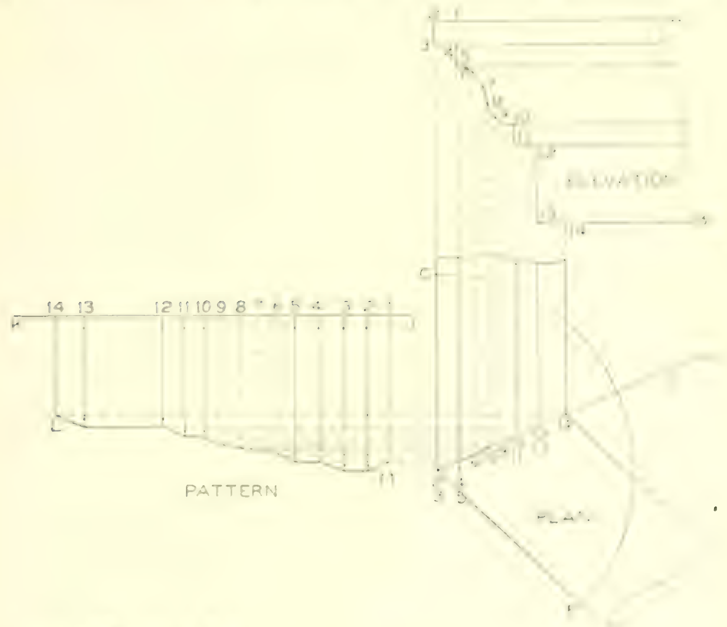


Fig. 290

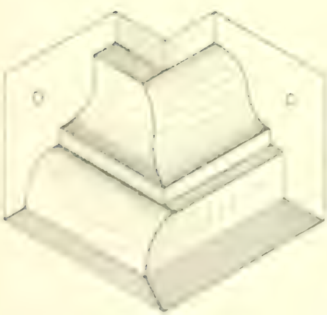


Fig. 291

H in plan from 1 to 14 as shown. At right angles to C 2, draw the line J K, upon which place the stretchout of the profile in elevation as shown by similar figures on the stretchout line, through which drop lines perpendicular to J K, which intersect with lines drawn parallel to J K from similarly numbered points of intersection on the miter-line 2 H. Trace a line as shown by L M, which is the pattern desired.

When two mouldings having different profiles are required to miter together as shown in Fig. 291, where C miters at right angles with D, two distinct operations are necessary, which are clearly shown in Figs. 292 and 293. The first operation is shown in Fig. 292, in which C represents the elevation of an ogee moulding which is to miter at right angles with a moulding of different profile as shown at D. Divide the profile C into equal spaces, from which points draw horizontal lines intersecting the moulding D from 1′ to 10′. At right angles to the line of the moulding C, draw the line A B, upon which place the stretchout of the profile C as shown by similar figures on A B. At right angles to A B, and through the points indicated by the figures, draw lines, which intersect with lines drawn parallel to A B from similarly numbered intersections in the profile D. Trace a line through the points thus obtained, as shown by E H. Then will E F G H be the pattern for C in elevation.

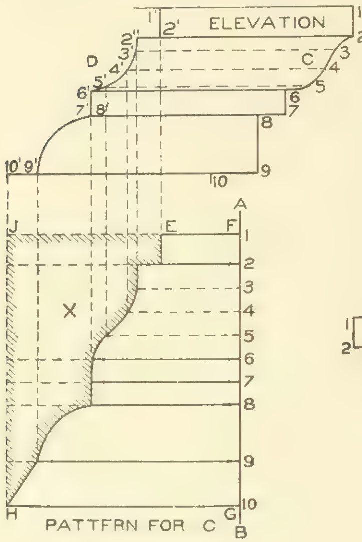


Fig. 292.

To obtain the pattern for D, draw the elevation of D (Fig. 293), which is to miter at right angles with a moulding whose profile is C. Proceed in precisely the same manner as explained in connection with Fig. 292. Divide the profile D in Fig. 293 into equal parts, as shown, from which draw horizontal lines cutting the profile C. At right angles

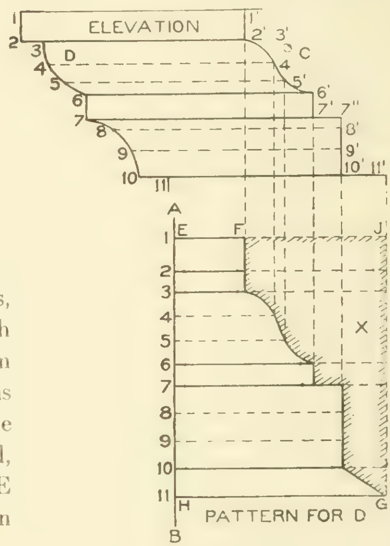


Fig. 293.

to the lines of the moulding D, draw the stretchout line A B, upon which place the stretchout of the profile D. At right angles to A B, and through the numbered points of division, draw lines as shown, which intersect by lines drawn parallel to A B from similarly numbered intersections in the profile C. Through these points of intersection draw F G. Then will E F G H be the desired pattern for D.

It should be understood that when the patterns in Figs. 292 and 293 are formed and joined together, they will form an inside miter, as is shown in Fig. 291. If, however, an outside miter were required, it would be necessary only to use the reverse cuts of the patterns in Figs. 292 and 293, as shown by E J H in Fig. 292 for the mould C, and F J G in Fig. 293 for the mould D.

Fig. 294

When joining a curved moulding with a straight moulding in either plan or elevation even though the curved or straight mouldings each have the same profile, it is necessary to establish the true miter-line before the pattern can be correctly developed, an example being given in Fig. 294, which shows an elevation of a curved moulding which is intersected by the horizontal mouldings A B. The method of obtaining this miter-line, also the pattern for the horizontal pieces, is clearly shown in Fig. 295. First draw the profile which the horizontal moulding is to have, as 1 10. Let the distance 9 B be established. Then, with C on the center line as center, and A C as radius, describe the arc B A. From any point on the line 9 B, as *a*, erect the vertical line *a b*. Through the various divisions in the profile 1 10, draw horizontal lines intersecting the vertical line *a b* from 1 to 10 as shown. From the center C, draw any radial line, as C *d*, cutting the arc B A at *e*. Now take the various divisions on *a b*, and place them from *e* to *d* as shown by points 1′ to 10′. Then, using C as center, with radii determined by the various points on *e d*, draw arcs intersecting horizontal lines of similar numbers drawn through the divisions on *a b*. Through these points of intersection, draw the miter-line shown. The student will note that this line is irregular.

Having obtained the miter-line, the pattern is obtained for the horizontal moulding by drawing the stretchout line E F at right angles to 9 B. On E F lay off the stretchout of the profile 1 10; and through the numbered points and at right angles to E F, draw horizontal lines, which intersect with lines drawn at right angles to 9 B from similarly numbered intersections in the miter-line determined by horizontal lines already drawn through the vertical line *a b*. Trace a line through the points thus obtained, as shown by H I J K, which is the desired pattern.

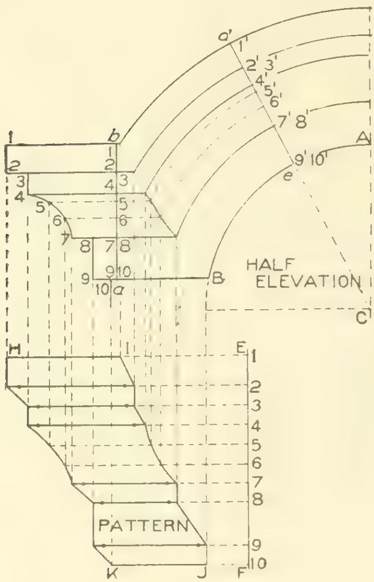


Fig. 295.

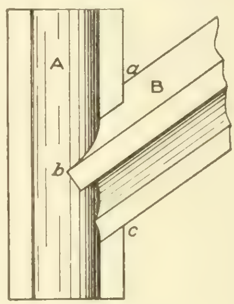


Fig. 296.

In Fig. 296 is shown a shaded view of a gable moulding intersecting a pilaster, the gable moulding B cutting against the vertical pilaster A, the joint-line being represented by *a b c*. To obtain this joint-line, without which the pattern for the gable moulding cannot be developed, an operation in projection is required. This is explained in Fig. 297, in which B C D shows the plan of the pilaster shown in elevation by E. In its proper position in plan, place the profile of the gable moulding, as shown by A, which divide into equal spaces as shown by the figures 1 to 8, through which draw horizontal lines intersecting the plan of the pilaster B C D as shown by similar figures. For convenience in projecting the various points, and to avoid a confusion of lines, number the intersections between the lines drawn from the profile A through the wash B 2, "7°", "4°", and "3°". At the desired point H in elevation, draw the lower line of the gable moulding, as H F. Take a tracing of the profile A in plan, with all of the various intersections on same, and place it in elevation as shown by A¹, placing the line 1 8 at right angles to H F. Through the various intersections 1, 7°, 4°, 3°, 2, 3, 4, 5, 6, 7, and 8 in A¹, and parallel to F H, draw lines indefinitely, which intersect by lines drawn at right angles to C B in plan from similarly numbered intersections in the pilaster C D B, thus obtaining the points of intersection 1^x to 8^x in elevation.

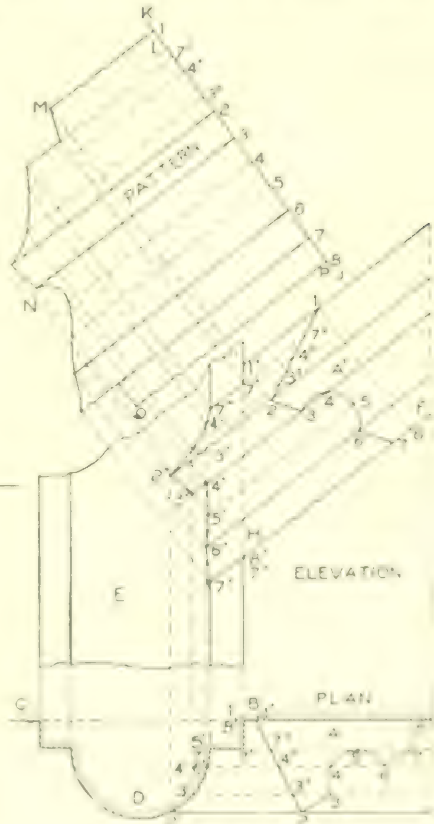


Fig. [illegible]

For the pattern, proceed as follows: At right angles to H F, draw the stretchout line J K, upon which place the stretchout of the profile A or A¹, with all the points of intersection on the wash 1 2. At right angles to J K, and through the numbered points, draw lines as shown, which intersect by lines drawn at right angles to H F from similarly numbered intersections in the joint-line 1^x 8^x. Through the points thus obtained, trace the miter-cut M N O. Then will L M N O P be the pattern for the gable moulding.

In Fig. 298 are shown gable mouldings mitering upon a wash. The mouldings A A intersect at any desired angle the wash B. In this case, as in the preceding problem, an operation in projection must be gone through, before the pattern can be obtained. This is clearly shown in Fig. 299. Draw the section of the horizontal moulding B¹ with the wash *a b*. From this section project lines, and draw the part elevation D C. Knowing the bevel the gable is to have, draw C B, in this case the top line of the moulding. Draw a section of the gable mould, as A, which divide into equal parts as shown from 1 to 8; and through the point of division draw lines parallel to B C, indefinitely, as shown. Take a tracing of the profile A, and place it in section as shown by A¹. Divide A into the same

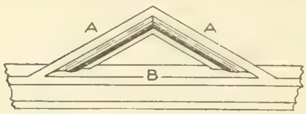


Fig. 298.

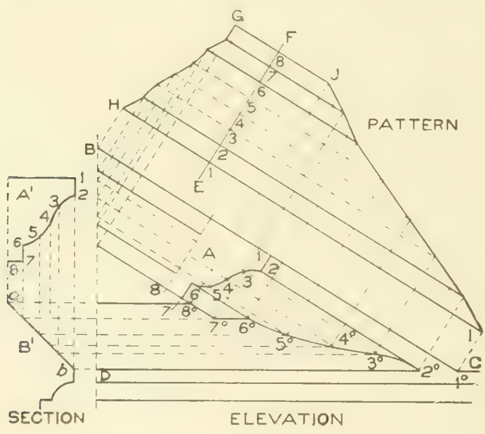


Fig. 299.

number of spaces as A; and from the various divisions in A¹ drop vertical lines intersecting the wash *a b* as shown, from which points draw horizontal lines intersecting lines drawn parallel to B C through similarly numbered points in A, at 1° to 8°. Trace a line through these intersections as shown, which represents the miter-line or line of joint in elevation.

For the pattern, draw any line as E F, at right angles to B C, upon which place the stretchout of the profile A, as shown by similar figures on the stretchout line E F. Through the numbered points of division and at right angles to E F, draw lines as shown, which intersect by lines drawn at right angles to B C, form similarly numbered intersections on 1° 8° and on the vertical line B D. A line traced through points thus obtained, as shown by G H I J, will be the desired pattern.

In Fig. 300 is shown a front view of a turret on which four gables are to be placed, as shown by A A; also the roofs over same, as shown by B B. The problem consists in obtaining the developments of the gable mouldings on a square turret. In developing this pattern, the half-elevation only is required, as shown in Fig. 301, in which first draw the center line E F; then establish the half-width of the turret, as C D, and draw the rake B C. At right angles to the line B C, and in its proper position as shown, draw the profile A, which divide into equal spaces as shown by the figures 1 to 6, through which, parallel to B C, draw lines intersecting the center line F E as shown, and extend the lines below C indefinitely. Now take a tracing of the profile A, and place it in position as shown by A¹, being careful to have it spaced in the same number of divisions, as shown from 1 to 6, through which, parallel to D C, erect lines intersecting similarly numbered lines drawn through the profile A, thus obtaining the intersections 1° to 6°, through which a line is traced, which represents the line of joint at the lower end between the two gables.

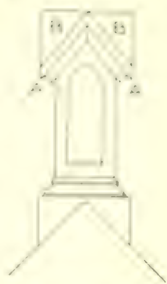


Fig. 300.

For the pattern, take a stretchout of A, and place it on the line J K drawn at right angles to B C, as shown by the figures 1 to 6 on J K. At right angles to J K, and through these points of division, draw lines, which intersect by lines drawn from similarly numbered intersections on F B and 1° 6°. Trace a line through the points thus obtained, as shown by F° B° C° 6°, which is the desired pattern, of which eight are required to complete the turret, four formed right and four left.

If the roof shown by B in Fig. 300 is desired to be added to the pattern in Fig. 301, then, at right angles to F° 6°, draw the line F° F¹ equal to F H in the half-elevation, and draw a line from F¹ to 6° in the pattern.

In Fig. 302 is shown front view of an angular pediment with horizontal returns at bottom A and top B. In this problem, as in others which will follow, a change of profile is necessary before the correct pattern for the returns can be developed. In other words, a new profile must be developed from the given or normal profile before the patterns for the required parts can be developed. It should be understood that all given profiles are always divided into equal spaces; therefore the modified profiles will contain unequal spaces, each one of

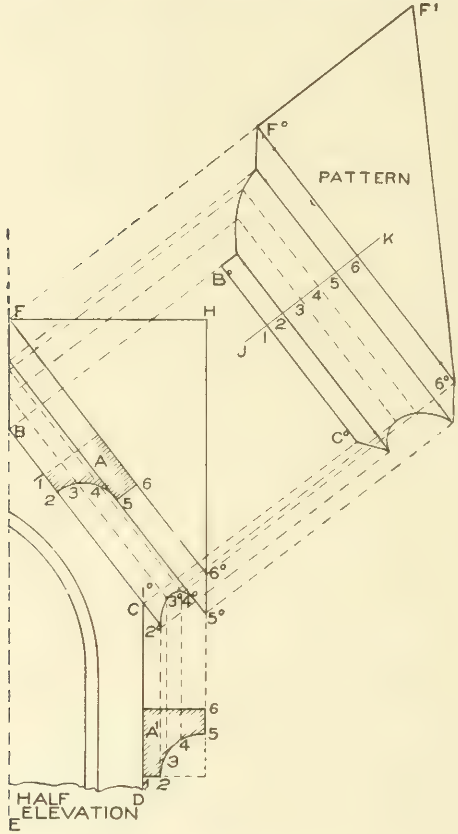


Fig. 301.

which must be carried separately onto the stretchout line. Bearing this in mind, we shall proceed to obtain the modified or changed profiles and patterns for the horizontal returns at top and foot of a gable moulding, as at B and A in Fig. 302, the given profile to be placed in the gable moulding C. In Fig. 303, let C represent the gable moulding placed at its proper angle with the horizontal moulding G H. Assuming that 6^x 6° is the proper angle, place the given profile A at right angles to the rake, as shown, and divide same into equal spaces as shown from 1 to 10, through which points, parallel to 6^x 6°, draw lines towards the top and bottom of the raking moulding. Assuming that the length 6^x 6° is correct, take a tracing of the profile A, and place it in a vertical position below at A^1 and above at A^2, being careful to have the points 6 and 6 in the profiles directly in a vertical position below the points 6^x and 6°, as shown. From the various intersections in the profiles A^1 and A^2 (which must contain the same number of spaces as the given profile A), erect vertical lines intersecting lines drawn through the profile A, as shown at the lower end from 1^x to 10^x, and at the upper end from 1° to 10°. Trace a line through the points thus obtained. Then will 1^x 10^x be the modified profile for the lower horizontal return, and 1° 10° the modified profile for the upper horizontal return.

Fig. 193

Note the difference in the shapes and spaces between these two modified profiles and the given profile A. It will be noticed that a portion of the gable moulding miters on the horizontal moulding G H from 6^x to $10'$.

For the pattern for the gable moulding, proceed as follows: At right angles to E F, draw the stretchout line J K, upon which place the stretchout of the given profile A, as shown by the figures 1 to 10 on J K. Through these figures, at right angles to J K, draw lines as shown, which intersect with lines drawn at right angies to E F from similarly numbered intersections in 1° 10° at the top and 1^x 6^x $10'$ at the lower end. Trace a line through the intersections thus obtained. Then will L M N O be the pattern for C.

For the pattern for the horizontal return at the top, draw a side view as shown at B, making P R the desired projection, and the profile 1 10 on B, with its various intersections, an exact reproduction of 1° 10° in the elevation. Extend the line R T as R S, and starting from 10, lay off the stretchout of the profile in B as shown by the figures 1 to 10 on R S, being careful to measure each space separately. At right angles to R S draw the usual measuring lines, which intersect by lines drawn parallel to S R from similarly numbered points in the profile in B. Trace a line through points thus obtained. Then will U V 10 1 be the pattern for the return B.

In similar manner, draw the side view of the lower horizontal return as shown at D, making the projection W 10 equal to P R

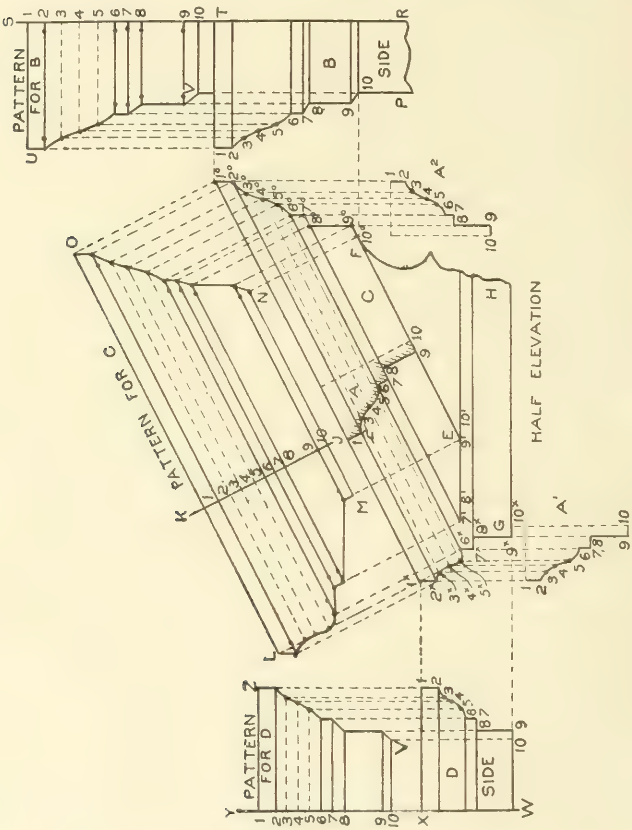


Fig. 303

in B. The profile shown from 1 to 10 in D, with all its divisions, is to be an exact reproduction of the profile 1^x to 10^x in elevation. Extend the line W X as X Y, upon which lay off the stretchout of the profile 1 10 in D, being careful that each space is measured separately, as they are all unequal. Through the figures on X Y draw lines as shown, which intersect by lines drawn parallel to W Y from the miter intersections in the profile in the side D. A line traced through points thus obtained, as shown by Z V, will be the desired cut, and 1 Z V 10 the pattern for the return D.

In Fig. 304 is shown a front view of a segmental pediment with upper and lower horizontal returns. This presents a problem of obtaining the pattern for horizontal returns at top and foot of a segmental pediment, shown respectively at A and B, the given profile to be placed in C. The principles used in obtaining these patterns are similar to those in the preceding problem, the only difference being that the moulding is curved in elevation. In Fig. 305 the true method is clearly given. First draw the center line B D, through which draw the horizontal line C C¹. From the line C C¹ establish the height E, and with the desired center, as B, draw the arc F C intersecting the line C¹ C at C. In its proper position on a vertical line F G, parallel to D B, draw the given profile of the curved moulding as shown by A, which divide into equal spaces as shown from 1 to 10. Through these figures, at right angles to F G, draw lines intersecting the center line D B as shown.

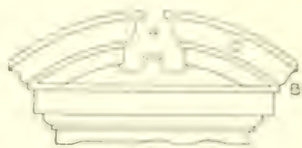


Fig. 304.

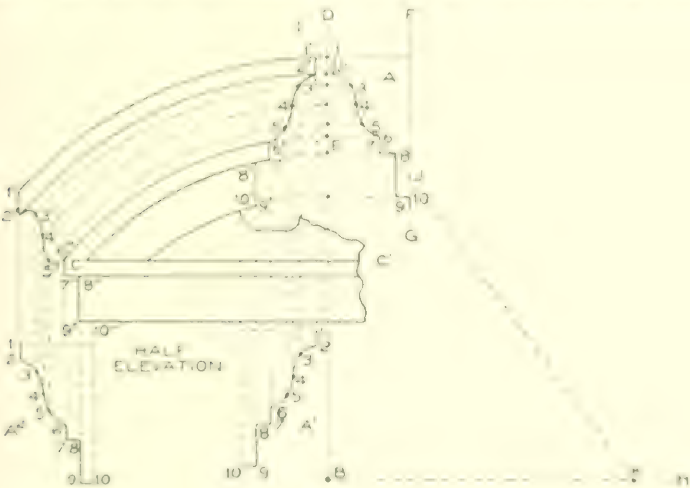


Fig. 305.

Then, using B as center, with radii of various lengths corresponding to the various distances obtained from A, describe arcs as shown, extending them indefinitely below the foot of the pediment. The point C or 6″ being established, take a tracing of the profile A, with all the various points of intersection in same, and place it as shown by A^2, being careful to have the point 6 in A^2 come directly below the point 6″ in elevation in a vertical position. Then, from the various intersections in A^2 erect vertical lines intersecting similarly numbered arcs drawn from the profile A. Trace a line as shown from 1″ to 10″, which is the modified profile for the foot of the curved moulding.

Establish at pleasure the point 1′ at the top, and take a tracing of the given profile A placing it in a vertical position below 1′, as shown by A^1. From the various intersections in A^1 erect vertical lines intersecting similarly numbered arcs as before. Through these intersections, shown from 1′ to 10′, trace the profile shown, which is the modified profile for the top return.

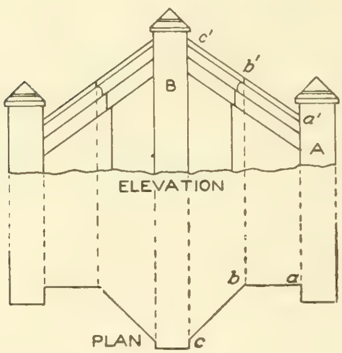


Fig. 306.

The curved moulding shown in elevation can be made either by hand or by machine. The general method of obtaining the blank or pattern for the curved moulding is to average a line through the extreme points of the profile A, as I J, extending it until it intersects a line drawn at right angles to D B from the center B, as B H, at K.

We will not go into any further demonstration about this curved work, as the matter will be taken up at its proper time later on.

To obtain the pattern for the upper and lower return mouldings, proceed in precisely the same manner as explained in connection with returns B and D in Fig. 303.

In Fig. 306 are shown the plan and elevation of a gable moulding in octagon plan. This problem should be carefully followed, as it presents an interesting study in projections; and the principles used in solving this are also applicable to other problems, no matter what angle or pitch the gable has. By referring to the plan, it will be seen that the moulding has an octagon angle in plan a b c while similar points in elevation a' b' c' run on a rake in one line, the top and foot of the moulding butting against the brick piers B and A.

The method of proceeding with work of this kind is explained in detail in Fig. 307, where the principles are thoroughly explained. Let A B C D E represent a plan view of the wall, over which a gable moulding is to be placed, as shown by G H I J, the given profile of the

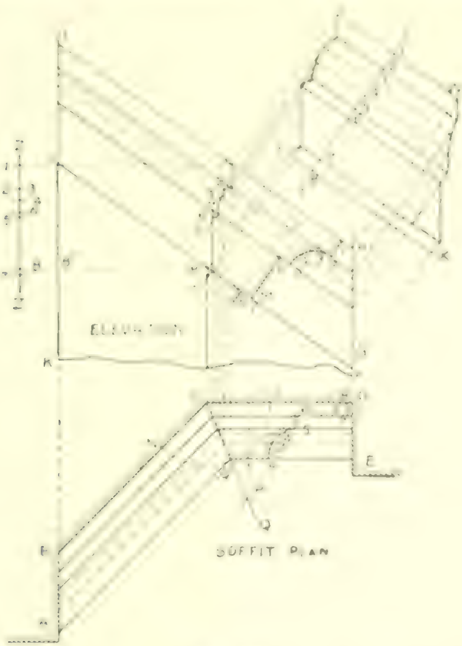


Fig. 307.

moulding being shown by L M. Divide the profile into equal spaces as shown by the figures 1 to 8. Parallel to I H or J G, and through the figures mentioned, draw lines indefinitely as shown. Bisect the angle B C D in plan, and obtain the miter-line as follows: With C as center, and any radius, describe the arc N O. With N and O as centers, and any radius greater than C N or C O, describe arcs intersecting each other at P. From the point C, and through the intersection P, draw the miter-line C Q. Transfer the profile L M in elevation to the position shown by R S in plan, dividing it into the same number of spaces as L M. Through the figures in the profile R S, and parallel to D C, draw lines intersecting the miter-line C Q, as shown. From the intersections on the miter-line, and parallel to C B, draw lines intersecting the surface B A. Now, at right angles to C D in plan, and from the

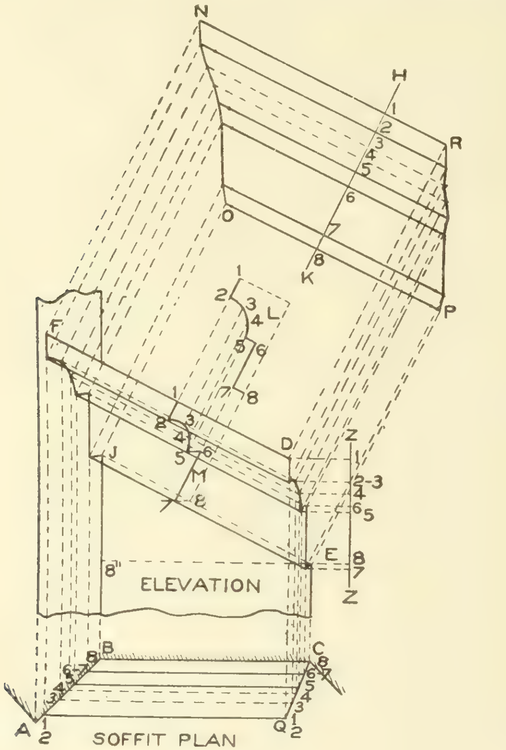


Fig. 308.

intersections on the miter-line C Q, draw vertical lines upward, intersecting lines of similar numbers drawn from points in profile L M in elevation parallel to J G. A line traced through points thus obtained, as shown from 1′ to 8′, will be the miter-line in elevation.

For the pattern for that part of the moulding shown by C D E Q′ in plan, and H G 8′ 1′ in elevation, proceed as follows: At right angles to 1 H in elevation, draw the line T U, upon which place the stretchout of the profile L M, as shown by the figures 1 to 8. At right angles to T U, and through these figures, draw lines as shown, which intersect with lines of similar numbers drawn at right angles to A H from intersections on the miter-line 1′ 8′ and from intersections against the vertical surface H G. Lines traced through points thus obtained, as shown by V W X Y, will be the pattern for that part of the gable shown in plan by C D E Q′ of Fig. 307.

