ESTIMATING
Sheet Metal Work

Tells in plain English how to figure the proper sizes of articles, how to take off the material required from the plans of any sheet metal job, how to buy material and cut it to advantage for different work, how to figure the actual overhead expense for any department, or kind of work handled, in your own shop, and explains the special risks to be considered in making bids, financing, etc.

By

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PREFACE

THE term "Estimating" in its general application means valuation of work or merchandise, based on no definite knowledge of cost. When the exact cost is known, the value can be stated instead of being "Estimated." Estimating, therefore, is employed before doing the work, while after the completion of the work, when values are known, the "Cost is determined."

It is generally necessary in conducting a business undertaking, to estimate or determine an approximate charge for work, when the exact values are not known. The estimator must therefore have an intense practical knowledge of the trade and should also be acquainted with the estimating methods which are employed, to determine the exact cost of business transactions, so as to be able to compile records of cost which give a positive basis for estimating of similar work to be performed thereafter.

The Authors have presented in this book all phases of estimating Sheet Metal Work employed by them during their many years of practical connection with the trade. In the first chapter of this book are explained geometrical and mathematical principles which should be understood by the estimator in order to be able to determine safely and scientifically the amount of material required.

In the following chapters of this book the application of these principles is shown on Sheet Metal Work of different nature, and all examples are taken from actual work performed.

Estimating is generally done for the purpose of determining "Selling or Charge Prices." While these are often influenced by the "Market" or the extent of "Competition," an exact knowledge of the cost is required if one wishes to know whether the job has been carried through with "Profit or Loss."

From the standpoint of the mechanic the cost of labor and material determines the cost of the job. From the standpoint of the business man, however, another very important item has to be added, namely: "Cost of Transacting Business," generally termed "Overhead Expenses." Beginning with Chapter XII, the customary method of finding the correct amount of overhead expense on a scientific basis is explained and application of this method shown in many examples taken from various branches of the Sheet Metal Trade.

The Authors have endeavored to explain the underlying scientific principles in plain language, so that they can be readily understood and correctly applied by anyone not familiar with the higher accounting methods.

To the man engaged in the conduct of the Sheet Metal Business, this book is presented as a manual for profitable business management. The experienced estimator should also find herein many valuable suggestions.

ADOLF HOPP.

October, 1921.

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CHAPTER I

MENSURATION AS APPLIED TO SHEET METAL WORK

A subject about which very little has been written is that of taking off quantities from architects' plans of sheet metal work used in building construction. While there are many first-class mechanics who can lay out the work, still they lack the knowledge necessary to figure the quantities from scale drawings. There are certain preliminary rules which must be observed, such as are used in mensuration, and while this part may seem simple to experienced estimators, it is necessary that it be thoroughly understood, therefore the first part of this book should be carefully studied and a few additional problems are here introduced as a preliminary step to the subject.

To become a good estimator one must be accurate in figures, for in large concerns much depends upon the estimator whose word is taken that all quantities have been accurately taken from architects' drawings before putting in the bid. A mistake on his part on a large contract is apt to run into thousands of dollars. The writer has in mind an estimate sent out on a large public school where the metal ventilation ducts were omitted in the wings, thereby causing an error in the bid of over $3,000. This is only one instance showing that accuracy is essential no matter how small or how large the contract may be.

The ability to estimate is the dividing line between the journeyman and the master. No matter how good or skilful a mechanic may be, he will never be able to open up his own shop and invite patronage in his line of work until he is able to make reliable estimates from architects' plans. To do this, experience and judgment are necessary; also an understanding of the more or less complicated plans which make up part of his work. A knowledge of current prices and discounts to the trade is also required. Price lists and catalogs of the various materials used should be kept at hand for ready reference, as they very often contain a great deal of specific information.

The only sure and correct method of estimating is by taking off the actual quantities in detail and carrying out the prices accurately, with the cost of labor, overhead expenses and profits. Accurate and complete drawings and specifications are necessary, the first (the drawing) to give the absolute quantity and the second (the specifications) to give the quality of material and labor. The various items should be taken off, similar portions grouped, the amount of labor estimated, and a complete schedule prepared and priced at current rates, cost of transportation, labor, expenses and profits, and the total sum reached should be correct if faithfully done.

LENGTH

One of the first problems arising in the shop is to find the true length of material required for round or other shaped pipes. The rule for obtaining the circumference of any circle is to multiply the diameter by 3.1416, or, as is sometimes used in practice, by 3 1-7.

Length of Material for Round Pipe

In Fig. 1, A represents a circle 4 inches in diameter. Then 4 inches $\times$ 3.1416 = 12.5664, or $12\frac{9}{16}$ inches approximately, the circumference, as shown rolled out from *a* to *b*.

To readily find the decimal equivalent to the fractional

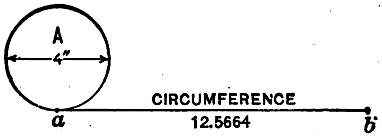


Fig. 1.—Finding Length of Material Required for a Round Pipe

parts of an inch, a table is given that can be used in all of the following problems.

Decimals Equivalent to the Fractional Parts of an Inch When Divided Into 32 Parts

Decimals	Parts of an Inch	Decimals	Parts of an Inch
.03125	1/32	.53125	1/2 and 1/32
.0625	1/16	.5625	1/2 and 1/16
.09375	3/32	.59375	1/2 and 3/32
.125	1/8	.625	5/8
.15625	1/8 and 1/32	.65625	5/8 and 1/32
.1875	1/8 and 1/16	.6875	5/8 and 1/16
.21875	1/8 and 3/32	.71875	5/8 and 3/32
.25	1/4	.75	3/4
.28125	1/4 and 1/32	.78125	3/4 and 1/32
.3125	1/4 and 1/16	.8125	3/4 and 1/16
.34375	1/4 and 3/32	.84375	3/4 and 3/32
.375	3/8	.875	7/8
.40625	3/8 and 1/32	.90625	7/8 and 1/32
.4375	3/8 and 1/16	.9375	7/8 and 1/16
.46875	3/8 and 3/32	.96875	7/8 and 3/32
.5	1/2	1.	1 inch

Thus we have in Fig. 1 a circumference of 12.5664. In the table we find the nearest decimal to be .5625, which equals 1/2 and 1/16 or 9/16, as stated above.

Length of Material for Square Pipe

Referring to Fig. 2, let *a b c d* represent a 4-inch square. To obtain the perimeter or amount of material for this pipe, it is only necessary to multiply 4 inches by 4, which equals 16 inches. As shown from *a* to *a′*, the

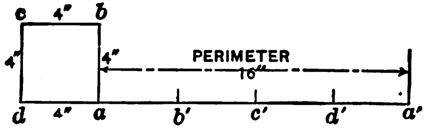


Fig. 2.—Finding Amount of Material for Square Pipe

distance represents the length of the sum of the sides of the square figure.

Length of Material for Hexagon

In the same manner the length of the perimeter of the hexagon is obtained in Fig. 3. In this each side measures 3 inches. The figure has six sides, so we have 6 × 3 inches = 18 inches, the length shown from *a* to *a′*.

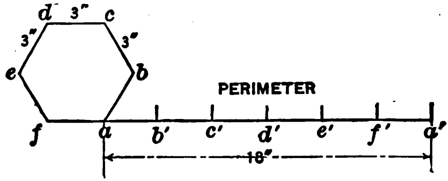
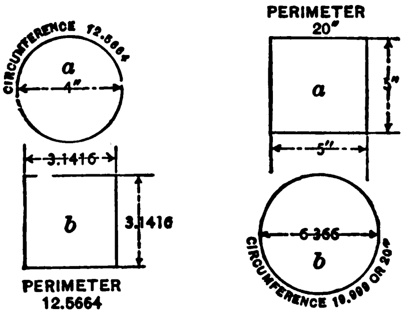


Fig. 3.—Finding Length of Perimeter of a Hexagon

Square and Circular Pipe of Given Dimensions

Sometimes a round pipe is to be formed to a square section at the opposite end, using the same amount of material as in the round pipe. This makes it desirable to know what the length of the sides at the square end will be. Knowing that the diameter of the circle *a* in Fig. 4 is 4 inches, and that the circumference is 12.5664, it is only necessary to divide by four, which will give 3.1416 inches, the length of the sides of the square *b*. If the circumference is not known, multiply the diameter by 0.7854; thus, 4 inches × 0.7854 = 3.1416 inches. This multiplied by four sides = 12.5664 inches, the perimeter for the square *b*, and is equal to the circumference of the circle *a*, proving the above rules.



Figs. 4 and 5.—Finding Square and Circular Sections of Pipe of Given Dimensions

If, however, the conditions are reversed, and each side of a given square measures 5 inches (as shown at *a* in Fig. 5), making the perimeter of the square 20 inches, and the diameter of a circle whose circumference would be equal to that perimeter is desired, multiply the length of one side, or 5 inches, by 1.2732, which equals 6.366 inches, the required diameter. Multiply this diameter, 6.366 inches, by 3.1416, and the product will be 20 inches, the perimeter of the square thus proving the rule.

Finding Length of Side of Square Inclosed by Given Circle

When double ventilation pipes are constructed, as shown in Fig. 6, where the outer pipe is a true circle and the inner pipe a square for the purpose of allowing an air space between the two pipes, and the length of the side of a square to pass inside of a given circle is desired, it is only necessary to multiply the diameter of the given pipe by 0.7071. Suppose the round pipe *a* were 6 inches in diameter, then 6 inches × 0.7071 = 4.2426, or nearly 4¼ inches, for the side of the desired square. The corners of the square will be tangent to the circle in this case.

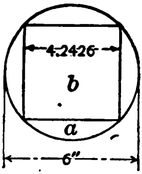


Fig. 6.—Finding length of Side of a Square to Be Inclosed By a Given Circle

Finding Length of Arc

To find the length of an arc, when only the angle and radius are known, multiply the number of degrees in the arc by the diameter of the circle and the product by 0.008727. In Fig. 7, to find the length of the 90-degree arc *a b*, whose radius is 4.5 inches, or diameter 9 inches, we follow the above rule, and have 90 × 9 = 810. 810 × 0.008727 = 7.0688 inches, the length of *a b*.

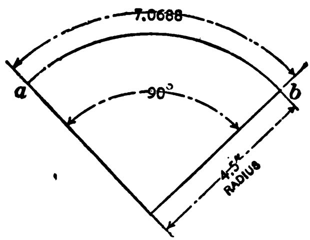


Fig. 7.—Finding Length of Arc When Angle and Radius Are Known

Circumference of Ellipse

When the length and width of an ellipse are given and the amount of material is required for its circumference, it is well to bear in mind that the circumference of an ellipse cannot be exactly determined without a very elaborate calculation, and the following formula is an approximation giving fairly close results:

$$\text{Circumference} = 3.1416\sqrt{\frac{D^2 + d^2}{2} - \frac{(D - d)^2}{8.8}}$$

Thus in Fig. 8 we have an ellipse, the major axis (D) of which is 10 inches, and the minor axis (d) is 6 inches. We would find the approximate circumference by following the above rule, $10 \times 10 = 100$; $6 \times 6 = 36$; $100 + 36 = 136$; $\frac{136}{2} = 68$. From this amount deduct $10 - 6 = 4$; $4 \times 4 = 16$; $\frac{16}{8.8} = 1.8181$; $68 - 1.8181 = 66.1819$. Now extract the square root of 66.1819 and multiply by 3.1416. $\sqrt{66.1819} = 8.1352$; $8.1352 \times 3.1416 = 25.56$ inches, the circumference of an ellipse 10 inches long by 6inches wide.

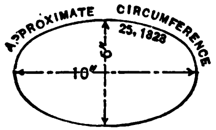


Fig. 8.—Finding Amount of Material for an Ellipse When Length and Width Are Given

A shorter method with less calculation is to add twice the length of the ellipse to the width, and the sum will give the circumference. Thus, $2 \times 10 = 20$; $20 + 6 = 26$. In this rule the error lies in giving a larger result, or .46 inch more than in the first formula.

Finding Length of Hypotenuse

When a large smoke stack is to be built at an angle, on a building, and the vertical height and horizontal projection are known, the length of the slant can be obtained by the rule illustrated in Fig. 9, which shows how the length of the hypotenuse is found in a right angle triangle, viz., add the square of the base to the square of the altitude, and the square root of the sum will be the hypotenuse. With a base of 6 inches and an altitude of 8 inches, we have $\sqrt{6^2 + 8^2} = \sqrt{36 + 64} = \sqrt{100} = 10$. The square

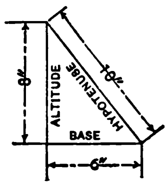


Fig. 9.—Finding Length of Hypotenuse in a Right Angle Triangle

root of 100 is 10, because 10 multiplied by itself equals 100. See page 11 for explanation of square root.

AREA

The area of any surface is the number of square inches or square feet within its outline. In connection with the illustrations immediately following, the rules are given for obtaining the areas of the various geometrical shapes, to enable the student to proceed intelligently when computing areas and capacities of various forms arising in practice. Many sheet metal workers understand how to compute the areas of the more common geometrical shapes; others do not know how to apply this branch of mathematics in practical work.

Area of Square Pipe

One of the most simple figures is the square, whose area the student usually masters first. In Fig. 10 it is shown by *a b c d*, each side measuring 9 inches. To obtain the area multiply the length of the side by itself; thus: $9 \times 9 = 81$ square inches.

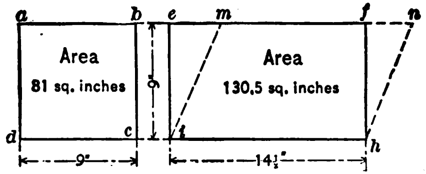


Fig. 10.—Areas in Square, Rectangle and Rhomboid

Area of Rectangular Pipe

To obtain the area of the rectangle *e f h i*, multiply the width by the length, thus: $9 \times 14.5 = 130.5$ square inches.

Area of Rhomboid

Suppose a surface had to be covered with sheet metal, the shape being that of a rhomboid, shown by *m n h i*, in which *m n* is parallel to and of the same length as *h i*; knowing the perpendicular height *e i* to be 9 inches, and the length to be 14½ inches, we would have the same area as that shown in the rectangle *e f h i*, because the triangle *f n h* equals the triangle *e m i*.

Area of Right Angle Triangle

When the area of a triangle is to be found, whether right or oblique, the base and perpendicular height being known, the rule is to multiply the perpendicular height by the base, and half the product is the area. In Fig. 11, let *a b c* represent a right triangle, whose base is 8 inches and height 12 inches; then $12 \times 8 = 96$. $96 \div 2 = 48$ square inches, the area. If the product 96 were not divided by two it would represent the area of the rectangle *a i c b*, but by drawing the diagonal *a c* we divide the rectangle into two right triangles, each equal to one-half of 96, or 48, as shown.

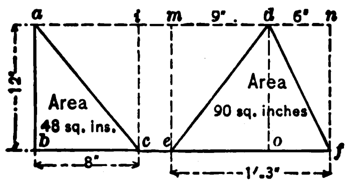


Fig. 11.—Areas in a Right and an Oblique Triangle

Area of Oblique Triangle

The diagram *e d f* represents an oblique triangle, whose base is 15 inches and perpendicular height to the apex, 12 inches. Following the above rule, we have

$12 \times 15 = 180$. $180 \div 2 = 90$ square inches area of *d e f*. To prove this, construct the rectangle *e m n f*, and from *d* drop the vertical line *d o*. The distances *m d* and *d n* are 9 and 6 inches, respectively. We then have two rectangles, one 9×12 and the other 6×12 inches, *d o e* and *d o f*. Following the explanation given in connection with *a b c*, we have $\frac{9 \times 12}{2} = 54$, and $\frac{6 \times 12}{2} = 36$; $36 + 54 = 90$ square inches, the same as the area of *d e f*.

Area of Triangle with Three Given Dimensions

Sometimes an irregular shaped structure is to be covered, and none of the angles, and only the dimensions of the three sides are known or can be obtained. The rule in this case is as follows: From half the sum of the three sides subtract each side separately; find the continued product of the half sum of the sides and the three remainders, and the square root of this product is equal to

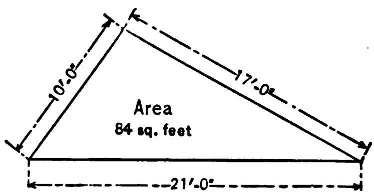


Fig. 12.—Area of Triangle When Three Sides Are Given

the area of the triangle. In Fig. 12 a portion of a surface is shown, each side measuring respectively 21, 17 and 10 feet. The sum of the three sides is $21 + 17 + 10 = 48$. $48 \div 2 = 24$, the half sum. Subtracting each side separately from half the sum of the sides, we get the three remainders, $24 - 21 = 3$ feet; $24 - 17 = 7$ feet, and $24 - 10 = 14$ feet. Now, $24 \times 3 \times 7 \times 14 = 7056$. $\sqrt{7056} = 84$.

Method of Obtaining the Square Root of a Number

The method of obtaining the square root is as follows: Pointing off the number 7056 into periods of two figures each, we get 70′56, showing that the complete part of the square root contains two figures. Then proceed as below:

Trial Divisor	Correct Divisor	Root
160	164	70′56(84 ans.
		64
		656
		656

It will be observed that the greatest number whose square is contained in 70 is 8; therefore 8 is the first root of the figure; $8 \times 8 = 64$. Subtracting 64 from 70 and bringing down the next period, 56, we get the first partial dividend, 656. The double of 8, the partial root already found, is 16, and annexing a cipher to this we get 160 as the first trial divisor. This trial divisor is contained in the partial dividend 656 four times, suggesting four as the second figure of the root. Adding 4 to 160 we obtain 164 as the correct divisor. When the product ($4 \times 164 = 656$) is subtracted from the partial dividend 656 there is no remainder. Eighty-four is the required square root, and $84 \times 84 = 7056$. The triangle in Fig. 12 contains 84 square feet, area.

Area of a Trapezoid

In Fig. 13 is shown a trapezoid, and in Fig. 14 a trapezium. The difference between the two is that the trapezoid has two sides parallel to each other, while the trapezium has no sides parallel. When computing the area of an irregular surface having two parallel sides

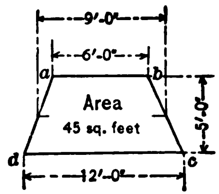


Fig. 13.—Area of Trapezoid

use the rule for obtaining the area of a trapezoid, shown in Fig. 13. Multiply half the sum of the parallel sides by the perpendicular height. Half the sum of the parallel sides in Fig. 13 is $6 + 12 = 18$; $18 \div 2 = 9$, the mean distance. Then 9×5 (the perpendicular height) $= 45$ square feet area in *a b c d*.

Area of Trapezium

In computing the area of *a d e c*, in Fig. 14, we divide it into two triangles and a trapezoid, by drawing vertical lines from the angles *a* and *d*, at right angles to *e c*. The bases of the two triangles are 4 and 2 feet, respectively, and the altitudes 8 and 12 feet, respectively; the mean distance of the trapezoid is $\frac{8+12}{2} = \frac{20}{2} = 10$. Then $\frac{8 \times 4}{2} = \frac{32}{2} = 16$, area of triangle *a b c*; $\frac{12 \times 2}{2} = \frac{24}{2} = 12$, area of triangle *d e f*; $10 \times 7 = 70$, area of trapezoid *b a d f*. Then $16 + 12 + 70 = 98$ square feet area in *a d e c*.

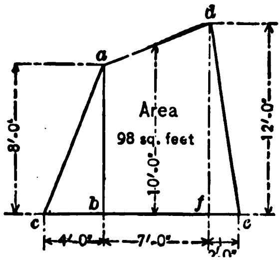


Fig. 14.—Area of Trapezium

Area of a Circle

To obtain the area of a circle, square the diameter and multiply by 0.7854. Fig. 15 shows a section of a pipe 10½ inches in diameter. To find the area, $10.5 \times$

10.5 = 110.25; 110.25 × 0.7854 = 86.59 square inches. Fig. 16 shows a square containing 1 square inch. The

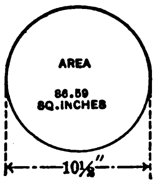


Fig. 15.—Area in Circle

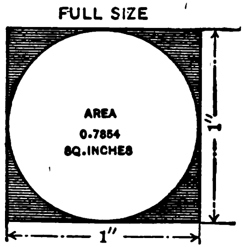


Fig. 16.—Area in Circle and Square

inscribed circle is 1 inch in diameter. Although it is 1 inch in diameter, it contains only 0.7854 square inch, the shaded part representing the missing 0.2146 square inch to complete the one square inch.

Area of a Ring

When the area of a ring is to be determined, as shown in Fig. 17, in which the outside diameter is 12 inches and the inside diameter 5 inches, deduct the square of the small diameter from the square of the large diameter and multiply the remainder by 0.7854. Following this rule, we have $12^2 - 5^2 = 12 \times 12 - 5 \times 5 = 144 - 25 = 119$; $119 \times 0.7854 = 93.462$ square inches in the ring.

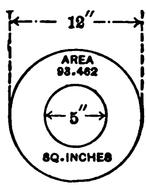


Fig. 17
Area in a Ring

Areas in Sector and Segment of a Circle

Sometimes a ventilating pipe is to be constructed, whose section is a sector of a circle, as shown by *a b c e* in Fig. 18, and it is necessary to know its area. In the illustration, the radius *e c* is $3\frac{3}{4}$ inches; the angle, *a e c*, 105 degrees, is determined by the use of the protractor; the chord *a c* is 6 inches, and the rise or middle ordinate *m b*, $1\frac{1}{2}$ inches. Before obtaining the area, it is necessary to know the length of the arc *a c*; this is obtained by the rule given in connection with Fig. 7, as follows:

In Fig. 18 we have $105 \times 7.5 \times 0.008727 = 6.872$ inches, the desired length of arc. To obtain the area of *a b c e*, multiply the length of the arc by half the radius. The radius is 3.75; $3.75 \div 2 = 1.875$. Then $1.875 \times 6.872 = 12.885$, the area of the sector.

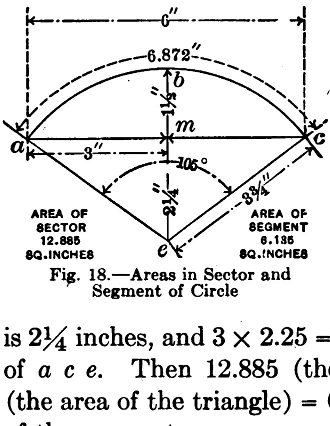


Fig. 18.—Areas in Sector and Segment of Circle

If the area of the segment *a b c a* is desired, knowing the area of the sector, it is only necessary to deduct from this amount the area of the triangle *a c e*. Thus half the distance of the chord *a c* is 3 inches, and the height from the chord *m* to the center *e* is $2\frac{1}{4}$ inches, and $3 \times 2.25 = 6.75$ square inches, the area of *a c e*. Then 12.885 (the area of the sector) $-$ 6.75 (the area of the triangle) $=$ 6.135 square inches, the area of the segment.

If the chord *a c* and the rise *m b* of the segment are given, and if the diameter of the circle of which the segment is a part is desired, divide the sum of the squares of half the chord and the rise by the rise, and the quotient is the desired diameter. Half of the chord *a c* is 3 inches, and the rise *m b* is $1\frac{1}{2}$ inches. Following the above rule, we have $3^2 + 1.5^2 = 11.25$; $11.25 \div 1.5 = 7.5$ inches, the diameter. As twice the radius *e c* equals $7\frac{1}{2}$ inches, the above rule is proven.

Area of Square Equal to Area of Given Circle and Vice Versa

It sometimes happens that a transition is to be made for a heating or ventilating pipe, from round to square, and the square end is to have the same area as the given round end. Let A in Fig. 19 represent a section of a 10-inch heating pipe; then, following the rule given in connection with Fig. 15, the area of A in Fig. 19 is 78.54 square inches. To find the dimensions of a square of equal area, multiply the given diameter by 0.8862. Thus $10 \times 0.8862 = 8.862$, or the side of the square B.

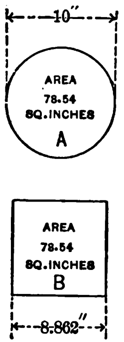


Fig. 19.—Square Whose Area Is Equal to Area of Given Circle

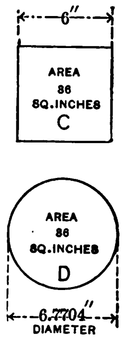


Fig. 20.—Circle Whose Area Is Equal to Area of Given Square

If, however, the conditions are reversed and the square end of the transition piece is given, say 6 inches, as shown in C, Fig. 20, then multiply the given side by 1.1284, and the product will be the diameter of a circle of equal area. Thus $6 \times 1.1284 = 6.7704$ inches, diameter of circle D.

Area of Ellipse

When the area of an ellipse is required, multiply the long diameter by the short diameter, and this product by 0.7854. In Fig. 21 an ellipse is shown whose long diameter is 14 inches and short diameter 8 inches. Then $8 \times 14 = 112$; $112 \times 0.7854 = 87.96$ square inches, area.

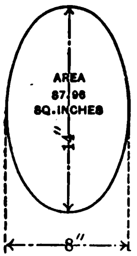


Fig. 21.—Area of Ellipse

The method for obtaining the dimensions of the opposite end of a transition piece, with one end a given ellipse and the opposite end to have similar area in either round, square or rectangular section, will be explained later in Chapter IV under the head "Piping and Duct Work."

Area of Regular Polygon

When a surface is to be covered with sheet metal whose shape is that of any regular polygon, the rule to be followed in obtaining the area is to multiply the sum of the sides by half the perpendicular distance from center to sides. For example, in Fig. 22 a regular polygon having six sides, and called a hexagon, is shown. The one side, *c d*, equals 10 inches, and the sum of the six sides, 6×10, or 60 inches. The whole perpendicular distance *b a* is 8.66 inches, which divided by two gives 4.33, or half the perpendicular distance. Then $60 \times 4.33 = 259.8$ square inches area in the hexagon.

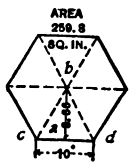


Fig. 22.—Area in Regular Polygon

CONVEX SURFACES

Surface of Sphere

When a sphere is to be made of copper or sheet iron, and it is necessary to know the amount of material it will require, the area is obtained by squaring the diameter of the sphere and multiplying by 3.1416. The sphere shown in Fig. 23 is 12 inches in diameter. To find its area, we have $12 \times 12 = 144$; $144 \times 3.1416 = 452.39$ square inches.

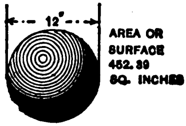


Fig. 23.—Surface of Sphere

Convex Surface of Cylinder

In Fig. 24, A is the plan of a cylinder 10 inches in diameter and B the elevation, 12 inches high. Find the convex surface of this cylinder. In this problem, as well as in others which will follow, the areas of the ends will not be considered; this was explained in previous problems. The rule for finding the area of the convex surface of any cylinder is to multiply the circumference by the height. As the cylinder is 10 inches in diameter and the height 12 inches, then $10 \times 3.1416 = 31.416$, or circumference; $31.416 \times 12 = 376.992$ square inches in convex surface.

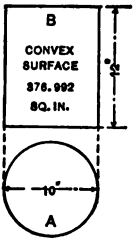


Fig. 24.—Convex Surface of Cylinder

Convex Surface of Frustum of Cylinder

In Fig. 25, A and B show the plan and elevation of a frustum of a cylinder. To obtain this convex surface, multiply one-half the sum of the greatest and least heights by the circumference. The greatest height is 18, the least 10; $10 + 18 = 28$; $\frac{28}{2} = 14$; $14 \times 3.1416 \times 12 = 527.78$ square inches, area.

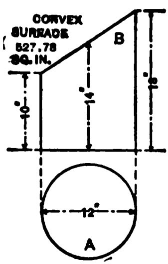


Fig. 25.—Convex Surface of Frustum of Cylinder

Convex Surface of Elliptical Cylinder and Frustum of Elliptical Cylinder

Another problem often arising in the shop is to find the convex surface of an elliptical tank. The same rule is employed as in a cylinder—that is, multiply the circumference by the height. In Fig. 26, A and B and A^1 and B^1 show, respectively, the plans and elevations of an elliptical cylinder and the frustum of an elliptical cylinder, whose long diameter is 20 inches and short diameter 12 inches.

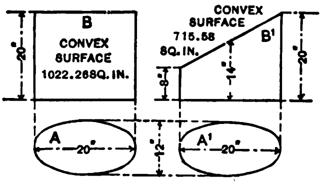


Fig. 26.—Convex Surface of Elliptical Cylinder and Frustum of Elliptical Cylinder

Following the rule given in Fig. 8 for obtaining the circumference, we have

$$3.1416\sqrt{\frac{D^2+d^2}{2}-\frac{(D-d)^2}{8.8}}.$$

Applying this rule to Fig. 26 we have

$$3.1416\sqrt{\frac{20^2+12^2}{2}-\frac{(20-12)^2}{8.8}}.$$

Thus $20 \times 20 = 400$; $12 \times 12 = 144$; $400 + 144 = 544$. $\frac{544}{2} = 272$. From this amount deduct $20 - 12 = 8$;

$8 \times 8 = 64$; $\frac{64}{8.8} = 7.2727$; $272 - 7.2727 = 264.7273$.

Now extract the square root of 264.7273 and multiply by 3.1416. $\sqrt{264.7273} = 16.27$; $16.27 \times 3.1416 = 51.113$, or the circumference of the ellipse. Then for the convex surface multiply the circumference by the height. Thus $51.113 \times 20 = 1022.26$ square inches in the convex surface B. For the frustum B[1] we have $\frac{8+20}{2} = \frac{28}{2} = 14$; 14×51.113 (the circumference) $= 715.58$ square inches. A shorter rule is to add twice the length of the ellipse to the width and find the convex surface by multiplying by the height. Thus $2 \times 20 + 12 = 52$; 52×20 (the height) $= 1040$, or a difference of about 18 square inches more than the actual surface, which is 1022.26, as shown above.

Convex Surface of Right Prism and Frustum of Right Prism

The same rules applicable to the cylinder are also applicable to prisms whose bases are regular polygons, whether they be right prisms or frustums. In Fig. 27, A and B represent, respectively, the plan and elevation of a prism 18 inches high, each side of the polygon being 6 inches. The perimeter of the hexagon is $6 \times 6 = 36$ inches; $36 \times 18 = 648$ square inches in the convex surface B. For the convex surface of the frustum, we have $\frac{10+18}{2} = \frac{28}{2} = 14$; 14×36 (the perimeter) $= 504$ square inches.

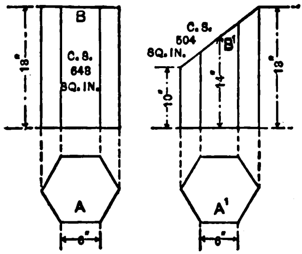


Fig. 27.—Convex Surface of Right Prism and of Frustum of Right Prism

Convex Surface of Right Cone

When the convex surface of any right cone or pyramid is desired, then multiply the circumference,

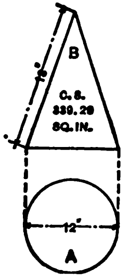


Fig. 28.—Convex Surface of Right Cone

or periphery, of base by half the slant height. In Fig. 28 A and B show the plan and elevation of a right cone, which will serve as an example. The diameter of the cone at its base is 12 inches; its circumference is therefore $12 \times 3.1416 = 37.6992$; half of the slant height is 9; then $9 \times 37.6992 = 339.29$ square inches in the convex surface of the cone B.

Convex Surface of Right Pyramid

Using the same rule for Fig. 29, whose base or plan A is a hexagon with 7-inch sides, we have $7 \times 6 = 42$; $9 \times 42 = 378$ square inches in the convex surface of the pyramid B.

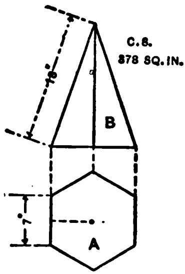


Fig. 29.—Convex Surface of Right Pyramid

Convex Surface of Frustum of Right Cone

Suppose the elevations in Figs. 28 and 29 were cut off parallel to the base, forming the frustums of a cone and pyramid. The rule for obtaining the area of these convex surfaces is to multiply the circumferences or peripheries of the two ends by half the slant height. An example of this problem is given in Fig. 30, in which the plan of the base A is 10 inches and the diameter at the top 5 inches. Then $5 \times 3.1416 = 15.708$, or circumference at top, and $10 \times 3.416 = 31.416$, or circumference at base; $15.708 + 31.416 = 47.124$; 47.124×5 (half the slant height) $= 235.62$ square inches of convex surface. To prove this problem, we will assume that we have a right cone in Fig. 30, whose base is 10 inches and slant height 20 inches. Then, following the rule given in connection with Fig. 28, we have 10 × 3.1416 × 10 = 314.16 square inches convex surface in whole cone. The area of the upper half of the cone shown by dotted lines, whose base is 5 inches, is 5 × 3.1416 × 5 = 78.54 square inches; 314.16 − 78.54 = 235.62 square inches, the area of the frustum of the cone, proving the problem.

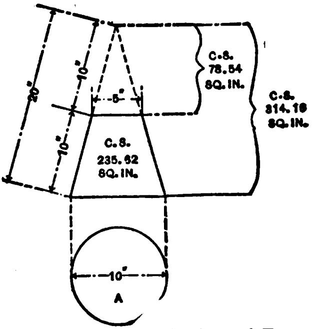


Fig. 30.—Convex Surface of Frustum of Right Cone

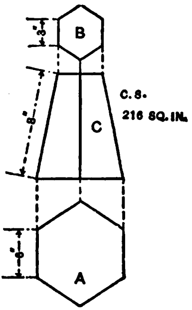


Fig. 31.—Convex Surface of Frustum of Right Pyramid

Convex Surface of Frustum of Right Pyramid

In Fig. 31, A is a regular polygon, with 6-inch sides, and the plan of the base of the frustum of a pyramid; B, the plan of the top, whose sides are 3 inches; C, the elevation, has a slant height of 8 inches. Then 6 × 6 = 36, or perimeter of base; 3 × 6 = 18, or perimeter of top; 36 + 18 = 54; one-half the slant height is 4; 4 × 54 = 216 square inches in C.

SOLID CONTENTS

Finding Capacities of Tanks, etc.

Some sheet metal workers would not know what to do if a customer came into the shop and required a tank constructed of No. 20 galvanized sheet iron to hold 63½ gallons, the tank to fit in a space 51 inches high. Knowing the number of gallons and the height, it would be necessary to know the diameter before the tank could be laid out. While rules given in various publications are understood by those who are versed in mensuration, the less skilful do not know how to apply them practically. In computing the capacity of any vessel we deal with cubic and liquid measures, and therefore it may not be out of place to present their respective tables.

Cubic or Solid Measure

1728 cubic inches = 1 cubic foot, or 12 × 12 × 12.
27 cubic feet = 1 cubic yard, or 3 × 3 × 3.
231 cubic inches = 1 United States gallon.
57.75 cubic inches = 1 United States quart.
28.875 cubic inches = 1 United States pint.
7.21875 cubic inches = 1 United States gill.

Liquid Measure

4 gills = 1 pint.
2 pints = 1 quart.
4 quarts = 1 gallon.
31½ gallons = 1 barrel.
63 gallons, or 2 barrels = 1 hogshead.
1 gallon = 4 quarts = 8 pints = 32 gills.

In the problems that follow practical examples are given, and the student should have no difficulty in learning to figure the capacity of any vessel.

Contents of Square Tank

One of the most simple forms to be computed is that of a cube or square tank, shown in Fig. 32. Here we have a tank 8 × 8 feet square and 8 feet high. The rule to be employed in finding the solidity, whether the base is a square or rectangle, is to multiply the length of any one side by its adjoining side and multiply the product obtained by the height. Then we have $8 \times 8 = 64$; $64 \times 8 = 512$ cubic feet. As a cubic foot contains 1728 cubic inches, we have 1728×512, or 884,736 cubic inches. To find the number of gallons the tank will hold divide 884,736 by 231, the number of cubic inches in a gallon, and we get $884{,}736 \div 231 = 3830$ gallons, and 6 cubic inches over.

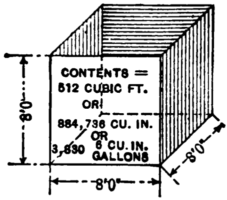


Fig. 32.—Contents of Cube

Contents of Hexagonal Tank

Suppose a tank is to be constructed whose base is any regular polygon. In Fig. 33, a tank is shown 5 feet high whose base is a hexagon, each side measuring 10 inches. The rule to be used is to multiply the area of the base by the height. Referring to Fig. 22, we find that the area of a hexagon whose side is 10 inches is 259.8 square inches, which multiplied by the height in Fig. 33 will give the cubic contents. The height shown is 5 feet. As the area of the base is in inches, then reduce the height to inches; then $60 \times 259.8 = 15{,}588$ cubic inches. For the number of gallons, $15{,}588 \div 231 = 67\frac{1}{2}$ gallons, scant.

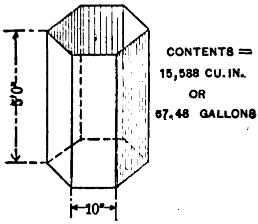


Fig. 33.—Contents of Hexagonal Prism

Contents of Round Tank

In Fig. 34 a cylinder or round tank is shown, the contents of which is obtained by the same rule as in the preceding figure. The bottom of this round tank is 10 inches

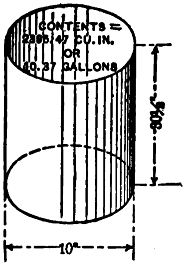


Fig. 34.—Contents of Cylinder

in diameter and its height 30½ inches. Then $10^2 \times 0.7854$ equals the area of the base; or $10 \times 10 = 100$; $100 \times 0.7854 = 78.54$ square inches; $30.5 \times 78.54 = 2395.47$ cubic inches. For the number of gallons, divide the above product by 231 and the quotient will be 10.37 gallons. A shorter rule can be used giving accurate results, viz.: Contents = $D^2H0.0034$, in which D equals the diameter and H the height of the tank. Applying it to the problem in Fig. 34, we have $10 \times 10 = 100$; $100 \times 30.5 = 3050$; $3050 \times 0.0034 = 10.37$, or the number of gallons. In using this simple rule we do away with multiplying by the decimal 0.7854; the factor 0.0034 being found by dividing 0.7854 by 231, the number of cubic inches in a gallon.

Contents of Sphere

When a copper ball is made to use as a float in a large tank, it is sometimes desirable to know the number of cubic inches in the ball. Thus in Fig. 35 we have a sphere 30 inches in diameter, whose capacity is found by multiplying the cube of the diameter by 0.5236, or $30^3 = 27{,}000$; $27{,}000 \times 0.5236 = 14{,}137.2$ cubic inches; $14{,}137.2 \div 231 = 61.2$ gallons capacity.

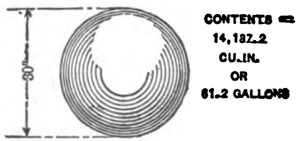


Fig. 35.—Contents of Sphere

Contents of Right Cone

When the contents are required of a cone or pyramid, the rule to follow is to multiply the area of the base by one-third the perpendicular height. Fig. 36 is a cone, whose base is 20 inches and whose vertical height is 48 inches. Following the above rule, we have 20 × 20 = 400; 400 × 0.7854 = 314.16 square inches of area, multiplying same by one-third the vertical height, 48, or 16, we have 314.16 × 16 = 5026.56 cubic inches. Dividing this by 231, the number of cubic inches in a gallon, we get 21.76 gallons.

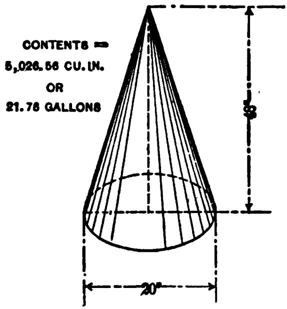


Fig. 36.—Contents of Cone

The same result can be obtained by a shorter method: Square the diameter, multiply by one-third the vertical height, and multiply by the factor 0.0034. Thus 20 ×20 = 400; 400 × 16 = 6400; 6400 × 0.0034 = 21.76, or the number of gallons. Following this rule, we omit multiplying the square of the diameter by 0.7854.

Contents of Right Pyramid

The method of computing the solidity of a pyramid is shown in Fig. 37. This shows a pyramid whose base is a hexagon, each side being 10 inches, and whose vertical height is 30 inches. As the area of a hexagon, each side of which is 10 inches, is 259.8 square inches, as explained in connection with Fig. 22, then multiply this amount by one-third the vertical height (30),

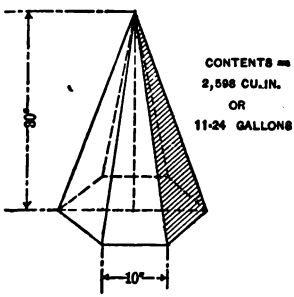


Fig. 37.—Contents of Pyramid

or 259.8 × 10 = 2598 cubic inches; divide by 231 and we get 11.24 gallons.

PRISMOIDAL FORMULA

The prismoidal formula can be used in calculating the volume or capacity of a prism, cylinder, cone, pyramid, frustum of a cone or pyramid, wedge, as well as many irregular shaped bodies. A prismoid is by definition a solid whose bases are polygons and lie in parallel planes and whose faces are quadrilaterals or triangles. To find the contents of a prismoid, or any of the above-mentioned solids, add together the areas of the two parallel planes and four times the area of a section taken midway between and parallel to them, and multiply the sum by one-sixth of the perpendicular distance between the parallel planes.

Applying this rule for obtaining the volume of a wedge, pyramid or cone, the area of the upper base is 0, because it runs to an apex. For prisms or cylinders the areas of the upper, lower and middle planes are equal. The prismoidal formula when applied to the frustum of a pyramid saves the labor of extracting the square root, as required under the old rule.

Contents of Right Cone

As an example let us apply the formula in obtaining the solidity of the cone shown in Fig. 36. Following the rule, we have as the area of the lower base 314.16 and the area of the upper base 0. Four times the area of the middle section, which is 10 inches in diameter, is 10 × 10 × 0.7854 = 78.54 × 4 = 314.16. The sum is 314.16 + 314.16 = 628.32. One-sixth the perpendicular height 48 = 8; 8 × 628.32 = 5026.56 cubic inches.

Contents of Square Hopper

In Figs. 38 and 39 the method of computing the volumes of the frustums of a square and hexagonal pyramid is shown. Fig. 38 shows an inverted hopper, usually made of heavy galvanized iron. Whether the shape is regular or irregular, the same method is used in determining the capacity. The top opening is 28 x 28 inches, the bottom 10 x 10 inches, and the sides, a section taken midway between the top and bottom, would equal $\frac{28 + 10}{2}$, or 19; then 19 x 19 inches would be the size for the middle section, *a b c d*. The area of the upper plane equals 28 × 28 inches, or 784 square inches; of the lower plane 10 × 10 inches, or 100 square inches, and of the middle plane 19 × 19 inches, or 361 square inches. Four times the middle plane is 1444. Then, following the rule, we have upper plane, 784, + lower plane, 100, + four times middle plane, 1444, = 2328. This is multiplied by one-sixth the vertical height, 39. Then $2328 \times \frac{39}{6} = 15{,}132$ cubic inches. This divided by 231, the number of cubic inches in a gallon, gives 65½ gallons and 1½ cubic inches over.

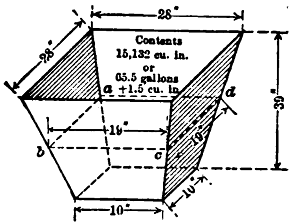


Fig. 38.—Contents of Hopper

Contents of Hexagonal Hopper

The same rule is applied to Figs. 39 to 42, inclusive. Fig. 39 shows a hopper hexagonal in shape; each side of the lower base is 20 inches, the upper base 10 inches, and a section taken midway between the two $\frac{10 + 20}{2}$, or 15 inches, as *a b*. To obtain the area of these planes multiply the square of one of the sides of the regular polygon by the multiplier given in the following table for the proper polygon:

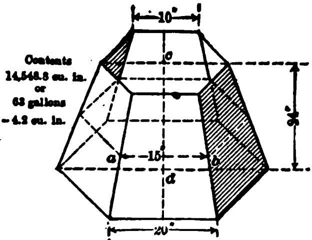


Fig. 39.—Contents of Frustum of Pyramid

Name	Sides to Polygon	Multiplier
Triangle.....	3	0.433
Square......	4	1.000
Pentagon....	5	1.720
Hexagon....	6	2.598
Heptagon...	7	3.634
Octagon.....	8	4.828
Nonagon....	9	6.182
Decagon....	10	7.694

As the shape in question is hexagon, we find the multiplier in the table to be 2.598. Then, following the above rule, the area of the lower plane is equal to $20 \times 20 = 400$; $400 \times 2.598 = 1039.2$. The area of the upper plane, $10 \times 10 \times 2.598 = 259.8$, and four times the area of the middle plane, $15 \times 15 \times 2.598 \times 4 = 2338.2$. Then $1039.2 + 259.8 + 2338.2 = 3637.2$. $3637.2 \times \frac{24}{6} = 14{,}548.8$ cubic inches contents. This divided by $231 = 63$ gallons, or 2 barrels, less 4.2 cubic inches.

Contents of Frustum of a Cone

Fig. 40 shows the frustum of a cone. A tank of this form is usually made from ¼-inch metal, riveted and reinforced with angles and tees. The top diameter is 6 feet, bottom 10 feet and the middle diameter $\frac{6 + 10}{2}$, or 8 feet. The area of the top section is $6 \times 6 \times 0.7854 = 28.2744$

square feet; the bottom area, $10 \times 10 \times 0.7854 = 78.54$ square feet; the middle area, $8 \times 8 \times 0.7854 = 50.2656$.

Then $28.2744 + 78.54 + (50.2656 \times 4) = 307.8768 \times \frac{12}{6}$

$= 615.7536$ cubic feet capacity. Multiply this amount by 1728, the number of cubic inches in a foot, and divide by 231, the number of cubic inches in a gallon, and we obtain the capacity in gallons. Thus, $615.7536 \times 1728 = 1{,}064{,}022.2208$ cubic inches, which divided by $231 = 4606$ gallons and 5 gills.

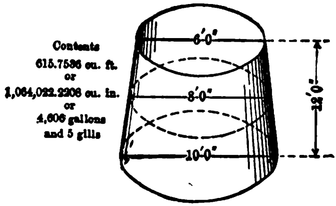


Fig. 40.—Contents of Frustum of Cone

Contents of Odd-Shaped Vessel or Prismoid

Fig. 41 shows an odd-shaped vessel, whose parallel bases are right angle triangles. The bottom base is 20×32 and contains 320 square inches; the top 8×20, and contains 80 square inches. The size of the middle section is obtained by adding 20 and 32 and dividing by 2; this gives the length *b c*, or 26 inches. In similar manner

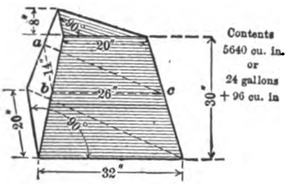


Fig. 41.—Contents of Prismoid

$\frac{8 + 20}{2} = 14$, length of *a b*. Then the area of *a b c* is

$\frac{14 \times 26}{2} = 182$. Then $80 + (182 \times 4) + 320 = 1128$.

$1128 \times \frac{30}{6} = 5640$ cubic inches. Divide this amount by 231 and we get 24 gallons and 96 cubic inches over.

Contents of a Wedge

Fig. 42 illustrates the method of obtaining the capacity of odd-shaped solids as applied to the form of a wedge, the rectangular base of which is 12 × 40 inches and the area 480 square inches. The top runs to an apex 14 inches wide, whose area is 0. A section taken midway between the top and bottom equals 6 × 27 inches and has an area of 162 square inches. Then $0 + (162 \times 4) + 480 = 1128$. $1128 \times \frac{36}{6} = 6768$ cubic inches, which, divided by 231 = 29 gallons, 1 quart and 11.25 cubic inches over.

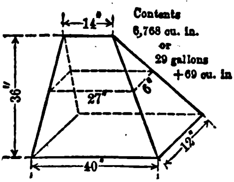


Fig. 42.—Contents of Wedge

CHAPTER II

PROBLEMS SOLVED BY THE STEEL SQUARE AND COMPASS

Testing the Square

All steel squares are supposed to be true. Some, however, receive very rough usage in the shop and on the job, and it may not be out of place to show how a steel square or other right angles may be tested: A square or right angle should always contain 90 degrees, and to

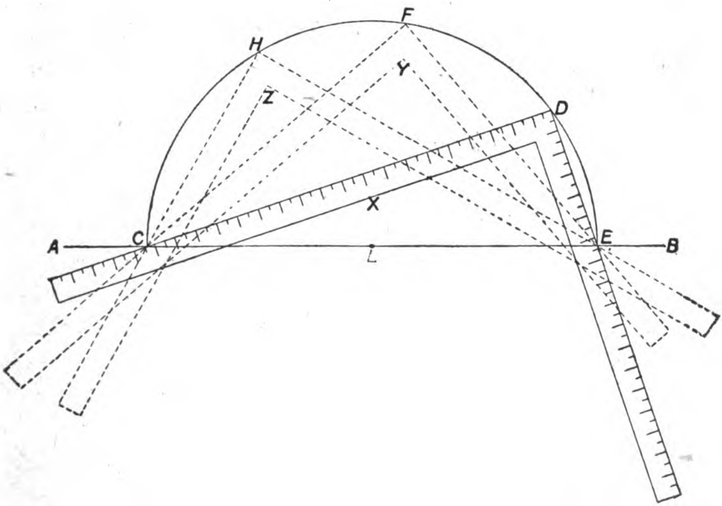


Fig. 43.—Proving the Accuracy cf a Right Angle or Steel Square

prove this, the square can be tested as illustrated in Fig. 43. Draw any line as A B and with any radius, using L as center, describe the semicircle C F E. Now if the square X or any other right angle to be tested is true, then one arm should meet the diameter at C, the other arm at E and the corner come directly on the circumference at D. It is immaterial in what position the right angle is placed; if placed as shown by Y, the arms should meet at C and E and the corner on the circle F. Or if placed as at Z, the arms meet at C and E and the corner at H. If pins were placed at C and E, and the blades of the square moved along the same, the corner will follow the curved line E C F. That this method is true, is proved by the diagram shown in Fig. 44.

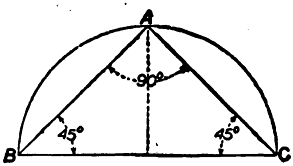


Fig. 44.—Proving the Method Shown in Fig. 43

Proving the Method

Any sized circle contains 360 degrees; a semicircle, therefore, contains one-half, or 180 degrees, as shown by B A C. B A C also represents a right angle triangle, whose angle A contains 90 degrees and each of the angles B and C 45 degrees. Then $90 + 45 + 45 = 180$, or the number of degrees in the semicircle B A C.

Circumference of Circle

In finding the approximate circumference of a circle, a square is often used to advantage; this is illustrated in the diagram A in Fig. 45. First draw a circle of the size wanted, taking 12 inches as an example. Place the corner of the steel square on the center of the circle and mark where the blades of the square cross the circle, as indicated in the accompanying diagram. Now connect these two points with a straight line, as shown in diagram B, and measure the small space in its widest part, and it will be found to be about 1¾ inch. This measurement added to three times the diameter will give the required

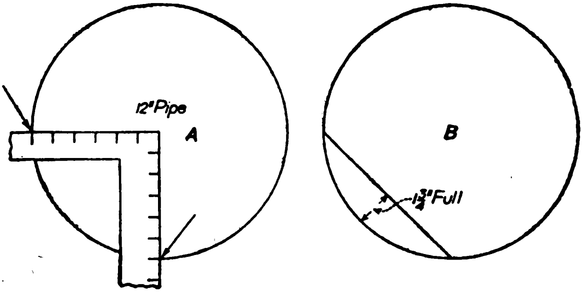


Fig. 45.—Quick Method of Finding Required Circumference

length of the metal needed for a 12-inch pipe. Thus for 12-inch pipe it would require $3 \times 12 = 36$, and 1¾ added, or 37¾.

Using the rule given in Fig. 1, the circumference of a 12-inch circle would be $12 \times 3.1416 = 37.69$; the above rule makes it 37.75, or .06 of an inch more; this is immaterial.

Dividing the Circle

The steel square can also be used for dividing any circle in any given number of parts, as explained in connection with Fig. 46.

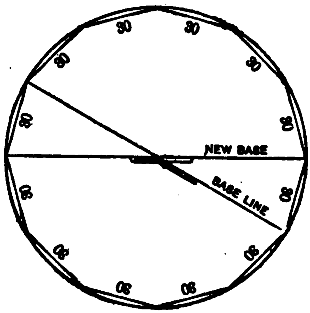


Fig. 46.—Dividing a Circle by the Steel Square

For example, suppose we have a circle 12 inches in diameter on which we desire to describe a 12-sided polygon. First divide 360 by 12, which gives us 30 degrees as the distance between points. Setting the bevel square at 30 degrees, by aid of the protractor, we proceed as indicated in the accompanying diagram, and from any diameter as the base line, secure a new base, using this from which to secure a second, and so continue to secure the new ones until the circumference is completed.

Constructing Stars

This same method is applicable to making stars having any number of points and shown in Figs. 47 and 48, where a five-pointed star is taken as an example.

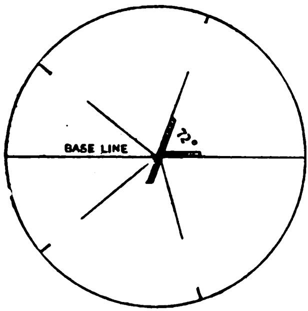


Fig. 47

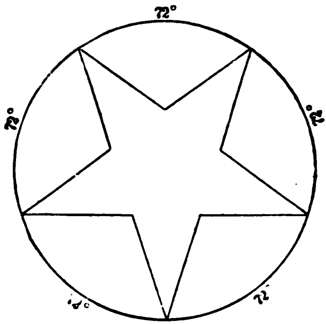


Fig. 48

Making a Five-Pointed Star with the Steel Square

Divide 360, the number of degrees in a circle, by the number of points desired. This will give in degrees the distance between points. Get the angle on the bevel square from the protractor, and start with any diameter as the base line, from which all the points may easily be obtained.

In Fig. 47 a circle with the base line on which the bevel square is laid to get the first point is shown. Use this line as a new base from which to get the second point. Reverse the bevel square on the original base line and secure another point, and from this line secure the last point in the star. Join the points as shown in Fig. 48.

Ascertaining Pitches of Roofs

A subject of great importance to the sheet metal worker, roofer and skylight maker is the method of finding the pitch of roofs. Few mechanics understand what is meant by the roof, skylight or gutter having a pitch of one-sixth, or a pitch of one-fourth, one-third or one-half. To make this clear and show how the steel square easily solves the problem, Fig. 49 has been prepared.

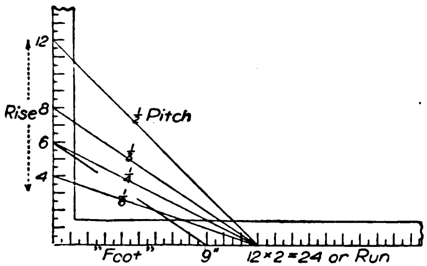


Fig. 49.—Finding Pitches of Roofs

It may be well to mention here that the run of a rafter set up in place is the horizontal measure from the extreme end of the foot to a plumb line from the ridge end. The rise is the distance from the top of the ridge end of the rafter to the level of the foot. The pitch is the proportion that the rise bears to the whole width or span of the building. Bearing this last rule in mind, to obtain for example one-sixth pitch, establish any point on the square, in this case the 12-inch mark; double this number and divide by the pitch desired and the quotient will be the rise. Thus $12 \times 2 = 24$; $24 \div 6$ (the desired pitch) $= 4$. Then 4 inches is the rise required on a 12-inch run for one-sixth pitch. The line drawn from 4 to 12 in the diagram represents a roof having one-sixth pitch. If one-fourth pitch is desired, then $\frac{12 \times 2}{4} = \frac{24}{4} = 6$, the desired rise; the one-fourth pitch being shown by a line drawn from 6 to 12. One-third pitch is obtained by $\frac{12 \times 2}{3} = \frac{24}{3} = 8$, or the desired rise. The one-third pitch is shown from 8 to 12 in the illustration. One-half pitch is a line drawn from 12 to 12, because $\frac{12 \times 2}{2} = \frac{24}{2} = 12$, the rise of one-half pitch as shown.

Any number can be taken on the foot of the square. Suppose we had selected the 9-inch mark instead of 12 and one-third pitch was required, what would the rise be?

Following the above rule, $\frac{9 \times 2}{3} = \frac{18}{3} = 6$-inch rise.

A line would then be drawn as shown from 6 to 9, and while the rise was but 6 inches on a 9-inch foot the pitch or angle of the roof would be similar to the one-third pitch drawn from 8 to 12. This applies to any pitch desired.

In Chapters X, XVI and XVII the reader will find practical examples for measuring roofs, taking off quantities for same and estimating this class of work.

Rectangle to Square

Fig. 50 shows how a rectangular section can be changed to a square section of equal area. Let *a b d* represent a section 2 × 4.5 feet, containing 9 square feet of area. Extend *d a* as *d i*, and with *a* as center and *a b* as radius, draw the quarter circle *b c*. Bisect *c d* at *e*. With *e* as center draw the semicircle *d c*. Extend *b a* until it intersects the circle at *f*; then, from *f*, complete the square *f h i a*, which will be 3 × 3 feet and contain 9 square feet.

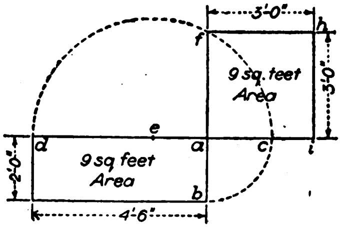


Fig. 50.—Rectangle to Square

Circle and Square of Equal Area

Fig. 51 shows how a circle is changed to a square of equal area. First draw the two diameters through the center *b*, indefinitely, as shown by *e h* and *f c*. Divide the radius *a b* into four equal parts and place one of the parts from *a* to *c* and from *d* to *e*. Draw *c e* and complete the square *c e f h*, which will measure, using the rule, 5 5/16 inches, the square of which will be its area and equal in area to the 6-inch circle. This can be proven as follows: Area of 6-inch circle (see table, page 51) = 28.27. Area of square of 5 5/16 = 5.3125 × 5.3125 = 28.28. For obtaining decimal equivalent of 5/16 see table on page 3.