In Fig. 308, on the other hand, the position of the plan is changed, so as to bring the line A Q horizontal. At right angles to B C draw the vertical line C E, on which locate any point, as E. In the same manner, at right angles to C B, draw the vertical line B J indefinitely. From the point E, parallel to B C, draw the line E 8″, intersecting the line J B, as shown. Now take the distance from 8″ to J in elevation, Fig. 307, and set it off from 8″ toward J in Fig. 308. Draw a line from J to E, which will represent the true rake for this portion of the moulding. Now take the various heights shown from 1 to 8 on the line Z Z in elevation in Fig. 307, and place them as shown by Z Z in elevation, Fig 308, being careful to place the point 8 of the line Z Z on the line 8″ E extended. At right angles to Z Z, and from points on same, draw lines, which intersect with lines drawn at right angles to B C from intersections of similar numbers on C Q in plan. A line traced through points thus obtained, as shown by D E in elevation, will be the miter-line on C Q in plan.

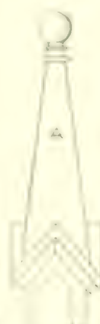


Fig. 309.

From the intersections on the miter-line D E, and parallel to E J, draw lines, which intersect with lines drawn from intersections of similar numbers on A H in plan at right angles to B C. A line traced through points thus obtained, as shown by F J, will be the miter-line or line of joint against the pier shown in plan by B A.

Before obtaining the pattern it will be necessary to obtain a true section or profile at right angles to the moulding F D. To do so, proceed as follows: Transfer the given profile L M in elevation in Fig. 307, with the divisions and figures on same, in a position at right angles to F D of Fig. 308, as shown at L. At right angles to F D, and from the intersections in the profile L, draw lines intersecting those of similar numbers in F D E J. Trace a line through intersections thus obtained, as shown from 1 to 8, thus giving the profile M, or true sections at right angles to F D.

For the pattern, proceed as follows: At right angles to F D, draw the line H K, upon which place the stretchout of the profile M, as shown by the figures. At right angles to H K, and through the figures, draw lines, which intersect with those of similar numbers drawn at

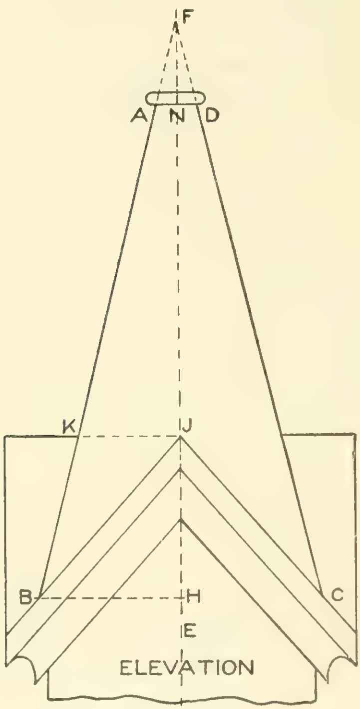


Fig. 310.

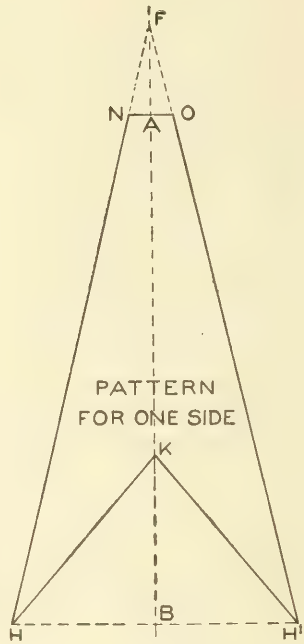


Fig. 311.

right angles to F D from points of intersection in the miter-lines D E and J F, as shown. Lines traced through points thus obtained, as shown by N O P R, will be the pattern for the raking moulding shown in plan, Fig. 307, by A B C Q′.

In Fig. 309 is shown a view of a spire, square in plan, intersecting four gables. In practice, each side A is developed separately in a manner shown in Fig. 310, in which first draw the center line through the center of the gable, as E F. Establish points B and C, from which draw lines to the apex F. At pleasure establish A D. At right angles to F E, and from B and J, draw the lines B H and J K respectively. For the pattern, take the distances B K, K A, and A F, and place them as shown by similar letters on the vertical line B F in Fig. 311. At right angles to B F, and through points B and A, draw lines as shown, making B H and B H^1 on the one hand, and A N and A O on the other hand, equal respectively to B H and A N in elevation in Fig. 310. Then, in Fig. 311, draw lines from N to H to K to H^1 to O, as shown, which represents the pattern for one side.

Fig. 312.

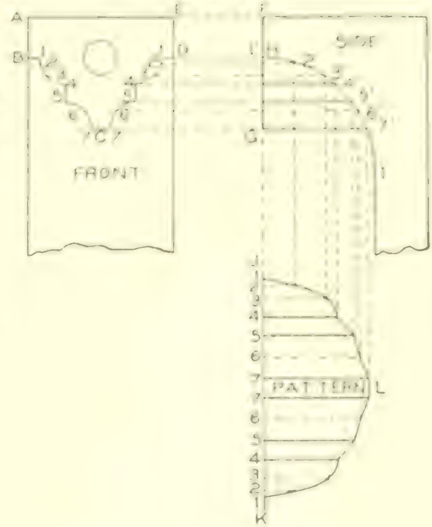


Fig. 313.

In Fig. 312 is shown a perspective view of a drop B mitering against the face of the bracket C as indicated at A. The principles for developing this problem are explained in Fig. 313, and can be applied to similar work no matter what the profiles of the drop or bracket may be. Let A B C D E represent the face or front view of the bracket drop, and F H G I the side of the drop and bracket. Divide one-half of the face, as D C, into equal spaces, as shown by the figures 1 to 7 on either side, from which points draw horizontal lines crossing H G in side view and intersecting the face H I of the bracket at points 1′ to 7′. In line with H G, draw the line J K, upon which place the stretch-out of the profile B C D, as shown by 1 to 7 to 7 to 1 on J K. At right angles to J K, draw the usual measuring lines as shown which intersect by lines drawn parallel to J K from similarly numbered intersections on H I. Trace a line through the points thus obtained. Then will J K L be the pattern for the return of the drop on the face of the bracket.

In Fig. 314, A shows a raking bracket placed in a gable moulding. When brackets are placed in a vertical position in any raking moulding, they are called "raking" brackets. B represents a raking bracket placed at the center of the gable. The patterns which will be developed for the bracket A are also used for B, the cuts being similar, the only difference being that one-half the width of the bracket in B is formed right and the other half left, the two halves being then joined at the angle as shown.

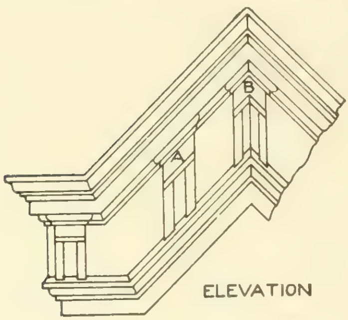


Fig. 314.

In Fig. 315 are shown the principles employed for obtaining the patterns for the side, face, sink strips, cap, and returns for a raking bracket. These principles can be applied to any form or angle in the bracket or gable moulding respectively. Let S U V T represent part of a front elevation of a raking cornice placed at its proper angles with any perpendicular line. In its proper position, draw the outline of the face of the bracket as shown by E G M O. Also, in its proper position as shown, draw the normal profile of the side of the bracket, indicated by 6-Y-Z-15; the normal profile of the cap-mould, as W and X; and the normal profile of the sink strip, as indicated by 10 10′ 15′ 15.

Complete the front elevation of the bracket by drawing lines parallel to E O from points 7 and 9 in the normal profile; and establish at pleasure the width of the sink strip in the face of the bracket, as at J K and L H. To complete the front elevation of the cap-mould of the bracket, proceed as follows: Extend the lines G E and M O of the front of the brackets, as shown by E 6 and O 6, on which, in a vertical position as shown, place duplicates (W^1, W^2) of the normal profiles W and X, divided into equal spaces as shown by the figures 1 to 6 in W^1 and W^2. From these intersections in W^1 and W^2, drop vertical lines, which intersect by lines drawn parallel to E O from similarly numbered intersections in X, and trace lines through the points thus obtained. Then will R E and O P represent respectively the true elevations, also the true profiles for the returns at top and foot of the cap of the raking bracket.

Now divide the normal profile of the bracket into equal spaces as shown by the figures 6 to 15, through which, parallel to E O, draw lines intersecting the normal sink profile from 10′ to 15′ and the face lines of the bracket FTG, HI, KL, and ONM, as shown. To obtain the

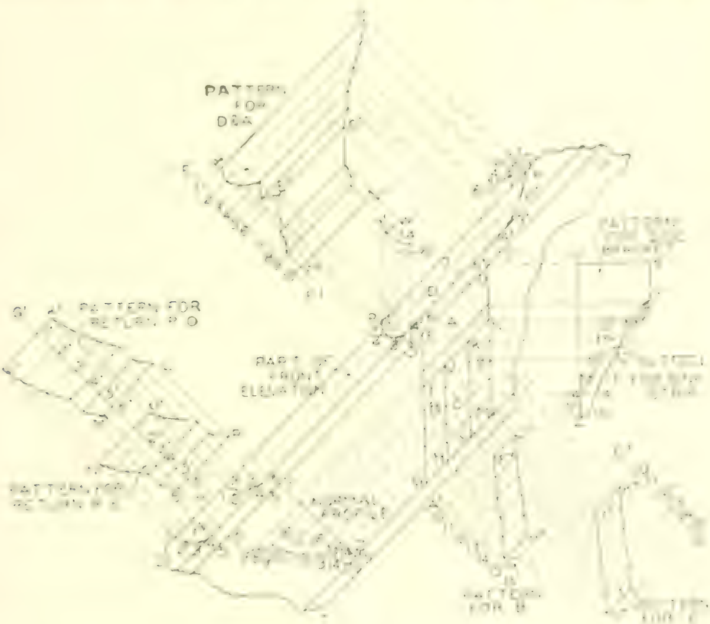


Fig. 315.

true profile for the side of the bracket on the lines OM and GL, proceed as follows: Parallel to OM, draw any line, as Y¹ Z¹, and at right angles to OM, and from the various intersections on the same, draw lines indefinitely, crossing to the line Y¹ Z¹ as shown. Now, measuring in each instance from the line Y Z in the normal profile, take the various distances to points 6 to 15 and 15′ to 10′, and place them on similarly numbered lines measuring in each and every instance from the line Y¹ Z¹, thus obtaining the points 6′ to 15′ and 15″ to 10″, as shown. Trace a line through the points thus obtained. Then will Y¹ 6′ 7′ 9′ 10′ 15′ Z¹ be the pattern for the side of the raking bracket.

and 10′ 10″ 15″ 15′ the pattern for the sink strip shown by the lines K L and H J in the front.

For the pattern for the face strip B, draw any line, as A^1 B^1, at right angles to G M, upon which place the stretchout of 10 15 in the normal profile, as shown from 10 to 15 on A^1 B^1. Through these points, at right angles to A^1 B^1, draw lines as shown, which intersect with lines drawn from similar intersections on the lines F G and H J. Trace a line through points thus obtained as shown by F° G° H° J°, which will be the pattern for the face B, B.

For the pattern for the sink-face C, draw C^1 D^1 at right angles to GM, upon which place the stretchout of 10′ 15′ in the normal profile as shown from 10′ to 15′ on C^1 D^1, through which, at right angles to C^1 D^1, draw lines, which intersect by lines drawn from similar intersections on K L and H J. Trace a line through the points so obtained as J° K° L° H°, which is the pattern for the sink-face C.

The pattern for the cap D and the face A will be developed in one piece, by drawing at right angles to EO the line E^1 F^1. At right angles to E^1 F^1, and through the figures, draw lines, which intersect with lines drawn at right angles to EO from similarly numbered intersections on REF and NOP. A line traced through the points thus obtained, as shown by R° E° F° and N° O° P° will be the pattern for D and A.

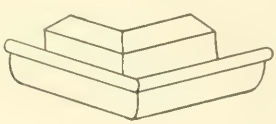


Fig. 316.

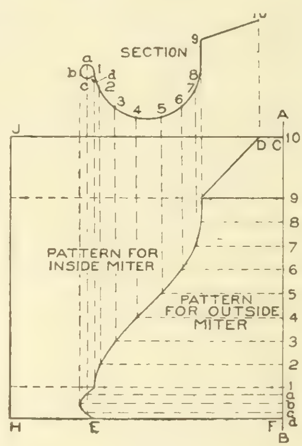


Fig. 317.

For the patterns for the cap returns R E and O P, draw any line at right angles to 1 1 in the normal profile, as H^1 G^1, upon which place the stretchouts of the profiles R E and O P, being careful to carry each space separately onto the line H^1 G^1, as shown respectively by 6^V 1^V and 6^X 1^X. Through these points draw lines at right angles to G^1 H^1, which intersect by lines drawn at right angles to 1 1 from similar numbers in W and X. Trace lines through the points thus obtained. Then will N¹ O² R¹ S¹ be the pattern for the lower return of the cap, R K; while P M¹ L² K¹ will be the pattern for the upper return, P O.

In Fig. 316 is shown a perspective view of a gutter or eave-trough at an exterior angle, for which an outside miter would be required. It is immaterial what shape the gutter has, the method of obtaining the pattern for the miter is the same. In Fig. 317 let 1 9 10 represent the section of the eave-trough with a bead or wire edge at *a b c*; divide the wire edge, including the gutter and flange, into an equal number of spaces, as shown by the small divisions *a* to 1 to 9 to 10. Draw any vertical line, as A B, upon which place the stretch-out of the gutter as shown by similar letters and numbers on A B, through which, at right angles to A B, draw lines, which intersect by

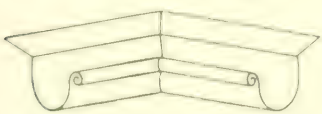


Fig. 318

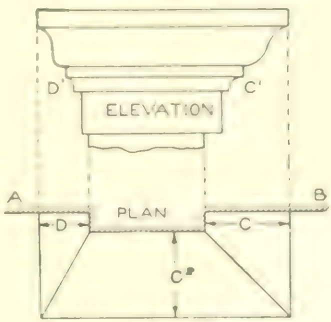


Fig. 319

lines drawn parallel to A B from similar points in the section. Trace a line through the points thus obtained. Then will C D E F be the pattern for the outside angle shown in Fig. 316.

If a pattern is required for an interior or inside angle, as is shown in Fig. 318, it is necessary only to extend the lines C D and F E in the pattern in Fig. 317, and draw any vertical line, as J H. Then will J D E H be the pattern for the inside angle shown in Fig. 318.

In Fig. 319 are shown a plan and elevation of a moulding which has more projection on the front than on the side. In other words, A B represents the plan of a brick pier, around which a cornice is to be constructed. The projection of the given profile is equal to C, the profile in elevation being shown by C¹. The projection of the front in plan is also equal to C, as shown by C². The projection of the left side of the cornice should be only as much as is shown by D in plan. This requires a change of profile through D, as shown by D¹. To obtain this true profile and the various patterns, proceed as shown in Fig. 320, in which A B C D represents the plan view of the wall, against which, in its proper position, the profile E is placed and divided into equal spaces, as shown by the figures 1 to 12. Through 1 2, parallel to C D, draw G F. Locate at pleasure the projection of the re-

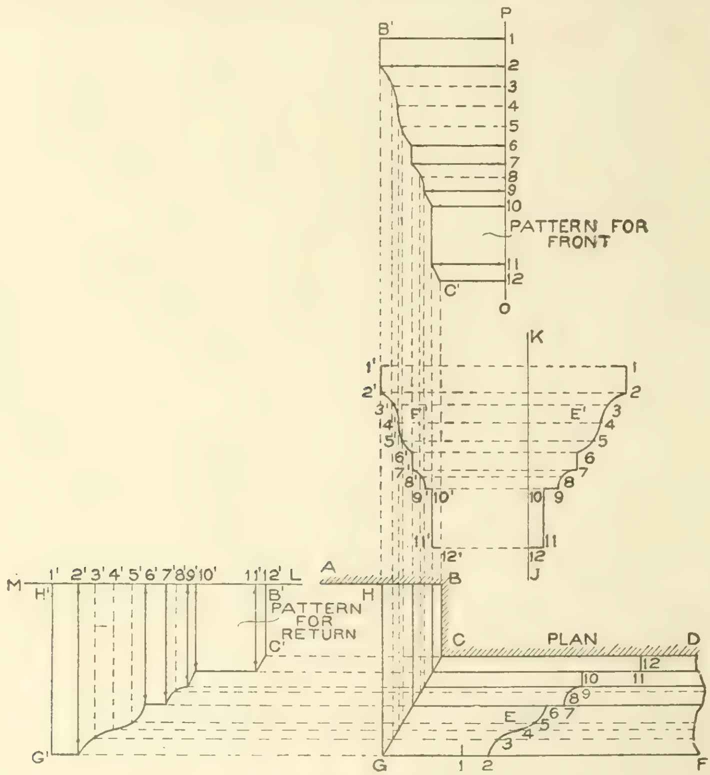


Fig. 320.

turn mould, as B H, and draw H G parallel to B C, intersecting F G at G. Draw the miter-line in plan, G C. From the various divisions in the profile E, draw lines parallel to C D, intersecting the miter-line C G as shown. From these intersections, erect vertical lines indefinitely, as shown. Parallel to these lines erect the line K J, upon which place a duplicate of the profile E, with the various divisions on same, as shown by E¹. Through these divisions draw horizontal lines in-

FRONT AND REAR VIEWS OF RESIDENCE OF HENRY STEINBRENNER, BELLFLOWER AVENUE, CLEVELAND, OHIO

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tersecting the similarly numbered vertical lines as shown by the intersections 1' to 12'. Trace a line through these points. Then will F^1 be the true section or profile on H B in plan.

For the pattern for the return H G C B in plan, extend the line B A, as B M, upon which place the stretchout of the profile F^1, being careful to measure each space separately (as they are unequal), as shown by figures 1' to 12' on M B.

At right angles to this line and through the figures, draw lines, which intersect by lines drawn at right angles to H G from similar points on C G. Trace a line through the points thus obtained. Then will H^1 G^1 C^1 B^1 be the pattern for the return mould.

The pattern for the face mould G C D F is obtained by taking a stretchout of the profile E and placing it on the vertical line P O, as shown by similar figures, through which, at right angles to P O, draw lines intersecting similarly numbered lines previously extended from C G in plan. Trace a line through these intersections. Then will 1 B^1 C^2 12 be the desired pattern for the face mould.

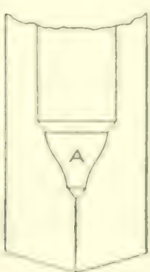


Fig. 321.

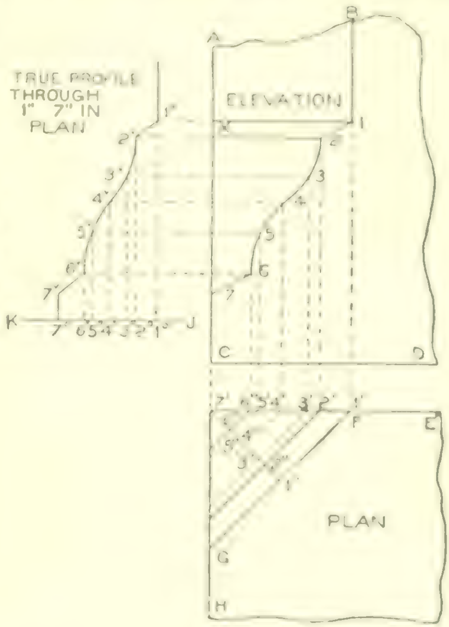


Fig. 320.

In Fig. 321 is shown a perspective view of a gore piece A joined to a chamfer. This presents a problem often arising in ornamental sheet-metal work, the development of which is given in Fig. 322. Let A B C D show the elevation of the corner on which a gore piece is required. H 7′ E in plan is a section through C D, and E F G H is a section through X I, all projected from the elevation as shown. The profile 1 7 can be drawn at pleasure, and at once becomes the pattern for the sides. Now divide the profile 1 7 into an equal number of spaces as shown, from which drop vertical lines onto the side 7′ E in plan, as shown from 1′ to 7′. From these points draw lines parallel to F G, intersecting the opposite side and crossing the line 7′ 1″ (which is drawn at right angles to F G from 7′) at 1″ 2″ 3″ 4″ 5″ 6″. Draw any line parallel to C D, as K J, upon which place all the intersections contained on 7′ 1″ in plan, as shown by 1° to 7° on K J. From these points erect perpendicular lines, which intersect by lines drawn from similarly numbered points in elevation parallel to C D. Through the points thus obtained trace a line. Then will 1^v to 7^v be the true profile on 7′ 1″ in plan.

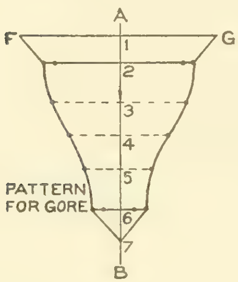


Fig. 323.

For the pattern for the gore, draw any vertical line, as A B in Fig 323, upon which place the stretchout of the profile 1^v 7^v in Fig. 322, as shown by similar figures on A B in Fig. 323. At right angles to AB, and through the figures, draw lines as shown, Now, measuring in each instance from the line 7′ 1″ in plan in Fig. 322, take the various distances to points 1′ to 7′, and place them in Fig. 323 on similarly numbered lines, measuring in each instance from the line A B, thus locating the points shown. Trace a line through the points thus obtained. Then will F G 7 be the pattern for the gore shown in plan in Fig. 322 by F G 7′.


Fig. 324.

In Fig. 324 is shown a face view of a six-pointed star, which often arises in cornice work. No matter how many points the star has, the principles which are explained for its development are applicable to any size or shape. Triangulation is employed in this problem, as shown in Fig. 325. First draw the half-outline of the star, as shown by A B C D E F G. Above and parallel to the line AG, draw JH of similar length, as shown. Draw the section of the star on A G in plan, as shown by J K H. Project K into plan as shown at I, and draw the miter-lines B I, C I, D I, E I, and F I. As K H is the true length on I G, it is necessary that we find the true length on I F. Using I F as radius and I as center, draw an arc intersecting I G at a. From a erect a line cutting J H in section at b. Draw a line from b to K, which is the true length on I F.

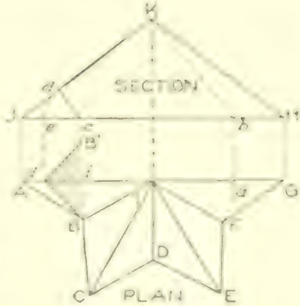


Fig. 325

For the pattern, proceed as shown in Fig. 326. Draw any line, as K H, equal in length to K H in Fig. 325. Then, using K b as radius and K in Fig. 326 as center, describe the arc b b, which intersect at a and a by an arc G G struck from H as center and with F G in plan in Fig. 325 as radius. Draw lines in Fig. 326 from K to a to H to a to K, which will be the pattern for one of the points of the star of which 6 are required.

When bending the points on the line HK, it is necessary to have a stay or profile so that we may know at what angle the bend should be made. To obtain this stay, erect from the corner B in Fig. 325 a line intersecting the base-line J H at c, from which point, at right angles to J K, draw c d. Using c as center, and c d as radius, strike an arc intersecting J H at e. From e drop a vertical line meeting A G in plan at d'. Set off e B¹ equal to e B, and draw a line from B to d′ to B¹, which is the true profile after which the pattern in Fig. 326 is to be bent. If the stay in Fig. 325 has been correctly developed, then d′ B¹ or d′ B must equal e a in Fig. 326 on both sides.

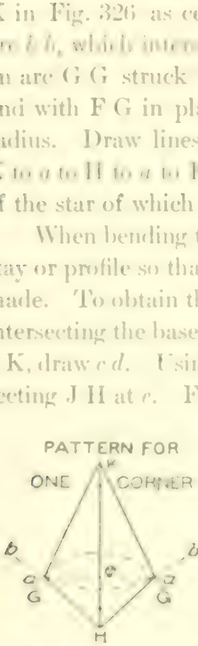


Fig. 326

In Fig. 327 is shown a finished elevation of a hipped roof, on the four corners of which a hip ridge A A is placed against the upper line B and cuts off on a vertical line at the bottom, as C and C. To obtain the true profile of this hip ridge, together with the top and lower cuts and the patterns for the lower heads, proceed as shown in Fig. 328, where the front elevation has been omitted, this not being necessary, as only the part plan and diagonal elevation are required. First draw the part plan as shown by A B C D E F A, placing the hip or diagonal line F C in a horizontal position; and make the distances between the lines F A and C B and between F E and C D equal, because the roof in this case has equal pitch all around. (The same principles, however, would be used if the roofs had unequal pitches.) Above the plan, draw the line G H. From the points F and C in plan, erect the lines F G and C I, extending C I to C^1 so that I C^1 will be the required height of the roof above G I at the point C in plan. Draw a line from G to C^1, and from C^1 draw a horizontal and vertical line indefinitely, as shown. Then will I G C^1 be a true section on the line of the roof on F C in plan.

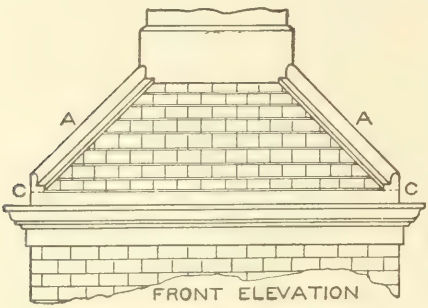


Fig. 327.

The next step is to obtain a true section of the angle of the roof at right angles to the hip line G C^1 in elevation. This is done by drawing at right angles to F C in plan, any line, as *a b*, intersecting the lines F A and F E as shown. Extend *a b* until it cuts the base-line G I in elevation at *c*. From *c*, at right angles to G C^1, draw a line, as *c d*, intersecting G C^1 at *d*. Take the distance *c d*, and place it in plan on the line F C, measuring from *i* to *d′*. Draw a line from *a* to *d′* to *b*, which is the true angle desired. On this angle, construct the desired shape of the hip ridge as shown by J, each half of which divide into equal spaces, as shown by the figures 1 to 6 to 1. As the line G C^1 represents the line of the roof, and as the point *d′* in plan in the true angle also represents that line, then take a tracing of the profile J with the various points of intersection on same, together with the true angle *a d′ b*, and place it in the elevation as shown by J^1 and *a′ d″ b′*, being careful to place the point *d″* on the line G C^1, making *a′ b′* parallel to G C^1. From the various points of intersection in the profile J, draw lines parallel to F C, intersecting B C and A F at points from 1 to 6, as shown. As both sides of the profile J are symmetrical, it is necessary only to draw lines through one-half.

In similar manner, in elevation, parallel to G C', draw lines through the various intersections in P, which intersect the lines drawn at right angles to F C in plan from similarly numbered points on A F

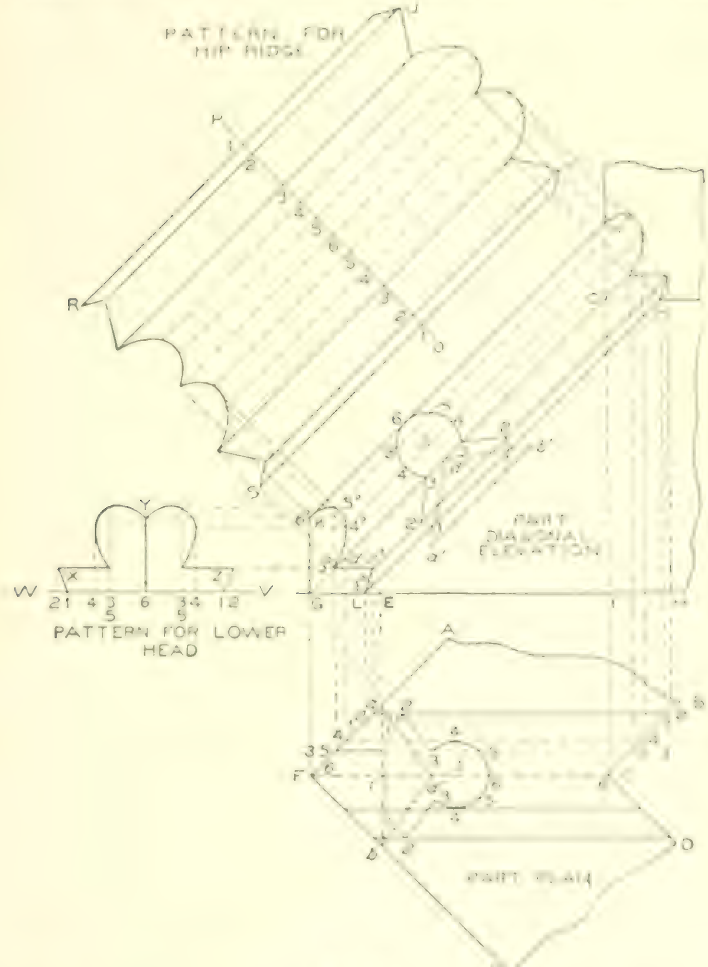


Fig. [illegible]

and B C. Trace a line through the points thus obtained. Then will K L be the miter line at the bottom, and M N the miter line at the top.