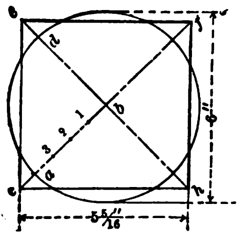


Fig. 51.—Circle to Square

Three Areas in One

Fig. 52 shows three separate square pipes, which are to be changed to one square pipe. One pipe is 2 × 2 inches; the second, 6 × 6 inches, and the third, 9 × 9 inches. Their total area is 121 square inches. In computation, we would simply extract the square root of 121 and obtain the side. In this case, draw, in Fig. 53, the right angle *a b c*, making *a b*, 2 inches, and *b c*, 6 inches. Draw *a c*, at right angles to which erect *c d*, 9 inches long. Draw *d a* and complete the square *a d e f*, each side of which will measure 11 inches and will contain 121 square inches area.

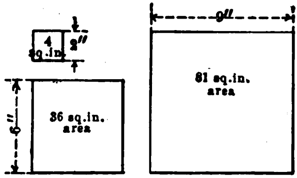


Fig. 52.—Three Squares

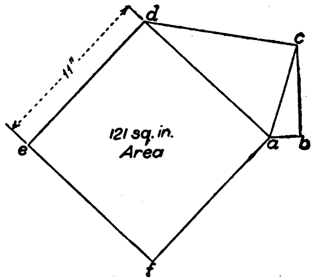


Fig. 53.—Method of Fig. 52

Circle, Two Times Area of Given Circle

Fig. 54 shows how to obtain a circle whose area is twice that of a given circle. Let A be the given circle; draw the diameter *a b*, at right angles to which draw *b c*, equal to *a b*. Draw *a c*; bisect the same and obtain *d*. With *d* as center and *d a* as radius draw the circle B, which will contain twice the area of A, and can be proved as follows: Let *a b* represent a 10-inch circle whose area equals 10 × 10 × 0.7854 = 78.54 square

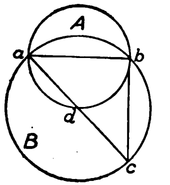


Fig. 54.—Circle of Two Times The Area

inches. $78.54 \times 2 = 157.08$. As *a b* and *b c* are both 10 inches, then *a c* will equal the square of *a b* and *b c*, or $10 \times 10 \times 2$, or 200 square inches. *a c* then represents a diameter of a circle whose square is 200; then $200 \times 0.7854 = 157.08$. The large circle then contains twice the area of the smaller one, and the diameter of the large circle would be the square root of 200, or 14.142, as shown in the table of square roots on page 137.

Two-Pronged Fork—First Example

In Fig. 55 the method of finding the diameters of two circles whose areas are to be equal to a given area, or *vice versa*, is shown, and Fig. 56 illustrates various examples solved by the steel square. Let A represent two

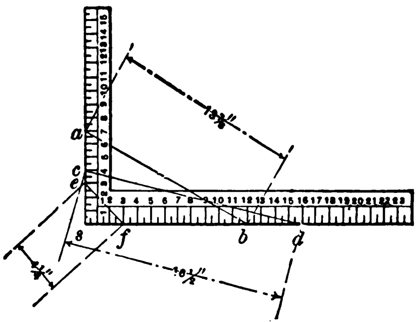


Fig. 55.—Use of Steel Square

branches of 3-inch pipes, which are to be connected to a pipe whose area is equal to the areas of the two 3-inch pipes; what must the diameter of the main pipe be? As both the given pipes are 3 inches, then simply lay the 2-foot rule from 3 to 3 on the square, in Fig. 55, as shown by *e f*; this will measure $4\frac{1}{4}$ inches, the diameter of the main pipe in A in Fig. 56, which will have twice the area of one 3-inch pipe. This can be proven by following the table of areas shown on page 51, where the area of a 3-inch circle equals 7.06; 7.06 × 2 = 14.12; area of $4\frac{1}{4}$-inch pipe as found from *e* to *f* on square, equals 14.18 square inches, thus proving by a slight difference of .06 the accuracy of the steel square solution. Suppose the diameter of the main, or $4\frac{1}{4}$-inch, pipe is given, and it was necessary to take two branch pipes of equal diameter from it. Lay the rule of $4\frac{1}{4}$ inches over the angle of the square in Fig. 55, so that the distances from *s* to *e* and *s* to *f* are equal, then each side will measure 3 inches, as shown, the diameter of the branches shown in Fig. 56.

Two-Pronged Fork—Second Example

In B are shown two branches, 7 and 12 inches, respectively; what must the diameter of the main be to equal their capacities? Set the rule on 7 and 12 in Fig. 55, as shown, from *a* to *b*, which will measure $13\frac{7}{8}$ inches, the diameter of the main pipe in B in Fig. 56.

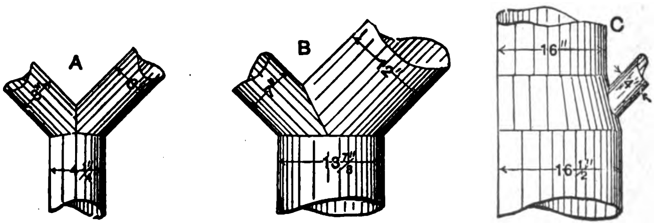


Fig. 56.—Problems for Steel Square Solution

Prove this by referring to the table of areas, where 7 inches equals an area of 38.48; 12 = 113.09 and $13\frac{7}{8}$ inches an area of 151.20. Thus 38.48 + 113.09 = 151.57, or about 1-3 square inch difference, and is unimportant.

Again, suppose the main pipe of $13\frac{7}{8}$ inches diameter were given and a 7-inch pipe were already in place, what diameter must the other branch be so that the two branches will have the capacity of the main? Place the 13⅞-inch mark of the rule on the 7-inch point, or *a*, in Fig. 55, and where the zero end intersects the lower edge of the square, which is at *b*, the 12-inch point on the square. This indicates that the diameter of the desired branch is 12 inches.

Branches

Suppose in C in Fig. 56 we have a 16-inch pipe, to which a 4-inch branch was added. How much must the main pipe increase in size? Place the rule on the square in Fig. 55 from 4 to 16, or from *c* to *d*, and it will measure 16½ inches, the size of the increased main in Fig. 56. Prove this as follows: Area of 16-inch pipe equals 201.06 plus area of 4-inch pipe, or 12.56, or a total of 213.62. Area of 16½-inch pipe equals 213.82 square inches, or a difference of ⅕ square inch, which is immaterial. The above rules can also be used to advantage when square pipes are to be used. The solving of problems of similar nature by computation instead of using the square will be found explained on page 56.

CHAPTER III

TIN AND SHEET METAL WARE

Square Tank

To obtain the unknown size of an article when the height and capacity are given, or *vice versa*. The first problem, shown in Fig. 58, represents a water tank. Assume that a customer has ordered an 8-gallon tank, whose base is to measure 11 × 14 inches. How high must it be to have the desired capacity? The rule for any square or rectangualr tank is: Reduce the gallons to cubic inches; divide this amount by the area of the base, the quotient being the desired height. As there are 231 cubic inches in the United States gallon (see table on page 22), then in 8 gallons there will be 8 × 231, or 1848 cubic inches. The base is 11 × 14 and contains 154 square inches area. Then 1848 ÷ 154 = 12 inches, the required height of the tank.

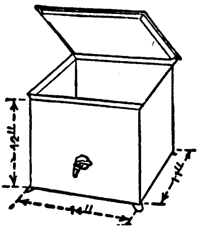


Fig. 58.—A Square Tank

Suppose the height and length of one of the sides and the capacity are given. What will the size of the remaining side be? Assuming the capacity to be 8 gallons, the height 12 inches and the given side 11 inches, then dividing the number of cubic inches in 8 gallons by 12 and the quotient by 11, the result will be the required side. Thus, 1848 ÷ 12 = 154; 154 ÷ 11 = 14, the required length of side.

Sphere

A copper ball, Fig. 59, to be used as a float must contain 22,449 35/100 cubic inches. What must the diameter be to contain the above number of cubic inches? The rule is to divide the number of cubic inches by 0.5236, and from the quotient obtained extract the cube root. As the sphere is to contain 22,449.35 cubic inches, then 22,449.35 ÷ 0.5236 = 42,875. The next step is to extract the cube root of this quotient.

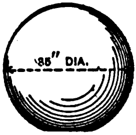


Fig. 59
A Sphere

Finding the Cube Root of a Number

When a number is multiplied by itself, as 5 × 5, the product, 25, is called the square of that number. When a number is multiplied by itself twice, as 5 × 5 × 5, the product, 125, is called the cube of that number. Therefore, the extraction of the cube root is nothing more than to find a number which, multiplied by itself twice, will result in the given number. To extract the cube root of 42,875, start at the decimal point and, counting to the left, separate the number into periods of three figures, as shown by 42′875.

	Number	Cube root
	42′875.	(35
	27	
Trial Divisor		
2700	15875	
	42875	

Find the greatest number whose cube is contained in the first or left hand period, 42; 4 × 4 × 4 × = 64, and is too great. Then take 3; 3 × 3 × 3 = 27. Therefore 3 is the first figure of the root. Subtracting 27 from 42 we obtain 15. Bring down the next period, 875, obtaining the first partial dividend, 15,875. Take three times the square of the root already found, which is $3^2 \times 3 = 3 \times 3 \times 3 = 27$. Annex two ciphers to it, and we have 2700 for the trial divisor. Dividing the trial divisor into 15,875, suggests 5 as the second figure of the root. Prove this by multiplying $35 \times 35 \times 35$, which equals 42,875, and leaves no remainder. Then 35 is the cube root of 42,875. Therefore the sphere in question must be 35 inches in diameter.

The trial divisor is sometimes contained in the partial dividend. Whether it is too high or not can be ascertained by cubing the root found, and if its product is higher than the partial dividend a lower number must be taken, whose cube will be equal to or smaller than the partial dividend. If there had been a remainder in the problem just shown, and it was desired to continue the root, periods of three ciphers each would have to be added to the whole number, 42,875, and continued as described above in order to obtain the decimal part of the root. See further explanations about roots in Chapter XIV, page 227.

Round Tank

Fig. 60 is an oil tank. Assume a tank whose diameter is 16 inches that must hold one barrel: Then what must be the height of the tank? Reduce the barrel to cubic inches, into which divide the area of the 16-inch circle. The quotient will be the required height. One barrel equals 31½ gallons, or 7276.5 cubic inches. The area of a 16-inch circle is 201.062 square inches; $7276.5 \div 201.062 = 36.19 +$. Therefore 36 1-5 inches is the desired height.

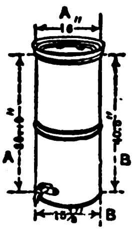


Fig. 60.
An Oil Tank.

Suppose the tank is to hold the same quantity and the height is to be $40\frac{1}{2}$ inches. What must the diameter be? In this case divide the number of cubic inches by the height and divide the quotient by 0.7854. From the quotient thus obtained extract the square root (see page 11 for explanation), which will be the desired diameter. 7276.5 cubic inches, the capacity of the tank, $\div$ 40.5 inches, the height, $= 179.6667$; $179.6667 \div 0.7854 = 228.758+$; $\sqrt{228.758} = 15.124$, or $15\frac{1}{8}$ inches, the desired diameter, as shown at B.

Wash Boiler

In Fig. 61 a 10-gallon wash boiler is shown, whose base is 10 inches wide, with semicircular ends, and the length of the straight part of the side from A to B being $9\frac{1}{4}$ inches. What must be its height? Reduce the capacity to cubic inches and divide it by the area of the bottom, the quotient will be the height. Ten gallons equal 2310 cubic inches. The area of the bottom equals the area of a 10-inch circle, which is 78.54, plus 92.5 (the area of the rectangle $9\frac{1}{4} \times 10$) = 171.04 square inches, $2310 \div 171.04 = 13.5$ inches, the height of the boiler.

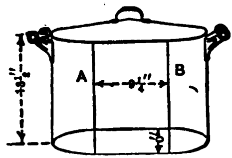


Fig. 61.—Wash Boiler

If the height of the boiler and the diameter of the semicircular ends are given, and the width of the straight side A B is required, find the capacity in cubic inches and divide by the height; from the quotient obtained subtract the area of the two semicircles and divide the remainder by the given width of the base, and the quotient will be the width. Thus: $2310 \div 13.5 = 171.11$; $171.11 - 78.54 = 92.57$; $92.57 \div 10 = 9.257$, the width of A B.

Flaring Pail

Figs. 62 and 63 show a flaring pail and a measure whose capacities and top and bottom diameters are given, and their height is to be found. The rule applicable to any form of flaring ware whose section is round, no matter what its capacity may be, is to find the number of cubic inches in the given capacity, which divide by the

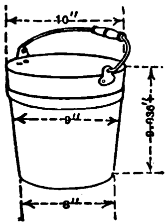


Fig. 62.—Flaring Pail

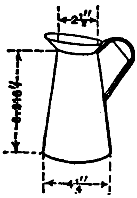


Fig. 63.—Flaring Measure

sum of the areas of the top and bottom diameters and four times the area of the middle section and multiply the quotient by six. As one quart contains 57.75 cubic inches (see table on page 22), the 10-quart pail, shown in Fig. 62, will contain 577.5 cubic inches. The area of the top diameter of 10 inches equals 78.54, the bottom diameter of 8 inches, 50.26, and the middle section, whose diameter is 9 inches, 63.61 square inches; $63.61 \times 4 = 254.44$ square inches. Then $254.44 + 50.26 + 78.54 = 383.24$; $577.50 \div 383.24 = 1.506 \times 6 = 9.036$ inches, the required height.

Flaring Measure

The measure shown in Fig. 63 is to hold one quart. Its top and bottom diameters are 2½ and 4¼ inches, respectively. What must the height be? Following the same rule as above we have: Area of top equals 4.90. Area of bottom equals 14.18. The middle diameter equals $\frac{2.5 + 4.25}{2} = 3.375$. Its area equals 8.94. $8.94 \times 4 = 35.76$. Combined areas $4.90 + 14.18 + 35.76 = 54.84$.

Capacity of one quart equals 57.75 cubic inches; divided by combined areas, or 54.84, leaves a quotient 1.053; this multiplied by 6 equals 6.318 inches, or height.

Elliptical Flaring Ware

Fig. 64 shows the method of finding the height in elliptical flaring ware when the top and bottom dimensions and capacity are given. The tub in this case is to hold 32 pints and $21\frac{3}{8}$ cubic inches, the top dimensions to be $11 \times 15\frac{1}{2}$ and the bottom $8 \times 12\frac{1}{2}$ inches. What must the height be? The rule is the same as in the preceding problem. It should be remembered that the area of an ellipse is found by multiplying the short diameter by the long diameter, and their product by 0.7854, as explained in connection with Fig. 21. Working this out in Fig. 64 we have $11 \times 15.5 = 170.5$; $170.5 \times 0.7854 = 133.91$, or area of top. $8 \times 12.5 = 100$; $100 \times 0.7854 = 78.54$, or area of bottom. For the dimension through the middle section, we have $\frac{8 + 11}{2} = 9.5$; $\frac{15.5 + 12.5}{2} = 14$; thus the middle section equals 9.5×14. Then $9.5 \times 14 = 133$; $133 \times 0.7854 = 104.45$; 104.45×4

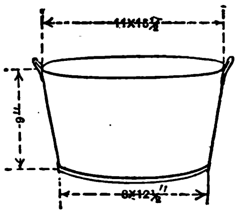


Fig. 64.—Flaring Elliptical Tub

= 417.80. Then 417.80 + 78.54 + 133.91 = 630.25. As one pint holds 28.875 cubic inches (see table on page 22), then 32 pints will hold 32 × 28.875, or 924 cubic inches. 924 + 21.375 (cubic inches over 32 pints) = 945.375. 945.375 ÷ 630.25 = 1.5; 1.5 × 6 = 9 inches, the height of the elliptical tub as shown.

Flaring Drip Pan

Another problem where the same rule is employed is shown in Fig. 65, in which a drip pan to hold 29 quarts and 13¼ cubic inches is illustrated. The top is to be 16 × 22 and the bottom 12 × 18 inches. The middle section is found as follows: $\frac{16 + 12}{2} = 14$; $\frac{18 + 22}{2} = 20$, or 14 × 20 inches.

Following the rule as before, we have: top, 16 × 22 = 352; bottom, 12 × 18 = 216; middle section, 14 × 20 = 280; 280 × 4 = 1120. Then 1120 + 216 + 352 = 1688. As one quart contains 57.75 cubic inches, 29 quarts will hold 29 × 57.75, or 1674.75; 1674.75 + 13.25 (cubic inches over 29 quarts) = 1688 cubic inches. 1688 ÷ 1688 = 1; 1 × 6 = 6, or the height in inches of the rectangular flaring pan.

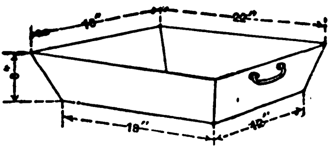


Fig. 65.—Flaring Pan

CHAPTER IV

PIPING AND DUCT WORK

Areas of Pipes Equal to Rectangular Pipe

The section of an 8 × 32 inch rectangular pipe is represented in Fig. 66 of the diagrams. If a transition is made to a perfectly square pipe, what must each side measure? In solving this problem proceed as follows: Extract the square root (see page 11) of the area of the rectangular pipe, 256 square inches, which is 16 inches, the size of the square pipe.

Supposing this 8 × 32 inch pipe was to form a transition to another rectangular pipe, the width of which was 12 inches, what must be its length to have the same area? Simply divide 256 by 12, and the quotient will be $21\frac{1}{3}$, making the size of the pipe $12 \times 21\frac{1}{3}$ inches.

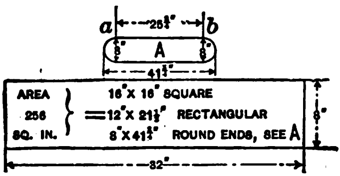


Fig. 66.—Pipes Equal to Rectangular Pipe

If this 8 × 32 inch pipe were to form a transition to an oblong pipe with semicircular ends, 8 inches in diameter, as shown at A, what must the length of the distance be, shown from *a* to *b*? As two semicircles make a full circle, then deduct the area of the 8-inch circle from 256, and divide the remainder by eight, as follows: Area of 8-inch circle = 50.26; 256 − 50.26 = 205.74; 205.74 ÷ 8 = 25.72, or $25\frac{3}{4}$ inches scant, the length from *a* to *b*.

Finding Similar Areas in a Furnace Boot Round to Rectangular

In Fig. 67 a fitting in hot air piping, known as a boot, is shown. With it a 14-inch round horizontal pipe and a vertical rectangular pipe whose width is 7 inches are joined. What must be the length of this rectangular pipe in order that it will have the same area as the 14-inch round pipe? The area of a 14-inch round pipe is 153.93, or approximately 154 square inches. Divide 154 by 7, and the quotient will be 22 inches, the desired length.

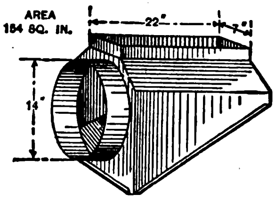


Fig. 67.—Furnace Boot

Suppose the size of the rectangular pipe is 7 × 22. What size round pipe will have similar area? Divide the area of the given pipe, or 154, by 0.7854, and extract the square root of the product (see page 11). Thus 154 ÷ 0.7854 = 196. $\sqrt{196} = 14$. Then 14 inches is the diameter of the round pipe.

Finding Similar Areas in a Chimney Base Round to Square

In Fig. 68 a chimney base is shown, measuring 8 × 6¼ inches at the bottom. The base is to form a transition from square to round. What must be the diameter at the top so that the area will be similar to the base?

The rule used in connection with Fig. 67 can be applied to this problem, but by referring to the following Table of Areas and Circumferences of Circles, much labor can be saved in computing.

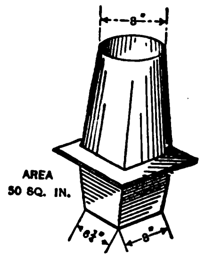


Fig. 68.—Chimney Base

Circumferences and Areas of Circles from 1 to 20

Diam.	Circum.	Area.	Diam.	Circum.	Area.	Diam.	Circum.	Area.
1	3.1416	.7854	7⅜	23.1693	42.7184	13¾	43.1970	148.490
1⅛	3.5343	.9940	7½	23.5620	44.1787	13⅞	43.5897	151.202
1¼	3.9270	1.2272	7⅝	23,9547	45.6636	14	43.9824	153.938
1⅜	4.3197	1.4849	7¾	24.3474	47.1731	14⅛	44.3751	156.700
1½	4.7124	1.7671	7⅞	24.7401	48.7071	14¼	44.7678	159.485
1⅝	5.1051	2.0739	8	25.1328	50.2656	14⅜	45.1605	162.296
1¾	5.4978	2.4053	8⅛	25.5255	51.8487	14½	45.5532	165.130
1⅞	5.8905	2.7612	8¼	25.9182	53.4563	14⅝	45.9459	167.990
2	6.2832	3.1416	8⅜	26.3109	55.0884	14¾	46.3386	170.874
2⅛	6.6759	3.5466	8½	26.7036	56.7451	14⅞	46.7313	173.782
2¼	7.0686	3.9761	8⅝	27.0963	58.4264	15	47.1240	176.715
2⅜	7.4613	4.4301	8¾	27.4890	60.1322	15⅛	47.5167	179.673
2½	7.8540	4.9087	8⅞	27.8817	61.8625	15¼	47.9094	182.655
2⅝	8.2467	5.4119	9	28.2744	63.6174	15⅜	48.3021	185.661
2¾	8.6394	5.9396	9⅛	28.6671	65.3968	15½	48.6948	188.692
2⅞	9.0321	6.4918	9¼	29.0598	67.2008	15⅝	49.0875	191.748
3	9.4248	7.0686	9⅜	29.4525	69.0293	15¾	49.4802	194.828
3⅛	9.8175	7.6699	9½	29.8452	70.8823	15⅞	49.8729	197.933
3¼	10.2102	8.2958	9⅝	30.2379	72.7599	16	50.2656	201.062
3⅜	10.6029	8.9462	9¾	30.6306	74.6621	16⅛	50.6583	204.216
3½	10.9956	9.6211	9⅞	31.0233	76.589	16¼	51.0510	207.395
3⅝	11.3883	10.3206	10	31.4160	78.540	16⅜	51.4437	210.598
3¾	11.7810	11.0447	10⅛	31.8087	80.516	16½	51.8364	213.825
3⅞	12.1737	11.7933	10¼	32.2014	82.516	16⅝	52.2291	217.077
4	12.5664	12.5664	10⅜	32.5941	84.541	16¾	52.6218	220.354
4⅛	12.9591	13.3641	10½	32.9868	86.590	16⅞	53.0145	223.655
4¼	13.3518	14.1863	10⅝	33.3795	88.664	17	53.4072	226.981
4⅜	13.7445	15.0330	10¾	33.7722	90.763	17⅛	53.7999	230.331
4½	14.1372	15.9043	10⅞	34.1649	92.886	17¼	54.1926	233.706
4⅝	14.5299	16.8002	11	34.5576	95.033	17⅜	54.5853	237.105
4¾	14.9226	17.7206	11⅛	34.9503	97.205	17½	54.9780	240.529
4⅞	15.3153	18.6555	11¼	35.3430	99.402	17⅝	55.3707	243.977
5	15.7080	19.6350	11⅜	35.7357	101.623	17¾	55.7634	247.450
5⅛	16.1007	20.6290	11½	36.1284	103.869	17⅞	56.1561	250.948
5¼	16.4934	21.6476	11⅝	36.5211	106.139	18	56.5488	254.470
5⅜	16.8861	22.6907	11¾	36.9138	108.434	18⅛	56.9415	258.016
5½	17.2788	23.7583	11⅞	37.3065	110.754	18¼	57.3342	261.587
5⅝	17.6715	24.8505	12	37.6992	113.098	18⅜	57.7269	265.183
5¾	18.0642	25.9673	12⅛	38.0919	115.466	18½	58.1196	268.803
5⅞	18.4569	27.1086	12¼	38.4846	117.859	18⅝	58.5123	272.448
6	18.8496	28.2744	12⅜	38.8773	120.277	18¾	58.9050	276.117
6⅛	19.2423	29.4648	12½	39.2700	122.719	18⅞	59.2977	279.811
6¼	19.6350	30.6797	12⅝	39.6627	125.185	19	59.6904	283.529
6⅜	20.0277	31.9191	12¾	40.0554	127.677	19⅛	60.0831	287.272
6½	20.4204	33.1831	12⅞	40.4481	130.192	19¼	60.4758	291.040
6⅝	20.8131	34.4717	13	40.8408	132.733	19⅜	60.8685	294.832
6¾	21.2058	35.7848	13⅛	41.2335	135.297	19½	61.2612	298.648
6⅞	21.5985	37.1224	13¼	41.6262	137.887	19⅝	61.6539	302.489
7	21.9912	38.4846	13⅜	42.0189	140.501	19¾	62.0466	306.355
7⅛	22.3839	39.8713	13½	42.4116	143.139	19⅞	62.4393	310.245
7¼	22.7766	41.2826	13⅝	42.8043	145.802	20	62.8320	314.160

Complete tables from 1 inch to 6 feet 11¾ inches, advancing by ¼ inches, and from 7 feet to 18 feet 11 inches, advancing by inches, can be found in the "Tinsmith's Helper and Pattern Book," by H. V. Williams, price $2.50, and from 1 to 55, advancing by ¼ inches, in "Metal Worker Shop Card No. 3," price 35 cents, published by the U. P. C. Book Co., Inc.

In the following examples the use of these tables will be explained when applied to sheet metal work. Referring to Fig. 68, the base measures 8 × 6¼ inches and equals 50 square inches area. Instead of computing, to obtain the diameter of the top of the base, simply refer to the Table of Areas and Circumferences of Circles, following the column under areas until 50.2656 is reached (the nearest to the required number 50), when we find it is the area of an 8-inch circle, which will be the top diameter of the base.

This method could have been used in Fig. 67, in which the area of the rectangular opening is 154 square inches. Follow the area column in the table until 153.938 is reached, which suggests a 14-inch circle, as shown.

Finding Similar Areas in a Furnace Boot Round to Elliptical

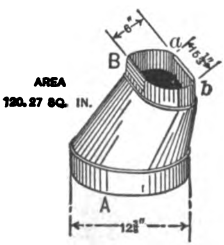


Fig. 69.—Furnace Boot

In Fig. 69 another form of boot is shown, in the computation of which use will be made of the table shown on page 51. In this case the inlet A is 12⅜ inches in diameter; following the diameter column on page 51 we find that a circle 12⅜ inches in diameter has an area of 120.27 square inches. If the outlet

B is to be oblong in shape with semicircular ends 6 inches in diameter, what must the length be of the straight side *a b*? Using the table, we find the area of a 6-inch circle, which is 28.27 square inches. Deduct this from 120.27, leaving 92. Divide this amount by six, the given width of the outlet, and the quotient will be 15⅓ inches, the desired length of *a b*. Both sections then equal 120.27 square inches.

Finding Increase in Size for Rectangular Duct with Branches

Figs. 70 and 71 show how to compute the amount that a duct must be increased in size in order to have the same area as its branches. Fig. 70 is a rectangular duct, whose depth is 6 inches throughout. Ducts of this kind are usually employed in ventilating work, and are increased in size every time a register is connected. A shows the first inlet, 6 × 15 inches, having 90 square inches area. The second inlet, B, is 6 × 8 inches, and has 48 square inches area. The combined area of A and B is 138 square inches. Now what size must the duct be beyond B to have the area of the two inlets A and B? Divide 138 by 6 and the quotient will be 23, the width of the duct. For scientific computation of duct sizes see explanation given with chart 81 and Fig. 82.

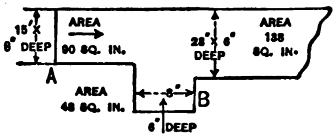


Fig. 70.—Pipe with Branches

Finding Increase in Size for Round Pipe with Branches

Fig. 71 shows the method employed when the pipe is round; in its computation use is again made of the table shown on page 51. The first inlet is 14 inches and the second 8. They contain, respectively, 153.93 and 50.26 square inches area. The combined area of the two inlets is 204.19 square inches. Following the table, on page 51, we find that the nearest area to 204.19 is 204.21 and that the circle that has this area is 16⅛ inches in diameter

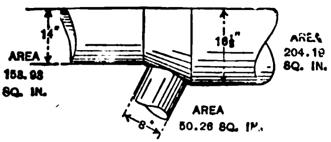


Fig. 71.—Pipe with Branches

Finding Similar Areas in Square, Triangular and Rectangular Pipes

A triangular ventilating pipe is shown in Fig. 72. The size of the pipe is 16 × 32, containing one-half of the product of its dimensions, or 256 square inches area. What must the size of the various pipes be if a transition is made to square, to rectangular 8 inches wide, and round? To obtain the size of the square pipe, simply extract the square root of 256, as explained on page 11. Then 16 × 16 is the size of the square pipe. The length of the section of the rectangular pipe, whose width is to be 8 inches, is obtained by dividing 256 by 8. The quotient will be 32, or the required length. For the size of the round pipe, which should have an area equal to the triangular, follow the column of areas in the table of circle areas on page 51, until 258.016 (the nearest to 256) is reached; this will be found to equal the area of a circle 18⅛ inches in diameter, and is the desired round pipe.