For the pattern, draw any line, as O P, at right angles to G C', upon which place the stretchout of J in plan or J^1 in elevation, as shown by the figures 1 to 6 to 1 on O P; and through these numbered points, at right angles to O P, draw lines, which intersect by lines drawn at right angles to G C^1 from similar intersections in the lower miter-line K L and upper miter-line N M. Trace a line through the points thus obtained. Then will R S T U be the desired pattern.

In practice it is necessary only to obtain one miter-cut—either the top or the bottom—and use the reverse for the opposite side. In other words, U T is that part falling out of R S, the same as R S is that part which cuts away from U T. The upper miter-cut butts against B in Fig. 327; while the lower cut requires a flat head, as shown at C. To obtain this flat head, extend the line I G in Fig. 328, as I W, upon which place twice the amount of spaces contained on the line A F in plan, as 6, 3 – 5, 4, 1, 2, as shown by similar figures on either side of 6 on the line V W. From these divisions erect vertical lines, which intersect by lines drawn parallel to V W from similarly numbered intersections in the miter-line K L G. A line traced through the points thus obtained, as shown by X Y Z, will be the pattern for the heads.

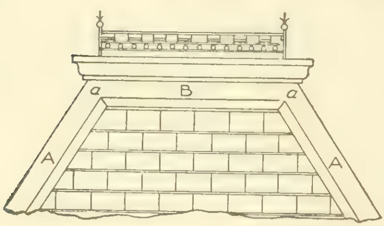


Fig. 329.

Where a hip ridge is required to miter with the apron of a deck moulding, as shown in Fig. 329, in which B represents the apron of the deck cornice, A and A the hip ridges mitering at *a* and *a*, a slightly different process from that described in the preceding problem is used. In this case the part elevation of the mansard roof must first be drawn as shown in Fig. 330. Let A B C K represent the part elevation of the mansard, the section of the deck moulding and apron being shown by D B E. Draw E X parallel to B C. E X then represents the line of the roof. In its proper position, at right angles to B C, draw a half-section of the hip mould, as shown by F G, which is an exact reproduction of B E of the deck mould. Through the corners of the hip mould at Y and G, draw lines parallel to B C, which intersect by lines drawn parallel to B A from V, W, and E in the deck cornice. Draw the miter-line H I, which completes the part elevation of the mansard.

Before the patterns can be obtained, a developed surface of the mansard must be drawn. Therefore, from B (Fig. 330), drop a vertical line, as B J, intersecting the line C K at J. Now take the distance of B C, and place it on a vertical line in Fig. 331, as shown by B C¹. Through these two points, draw the horizontal lines B A and C K as shown. Take the projection J to C in Fig. 330, and place it as

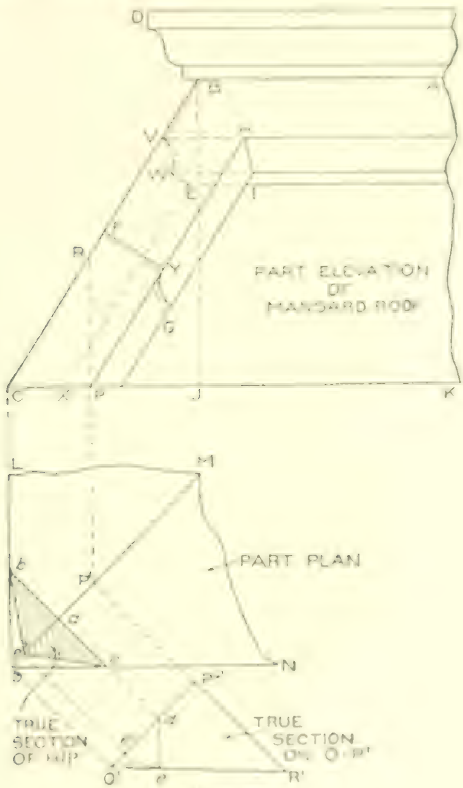


Fig. 330

shown from C¹ to C in Fig. 331, and draw a line from C to B. Then will A B C K be the developed surface of A B C K in Fig. 330.

As both the profiles B V W E and F A H are similar, take a tracing of either, and place it as shown by D and D¹ respectively in Fig. 331. Divide both into the same number of equal spaces, as shown. Bisect the angle A B C by establishing a and b, and, using these as centers, by describing arcs intersecting at c; then draw d B, which represents the miter-line. Through the points in D and D^1, draw lines parallel to their respective moulds, as shown, intersecting the miter-line B d and the base-line C C^1.

For the pattern for the hip, draw any line, as E F, at right angles to B C, upon which place twice the stretchout of D, as shown by the divisions 6 to 1 to 6 on EF. Through these divisions draw lines at

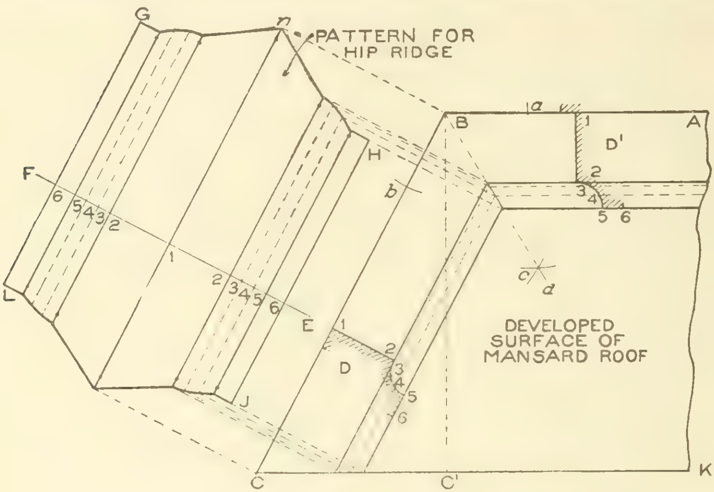


Fig. 331.

right angles to E F, intersecting similarly numbered lines drawn at right angles to B C from the divisions on B d and C C^1. Trace a line through the points thus obtained. Then will G H J L be the pattern for the hip ridge.

When bending this ridge in the machine, it is necessary to know at what angle the line 1 in the pattern will be bent. A true section must be obtained at right angles to the line of hip, for which proceed as shown in Fig. 330. Directly in line with the elevation, construct a part plan L M N O, through which, at an angle of 45 degrees (because the angle L O N is a right angle), draw the hip line O M. Establish at pleasure any point, as P^1 on O M, from which erect the vertical line into the elevation crossing the base-line C K at P and the ridge-line C B at R. Parallel to O M in plan, draw O^1 P^2, equal to O P^1, as shown. Extend P^1 P^2 as P^2 R^1, which make equal to PR in elevation.

Draw a line from R^1 to O^3. Then $O^3 R^1 P^3$ represents a true section on OP^3 in plan. Through any point, as *a*, at right angles to OM, draw *bc*, cutting L O and O N at *b* and *c* respectively. Extend *b c* until it intersects $O^3 P^3$ at *d*. From *d*, at right angles to $O^3 R^1$, draw the line *d e*. With *d* as center, and *de* as radius, draw the arc $e e^1$, intersecting $O^3 P^3$ at e^1, from which point, at right angles to OM in plan, draw a line intersecting OM at e^2. Draw a line from *b* to e^2 to *c*, which represents the true section of the hip after which the pattern shown in Fig. 331 is formed.

The pattern for the deck mould D E in Fig. 330 is obtained in the same way as the square miter shown in Fig. 277; while the pattern for the apron D^1 in Fig. 331 is the same as the one-half pattern of the hip ridge shown by *n* H 1 6.

In Fig. 332 is shown a front elevation of an eye-brow dormer. In this view A B C represents the front view of the dormer, the arcs being

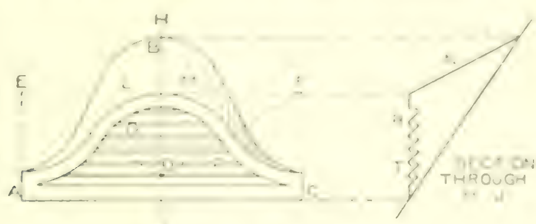


Fig. 332.

struck from the center points D, E, and F. A section taken on the line H J in elevation is shown at the right; L M shows the roof of the dormer, indicated in the section by N; while the louvers are shown in elevation by O P and in section by R T.

In Fig. 333 is shown how to obtain the various patterns for the various parts of the dormer. ABC represents the half-elevation of the dormer, and EFG a side view, of which EG is the line of the dormer, EF that of the roof, and GF the line of the pitched roof against which the dormer is required to miter.

The front and side views being placed in their proper relative positions, the first step is to obtain a true section at right angles to EF. Proceed as follows: Divide the curve A to B into a number of equal spaces, as shown from 1 to 9. At right angles to A C, and from the figures on A B, draw lines intersecting E G in side view as shown.

From these intersections, and parallel to EF, draw lines intersecting the roof-line GF at 1^5, 2^5, 3^5, etc. Parallel to EF, and from the point

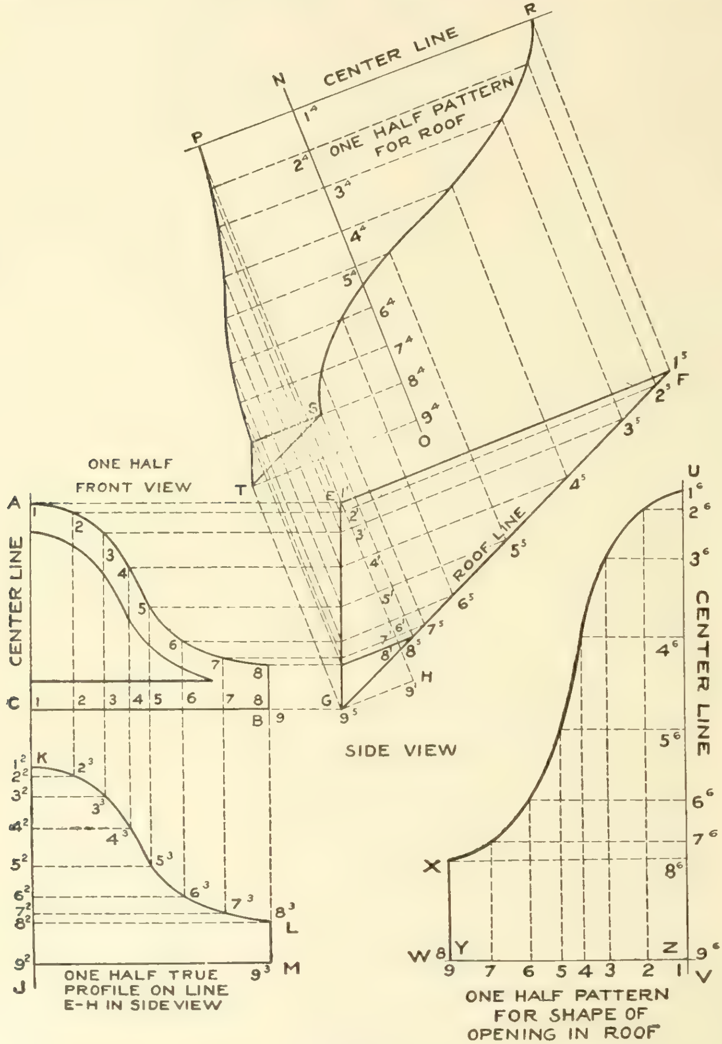


Fig. 333.

G, draw any line indefinitely, as G H. At right angles to EF, and from the point E, draw the line EH, intersecting lines previously drawn, as 1^3, 2^3, 3^3, etc., as shown. Now take a duplicate of the line E H with the various intersections thereon, and place 1^3 on the center line AC extended as KJ. At right angles to KJ, and from the figures 1^3, 2^3, 3^3, etc., draw lines, which intersect with those of similar numbers drawn at right angles to C B and from similarly numbered points on the curve A B. Trace a line through the points of intersection thus obtained. Then KLMJ will be one-half the true profile on the line E H in side view, from which the stretchout will be obtained in the development of the pattern.

For the pattern for the roof of the dormer, draw at right angles to EF in side view the line N O, upon which place the stretchout of one-half the true profile on the line EH as shown by the small figures 1^4, 2^4, 3^4, etc. Then, at right angles to N O, and through the figures, draw lines, which intersect with those of similar numbers drawn at right angles to EF from intersections on EG and GF. Trace a line through the points thus obtained. Then will PRST represent one-half the pattern for the roof.

To obtain the pattern for the shape of the opening to be cut into the roof, transfer the line GF, with the various intersections thereon, to any vertical line, as U V, as shown by the figures 1^6, 2^6, 3^6, etc. In similar manner, transfer the line CB in front view, with the various intersections on same, to the line ZW, drawn at right angles to UV, as shown by the figures 1, 2, 3, etc. At right angles to UV, and from the figures, draw lines, which intersect with those of similar numbers drawn at right angles to YZ. Through these points, trace a line. Then will UXYZ be the half-pattern for the shape of the opening to be cut into the main roof.

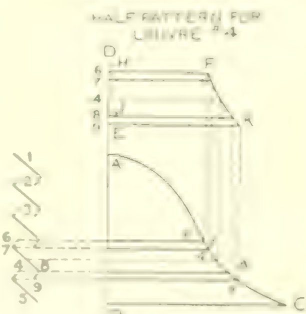


Fig. 334

For the pattern for the ventilating slats or louvers, should they be required in the dormer, proceed as shown in Fig. 334. In this figure, A B C is a reproduction of the inside opening shown in Fig. 333. Let 1, 2, 3, 4, 5 in Fig. 334 represent the sections of the louvers which will be placed in the opening. As the methods of obtaining the patterns for all louvers are alike, the pattern for louver No. 4 will illustrate the principles employed. Number the various bends of louver No. 4 as shown by points 6, 7, 8, and 9. At right angles to A B, and from these points, draw lines intersecting the curve A C as 6^1, 7^1, 4^1, 8^1, and 9^1. On B A extended as E D, place the stretchout of louver No. 4 as shown by the figures on ED. Since the miter-line AC is a curve, it will be necessary to introduce intermediate points between 7 and 8 of the profile, in order to obtain this curve in the pattern. In this instance the point marked 4 has been added.

Now, at right angles to DE, and through the figures, draw lines, which intersect with those of similar numbers, drawn parallel to AB from intersections 6^1 to 9^1 on the curve AC. A line traced through the points thus obtained, as FKJH, will be the half-pattern for louver No. 4. The pattern for the face of the dormer is pricked onto the metal direct from the front view in Fig. 333, in which A 8 B C is the half-pattern.

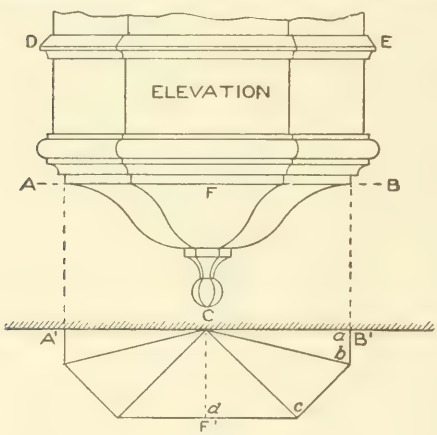


Fig. 335.

In laying out the patterns for bay window work, it often happens that each side of the window has an unequal projection, as is shown in Fig. 335, in which DEF shows an elevation of an octagonal base of a bay window having unequal projections. All that part of the bay above the line AB is obtained by the method shown in Fig. 290, while the finish of the bay shown by ABC in Fig. 335 will be treated here. In some cases the lower ball C is a half-spun ball. A^1 B^1 F^1 is a true section through A B. It will be noticed that the lines C*a*, C*c*, and C*d*, drawn respectively at right angles to *ab*, *bc*, and *cd*, are each of different lengths, thereby making it necessary to obtain a true profile on each of these lines, before the patterns can be obtained. This is clearly explained in connection with Fig. 336, in which only a half-elevation and plan are required as both sides are symmetrical. First draw the center line AB, on which draw the half-elevation of the base of the bay, as shown by CDE. At right angles to AB draw the wall line in plan, as FK; and in its proper position in relation to the line CD in elevation, draw the desired half-plan, as shown by GHIJ. From the corners H and I draw the miter-lines HF and IF, as shown. As DE

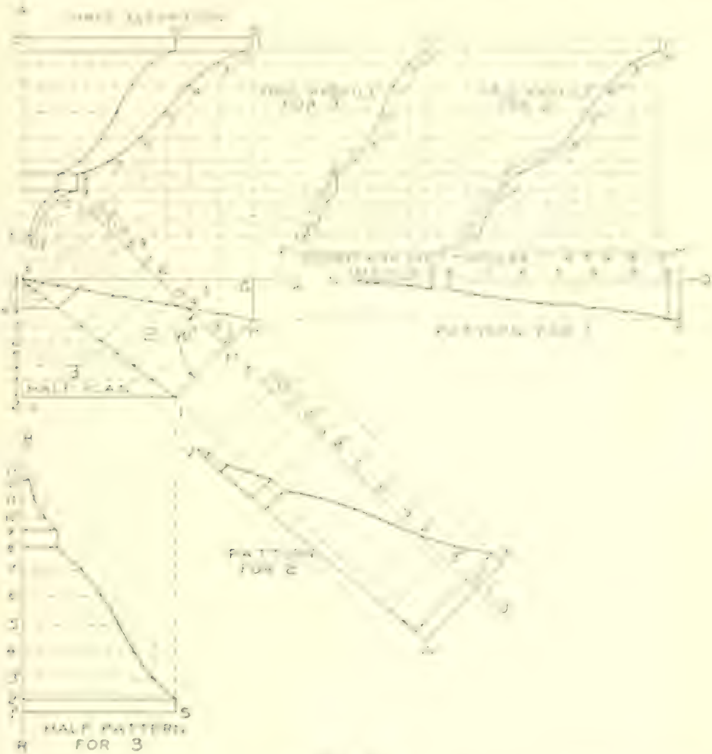


Fig. [illegible]

represents the given profile through FG in plan, then divide the profile DE into an equal number of spaces as shown by the figures 1 to 15. From these points drop vertical lines intersecting the miter-line FH in plan, as shown. From these intersections, parallel to HI, draw lines intersecting the miter-lines IF, from which points, parallel to IJ, draw lines intersecting the center line FB. Through the various points of intersection in DE, draw horizontal lines indefinitely right and left as shown.

If for any reason it is desired to show the elevation of the miter-line FI in plan (it not being necessary in the development of the pattern), then erect vertical lines from the various intersections on FI, intersecting similar lines in elevation. To avoid a confusion in the drawing, these lines have not been shown. Trace a line through points thus obtained, as shown by D^1 13, which is the desired miter-line in elevation.

The next step is to obtain the true profile at right angles to HI and IJ in plan. To obtain the true profile through No. 3 in plan, take a tracing of J F, with the various intersections thereon, and place it on a line drawn parallel to CD in elevation, as J^1 F^1, with the intersections 1 to 13, as shown. From these intersections, at right angles to J^1 F^1, erect lines intersecting similar lines drawn through the profile DE in elevation. Trace a line through the points thus obtained, as shown by 1′ to 13′, which represents the true profile for part 3 in plan. At right angles to IH in plan, draw any line, as ML, and extend the various lines drawn parallel to IH until they intersect LM at points 1 to 13, as shown.

Take a tracing of LM, with the various points of intersection, and place it on any horizontal line, as L^1 M^1, as shown by the figures 1 to 13, from which, at right angles to L^1 M^1, erect vertical lines intersecting similarly numbered horizontal lines drawn through the profile DE. Trace a line through the points thus obtained. Then will 1″ – 13″ be the true profile through No. 2 in plan at right angles to HI.

For the pattern for No. 1 in plan, extend the line FK, as NO, upon which place the stretchout of the profile DE as shown by the figures 1 to 13 on NO. At right angles to NO, and from the figures, draw lines, which intersect with lines (partly shown) drawn parallel to FG from similar intersections on the miter-line FH. Trace a line through the points thus obtained; then will 1 P 13 be the pattern for part 1 in plan.

At right angles to H I, draw any line, as T U, upon which place the stretchout of profile No. 2, being careful to measure each space separately, as they are all unequal, as shown by the small figures 1″ to 13″ on TU. Through these figures, at right angles to TU, draw lines as shown, which intersect by lines (not shown in the drawing) drawn at right angles to I H from similar points on the miter-lines HF and FI.

Trace a line through the points thus obtained. Then will V W X be the pattern for part 2 in plan.

For the half-pattern for part 3 in plan, extend the center line A B in plan as B R, upon which place the stretchout of the true profile for 3, being careful to measure each space separately, as shown by the figures 1′ to 13′ on BR. At right angles to B R draw lines through the figures, which intersect by lines drawn at right angles to J I from similar points of intersection on the miter-line F I. A line traced through points thus obtained, as 1′ S 13′, will be the half-pattern for part 3.

DEVELOPMENT OF BLANKS FOR CURVED MOULDINGS

Our first attention will be given to the methods of construction, it being necessary that we know the methods of construction before the blank can be laid out. For example, in Fig. 337 is a part elevation of a dormer window, with a semicircular top whose profile has an ogee, fillet, and cove. If this job were undertaken by a firm who had no circular moulding machine, as is the case in many of the smaller shops, the mould would have to be made by hand. The method of construction in this case would then be as shown in Fig. 338, which shows an enlarged section through *a b* in Fig. 337. Thus the strips *a*, *b*, and *c* in Fig. 338 would be cut to the required size, and would be nothing more than straight strips of metal, while *d d′* would be an angle, the lower side *d′* being notched with the shears and turned to the required circle. The face strips *e*, *f*, and *h* would represent arcs of circles to correspond to their various diameters obtained from the full-sized elevation. These face and sink strips would all be soldered together, and form a succession of square angles, as shown in which the ogee, as shown by *e f*, and the cove, as shown by *m*, would be fitted. In obtaining the patterns for the blanks hammered by hand, the averaged lines would be drawn as shown by *k l* for the ogee and *n o* for the cove. The method or principles of averaging these and other moulds will be explained as we proceed.

Fig. 338.

In Fig. 339 is shown the same mould as in the previous figure, a different method of construction being employed than the one made by hand and the one hammered up by machine. In machine work this mould can be hammered in one piece, 8 feet long or of the length of the sheets in use, if such length is required, the machine taking in the full

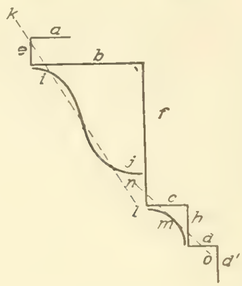


Fig. 338.

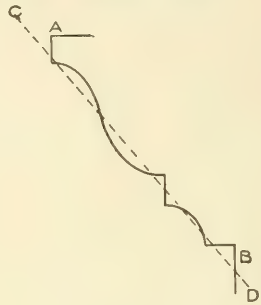


Fig. 339.

mould from A to B. The pattern for work of this kind is averaged by drawing a line as shown by C D. This method will also be explained more fully as we proceed.

SHOP TOOLS EMPLOYED

When working any circular mould by hand, all that is required in the way of tools is various-sized raising and stretching hammers, square stake, blow-horn stake, and mandrel including raising blocks made of wood or lead. A first-rate knowledge must be employed by the mechanic in the handling and working of these small tools. In a thoroughly up-to-date shop will be found what are known as "curved moulding" machines, which can be operated by foot or power, and which have the advantage over hand operation of saving time and labor, and also turning out first-class work, as all seams are avoided.

PRINCIPLES EMPLOYED FOR OBTAINING APPROXIMATE BLANKS FOR CURVED MOULDINGS HAMMERED BY HAND

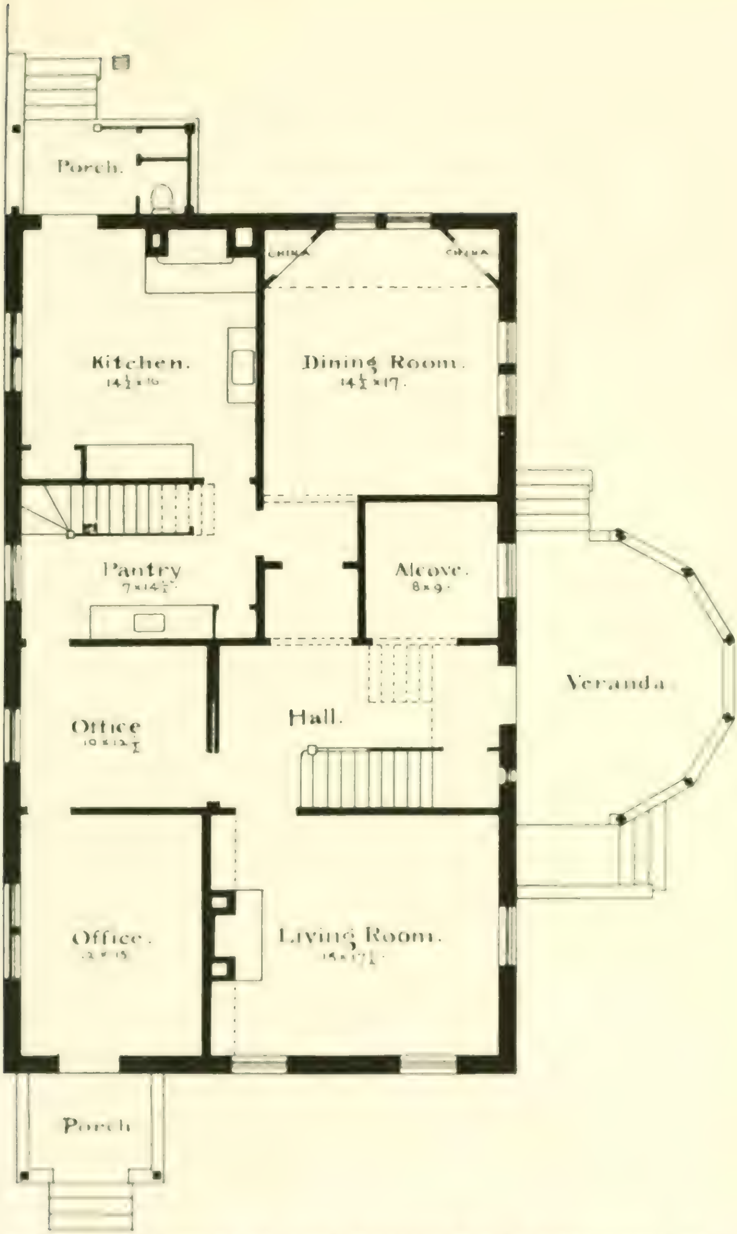
The governing principles underlying all such operations are the same as every sheet-metal worker uses in the laying out of the simple patterns in flaring ware. In other words, one who understands how to lay out the pattern for a frustum of a cone understands the principles of developing the blanks for curved mouldings. The principles will be described in detail in what follows.

Our first problem is that of obtaining a blank for a plain flare, shown in Fig. 340. First draw the center line A B, and construct the half-elevation of the mould, as C D E F. Extend D E until it inter-

RESIDENCE OF DR. FOLTZ, CHESTNUT HILL, PHILADELPHIA, PA.

George T. Pearson, Architect, Philadelphia, Pa.

Planned to Meet the Requirements of a Physician's Residence and Office. The Exterior Treatment, as Indicated by the Timber Framings, Truncation of Roof, etc., is in the Dutch Style, the Base being Stone, Then a Band of Flemish-Bond, Dark Header Brickwork, and, above that, Rough Brick Walls Stuccoed. Plan Shown on Opposite P



PLAN OF RESIDENCE OF DR. FOLTZ, CHESTNUT HILL, PHILADELPHIA, PA.

George T. Pearson, Architect, Philadelphia, Pa.

Interior Woodwork is Finished in Dutch Style [illegible] Hall and Dining Room, and [illegible] Wood in Living Room and [illegible] [illegible] Exterior View Shown on Opposite Page.

sects the center line A B at G. At right angles to A B from any point, as H, draw H 1 equal to C D, as shown. Using H as center and with H 1 as radius, describe the quarter-circle 1 7, which is a section on C D. Divide 1 7 into equal spaces, as shown. Now using G as center, with radii equal to G E and G D, describe the arcs D 7′ and E E°. From any point, as 1′, draw the radial line 1′ G, intersecting the inner arc at E*. Take a stretchout of the quarter-section; place it as shown

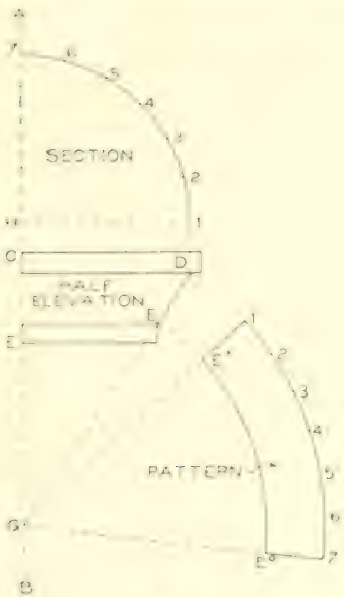


Fig. 340.

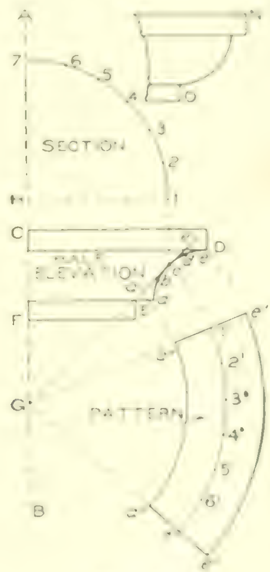


Fig. 341.

from 1′ to 7′, and draw a line from 7′ to G, intersecting the inner arc at E°. Then will E* 1′ 7′ E° be the quarter-pattern for the flare D E in elevation. If the pattern is required in two halves, join two pieces; if required in one piece, join four pieces.

In Fig. 341 is shown a curved mould whose profile contains a cove. To work this profile, the blank must be stretched with the stretching hammer. *We mention this here so that the student will pay attention to the rule for obtaining patterns for stretched moulds.* First draw the center line A B; also the half-elevation of the moulding, as C D E F. Divide the cove E D into an equal number of spaces, as shown from *a* to *e*. Through the center of the cove *c* draw a line parallel to *e a*, extending it until it meets the center line A B at G, which is the center point from which to strike the pattern. Take the stretchout of the cove *c e* and *c a*, and place it as shown by *c e′* and *c a′*. When stretching the flare *a′ e′*, *c* remains stationary, *e′* and *a′* being hammered towards *e* and *a* respectively. Therefore, from *c* erect a vertical line intersecting H 1, drawn at right angles to A B, at 1. Using H as center and H 1 as radius, describe the arc 1 7, which divide into equal spaces as shown. With G as center, and radii equal to G *a′*, G*c*, and G *e′*, describe the arcs *e″ e″*, 1′ 7′, and *a″ a″*. Draw a line from *e″* to G, intersecting the center and lower arcs at 1′ and *a″*. Starting from 1′, lay off the stretchout of the quarter-section as shown from 1′ to 7′. Through 7′ draw a line towards G, intersecting the inner arc at *a″*; and, extending the line upward, intersect the outer arc at *e″*. Then will *a″ e″ e″ a″* be the quarter-pattern for the cove E D in elevation.

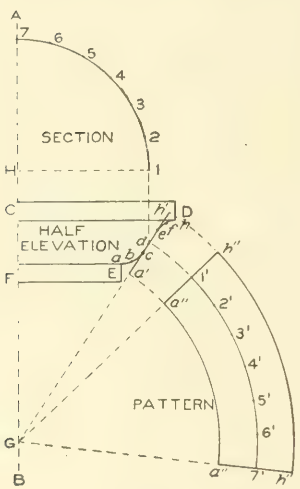


Fig. 342.

If the quarter-round N O were required in place of the cove E D, then, as this quarter-round would require to be raised, the rule given in the former Instruction Paper on Sheet Metal Work would be applied to all cases of raised mouldings.

In Fig. 342 is shown a curved mould whose profile is an ogee. In this case as in the preceding, draw the center line and half-elevation, and divide the ogee into a number of equal parts, as shown from *a* to *h*. Through the flaring portion of the ogee, as *c e*, draw a line, extending it upward and downward until it intersects the center line A B at G. Take the stretchouts from *a* to *c* and from *e* to *h* and place them respectively from *c* to *a′* and from *e* to *h′* on the line *h′* G. Then, in working the ogee, that portion of the flare from *c* to *e* remains stationary; the part from *e* to *h′* will be stretched to form *e h*; while that part shown from *c* to *a′* will be raised to form *c a*. From any point in the stationary flare, as *d*, erect a line meeting the line H 1, drawn at right angles to A B, at 1. Using H as center and H 1 as radius, describe the quarter-section, and divide same into equal spaces, as shown. With G as center and with radii equal to G a', G 1', and G h', describe the arcs a'' a'', 1' 7', and h'' h''. From h'' draw a line to G. Starting at 1', lay off the stretchout of the section as shown from 1' to 7'. Through 7' draw a line to G, as before described. Then will h'' a'' a'' h'' be the quarter-pattern for the ogee E D.

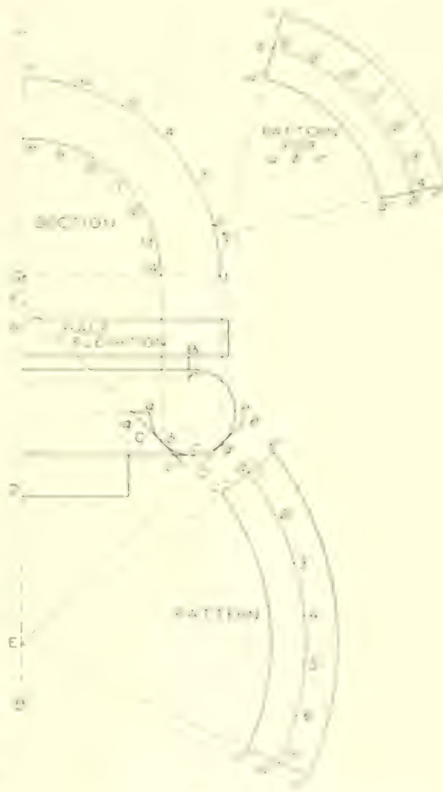


Fig. 343

In Fig. 343 is shown how the blanks are developed when a bead moulding is employed. As before, first draw the center line A^1 B^1 and the half-elevation A B C D. As the bead takes up $\frac{3}{4}$ of a circle, as shown by *a c e f*, and as the pattern for *f e* will be the same as for *e c*, then will the pattern for *c e* only be shown, which can also be used for *e f*. Bisect *a c* and *c e*, obtaining the points *b* and *d*, which represent the stationary points in the patterns. Take the stretchouts of *b* to *a* and *b* to *c*, and place them as shown from *b* to *a'* and from *b* to *c'*; also take the stretchouts of *d* to *c* and *d* to *e*, and place them from *d* to *c''* and from *d* to *e'* on lines drawn parallel respectively to *a c* and *c e* from points *b* and *d*. Extend the lines *e' c'* and *c' a'* until they intersect the center line A^1 B^1 at E and F respectively. From the points *b* and *d* erect lines intersecting the line G 1, drawn at right angles to A^1

B', at 14 and 1 respectively. Using G as center, and with radii equal to G 14 and G 1, describe quarter-sections, as shown. Divide both into equal parts, as shown from 1 to 7, and from 8 to 14. With E as center, and with radii equal to E *c'*, E *d*, and E *e'*, describe the arcs *c'' c''*, *d' d'*, and *e'' e''*. From any point on one end, as *e''*, draw a radial line to E, intersecting the inner arcs at *d'* and *c''*. Now take the stretchout of the section from 1 to 7, and, starting at *d'*, lay off the stretchout as shown from 1' to 7'. Through 7' draw a line towards E, intersecting the inner arc at *c''* and the outer one at *e''*. Then will *c'' e'' e'' c''* be the quarter-pattern for that part of the bead shown by *c e*, also for *e f*, in elevation. For the pattern for that part shown by *a c*, use F^1 as center; and with radii equal to F *a'*, F *b*, and F *c'*, describe the arcs *a'' a''*, *b' b'*, and *c'' c''*. From any point on the arc *b' b'*, as 8', lay off the stretchout of the quarter-section 8 14, as shown from 8' to 14'. Through these two points draw lines towards F^1, intersecting the inner arcs at *a'' a''*; and extend them until they intersect the outer arc at *c''* and *c''*. Then will *c'' a'' a'' c''* be the desired pattern.

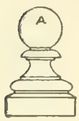


Fig. 344.

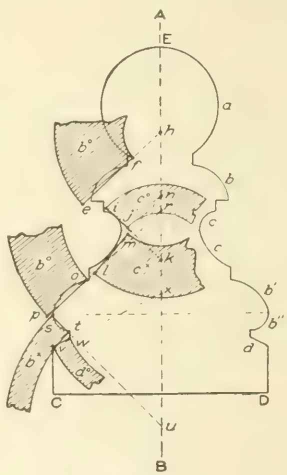


Fig. 345.

In Fig. 344 is shown an illustration of a round finial which contains moulds, the principles of which have already been described in the preceding problems. The ball A is made of either horizontal or vertical sections. In Fig. 345 is shown how the moulds in a finial of this kind are averaged. The method of obtaining the true length of each pattern piece will be omitted, as this was thoroughly covered in the preceding problems. First draw the center line A B, on either side of which draw the section of the finial, as shown by C D E. The blanks for the ball *a* will be obtained as explained in the Instruction Paper on Sheet Metal Work. The mould *b* is averaged as shown by the line *e f*, extending same until it intersects the center line at *h*, *e f* representing the stretchout of the mould obtained, as explained in the paper on Sheet Metal Work. Using k as center, with $k\ f$ and $k\ i$ as radii, describe the blank b^2.

In the next mould, $c\ c'$, a seam is located at some as shown by the dotted line. Then average C' by the line $i\ j$, extending same until it meets the center line at k; also average c'' by the line $l\ m$, extending this also until the center line is intersected at n. Then $i\ j$ and $l\ m$ represent respectively the stretchouts of the mould $c\ c'$, the blanks c° and c^3 being struck respectively from the centers k and n. The mould $b'\ b''$ also has a seam, as shown by the dotted line, the moulds being averaged by the lines $p\ o$ and $s\ t$, which, if extended, intersect the center line at r and u. These points are the centers, respectively, for striking the blanks b^2 and b^x. The flaring piece d is struck from the center x, with radii equal to $x\ w$ and $x\ v$, thus obtaining the blank d^x.

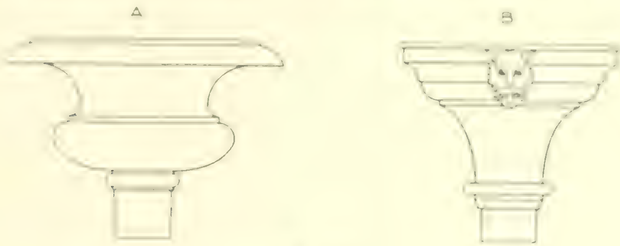


Fig. 346.

By referring to the various rules given in previous problems, the true length of the blanks can be obtained.

The principles used for blanks hammered by hand can be applied to almost any form that will arise, as, for example, in the case shown in Fig. 346, in which A and B represent circular leader heads; or in that shown in Fig. 347, in which A and B show two styles of balusters, a and b (in both) representing the square tops and bases. Another example is that of a round finial, as in Fig. 348, A showing the hood which slips over the apex of the roof. While these forms can be bought, yet in some cases where a special design is brought out by the architect, it is necessary that they be made by hand, especially when but one is required.

The last problem on handwork is shown in Fig. 349, that of obtaining the blanks for the bottom of a circular bay. The curved moulding A will be hammered by hand or by machine, as will be explained later on, while the bottom B is the problem before us. The plan, it will be seen, is the arc of a circle; and, to obtain the various blanks, proceed as shown in Fig. 350, in which A B C is the elevation of the bottom of the bay, I J K being a plan view on A C, showing the

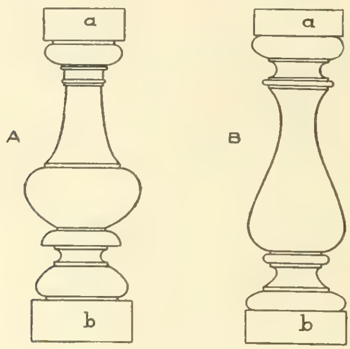


Fig. 347.

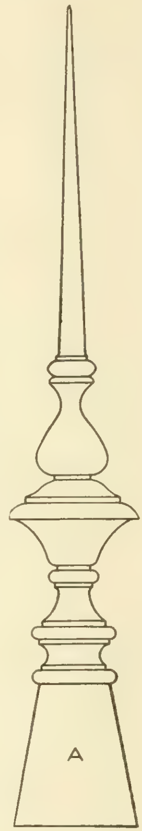


Fig. 348.

curve struck from the center H. In this case the front view of the bottom of the bay is given, and must have the shape indicated by A B C taken on the line I J in plan. It therefore becomes necessary to establish a true section on the center line S K in plan, from which to obtain the radii for the blanks or

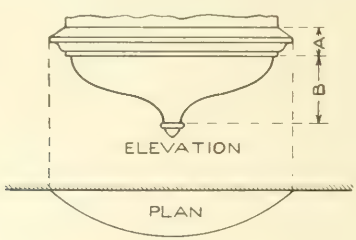


Fig. 349.

patterns. To obtain this true section, divide the curve A B into any number of equal parts, as shown from 1 to 6. From the points of division, at right angles to A C, drop lines as shown, intersecting the wall line I J at points 1′ to 6′. Then, using H as center, and radii equal to H 6′, H 5′, H 4′, H 3′, and H 2′, draw arcs crossing the center line D E shown from 1″ to 6″. At any convenient point opposite the front elevation draw any vertical line, as T U. Extend the lines from the spaces in the profile A B until they intersect the vertical line T U as shown. Now, measuring in every instance from the point S in plan, take the various distances to the num-

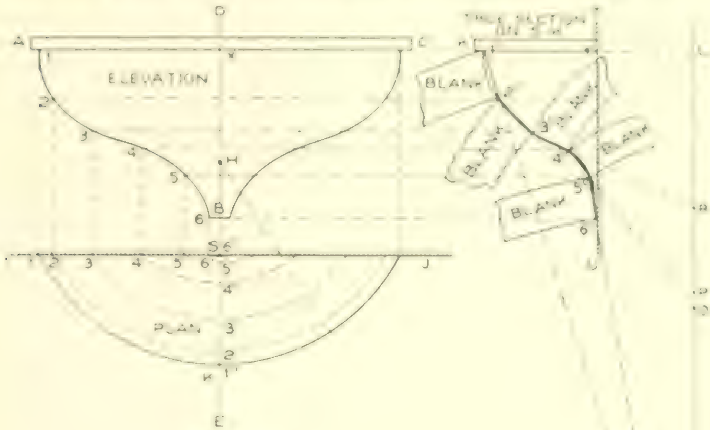


Fig. 350

bered points in plan and place them upon lines of similar numbers, measuring in every instance from the line T U in section. Thus take the distance S K in plan, and place it as shown from the line T U to K[1]; then again, take the distance from S to 2″ in plan, and place it as shown from the line T U to 2″ on line 2 in section. Proceed in this manner until all the points in the true section have been obtained. Trace a line as shown, when 1″ to 6″ to Y will be the true section on the line S K in plan.

It should be understood that the usual method for making the bottom of bays round in plan is to divide the profile of the moulding into such parts as can be best raised or stretched. Assuming that this has been done take the distance from 1″ in plan to the center point H, and place it as shown from 1″ to L in section. From the point L, draw a vertical line L M, as shown. For the pattern for the mould 1″ 2″, average a line through the extreme points, as shown, and extend the same until it meets L M at N. Then, with N as center, and with radii equal to N 2″ and N 1″, describe the blank shown. The length of this blank is obtained by measuring on the arc 1′ 1″ in plan, and placing this stretchout on the arc 1″ of the blank. The other blanks are obtained in precisely the same manner. Thus P is the center for the blank 2″ 3″; R, for the blank 3″ 4″; O, for the blank 4″ 5″; and M, for the blank 5″ 6″.

The moulds 1″ 2″, 2″ 3″, and 3″ 4″ will be raised; while the blanks 4″ 5″ and 5″ 6″ will be stretched.

APPROXIMATE BLANKS FOR CURVED MOULDINGS HAMMERED BY MACHINE

The principles employed in averaging the profile for a moulding to be rolled or hammered by machine do not differ to any material extent from those used in the case of mouldings hammered by hand.

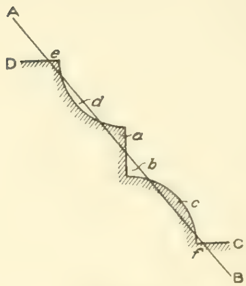


Fig. 351.

Fig. 351 shows the general method of averaging the profile of a moulding in determining the radius of the blank or pattern. It will be seen that A B is drawn in such a manner, so to speak, as to average the inequalities of the profile D C required to be made. Thus distances *a* and *b* are equal, as are the distances *c* and *d*, and *e* and *f*. It is very difficult to indicate definite rules to be observed in drawing a line of this kind, or, in other words, in averaging the profile. Nothing short of actual experience and intimate knowledge of the material in which the moulding is to be made, will enable the operator

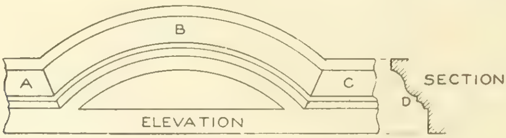


Fig. 352.

to decide correctly in all cases. There is, however, no danger of making very grave errors in this respect, because the capacity of the machines in use is such, that, were the pattern less advantageously planned in this particular than it should be, still, by passing it through the dies or rolls an extra time or two, it would be brought to the required shape.

In Fig. 352 is shown a part elevation of a circular moulding as it would occur in a segmental pediment, window cap, or other structure arising in sheet-metal cornice work. B shows the curved moulding, joining two horizontal pieces A and C, the true section of all the moulds being shown by D.

In this connection it may be proper to remark that in practice, no miters are cut on the circular blanks, the miter-cuts being placed on the horizontal pieces, and the circular moulding trimmed after it has been formed up.

In Fig. 353 is shown the method of obtaining the blanks for mouldings curved in elevation, no matter what their radius or profile

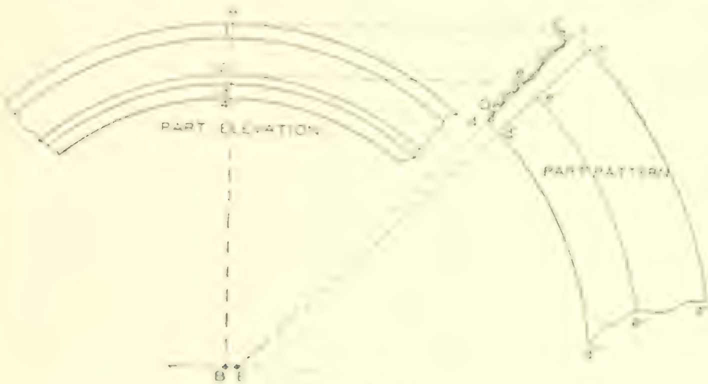


Fig. 353.

may be. First draw the center line A B, and, with the desired center, as B, describe the outer curve A. At right angles to A B, in its proper position, draw a section of the profile as shown by C D. From the various members in this section, project lines to the center line A B, as 1, 2, 3, and 4; and, using B as center, describe the various arcs and complete the elevation as shown by A B C in Fig. 352, only partly shown in Fig. 353. In the manner before described, average the profile C D by the line $c\ d$, extending it until it intersects the line drawn through the center B at right angles to A B, at E. Then E is the center from which to strike the pattern. Centrally on the section C D, establish e on the line $c\ d$, where it intersects the mould, and take the stretchout from e to C and from e to D, and place it as shown respectively from e to c and from e to d on the line $c\ d$. Now, using E as center, with radii equal to E d, E e, and E c, describe the arcs $d' d''$, $e' e''$, and $c' c''$. Draw a line from c' to E, intersecting the middle and inner arc at e' and d'. The arc $e' e''$ then becomes the measuring line to obtain the length of the pattern, the length being measured on the arc 2 in elevation, which corresponds to the point e in section.

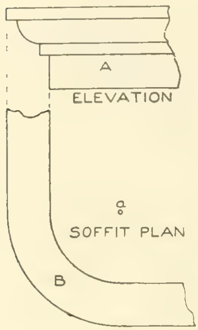


Fig. 354.

In Fig. 354 is shown the elevation of a moulding A curved in plan B, the arc being struck from the given point a. This is apt to occur when the moulding or cornice is placed on a building whose corner is round. To obtain the pattern when the moulding is curved in plan, proceed as shown in Fig. 355. Draw the section of the moulding, as A B, A C being the mould for which the pattern is desired. C B represents a straight strip which is attached to the mould after it is hammered or rolled to shape. In practice the elevation is not required. At pleasure, below the section, draw the horizontal line E D. From the extreme or outside edge of the mould, as b, drop a line intersecting the horizontal line E D at E. Knowing the radius of the arc on b in section, place it on the line E D, thus obtaining the point D. With D as center, describe the arc E F, intersecting a line drawn at right angle to E D from D. Average a line through the section, as G H, intersecting the line D F, drawn vertical from the center D, at J. Establish at pleasure the stationary point a, from which drop a line cutting E D at a'. Using D as center, and with D a' as radius, describe the arc a' a'', which is the measuring line when laying out the pattern. Now take the stretch-

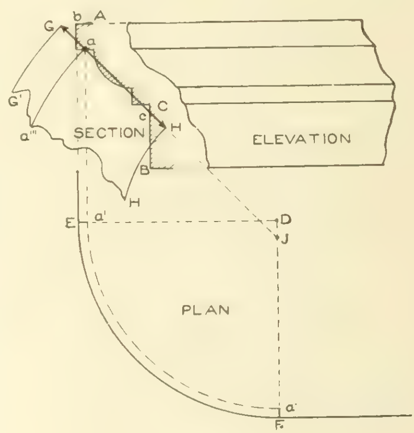


Fig. 355.

outs from a to b and from a to c, and place them on the stretchout line from a to G and from a to H respectively. Using J as center with radii extending to the various points G, a, and H, describe the arcs G G¹, $a\ a'''$, and H H¹. On the arc $a'\ a'''$, the pattern is measured to correspond to the arc $a'\ a''$ in plan.

In Fig. 356 is shown a front view of an ornamental bull's-eye window, showing the circular mould A B C D, which in this case we desire to lay out in one piece, so that, when hammered or rolled in the machine, it will have the desired diameter. The same principles can be applied to the upper mould E F, as were used in connection with Figs. 352 and 353.

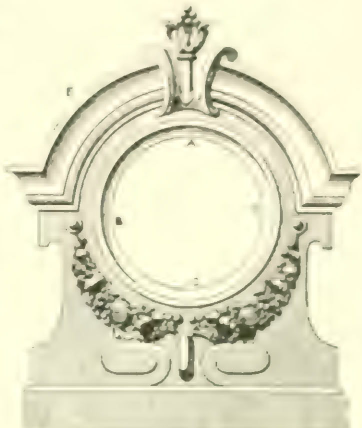


Fig. 356.

To obtain the blank for the bull's-eye window shown in Fig. 356 proceed as shown in Fig. 357. Let A B C D represent the elevation of the bull's-eye struck from the center E. Through E draw the horizontal and perpendicular lines shown. In its proper position draw a section of the window as shown by F G. Through the face of the mould, as H I, arrange the line H¹ I¹, extending it until it intersects

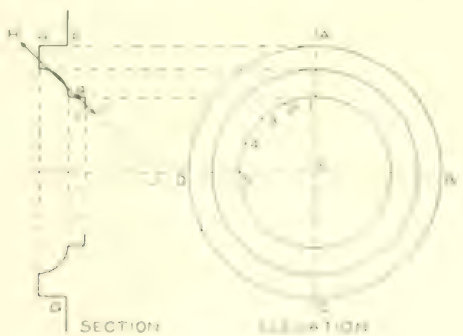


Fig. 357

the center line B D at J. Where the average line intersects the mould at a, establish this as a stationary point; and take the stretchouts from a to I and from a to H, and lay them off on the line H^1 I^1 from a to I^1 and a to H^1 respectively. As 1 5 in elevation represents the quarter-circle on the point a in section, divide this quarter-circle into equal spaces, as shown. Now, with radii equal to J I^1, J a, and J H^1, and with J in Fig. 358 as center, describe the arcs H H, a a, and I I. From any point, as H, on one side, draw a line to J, intersecting the middle and inner arcs at a and I. Take the stretchout of the quarter-circle from 1 to 5 in elevation in Fig. 357, and place it on the arc a a as shown from 1 to 5. Step this off four times, as shown by 5′, 5″, and 5‴. From J draw a line through 5‴, intersecting the inner and outer arcs at I and H. Then will H a a H be the full pattern.

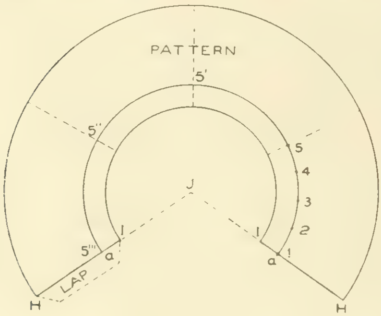


Fig. 358.

MARSHALL FIELD WHOLESALE STORE, CHICAGO, ILL.

H. H. Richardson and Shepley, Rutan & Coolidge, Architects. General Exterior.

GATE LODGE OF J. H. MOORE AT LAKE GENEVA, WIS.

Jarvis Hunt, Architect, Chicago, Ill.

Roofs Covered with Shingle Tiles, Dull Browns and Dull Greens, the Tile for the Gables being Specially Burned.

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PLASTERING

The subject of plastering in relation to modern dwellings is necessarily divided into two sections. The first treats of the plastering of walls on the *interior* of the house; the second will briefly describe some of the various ways of finishing in cement plaster the house *exterior*.

INTERIOR PLASTERING

The installation of interior plastering marks the division between the completion of the *rough work* on the residence, and the very beginning of the placing of the *finish* that is to follow.

The plastering cannot be started until the walls and ceilings have been lathed, and the ceilings must be furred before even the lathing can be begun. When the building is ready for lathing, all of the rough studding, framework, and partitions must be set in place; and the piping and wiring necessary in the plumbing, heating, lighting, etc., of the dwelling, must be installed and tested before the lathing or furring can be started.

The apparent break in the progress of building necessary to lath, plaster, and dry out a house, need not be altogether time lost for any of the various trades. Those unable to resume work until this intermediary process has been completed, can be securing their necessary materials and fixtures and arranging them ready for installation. The carpenter can be getting out his mill work and finish, be ready to put in his window-sash, set his standing finish in place around doors and windows, lay the upper floors, etc., and complete the remainder of his contract. The painter and paperer then commence their work; the electricians, plumbers, and heating contractors install their service fixtures, and the dwelling is soon ready for occupation.

The studs of a building are spaced sixteen inches apart on centers, so that each lath receives four nailings. Each end of the lath rests upon the center of a stud; and the two intermediate studs provide fastenings at spaces equally distant in its length. The ceilings are customarily furred to provide lath nailings, four—and in better work, five—nailings to the lath, with furrings seven-eighths of an inch thick and one and one-quarter inches or more wide, running crosswise of the floor joists. This furring is intended to level up the bottom of the joists, and distributes the unequal result of their skrinkage or uneven settlement from the weight above, thus preventing plaster cracks.

Before beginning lathing, the carpenter should see that each partition, at its intersection with another wall, is started with a stud nailed directly against the crossing studding. This makes it impossible for the lather to run the ends of his laths in behind or over the partitions—a careless practice that provides a very unstable internal plaster angle. The carpenter also sets plaster furrings, three-quarters of an inch thick, around all window and door openings and around the walls at the height of the top of his base skirting, so as to mark the points where the work of both plasterer and lather end, and to provide nailings for the finish woodwork. It is essential for the carpenter to place any necessary furring for cornices, door-caps, etc., before the lathing is begun; also any other furring blocks that may be required by the plumber to secure the setting of his fixtures or to support and carry his pipes.

LATHING

Wood Laths. Wood laths are put up in bundles of 100 laths; and are nailed upon the studdings of the wooden frame, with a space of one-quarter inch between them. This distance is sufficient to allow for lath shrinkage or swelling, and still provide a firm clinch for the plastering. If the space is much less than this, the plaster clinch will be weakened. If much more, the laths may possibly sag down on the ceilings with the extra weight of plaster. In no instance should these spaces between laths exceed a width of three-eighths of an inch.

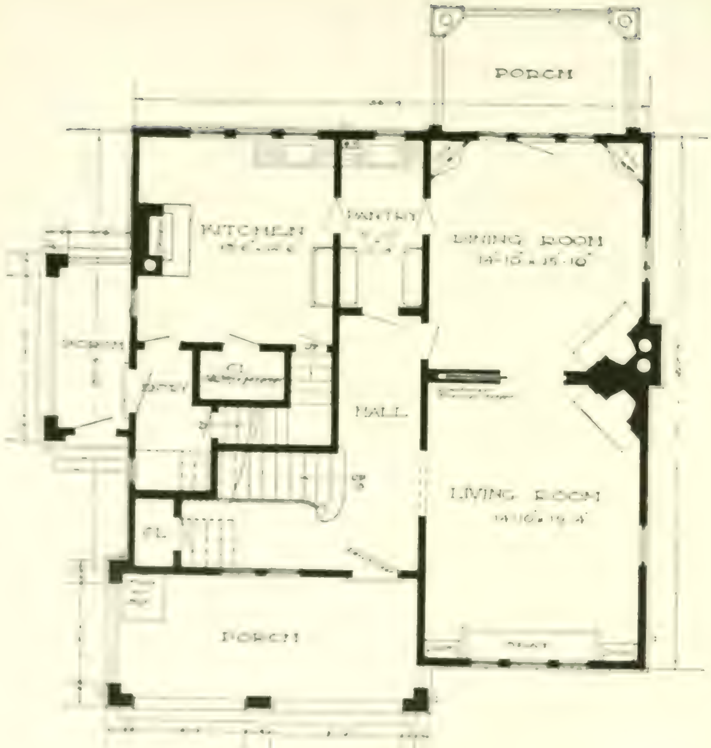
The *clinch*, or *key*, of the plaster is formed by the mortar being pressed through the spaces between the laths and then spreading out back of the laths upon both sides of the crack, so forming a tie, or clinch, that holds the mortar firmly and securely in place.