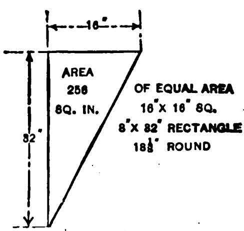


Fig. 72.—Triangular Pipe

Finding Similar Areas in Round, Square and Elliptical Pipes

Fig. 73 shows the section of an elliptical pipe measuring 8 × 12½ inches. The area of this ellipse is 12.5 × 8 × 0.7854 = 78.54 square inches, as explained in connection with Fig. 21. Now in Fig. 73, suppose a transition is to be made to round, square or rectangular pipe, 6 inches wide, whose areas must be similar to the ellipse, what must their sizes be? Following the column of areas on page 51, we find the area 78.54 is for a 10-inch round pipe. For the size of the side of a square pipe, extract the square root of 78.54 as explained on page 11. Thus we have $\sqrt{78.54} = 8.862+$ inches. Now following the table of decimal equivalents on page 3, we find the nearest decimal to .862 is .875 and is equivalent to ⅞ inch. Then 8.862 equals 8⅞ inches. Thus the square pipe would be 8⅞ × 8⅞ inches. For the length of the rectangular pipe, whose given width is 6 inches, divide 78.54 by 6, and the quotient will be 13.09. Again following the table of decimal equivalents, we find the nearest decimal to .09 to be .09375, which is equivalent to 3/32 inch. Then 6 × 13 3/32 inches will be the size of the rectangular pipe.

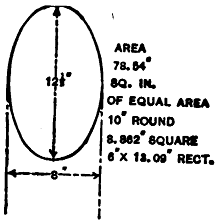


Fig. 73.—Elliptical Pipe

Finding Combined Areas in Two-Pronged Fork

In putting up ventilating, blower and blast pipes, it is often the case that a number of branches are connected to one main, and the main pipe must have the combined area of the branches. An example of this is shown in

Fig. 74, where two round branches are connected to a rectangular main pipe, whose width must be 12⅛ inches. What must the length of the section of this main pipe be to have a combined area of the two branches? Following the table of areas on page 51, we find the area of the 10-inch pipe is 78.54 square inches. The area of the 12⅛-inch pipe is 115.46 square inches. The sum of these two areas is 194 square inches; 194 ÷ 12⅛, or 12.125 (see decimal equivalents on page 3), the width of the main pipe = 16. Therefore the size of the main pipe is 12⅛ × 16.

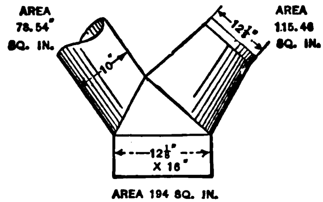


Fig. 74.—Two-Pronged Fork

The solving of a similar problem by "Steel Square and Compass" will be found on pages 39 and 40.

Finding Combined Areas in Three-Pronged Fork

Fig. 75 shows three branches of round pipe, connecting in fork shape to a round main. Each of the branches, A, B and C, is 11⅛ inches diameter, the combined area of which equals 291.61 (see table of areas on page 51) square inches. What must the size of the main be? Following the table of areas, we find the nearest number to 291.61 is 291.04, which is the area of a pipe 19¼ inches diameter.

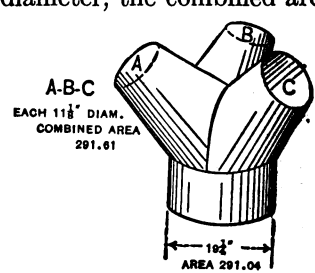


Fig. 75.—Three-Pronged Fork

Finding Degree of Miter Line in Pieced Elbows

The making of pieced elbows and the method of computing the degree of the miter line with the use of the protractor is simply explained in connection with Fig. 76. This will enable the student to lay out any size elbow no matter what its diameter or its throat may be, or the number of pieces it may contain, without drawing the entire elbow. An elbow whose diameter is, say, 30 inches and whose throat is 40 inches, requires by the old method a quadrant or quarter circle having a 70-inch radius; this is done away with in the method given.

Let A F represent the horizontal line to be drawn first and upon which the protractor is placed in the position shown. Now to find the angle of the miter line for the three-pieced elbow shown by B, always bear in mind that each of the end pieces in the elbow count one, and each of the other pieces in the elbow, count two. As there are two end pieces in B, they will give two, and as there is but one middle piece that will also give two, making a count of four. As the finished elbow is to have an angle of 90 degrees, then divide 90 by 4, and the result will be 22½, or the number of degrees of the angle of the miter line.

From the center of the protractor C, draw a line through the 22½ degrees as shown, extending it by C D. This line C D is then the miter line for a three-pieced elbow, no matter what throat or diameter the elbow may have. To lay off the elbow correctly, always measure the throat from the center C of the protractor. In other words (in this case) C 1 is the throat and 1-5 the diameter of the pipe. From 1 and 5 erect perpendiculars until they intersect the miter line C D at 1 and 5 respectively.

1-5-5-1 represents the end piece of a three-pieced elbow, and is all that is required in laying out the pattern.

Using the old method, the quadrant 5 S T 1 would have to be first drawn before the miter line could be obtained, and if the throat C 1 was 20 inches, and the diam-

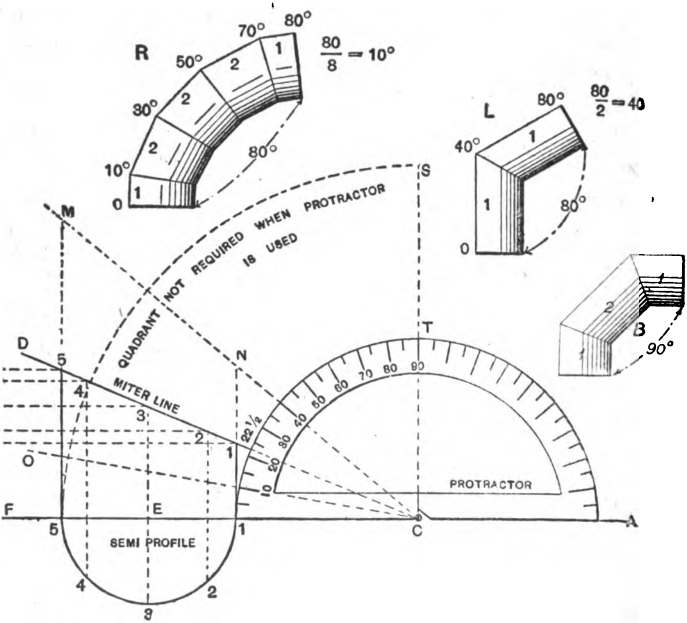


Fig. 76.—Finding the Degree of the Miter Line in Pieced Elbows, by Computation and the Protractor

eter 1-5, 18 inches, the quadrant 5 S would have to be struck with a 38-inch radius, taking up too much time and space. By the use of the protractor no quadrant is required. This rule is applicable whether the profile of the elbow is round, oval, square or rectangular.

Now using E, which is the bisection of 1-5, as center, draw the semiprofile of the pipe, and divide into equal divisions, as shown from 1 to 5. From these divisions erect perpendicular lines until they intersect the miter line D C, shown also from 1 to 5, from which points the pattern is developed in the usual manner.

Regardless of the angle the finished elbow may have, or the number of pieces it contains, always count each of the end pieces as one and each of the middle pieces as two, the addition of which is divided into the degree or angle of the finished elbow, in order to find its degree of angle for its miter line. Two examples are given:

Let us assume that an elbow is to be made of two pieces to have an angle of 80 degrees when completed, as shown in diagram L, which contains two end pieces. Then 80 ÷ 2 = 40, or the degree of the miter line. If this elbow had the same profile and throat as the one previously explained, then the lines in the semiprofile would simply be extended until they would intersect the miter line drawn through the fortieth degree shown by C M.

A five-pieced elbow, to contain 80 degrees when completed, is represented by R. Following the rule, the two end pieces count two and the three middle pieces six, making eight for the total count: 80 ÷ 8 = 10, the number of degrees of the miter line shown from C to O.

Finding Circumference of Pipes Made of Heavy Material

When stacks or piping are made of heavy metal having a given inside diameter, an allowance must be made to the girth, for the thickness of the metal in use, to maintain the inside diameter. The rule is: Circumference equals 3.1416 times inside diameter of pipe, plus seven times the thickness of metal in use. For example, let us assume that a stack is to be constructed of one-quarter inch thick metal, the inside diameter to be 24 inches. What circumference would be required to maintain the inside diameter?

Following the rule, $24 \times 3.1416 = 75.39$; $75.39 + 1.75$ (seven times thickness of metal) $= 77.14$.

Obtaining Radius for Flaring Work Without Using Center

In Fig. 77 the method of obtaining the length of radius by computation is shown. This rule saves the time and labor of laying out the full size drawing of an article having little flare, and of obtaining the blank for a curved molding in cornice work, like diagram A[1] by *a b*. Let us suppose that a flaring collar is required, whose base, D C, is 40 inches in diameter, and top, A B, is 36 inches. How can the length of the radius be found? Multiply the large diameter by the slant height and divide by the difference between the large and small diameters. The large diameter is 40 inches, the slant height 8 inches, the small diameter 36 inches, and the difference between the large and the small is 4 inches. Then $8 \times \frac{40}{4} =$ 80, or the length of the radius E C.

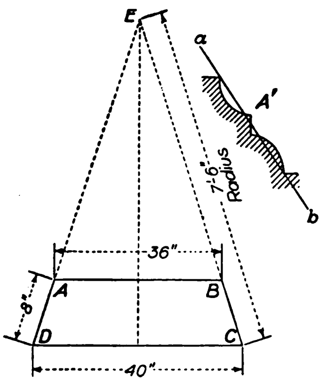


Fig. 77.—Obtaining Radius

Practical Application to Heavy Stack Work

This same rule can be applied to advantage in laying conical sections of pipe, made of heavy metal, when a small end must enter the large end and be riveted, as is shown at B in Fig. 78.

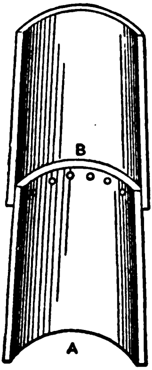


Fig. 78.—Sectional View of Joint Between Two Sections

In this case the flare is so little that if lines were extended as in ordinary flaring work, it would require a space seldom found in the shop. To lay out the pattern for a conical section when the diameters A and B and the slant height B A are known. Let A B C D in Fig. 79 represent a section of a tapering pipe, for which we desire to find the radius by computation—that is, without extending the lines D A and C B till they meet. We will assume that ½-inch metal is being used, so that D C equals 20 inches and A B 19 inches. To find the length of the radius the following rule can be used: Multiply the large diameter by the slant height and divide the result by the difference between the large diameter and the small diameter. The large diameter D C is 20 inches, and the slant height A D may be 24 inches or whatever length is desired. The difference between the large and small diameter is 1 inch. Thus we have 20 × 24 = 480 ÷ 1 = 480 inches, or 40 feet, the required length of radius. Now, knowing the radius, we can obtain the depth of the curve, or the

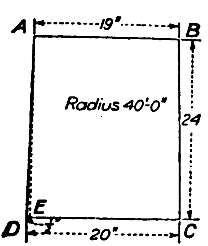


Fig. 79.—Diagram of One Section of a Pipe, to be Constructed of Heavy Metal

spring, on the center line as follows: Fig. 80 shows the method of describing the pattern when the length of the radius is known, but is not used, and is similar in principle to the method described in connection with Fig. 89, for obtaining the patterns for a curved moulding. First draw a line to represent a portion of the radius, as A B. At right angles to this line erect the line C D, a little longer than one-half of the circumference of the large diameter

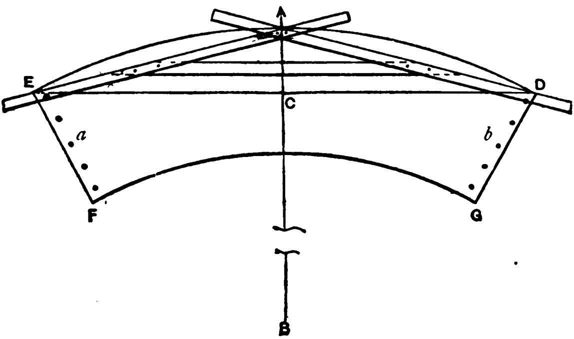


Fig. 80.—Mechanical Method of Drawing the Arc of a Circle through Three Given Points

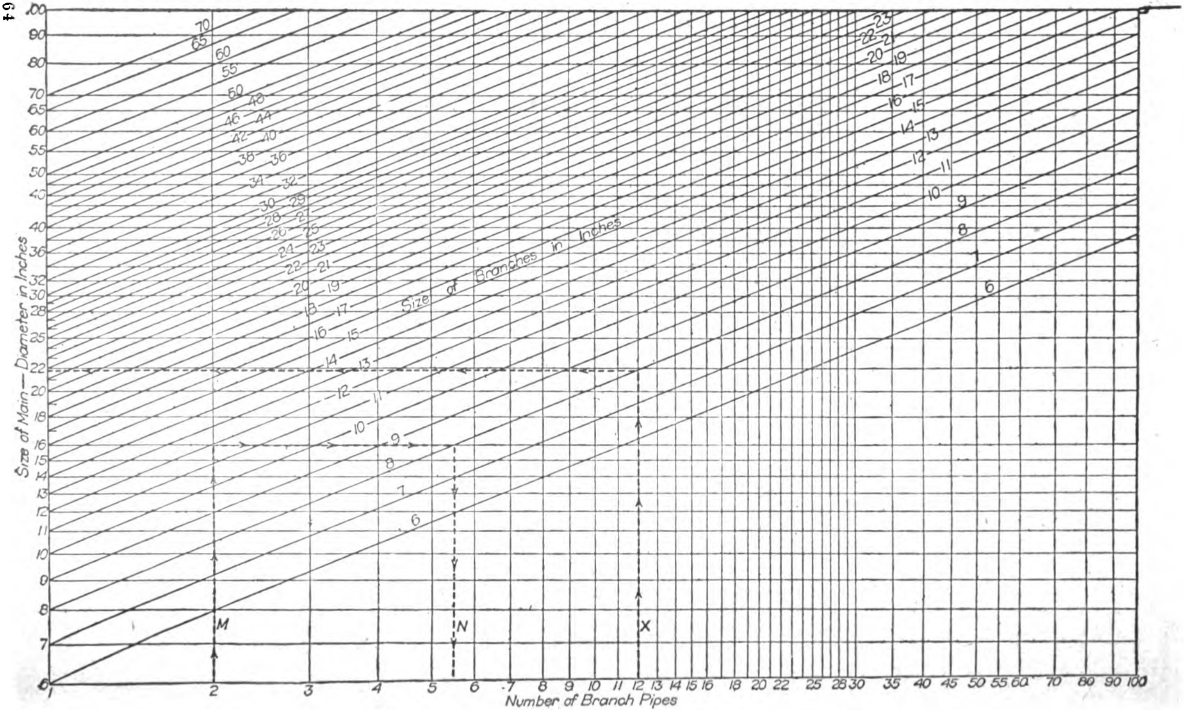
D C in Fig. 79, or, say, 3 feet. The problem then becomes to place the point A in Fig. 80 at such a distance above C that the required arc of the pattern will pass through the two points A and D. This is accomplished in this way: Square the distance E D, or 6 feet, and divide by 8 × 40 feet (the radius). Thus $6 \times 6 = 36$; $8 \times 40 = 320$; $36 \div 320 = \frac{36}{320} = \frac{9}{80}$ of a foot; $12 \times \frac{9}{80} = \frac{108}{80}$ or 1.35 inches as the depth of the curve, or the distance of the point A, from C. Referring to the table of equivalents on page 3, we find the nearest decimal to .35 is .34375 and equals 11/32 inch. The distance from A to C then equals 1 11/32 inches. Having found the point A, the arc of the circle is drawn by extending D C as D E, making C E equal to C D. Then D E is the chord and C A the rise. Drive nails at E and D. Make a triangle, as shown, of strips of metal or wood, so that the vertex comes at A, and stiffen the same with a cross brace. Now by moving the triangle, always keeping the sides touching the nails at E and D, the arc may be traced by a pencil held at A. Set off half of the circumference of the large diameter D C in Fig. 79 on the arc just drawn on either side of the center A in Fig. 80, as shown by E and D. Knowing the height of A D in Fig. 79, draw an arc parallel to the arc E A D in Fig. 80, as shown by F G. Then take one-half the circumference of the small diameter A B in Fig. 79 and set it off on either side of the center line A B, on the inner arc, F G, in Fig. 80. Draw the radial lines E F and D G, which completes the pattern. Allow laps, and punch holes for riveting at *a* and *b*.

CHART FOR PROPORTIONING TRUNK MAIN SYSTEMS

An important item in the economical design of heating and ventilating systems is the proportioning of the trunk mains to adequately supply the branch leaders which deliver the heat to rooms. The basic methods used in such systems are the same, whether the air is distributed by natural draft or forced into the rooms through the ducts by a fan.

The working of both these warm-air systems depends on a movement of air, and they therefore insure that the

CHART FOR COMPUTING PIPE SIZES (FIG. 81)



EXPLANATION FOR USE OF CHART, FIG. 81

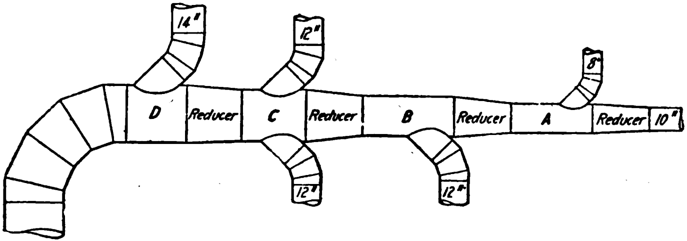


Fig. 82

ILLUSTRATION:
Reduce all to basis of smallest Branch
A supplies
1-8" = 1
1-10" = 2 } 3-8" = 13" for A
B supplies
3-8" (A)
1-12" = 3 } 6-8" = 17" for B
C supplies
6-8" (B)
2-12" = 6 } 12-8" = 22" for C
D supplies
12-8" (C)
1-14" = 4 } 16-8" = 25" for D

Fig. 82-A

For the solution of all problems follow lines from points to point of intersection and follow horizontal line to answer on scales as shown. To find size of main equal to a number of branches follow out as shown by line X. Thus, 12—8-inch branches equal 21.7 or a 22-inch main.

To find the number of branches of a required size equal to a number of branches of a given size, follow out the lines as shown by *M-N*, reading from right to left or vice versa. Thus, 2—12-inch branches equal 5.5 or 6—8-inch branches.

rooms will be ventilated as well as heated, a feature other systems do not possess. The warm-air furnace is generally used for heating the air in natural draft or gravity systems. In the mechanical system both the warm-air furnace and hot-blast steam coils or radiators are employed as air heaters.

In the larger installations, whether gravity or fan circulation is relied on, the trunk main system of piping has been found to give economical service. The more extensive application of trunk main piping instead of individual leaders from the furnace to each room, should result in more warm-air furnace installations in larger buildings.

With individual leaders, the combined friction in the pipes is generally greater than in the trunk main; the total pipe surface exposed is relatively larger with a resultant greater heat loss by radiation. In the trunk main system of piping, these factors are reduced and the cross-sectional area of the main when properly proportioned is less than the combined area of all the branches from it.

There is no advantage in proportioning a trunk line system by equalizing the pipe areas; it is uneconomical besides. The proper basis for adequate service is to design the system by equalizing the pipe capacities.

Determining Pipe Capacities Without Computation

The chart herewith has been prepared as an aid for this purpose when designing such systems. It shows the size of main required to feed any number of branches (from 6 to 100) to 100 inches in diameter, round pipe being considered, as it gives the best results. The diagram also shows the number of pipes of a given size that equal in capacity a number of pipes of a required size. These various results are obtained without computation by simply following the respective scales given on the chart. The figures embodied in this presentation are based on the laws of friction of gases in pipes, and give adequate sizes to supply the required volume of air. Suppose it is necessary to connect twelve 8-inch branches to one trunk main. The diagram shows that a 22-inch duct would be adequate. By the ordinary rule of combining all the branch pipe areas the result would be 12 times the area of an 8-inch pipe, which is 50 square inches, or a total of 600 square inches, equal to a 28-inch main. It is a waste of material and labor, therefore poor economy, to install pipes that are larger than required as computed on a scientific basis.

The diagram is simple to use. After working out several examples with its aid there is no difficulty in understanding its application to almost any condition. A diagram of this sort is merely a graphical presentation of a series of mathematical computations conveniently combined for ready reference. It is compact and contains considerable data for its size, and does not split hairs on fractions, thus doing away with a lot of figures, as in a tabulation, which tend to confuse. If it is chosen to work down to a fine point and consider the decimal fractions, they are here, but are inconspicuous. The logarithmic division of the chart takes care of this feature. For practical purposes, the use of whole numbers and the nearest commercial pipe size is recommended.

How to Use the Chart in Everyday Work

Without having to figure out any complicated formula, the chart gives practical results for any condition. It does not matter how the sizes of branches were arrived at. The diagram will give the size of main on the same basis for adequately handling the necessary volume of air because it is equalized by the pipe capacities.

Take an instance where six outlets have to be supplied by one main duct (Fig. 82, Page 65). The layout and the sizes of the branches are shown in Fig. 82A. The branch outlets indicated have been figured to provide an adequate supply of air for a given condition. The problem is to proportion a main that will deliver the required air volume to each section as illustrated. For convenience these sections of the main have been marked A, B, C and D, starting from the branch farthest from the furnace, fan or steam air heater as the case may be.

How to Find Size of Main to Supply Branches

Section A must supply one 8-inch and one 10-inch branch. To determine the size of main for this service, all branches must first be reduced to a common basis on equal terms, and this is done by converting all sizes into the equivalent of the smallest size branch, which in this instance is 8 inches. One 10-inch pipe is found to be the same as two 8-inch, as in the chart, and adding the one 8-inch gives an equivalent of three 8-inch pipes that section A must handle. The diagram shows that a 13-inch round pipe will feed these branches. The other sections are treated in like manner, with the results given in the illustration.

Two of the typical steps are indicated in the chart by broken lines with arrows showing the direction in which to read. Thus to reduce two 12-inch branches to the equivalent number of 8-inches, find the two on the lower scale and read up, as indicated by line M, until it intersects the diagonal for 12-inch pipe. From there follow across horizontally until the diagonal line for 8-inch branches is reached, and from this intersection read down, as indicated by line N, to the scale which shows that 5.5 is the equivalent number of 8-inch branches. It is not necessary to regard the fractions for practical purposes, and the answer in this instance therefore gives six 8-inch branches as the equal of two 12-inch pipes. Under some conditions, such as reducing a larger number of branches to a smaller number of a larger size, the working would be the same except that the reading on the diagram would be from right to left, that is, from line N to M, if that were the condition.

The trunk main for section C in this example has to supply the equivalent of twelve 8-inch branches. This step is indicated in the diagram by line X. Find 12 on the lower scale, giving the number of branch pipes, and follow up to the point of intersection on the diagonal line for 8-inch branches, and then read across horizontally to the left-hand scale, which gives the diameter of the main as 21.7, or 22 inches, which is the nearest practical size.

All the parts in the illustration were worked out in this way, using the diagram with results as marked. The size of trunk main is 25 inches at the furnace. This gives a pipe area of 490 square inches, while the combined area of all branches handling the aggregate volume of air is 620 square inches.

This illustrates how all problems of sizes for trunk mains may be solved with the aid of the chart here presented, no matter what system of heat supply is used—and no figuring is necessary.

DESIGNING REFUSE REMOVAL SYSTEMS

The removal of waste material from machines in industrial plants by means of fans or blowers has been in general use for over 70 years. It is the most efficient and satisfactory method known; yet even now the minimum velocity or volume of air required to convey substances of varying specific volumes and densities is not known to any definite extent. With this lack of fundamental data, it is impossible to do more than give a general insight into the methods which have been successfully employed for years, to point out the opportunities for improvement and to consider such information as will likely be of most benefit in the practical application of such systems.

In the early days it was necessary to do considerable experimenting to determine the correct sizes of pipes to attach to machines of the varying types and capacities. In due course of time a standard size of pipe was generally adopted for a given duty on a machine of a certain type and capacity, and these sizes have become almost universal.

The way these sizes were arrived at was very crude. In those days (and even by some at the present time) it was generally supposed that the pressure pushed the stuff along. Nobody thought it was the velocity.

Hence experimenters would put up a system of pipes, add the areas of the branches together to determine the size of fan inlet and then try the fan at varying speeds, try different shapes and proportions of the hoods, etc., until the system seemed to work all right. Probably the very next job would fail to work because the piping system was more extensive or the outlet from the shaving vault was too small, thus causing undue back pressure or some other of the many things which can happen around such plants.

About the time the general form of hoods and pipe sizes had been standardized, considerable stir was created by inventors of "dust arrestors" or "dust separators" or "dust collectors," as they are variously known by different makers.

So much for the history of refuse-handling systems, which, it is clearly evident, have been made up of cut and try methods from the beginning.

What causes greatest surprise is the fact that so little attention has been paid to this problem by our universities and professional experimentalists.

Investigations and experiments should first determine what velocity is required to move different substances of varying weights and bulk. Then should be determined what proportionate volume of air is required to move in a unit of time a specific volume of different substances having varying weights and bulk. Air pressure is only a measure of velocity and resistance, beyond which it has nothing to do with the moving of material, as many suppose.

The relative area of a substance has a great deal to do with the ease with which it can be moved by air. For instance, a comparatively low velocity will move a cubic foot of powdered coal which will pass through a 100-mesh wire screen. It will take double the velocity to move a cubic foot of coal which will pass through a 25-mesh screen. But a centrifugal fan cannot produce high enough velocity to move a cubic foot of coal in a solid block.

The same is true of many other substances; take for instance shavings and dust from planing-mill machinery. Twenty feet per second will move the lighter dust; 40 feet will move the shavings; 50 feet will move the sawdust, but there are knots, blocks, etc., which also have to be taken care of, and these sometimes require 60 feet or more per second. Hence the velocity has to be selected which will take care of the largest and heaviest pieces likely to enter the system.

From this it will readily be seen how essential it is for economical operation to know what is the lowest velocity required to move a given substance, as the frictional loss multiplies directly as the square of, and the power to drive the fan directly as the cube of the velocity. For example: if only 40 feet per second is necessary and 80 feet is provided and at the lower velocity it requires 25 h.p., it would require 200 h.p. at the higher speed. This is not an absurd comparison, as there are many plants where just such a comparative waste of power is taking place.

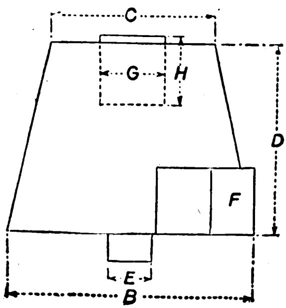


Fig. 83.—Diagram of Verrell Collector

Frequently the velocity as predetermined may be correct, but the volume of air for the volume of material to be handled in a given unit of time may be insufficient. In other words, the ducts are too small. Hence the fan has to be speeded up to create a higher velocity in order to move the requisite volume of air. This has exactly the same effect on the power as would the velocity if it had been figured too high at first.

Example of Extravagance of Small Pipes

An example of this latter character came under observation about a year ago, in one of the largest mills in the South.

A careful analysis of the situation showed it would require 438 h.p. additional to do the work with the existing plant of exhaust system of small size pipe by speeding it up; whereas, by revising the plant on a larger scale, proportionate to the work to be done, it would require 156 h.p. additional. Hence the saving would be 282 h.p. by changing the plant over. At the conservative figure of $40 per h.p. per annum, this would indicate a saving of $11,280, which, at 5 per cent, would represent the interest on an investment of $225,000. The owners of this plant have spent thousands of dollars experimenting on processes to utilize the waste from this mill for making various by-products, some of which have great value; hence they are more conservative about the consumption of refuse for fuel than are many others in a similar line of work.

Points on Laying Out Piping

Next one should map out the general scheme for the piping system, being guided by the following considerations in the order in which they are given: 1. The most convenient place to pipe the fan. 2. The most convenient place to drive the fan. 3. The most convenient place to give the most direct line of discharge to the final receptacle.

Proportioning Branch Pipes

Next in order is to determine the size of the branch pipes to each machine, which can be done by the aid of the accompanying table I, as this gives the standard diameters to attach to the hoods enclosing the knives and saws of ordinary machines.

TABLE I—SIZES OF BRANCH PIPES FOR PLANING MILL MACHINERY

Upper Cylinder, Length of Knives	Diameter of Pipe	Lower Cylinder, Length of Knives	Diameter of Pipe
5 inches	4 inches	5 inches	4 inches
10 "	5 "	10 "	5 "
14 "	6 "	14 "	5 "
24 "	7 "	24 "	6 "
30 "	7 "	30 "	7 "

	Diameter of Pipe, Inches		Diameter of Pipe, Inches
Matcher heads, each	5	Mortiser, floor spout	6
Sash and cabinet shaper, each head	4	Floor sweep-up	6
Door tenoner	5	Rip-saw and re-saws	
Sash tenoner	4	10 to 16 inches diameter	4
Door and sash sticker, each head	4	18 to 24 inches diameter	5
Blind slat sticker	4	42 to 60 inches diameter	6
Blind rail router	4	Cut-off and grooving saws	
Panel raiser, each head	4	10 to 16 inches diameter	4
Sand drum, 24 inches long	4	18 to 24 inches diameter	5
Sand drum, 30 inches long	5	Band saws, small	3

Molders, buzz planers, pony planers, diagonal planers, jointers and all other machines having knives or saws of dimensions given will require pipes of their respective diameters. Timber planers require 25 per cent larger pipes than ordinary planers. High speed planers and matchers require about 50 per cent more area than is indicated in above table.

On the plan mark the sizes of the various branches; then add these areas together whenever two or more pipes join and find the resulting diameter of the main. Continue this process until every branch is taken care of back to the fan, which finally determines the minimum diameter which the fan inlet may be.