It occasionally becomes necessary to lath on very thin furrings to cover over a heating pipe, a brick or iron support, or some other such exceptional instance of construction. In that case a wider space

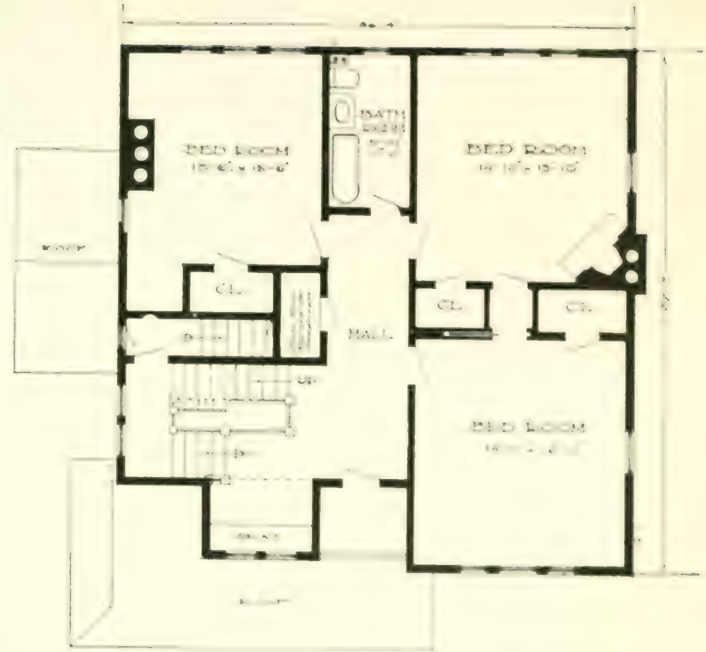
RESIDENCE OF C. D. DU BOIS, MONTCLAIR, NEW JERSEY

N. Le Brun & Sons, Architects, New York.

Walls of Stucco on Herringbone Expanded Steel Lath. For Plans, See Opposite Page.



FIRST FLOOR PLAN



SECOND FLOOR PLAN

RESIDENCE OF C. D. DU BOIS, MONTCLAIR, NEW JERSEY
N. Le Brun & Sons, Architects, New York

between the laths may strengthen the plaster clinch, or, better still, a strip of expanded metal may be used over or around such obstructions.

The best wooden laths are made of pine or spruce, and are only partially seasoned. They should be free from sap, bark, and dead knots. Both bark and knots are likely to loosen from the surrounding wood and so destroy the hold of the plaster; while the face of the plaster is occasionally stained from pitchy knotholes, bark, or sap. All laths are now machine-sawn. The old-fashioned split lath has not been in the market for now more than fifty years.

If the laths are too dry, the wet mortar is likely to cause them to warp and twist; and if it hardens or sets before the laths become saturated, their swelling is likely to produce parallel plaster cracks. Better results can be obtained by using wet laths, when both mortar and laths dry out together.

In specifying the nailing of wood laths, it is sometimes thought to ensure better work if two nailings are required at each end of the lath, either upon the ceiling alone or upon both wall and ceiling. It is more than doubtful if this requirement produces the desired result, as two nails in the lath end are likely to start a split, which may be increased by the pressure necessary in applying the mortar, until the entire end of the lath is partially or wholly loosened from its support before the plastering is all upon the wall. Large lath nails, instead of making the work more secure, weaken it in the same way. The common-sized inch-and-one-eighth long—"three-penny fine"—nails fasten the laths securely, even the ceiling nails rarely pulling out. About five pounds of nails will be necessary to each one thousand laths.

The joints of laths are ordinarily broken every eight courses. This means that not more than eight adjoining lath ends are nailed upon one stud or furring, the next eight laths, in both directions, being carried by, ending upon the next wall stud or ceiling furring to either right or left, thus alternating the break and obviating the possibility of an extended crack occurring at the line of lath jointure. Some lathers find a small handful of these laths more convenient to handle than a larger bundle, in which case it is simpler and easier for them to break joints every six laths which is equally good construction. Occasionally studding is placed twelve inches apart, and the lath joints broken for every other lath. Such precautions, however, are not necessary in the ordinary dwelling. They increase expense; and the closer spacing of the studs, especially, provides more undesirable weight to be carried by the house frame.

Wherever the wood studding of partitions comes up against the brickwork of chimneys or a terra-cotta or brick wall, strips of expanded metal or wire-mesh lath should be employed, extending seven or eight inches over upon either side of such a joint; and, if such a joint occurs in an internal angle, future cracking from a difference in settlement or shrinkage may be prevented by cutting through each plaster coat, when soft, with a sharp trowel.

Metal Lath. Of late years many varieties of metal lath have been placed upon the market. The use of such lath is generally required on boiler-room ceilings, and in other places exposed to strong artificial heat. Many varieties of metal lath—including all those made of wire—require supports at closer intervals than is provided by the studding, nine inches being generally considered the best distance. This necessitates either a closer spacing of studs than is otherwise necessary or desirable, or a series of furrings fastened to the wall studding.

There are some metal laths—generally those made on the expanded principle—that are sufficiently stiff, in one direction, to allow of a spacing of supports greater than nine inches; but, for ordinary wire cloth, no wider distance should ever be allowed, unless the cloth is itself artificially stiffened. All metal lath should be securely fastened by staples, and stretched before nailing, to increase its stiffness as much as possible.

In using metal lath, care should be taken to prevent plaster cracks along the line of jointure. The use of metal lath also requires three coats of plaster, in order to stiffen the lath sufficiently to resist the pressure required to finish the last coat.

Lathing and plastering are generally estimated, and the various materials are all figured, by the square yard. In small work, no openings are deducted unless they exceed sixty square feet in area. In figuring up plaster by quantity, when openings are allowed for, it is sometimes customary to add half of the contents when measuring closets; while small triangular wall pieces are figured as though square, in order to make up for the extra amount of labor required in plastering such restricted or odd-sized surfaces.

The use of expanded metal or wire lath is frequently demanded by the building laws of some cities, and is always required on a fire-proof or first-class building.

Several makes of *plaster board* are in the market and being extensively advertised. They come in eight inch wide boards or large sheets of 32 by 36 inches, and are nailed directly upon the wall framing. One coat of plaster—in three-coat work—may then be dispensed with. These boards save time, being rapidly set in place even by unskilled carpenters, and the plaster itself dries out much more rapidly. They are, however, frequently the cause of cracks that appear in the finished plaster where the edges of the boards come together—sometimes even after the wall has been papered.

PLASTER MATERIALS

Plaster is principally composed of *lime*, *sand*, *hair*, and *water*.

Lime is obtained in different sections of the country from calcined limestone, the carbonic acid and moisture contained in the stone being driven off by the burning process. The whole theory of plastering is based upon the reduction of limestone to lime, and its chemical recombination, when distributed upon the walls of a house, into something approaching its original state. The *slaking* of the lime provides the moisture necessary for the process of crystallization that produces the *set* of the mortar; while the sole purpose of applying it upon the wall in several coats is to present that much more surface to absorb the carbonic acid—of which it was originally deprived in burning—from the air. The thinner the coats and the larger their total exposed surface, the greater the absorption of this strengthening constituent. For this reason—and solely for this reason—is three-coat plaster work to be considered as better than two.

Properly burnt lime slakes easily and completely, when water is added, until it is converted into a fine dust, which, in its turn, is moistened and turned into a paste under action of the water, which bubbles and hisses with the heat generated by the process. This is what is called the *slaking* of lime. Very rich and pure lime—the best for plastering—increases to about twice its original bulk by being slaked, and is then almost pure white in color. Lime should always be as fresh as possible, and must be delivered in tightly sealed barrels. Care should also be taken to ascertain that it has been burned with wood and not with coal.

Sand is broken or rotten rock which has become decomposed spontaneously or by the action of running water. That made by running water, or from stones worn small by rolling over and over upon the beach, is composed of particles so nearly round in contour and so lacking in angularities of surface that they are not good material for mixing in any mortar where *strength* is a requisite or necessity. The particles of rotten rock decomposed by exposure are better adapted to make good sand for mixing with mortar, their shape being more irregular, with many sharp and angular corners. Sand obtained from ledge stones contains the essential elements of those stones, quartz, feldspar, and mica being present in granite formations, and lava, obsidian, etc., in volcanic sand. The sand coming from the softer stones is generally more thoroughly disintegrated, being frequently so rotten as to be entirely unsuitable for use in plastering. In most parts of the country the principal supply of sand now comes from the beds of ancient lakes or rivers, and is called *pit sand.* True sand, no matter how fine, may always be distinguished from dust by dropping it into a glass of water, as it will invariably sink to the bottom without leaving any appreciable dirt upon the surface.

For plastering purposes, sharply angular sand is not absolutely essential. Good river sand, the coarser the better, is obtained so easily, and is so clean and free from dirt, clay, and earth stains, that it is most generally employed for plaster.

The third necessary constituent is *hair.* The best hair upon the market is cattle hair obtained from the tanneries. The hair should be of good length; and, if too lumpy or clotted, it should be separated by soaking in water the day before mixing it with the mortar, as this method of separating the hair is less dusty and more healthful than beating or whipping it dry to obtain the same result.

Occasionally brick dust is added to the mortar for coloring, when it is likely that the mortar will set more rapidly—especially if the dust is mixed in shortly before using and is dry at the time of mixing. All brick dust should be sifted through a fine sieve. Besides brick dust, a variety of colorings for mortar are used—such as lampblack, ivory black, powdered charcoal, Spanish brown, raw umber, burnt umber, red aniline, Venetian red, Indian red, vermilion, ultramarine blue, indigo blue, chrome yellow, and, occasionally, pulverized clay. Mineral colors should be preferred to earth colorings. The latter weaken the plaster and fade rapidly. Variously colored sands—when they can be obtained—make the best and most durable materials possible for tinting the final plaster coat.

It is impossible to state arbitrary, set, hard-and-fast proportions for the mixing of plastering for either exterior or interior work. The different makes of lime and grades of sand, alone, vary sufficiently to make any such statements exceedingly inadvisable; while the purpose and conditions under which the plaster is to be used, frequently occasion considerable changes in its proportions.

"Working" the Lime. The first process in the making of plaster is the *slaking* of the lime. This consists, as already said, in simply reducing the hard, brittle lumps of its original form to a smooth paste by mixing it with water. It is of the utmost importance that the lime should be entirely and completely slaked, and the paste smoothly and evenly *worked*, before adding any of the other ingredients.

The lime is slaked in a *mortar-bed*, a box of boards about 4 feet wide and 7 feet long, and a foot to eighteen inches high, set in some convenient location with its bottom about level with the top of a second box placed at one end, and about two feet lower in grade. Both mortar and lime-slaking beds should have tight bottoms and strong sides, well braced to resist the pressure that will come upon them when they are full. A quantity of sand already screened should also be near at hand. Poorly screened sand later causes extra trouble and work. Gravel in the mortar delays workmen while plastering and floating, and much good plaster material will be lost in hurriedly throwing or picking out these gravel stones in the rush of applying the mortar on the wall.

The burnt lime is emptied into the upper box, and water is poured on while a workman breaks up the lumps and works the mass back and forth in various directions with a hoe. The thorough working of the material at this stage is necessary to ensure its complete slaking. The tendency of the careless workman is to hoe back and forth in the center of the bed without any regard as to whether he is stirring up the mortar that is down on the bottom boards, or whether the corners are drawn into the mixture and worked as evenly as the remainder of the box. If the paste is not thoroughly and evenly worked to an equal consistency throughout, if the water is not conducted to every particle of lime, or if the other ingredients are mixed in before the paste is evenly prepared, the lime will be apt to *blister* and slake out unevenly, causing trouble after it is upon the wall. If the corners, for instance, are imperfectly mixed, lumps of clear lime will afterward appear. Many of these lumps will pass unnoticed under the hoe of the workman tempering the mortar, and will not be found until they are flattened out under the wall trowel of the plasterer.

If too much water is used in slaking the lime—especially if a too great amount is added at once—the pile is *chilled* and forms into lumps that slake too tardily. If too little water is added, the lime is left so dry (*burns*, as the plasterers call it) that many small particles entirely fail to slake through lack of sufficient moisture. When too much water *drowns* the lime in the first place, it becomes so thoroughly chilled that a considerable portion of its strength is lost; and the process of slaking is, by the very excess of water, much retarded. The process is also slowed up if very cold water is added, although the water soon becomes heated from the reaction of the lime. At the start, just enough water should be put on to initiate the slaking process. After this, as the slaking proceeds, more water should be added as needed, taking care to keep the lime thoroughly moist at all times. A very active and quick slaking lime should be covered with water from the very beginning, to guard against the possibility of burning. If the lime once *burns*, it will afterward be impossible, by any amount of working, to get out all the fine lumps that are then caused. Rich lime will afterwards work cool, is little likely to crack, and bears troweling when being finished, without the surface peeling off, blistering, or staining.

If lumps of unslaked lime escape through the screen when the lime is run off, and get mixed into the mortar, it becomes very difficult to eradicate them afterward. It is not possible for the plasterer to get these lumps out of the mortar when working it on the wall; and the results of their afterwards slaking out will continue to appear long after the house is finished. If they occur in the first coat, at various times after the work is completed—frequently extending throughout the entire first year—these lime lumps will suddenly *blow* or expand, forcing out the surface plastering outside them and making a large blister or lump, generally about an inch in diameter, which, if upon the ceiling, almost invariably falls off. If this unslaked lime gets into the final coat, much the same result occurs, although the particles are of necessity smaller in size. Instead of being large, the resulting holes are then comparatively small, running generally about the size of the head of a pin, and the entire surface of the plastering is frequently pitted, the particles thrown off appearing about the room in the shape of a white dust.

In the brown rough-coat, the spots of white, unslaked lime are quite easy to see, as they are often the size of a bean or pea. However, in the final white coat, these spots, being smaller and of the same color as the rest of the mortar, do not show.

After it has once begun to warm up, the lime should be worked or stirred thoroughly during the process of slaking, so that, after the action has been completed, it will be of the consistency of a pasty cream. After slaking, the lime should be run off through a fine sieve (No. 5 screen) put at the end of the slaking box, into the next lower compartment, or mortar-bed. The screen is intended to keep out any lime lumps too large to slake before the mortar is used, or any fibrous settlement that may be found in the lime, and to allow only a pure and thoroughly mixed hydrate to be admitted to the bed.

When drawing or running off the lime, a large supply of sand already screened should be at hand to scatter in the bottom of the mortar-bed and to use for stopping leaks that may appear as the box gradually fills. This screened sand should be sufficient in amount to complete the mortar mixture. An ample supply of water, either in barrels or in hose piped from a hydrant, should also be ready at hand—to avoid any possibility of the lime burning.

For the *putty* or *finish coat*, the paste should be made even thinner before running off, and may be of the consistency of milk. The sieve through which it is strained should also be finer, of about the mesh of an ordinary flour or meal screen. The paste for this coat is often obtained by running off the lime a second time, as by this means a cooler working putty is secured.

The length of time that mortar for plastering should be mixed before being used, is a much-discussed question. It is generally stated in architectural specifications, that "the mortar should be mixed ten days or two weeks before using." As a matter of fact, this requirement is not always either wise or desirable. It is true that, in old English work, lime mortar was left covered over with earth to stand for long periods of time, often six months to three years elapsing before it was used. In this country, such slow-going methods are not to be expected. While lime does gain in strength by standing in this thin putty state before sand or other materials have been mixed with it, yet three or four weeks, at the least, are necessary before the increase becomes very apparent. It is also necessary that the paste should remain moist, by being kept covered all the time. At the end of the fourth month its strength will have increased about one-fifth, and most of this gain has been made during that month. From then on the gain continues, but gradually decreases in amount.

It is more economical for the plasterer to use a lime that has been slaked for some weeks, as, when tempered down, it will work freely with the admixture of a much larger proportion of sand than is taken up by lime mixed as soon as it can be readily worked. This extra amount of sand does not add to the strength of the mortar; but, as it causes the lime to cover a greater surface, it is a considerable economy for the contractor, made, however, at the expense of the quality of his work.

Lime mortar need be left standing only long enough for all its particles to be thoroughly slaked, and, if properly mixed and wet down in the first case, a great deal of time need not be required to effect that result. This once secured, the quicker the mortar is mixed and put upon the building, the better and stronger will be the plastering that is obtained. It is further claimed that the accompanying loss of limewater is also very harmful, as this water—from the properties which it has already absorbed from the lime—is much better suited for carrying on the process of mixing than newly added clean water. Yet, if the lime has been long standing, it may be necessary to add clean water to replace the water lost by evaporation or seepage, although mortar mixed with clean water never becomes so hard as that mixed with the water obtained in slaking the lime.

The sand and hair are next added, the hair being put in before the mortar becomes too stiff to work readily. After the sand is mixed, the mortar should not be left to stand for any length of time, as it would become considerably *set* and a loss of strength would result. If the mortar does become set in the bed, reworking would be necessary before it could be put upon the walls. The strength then lost bears a direct relation to the length of time it has stood, and the solidity it has attained, before this final working up.

In plastering mortar where hair is required, a still further loss of strength would result, as the hair would be so rotted or eaten by its long exposure to the action of the wet lime as to be almost or quite worthless. The hair cannot well be mixed evenly, except at the time when the mortar is first run off, while it is in a very thin paste. If, after a lime-and-sand mixture had been standing for some months, it were attempted to bring it to a sufficiently fluid state to receive the hair properly, by wetting it down a second time, a considerable proportion—varying from a quarter up to almost a half—of its strength would be sacrificed.

Bearing these facts in mind—once certain that the lime is slaked—it would appear better that not more than a week should elapse before the use of this mortar; and a less time than that is, under many circumstances, undoubtedly desirable. It is evident that no more lime-and-sand mortar should be mixed at one time than can be used within a few days at the most. The length of time that mortar should be allowed to stand, is determined more or less by the dryness or moisture of the atmosphere. The dryer the atmosphere, the shorter the time, as the setting of the mortar is, in part, a chemical result of the drying out, or evaporation, of the *water of crystallization*, as it is called.

It has already been said that limes made in different parts of the country vary extensively in their chemical composition and properties. A knowledge of the chemical composition of lime mortars and the individual peculiarities of the lime locally used, is necessary before applying or attempting to utilize the principles here set forth. In the eastern part of the United States, the limes frequently contain from a third to a half of carbonate of magnesia; and the mortar in which such limes are employed sets very readily.

To sum up, the lime should be slaked as evenly and thoroughly as possible. It should be run off from the slaking bed through a fine sieve into the mortar-bed. It should lie there no longer than is absolutely necessary; and if it could be possible to add the hair and sand while the original mixture is sufficiently moist to take up and work the entire amount of the latter material to be added, the resulting mixture would undoubtedly be that much the stronger and more durable.

Mixing the Mortar. The amount of sand to be mixed in with the lime paste is a variable quantity, depending upon the sand itself.

upon the quality and thickness of the lime paste, and also upon the nature of the work for which the mortar is intended. With exceptionally rich limes, sand to the amount of about two times the bulk of the lime—measuring the slaked lime in the form of a rather firm paste—may be added. As will be seen, this is a most uncertain proportion, for a great deal depends upon the firmness of the lime paste alone. Allowing for variation in size of the lumps of lime and their closer or looser packing together, it may perhaps be better to say that the sand should bear a relation to the lime, before it is slaked, of from three to four and one-half times its bulk.

The richer the lime and the finer the particles of sand, the more of the latter should be employed, although the finer sand does not make as hard or as good mortar as the coarser variety. If both are clean and sharp, the finer and coarser varieties of sand may be mixed together with good results. Most laborers are apt to stop adding sand, merely because the mortar mixture becomes hard to work when the paste becomes too thick. This is poor policy, inasmuch as the mixture becomes much harder to work when the tempering is partly completed, a day or two later.

The fineness of the sand is an important factor. A rather coarse as well as sharp sand is considered best, as the amount and capacity of the voids left in such a mixture would be of such size as, without any doubt, would provide space to contain lime sufficient to cement this granular mass very firmly together. The close pressure and contact of the sand particles would also lessen the possibility of settlement or shrinkage, with accompanying *map-cracks*. The hair may be mixed in either before the adding of the sand or when but a very small proportion of the latter has been worked into the lime mixture. The hair is generally mixed with the mortar by means of an iron rake. It should be thoroughly mixed, and enough should be used to make it impossible to find any small sections of the mortar in which the hair cannot be seen. This will require from one and one-half to two bushels of hair to a cask of lime.

If the mortar is to be used as a first coat on stone, brick, or similar surfaces, it will carry more sand, and hair is not considered so essential, a half-bushel to the barrel of lime being generally ample. If too little sand is used, the plaster is liable to dry too quickly when setting, and, after it is dry, will crumble very easily, showing up too white, or ashy gray, in appearance. If too much sand has been used, the plastering is liable to fall off, and will crumble when rubbed between the fingers.

Mortar for a second coat on lath may be of about the same consistency of mixture. For the final coat (the *putty coat* or *hard finish*) but very little sand is used. The harder the finish, the less the amount of sand. For this coat, the sand is mixed at the time when the putty is run off. For hard finish, when marble dust, brick dust, or anything of that sort is added, it is generally mixed together on the mortar-board immediately before applying. Stucco, or plaster of Paris, is never mixed with putty until immediately before using, on account of its rapid setting, which occurs in a few moments after mixing. When once set before being applied, it becomes useless. No more water than is necessary should be added, either in the mixing of the mortar at first or in its subsequent tempering, as over-much wetting of the lime deprives it of a considerable proportion of its strength, and also retards the setting process by giving that much more moisture that is necessary to be disposed of by evaporation or crystallization.

A bushel of lime is standardized to weigh 80 pounds; 200 pounds is allowed to the barrel; a bushel contains about one and one-quarter cubic feet. A barrel of sand is supposed to contain 3 cubic feet of sand, and a bushel of sand weighs about 120 pounds, and wet mortar 130 or 132 pounds. When hard, mortar is figured to weigh about 110 pounds to the cubic foot.

To summarize—one barrel of lime, 200 pounds, will take about a cubic yard of sand. In most localities a load of sand is supposed to contain twenty-seven cubic feet, or a cubic yard; but it is frequently less than this, extending down to two-thirds of the amount. To the barrel of lime should also be used about two barrels of water and—as we have seen—upwards of two bushels of hair for a first coat. Hair comes in paper bags weighing generally something under eight pounds and containing enough hair to beat up into a measured bushel. This amount of material, when the lime has been slaked and the whole mixed together, will amount to 35 or 40 pails, about 3 barrels of mortar; and the amount should cover about 40 square yards of lathed area, requiring about 600 laths to surface.

The final skim coat is mixed roughly to the following proportions: A cask of lime to a half-tub of water, which should take up about a barrel of the hard, clean sand used in the surface coat. Generally the plasterer uses a larger barrel or hogshead for water, than the cask in which the lime is delivered. Also, in some localities, the lime will run somewhat more than 200 pounds to the barrel, Maine lime from Rockland being supposed to average 220 pounds. Rockland lime is considered in the East good lime for scratch and brown coats, but many masons prefer Jacob's lime for the finish coat.

It should be remembered that the bulk of the completed mortar mixture does not equal the total combined bulk of its various ingredients, but is less than the aggregate bulk by about one-quarter.

PLASTERING

Interior plastering is now applied either in two or in three coatings. Three coats are always necessary on metal or wire lath, the first coat being required to stiffen the body of the material sufficiently to allow thorough working of the remaining coats. Even upon wood laths, three coats make a better job of plastering than two. Extra strength and body are obtained by the addition of the extra coat, provided time be allowed to dry out each of the coats thoroughly before the next coating is added. It has now, nevertheless, become the general custom to employ but two coats on the less expensive grades of residence work.

The plaster mortar is applied to the walls with a hand trowel of steel, about four and one-half inches wide by twelve inches long, having a wooden handle that is parallel with the back of the blade. After the mortar is put on and roughly smoothed out with the steel trowel, the *darby*, a long wooden trowel, about four inches wide and three feet in length, is taken by the workman and used—with a scouring motion—to level the plaster surface and work it to an even thickness and uniform density. The flat part of the darby is generally of hard pine, a half-inch or slightly more in thickness.

Three-Coat Work. The best interior plaster work always used to be put on in three coats, and was worked to a final thickness of about seven-eighths of an inch. Of the three coatings, the first is the thickest, so that, when dry, it may be strong enough to resist the pressure of working the coat or coats to follow. A large part of the advantage of three-coat plastering is obtained by thoroughly drying each coat out before applying another, thus securing the added density and strength made possible by forcing the subsequent coating firmly and strongly against the surface upon which it is being placed. Rubbing or troweling up the rough mortar before it finally dries and sets, also makes it much more compact than is possible from working it at the time when it is first applied.

The first coat, called the *scratch coat*, contains the greatest proportion of hair, that being useful in strengthening the key or clinch of the plaster behind the edges of the wooden laths, through the crevices between which it has been forced. Before this coat thoroughly dries, the surface is *scratched* (hence its name) with a tool designed for that purpose. The surface of the second coat also is sometimes scratched with nails set into a wooden float or darby like that used to rub over the surface, before adding the finish coat. When one coat is entirely dried out before another is applied, this scratching is always necessary, the scratches forming a clinch or tie permitting the subsequent coat to unite the more firmly to the preceding.

The second coat generally contains a larger proportion of sand and much less hair than is necessary in the first coat. The surface of this second coat—or *brown coat*, as it is called—must be brought up true and even, especially at all angles, and be plumb upon the walls. Before the finishing coat is applied, lumps must be removed and all other imperfections corrected, and the mortar must become sufficiently set to allow the entire surface to be rubbed up with a float or darby and so made compact and firm.

To save time, the plasterer adopted the custom of putting his second coat on over the first while the latter was still green. The combined mass (practically one thick coat) was then darbied and treated the same as in two-coat work, over which about the only advantage of this method was in providing a rougher sand surface on the second coat than was possible when more hair (always necessary in first coat) was included. Otherwise, substantially the same results as are secured by thus working two coats together are obtained in the first coat of ordinary two-coat work, at a saving of both labor and time. While this method does not furnish so good or so permanent a job of plastering, it is modernly considered as meeting the requirements of three-coat work, when so specified.

The saving in this sort of three-coat plastering is made chiefly by the plasterer, in the expense of doing his work. The owner pays more money than a two-coat job would cost him, and actually receives substantially the same grade of work. The second coat, too, dries more slowly when applied before the first coat is dry and hard, and there is therefore not so much saving in time as is generally believed. If three-coat work is attempted at all, it should be insisted that the first coat be thoroughly dry before the second is added.

The final coat is generally composed of lime putty, with a small proportion of white, clean sand, gauged with plaster of Paris. This gives the whitest finished surface. If a color is considered desirable, a colored sand may be used. All lath cracks or settlement cracks occurring in the previous coats should be cut out and patched before the last coat is applied. The final coat is about one-eighth of an inch thick, and the surface is burnished with the steel trowel to an even and straight surface, and worked sufficiently to free it from chip cracks or other surface defects. The lime for the white finish mortar should be run through a sieve of not less than ten meshes to the inch.

From thus combining the first two coats when green, the next step naturally, in the development of methods of work, was to apply but one coat, making it of increased thickness, and scratching it ready to receive the finish skim or white coat, except when it was desirable to finish the plaster with a rough surface, or to *sand-scour* it, as the last process is sometimes called.

Rough Plaster Finish. If the mortar is to be finished with a sand or rough finish, two coats are applied.

The second coat—which should be put on only after the first is thoroughly dry—is substantially the same as the brown coat described above, the rough finish being secured by working the surface of the second coat, before it dries, with a soft-faced float and a mixture of sand with some lime added. Sometimes the surface of the float is of carpet or felt, sometimes of cork or other soft wood. Only so large a surface as may be readily covered at one time, can be floated, darbied, etc., before it has time to set. In this case no hair whatsoever is put in the second coat, as the hair destroys the evenness of the surface that is obtained by the scouring action of the particles of sand rolling around between the surface of the float and the face of the plaster. A long float is generally used for scouring, and the surface is worked to an even and true face, care being taken not to leave any marks from the instrument itself.

While it is generally the custom to add rough plaster finish on the second coat, in inexpensive work, especially for summer residences, a very artistic effect can be obtained by rough-working the surface of the first coat. If one-coat finish is employed, hair must be used, and the consistency of the coat must remain much the same, whether it is surface-finished or not. In that case, however, it is not possible to work the surface as true and as even as the surface of a second coat.

Two-Coat Work. Most plaster work now consists of only two coats.

The brown mortar employed for the first coat should be made of fresh lime used as soon as it is stiff enough to be worked, with strong, well-distributed cattle hair and coarse, clean sand. The first coat of mortar must always be put on with sufficient pressure to force the plaster through between the laths, and so ensure a good clinch. The face of this coat must be made as true and even as possible on surfaces and angles, and plumb on the walls. After the first coat is sufficiently set, it may be worked again with a float consisting of a piece of hard pine about the size of the trowel. Sometimes the face of this float is covered with felt or other material to produce a rough textural treatment on the plaster surface. The first coat should run a strong five-eighths inch in thickness, and should be thoroughly dried out.