If the fan selected is a size or two larger than the sum of the areas would indicate, it will do the work when running at a very much slower speed, and will require less power. For example, supposing the plant requires a 12-inch main, which with the branches and separator offers a resistance of, say, 4¾-inch water gauge. If a fan having a 12-inch inlet should be attached it would have to run at about 1,865 r.p.m., requiring 5⅞ h.p.; whereas, if a fan having an 18-inch inlet were attached to produce the same velocity, it would only have to run at 1,040 r.p.m., requiring 5¼ h.p. Thus the speed would be reduced 44 per cent and the power reduced more than 10 per cent.

Calculating Size of Dust Separator

Having determined the size of the fan the next in order is to determine the size of the dust separator. The purpose of a separator is to remove the shavings and dust from the air blast, delivering the former into some convenient receptacle or on the grates beneath the boiler, allowing the air to escape freely with little or no pressure or resistance into the atmosphere.

All the separators on the market, save one, employ centrifugal force to accomplish the separation, the one exception depending upon centripetal action. Every maker of separators sets up great claims for his particular device and some do work better than others, but, more often than not, the real difference in the results obtained, if there is any, is due to differences in engineering. The accompanying table II gives the principal dimensions of one of the standard makes of cone bottom separator. Any other good separator of this type will not be much different in its proportions.

The centripetal type of separator referred to is made by a concern in Minneapolis. The dimensions of it do not vary to any great extent from the dimensions in table II. The discharge pipe from the fan connects into the central opening in the top, where the air usually escapes from most separators.

TABLE II—PROPORTIONS OF PARTS OF DUST SEPARATORS

Openings				Dimensions			
No. and Diam. of Inlet	Size of Inlet, Inches	Diam. Air Outlet, Inches	Diam. Dust Outlet, Inches	Outside Diam. Cylinder, Inches	Height Cylinder, Inches	Length Cone, Inches	Approximate Weight, Pounds
5	2½x 9	8½	3	29½	14	26½	70
6	3 x10½	10	4	35½	15½	32½	100
7	3½x13½	13	6	41½	18½	37½	140
8	4½x16	15	6	47½	21	43½	175
9	5 x18	17	6	53½	23	50	245
10	5½x21	20	10	59½	26	56	315
12	6½x24	23½	10	65½	29	61½	395
13	7 x27	26	10	71½	32	67½	490
14	8 x30	28	10	77½	35	72½	575
16	8½x32	31	10	83½	38	77½	715
17	9 x35	33	10	89½	41	82½	875
18	9 x40	36	10	93½	46	85½	930
20	10 x41	39	10	97½	47	89	1,000
22	10½x43	41	11	101½	49	93	1,095
23	11 x45	44	11	105½	51	97	1,455
24	11 x48	46	12	109½	54	99½	1,600
25	11 x51	49	12	113½	57	103½	1,700
26	11½x54	52	12	117½	60	109½	1,855
28	12 x57	55	12	121½	63	111½	2,035
30	12 x60	58	12	125½	66	115½	2,155
32	12½x63	61	13	129½	69	118½	2,250
34	13 x66	64	13	133½	72	122½	2,420
36	13½x69	67	13	137½	75	126½	2,555
38	14 x72	70	14	141½	78	129½	2,745
40	14½x75	73	14	145½	81	133½	2,900
42	15 x78	76	14	149½	84	137½	3,065
44	15½x81	79	14	153½	87	141½	3,235
46	16 x84	82	14	157½	90	145½	3,395

The above recommendations apply to shavings, but not to light buffing dust etc., for which the separators must be selected to suit operating conditions.

The accompanying table III gives the dimensions of another type known as a flat bottom separator, patented and owned by a Grand Rapids concern. It works well, has the advantages of being only about two-thirds the height of the other types, and is, comparatively, very easy to erect.

Requisites of a Good Separator

A good separator should not set up a resistance to the flow of air, which is in excess of the velocity head due to the flow. In other words, if the air velocity is 60 feet per second in the discharge pipe, the separator should not offer a resistance that will increase the discharge

TABLE III—PROPORTIONS OF STANDARD VERRELL COLLECTORS

No.	Diam. Pipe from Fan	Area of Dust Inlet	B	C	D	E	F	G	H	Wgt. Lb.
000	6	28	..	..	..	..	.....	..	..	..
00	7	38	32	26	37	7	6x7	10	12	70
0	8	50	..	..	..	..	.....	..	..	..
1	10	78	42	38	48	12	10x12	14	14	180
2	12	113	46	37	48	12	10x12	17	14	240
3	14	154	54	42	60	16	10x14	17	16	471
4	16	201	60	45	72	16	14x16	22	26	490
5	18	254	66	54	72	16	16x20	25	26	500
6	20	314	72	58½	76½	16	14x24½	27½	26	530
7	22	380	84	65½	96	16	16x25	32	27	682
8	24	452	87	7¾	96	16	18x26	34	27	889
9	26	531	96	78	96	16	18x32	37	27	1,137
10	28	616	102	84	96	16	18x37½	40	27	1,250
11	30	707	111	..	..	16	....	..	..	1,500
12	32	804	114	90	120	16	22x41½	46	27	1,800
13	34	908	117	97	120	16	23x44	48	27	2,000
14	36	1,018	129	105½	120	16	24x45½	50	27	2,050
15	38	1,134	132⅝	111	120	16	26x44½	53	27	2,150
16	40	1,257	...	...	...	..	.....	..	..	.....
17	42	1,385	...	...	...	..	.....	..	..	.....

pressure more than 0.81 inch water gauge. All makes of separators are regularly built either right or left hand.

Warm Air Furnace Heating

A comprehensive treatment of the design and installation of furnace heating systems covering the matter more fully than is possible in this work is available to those who wish to take up the study in "Furnace Heating," by Wm. G. Snow, a past president of the A. S. H. & V. E. This work treats the subject on the heat unit basis, with illustrations and plans of different types of buildings, and gives tables applying to the work. It makes certain the success of those who follow its teachings, as has been testified by an immense number who use the work for reference.

It has an appendix showing the types of fittings used in furnace practice, with the patterns and instructions for their production.

The work also has an appendix of special articles relating to tests and similar instructive matter.

CHAPTER V

CHIMNEY TOPS AND VENTILATORS

Obtaining Proportions for Ventilators

Another subject of importance to sheet metal workers, is finding the proper proportions for ventilators and chimney caps, as shown in Fig. 84, in which the given diameter of the ventilator is 24 inches. It is immaterial what the diameter of the ventilator may be, the rule for obtaining the proportions will be as follows:

Draw a line, A B, of indefinite length, on which set off the diameter of the ventilator, taken as 24 inches in this case. Describe a semicircle, *c d*, for the one-half plan of the ventilator shaft, and with the same radius and with *c* as the center describe another semicircle, A *o*. Divide this diameter, A *o*, into four equal parts, or 6 inches each, as indicated in the plan, by 1 2 3 4. Now draw vertical lines on the points 1 and 2, intersecting the semicircle A *o* at the points E and F. With a radius *o* F and with *o* as the center describe the semicircle *g*, which establishes the points X X in the elevation, or 34 inches in diameter. With *o* E as radius and *o* as the center describe the semicircle *h* B, which establishes the points P P in the elevation, or a trifle less than 42 inches in diameter. With these points established, we now have the diameter of the wind guard P P and also the diameter of the hood of the ventilator X X.

The height of the wind guard is made equal to seven-eighths of the diameter of the ventilator. Thus, for a 24-inch ventilator the guard would be $\frac{7}{8} \times 24$ inches, or

21 inches in height. Its diameter would be $\frac{7}{8} \times 2 \times 24$ inches, or 3 feet 6 inches, as before obtained. The hood would be 2 feet 10 inches in diameter as previously obtained. The cylindrical height between the top of the ventilator shaft and the base of the hood should be twice the area of the 24-inch shaft. The area of a round pipe is equivalent to the square of the diameter multiplied by

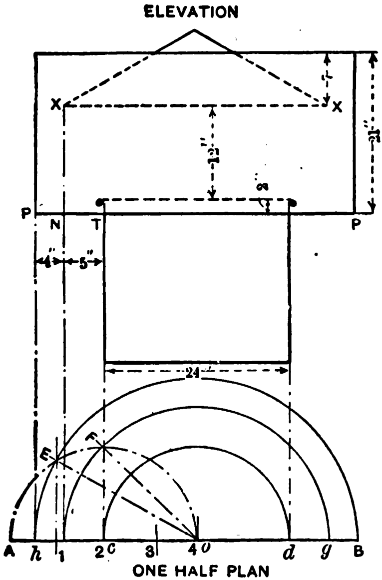


Fig. 84.—Proper Proportions for a Ventilator

0.7854, so that for a 24-inch pipe it is $24 \times 24 \times 0.7854 = 452+$. Twice this area is accordingly $904+$. What is now to be considered is the imaginary cylindrical surface between the top of the shaft and its hood, which cylinder has for its base the circle of the shaft itself. As the area of a cylindrical surface is equal to the product of the circumference of the base multiplied by the height of the surface, if we divide the area, 904, by the circumference of the 24-inch pipe, which is $24 \times 3.1416 = 75.39$, the quotient will be a small fraction less than 12. This is the desired height in inches as shown in the illustration and is one-half the diameter of the 24-inch pipe. The air space P N in the elevation, or g B in the plan, is also equal to a little more than the area of the 24-inch pipe, as is also the air space N T of the elevation or d g of the plan.

This can be proven by following the rule given in Fig. 17 for finding the area of a ring as follows: Deduct the square of the small diameter from the square of the large diameter and multiply the remainder by 0.7854. Thus in Fig. 84 *h* B in plan equals 42 inches and 1 *g* equals 34 inches; then $42 \times 42 = 1764$; $34 \times 34 = 1156$; $1764 - 1156 = 608$; $608 \times 0.7854 = 477.52$ square inches, or the area of the space between the wind guard P and outer edge of hood X, as shown by P N in elevation or *h* 1 *g* B in plan. The above area of 477.52 is greater than desired, because the diameter *h* B in plan or P P in elevation is a trifle less than 42 inches in diameter. Again, the diameter 1 *g* in plan or X X in elevation equals 34 inches and when squared equals 1156; the diameter of the pipe *c d* equals 24. Then $24 \times 24 = 576$; $1156 - 576 = 580$; $580 \times 0.7854 = 455.53$ square inches, or the area of the space between the shaft T and outer edge of hood N, as shown in elevation, or the space shown by 1 *c d g* in plan. It will be noticed that in the spaces in the two rings just described, the areas are greater than desired, and adding to the efficiency of the ventilator. It is thus clear that the area between *d* B of the plan is twice the area of the 24-inch pipe, and the sum of the two spaces *d g* and *g* B just considered.

The cone for the hood is at an angle of 30 degrees. This, of course, can be made to suit individual taste. The hood should be closed at the base, as indicated in the elevation by the dotted line X X, perhaps better still with an inverted cone to give the air an easy passage. The wind guard can be placed one-third its height above the base of the cone, or 7 inches as shown; this leaves the guard 2 inches below the top of the shaft.

Finding Proportions for Emerson Ventilator

Another ventilator generally used is known as the Emerson ventilator, shown in Fig. 85.

To obtain the proportions, make the distance from *a* to *b* and from *e* to *f* equal to twice the diameter of the pipe *c*. Draw the flares at 45 degrees, and extend them until they intersect at *d*, the distance above *h*, at which the top is to be placed, thus making *d h* equal to one-half the diameter of the pipe *c*.

Thus, if *c* were 24 inches, *a b* and *e f* would be 2 × 24 or 48 inches in diameter. By making the flares 45 degrees, then *j i* becomes 12 inches, the same as *a i*, which will also make the distance *d h* 12 inches, the same as *j i*. As the cylindrical surface between the top of the shaft *h* and top roof *d* should be twice the area of the 24-inch shaft *c*, then the area of this imaginary cylindrical surface can be proven as follows: Area of 24-inch shaft equals 24 × 24 × 0.7854 = 452.39; 2 ×

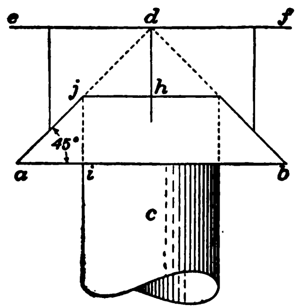


Fig. 85.—Proportions for Emerson Ventilator

452.39 = 904.78. As the area of the imaginary cylindrical surface is equal to the circumference of the 24-inch shaft multiplied by the height of *h d* or 12 inches, then, 24 × 3.1416 = 75.3984; 75.3984 × 12 = 904.78 square inches or twice the area of the 24-inch shaft.

CHAPTER VI

ARCHITECTURAL SHEET METAL WORK

Finding Radius for Circular Wall

We now come to a point where a few short rules in computation may be of value to the sheet metal worker. In Fig. 86 let A B represent a wall with a rounded corner from *a* to *b*, on which a molding, gutter or cornice is to be placed, and it is necessary to find the radius. To do this, measure the distance from *a* to *b*; this is five feet. Bisect *a b*, obtaining *d*, and from *d* measure the distance, at right angles to *a b*, to the outside of the curve at *c*, which in this case measures 1 foot 3 inches. Now, following the rule given in connection with Fig. 18, divide the sum of the squares of one-half the chord and the rise by the rise, and one-half the quotient will be the desired radius. Thus, reducing to inches, we have, in Fig. 86,

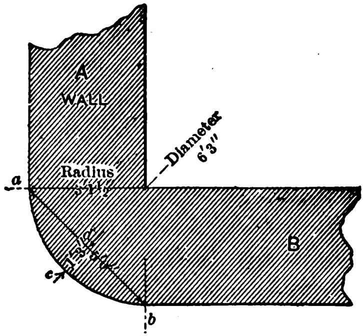


Fig. 86.
Finding Diameter of Circular Wall

$$\frac{30^2 + 15^2}{15} = \frac{900 + 225}{15} = \frac{1125}{15} = 75;\ 75 \div 2 = 37\tfrac{1}{2}$$ inches, or 3 feet $1\tfrac{1}{2}$ inches radius.

Finding Radius and Developing Pattern Without the Use of the Radius in a Circular Molding

Fig. 87 shows how the radius is computed by scale for striking the patterns for flaring strips used in making up circular gutters, moldings or other flaring ware. The formula will also be given and applied for obtaining the pattern without using the radius, or having any recourse to a center, when developing the flaring strip. This rule will be found useful when developing patterns for flaring articles, when the radius is of such length as to make it impractical to use.

To show how the rule is used in practice, let M in Fig. 87 represent a circular tower, around the eave of which a circular molding indicated by X is to be placed, the diameter of the tower being 32 feet in this case. Let A represent the full size drawing of the mold X, and B C the wall line. In the usual method, the line D E would be drawn parallel to and at a distance of 16 feet from B C (being one-half of the 32 feet shown in the plan) and the radius with which to strike the pattern would be obtained by averaging a line *d b* through the mold A and extending it until it met the center line D E, when the full size radius would be obtained.

This same radius can be obtained with less labor and less space by means of a scale drawing as follows: As the diameter of the tower is 32 feet, take one-half, or 16, and scale this to any desired scale, in this case ⅛ inch to the foot. Having the full size drawing A in its proper position against the wall line C B, draw the line D E parallel to and at a distance of 2 inches from B C, which will represent 16 feet by the ⅛-inch scale. Average a line through the mold A as shown by *a b*, and extend it

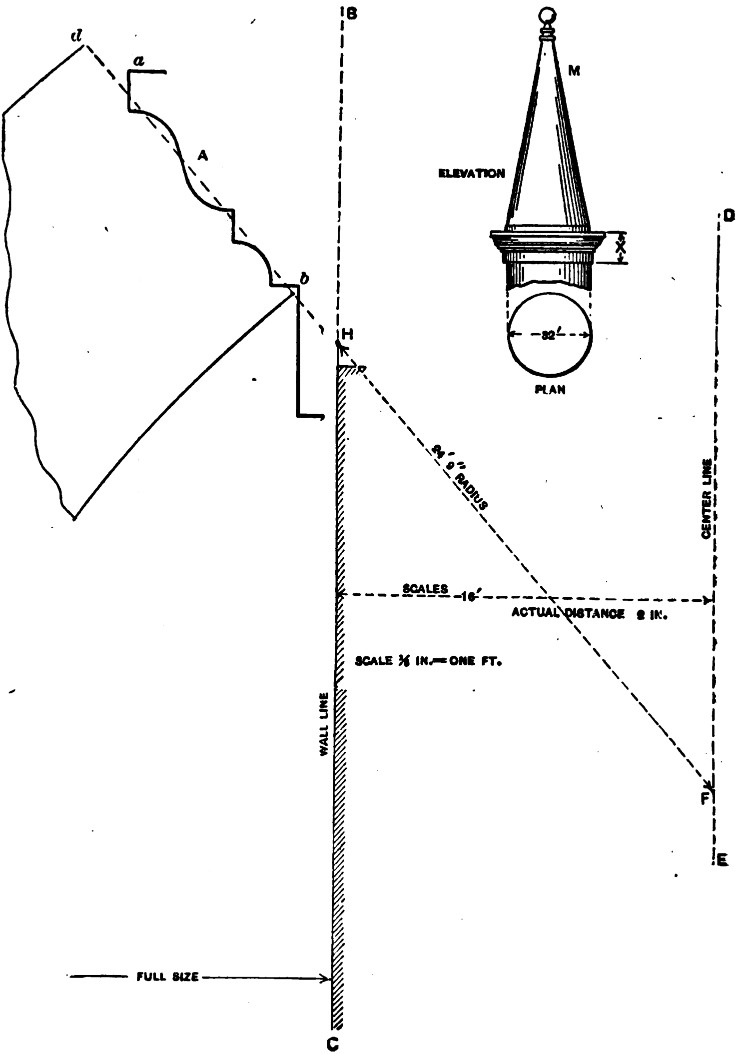


Fig. 87.—Obtaining Radius by Means of a Scale Drawing

until it intersects the center line D E at F. Then as all that part to the right of the line B C is drawn to ⅛-inch scale, and that part to the left of B C is full size, then scale the length from F to H ⅛ inch to the foot, while all that part outside of H shows its true length. Then F H will scale 24 feet 9 inches, and was obtained in an actual distance of 2 inches. (The scale used by Mr. Neubecker was ¼ inch to the foot, making the distance between B C and D E 4 inches, and more convenient and accurate than the ⅛-inch scale necessitated by the space limitations of the printed page.)

Now starting from *b* in the mold A, obtain the girth from *b* to *a* and place it as shown from *b* to *d*. We will assume that the distance from H to *b* measures 3 inches and the girth from *b* to *d* 1 foot 3 inches. Then the radius from F to *d* would be 24 feet 9 inches + 3 inches + 1 foot 3 inches = 26 feet 3 inches, which would be impractical to use, and therefore a rule must be employed for obtaining the pattern without having recourse to the center of so long a radius.

The Formula

This is accomplished by using the formula shown in Fig. 88 in which R represents the radius and W the width of the metal sheet from which the pattern is to be cut. Now if we can find the height of H it will be a simple matter to construct a fixed triangle and draw the segment *a b c*. The following simple formula will give the height of H, no

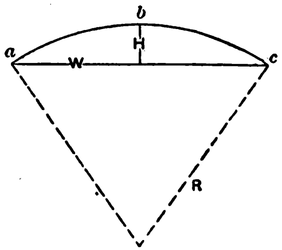


Fig. 88
Explaining the Formula

matter what the radius or width of sheet is used. $H = W^2 \div 8\ R$. This formula saves the labor of extracting the square root and is accurate enough for all practical purposes. If, however, a strictly accurate rule is desired, the following formula can be used. $H = R - \sqrt{R^2 - \frac{W^2}{4}}$, or 3.68 inches.

Practical Application of the Formula

Fig. 89 shows the practical application of the formula explained in connection with Fig. 88. Our radius in this case is 26 feet 3 inches, and the length of the sheet from which the pattern is to be cut is 8 feet. Using the above

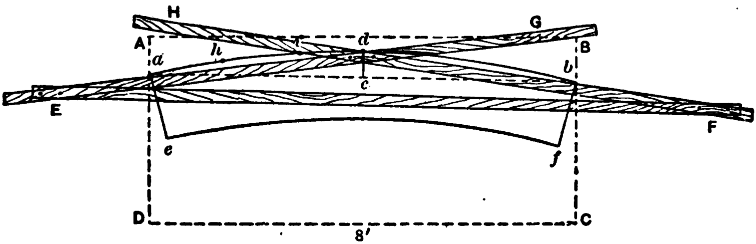


Fig. 89.—Practical Application of Formula

rule and reducing all terms to inches we have $H = 96^2 \div (8 \times 315) = 9216 \div 2520 = 3.65$, or 3 3/5 inches, the height of *c d* in Fig. 89. Now using a 96-inch sheet as shown by A B C D, drive a nail at *a* and *b*. Draw a line from *a* to *b*, bisect it and obtain *c*. Erect the vertical line *c d*, equal in height to 3 3/5 inches. Then make a triangle shown by E F G H from metal or wood strips and stiffen it by the cross brace E F, constructing it so that the vertex comes at *d*, and the strips E G and F H touch the nails at *a* and *b*. Moving the triangle, and always keeping the sides touching the nails at *a* and *b*, the arc may be traced by a pencil held at *d* and as shown by *a d b*.

The width of the flare *d b* in Fig. 87 being 1 foot 3 inches, draw a line parallel to the arc *a d b* in Fig. 89 and 15 inches distant, as shown by *e f*. From *a* and *b* radial lines can be drawn approximately by dividing the arc *a b* into three or more parts, and drawing *a e* at right angles to the first two points, as *a h* on either side. Then *a b f e* represents the flaring strip cut from an 8-foot sheet, a number of sheets being required to complete the circle, making allowance for laps and trimming of the ends. The approximate amount is determined by multiplying the diameter 32×3.1416 and dividing the length of the arc *e f* into the product.

Finding Height of Inaccessible Point

Fig. 90 shows how the area of a given object can be obtained, even though it is so far away that measurements cannot be taken. This is obtained by proportion of triangles. Let us assume in this case that the spire shown at A is to be covered with metal or slate. If we obtain the contract, we will erect scaffolding to do the work; but it will not pay to erect scaffolding to take the measurements, and measurements must be obtained to estimate on the job. As we can get to the ridge of the roof, B C, the number of square feet in the four sides of the tower is obtained as follows: Measure a given distance from the bottom of the roof of the spire, *b*—in this case 60 feet—to *a*. At *a* place a rod so high as to make the imaginary line *b a* horizontal. Take another rod and place it vertically at a distance of about 5 feet from *a*, as shown at C. Then, with the eye at *a*, cast the line of sight from *a* to the top of the spire, at *d*, and mark the second rod where the line of sight crosses it at C, and measure the distance from C on *a d* to *e* on *a b*, which in this case is 4 feet 1 inch. Then, C *e* is to *d b* as *e a* is to *b a*. In other words, if we obtain a rise of 4 feet 1 inch to a run of 5 feet, there will be as many vertical heights of 4 feet 1 inch as 5 is contained in 60. Thus $\frac{60}{5} = 12$; $12 \times$ 4 feet 1 inch = 49 feet, the vertical height of the spire A. As the vertical height is 49 feet the pitch *d b* will be a

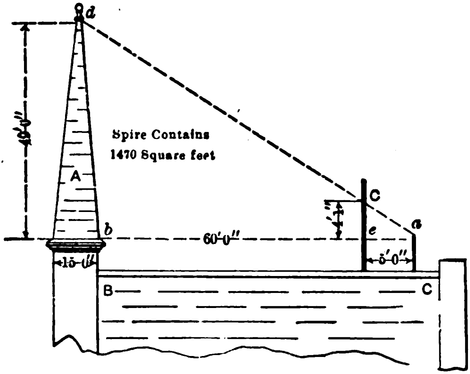


Fig. 90.—Finding Height of Inaccessible Point

fraction of a foot more, but 49 will be safe enough for estimating purposes. The spire is 15 feet wide at its base, thus $15 \times 49 = 735$; $735 \times 4 = 2940$; $2940 \div 2 =$ 1470 square feet of surface on four sides of spire.

Measuring a Copper Cupola

Some foremen in the shops have very little trouble in laying out special work, when the working measurements are placed before them, but there are many good mechanics and cutters who find it difficult to measure up at the building, the rough framing that is to be covered with architectural sheet metal work. The method used in measuring up the metal cupolas on the fireproof wings of St. Mary's Hospital in Brooklyn, N. Y., clearly demonstrates how the rough framing is measured up and the structural details and working measurements for the sheet metal coverings obtained, whether the framing is of angle iron or wood construction.

The cupolas, made from 20-ounce cold rolled copper, and shown in the front elevation in Fig. 91, were placed, one in the center of the deck roof and one on each wing of the main buildings. The rough framing was constructed of angle and T-irons filled with fireproof blocks, as shown by A and B in the half plan. The main deck roofs were covered with batten style of copper roofing, and to this batten roof the base of the cupola G was connected.

The main cornice has a gutter formed in it as shown in the vertical section H, to which the flat seam roof was connected, and over which the cross was placed.

GENERAL SPECIFICATION

The Scale Drawings

Upon receipt of the architect's scale drawings, the first step necessary is to study the various elevations, horizontal and vertical sections, so as to intelligently understand what parts are to be measured up. Note that the window jambs fit between the angles in the plan as shown; that the sill and head of the windows fit between the angles shown in the vertical section and that the angle iron brackets shown by J in the vertical section, support the main cornice and gutter lining and are put in place by the iron contractor.

In order to avoid errors and mistakes in construction

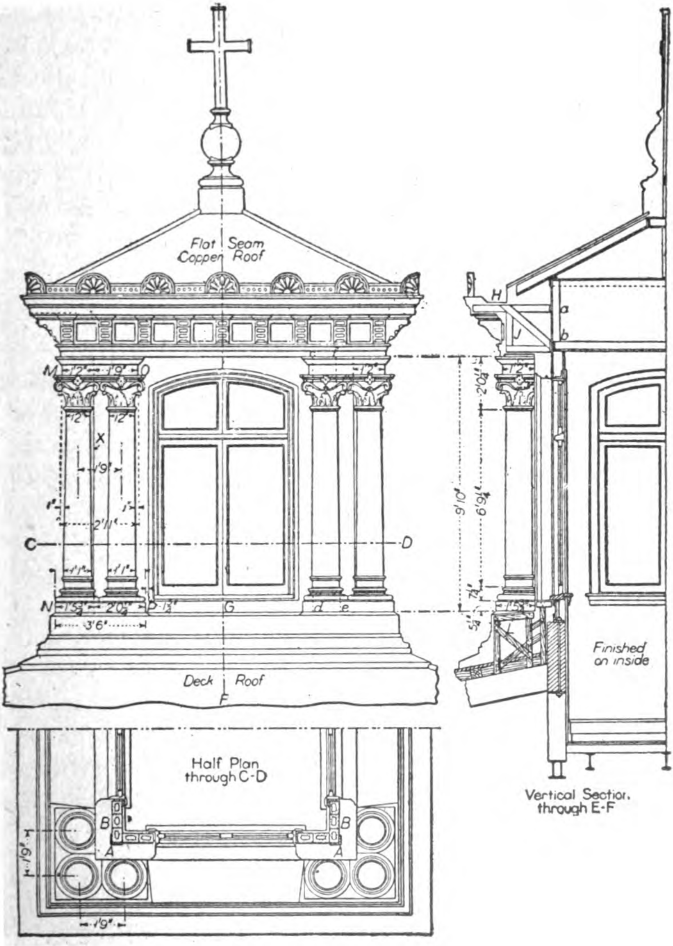


Fig. 91.—Front Elevation, Half Plan and Sectional View of Sheet Metal Cupola

it is necessary that the sheet metal worker as well as the iron worker and carpenter should confer and work together. In other words, if the sheet metal worker lays out his own details or receives them from the architect, the carpenter should receive a copy of the base G, and construct his wood blocking L accordingly. The iron worker should also receive a copy of the detail of the main cornice; he can then construct the angle iron brackets J, which are bolted to the frame structure at *a* and *b*, before the cornice is placed in position.

Measuring Up the Rough Framing for Cupola

An intelligent understanding of what the metal worker must measure up, having been reached, a rule and bevel are all that are required; a long rod for measuring the vertical heights is usually found at the building. The chances are that the angle iron construction, with the fireproof blockings, are built in a manner similar to that in Fig. 92, and the entire building is in the "frame" without any roof covering or other convenience for measuring at hand. Of course this important work cannot wait until the roof is inclosed, for the measurements must be taken as early as possible so that the work can be laid out in the shop to avoid any unnecessary delay. It is customary to insert a penalty clause in the contract for this work.