It is generally inadvisable to attempt to trowel a two-coat job very smoothly. If the attempt is made to float the first coat when it is too thin or insufficiently set, the instrument is likely to leave marks on the wall, and the plastering is itself likely to crack. It is better to err on the side of caution, as, if the plaster has become slightly too dry, it may easily be dampened by sprinkling water upon it with the plasterer's broad calcimine brush and following it immediately with the float. The use of water in this way has accompanying advantages in that it tends to harden the plastering and to prevent the hairs gathering along the edge of the float, when otherwise they would have to be shaken off every few moments to prevent their rolling under the instrument and being pressed into the surface of the plaster in tufts and rolls, in such a way as to show through even the finish coat.

Care should be taken to see that each coat invariably is absolutely dry and hard before the addition of another coat is attempted. Otherwise the later coat will fall off, in greater or less part, and it will be quite impossible ever to obtain a good surface finish; while if it should happen that the first coat is only partially dry when the second is applied, it will be seriously injured by the pressure brought upon it when floating. Its clinch to the lath is thus often partially or wholly broken, sometimes the plaster falling entirely off, leaving the laths exposed.

The finish second coat in two-coat work is the same as the final skim coat in three-coat work.

The Finish Coat. The *finish*, *skim*, or *white coat* should never be applied until the earlier coat or coats are thoroughly dry and hard, as it is liable to crack if put on before—quite aside from the possible danger of injuring the first-coat work by the pressure of troweling before it is entirely dry and set. A simple putty coat should carry more sand than when the finish is hardened by the addition of plaster. If plaster is used, the mortar should always be *gauged* (that is, plaster should be mixed with the putty) *after* it is placed on the mortar-board. The usual process of gauging consists in making a hollow with the trowel in the midst of the pile of lime putty lying upon the mortar-board. This hollow is filled with water, and the plaster sprinkled upon it, the whole then being mixed rapidly with the trowel and put upon the wall immediately, before the plaster has time to set. The proportion of lime and plaster, while variable, averages probably one-fourth to one-fifth plaster.

The finish is skimmed in a very thin coating that is generally less than one-eighth of an inch in thickness. It is immediately troweled several times, dampened with a wet brush, and thoroughly troweled to smooth up the surface and prevent it from chipping or cracking. The water prevents the steel trowel staining the surface, but the plaster should not be too wet, as it will then blister or peel. The whole surface of the finish coat, whether of putty or hard finish, should finally be brushed over once or twice with a wet brush; while, if a polished (or buffed) surface is required, it may be gained by brushing —without dipping the brush into the water—until a glossy surface is obtained.

Especial care should be taken, in the final coat, to finish all joints smoothly and evenly so that the point of jointure will not be apparent. The ceilings are completed first; then the upper part of the wall; and lastly the bottom portions which can be reached from the floor and thus more carefully finished up to the joint.

HOUSE AT PARKERSBURG, W. VA.

R. C. Spencer, Jr., Architect, Chicago, Ill.

Red Brick to Water Table. Rough-Cast Plaster on Metal Lath on Stud Frame above Water Table. Woodwork is Undressed. Stained Shingle Roofs.

SHAKESPEARE'S HOUSE AT STRATFORD-ON-AVON

Here Shakespeare was Born, April 23, 1564. Building Restored in 1857.

The plasterer generally scaffolds the room with boards at a sufficient height to enable him easily to reach the ceiling overhead without raising his arms too high to work each of the coats evenly. The plaster is applied on the upper part of the walls from the same scaffolding, and the remainder of the work is completed from the floor. If too much time elapses in joining the coats at this point, the joint is likely to show—which is, of course, not serious unless the walls are to be left untreated. Occasionally two men working along together, one on the scaffolding and one on the floor, finish the walls at the same time.

If the old-fashioned wooden angle-beads are used, the plaster should be neatly cut out from each side, forming a small V-sunk angle that prevents the thin edge running up against the corner-bead from breaking off. As a matter of fact, the use of a metal corner-bead makes a far truer, sharper, and straighter angle, and one that does not afterward tear or break the papering when it is put upon the wall. Angles in the plaster are generally finished with a wooden paddle.

As the hair is used principally to insure a clinch back of the lath, if plaster is applied on a stone or brick wall, a scratch coat is seldom necessary; and the coat of brown mortar is very often used without hair and of about the composition of brick mason's mortar. If a scratch coat is used under these conditions, it is generally mixed with more sand and less hair than when put upon laths.

For a finish where plaster mouldings are to be used, or when for any purpose an unusually straight, level, and plumb surface of plaster is required, three-coat work, put on in the old-fashioned manner, should be demanded. This is necessary in order to get a surface sufficiently level and true to run plaster mouldings evenly, and to avoid the inequalities that are almost certain to occur in all two-coat plastering.

The second and third coats allow opportunities to obtain a straight and level plaster surface. Individual spots are brought up to an even surface, the plaster then being added and carefully worked between and amongst them, bringing it all to the same face by means of the straight edge. Occasionally it happens that the rough coat is so uneven that some filling in is absolutely necessary to make the wall sufficiently even to receive the last coat. In that case, a mixture of half plaster and half putty may be used in leveling up the rough work.

If no finish coat is to be put on, the surface should be troweled smoothly as the mortar is applied, care being taken to leave no marks, hollows, or uneven places; but if the wall is to be finished or frescoed, it should be left with a floated surface.

Patent Plasters. Patent plasters, such as adamant, etc., are not often employed for private dwellings, being chiefly suitable for mercantile purposes. The patent plaster has certain advantages that are self-evident—such as quick drying and hardening. Its surface hardens more quickly and resists abrasure longer than the ordinary lime plastering However, a break once occurring, the extreme stiffness of the mixture makes it liable to extend further and to be of a more serious nature than if the softer, more flexible lime plaster covering had been injured in the same manner.

The extra stiffness of most patent plasters is caused by the cement that generally forms an important part of their composition. These plasters are sold ready for use, requiring merely the addition of a sufficient amount of water. They are therefore especially adapted for use by the inexperienced, and are valuable for executing small pieces of work, as they do not present the liabilities to failure, or loss of time and delay, occasioned by mixing up batches of lime mortar.

Back Plastering. Occasionally a wood-framed house is *back-plastered* for warmth. This process consists in nailing a strip of seven-eighths inch furring against the inside of the boarding on each side of the studs. The space between the studding is then lathed (of necessity a slow and bothersome job) and plastered one rough coat of hair mortar, which should be allowed to dry before any lathing is placed over it on the inside face of the studding. As a matter of practice, the efficiency of back plaster is much injured by the fact that the studding, in seasoning after the plaster is set, is likely to shrink away from the plaster, leaving a narrow perpendicular crack on each side of the stud, which permits of the passage of cold air.

Plaster Cracks. Cracks in plaster occur from several causes. If the distance between the ends of the laths, where they join on the studding or furring, is too great, the larger amount of plaster in that place, when drying out, may cause a short crack. Any such spaces should, however, be filled by the lather before plastering is begun. Sometimes, too, especially in the first coats, cracks are caused by the shrinkage or expansion of the wooden laths after the mortar has wholly or partially set. The result is a series of narrow cracks parallel to each other and the width of the laths apart. *Lath cracks* are ordinarily filled in and covered up by later coats, and so do not often appear in the finished plastering. They may, too, be worked out when floating up the coat before it finally sets. If wide or deep, however, they should be cut out to a width of an inch or so, and filled in with new mortar before adding the last coat.

Cracks of a like appearance are sometimes caused by the rough mortar being too rich, or by draughts of air from open doors or windows drying out portions of the plastering too quickly. The too rapid drying of plaster with stoves or salamanders, often produces a like result from similar causes. An experienced plasterer should be able to determine the responsible cause and take measures accordingly, using more sand if the mortar is too rich, screening openings to prevent draughts, and using less fire in his drying stoves. In green work, damage already done may be repaired by refloating again before the work becomes too dry, softening the mortar with water if necessary.

Cracks sometimes occur in the angles at the ceiling or corners of the room. When in this location, they may be caused by the shrinkage or settlement of the partition or floor. In the perpendicular angles, especially, they may extend only to the depth of the finishing coat. In that case, the causes are likely to be either too thick plaster, insufficient troweling, or an insufficient amount of plaster in the gauged coat—causes which are easily remedied in the remainder of the work.

Cracks running diagonally across a partition, or radiating from the corners of doors and window openings, are caused by the unequal settlement or shrinkage of the building. They frequently occur at a perpendicular angle where a wood partition is brought up against a brick wall, or at the ceiling line where a wooden floor comes up against a brick supporting wall.

Cracks occur in the final finish when the putty is not gauged enough, or not troweled or brushed enough, when it is put on too thick, and when too little sand has been used. These cracks are called *chipped cracks.* Plaster, when apparently perfect and without cracks, will sometimes crumble, either from too rapid drying or from the use of too much sand. Either too much or too little sand materially injures the strength of mortar.

If unclean sand, dirt, or clay has become mixed with the mortar, it not only weakens the lime but prevents its adhesion to the sand particles, so that no real set of the mortar ever occurs. Of course, at all times, poor materials—sand, lime, or hair—may be responsible for defects in plastering. Plaster occasionally falls off even when apparently hard and good, if the laths are too near together, if there is insufficient hair, if the mortar is too rich or too sandy, or if it had not been pressed against the laths with sufficient force when being applied; or it may become loosened by the springing of the laths under the pressure of floating it too hard. On brickwork the mortar requires considerable more sand than for application on laths.

Lime must have time to set before it dries out. Therefore, to last well, it should dry slowly. A stiffer working mortar makes better and harder plaster than thin or wet material, provided, of course, it is thin enough to clinch well to the lath in first-coat work, or to adhere to brick and dry scratched surfaces, and to spread evenly, in second-coat work. Stiffer mortar can safely be applied upon wet mortar than on dry; and wide-spaced lathing will take stiffer mortar than close-laid laths. When two coats of mortar have been put on, and the last coat falls from the first, it is generally because the first coat was not wholly dry when the second was applied. The coats must either be entirely dry or quite green to be successfully combined.

If possible, it is better to have the workman use makes of materials, especially lime, having those properties with which he is acquainted. Attention has already been called to the fact that different makes of lime vary considerably in their chemical composition. It is not even certain that lime of the same make will always run even in production, year after year. Of course, lime that has been slaked by exposure to air or water while in the barrel, and before it is used, is worthless. As this occasionally happens, it is well to be watchful and see that such bad material is never added to the plaster bed.

As a final warning, be certain that the last coat of plaster has dried out hard and strong before any wood finish is installed, as otherwise the wood will absorb the moisture from the plaster, causing it to swell and therefore opening cracks that are never likely afterward to be altogether closed. All wood finish should also be kept out of the house while plastering is going on, as it will absorb moisture from the air around it. The reason that sash are not ordinarily set until after the plastering is finished, is because they absorb so much of the moisture as to cause the sash to swell in place. It is generally considered preferable to fill the window openings or doors with screens of cotton cloth, as this prevents direct draughts and still allows of a circulation of air that dries plastering much more rapidly than artificial heat, or than it would dry if these openings were closed by solid doors and glazed sash. In very bad weather the screen of cotton may be slightly strengthened, if necessary, by the application of a coat of whitewash on the inner side. Contrary to what might be supposed, the cloth window-screen is almost as good a protection against external cold and frost as is the glazed window, although the current of air passing through the cloth meshes of these screens into and out of the house, causes a slight loss of heat, adding somewhat to the expense for fuel required to dry out a plastered building. In good drying weather, these screens should be taken out and left out during the day, but should be replaced at night or in damp weather, when the plaster otherwise is likely to reabsorb moisture from the air and so delay the time of its final drying out.

If avoidable, the artificial drying of plaster by salamanders should not be employed; natural drying by sun and air is, under all circumstances, preferable. The salamander not only dries the room in which it is placed, too quickly—especially the ceiling above—but fills the air and the plaster itself with gas fumes, and, by steaming, is frequently the cause of the rotting of plaster or hair, thus reducing its vitality and life. Heating a house to dry out the plaster by means of the regularly installed heating plant, is preferable to the use of salamanders, the chief objection in this case being occasioned by the unduly rapid drying-out of wall plaster back of or above registers and radiators. The situation is helped if the radiator is set out from the wall and some screen is placed between it and the plaster. A screen may also be employed against the wall over a hot-air register, but there is no means of protecting the plaster on either side of a partition through which a hot-air or steam pipe passes. Such plaster is bound to be severely strained by being dried too quickly.

If plaster is frozen when wet, it is likely to loosen up and injure the whole mass so that it may eventually fall off. The effects of freezing are less troublesome if the wall is frozen after it is dried and has once set. If only slightly frosted, and thawed immediately and floated again, it may often be saved, the effect in that case being not much different from what it would be if the wall had been surface-moistened and refloated.

Plaster Moulding. Plaster mouldings upon ceilings and walls are less frequently employed now than a few years ago, when, especially at the intersection of wall and ceiling, a heavy cornice of plaster was the common method of finish. Nowadays a cornice of wood is more commonly used.

Briefly described, the running of a moulded plaster cornice is as follows: Two parallel strips, or *screeds,* are run on the ceiling and the side wall, with their nearer edges evenly straightened. These edges are then fitted to the mould—a piece of metal cut out to a reversed section of the cornice outline. The mould is run along the strips fastened to the wall for guiding it, the lower edge being cut out and fitted to run upon them.

The plaster necessary to fill up the mouldings of the cornice may be tied back to the wall and ceiling by rows of nails driven so as to stand at about the location of its greatest thickness; while a strip of metal lath, filling in the angle upon projecting furrings, will offer the best possible clinch, and will help to reduce the thickness of the plaster and render its drying and shrinkage more equable and its surface less likely to crack.

When all is ready, enough putty and plaster are gauged in about equal parts to run the cornice down the length of one side of the room. The moulding form is then rested upon the supporting and guiding strip against the wall, and drawn along from right to left, pressed against the mass of mortar which is thrown into the angle just ahead of it by the trowel, the space immediately in front of the moulded strip being kept sufficiently full of plaster mortar to fill out the moulding entirely at all times. When the length is completed, or the gauged material is used up, the mould is moved back and forth along the length of cornice that has just been run, scraping away all the plaster except that included within the outline of the mould.

Where hollows occur, the gauged material scraped off by the mould should at once be thrown on again at these places, so that they may be immediately filled and brought up to the right section outline by again running the mould over these portions. The gauged putty will set in a few moments, and each side of the room or section of the moulding must be run and completed or filled out very rapidly. The corners at the angles of the room may be filled in by hand, or a section of the mould may be separately run upon the floor, sawn in a mitre box, mitred and fitted in place upon the wall, the joint between the cast and run moulding being then carefully patched and evened off.

The extra amount of plaster included in the thickness of extreme projecting mouldings is the cause of occasional surface cracking, while other cracks are occasioned by the settlement, shrinkage, and movement of the house frame. For these and other reasons, it is now generally considered that a wooden cornice, despite its defects of shrinkage, is better suited than plaster to this purpose.

Finally, the moulding may be sprinkled with the brush and the mould may be run over it several times more, ending by finishing with a brush so as to give the moulding a gloss just as on the wall plastering. The same process is repeated for different kinds of plaster moulding, merely varying the method to provide for the different conditions set by circumstances, a circular moulding around the lighting outlet in the middle of the room, for instance, being swung from a peg driven into the center of the gas pipe or outlet box. Other kinds of plaster mouldings are run by unimportant variations of the processes described.

Cast ornaments are made separately in moulds, into which the plaster is poured. Most of these separate moulds are made of plaster hardened with glue or shellac, or surfaced with beeswax, and are generally oiled before being used. Plaster ornaments are fastened in place with fresh plaster or glue; occasionally a few screws are used, in which case the heads should be countersunk and covered in with plaster so as not to show.

EXTERIOR PLASTERING

Although exterior plaster surfacing for dwellings has been in use in Europe for many years, it has but recently met with favor in this country. In Italy, plaster, or stucco, applied in large, unbroken expanses upon a stone or brick building, has long been a favorite method of construction. Frequently, too, this plaster surface is stained or colored and worked up into different designs. In England, France and Germany, plaster has been more frequently used in connection with a half-timbered frame, although these countries also contain instances of its use in large, unbroken, simple surfaces.

In modern American work, it is not often that a brick wall is covered with plaster, as the æsthetic possibilities in the use of rough hard-burnt brickwork have now long been recognized; and when this—the cheapest brick-building material—is employed upon a dwelling, it is itself utilized for the exterior surface and to obtain the exterior effect of the structure.

Plaster has been used in this country in imitation timbered houses for some years; but recently its employment in large, simple surfaces, unbroken by the cross-barring strips of dark wood, has become popular —a treatment much more appropriate to this country. We also possess some examples of brick and stone houses, two hundred years old or thereabouts, that were covered and surfaced with white plastering; but in the most recent of American plastered dwellings, this effect has been simulated by applying the plaster to a wooden frame lathed with a fine-meshed wire cloth.

In any plastered building, the cornices should be projected sufficiently far to protect the walls and all exposed upper surfaces of the plastering. The farther this projection, the more certain the safety of the plaster, especially in the northern sections of the country.

The essentials for successfully-wearing exterior plaster applied in modern fashion, are: A well-seasoned, shrunk, and settled frame; a solid, immovable foundation; and a carefully applied and thoroughly worked job of plastering. The framework should be somewhat better constructed and more carefully arranged to prevent movement or settlement than on an all-wooden building. Other than this, the dwelling to be plastered outside does not differ, in any part, from the ordinary house, until the structure has been framed and boarded in. For plastering, the boarding is then covered with a slightly better and more waterproof grade of paper than if shingling or clapboarding were intended. Outside of this papering, the house is furred with strips of furring, seven-eighths of an inch thick by one and one-eighth to one and one-quarter inches wide (for metal lathing they are to be placed nine inches apart, for wood laths twelve inches, on centers), and the lathing is applied upon these strips.

METAL LATH

The best lath for exterior plastering is probably the No. 19 Clinton wire cloth. The wire is sufficiently large to be durable, and the mesh sufficiently open to allow the mortar to pass through and completely fill and close in over the back of the wire, thus protecting it from exposure to the elements or damage from water and rust, even if the plaster surface should leak sufficiently to admit water behind this covering. Expanded metal is also used for this purpose, but it is not generally considered so good a material, from the fact that it is impossible to cover entirely and protect the back of this lath with plastering, and therefore there is no means of certainly protecting it from the possibility of rusting.

Occasionally, on a small, low house of not over a story and a-half of wall height, the boarding may be omitted altogether. The metal lath is then placed directly upon the furred studs, and plastered both outside and in to insure its absolute protection from damage by water. However, the shrinking of the studs opens a small crevice along each side—which has already been mentioned as occurring in back plastering—and it is thus possible that water may enter from the back and do considerable damage, even through the narrow space that this shrinkage provides. The omission of the outer boarding also somewhat injures the stiffness of the house, as a frame constructed in this way is not so well braced as when the boarding is applied. Neither are the dwellers in the house so completely protected from the exterior weather, as the second air-space obtained between the papering and the exterior plastering is lost. This extra air-space is of assistance in keeping the house more equably warm in winter and cool in summer.

In the use of metal lath, it is always to be remembered that the *absolute* essential is to protect the lath from the action of water and rust. This once done—in whatever fashion—a permanent and lasting plaster surface is ensured. Sometimes the metal lath is wired and fastened to perpendicular iron furrings of tee-irons or angles, held to the wood frame with staples or some similar fastening, allowing any possible movement of the frame to occur without affecting or straining the plaster surface, which is by this means disassociated from, while directly supported by, the house frame. Cracks around the windows and the angles of the buildings are thus prevented. But it is a more expensive form of construction, and is not now employed except in the larger and more expensive residences.

From the use of wire lath, there are occasionally obtained small surface cracks, especially if the lath joint happens to come at a place where some strain is afterward placed upon it, and particularly where it is weakened from the movement of adjacent portions of the building. For instance, if a perpendicular lath lap is made on the line of the edge of the window finish, a crack on the line of this joint is almost certain to appear in the plaster, extending both above and below the wood-surrounded opening. Care should be taken to cut the strips of lathing so that the joint will come at least nine or ten inches on either side of the edge of the window or door finish. All furrings should also be kept away and back from all angles, internal or external, upon the walls, so that a certain clinch may be effected by the plastering at these important points.

WOOD LATH

Wood lath is occasionally used, and, in certain sections of the country, apparently with good results. It may be employed in two ways—one, in the ordinary manner, only spacing the laths somewhat further apart than would be advisable on the interior of the dwelling. The other method consists in laying the laths diagonally over the building in such a manner as to form a criss-cross lattice-work. In this case the distance between the laths is from three-quarters to seven-eighths of an inch, so as to allow the plaster to enter easily and form a solid clinch behind these lattice openings. The purpose of the diagonal criss-cross lattice is to provide more or less flexibility for the wall covering, so as to take up, without injuring or cracking the plastering, a certain amount of the movement that may always be expected in a wooden-framed dwelling. This method of employing lath, by the way, is in most localities almost as expensive as the use of wire or metal lath, which is probably a safer and surer material to employ. As large and as good a quality of heavy wood lath as can be secured, should be provided for exterior work. Lath cracks are also then to be expected, from the same reasons that apply to interior work; while the mortar should be somewhat softer and slower drying when used upon this material than when employed upon a metal surface.

If possible, it is advisable so to arrange the work upon the house that, after the completion of the frame, some time will still elapse before the plaster is applied. If the frame can be boarded in, and the interior of the house plastered and finished under artificial heat during the winter, and the exterior plaster added in the spring, probably the best results are to be expected. Opportunity is then provided for the frame to shrink, settle, and contract. Most of the weight to be placed inside of the building is then also installed before the exterior surface is applied, so that much less strain and movement may be expected afterward to affect it than would be probable under the opposite conditions.

PUTTING ON THE PLASTER

Exterior plaster requires three-coat work. The first or scratch coat is indispensable when metal or wire lath is used, but almost equally important over wood lath. This first coat should be scratched or roughened while drying, and must be thoroughly dry before the second coat is applied. A greater time ought to elapse between the applications of exterior than of interior plaster coats, inasmuch as it then becomes possible to cut out many of the larger and more important cracks than have had time to appear, and to patch them before the second coat is put upon the house. The second or brown coat is then the less likely to crack; and, if a further extra time is allowed the plastering to dry, it can also be patched at the last moment before the final slap-dash or finishing coat is put upon the walls. This slower progress aids in giving a more permanent job and one that is at the same time less likely to give annoyance from surface cracks afterward making their appearance in the finish plastering.

The question of proportion in mixing the plaster is quite as variable here as in the case of interior plastering, and it is equally impossible to give absolutely definite directions. Different plasterers, each being guided by the experience obtained from working in different sections of the country, prefer their individually different ways of proportioning or mixing their materials. In the first coat, cement is added to the lime mortar in proportions varying between ten and forty per cent of the mixture. Some plasterers prefer that the first coat should be less stiffened with cement than the second. With others the reverse is true; while, contrary to the general supposition, the exterior coat appears in the majority of cases to contain only that amount of cement necessary to provide the tone or color that is desired for the exterior treatment. Conditions also greatly affect these proportions. When the plaster is added last on a well-seasoned and shrunk frame, for instance, it is worked stiffer than when the building is newer and still far from finished.

The final coat for exterior plaster is generally applied as a *slap-dash* finish, the surface texture being given by the throwing of handfuls of variously sized pebbles or gravel upon the fresh outer coat, thus pitting or marking up its surface. The smaller the size of the particles employed for this purpose, the more likely they are to stick and remain in the fresh putty, slightly tinting the surface with the color—if any—of the gravel employed.

The coloring of exterior plastering is done in much the same way as when it is used inside the dwelling. As a rule, it may be said that not sufficient consideration is bestowed in this country upon the possibilities provided by the use of color for exterior plaster work.

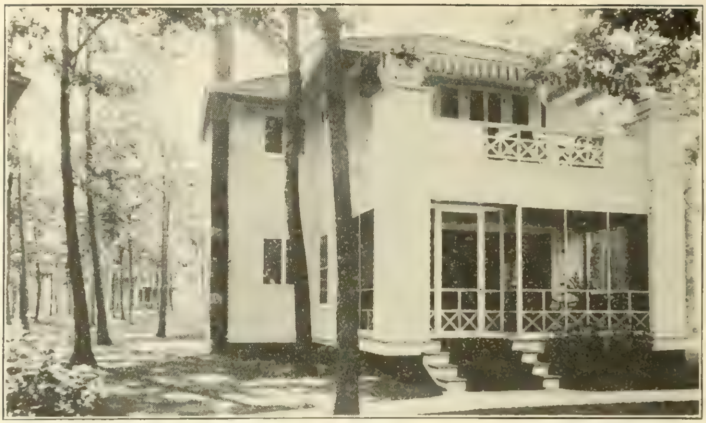
It is agreed that the utmost care to prevent absolutely any leakage is necessary on the part of the workman in the carrying out of this class of work; and it is here that the success or failure of exterior plastering most often hinges. Of course, the joints occasioned by the juxtaposition of the wood finish and plaster around window and door openings offer many opportunities for leakage. The plaster should here be carefully flashed; and, if possible, an outer architrave backband should afterward be put on so as to cover and protect this joint. Otherwise, a key should be provided for the plastering, by cutting away or hollowing out a space near the inner edge of the wood facure, into which the plaster may be pressed by the workman, and leakage thus prevented even if the wood, as is quite likely, shrinks slightly away from the plaster after it has been put in place.

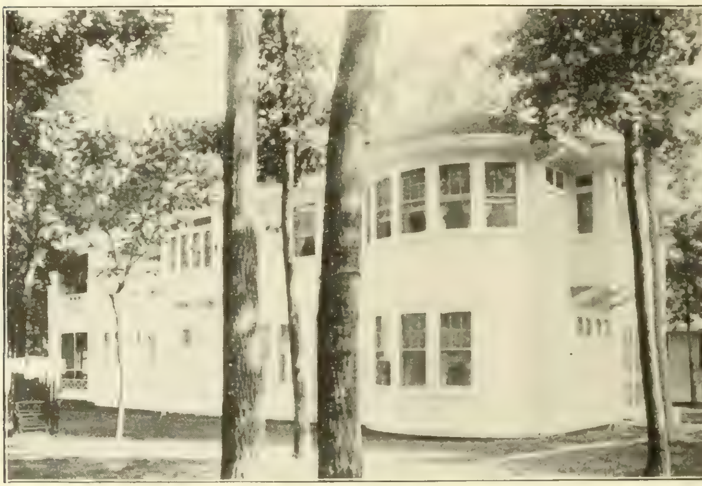
The problem of making tight this exterior plaster wall is complicated and rendered more difficult when it is divided into panels by a so-called *half-timber* treatment. In this style of design, a great number of joints between plaster and wood are occasioned where the wide wood boards are almost certain to shrink away from the plastering, and where, too, it is impossible to protect these joints by outer applied battens in any way capable of covering such an opening as may occur. Thorough flashing on all upper exposed surfaces, assisted by protecting overhang of the roof eaves, and broad keys provided for the entrance of the plaster at all perpendicular and lower horizontal joints must alone be relied upon.

Under our circumstances, so far as the average nature of the work is concerned, does the mortar play so important a part as the depending of great care upon the thorough surfacing, working and finishing of the mortar, pressing it into every crevice intended to receive it, flushing thoroughly every exposed or upper surface provided by the bricks, and taking every precaution to work out all possible unnoticed defects where water could possibly penetrate the surface. Every care and endeavor is directed to providing a solid, evenly worked, and permanent coating which will, in every possible way, throw off and prevent moisture being admitted into the space back of the plaster coating—that vulnerable portion where its attack is most effectually concealed and most to be dreaded.

The exterior plaster treatment of a cement or concrete wall is a problem that from now on will continue to be of rapidly increasing importance. Here, however, it is but necessary to use the cement as nearly *neat* as possible, adding lime or a make of white cement in case a brighter surface color is desirable. The problem of the aesthetic treatment of concrete construction is one that requires separate and particular consideration. Its solution has, as yet, been hardly attempted. Hollow terra-cotta tile is another material that is being moderately used more and more as a structural base to take an exterior plaster surface finish.

The student desiring to obtain a wider knowledge of the intricate subject of exterior plastering, may be referred to several articles published in the 1907 numbers of *The Architectural Review*, Boston. For a work treating historically and practically of the entire art and craft of plastering—within and without the dwelling—see Mr. William Millar's treatise "Plaster, Plain and Decorative." It would be as well to remember, in consulting the latter volume, that it was issued in 1897, and that the subject is treated from the point of view of an English workman, accustomed to methods and materials somewhat different from those common in American practice.





EXTERIORS AND INTERIOR OF HOUSE SHOWN IN PLAN ON PAGE 331

PAINTING

Introductory. The first thing a man wishes to know when he contemplates painting a house is the cost. This will obviously depend on the cost of labor, of materials, and the kind of materials chosen. The outside of a house is painted, either in whole or in part; the interior may be painted or varnished. Some houses have their walls partly covered with shingles; these shingles are sometimes painted, and sometimes—in fact, often—left unpainted; but what is called the *trim*—that is, the boarding about the eaves, windows, doors, the base-board, and corner-pieces—is painted. Shingles, either wall or roof, are often stained with a creosote stain consisting of a coloring matter dissolved or suspended in a liquid called *creosote*, which is applied for the purpose of preserving them; and though instances can be cited in which wall-shingles that were never stained are still doing good service although believed to be now two hundred and fifty years old, yet the use of creosote will undoubtedly prolong the life of modern, sawn shingles, as it is noxious to insect life and a powerful deterrent of natural decay. The color of unpainted new shingles is generally disliked, but after four or five years wall-shingles take on a beautiful, soft color. The question of staining shingles is a matter of taste.

Most houses are exteriorly painted with paint based on white lead or zinc. Some idea of the cost may perhaps be gained from the following considerations:

White lead is sold either ground with a little oil to a thick paste, or—less commonly—in the dry state.

A mixture of 100 pounds of dry white lead with 5 gallons of linseed oil makes 6½ gallons of paint, weighing 21.3 lbs. per gal.

Approximate figures are: 15 lbs. paste lead and 0.5 lbs. oil equals 1 gal. (1 gal. oil equals 7.7 lbs.); 14 lbs. dry lead and 7½ lbs. oil equals 1 gal.

A mixture of 100 pounds of white zinc and 8½ gal. oil makes 10⅓ gal. of paint; 12 lbs. zinc and 1 gal. oil make 1.2 gal., or 9.3 lbs. zinc and 5.7 lbs. oil make 1 gal. white zinc paint weighing 15.2 lbs. Dark-colored paints made from iron oxides, ochers, and the like weigh 12 to 14 pounds per gallon, but exact figures cannot be given, as the raw materials differ greatly.

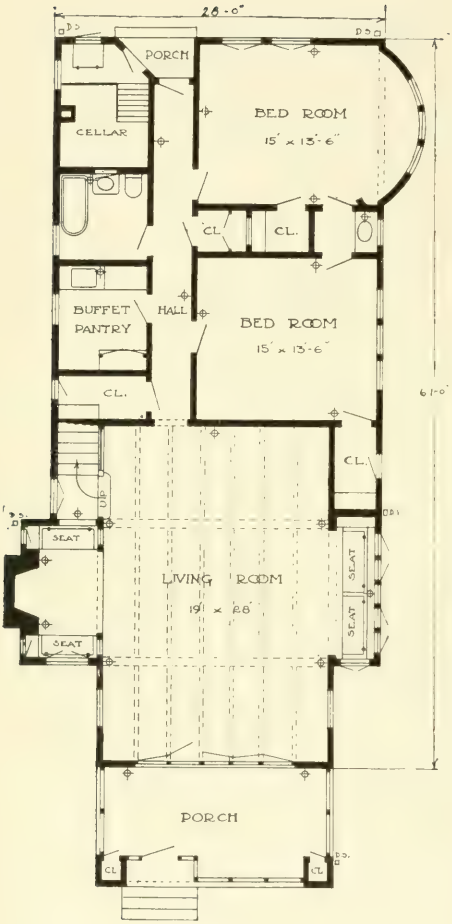
Here should be noted the difference between the priming coat and the succeeding ones. A *priming* coat is the first coat applied to the clean wooden surface; it differs from the other coats in containing more oil, because the wood will soak up the oil and leave the coloring matter of the paint on the outside.

To make the paint for the priming coat, take a gallon of the paint already described and mix with it a gallon of raw linseed oil. Paint thus made is, of course, lower in price; it is also much thinner; but such is the absorbent power of the wood, that the priming paint does not cover as much surface as the succeeding coats per gallon. A gallon of this thin priming coat covers 300 to 400 sq. ft., while a gallon of second or third-coat paint, well brushed out, will cover about twice this surface; this is because the surface for all but the first coat is hard and non-absorbent. Priming coats are used for both outside and inside work, as will be described later.

The dark-colored paints are usually cheaper than those made from lead and zinc, and if made of good materials are not inferior in durability; the extraordinary claims made by the zinc and lead manufacturers are to be received with much doubt. Some of the dark-colored paints are the most durable that can be applied on wood. The chief cost of painting is, however, that of labor, which varies according to locality and other conditions, seldom being less than twice that of materials.

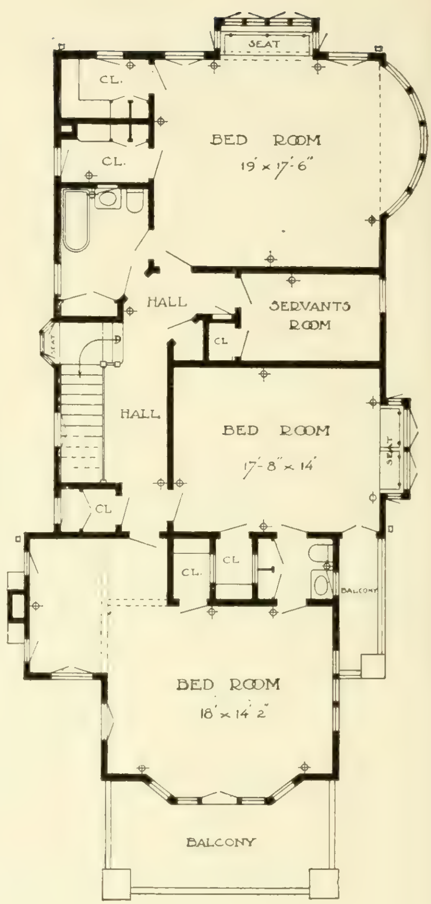
For light-colored paints, it is better to use raw linseed oil to which pale japan dryer may be added, as described later; for dark colors, either this or boiled oil, boiled oil being darker in color. The cost is practically the same; also the durability.

On inside work may be used either oil or enamel paint, as described later, the former being the cheaper, the latter the handsomer and slightly more durable; or the wood may be finished in its natural color, by varnishing it either with an oleo-resinous varnish or with shellac varnish. The oleo-resinous varnishes darken the wood very appreciably, while white shellac varnish keeps it more nearly in its natural color; although the latter does not prevent the natural darkening action of light, it may retard it. Shellac varnish is the more expensive finish of the two, if well applied. What is sometimes called *oil finish* generally consists in the application of a cheap varnish called *hard oil*, which is usually made of common rosin, linseed oil, and benzine. Its only merit is that it is cheap.



FIRST FLOOR PLAN

SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 FEET



SECOND FLOOR PLAN

SCALE 0 1 2 3 4 5 6 7 8 9 10 11 12 FEET

SUMMER HOME OF DR. J. B. McFATRICH, LAKE GENEVA, WIS.

W. Carbys Zimmerman, Architect, Chicago, Ill.

Frame House Built in 1906. Plan is Conditioned by Narrowness of Lot Overlooking the Lake. The Interesting Feature is the Screened-in Porch, which, by a Series of Folding Doors, can be Made Part of the Living Room. The High Frieze in the Living Room is Decorated with Woodland Scenes Showing the Lake and Hills in the Distance. Exterior and Interior Views Shown on Page 328.

It would indeed be possible to apply neither paint nor varnish, but merely to saturate the wood with oil, and this would be truly an oil finish; it would, however, make the wood dark and dingy, and would readily retain dirt, and is a practice seldom followed except sometimes on floors—especially kitchen floors—and sink shelves. These are at frequent intervals oiled with a mixture of equal parts boiled oil and turpentine.

It is the purpose of this Instruction Paper to describe only good and approved methods. It will readily be understood, and will certainly be observed in practice, that these methods may be abbreviated by the omission of some details that are here specified as desirable. For instance, it is difficult to get interior finish sandpapered or rubbed between coats, even if so contracted; but this is the right practice. Two coats of varnish often have to serve in the place of four. No one, however, needs to be told these things. The methods herein described are not luxurious or extravagant; they are, on fairly good houses, truly economical; and we are not considering temporary structures.

It is not uncommon to find part of a house, as the living rooms, finished in varnish, and the kitchen and pantry painted with oil paints, which are lighter in color and more easily renewed. The sleeping rooms, on the other hand, are often finished in enamel paints, because color effects are desired to harmonize with the furnishings; and bathrooms are almost always done in enamel for sanitary considerations. The taste and inclination of the owner are to be consulted in regard to all these matters.

PAINTERS' SUPPLIES

Pigments and Vehicles. Paint is a mixture of a finely-divided solid substance with a liquid which, when spread on a solid surface with a brush or otherwise, will adhere and in a short time form—by evaporation, or more commonly by oxidation—a somewhat hard and tough film. The finely divided solid is called the *pigment;* the liquid part, the *vehicle.* The most common vehicle is *linseed oil.* This is an oil obtained by pressure (or extraction by solvents) from flaxseed. When spread out in a film and exposed to the air, linseed oil is converted into a tough, leathery, elastic substance called *linoxyn,* insoluble in water and all common solvents. This change is brought about by absorption and chemical union of the oxygen of the air, whereby the weight of the oil is increased about one-fifth or one-sixth. It is therefore a mistake to suppose that oil paint gets dry as whitewash does, by the evaporation of the liquid. Instead of that, it gets heavier. There are some other vegetable oils which have this property in some degree, but none which are used for paints to any considerable extent; some are used a little for artists' colors.

Linseed oil should stand at least a month or two before using. It should then be perfectly free from sediment or cloudiness; if it is not so, this is a sign that the oil has not been properly aged, and such oil is not fit for making paints. In this natural state, it is called *raw oil;* and the price of linseed oil as commonly quoted refers to raw oil. *Boiled oil* is this raw oil which has been heated, usually to 450° or 500° F., with the addition of a small amount of oxide of lead or oxide of manganese, or a mixture of the two (occasionally some other lead or manganese compounds are used). Boiled oil is darker (browner) in color than raw oil, but differs from it chiefly in that it dries five to ten times as rapidly. A thin film of raw oil on a glass or metal surface will dry at ordinary temperatures in five or six days, so as to feel no longer greasy; but boiled oil will do the same in a day or half a day. Oil dries best in warm, dry weather and out of doors.

The pigment is mixed with the oil by stirring the two together. This is usually done by power, in a vessel called a *paint mixer.* The mixture should then be run through a *paint mill;* some paint mills are of steel, but the best have a pair of mill-stones, between which the paint is ground and most thoroughly mixed. Paints mixed in this manner are much better than those which are mixed only by stirring.

Besides oil and pigment, paint sometimes contains a volatile *thinner,* the most important thinners being *turpentine* and *benzine.* Turpentine is a well-known essential oil, volatile, boiling at about 320° F., but evaporating at ordinary temperatures when exposed to the air. Benzine is a mineral oil, lighter than kerosene and heavier than gasoline; the kind used in paint and varnish is called "62-degree benzine," its specific gravity being 62° on the Baumé scale for liquids lighter than water. Linseed oil weighs 7.7 lbs. per gallon; turpentine, 7.2 lbs.; and 62° benzine, 6.1 lbs. But linseed oil is sold by the oil makers and dealers on the basis of 7.5 lbs. per gallon.

A dryer, in some form, is an essential ingredient of oil paint. A *dryer* is a compound of lead or manganese (generally lead), soluble in oil, and is usually sold, under the name of *paint dryer* or *paint japan*, as a solution of such material in a mixture of oil, turpentine, and benzine. It is usually of such strength that an addition of from 5 to 10 per cent of it to a raw-oil paint will make it dry in from six to twelve hours sufficiently to be carefully handled. Paints are not dry enough to use, until they have stood four times as long as this; and they continue to harden for months. The strongest drying japans are dark in color; but such are more injurious to the durability of the paint than those which are paler, especially if the latter do not contain rosin. The buyer should always ask for a guarantee that the dryer is free from rosin, if great durability in the paint is needed. Not more than 10 per cent of any dryer or japan should ever be used in any paint. Slowly drying paints are more durable than quick ones.

In house painting, the white pigments are the most important, because they are the base of all light-colored paints. The most important white pigment is *white lead*. This is sold either as a dry powder, or (more commonly) as paste white lead, which is made of 90 lbs. dry white lead and 10 lbs. linseed oil. This can be thinned with boiled oil to make a white paint. White lead is a very heavy pigment; and with a given quantity of oil, more of it can be mixed than of any other pigment, except red lead. It has great opacity, or covering power. It is discolored by gases containing sulphur, becoming brown or black; and unless exposed to fairly strong light, it becomes yellowish even in pure air. It is better if it has been mixed with the oil for some time—a year or more.

White zinc is a somewhat purer white than white lead; not so opaque. Three coats of lead are reckoned equal to five coats of zinc. It becomes harder than lead, but is somewhat liable to peel off; white lead, after exposure to the air for a long time, becomes dry and powdery on its surface, and *chalks*.

A mixture of two parts of lead and one of zinc is much liked. *Zinc-lead*, however, is the name of an entirely different pigment, made by furnacing ores containing about equal parts of lead and zinc, in which the lead is present as a sulphate. This pigment is free from the liability to turn brown if exposed to sulphur gases; it is said to be not quite so pure a white as the preceding. It is a comparatively new pigment, but is coming rapidly into use, being somewhat cheaper than the others. *Lithopone* is another white pigment of considerable merit.

Adulterants. All these pigments may be *adulterated* with barytes, or with *terra alba* (sulphate of lime), sometimes with whiting (carbonate of lime). These adulterants are powdered minerals. Barytes is a good pigment, so far as protective action goes; and terra alba is thought by some good authorities to be unobjectionable; but whiting is injurious. All of them are transparent in oil, and lessen the opacity or whitening power of the paint.

From these white paints, *colored paints* are made by adding *tinting colors*, of which the yellow is chiefly *chrome yellow*, or chromate of lead; the blue may be either *ultramarine* or *prussian blue*; and the green is *chrome green*, a mixture of chrome yellow and prussian blue. The reds are (in house paints) made from *coal-tar colors*, and most of them are now fairly fast to light. Some dull yellow colors are made from *ochers*, which are clays tinted with iron oxides, roasted and ground. These are permanent colors.

The dark-colored paints may not contain lead or zinc at all. The deep yellows, greens, and blues are made from the colors already named as tinting colors, none of which are entirely fast to light; the dark reds and browns are chiefly *iron oxides*, which are a valuable class of paints, very permanent on wood. The blacks are either *lamp-black* or *drop-black* (bone-black) and other carbon colors; and these are often added in small quantity to secure some desired tone or shade of color.

The zinc and lead pigments have some action on oil, and in their case it is considered the best practice to apply thin coats; but the dark pigments do not act on oil, and, of these, thick coats are best for durability.

Paint and Varnish Brushes. A brush that has only a low price to recommend it will prove a poor investment. If properly cared for, brushes last a long time, and it pays to have good ones. The first sign of a good brush is uniform quality from outside to center. Inferior brushes have inferior bristles in the middle, and some poor brushes are actually hollow. For ordinary oil painting, the bristles on a large new brush should be five or six inches long, uniformly flexible, and as stiff as can be found; they will be flexible enough anyway, but all should be alike.

Paint brushes are *round*, *flat*, or *oval*. A favorite brush for ordinary outside work is what is called a *pound brush*, a large round brush with stiff bristles six inches long. Such a brush should be *bridled* when it is new—a "bridle" being a piece of cord wound around the bristles to shorten their effective length; as the bristles become worn off, the bridle may be removed. A 2½-inch oval brush (2½ inches wide) is a highly satisfactory tool to use in general painting, and is the brush recommended by the paint committee of the American Society for Testing Materials. It is worth noting that this committee, made up equally of expert paint manufacturers and experts employed by the large consumers, unanimously agreed that no larger brush than this should be used in making paint tests.

The use of brushes five inches wide is common for outside work; but while such brushes may be had of the best quality, they are heavy and laborious to use, and the workman who uses such a brush will not brush the paint sufficiently to get the best result. If a flat brush is used, it should not exceed 3½ inches in width; and three inches is better. A good 2½-inch oval varnish brush is a most excellent brush for all large work in either paint or varnish. The painter should also have a good 1½-inch oval brush for smaller work, and a number of round or oval brushes, called *sash tools*, of different smaller sizes, for more delicate work, such as sash and frame painting. Stiff-bristle brushes, which have been worn off short, are suitable for such work as rubbing-in filling. For varnishing large surfaces, flat bristle brushes 2½ inches wide are good; also similar ones 2 inches, 1½ inches, and 1 inch wide are useful. All flat brushes should have chiseled edges. For flowing varnish, it is necessary to have thick, flat, camel's-hair brushes, running up to 3½ inches in width, although most house varnishing may be done with brushes not over 2½ inches wide.

Besides paint brushes, the workman will need some ordinary *scrubbing brushes* and one or two painters' *dusting brushes*, to have the surface properly cleaned.

Steel-wire brushes, with stiff steel wire instead of bristles, shaped like scrubbing brushes, are used for cleaning off old paint and for cleaning structural metal work. These are of various sizes; and the steel wires are of different lengths and sizes, hence differing in stiffness. They may be had at hardware stores.

Care of Brushes. Hair and bristle brushes must be kept clean and soft; this can be done by care and faithfulness. They should not be allowed to become dry with paint or varnish in them. To prevent this, wash them out in oil or turpentine as soon as you are through using them; or they may be left in the paint or varnish for a few days. They may be kept over night by wrapping them very closely in paper if they have been used in a slow-drying material; in this way they may be carried from one place to another. Brushes should not be left to dry with even clean oil or turpentine in them; if they are to be put away, they should be well washed first with soap and water, then with clean water, then hung up until thoroughly dry.

In use, brushes are best kept in what is called a *brush safe*. A deep wooden pail, with nails driven in its sides at different distances from the bottom, and with a close cover, makes a good receptacle for brushes. The brushes have holes in their handles, or loops of cord tied to them, and are hung on these nails; their bristles dip into some turpentine or oil in the bottom of the pail; they are so hung that they do not dip into the liquid above where the bristles project from the binding. If brushes are left standing on the bristles on the bottom of a vessel, they soon become one-sided and distorted in shape. Tin brush-safes may be bought of any large dealer in brushes.

A brush which has dried with paint or varnish in it, may be recovered by soaking it in a non-alkaline varnish-remover. This will in time soften it so that it may be used again, but it is not improved by such treatment. Brushes used in shellac should be washed out with alcohol instead of turpentine or benzine. No brush is good unless it is clean.

Fillers. Fillers are of two kinds—*paste* and *liquid*. Paste fillers are something like a very thick paint, and are composed of some solid powdered substance, usually silica or powdered quartz, mixed with a quick-drying varnish thinned with turpentine or benzine. This is applied to the dry surface of the wood with a stiff, short-bristle brush, or is put on with a clean, white cotton cloth, and well rubbed into the pores of the wood. After half an hour or so, the surface of the wood is wiped off with a wad of excelsior or a clean cloth or a piece of felt. A liquid filler is a quick-drying varnish; and most of the liquid fillers on the market are cheap rosin varnishes loaded with dryers, and should never be used.. Paste fillers are the best in almost all cases.

HOUSE PAINTING

Inside Work. All window and door frames, whether they are to be finished with paint or varnish, should receive a good coat of paint made with some cheap pigment, such as iron oxide, and boiled oil, applied to the back of the frame, before they are brought from the shop to the house; this prevents the absorption of moisture and hinders decay. If they are to be painted, they should receive a priming coat in the shop, if possible; if not, it should be applied as soon as practicable. The priming coat is composed of white lead and boiled oil or raw oil, with five to ten per cent of dryer; and should be almost all oil, with very little pigment. Turpentine is not a good thing in a priming coat, because the object is to fill the pores of the wood, and turpentine evaporates. As soon as this is dry to the touch, all holes are to be filled with putty. The best putty for this purpose is white lead putty, made by mixing a little raw oil with dry white lead, or by adding dry lead to paste lead until it is of the right consistency. This kind of putty hardens quickly as compared with common putty, and is the best for this purpose. A steel putty-knife should not be used on interior woodwork, as it is almost certain to scratch it; a hardwood stick, suitably shaped, should be used. All cracks, joints, and nail-holes should be carefully filled. All knots and sappy places should be varnished with shellac varnish; this prevents the pitch and moisture from attacking the paint. The shellac should be applied where it is needed, before the priming coat. The priming coat should be given time to get quite dry; at least a day—two days, if possible; and a week is better yet. Then it is ready for the second coat. This should contain a considerable amount of turpentine. If no turpentine is used, the surface is likely to be glossy, and the next coat of paint will not adhere well; but by replacing part of the oil with turpentine, we get what painters call a *flat coat*—that is, one which is not glossy; if this is made from paste lead or any paste paint, it can be produced by thinning the paste with a mixture of oil and turpentine in equal proportions; some painters prefer one-third oil and two-thirds turpentine. This is for inside work only. This coat should be allowed to dry thoroughly; if it takes ten hours for the paint to be dry enough to handle, then at least four times ten hours *additional* should elapse before the next coat is applied; this is a good general rule; and as much more time as possible should be allowed. If the finish is to be ordinary oil paint, the next coat may be paint, thinned with about half as much turpentine as before, or with no turpentine at all. In the latter case, when the coat is thoroughly dry, it must be carefully examined, and, if glossy, it should be rubbed with something to take off the gloss; curled hair is often used, or a light rubbing with pumice and water. Then the final coat, which has no turpentine in it, may be applied.

But if the finish is to be with an enamel paint, the second coat, when quite dry, should be very lightly sandpapered with fine sandpaper, and the third coat should be of like composition to the second, treated the same way; then the enamel paint is applied. For a really first-class job, when this is quite dry, it should be rubbed down with curled hair or pumice and water, and another coat of enamel put on. This may be left with the natural gloss if desired; or it may be rubbed with pumice and water to a flat (dull) surface.

Painting Plastered Walls. Old plastered walls may be painted with oil or enamel paints as though they were wood, remembering that the priming coat will have almost all of its oil absorbed by the plaster. New plastered walls do not take paint well, on account of their alkaline character, which gradually disappears with exposure to the atmosphere. It is well to let a wall remain unpainted at least a year. But if it is necessary to paint a freshly plastered wall, the wall is prepared by some painters by washing it with a solution of sugar in vinegar, the sugar uniting with the lime to some extent; or more commonly— by washing it first with a strong solution of common alum and then with a solution of soap. After this is dry, it is washed with clean water, allowed to dry, and then painted. The alum and soap form an insoluble compound which closes the pores of the plaster to some extent, and prevents the lime from acting on the paint.

Outside Work. Exterior paints are more elastic, as they need to be far more lasting, than those used on interiors, since the effect of exposure to the sun and rain destroys paint more than almost anything else does. Paint on the interior of a house will last almost indefinitely; but on the outside the best paint is not very durable. The surface, if new, should be cleaned by brushing; knots should be shellacked; after which the priming coat should be applied. This may be the same paint which is selected for the finish, only thinned with boiled oil (or raw oil and dryer), using one to one and a-third gallons of oil to each gallon of paint. The reason why ordinary paint may not be used as a primer, is that the wood absorbs the oil, leaving the pigment as a comparatively nonadhesive powder on the surface, from which the next coat will probably peel off. The next step is to putty up all nailholes and other defects. For the second coat, many experts advise the addition of half a pint of turpentine to the gallon of paint; others make no addition to it. The third coat is applied after the second is thoroughly dry; if a week or a month can elapse between these coats, so much the better.

Repainting. If the old paint has been on a long time, it is liable to be permeated by minute cracks, which admit moisture to the surface of the wood and loosen the paint. If now we paint over this, the new paint, which shrinks in drying, tends to pull off the old paint, and of course the whole peels off in patches. If the old paint is in this state, it must be removed before the new paint is applied. This can be done by *burning off*. For this work a *painter's torch* is required, which is a lamp burning alcohol, gasoline, or kerosene, and is so constructed that a blast of flame can be directed against the surface. This melts or softens the old paint, which is then immediately scraped off with a steel scraper. The paint is not literally burned, but is softened by heat so that it can be scraped off. In some cases it is sufficient to remove as much as possible with a steel brush; this is a brush like a scrubbing brush, with steel wires instead of bristles, and, when vigorously used, will take off the loose paint.

Old paint, however, is not always in this condition. If it adheres well, it may be cleaned with an ordinary scrubbing brush and water, and when it is quite dry, the new paint may be applied. Sometimes the paint seems in good condition, only it has faded and lost its luster; in such cases a coat of boiled oil, or raw oil with dryer, is all that is needed.

It is well to paint the trim—that is, the window-casings, door-casings, corner-pieces, and the like—before painting the body of the house; then the paint can be applied to the flat surfaces more neatly than is otherwise likely to be done. Paint should be applied in thin coats, well brushed on; it is not unusual to see paint come off from re-entrant angles while it is still good on flat surfaces, because it was difficult to brush the paint properly in those places. There is a great difference in durability between a thin paint flowed on with a large, flat brush, and one of proper consistency well brushed out with a brush of medium size. In all painting on wood, it is desirable to brush it on with the grain of the wood; and by painting only a few boards at once, we may avoid laps by painting the whole length. Rough surfaces hold paint better, and more of it, than smooth. A gallon of paint will cover, one coat (on a painted or well-primed surface), about 600 square feet, not flowed on, but well brushed out in a thin film. The priming coat will not cover more than 300 or 400 square feet to the gallon. In measuring the outside of a house for surface, make no deductions for doors and windows; if the trim is to be painted a different color, from one-sixth to one-third of the paint will be required of that color. Paint should be stirred frequently while using. A coat of dry paint is from $\frac{1}{500}$ to $\frac{1}{1,000}$ of an inch in thickness.

Roof Painting. Roof paints should contain a larger proportion of oil to pigment than other paints, and less dryer (or none at all). Many think that the addition of ten to twenty per cent of fish oil to a paint for roofs is advantageous; fish oil greatly retards drying and prevents the paint from becoming brittle. Tin roofs, if new, should be thoroughly scrubbed with soap and water, or with pieces of harsh cloth, such as burlap, well wet with benzine. They may then be painted.

Paint dries relatively fast on roofs; but as a roof paint is very slow-drying, plenty of time must be allowed between coats. A new roof should receive three coats. Metal gutters and spouts are to be treated the same way. Do not forget that new tin or galvanized iron is difficult to paint; have it very thoroughly scrubbed, even though it looks perfectly clean, and then rub the paint on well with the brush. Metal spouts will usually be painted the same color as the wall of the house.

Sometimes shingle roofs are painted with fireproof paint. This is not really fireproof, but considerably retards the spread of fire, after it has become thoroughly dry; when fresh, it does not even do that; nor does it have much effect after it has been on a year or so. It may be made by adding to a gallon of any good paint about a pound of powdered boracic acid. When strongly heated, this material fuses and forms a sort of glass, which keeps the air from the wood. It is after a time washed out by the rain.

Canvas roofs are prepared in the following manner: The canvas

(10-ounce duck is often used) is first nailed down, care being taken to draw it tight; it will show some wrinkles, but these are not to be allowed to accumulate to form a large wrinkle or fold. Then the canvas is thoroughly wet; it shrinks, and all the little wrinkles disappear. It is a common practice to paint it while it is still wet, this being an exception to all other practice; but some wait until it is dry. The writer has been accustomed to the latter method, and has not found that the canvas shows wrinkles on drying, while the results are all that can be desired. A well-painted canvas roof is very durable and satisfactory.

PAINTING STRUCTURAL METAL

Steel is a more perishable material than wood, and more difficult to paint. Without regular expenditure for maintenance, wooden bridges last longer than steel ones; there are wooden roof beams a thousand years old; and iron roofs are so short-lived that they are used only over furnaces and the like, where wooden ones would take fire. The painting of structural steel is therefore important; and it is also difficult, if we are to judge by results.

In the first place comes the preparation of the surface. When we paint wood, we have the surface clean and dry; and then we soak it with oil, so as to have the paint bound to it in the most intimate manner. Iron and steel, on the other hand, always come to us dirty, and covered with oxide; and as the surface is not porous, the paint does not penetrate it, but has to stick on the outside the best way it can. If we paint over the dirt and scale, and that ever comes off, the paint comes off with it; if the metal is actively rusting, and we paint over the rust, the corrosion is perhaps made slower, but it does not stop.

Air and moisture cause rust; if we can keep them away, the metal will last; but, unfortunately, all paint is very slightly porous, and if exposed to the weather it in time deteriorates. The most essential thing in painting metal is to *get the paint on the metal*, not on an intermediate coating.

There are only two ways to clean steel perfectly. One is by pickling it in dilute acid (usually 10 to 20 per cent sulphuric acid), followed by washing to remove the acid; and the other is by the use of the sand-blast. Neither of these processes is available to the ordinary painter, who must do the next best thing. This is to remove absolutely all dirt and all loose scale and oxide. First clean off the dirt, if any, with brushes, as it would be cleaned off any other surface. Then, with scrapers and steel-wire brushes, clean off all the scale which will come off. If there is any new rust (not mill scale), it must be well scraped out and cleaned off. This is indispensable. When this is done, immediately paint it, before it begins rusting again.