Two or three mason's planks can be laid around the rough framing; on these the measurer can stand safely and take the measurements, by making a rough sketch of the framing in a note book, then set the bevel, to obtain the angle between the vertical brick wall and the deck roof as shown by *a* in Fig. 92. Measure the distance between the inner corners of the bevel, and make a note of it, so that it can be opened again to the proper angle,

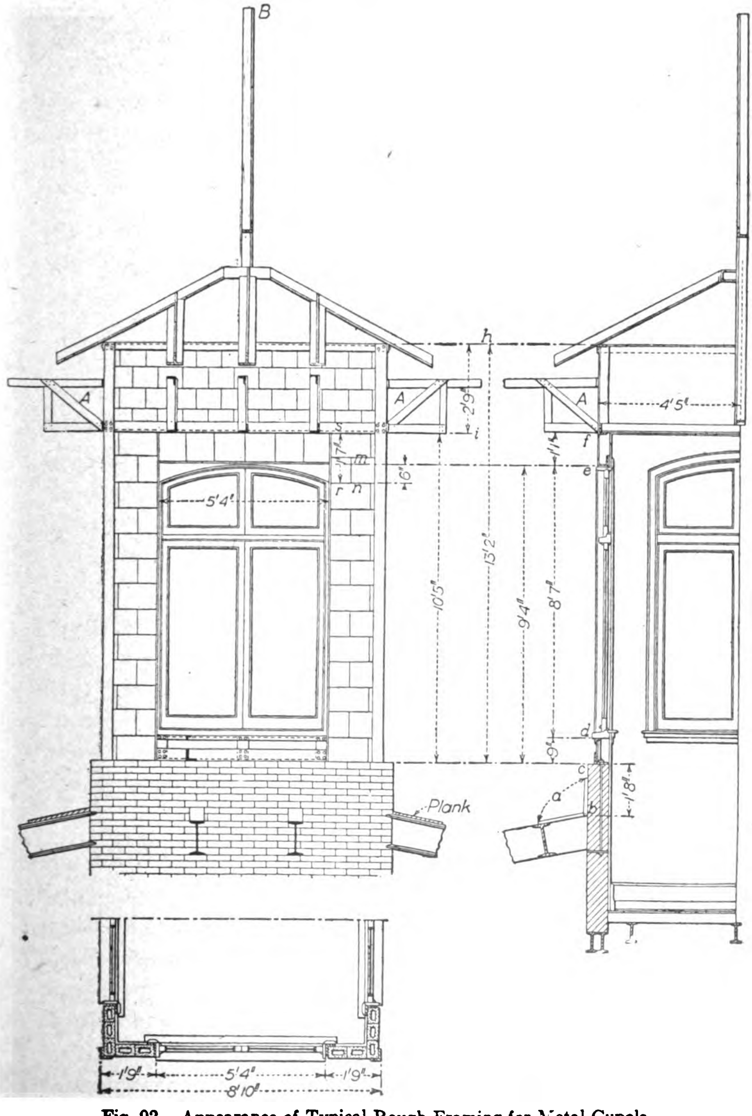


Fig. 92.—Appearance of Typical Rough Framing for Metal Cupola

at the shop, and measure the height of the wall above the roof beam, from *b* to *c*. From the top of the wall *c*, measure the distances to the sill angle *d*; to the head *e*; to the angle *f*; to the highest angle *h*, and also the distance between *h* and *i*, all as indicated by full size measurements in the illustration.

In this job the window frames are already in position, and the spring of the arch is taken as 6 inches from *n* to *m*. As the four sides of the cupola are the same, the horizontal measurements can be taken as indicated in the half plan; the width of the piers and window opening amounts to 8 feet 10 inches across. The angle iron brackets A, having been made after the detail of the cornice, furnished by the sheet metal contractor to the iron worker, it is not necessary to take measurements of these brackets. The vertical angle B, over and to which the cross is secured, is made a length corresponding to the height of the cross.

After the measurements are taken they can be verified by means of addition and subtraction, and form the basis in finding the true working measurements for the architectural sheet metal covering, shown in connection with Fig. 93. All of the measurements taken from Fig. 92 are net, with no allowance for laps, seams or locks.

Measuring the Sheet Metal Work for Cupola

The measurements from the plan in Fig. 92 have been reproduced on similar parts in the plan shown in Fig. 93. As the mullions P and P in plan will project 7½ inches on each side, the distance from P to P will measure 10 feet 1 inch. The face of the mullion is 2 feet 4½ inches, including the mold, which measures 2½ inches. A little study in the plan and elevation will verify the

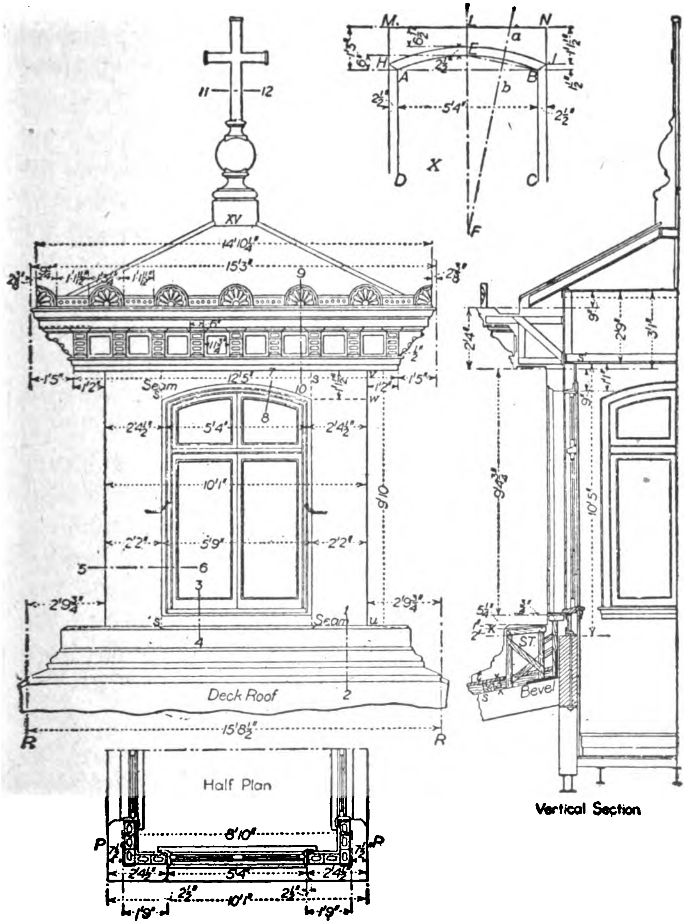


Fig. 93.—Half Plan, Elevation and Vertical Section with Measurements for Copper Work

measurements. By referring to the front elevation it will be found that the lowest point of the base mold projects beyond the face of the mullion 2 feet 9¾ inches, thus making the distance from R to R 15 feet 8½ inches.

When the detail of the base is being drawn the bevel is first opened to the proper angle (obtained by previous measurements at the building) and placed on the detail as shown in the vertical section in Fig. 93. The roof line is now extended to *s*, over which a 3-inch parallel line *t* is drawn, 2 inches for the sleeper and 1 inch for the roofing board. When the detail was being drawn the corner *x* in this case had to be 2 inches above the top of the wall. This corner *x* gives a fixed point in the sheet metal work, from which the balance of the measurements can be located.

After drawing the base detail, the studding is drawn in position, as shown by S T. As the height from the top of the wall to the corner X is 2 inches and the pitch of the wash above *x* is 1 inch, and the drip of the cornice will set 4 inches below the angle shown, and the height from the top of the wall to the angle iron cross piece is 10 feet 5 inches, then by a little calculation it is found that the mullion face from U to V measures 9 feet 10 inches, or in other words $2 + 1 + 4 = 7$; 10 feet 5 inches − 7 inches = 9 feet 10 inches. From V down to the lowest edge of the top of the sill equals 9 feet 10 inches − 5¼ inches (the height of the sill) or 9 feet 4¾ inches as shown. The distance from *c* to *d* in Fig. 92 measures 9 inches. Adding together in Fig. 93, 2 + 1 + 5¼ + ¾ (the wash of the sill) = 9 inches, proves the measurement.

Referring again to Fig. 92, the spring of the arch on a 5-foot 4-inch span is seen to be 6 inches, and the height from *e* to *f* is 1 foot 1 inch. Reproduce these measurements in Fig. 93 and find the height of 1 foot 1½ inches from V to W as follows: Draw any two parallel lines A D and B C as in diagram X 5 feet 4 inches apart, and draw the horizontal line A B. Bisect A B and through this point draw the center line L F. From the line A B set off the rise of the arc or 6 inches, shown by E. Draw a line from E to B, bisect this, and through the intersections *a* and *b* draw a line intersecting the center line at F, the center for describing the arc A E B.

As the projection of the mullion molds is 2½ inches set off this distance on the two sides and arc, and draw the miter lines A H and B J. The distance from *r* to *s* in Fig. 92 is 1 foot 7 inches and as the cornice drops 4 inches below s^1 in the vertical section in Fig. 93, leaves 1 foot 3 inches. Now measure up 1 foot 3 inches from the line A B in diagram X, and draw the parallel line M N. The vertical height of the miter line J B is 1½ inches, and it will be found that 1 foot 1½ inches is the net height. The net pattern, in diagram X, is M N J E H, minus the curved mold, with a seam at *s* and *s* in the front elevation.

Measurements for the Main Cornice of Cupola

The projection of the foot mold of the cornice over the face of the mullion is 1 foot 2 inches on each side; then 1 foot 2 inches + 1 foot 2 inches + 10 feet 1 inch = 12 feet 5 inches, the true length of the foot molding. With this measurement of 12 feet 5 inches the spacing between the brackets is arranged. There are 9 brackets, each 6 inches wide, the end brackets setting ½ inch inside the line of the foot mold. Deducting 9 × 6 + 2 × ½ from 12 feet 5 inches, and dividing by 8, or the number of panels, it is found that the space between the brackets is 11¾ inches. Note on the detail that the crown mold projects over the foot mold 1 foot 5 inches on each side, and makes the length of the crown mold 15 feet 3 inches. From this, the spacing of the cresting is found as shown by the measurements of 2⅜ inches, 9¼ inches, 1 foot, 1 11/12 inches, and 1 foot 3¼ inches.

Columns, Bases and Capitals for Cupola

The heights of the columns, bases and capitals are found by referring to Fig. 91; this shows that the columns are spaced 1 foot 9 inches on centers. The diameter of the columns at the neck is 12 inches, while at the base it is 13 inches. The projection of the column base over the outside of the column is 4 inches, making the distance from N to P 3 feet 6 inches. Thus 1 foot 9 inches + 6½ + 6½ + 4 + 4 = 3 feet 6 inches. The projection of this base in the vertical section is 1 foot 5¾ inches, then 3 feet 6 inches, minus 1 foot 5¾ inches, leaves 2 feet ¼ inch. As the face of the mullion is 2 feet 2 inches in Fig. 93, then 2 feet 2 inches, minus 2 feet ¼ inch, leaves 1¾ inches, or the space between the edges of the base and mullion as shown by P in Fig. 91.

To obtain the true length of M O in the front elevation in Fig. 91, adding together 1 foot 9 inches + 6 + 6 + 1 + 1 = 2 feet 11 inches. The projection of this mold M O in the vertical section is 1 foot 2 inches, then; 2 feet 11 inches minus 1 foot 2 inches, leaves 1 foot 9 inches or the distance of the projection inside of the mullion face X in the front elevation. As the height from the top of the base mold U to the bottom of the foot mold V in Fig. 93 is 9 feet 10 inches, this measurement is transferred to a similar position in Fig. 91, and from it the heights of the capitals, columns and bases are determined by simple subtraction and addition, shown by the full-size measurements in the illustrations as follows: Height of capital 2 feet $\frac{1}{4}$ inch; height of base $5\frac{1}{4} + 7\frac{1}{4} = 12\frac{1}{2}$ inches. 2 feet $\frac{1}{4}$ inch + 1 foot $\frac{1}{2}$ inch = 3 feet $\frac{3}{4}$ inch. Then 9 feet 10 inches − 3 feet $\frac{3}{4}$ inch = 6 feet $9\frac{1}{4}$ inches or the length of the column.

CHAPTER VII

ESTIMATING QUANTITIES FOR METAL CEILINGS

The statement that many tinners and sheet metal workers have not taken up the sale of metal ceilings, because they have considered it too complicated a proposition has led to the preparation of this article, which is intended to show that there is nothing in connection with the sale of a metal ceiling which should deter any merchant mechanic of ordinary ability from enjoying the profits which he can make from this branch of the industry. If he will but study the proposition he will find there is nothing complicated about measuring and estimating on ceilings for the general run of rooms, and after he has been looking into the matter for a short time he will soon be able to measure and make up an intelligent estimate if he is supplied with one or more of the manufacturers' catalogues and discounts on the materials illustrated therein.

The first step after one has been asked to give an estimate on a metal ceiling, is to get the proper measurements from the building or take off the proper measurements from the plans if the building is not completed. In making up an estimate from plans, it will be necessary to note to what scale the plans are drawn, after which the proper sizes can readily be figured. It might be stated that the majority of plans are drawn on a scale of 1/4 inch to 1 foot, but now and then the mechanic will come across a plan, especially on large public work, drawn to a scale of 1/8 inch to 1 foot. This means, of course, that each $\frac{1}{8}$ inch on the plan or blueprint represents 1 foot on the ceiling.

Metal ceilings are ordinarily sold at a specified price per 100 square feet, called a square. This price ordinarily covers the different parts of the ceilings, including the centerpiece, plates, molding, fillers, cornices and the like. The metal ceiling catalogue issued ordinarily by the regular manufacturer of metal ceilings, is usually complete in its information given on the different designs; that is, it ordinarily shows the design of field plates and then gives explicitly just what molding, cornices, centerpieces, fillers and the like are included in the price of that particular design of field plate. In case there are exceptions, and the centerpiece and any other part of the ceiling is extra, the catalogue usually so specifies and there is little chance for the sheet metal man making an error on this point.

Ordinarily, if the rule given hereinafter is followed, there will be little difficulty in arriving at the number of square feet required for a room of regular rectangular dimensions. Supposing, for instance, that a metal ceiling had to be estimated on for a rectangular room 25 x 40 feet, similar to that in Fig. 94, without a bay window. Assuming that a 16-inch cornice is to be selected, it will mean that, in addition to the area of the ceiling, a strip extending entirely around the room 16 inches wide, or deep, as you may choose to call it, will have to be covered, or, in other words, instead of the area to be covered being 25 x 40 feet it will mean that to these dimensions 16 inches will have to be added on one end of the room and 16 inches on the dimensions of the other end of the room. It is customary to add 2 inches on each side and end for variation and the filler. Thus, for a room like that in Fig. 94 without a bay window, the simplest method for calculating the area of ceiling required would be as given in the accompanying table.

METHOD OF FIGURING METAL CEILINGS FOR ORDINARY RECTANGULAR ROOM

Size of room...........................	25 feet 0 inches x 40 feet 0 inches
16-inch cornice will add....................	2 feet 8 inches x 2 feet 8 inches
Variation and filler........................	0 feet 4 inches x 0 feet 4 inches
Total dimensions to be covered by metal..	28 feet 0 inches x 43 feet 0 inches

Thus it will be seen that the total girth of metal employed in the covering of a room of this size is 28 feet x 43 feet and that by multiplying these dimensions it will be found that there are 1,204 square feet of metal in the room. For the ordinary type of ceilings, say, worth $3 per square, the cost will be $36.12. This will ordinarily include the cornice, the filler, the mold and all the plates necessary to make up the ceiling. If there are any extras the catalogue will so specify in the reading matter in connection with the description of the plates.

If, for instance, the room is irregular in shape and has a bay window like that in Fig. 94 and the dimensions of the window are as shown, namely, 2 feet x 12 feet for all purposes, it will answer every requirement to add the product of 2 x 12, which is 24, or, in other words, to add 24 square feet to the 1,204 square feet. Of course, this is not the exact figure for the bay window, but is near enough for all practical purposes. Furthermore, it is customary to send in with the order a sketch of the room giving the dimensions, similar to those marked on Fig. 94. It will readily be seen in cases of this kind that the sketch is necessary so that the proper amount of cornice, filler and molding may be shipped with the order.

When an irregular shaped room like that in Fig. 95 is encountered, the area may be obtained by adding together the two irregular dimensions; that is, the 15-foot dimension on one end and the 12-foot dimension on the other, making 27 feet, and dividing this by 2. This gives an average width of 13 feet 6 inches for the room. If the room is 21 feet long the approximate total number of square feet in the surface of the ceiling can be arrived at by multiplying 13 feet 6 inches by 21.

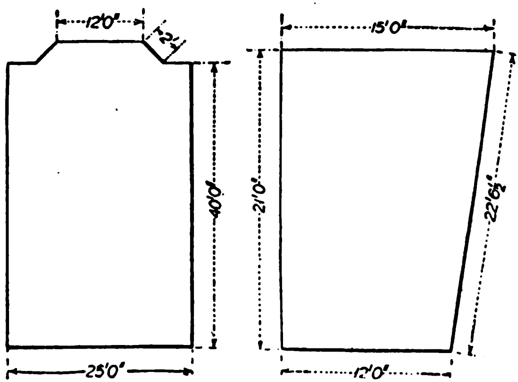


Fig. 94 Fig. 95
Diagrams for Estimating Metal Ceilings

In other words, an irregular shaped room like that shown in Fig. 95 may be treated as a rectangular room 21 feet x 13½ feet, and the rule as per the table in the foregoing applied.

The tinner will find that if he possesses the book "The New Tinsmith's Helper," he can readily figure any area of room which comes up for consideration. This is sold by the U. P. C. Book Co., Inc., New York City.

In measuring a building, particular care should be taken to notice whether or not the cornice can be used all around the room. This should be noted on the sketch sent in, and in case the cornice cannot be used all around the room, information should be given as to what width molding can be used across the finish so that the manufacturer will then know where to use the flat molding on the ceiling. Wherever there are centerpieces to be placed in the ceiling, those should also be noted on the drawing. In making these drawings for the side walls it is best to mark the position and size of any openings, such as doors and windows, as otherwise the manufacturer will ship enough side wall to cover solid in spaces of that description.

Now and then the contractor will come across rooms in which there are small beams or steel girders projecting down from the ceiling through the center of the room. It will be necessary to figure, of course, on covering the surfaces of these regardless of how many there may be. For instance, if a ceiling beam 15 inches deep extends down into a room in the center, there will be two sides of it to be covered, which would add 30 inches to the size of the room; also 2 inches to each side for variation and filler, which would add 4 inches extra.

After the room has been measured up, the sheet metal man should get his customer to select the ceiling design which he wishes. The next step is to determine if the pattern will work out to advantage in such a room. In this connection it might be well to state that it is not advisable to sell ceilings in small rooms that take a large cornice and large expanse of border and filler.

A case recently came to attention where a ceiling had been sold of that design for a hall 3 feet wide and 14 feet long. When the order came in, the company, on checking it up, found that there was only room enough in the hall to put in the two cornices, one on each side of the room, and a small strip of filler throughout the center. When such cases come up and a selection of that kind is made, it will be necessary to explain to the customer that such a pattern is not suitable.

The sheet metal man will readily be able to figure out whether a design will work out in a room by counting the multiples of the plates shown in the design. For instance, take a design where there is to be allowed 18 inches for cornice, 14 inches for filler and 21 inches for border before any calculation is made for the field. If calculations are made on this, it will be seen that this design would not work out for a room 8 feet x 20 feet, as it could not be put in without spoiling the whole effect.

The price quoted for metal ceilings in the ordinary run of catalogues does not include the furring strips. Therefore, in case it should be necessary to ask for a price on a metal ceiling for a particular room, it should be specified in the inquiry whether or not the price wanted is to include the furring strips. It is found that in most territories, however, the furring strips may be procured locally at a lower rate than they can be shipped by the sheet metal manufacturers. Ordinarily the sheet metal man can get a price locally per 100 lineal feet on 7/8-inch x1¼-inch soft poplar or cypress furring strips. It takes about 150 lineal feet of 7/8-inch x 1¼-inch furring strips to apply 100 square feet of metal ceiling.

When the sheet metal man takes a contract for the metal ceilings erected, he should, of course, remember that the prices quoted in the catalogue do not include the painting, and the contractor should have it understood with his customer that his price does not cover the cost of painting the ceilings after they are in place, but that the price does include one priming coat of paint on the material before it leaves the factory.

The sheet metal man will soon be able to estimate on the cost of labor for erecting. In practically all cases he can get an approximate figure from the manufacturer for any particular design. He will understand, of course, that the price on erection work varies considerably, especially when the designs are worked out with molding and the labor has to be increased.

CHAPTER VIII

PROPORTIONING SKYLIGHT AND WINDOW AREAS

While in science the lighting question requires the expert advice of the specialized illuminating engineer, the sheet metal contractor must solve it practically in his daily work. The installation of skylights or hollow metal windows in new or remodeled buildings and the lighting of spaces for special purposes or conditions calls for a knowledge of the principles underlying the art of illumination.

The rough and ready thumb rules that skylight builders seem to use vary widely. When two or three contractors are asked to propose a skylight size for a given condition, the results show different proportions conforming to the ideas of the different contractors. A comparison of such skylight areas proposed by two or three men gives just that many different sizes for the same requirements.

Common Practice

The architect in designing his industrial or shop building does little better as regards the window and skylight sizes. The common method is to fill in the holes of the wall space forming the architectural design with windows. The more recent trend is to make the walls mainly glass and fill in the small portions at the supporting or structural members with brick or concrete wall. This last construction is the so-called modern "daylight" type building. In apartment and sometimes public buildings the city or state laws are followed because a minimum window space is made mandatory. Such building code requirements usually specify the ratio of 1 to 8 or 1 to 10, which is an average of 1 square foot glass area to 9 square feet floor space. Examples of

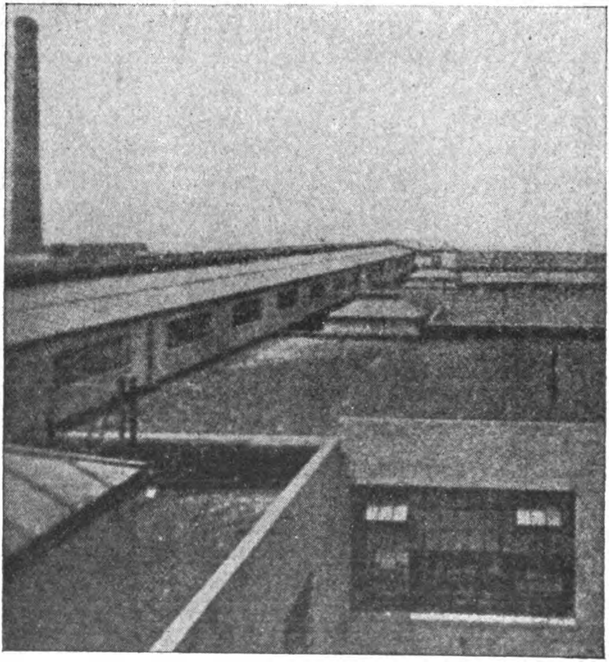


Fig. 96-A.—Windows and Skylight Arbitrarily Arranged Without Regard to Scientific Rules

modern buildings further emphasize the wide difference in the practice of proportioning windows and skylights. Analysis of actual instances shows a variation of 1 square foot of glass for 12 square feet of floor area to 1¼ square feet glass for 1 square foot of floor space.

Different classes of work in various types of buildings require different light intensities. This in a way may account for the extremes above noted. Some buildings are located in open spaces, while others are crowded in among, and are made dark by, adjoining structures. In such cases the ratio of glass to floor area would be either high or low, according to the physical conditions.

All these factors have led to the systematic study of the lighting subject as a branch of applied science, to which has been given the name of illuminating engineering. A general understanding of the established principles of this new science will aid in intelligently taking up the problem of selecting a method of lighting best suited to a particular condition. However, without delving into the theory of illumination, the results of an extensive research and study of the subject for the practical use of the sheet metal trade is presented below. An original formula in simple multiplication and division is given as the solution of the natural lighting problem.

Artificial Lighting

Illuminating engineering is a well-defined and mathematical science as applied to artificial gas and electric lighting. These light sources have a known value which remains practically constant. Natural or daylighting is more intricate because it depends on the hours of sunshine and further on the sunlight intensity—a factor which varies through the entire day and during every month of the year. Expressing the sunlight intensity in degrees Fahrenheit, these variables may be made more readily understood. In January at 9 o'clock in the morning the sunlight intensity is about 45 degrees, at noontime 65 degrees, and at 4 o'clock in the afternoon

48 degrees. In March at the same periods of the day sunlight intensities show as 57, 72 and 60 degrees respectively. In July the variations are 106, 121 and 105 degrees at the stated periods of the day. In December the values drop to about 48 degrees in the morning, 63 degrees at noon and 48 degrees in the afternoon. The averages of these sunlight variations for the year show intensities of 74, 89 and 76 degrees respectively between the hours of 9 a.m. and 4 p.m.

These different intensities have a corresponding value as an effective natural lighting medium for the interior of buildings. By a close study of the sunlight variations over a number of years and relating these figures to actual lighting conditions in different buildings, an empirical basis for practical computation of skylight and window sizes may be established. A minimum intensity effective for general daylight illumination must form the basis of glass area computation.

The first question that would naturally arise is, what should this intensity be to give an indoor condition for seeing plainly? A general answer would undoubtedly state that an abundance of light is necessary. While this is primarily true, there are many controlling factors. Too much light as well as too little light means eye strain and fatigue. For a given condition there is a certain light intensity which enables the eye to see with maximum sharpness and ease.

Light and the Eye

The scientific study of illumination has resulted in establishing certain important facts or laws which relate to the use of light and the organs of vision. The physical condition of the eye during the sunlight period of the day is such that a higher light intensity is required in comparison with artificial lighting during the dark hours of the working period or at night. With gas and electric lighting the intensity for ordinary operations is about 1-foot candle while for the same results with natural lighting an intensity of 3-foot candles must be provided as a minimum.

The foot candle term, mentioned above, is used by

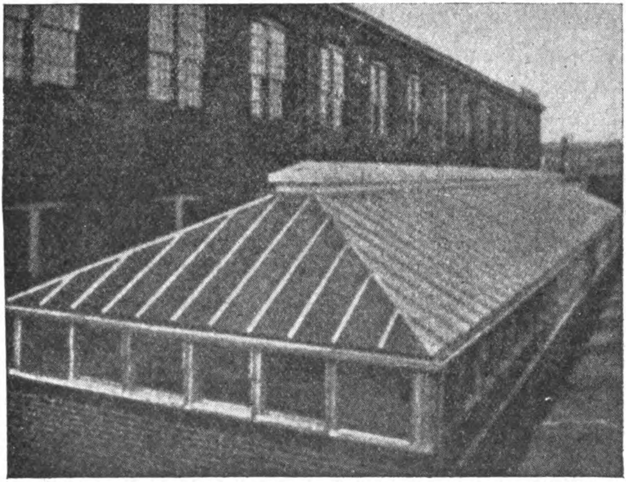


Fig. 96-B.—Large Skylight Over Low Building, and Metal Windows in Taller Building Provide Natural Light for the Interiors

illuminating engineers to express the light intensity incident at right angles upon a plane one foot distant from a light source of one candle power. The term candle power is the unit of intensity of light emitted from a lamp or other light source and was originally determined by the horizontal intensity of a certain specified candle known as the British standard candle.

but in modern practice an electrical incandescent lamp is used as the standard of measurement.

In problems of artificial illumination these standards can be readily employed for practical conditions by the application of the law of inverse squares or by the cosine law depending respectively on whether the working surface is normal to the lighting source or illumination is oblique.

For this practical treatment of the subject on an empirical basis, side windows and skylights are taken at the same effective working value. While the skylight or other similar form of roof lighting has a greater value than a window when first installed, this is diminished and brought down to the same effect after a short time in service because of the more rapid dust accumulation on the horizontal or oblique glass surfaces, and also because of the angle at which the glass is usually installed.

Diffusion of Light

In providing a system of illumination, it should be the aim of the designer to give a result which will produce distinctness and ease of vision, and this depends on what is known as diffusion. Daylight has a distinct natural advantage in this respect for even on a cloudy day it gives perfectly diffused light rays of equal power, which come from all directions. Perfectly diffused light produces no shadow whatever and is distinctly agreeable as well as easy to the eyes. Such light is commonly spoken of as "soft light," while undiffused light is spoken of as "hard light" or as being "hard on the eyes." E. L. Elliott says that it is largely due to its high state of diffusion that daylight, even when vastly more intense than artificial illumination, is the easiest of all light on the eyes. It is a common and serious mistake in case of weak or over-strained eyes to reduce the intensity of the light instead of increasing the diffusion.

Summing up, it may be said that in the commercial use of light for interiors the real and only object is to enable the eye to perform its practical function of seeing with distinctness and ease. The success of any lighting system can therefore be measured only by the extent to which it accomplishes this object at the least expense for upkeep and repairs. Natural daylight practically and economically fulfills this condition.

The Light Source

Any light transmitting glass area used for daylight illumination in buildings may be taken as the actual

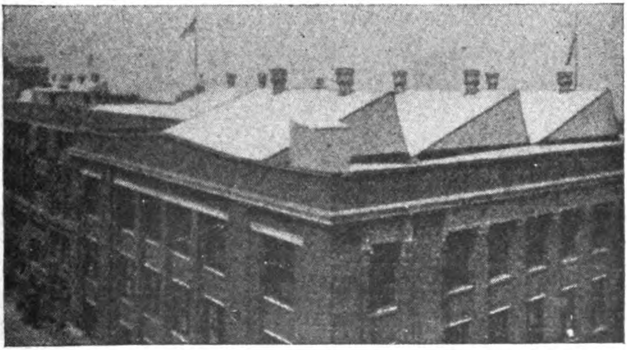


Fig. 96-C.—Saw-tooth Type Roof Skylights Installed for Natural Lighting in Top Floor of Large Building

light source when that glass area has an unobstructed view of the sky without proximity to other buildings, trees or similar objects. The light intensity is then considered as that equal to the sky density. As such unobstructed window or skylight will give an effective lighting intensity to all parts of the room space to a point not exceeding 25 feet, then the sunlight intensity becomes a unit of measure for such condition. This value may, therefore, be taken as the equivalent intensity in foot candles that will give effective light on the working surfaces in such space or building interior.

The foregoing considerations give an insight into the different points involved in natural lighting problems and show the basic factors included in the empirical formula here proposed for computing window and skylight sizes for all classes of buildings.

Formula for Computing the Required Glass Area

When the light intensity required for a given type of building is known, it is only necessary to multiply the working floor area by this value and make correction by a constant which, as shown below, is a divisor of 35 for unobstructed buildings. Thus, to find the square feet of glass area for any condition of natural lighting, the computation is

$$\frac{\text{square foot floor area} \times \text{foot-candle intensity}}{35} = \text{glass area.}$$

The use of this formula gives results that correspond with good practice and makes certain that an adequate glass surface is installed for satisfactory natural lighting under specific working conditions. The results do not show a constant ratio of glass to floor surface, but vary with the class of work carried on in the building.

As a guide to the light intensities required for different operations and various classes of buildings, the following tabulation has been prepared. It is designed as an aid for the contractor who is called upon to proportion sky-

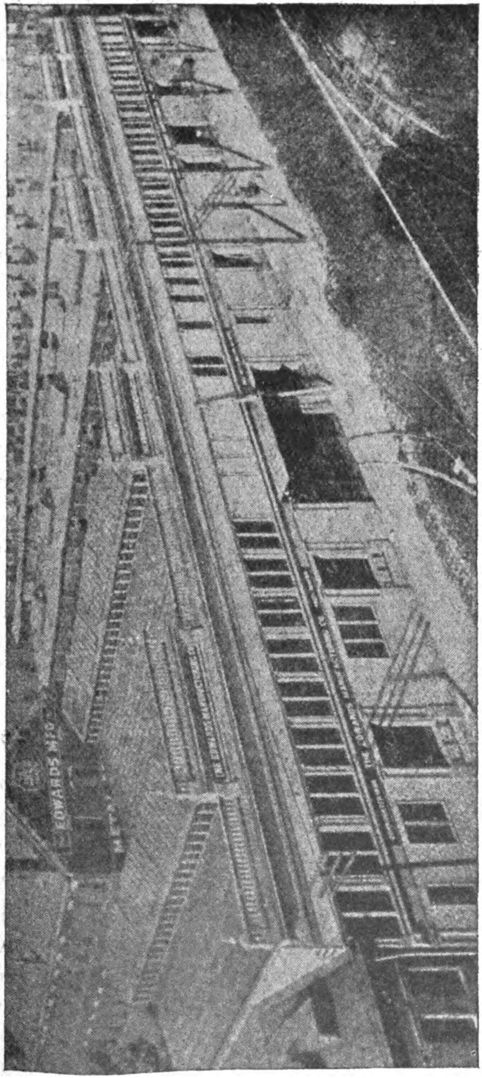


Fig. 96-D.—Example of Natural Daylight Illumination in a Cincinnati Sheet Metal Plant Provided by Roof and Side Window Lights

lights and windows for new or remodeled buildings. Using the values presented in conjunction with the formula a good working basis is established. It should be noted that a range of intensities is recommended for any given condition. Thus, for an art gallery, as in the table, the recommended intensities vary from 10 to 20-foot candles. The first figure or 10-foot candles is the minimum value that will give satisfactory results. The range above 10 and up to 20-foot candles is for a condition where an abundance of natural light is wanted for the longest possible period of the day.

Where funds are available, it is advisable to install more glass than that found as necessary in computing the requirements on a basis of the minimum intensity. The more glass installed the lower will be the normal demand for artificial light and such provision would therefore save a good many hours during the year when gas or electricity would otherwise be used. This of course means a saving that can actually be counted in dollars and cents. In all cases, when locating the windows, their tops should be as near the ceiling line as practicable.

Effective Daylight at Different Times of the Year

With careful design, advantage may be taken of all the effective hours of daylight. By providing an adequate glass area for natural interior illumination, there will be an economy because the use of artificial light will be reduced to a minimum. Taking the working day at 10 hours and deducting legal holidays, Sundays and half days for Saturdays gives a total of 2,770 net working hours for the twelve months of the year. The probable effective daylight under sunlight conditions prevailing in the eastern section of the country will amount to 2,248 hours for the year. When the glass area has been properly proportioned, it is apparent that artificial light will be required for only 522 hours during the year.

The distribution of these lighting requirements is shown graphically in Fig. 97-A. The effective daylight for each month of the year is compared with the total working hours of the month, which shows by the shaded

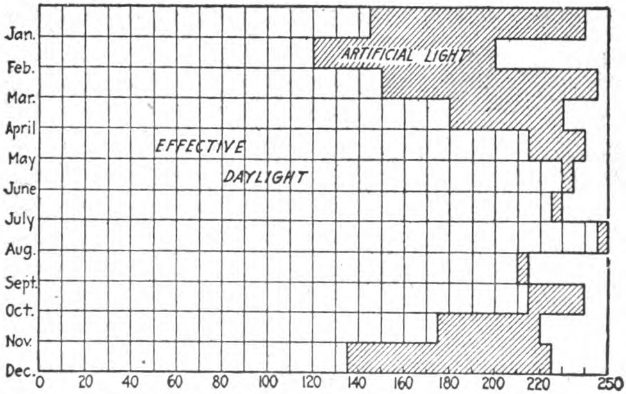


Fig. 97-A.—Hours of Effective Daylight for Each Month of the Year

portion the dark periods when artificial light will have to be used. The net total hours for each form of light for any given month may, therefore, be read directly with the aid of the diagram. To illustrate its use, find the hours of artificial and natural light that are effective in the month of December. Reading along the bar representing December, it is seen that daylight prevails for 135 hours, as on the bottom scale. The shaded portion shows that in December the working period totals 225 hours. The difference between 225 and 135, which is 90, gives the hours in which artificial light will have to be used if work is to continue during the dark periods of the month.

Average cases of ordinary typical shop arrangements show that for a 10-hour working day the artificial lighting requirements are for 700 to 1,000 hours a year. This would indicate that such light is not used economically or that the glass area provided for natural lighting is deficient. This last point will be made clear by a study of the diagram which indicates that artificial light need

TABLE OF INTENSITIES IN FOOT-CANDLES REQUIRED FOR NATURAL LIGHTING IN DIFFERENT CLASSES OF BUILDINGS

Art gallery	10–20	Library stack room	4–6
Auditorium	3–8	Machine shop, fine work	15–25
Automobile showroom	8–16	Coarse work	6–12
Ball room	6–10	Buffing and grinding	6–8
Bank, general	6–10	Assembling and erecting	3–8
Bar room	6–10	Inspecting	12–20
Barber shop	8–16	Moving picture theatre	3–5
Bookbinding	6–12	Office	8–18
Cafe	6–10	Paint shop	8–18
Canning plants	3–7	Pattern shop, wood	8–16
Carpenter shop	6–15	Pattern shop, metal	12–20
Cotton mill, general	3–10	Power house	6–10
Drawing in	6–12	Printing, general	8–16
Weaving, dark goods	9–15	Linotype and monotype	15–30
Inspecting	10–25	Typesetting	15–25
Dance hall	3–8	Residence	6–8
Drafting room	15–30	School, general	8–16
Factory, general	7–14	Assembly room	6–10
Forge and blacksmithing	3–6	Sheet metal shop	6–10
Foundry	6–10	Silk mills, general	6–10
Garage	3–8	Quilling and warping	8–16
Gymnasium	3–10	Weaving	12–18
Hospital, general	3–10	Dyeing inspection	30–60
Operating table	30–60	Steel works and rolling mills	3–6
Hotel, general	6–10	Stores, general	8–20
Lobby	6–12	Swimming pool	3–8
Bedrooms	4–6	Theatre lobby	6–12
Lavatory	4–6	Auditorium	3–8
Library, general	8–12		

Fig. 97-B

not be used more than 522 hours when the natural lighting system is properly proportioned.

Then, if only 522 hours of artificial light are necessary when the glass area of the building has been well proportioned for the working conditions, it is self-evident that a saving in the use of artificial light must result. In buildings where the use of gas or electric light is required for 700 hours the addition of the necessary glass area to give adequate natural light would therefore reduce the lighting bills by about 25 per cent. This means that for every hundred dollars of the gas or electric bill, there would be a saving of $25. While such bills are being paid for year in and year out, continuously, a saving may be effected annually by an initial expenditure for adequate natural lighting through providing sufficient glass area when the building is erected.

Practical Examples of Glass Surface Computation

Daylight is also an important factor in factory buildings for promoting hygiene and safety. These features become particularly marked, especially in the mechanical, metal working industries and fabricating steel plants. As a safeguard against accidents, the "safety first" movement with the resultant conservation of human life has been found effective mostly during the months of the year when artificial lighting is used the least. Observations show that industrial fatalities and serious accidents increase as the daylight facilities decrease. Adequate natural lighting may therefore be classed as an important means of accident prevention.

With this understanding, the formula and figures in the tabulation may be employed in practical computation. Take a one-story sheet metal shop to be built where there is no obstruction to the light direct from the sky either in vertical or horizontal lines. The dimensions are 40 feet wide, 60 feet long and 20 feet high. The entire floor space is to be about equally lighted for working conditions and this is an area of 40 x 60 or 2,400 square feet. According to the figures in the tabulation 6-foot candles is the minimum intensity for satisfactory natural lighting. With these conditions known the amount of glass surface required is found to be:

$$\text{glass area} = \frac{2{,}400 \times 6}{35} = \frac{14{,}400}{35} = 411 \text{ square feet.}$$

This amount of required glass shows that the sheet metal shop in question would be provided with 1 square foot of glass to about 6 square feet of floor surface.

Now suppose that this building, or another of the same size, were to be used as a drafting room instead of a sheet metal shop. The tabulation shows that a minimum intensity of 15-foot candles is necessary for this work. The glass requirements under the new condition would then be:

$$\text{glass area} = \frac{2{,}400 \times 15}{35} = 1{,}028 \text{ square feet.}$$

This glass surface shows a ratio of 1 square foot glass to about 2½ square feet floor working space.

Other instances for any condition may be computed in the same simple manner by the use of the formula and with the aid of the figures in the tabulation.

It was pointed out that sufficient sunlight prevails during the working hours of the year to provide proper quantities of daylight for natural illumination of interiors. The main factor is the installation of adequate window and skylight spaces to actually realize on these economies. How to proportion the glass surface to fulfill different building conditions was explained with the aid of a formula and tabulation of required lighting intensities.

Just where the variation comes in may be made clear by considering the lighting of a hospital.

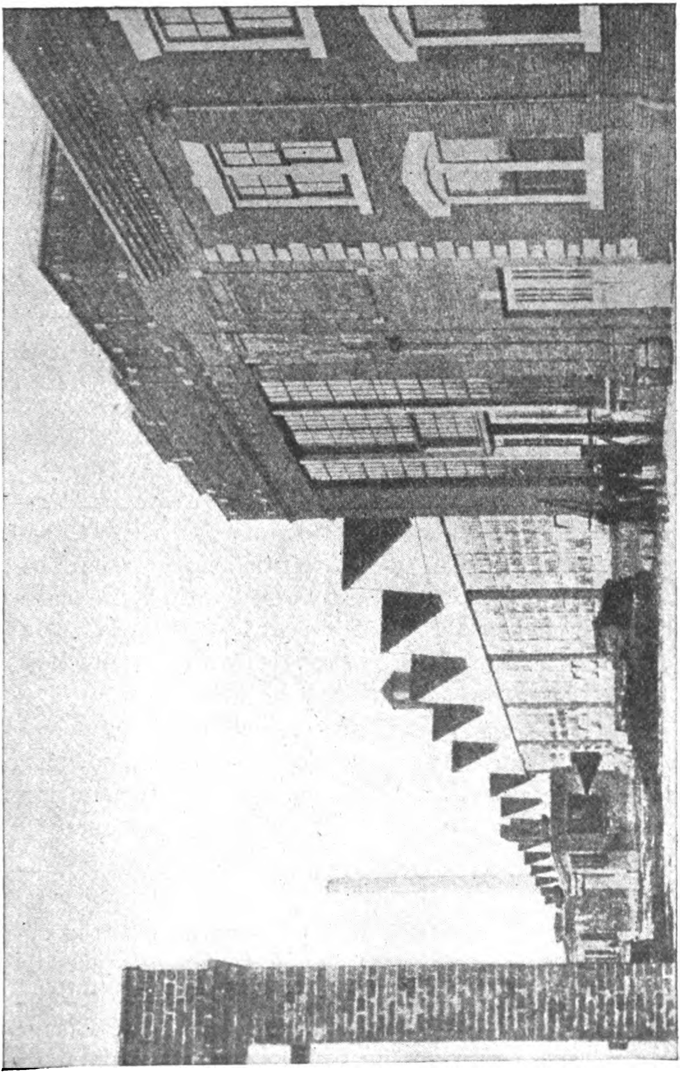


Fig. 98.—Another Example of Effective Natural Daylight Illumination

The ward to be illuminated by natural daylight is 40 x 60 feet in size, which is a floor area of 2,400 square feet. The light intensity taken from the figures in the tabulation is a minimum of 6-foot candles. The amount of glass required is then

$$\frac{2{,}400 \times 6}{35} = 411 \text{ square feet glass.}$$

Consider the operating room which is 25 x 30 or 750 square feet. The minimum light intensity for satisfactory natural lighting is 30-foot candles according to the figures in the tabulation. The glass surface required is then

$$\frac{750 \times 30}{35} = 643 \text{ square feet glass}$$

No doubt a skylight would be installed as an operating room requires direct light on the working surface. Comparing these two conditions shows that the glass surface provided for lighting the ward bears a ratio of 1 square foot glass to about 6 square feet of floor surface. The operating room, however, is provided with 1 square foot of glass to a little over 1 square foot of floor surface.

It will be noted that the formula gives results corresponding with the lighting demands of each particular building requirement. The method of computation holds good for any class of building but the figures apply only to buildings that have their light unobstructed—buildings located in an open space.

When a building has its light obstructed by surrounding structures, the effective value of the glass area is reduced. Then it is necessary to raise the required light intensity or add to the result of the computation. Either method will give the increase in glass area required to compensate for the obstructions about the building. Just what this additional glass area should be depends on the physical conditions and the specific local requirements of the job. Judgment based on experience must therefore be used in each particular case.

Allowances for Obstructions

An idea as to what the additional glass should be in simple structures is given by the diagram in Fig. 99-A.

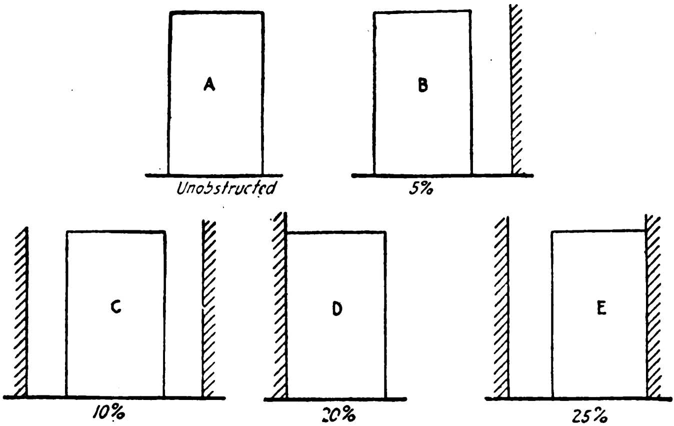


Fig. 99-A.—Diagram Showing Additional Glass Required for Obstructed Buildings

In this illustration A is an unobstructed building. The house B is obstructed on one side and requires a nominal increase of 5 per cent over the computed glass area as found by the formula. Building C is located between two other structures and the greater part of the light comes from the courtyard, necessitating an addition of 10 per cent glass area. Building D is erected with a party wall close up to its next door neighbor and to make the natural lighting satisfactory, 20 per cent glass must be added to the nominal requirement. The worst condition is perhaps illustrated by the case of building E which is shut in entirely on one side and further obstructed on the other side, this condition requiring 25 per cent more glass than an unobstructed building.

These percentages given as corrections or rather additions to the results determined by the formula are based on extensive independent observations in the writer's experience. These figures should not be followed as law for they are not final. However, in the absence of any other guide, they will be found helpful. Such factors as the height of the obstruction, the width of the abutting courtyard, alley and even the street must be considered. Allowance must also be made for the color of the walls of obstructing buildings, together with the color of the interior that is being lighted and further discretion must be used when the obstructing buildings are of a light-absorbing or light-reflecting material and color.

After determining the glass surface required for a given condition of natural illumination, it is important that the glass lights be so located that the maximum lighting effect is obtained with an even distribution over the entire floor surface at the working plane.

For practical purposes a side window may be taken as the most effective lighting medium when it occupies the greatest vertical dimension of the wall, measuring from the starting point which should be close to the ceiling line down to a point as near the floor line as practicable. The other dimension or width will take its own course when the total surface installed is sufficient for adequate lighting. Simply stated, a window with its top near the ceiling will give better lighting results than one starting at some central point in the wall space. Consider the following example of a room which has a wall 8 feet wide and a clear height of 10 feet. The conditions are such that 40 square feet of glass are required. For best results and effective light evenly distributed, a window space measuring 5 feet wide by 8 feet high with the top starting close at the ceiling should be installed. If a window of 40 square feet glass made 6 feet high and a little more than 6½ feet wide were installed in the center of the wall, the lighting results would not be as satisfactory as with the same glass area distributed vertically rather than horizontally over the wall space.

Adequate natural lighting can only be provided after carefully weighing all the important factors that make up the problem and the satisfaction of the final outcome will depend a great deal on the designer's seasoned experience. Shading devices and special makes of glass are important adjuncts in providing proper daylight conditions and are particularly necessary in some cases to prevent excessive brilliancy or glare.

The windows and skylights or other glass light sources for buildings should be arranged with reasonably uniform bays in such manner that the darkest part of any working space will have under normal sunlight conditions not less than the minimum light intensity as given in the tabulation.

Economic Importance of Ample Lighting—A Field for the Sheet Metal Worker

It is a recognized fact that cheerful surroundings in a shop tend to produce greater plant efficiency. With the comfort of the workers provided for during the working hours the fatigue is not so great, with the result that production is maintained at a high level. Among the features necessary are adequate systems of lighting, heating and plumbing—work which falls to the lot of the contractor who runs a combination shop.

While plumbing and heating have received due attention in the proportioning of the systems, it still remains for the sheet metal contractor to emphasize the importance of hollow metal windows and skylights of ample proportions as the means of providing adequate natural lighting facilities.

It has been truly said that a workman is no better than his eyes. A blind workman and a dark factory are equally useless. Under present methods, and conditions as they exist, light is even cheaper than labor. The highest cost in manufacturing processes is still manual labor. Records have shown that 1 per cent of the average daily wage is ample to provide all the necessary illumination for the entire working day.

Considerable improvements have been noted in the methods of artificial gas and electric lighting and large sums of money have been spent by owners of all classes of commercial buildings to bring their lighting systems up to date. This fact indicates that the advantages of adequate lighting facilities are recognized and it also emphasizes the point that considerable economy is practised by providing adequate natural day lighting. Ample size windows and skylights not only mean a saving of dollars and cents by reducing the gas and electric bills, but also aid in the conservation of the nation's resources by the saving of coal used in making the required gas or electricity.

The influence of the duration and intensity of natural light in working hours on fatal and serious accidents is particularly noticeable in such as foundries, bridge building, shipbuilding, engineering, steel and iron works, and other metal-working operations that have to be carried on within large spaces.

Types of Skylights

In line with windows, the next important form of natural lighting is through the medium of the simple skylight, three types of which are shown in Fig. 99B.

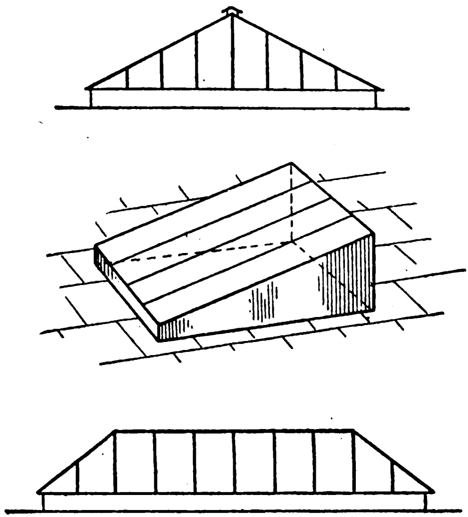


Fig. 99-B.—Three Types of Simple Skylights

Most of the commercial buildings within city limits receive their daylight through fireproof metal windows and through sheet metal skylights of the type illustrated. Where shops, foundries, and power houses are erected in thickly settled sections, the more recent of these are built with monitors for "lantern" roof lighting. Simple types of these designs are shown in the diagram of Fig. 100. The more pretentious machine shops, foundries, and metal working plants of the single story or ground floor type sometimes resort to the saw-tooth roof, shown

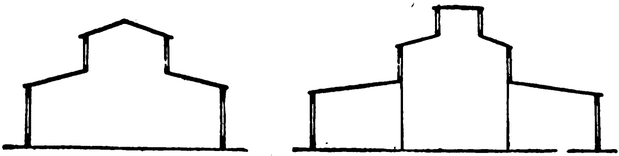


Fig. 100.—Simple Forms of Monitor-Light Roof Constructions

to the left in Fig. 101. A more recent construction that has been adopted in well built factory buildings employs a patented truss for the support of the roof lighting. This lighting method is shown in the right hand diagram of Fig. 101.

The type of building construction employed is the main factor in deciding on the style of roof lighting installed. That there are advantages to be gained by roof lighting systems other than abundant daylight is emphasized by the fact that they are being widely adopted. All systems of roof lighting are valuable adjuncts to natural ventilation under some conditions.

Regardless of the type of roof light construction or the

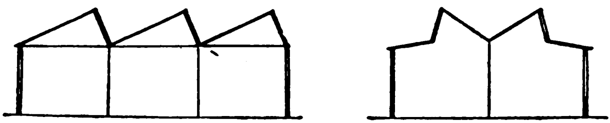


Fig. 101.—Saw-tooth and Patented Truss Roof-light Constructions

style of windows used, the same considerations apply in the selection of the amount of glass surface required for natural daylighting for the interior of the building. The limitations of plain or window glass may be placed at

25 feet, which means that a window or skylight should not be expected to give the minimum light intensity for a distance greater than 25 feet away from the light source either sidewise or downward according to conditions.

It follows therefore that a building or room not more than 25 feet wide ordinarily need not have windows on more than one side. That side should be the wall with windows through which the daylight will come in to the left of the men who work in the space.

If the conditions in such case require a high light intensity it is advisable to install a skylight in the roof, but in the opposite side as related to the windows. Of course, for architectural design when the building is not obstructed, it might be desirable to use windows on the other wall instead of roof lighting.

Take the case of a pattern shop for metal work which is built up against another building of the plant and unobstructed on the other side. The building measures 25 x 50 x 20 feet, as shown in the diagram of Fig. 102. It is proposed to light this structure by means of windows on one side only. Therefore if any additional glass is required, it will have to be in the form of a skylight. Referring to the figures in the tabulation, it is found that the minimum light intensity required is 12 foot candles. Because artificial lighting is expensive in this locality, as much use as possible must be made of daylight. Therefore, in figuring the glass for lighting requirements an intensity of 18 foot candles will be used in the computation. The floor area is 25 x 50 or 1250 square feet, and according to the formula,

$$\text{glass area} = \frac{1250 \times 18}{35} = 644 \text{ square feet.}$$

This lighting surface gives a ratio of 1 square foot glass surface to about 2 square feet floor area.

The wall which is to receive the windows is 20 x 50

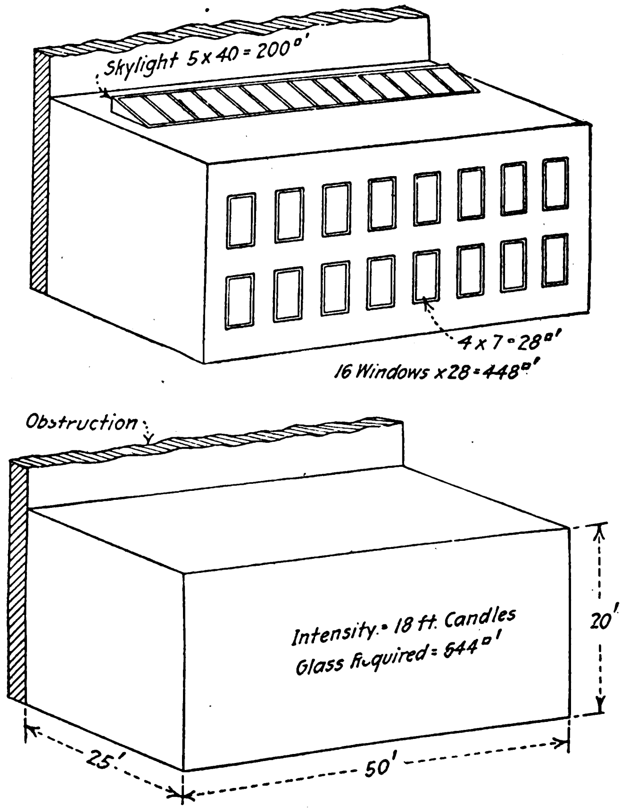


Fig. 102.—Example of Natural Lighting for a Simple Structure

feet, as shown in the diagram. This gives an opportunity for using eight windows arranged two tiers high, as illustrated to the right in Fig. 102. These windows can be made as large as 4 x 7 feet with an area of 28 square feet. There being sixteen windows each with 28 square feet glass gives a total of 448 square feet glass. The computation calls for 644 square feet glass which means that 196 square feet additional must be provided. The skylight to be used for this purpose will be installed in the roof in the part of the building opposite the wall with the windows, as shown in Fig. 102. This skylight will have to be of about 200 square feet glass area and can be made 5 x 40 feet in size. With these provisions the building will be adequately lighted throughout the entire working space.

Lighting Effects Through Different Kinds of Glass

All the foregoing considerations bear directly on the use of plain, ordinary window glass. Wired glass will reduce the relative lighting effect about 10 per cent, which necessitates a corresponding increase in glass surface when wired lights are used. Glass with a rough surface will likewise reduce the amount of light on the inside of the building because it collects dust very readily. Other makes of special glass, however, tend to increase the light-transmitting value and, under some conditions, aid in giving a satisfactory working intensity in parts of the space that would otherwise be relatively dark.

Ribbed glass is a term that covers the general class of these special glasses, typical types of which are the "factory" ribbed and "prism" glasses, shown in the sectional views of Fig. 103.

Ordinary window glass may be relied on to carry the daylight a distance of 15 to 25 feet into the building with effective light for the benches or working surfaces at that point. The use of ribbed glass, however, when placed in upper sashes tends to spread the effective light and by the resultant increase in distribution over the area of floor space which remains the same, the amount of glass nominally required may be reduced for unobstructed buildings not more than 25 feet wide.

Substituting ribbed glass for ordinary glass has the effect of throwing more light to distant points with a result that a working space, opposite to and away from the window, which would ordinarily receive poor daylight, is supplied with an abundance of effective light. On account of its inherent value of throwing light to more

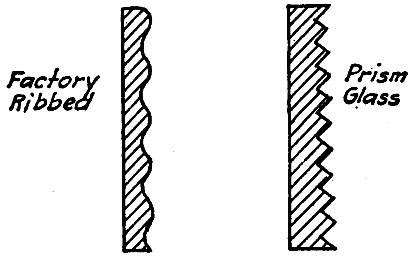


Fig. 103.—Sections of Ribbed Window Glass

distant points, the use of ribbed glass to carry the light 25 feet inside a building greatly reduces the percentage to be added for obstructions. Of the different types of ribbed glass, the so-called factory ribbed with 15 to 21 ribs to the inch and prism glass with sharp, flat prisms and one side smooth will be found to give satisfactory results under a good many conditions.

The use of some form of ribbed glass is best adapted to building conditions where the light source has a small sky angle. This condition is caused by obstructions in the form of other structures being close to the building which is being lighted and the daylight then comes mainly from an alley or narrow courtyard. Without increasing the glass area nominally required, ribbed glass under such conditions will prove very effective.

In this regard, experience has shown that where side windows only are used for daylighting of the interior, factory ribbed glass in the upper sash will prove effective for spaces 25 to 40 feet deep. For conditions of greater depth, say 60 feet, prism glass should be used. For even distribution of light, however, a skylight or other form of roof lighting is preferable.

Only Clean Glass Effective

The imperative need of keeping glass clean is made the closing feature of this treatment of lighting through glass. The amount of the reduction in lighting that dust accumulation on the glass or discoloration will cause will justify the cost of the labor necessary to wash or clean the glass as often as needed. It is of too great importance to be overlooked by those who have made an outlay for daylight outfits. It is more important than keeping interior walls clean and of a light color.