One of the most popular materials for a first coat is red lead in oil. This must be mixed on the spot, shortly before it is used, because it will harden into a cake in the pail or can if allowed to stand very long. From 30 to 33 pounds of dry red lead is to be mixed with each gallon of oil—not less than 28 in any case. This is immediately painted on the metal; if it is put on in too thick a coat, it will run and be uneven. Some use raw oil, others boiled oil; it does not make much difference which is used. The paint dries rapidly; and as soon as it seems hard, a second coat of the paint can be applied. Red lead is different from all other paints in this, that it will finish hardening just as well away from the air. This is because it does not dry by oxidation, as other paints do, but by the lead combining chemically with the oil, just as water combines with Portland cement. In the opinion of the writer, red lead should have one or two coats of some good paint, other than red lead, over it. But red lead is not the only first coating which may be used. Any good paint may be used—a good graphite paint, or other carbon paint, or some of the varnish-like coatings containing linseed oil and asphaltum which are made for the purpose. It is important, in using any of these, to let plenty of time for drying elapse between coats. Not less than two coats is permissible, and three are desirable.

Projecting angles, edges, and bolt and rivet heads are the places which first show rust through the paint. This is partly because the brush draws the paint thin at such places. To overcome this, it is now becoming common practice to go over the work after the first coat, and paint all edges for about an inch from the edge or angle, and all bolt and rivet heads, with an extra or striping coat; then, when the second coat goes on over the whole, there is the equivalent of two full coats everywhere.

Painting on iron, as on wood, should be done in dry weather, when it is not very cold—at any rate not below 50° F. Full, heavy coats should be used, and well brushed on. Care must be taken to get the paint into all cracks and corners.

VARNISH

A varnish is a liquid made to be applied to a surface in a thin film, which, on exposure to the air, hardens into a protective coating that is usually glossy and almost transparent. There are two principal classes—*spirit* and *oleo-resinous varnishes*.

Spirit varnishes, of which *shellac** is the most important, are made by dissolving a resin (or sometimes some other substance) in a volatile solvent, such as alcohol. They dry by evaporation, the solvent going off and leaving the resin spread out in a thin film, the liquid or vehicle having really served as a mechanical means of spreading the resin over the surface. Shellac is a resin which comes on the market in large, thin flakes. It may be dissolved in denatured (or any other) alcohol in the following manner:

Put the alcohol in an earthenware jar, and weigh out five pounds of gum shellac for each gallon of alcohol. Just before leaving at night, carefully and gently drop the shellac, little by little, into the jar of alcohol, then put on the cover and leave it until morning. Do not on any account stir it. In the morning the flakes of shellac will be soaked and swollen; but if you had stirred them in, the night before, they would have stuck together in lumps. Now, during the day, stir the mass with a wooden stick once every hour or so; do not put any metal in it, especially iron; one iron nail will spoil the color of a whole barrel of shellac. By the next morning—perhaps before—the shellac will be ready for use. It does not make a clear solution, because the gum shellac contains some wax, which does not dissolve, and so the varnish is milky or cloudy; it is, however, ready for use. As the alcohol is volatile, the jar should be kept covered; and after it is made, the varnish should be put in glass bottles or clean tin cans.

There are many grades of shellac gum, the best being known by the letters D C; but there are others nearly as good. The common shellac is brownish yellow, and is called *orange shellac*; this is the natural shellac color. White shellac is made from this by bleaching with chlorine; but it is not of so good quality as the unbleached; it has, of course, the advantage of being much paler in color. White shellac gum will, on long standing, sometimes become insoluble. Shellac

* [illegible]

varnish may be thinned with alcohol, and often this is necessary. Shellac is too often adulterated with common rosin, which greatly lessens its value. This is easily detected by a chemical test.

Damar is a white resin which is soluble in spirits of turpentine—five or six pounds of resin to a gallon of turpentine. It is the most nearly colorless varnish we have, but never becomes very hard. It is used to a considerable extent as a vehicle for white lead and zinc, to make a very white enamel paint. It is not durable if exposed to the weather.

More important than spirit varnishes are the oleo-resinous varnishes, which consist of certain resins dissolved in linseed oil, the mixture being thinned with turpentine or benzine. In making these, the resin is put in a copper kettle and heated until it is thoroughly melted; then some hot oil is added to it, and the mixture cooked until the whole is thoroughly combined. The kettle is then taken from the fire, and when partly cool, the turpentine is stirred in. The resin makes the film hard and lustrous, and the oil makes it tough. Thus the larger the proportion of resin, the harder and more brilliant will be the film; the larger the proportion of oil, the tougher, more elastic, and more durable it will be, and the slower it will dry. Most of the color of varnish comes from the resin; the paler this is, the paler will be the varnish. The pale gums are higher in price than the dark ones, but are no better in any respect except color. Dark varnishes may be just as good (except in color) as pale ones—in fact may be better, for the dark resins are often harder and better than the pale ones of the same sort. The hard and quick-drying varnishes are suitable for furniture; the medium, for interior house-varnishes; the slow and elastic, for exposure to the weather.

Varnishing. The wood should be dry. For this reason it is better, if necessary to clean it, to avoid washing as much as possible, using sandpaper instead, which will also make it smooth. Of course the carpenter is supposed to do this, but the painter must not neglect it on that account. When in proper condition, it first receives, if it is an *open-grain* wood, a coat of paste filler. The open-grained woods in most common use are oak, chestnut, and ash. The woods classed as *close-grain* woods are white pine, maple, birch, yellow pine, whitewood, cherry, and sycamore. These latter do not need filling. If filler is used, it should be well rubbed in with a short, stiff brush; and when it has set, say in fifteen to thirty minutes, it is rubbed off with a handful of excelsior, rubbing across the grain, and rubbing hard, so as to force the filler well into the pores of the wood. Then it should stand 24 to 48 hours.

When purchased, a paste filler is too thick to be used with a brush, and must be thinned with turpentine or benzine; at the same time it may be stained to any desired color with an oil or varnish stain. These stains can be purchased of any desired color. If a close-grained wood is under treatment, the first thing is to apply a stain if it is desired to stain the wood; but it is common practice to finish in the natural color. Stains usually require a good deal of thinning before using; the amount of thinning will determine the depth of color. Water stains are seldom used, as they tend to raise the grain of the wood.

In cleaning off the filler, be careful to clean out corners and mouldings, using for this purpose, properly shaped hardwood sticks; do not use any steel tool.

Where rooms are to be finished in the natural color of the wood, it is nevertheless a common practice to stain the window-sashes; a cherry or light mahogany stain is often used. Fillers are sometimes used on close-grain woods; but this is not advisable, as they tend to prevent the varnish from getting a good hold on the wood.

Next comes the varnishing. Window-sills, jambs, inside blinds, and other surfaces exposed to the direct rays of the sun, are to be treated as exterior woodwork, and are not varnished with the ordinary interior varnish used on the rest of the work. The floors also are left out of account for the present. The rest of the woodwork receives its first coat of varnish; apply it, as much as possible, with the grain of the wood, brushing it out well in a thin coat. The varnish ought to dry dust free (*i.e.*, so that dust will not stick to it) over night; but at least five days should elapse between coats. When dry, it should be rubbed with curled hair or excelsior enough to remove the gloss, so that the next coat of varnish will adhere properly; a better result will be had if it is lightly sandpapered with 00 paper. The second coat is treated like the first. The third is not sandpapered, but rubbed with curled hair; the fourth or finishing coat may be left with the natural gloss, or, if preferred, it may be rubbed with fine pumice and water to a smooth, dull surface. For this purpose the varnish dealers sell felt about an inch thick, which is well wet in clean water, a little dry pumice powder is put on it; and the rubbing is done with this. The varnish must be quite hard and dry before this is attempted. Varnishing, if properly done, is slow work; that is, much time must be allowed for each coat to dry thoroughly.

The varnish which is used on interior woodwork should not dry too quickly; it should dry enough over night so that dust will not stick to it, and in twenty-four hours should be hard enough to handle freely; but if a chair, for example, were varnished with it, it would not be entirely safe to sit on it for a week. It should, however, finally become perfectly free from tack, which it will not do if it is a rosin varnish. At present prices (and it is not probable that they will ever be lower) varnishes for interior woodwork are sold, according to color and quality, at prices ranging from $2.50 to $4.00 a gallon. It is in the highest degree inadmissible to use a cheap varnish for undercoats; the outer coats will crack if this is done. A good varnish that dries too quickly, such as what is called a *rubbing varnish*, or one intended for furniture, has not the durability needed for this work. It is economy to use a good varnish. The writer has in mind a house which was properly varnished eighteen years ago and has been constantly occupied by a large family, yet the varnish is still in fair condition; if it were lightly sandpapered and one new coat applied, it would be like new—as good as it is possible for a surface to be. Cheap rosin varnishes never look well, even when new, never keep clean, and deteriorate rapidly.

Shellac. Interiors are sometimes finished with shellac. This varnish is not used on exterior work, but it is a good varnish for interiors. All varnishes containing oil darken the color of wood; but white shellac is comparatively free from this objection; at any rate it does it less than anything else. Orange shellac is a dark varnish, and even white shellac darkens with age to an appreciable degree. Orange shellac is more durable than white, and should be used wherever admissible, rather than white; but it is usually necessary to use white shellac for this service. If shellac is made up as heavy as has been described—five pounds to a gallon of alcohol, and this is the standard—it should be thinned considerably with alcohol before using on interior woodwork. It must be applied in thin coats, and given plenty of time to dry. It is very deceptive about this; it appears to be dry and hard in an hour, and it is hard enough to handle freely; but if we apply coat after coat, even six hours apart, we shall find that the wood is finally covered with a waxy mass which will be the source of nothing but trouble. The first coat sinks rapidly into the wood; a second coat may be applied six hours later; but after that, allow two days at least between coats. Shellac makes a very thin coat; so it is necessary to apply a large number of coats, at least twice as many as of oleo-resinous varnishes, to get a sufficient thickness of coating. Because of this labor, shellac is an expensive finish; but it is handsome and durable. The treatment of it, as regards rubbing, etc., is the same as has been described for other varnish.

Varnish makers usually advise that shellac should never be used as a priming coat for other varnish; this is probably because they wish to sell more of their own goods, for shellac is really an excellent first coat, except for exterior work, where it should not be used. Of course, wood should be filled before shellacking, the same as for other varnish. Varnish does not, however, wear well over a heavily shellacked surface. Shellac makes a good floor varnish, discoloring the wood very little, and wearing fairly well. After the floor has been well varnished with it, very thin coats, applied rather frequently—say every one to four months, according to use—will keep the floor in fine condition; and after applying one of these thin coats (of thinned shellac), it will be dry enough to use in an hour. This can be applied with a very wide, flat brush, and a man can go over the floor of an ordinary room in a few minutes. Shellac brushes should be washed out with alcohol immediately after using.

Exterior Varnishing. Varnishes dry much more rapidly out of doors than within, so that it is practicable to use more elastic and durable materials. The conditions, in fact, are so severe that the best are not good enough. In the first place, do not use any filler on exterior work; it will probably crumble and come out. Do not use shellac; as an undercoat exposed to the hot sun, it will soften and blister. Use only the best *spar varnish*, such as is made for varnishing the spars of yachts; fill the wood with it; sandpaper lightly between coats, just enough so that each succeeding coat will take hold well; finish with a coat well flowed on; and leave it with its natural gloss, which is more lasting than a rubbed surface. This is the treatment for hand-rails, outside doors, inside blinds, window-sills and jambs, and everything exposed to the direct sun. Hand-rails and outside doors should be refinished every year; varnish will not last on an outside door more than one-twentieth as long as it will on an inside door. Never use interior varnish for outside work.

ENAMEL PAINTS

Varnishes are all more or less brownish yellow or yellowish brown. Therefore a coat of varnish applied over a paint obscures and changes its color to some extent. To overcome this as much as possible, the varnish, instead of oil, is mixed with the pigment, as a vehicle. In this way the pigment comes to the surface and displays its color. These paints, if made with good varnish, are durable; the method of application has already been described. If necessary to thin them, do it with spar varnish instead of oil; a good interior varnish may be used, but it injures the flowing quality of the paint somewhat.

White lead and zinc are sometimes mixed with damar varnish. This makes the whitest enamel paint, but it never gets very hard, never has much luster, and is not very durable. It is very white, is easily applied, and dries quickly.

A NEW VARNISH FINISH

A method of finishing open-grained interior woodwork, which has been practiced for a few years, consists in first staining the wood with a water-stain—dyeing it, usually—and then, when it is dry, filling the pores of the wood with a paste filler which has been colored by the addition of a pigment. For example, the wood may receive a stain of any dark color, and the wood-filler be mixed with white lead. This shows the open or porous part of the grain in white on a dark background. By using artistic combinations of color in the stain and filler, very beautiful effects can be produced, and this finish has been used in some of the most handsome and costly public and private buildings. Thus, if a room is to be decorated in green, the woodwork can be made to harmonize with the prevailing color. An oil stain must not be used on the wood, as it will not work well with the filler. The colored filler is applied and rubbed off in the same way that any paste filler is used, and then the varnish is applied over it in the usual way.

FLOOR FINISHING

The primary trouble with floors is that people walk on them. If they did not, there would be no trouble at all. Four coats of varnish, or even paint, having an aggregate thickness of less than one one-hundredth of an inch, will not last indefinitely under the wear of individual heels.

Probably the simplest treatment for floors is painting them. The paint should contain a large proportion of a hard oleoresinous varnish; an ordinary oil paint is not hard enough. If an oil paint is used, it must be heavily charged with dryer, for a floor paint should dry in twelve hours. Good quick-drying floor paints are in the market.

Floors of choice wood, however, are not usually painted; they may be either varnished or waxed. If they are of oak or other open-grained wood, they must be filled with a paste filler; otherwise the varnish is applied directly to the wood. Floor varnish is quicker in drying, and harder than interior finishing varnish, but should not be so hard as to be brittle; rubbing varnish is too hard. If the floor is to be stained, this is done with an oil stain before varnishing; if it is a floor which has previously been varnished, so that the stain will not penetrate the wood, the stain may be mixed with the varnish, although the effect is not then so good.

Floor wax is not made of beeswax, but of a harder vegetable wax, and is sold by all paint dealers. The floor should receive one coat of shellac; then the floor wax may be rubbed on with a stiff brush, and when it is dry, which will be in a few hours, it may be polished by rubbing with a clean cloth or with a heavy, weighted floor brush made for the purpose. It should receive another coat every week until four or six coats have been applied; after this a little of the floor wax, thinned if necessary with turpentine, should be applied often enough to keep the floor looking well. Alkalies dissolve the wax, and in cleaning the floor only a little soap should be used in the water with which the floor is washed. A wax finish kept polished with a polishing brush, is the handsomest surface than can be obtained for a floor; but it is so slippery that it is somewhat dangerous. It does not discolor the wood. Interior trim (but not hand-rails) is sometimes wax-finished. This finish requires a good deal of care, as it is likely to catch dust; otherwise it is handsome and durable.

Old floors which require cleaning and revarnishing should have the old varnish or paint removed by a good varnish-remover, one of the modern sort, free from alkali. This is painted over the surface, and after a short time, removed with a scraper. The last of the varnish-remover is taken out with a rag wet with turpentine or benzine, care being taken that there is no fire of any sort in the room or any neighboring room. This will not only take off the old varnish, but the old filler also; and the floor must be treated like a new floor. Any stains on the floor may be treated with a hot solution of oxalic acid, one part to ten of water; when the stains disappear, wash well with clear water; let the floor dry a day; sandpaper; and it is ready for varnishing again. This treatment—removal of old paint or varnish by a liquid varnish-remover—is applicable to all varnished or painted work. The outside of a house could have the old paint taken off in this way, but *burning off* is cheaper and quicker. These varnish-removers are mixtures of benzole, acetone, alcohol, and other liquids, and the best of them are patented.

ALUMINUM AND BRONZE PAINTS

Radiators and pipes are often painted with aluminum or bronze paints. These consist of metallic powders, in fine flakes, mixed with some varnish—usually with a pyroxylin varnish, which is a thin solution of a variety of gun-cotton in a suitable solvent, generally acetate of amyl. If one of these paints—which smell somewhat like bananas—becomes thickened in the can by evaporation, it can usually be thinned with acetate of amyl, if some of the special thinner cannot be had; brushes can be washed out in the same. A good aluminum paint is durable, even exposed to the weather. One coat is usually enough, two certainly so.

GLAZING

House painters are usually expected to understand the art of setting window-glass; it is not difficult to learn. Glass is classified as *sheet* or *cylinder glass* and *plate glass*. Sheet glass is made, at the glass works, by blowing a quantity of glass, first, into a hollow globe; then, by more blowing and manipulation, this is stretched out into a hollow cylinder perhaps a foot in diameter and five feet long; this cylinder (whence the name "cylinder glass") is cut open, and, after reheating, is flattened out into a sheet, whence the name "sheet glass;" after annealing, it is cut up into convenient sizes. It is made of two thicknesses—*single thick*, which is about one-sixteenth of an inch, and *double thick*, one-eighth of an inch; but it does not run perfectly uniform. All sheet glass contains streaks, bubbles, and specks of dirt, and is more or less irregular or wavy in its surface; and in respect to this it is graded as first, second, and third quality; in American glass these grades are usually marked "AA," "A," and "B;" and anything poorer than "B" is called *stock sheets*. Foreign glass is not thus marked, each maker having his own arbitrary marks. Single-thick glass is used for sizes not greater than about 28 by 34 inches; double-thick, up to 40 by 60. For larger sizes, plate glass only is used; but of course either plate or double-thick can be used for small sizes, if desired.

Plate glass is cast in plates; the liquid glass is poured out on an iron table, about 15 feet wide and 25 feet long, and smoothed down to a uniform thickness of half or five-eighths of an inch by passing a roller over it, like rolling pie-crust; after this it is ground down with sand, emery, and polishing powder to a quarter or five-sixteenths of an inch in thickness. It is therefore much more costly than sheet glass, but is also more perfect.

Crystal is a very thin plate glass, about one-eighth of an inch thick, and is used where ordinary plate is too heavy, as in movable sash. It is the finest of all window glass. There are two grades of plate glass, known as *glazing* (for windows) and *silvering* (for mirrors), the latter being the best. In the first place, the sash is prepared for the glass. It must receive a priming coat; if it is to be painted, it is primed with white lead and boiled linseed oil, the mixture having very little or no turpentine added; if it is to be varnished, it is primed with boiled oil alone. If it is not primed, the putty will not stick; the wood will draw the oil out of the putty and leave it crumbly. Next, the glass is fitted to the sash. It is cut either with a glass-cutter's diamond or with a wheel cutter, the latter being a little sharp-edged steel wheel set in a handle. If well made, the wheels may be bought separate and are replaceable. The wheel cutters are generally used on sheet glass, but plate glass is cut only with a diamond, which makes a deeper cut. The wheels are kept wet with kerosene; the workman has a little bottle or cup of kerosene on the bench, and dips the wheel in it.

The glass being cut to the right size, a layer of putty is spread, with the putty-knife, along the [illegible] in the sash to [illegible] the glass [illegible] rest. This is called *bedding* the glass, and should always be done. It is not uncommonly omitted with pine sash; but it absolutely must be done with all hardwood sash, metal or metal-lined sash, and for all plate and crystal glass; and it ought to be done in all cases. Then the glass is gently pressed into place, after which it is fastened with *glaziers' points,* which are triangular bits of metal. No. 2 points are used on single-thick, and No. 1, which are larger, are used on double-thick glass; they are put in 9 to 12 inches apart. They are driven, not with a hammer, but with the thin side of a two-inch chisel, the flat side of which lies on the glass, the edge of the chisel away from the surface so as to avoid scratching it. The chisel is also useful for adjusting the position of the pane; if it is smaller than the sash, it is so placed that when the sash is in its natural upright position the pane of glass will rest with its lower edge bearing on the wood. The points are commonly of zinc, which bends easily; and when the pane is properly placed, if there is on one side a space between it and the wood, the chisel is held over this crack, and with its edge an indentation or crimp is made in the little triangular zinc point which has already been driven; this crimp prevents the glass from sliding back against the wood. This is the reason zinc is used for the points; it will bend. Steel points are sometimes used for plate glass, because of their greater strength, the glass being heavy. To drive through the sheet metal of metal-covered sash, steel slugs are used; these are about $\frac{1}{20}$ inch thick, about $\frac{7}{8}$ inch long, and $\frac{7}{16}$ inch wide at the wide end, triangular, and sharp-pointed.

There is a machine for driving points, but it is not much used except on small glass set in soft-wood sash.

The glass being properly secured by points, it is ready for puttying. To do this, the professionals set the sash up in a nearly vertical position on an easel; the glass is puttied on the right-hand side and across the bottom; then the sash is turned the other edge up, and the operation is repeated. This finishes the work.

The most important things about glazing are to use a sufficient number of points and to use good putty. Ordinary (pure) putty is made of whiting, which is pulverized chalk, mixed with enough linseed oil to give it the consistence of stiff dough. The workman can make it from these materials with his hands; everyone can make his own putty. As a matter of fact, however, the putty of commerce is made by machinery; and also, as a matter of fact, it is in general abominably adulterated. It would seem as though whiting and linseed oil were materials cheap enough; and in reality putty can be sold for about three cents a pound, or sixty dollars a ton; and a dollar's worth will putty all the glass in an ordinary house. Pure putty, however, is almost impossible to get. Marble dust is substituted for whiting, and a mixture of rosin and mineral oils for the oil, and the cost reduced about half. It is the use of this miserable stuff which causes nine-tenths of the troubles with windows. If the glazier cannot be sure of his putty otherwise, he should make it himself.

The best putty for glazing is a mixture of pure whiting putty with one-tenth white lead putty. This makes it set a little more quickly, and it becomes harder. Pure white lead putty gets too hard; it is too difficult to remove it in case of breakage of glass.

If the glass has not been bedded in putty, it is customary to go around the indoors side of the glass, and crowd some putty into the crack between it and the sash. This is called *backing* the glass. Large plates of plate glass are not puttied, but are held in place with strips of moulding nailed on the sash, in which case the crack between the glass and the moulding is backed with putty.

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for College, Civil Service, or Engineer's License. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRIC WIRING

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1. Explain the three-wire system of wiring.

2. In case a test shows excessive leakage, or a ground or short circuit, how would you locate the trouble and remedy it?

3. Describe the construction and use of outlet-boxes.

4. What is the principal difference between alternating and direct-current circuits, so far as concerns the wiring system?

5. Compare the advantages of the two-wire and three-wire systems of wiring.

6. Under what general heads are approved methods of wiring classified?

7. A single-phase induction motor is to be supplied with 25 amperes at 220 volts; alternations 12,000 per minute; power factor .8. The transformer is 200 feet from the motor, the line consisting of No. 4 wire, 9 inches between centers of conductors. The transformer reduces in the ratio $\frac{2,500}{250}$, has a capacity of 30 amperes at 220 volts, and, when delivering this current and voltage, has a resistance E. M. F. of 2.5 per cent, and a reactance E. M. F. of 5 per cent. Calculate the drop. (Use table and chart.)

8. What are the distinctive features of the different kinds of metal conduit?

9. Suppose power to be delivered, 300 K. W.; E. M. F. to be delivered, 2,200 volts; distance of transmission, 15,000 feet; size of wire, No. 00; distance between wires, 24 inches; power factor of load, .7; frequency, 100 cycles per second. Calculate line loss and drop in per cent of E. M. F. delivered. (Use table and chart.)

10. In installing A. C. circuits, what requirements are insisted on as to the placing of conductors in conduits?

11. Describe the manufacture, use, and special advantages of the different kinds of armored cable.

12. Describe three different methods of testing? Which is to be preferred?

13. What conditions determine whether a two-wire or three-wire system of wiring should be used?

14. In locating cut-out cabinets and distributing centers, what requirements should be fulfilled?

15. What is "knob and tube" wiring? Explain its use and discuss its advantages or disadvantages.

16. How far apart should insulators be placed?

17. What tests should be made before an electric wiring equipment is finally passed for acceptance? Give reasons.

18. What regulations govern the use of fibrous tubing?

19. What is meant by mutual induction?

20. What are the advantages and disadvantages of overhead linework as compared with underground linework?

21. Describe and illustrate by sketches proper methods of supporting and protecting conductors.

22. Discuss the advantages of running conductors exposed on insulators.

23. Illustrate by diagram, proper and improper methods of grouping conductors of two two-wire circuits.

24. What dangers are inherent in the use of moulding? What precautions should be taken to avoid them?

25. Describe the proper methods of laying out branch circuits, (*a*) in fireproof buildings; (*b*) in wooden frame buildings. Give sketches.

26. What methods of installing wiring are best adapted for the following classes of buildings, (*a*) fireproof structures; (*b*) mills, factories, etc.; (*c*) finished buildings; (*d*) wooden frame buildings?

27. What is skin effect? Its bearing on the problem of wiring?

28. In selecting runways for mains and feeders, what precautions should be taken?

REVIEW QUESTIONS

ON THE SUBJECT OF

ELECTRIC LIGHTING.

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1. State the current, voltage, candle power, and efficiency of the incandescent lamp most commonly used.

2. What do you understand by the "smashing point"?

3. Give the main points of difference between the three forms of arc lamp mechanism.

4. Mention the three principal parts of the Nernst lamp.

5. Describe with sketch the anti-parallel system of feeding.

6. Prove the law that illumination varies inversely with the square of the distance.

7. Why is arc light photometry a more difficult problem than incandescent?

8. Calculate the illumination three feet above the floor at the center of a room 18 feet square and 12 feet high, lighted by four 10-candle-power lamps 9 feet above the floor at the center of the side walls, assuming the coefficient of reflection to be 50%.

9. What material is used for the filament of incandescent lamps? Explain why.

10. From the curve given in Fig. 4, determine the efficiency which corresponds to the temperature of 1300° Centigrade.

11. What is the object of double carbons in an arc lamp?

12. What is meant by mean spherical candle power?

13. What is the function of the heater in the Nernst lamp?

14. Describe the Bunsen Photometer.

15. How does the lighting of public halls differ from that of residences?

16. Why cannot platinum wire be used for the filament of incandescent lamps?

17. In a direct-current arc lamp, which carbon burns away the more rapidly?

18. How are arc lamps rated?

19. What are the important advantages of the two-wire parallel system of distribution?

20. Name and describe the most desirable standard for photometric measurements.

21. How many measurements should be taken in the determination of spherical intensity?

22. What is meant by flashing? Explain.

23. Define emissivity.

24. If the voltage of an incandescent lamp be increased 4% above normal, what is the effect on the candle-power, efficiency and light?

25. Explain the Cooper-Hewitt lamp, stating the two methods of starting.

26. Compare the open and enclosed arc lamps.

27. Why is the positive carbon placed above the negative in a direct-current arc lamp?

28. Sketch and name the different forms of incandescent lamp filaments.

29. Under what conditions can a 3.1-watt incandescent lamp be used?

30. What is the function of the arc lamp mechanism?

31. What are the advantages of the three-wire system?

32. Why is it necessary to exhaust the bulb of an incandescent lamp?

33. At what point in their life should incandescent lamps be replaced?

34. What is the object of a resistance in series with the arc lamp in constant-potential direct-current systems?

35. Name the advantages of the Nernst lamp.

36. What sort of lamps and of what candle-power should be used in residence lighting?

37. Give the characteristics of the Cooper-Hewitt lamp.

38. What will be the external resistance on a 110 volt constant-potential system, if the load consists of 437 lamps of 16 candle-power?

REVIEW QUESTIONS

ON THE SUBJECT OF

PLASTERING

1. Describe the proper method of spacing, nailing, and joining wood lath.

2. Of what materials is mortar composed? What are the requirements of each to insure good results?

3. Compare the relative advantages of metal and wood lathing for both interior and exterior plastering.

4. How are estimates for lathing and plastering made?

5. What precautions are absolutely necessary in the placing of metal lath?

6. If wood lathing is used on exterior work, how should it be laid?

7. When, if ever, is wire lath preferable to expanded metal?

8. Describe in detail the process of slaking the lime and mixing the mortar for ordinary interior plaster work in dwelling-houses. What precautions are to be observed?

9. Should mortar be used as soon as mixed? Discuss this question in all its bearings.

10. How would you mix the mortar for exterior work?

11. If lime is not thoroughly slaked, what trouble is likely to develop?

12. What will be the effect of using too much lime in mixing mortar? too much sand?

13. What are the essentials for durable exterior plastering?

14. Discuss the relative advantages of three-coat and two-coat work. In what kind of work are three coats always necessary?

15. In interior work, what precautions must be observed in laying the successive coats of plaster? In exterior work?

REVIEW QUESTIONS

ON THE SUBJECT OF

PAINTING

1. What is the difference between raw and boiled oil? When is one preferable to the other?

2. What would you consider a good brush outfit for painting and varnishing the interior woodwork and exterior finish of a modern frame dwelling?

3. How would you make your own putty if you could not buy a satisfactory grade?

4. Describe the principal ingredients used as *pigments*. As *vehicles*.

5. What are *thinners? Dryers? Fillers?*

6. How are painters' brushes kept in good condition?

7. How are paints adulterated?

8. Describe the process of mixing the successive coats of paint for ordinary interior (not floor) and exterior woodwork.

9. Describe the process of preparing the woodwork and applying the successive coats of paint in ordinary interior (not floor) and exterior work.

10. What points require particular attention in the repainting of an old job?

11. Describe the process of painting a plastered wall.

12. Describe the material and methods of work in roof painting.

13. What is enamel paint? How would you do a job of enameling the woodwork, say, in a bathroom?

14. Describe in detail the process of painting structural metal.

15. How are varnishes classified?

16. Describe the method of preparing and applying shellac varnish.

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