CHAPTER IX

COMPUTATION IN SKYLIGHT WORK

A subject to which very little or no attention has been given is mensuration for the skylight maker, for finding the true lengths of the ventilator, ridge bar, hip bar, common bar and jack bar. The mechanic has but to master a few rules, to find the factors, after which the various lengths for the ventilator and bars can be found by simple arithmetic, regardless of the pitch of the skylight or its

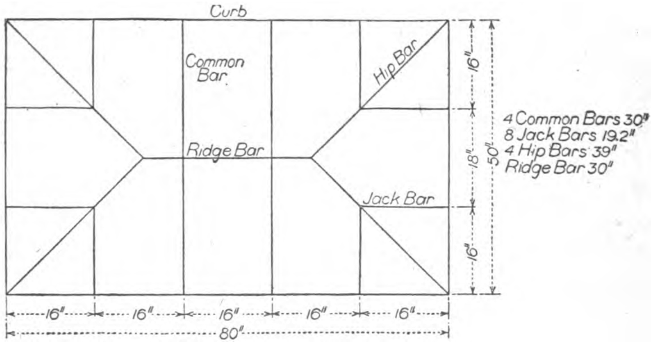


Fig. 104.—Plan of Hipped Skylight with Bar Spacings

size. When once the factor is obtained for the desired pitch, the same factor is used for obtaining the various lengths of the bars, for any size skylight, if same is to have the same pitch as that from which the factor was computed. In practice but two pitches of skylights are employed, namely: one-third pitch, the regulation pitch, and sometimes, to save glass, one-fourth pitch. Some mechanics use a pitch of 7-inch rise to 12-inch run. Whichever pitch is decided upon the following rules hold good. To make the various steps perfectly clear, Fig. 104 has been prepared, and shows the plan view of a hipped skylight with a ridge bar, and the various names of the bars and curb indicated. As an example in computing, we will assume that the skylight measures 4 feet 2 inches by 6 feet 8 inches on the curb line, or 50 × 80 inches. Knowing the size of the curb, the first step is to draw any rough sketch, on which place the bar spacings, as shown, to give the number of bars required. In this case the 80-inch curb has been divided in five spaces of 16 inches each, and the 50-inch curb in 3 spaces, two of 16 inches and one of 18, thus allowing the jack bars to intersect on the hip bar.

Finding the Factor for Common and Jack Bars

Now to find the factor for obtaining the true lengths of the common and jack bars, proceed as follows: Decide what pitch the skylight is to have, in this case one-third; this will have a rise of 8 inches on a 12-inch run, as explained in connection with Fig. 49, and illustrated in Fig. 105 by A B C. This sketch is only shown to make operation in computation clear and is not necessary in practice. Before the factor can be obtained the length of the hypotenuse A C must first be found, by following the rule given in connection with Fig. 9: Add the square of the base to the square of the altitude, and the square root of the sum will be the hypotenuse. Following the diagram in Fig. 105, the square of the base is 12 × 12, or 144; the square of the altitude or rise is 8 × 8, or 64; $144 + 64 = 208$; $\sqrt{208} = 14.42$. (See page 11 for explanation of square root.) While it is well to understand the extraction of the square root, time can be saved by using a table of square roots of numbers, shown on page 137, from number 100 to 400, inclusive. Complete tables can be found in engineers' pocket books giving the square and cube roots of numbers from 1 to 1000, inclusive. The numbers given, 100 to 400, are sufficient for skylight computation. Having the table of square roots at hand and knowing the number to be 208, as found above, simply follow the column of "numbers" to 208, the square root of which will be equal to 14.422, or 14.42, as shown in Fig. 105. As the base of the triangle of which the hypotenuse is a part measures 12 inches, then divide 14.42 by 12, and the quotient will be 1.2, the desired factor for obtaining the true lengths of the common and jack bars for hipped skylights having one-third pitch.

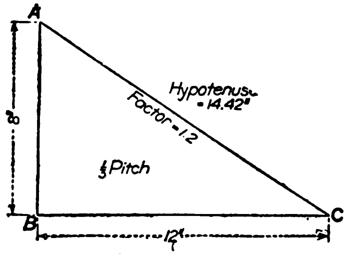


Fig. 105.—Finding Factor for Common and Jack Bars

Finding Factor for Hip Bar

The next step is to find the factor for obtaining the true lengths of hip bars having one-third pitch, and Fig. 106 has been prepared to make this operation clear, although in practical work the diagram can be omitted. A rough diagram is shown 24 inches square; by drawing the two diag-

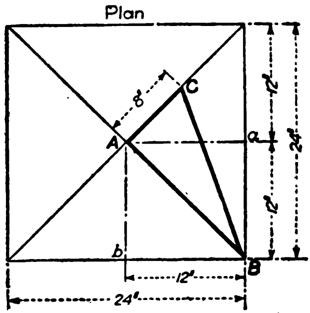


Fig. 106.—Finding the Hypotenuse of Hip Bar

Table of Square Roots of Numbers from 100 to 400

No.	Sq. Rt.	No.	Sq. Rt.	No.	Sq. Rt.	No.	Sq. Rt.	No.	Sq. Rt.
100	10.000								
101	10.050	161	12.689	221	14.866	281	16.763	341	18.466
102	10.099	162	12.728	222	14.900	282	16.793	342	18.493
103	10.149	163	12.767	223	14.933	283	16.823	343	18.520
104	10.198	164	12.806	224	14.967	284	16.852	344	18.547
105	10.247	165	12.845	225	15.000	285	16.882	345	18.574
106	10.296	166	12.884	226	15.033	286	16.911	346	18.601
107	10.344	167	12.923	227	15.066	287	16.941	347	18.628
108	10.392	168	12.961	228	15.100	288	16.971	348	18.655
109	10.440	169	13.000	229	15.133	289	17.000	349	18.681
110	10.488	170	13.038	230	15.166	290	17.029	350	18.708
111	10.536	171	13.077	231	15.199	291	17.059	351	18.735
112	10.583	172	13.115	232	15.231	292	17.088	352	18.762
113	10.630	173	13.153	233	15.264	293	17.117	353	18.788
114	10.677	174	13.191	234	15.297	294	17.146	354	18.815
115	10.724	175	13.229	235	15.330	295	17.176	355	18.841
116	10.770	176	13.266	236	15.362	296	17.205	356	18.868
117	10.817	177	13.304	237	15.395	297	17.234	357	18.894
118	10.863	178	13.342	238	15.427	298	17.263	358	18.921
119	10.909	179	13.379	239	15.460	299	17.292	359	18.947
120	10.954	180	13.416	240	15.492	300	17.320	360	18.974
121	11.000	181	13.454	241	15.524	301	17.349	361	19.000
122	11.045	182	13.491	242	15.556	302	17.378	362	19.026
123	11.090	183	13.528	243	15.588	303	17.407	363	19.053
124	11.135	184	13.565	244	15.620	304	17.436	364	19.079
125	11.180	185	13.601	245	15.652	305	17.464	365	19.105
126	11.225	186	13.638	246	15.684	306	17.493	366	19.131
127	11.269	187	13.675	247	15.716	307	17.521	367	19.157
128	11.314	188	13.711	248	15.748	308	17.550	368	19.183
129	11.358	189	13.748	249	15.780	309	17.578	369	19.209
130	11.402	190	13.784	250	15.811	310	17.607	370	19.235
131	11.445	191	13.820	251	15.843	311	17.635	371	19.261
132	11.489	192	13.856	252	15.874	312	17.663	372	19.287
133	11.533	193	13.892	253	15.906	313	17.692	373	19.313
134	11.576	194	13.928	254	15.937	314	17.720	374	19.339
135	11.619	195	13.964	255	15.969	315	17.748	375	19.365
136	11.662	196	14.000	256	16.000	316	17.776	376	19.391
137	11.705	197	14.036	257	16.031	317	17.804	377	19.416
138	11.747	198	14.071	258	16.062	318	17.833	378	19.442
139	11.790	199	14.107	259	16.093	319	17.861	379	19.468
140	11.832	200	14.142	260	16.124	320	17.888	380	19.494
141	11.874	201	14.177	261	16.155	321	17.916	381	19.519
142	11.916	202	14.213	262	16.186	322	17.944	382	19.545
143	11.958	203	14.248	263	16.217	323	17.972	383	19.570
144	12.000	204	14.283	264	16.248	324	18.000	384	19.596
145	12.042	205	14.318	265	16.279	325	18.028	385	19.621
146	12.083	206	14.353	266	16.309	326	18.055	386	19.647
147	12.124	207	14.387	267	16.340	327	18.083	387	19.672
148	12.165	208	14.422	268	16.371	328	18.111	388	19.698
149	12.207	209	14.457	269	16.401	329	18.138	389	19.723
150	12.247	210	14.491	270	16.432	330	18.166	390	19.748
151	12.288	211	14.526	271	16.462	331	18.193	391	19.774
152	12.329	212	14.560	272	16.492	332	18.221	392	19.799
153	12.369	213	14.594	273	16.523	333	18.248	393	19.824
154	12.410	214	14.629	274	16.553	334	18.276	394	19.849
155	12.450	215	14.663	275	16.583	335	18.303	395	19.875
156	12.490	216	14.697	276	16.613	336	18.330	396	19.900
157	12.530	217	14.731	277	16.643	337	18.358	397	19.925
158	12.570	218	14.765	278	16.673	338	18.385	398	19.950
159	12.609	219	14.799	279	16.703	339	18.412	399	19.975
160	12.649	220	14.832	280	16.733	340	18.439	400	20.000

onal lines from corner to corner, they will represent the four hip bars. From A, at the intersection of the hips, draw the vertical line A *b* and the horizontal line A *a*; then A *a* B *b* represent a one-quarter plan of a skylight 24 inches square and the distances from *a* to B and B to *b* will each measure 12 inches as shown. As the skylight is to have one-third pitch, then lay off, at right angles to A B a distance of 8 inches (the rise) from A to C and draw a line from C to B, which will be the line of the hip bar, the length of which is to be found; it is made still clearer in Fig. 107, where B C D is an enlarged reproduction of the one-eighth plan shown by B *b* A in Fig. 106. As stated before, the diagrams in Figs. 106 and 107 are not necessary in making the calculation, but are only shown to make each succeeding step clear. As B C and C D in Fig. 107 are each equal to 12 inches, then the square of D B will equal the sum of the squares of these two sides B C and C D. Then $12^2 \times 2 = 144 \times 2 = 288$, or the square of D B. Now at right angles to B D, draw the rise, or 8 inches, as shown, and find the length of the hypotenuse A B the same way as was described in connection with Fig. 105. Thus in Fig. 107 the square of B D equals 288 and the square of D A equals 64. $288 + 64 = 352$. $\sqrt{352} = 18.762$ (see table on page 137), or 18.76 inches,

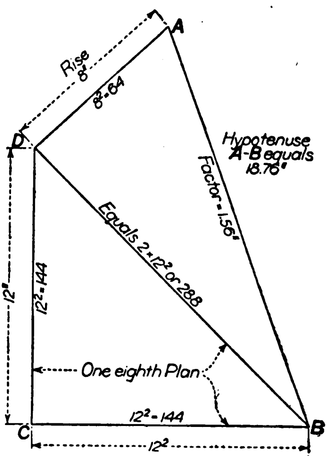


Fig. 107.—Finding Factor for Hip Bar

the length of A B. As the basis of our calculations were 12 inches, as shown by B C and C D, then divide 18.76 by 12; thus 18.76 ÷ 12 = 1.56 inches, or the factor to be used in finding the true lengths of hip bars having one-third pitch. This factor, 1.56, for the hip bar and previously obtained 1.2 for the common and jack bars, are all that is required for obtaining true lengths for bars in any size skylight having one-third pitch.

Applying the Factor in Finding the True Length of Skylight Bars

How to apply these factors to practical use, will now be explained. Regardless of the size of the skylight, always divide the short side of the curb by two, and the quotient will be the number to be multiplied by the factor 1.2 for the common bar, and 1.56 for the hip bar. Bearing this in mind, the following formulas can be used for skylights having one-third pitch, in which S will indicate the short side of the curb and L the long side. Common bars $=\frac{S}{2}\times 1.2$ and Hip bars $=\frac{S}{2}\times 1.56$. Taking the size of the skylight shown in Fig. 104 as an example, we have the short side of 50 inches; this divided by 2 leaves 25; 25 × 1.2 = 30 inches, the length of the four common bars as shown. In a similar manner 25 × 1.56 = 39 inches, the length of the four hip bars. For the length of the jack bars, always take the distance of the bar spacing shown in plan, and multiply this number by 1.2. The distance shown in plan is 16 inches; then 16 × 1.2 equals 19.2 inches, the length of the eight jack bars, or 19¼ inches could be used. If strict accuracy is required we can find the decimal equivalent to .2.

following the table given on page 3, where the nearest decimal to .2 is .21875, and equals 7/32 inch. Hence, 19 7/32 inches can be used.

Formula for Finding Length of Ridge Bar

The formula for obtaining the length of the ridge bar, in which L will indicate the long side of the curb and S the short side, is as follows: L – S = length of ridge bar. Thus 80 – 50 = 30 inches, the desired length.

Finding Length of Jack Bars Having Unequal Spacing

When a number of jack bars are used in a one-third pitch skylight and are spaced either equally or unequally, as shown in Fig. 108, their lengths are obtained by using the factor 1.2 as before. Thus the length of the jack bar A would equal 15 × 1.2 = 18 inches; the length of the jack bar B would equal 2 × 18, or 36 inches, because the distances *a* A and A B are equal. This can be proven as follows: 15 + 15 = 30; 30 × 1.2 = 36. The length of the jack bar C would be found by adding together the unequal spaces, as 15 + 17 = 32, and multiplying 32 × 1.2, which will be 38.4, or 38 13/32 inches. (See table of equivalents on page 3.) When a very large skylight, like the one in Fig. 109,

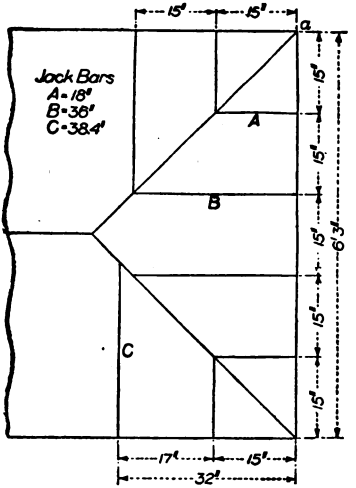


Fig. 108.—Jack Bars with Equal and Unequal Spacings

contains very many equal and unequal spacings of jack bars, the length of the various bars for one-third pitch skylight are obtained as follows; Jack bar A = 16 × 1.2 = 19.2 inches; jack bar B = 2 × 19.2 = 38.4 inches; jack bar C = 3 × 19.2 = 57.6 inches. Jack bar D = 17 ×

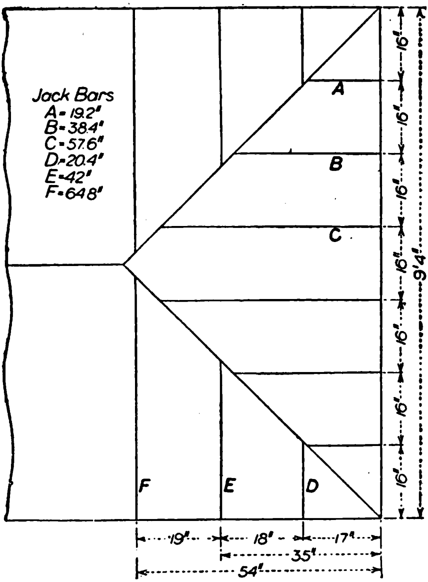


Fig. 109.—Another Problem in Computing Lengths of Jack Bars

1.2, or 20.4 inches. For the length of jack bar E, add 17 and 18; then 35 × 1.2 = 42 inches. Jack bar F equals 17 + 18 + 19 = 54; 54 × 1.2 = 64.8.

Finding Length of Ventilator and Bars

When a skylight is to have a ridge ventilator (see Fig. 110), to find the length of the ventilator, as well as the lengths of the common, hip and jack bars, let L indicate the long side of the curb, S the short side and V the given width of the ventilator. Then Length of Ventilator $= L - S + V$. Length of Common bar $= \frac{S - V}{2} \times 1.2$.

Length of Hip bar $= \frac{S - V}{2} \times 1.56$.

As the size of the curb is 36×60 inches and the given width of the ventilator is 6 inches, the length of the ventilator is $60 - 36 = 24$; $24 + 6 = 30$ inches; or, in other words, from the length of the curb, or 60, take the width of the curb, or 36; this leaves 24, to which add the given width of the ventilator, or 6, and you have the sum of 30 inches, the length of the ventilator. It should be

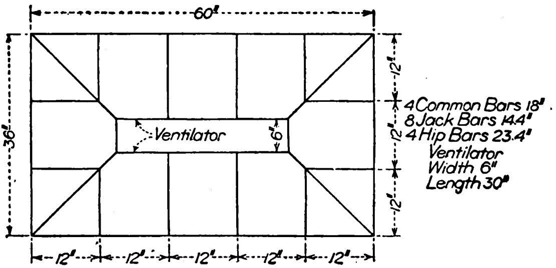


Fig. 110.—Plan of Hipped Ventilating Skylight

understood that the width of the ventilator must be known before any calculations can be made; but whatever that width may be, the above formula holds good. Following the formula for the common bar, we have, short side of curb, 36 inches; from this subtract the given width of the ventilator, or 6 inches; the remainder will be 30 inches; divide 30 by 2 and the quotient is 15; $15 \times 1.2 = 18$ inches, the length of the common bars. Using this same number, 15, just obtained, multiply this by 1.56 for the hip bar. Thus $15 \times 1.56 = 23.4$. The above rules apply to any size skylight of one-third pitch, having any given width of ventilator.

Finding Length of Bars in Semi-Hipped Skylight

Another style of skylight which is often used is part of a hipped skylight butting against a wall, as shown in Fig. 111, representing a vent, shaft 36 × 54 inches, over which a semi-hipped skylight is to be placed. In making up these skylights the question which arises is, which

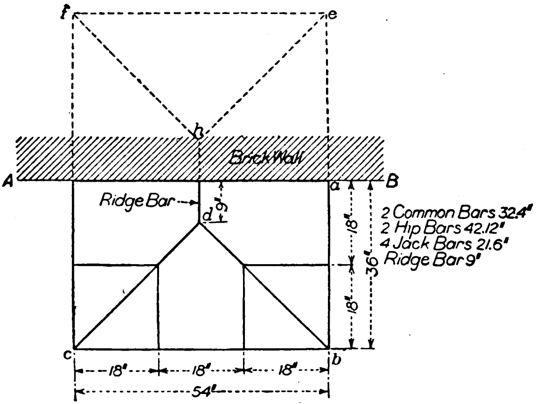


Fig. 111.—Computing the Various Lengths of Hipped Skylight Butting Against a Wall

way will the ridge bar run—at right angles to the line of the wall, or parallel to it? This question is easily solved by doubling the shaft measurements *a b*, or 2 × 36 = 72. 72 being greater than 54, then assume that 54 is the short side of a complete skylight, *f e b c*, whose length is 72 inches from *b* to *e*, and that the wall line A B is the center line through the skylight. This brings the ridge bar in the position shown by *h d*, at right angles to the wall line A B. The various lengths of the half skylight having one-third pitch can be obtained by the rules previously given, using the factors, 1.2 and 1.56 as follows:

Common bar = 54 ÷ 2 = 27; 27 × 1.2 = 32.4 inches.
Hip bar = 54 ÷ 2 = 27; 27 × 1.56 = 42.12 inches.
Jack bar = 18 × 1.2 = 21.6 inches. The decimal equivalents can be found by referring to page 3.

The ridge bar is computed by subtracting the short side, 54, from the long side, 72 (2 × 36), leaving 18 for a full skylight. Divide 18 by 2, and the quotient will be 9 inches, the required length. Fig. 112 shows another ex-

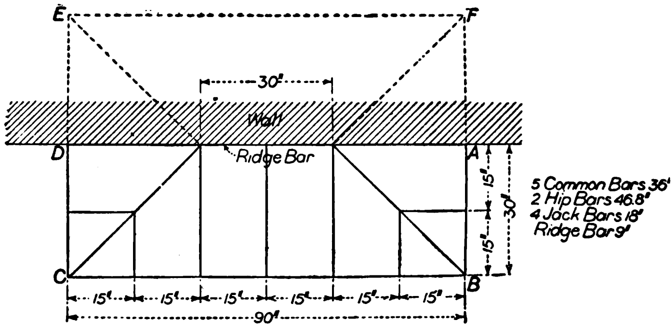


Fig. 112.—Another Example in Vent Shaft Skylight

ample in shaft skylights where the ridge bar runs parallel with the wall. Let us assume the size of the shaft as 30 × 90 inches. Double the side of the shaft A B, as 2 × 30 = 60. 60 being less than 90, then assume that 90 is the long side of a completed skylight B C E F, and that the wall line D A is the center line through the skylight. This will bring the ridge bar parallel to the wall line D A. The various lengths of the various bars of this skylight whose pitch is one-third is then obtained as follows:

Common bar = 60 ÷ 2 = 30; 30 × 1.2 = 36 inches.

Hip bar = 60 ÷ 2 = 30; 30 × 1.56 = 46.8 inches.
Jack bar = 15 × 1.2 = 18 inches.
Ridge bar = 90 − 60 = 30 inches.

The rules given in connection with Figs. 111 and 112 also apply to semi-hipped skylights with ridge ventilators. Obtain the sizes of the ventilators in the manner explained in connection with Fig. 110, and then take one-half of the ventilator whether it runs at right angles to, or parallel with the wall, in the same manner as one-half of the ridge bar was found in Fig. 111.

Finding Length of Bars in Flat Skylights

When large flat skylights are constructed and only the run and rise are known, the length of the bar or rafter can be computed as shown in connection with Fig. 113,

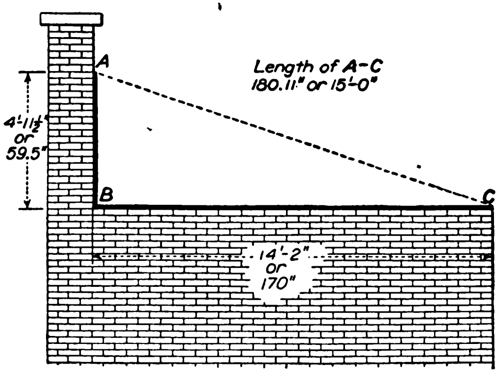


Fig. 113.—Finding the Length of Bar in Flat Skylight

where a side elevation of a flat skylight over an elevator shaft or studio is shown, to be re-enforced with angle iron construction, the length of the rafter A C being desired. The rise from A to B is 4 feet 11½ inches, and the run from B to C 14 feet 2 inches. While these measurements could be taken direct at the building, or might be laid out full size on the floor, and the length of A C found, it takes but a few minutes to compute them. Following the rule given for the extraction of the square root on page 11, add the square of the rise to the square of the run, and the square root of the sum will be the rafter or bar hypotenuse. The rise being 4 feet 11½ inches, or 59.5 inches, and the run being 14 feet 2 inches, or 170 inches, we have

$\sqrt{59.5^2 + 170^2} = \sqrt{3540.25 + 28900} = \sqrt{32440.25} =$ 180.111 inches, or $59.5 \times 59.5 = 3540.25$; $170 \times 170 =$

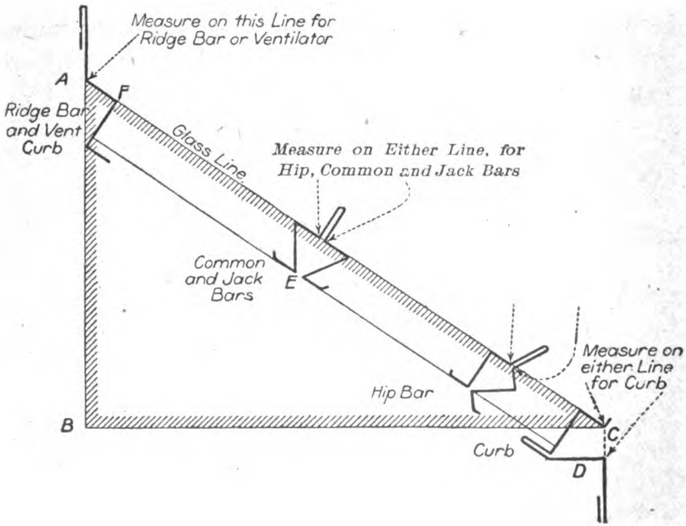


Fig. 114.—The Various Measuring Points for Curb, Ventilator, Ridge, Common, Hip and Jack Bars

28900; $28900 + 3540.25 = 32440.25$. The square root of 32440.25 equals 180.111 inches, or 15 feet, the length of the bar from A to C.

The Proper Measuring Points

The reader may say, now that I understand how to find the various lengths of the various bars and ventilators, from what point will I place these measurements on the various skylight patterns? To answer this question clearly, Fig. 114 has been prepared, showing the regulation sections of curb, common and jack bars, hip bar, ridge bar and ventilator curb.

All measurements obtained by the rules previously given should be laid off on the lines or bends indicated by the arrows in the various sections. A B in the diagram indicates the rise, B C the run and C A the hypotenuse. Notice that the hypotenuse A C represents the glass line, and for that reason all measurements are taken on the glass line as indicated by the arrows. In this connection it may be well to say that regardless of the pitch of the skylight, whether one-fourth, one-fifth or one-sixth, the rise will always equal the quotient, obtained by dividing the span by the pitch desired, then the rules previously given for the various lengths of the bars and ventilator can be followed.

CHAPTER X

MEASURING ROOFS

For the benefit of mechanics who do not understand figuring from architect's or scale drawings the following twelve problems are given on computing roof surfaces.

These problems include rules for obtaining the true amount of material required for covering flat or hipped roofs and square, octagonal and conical towers; also the methods of finding the true lengths of the hips and valleys on pitched roofs. The diagrams shown are not drawn to scale in the manner of architects' drawings; but the measurements on the diagram are assumed, and will clearly show the principles to be applied when figuring from scale drawings.

The Plans

When measurements are taken, assuming that the plans from which we are figuring are drawn to a ¼-inch scale, ¼ inch represents 1 foot, ⅛ inch equals 6 inches, and continued in proportion. If the plans were drawn to a ½-inch scale, then ½ inch would equal 12 inches, ¼ inch equal 6 inches, ⅛ inch equal 3 inches, 1/16 inch equal 1½ inches, etc.

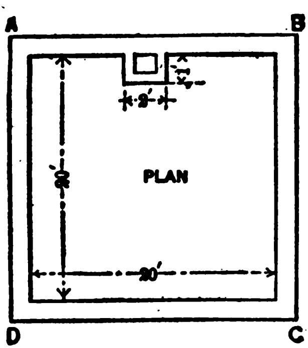


Fig. 115.—Plan of Square Roof

Material on Flat Roof

In the first three problems, Figs. 115 to 117, inclusive, are supposed to be covered with flat seam tin or felt roofing; while Figs. 118 to 126, inclusive, can be covered with either slate, tin, tile or shingle. The first problem will be to figure the amount of material required on a flat roof, shown in Fig. 115 by A B C D, and measuring 20 × 20 feet. Now, multiplying 20 × 20 feet gives 400 square feet. The chimney measures 1 × 2 feet and equals 2 square feet; deduct this from 400 square feet and the remainder, 398 square feet, will be the true amount of surface to be covered. Allowance should be made for the flashings turning up against and into the wall at the sides.

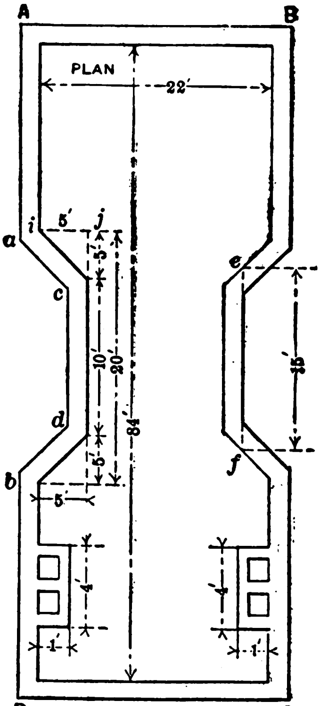


Fig. 116.—Roof of Building with Air Shafts at the Sides

Roof with Air Shafts at Side

The next problem is a little more difficult, and shows a plan having air shafts at the sides. A B C D, Fig. 116, represents the general plan view of the roof, which measures 22 × 84 feet. In a roof of this kind we will make no allowance for air shafts at first, but deduct these and the chimneys later. Thus 84 × 22 feet equals 1,848 square feet.

The shafts at each side are cut at an angle of 45 degrees, and measure from the outer corners *a* to *b* 20 feet, and from the inner corners *c* to *d* 10 feet. Now, as the angles are 45 degrees, we must average the distance between 10 and 20 feet as follows: $\frac{10 + 20}{2} = \frac{30}{2} = 15$ feet from *e* to *f*. From *i* to *j* on a horizontal line is 5 feet;

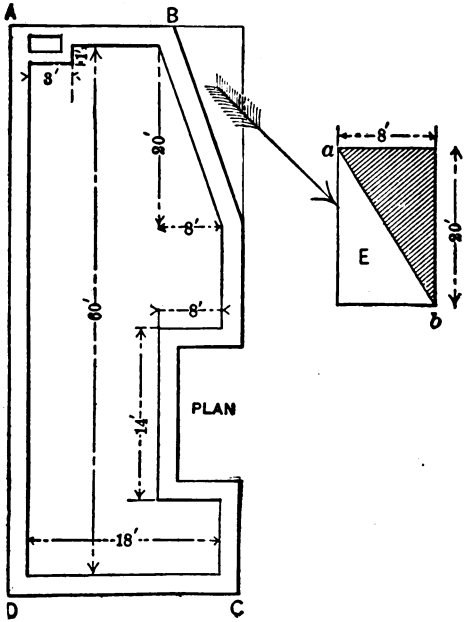


Fig. 117.—Another Shape of Flat Roof

multiply 5 × 15 feet, which gives 75 square feet; double this for the two shafts, making 150 square feet.

Two chimneys are shown, each 1 × 4 feet; 4 × 2 feet equals 8 feet, plus 150 feet equals 158 square feet. Deducting 158 square feet from 1,848 square feet leaves 1,690 square feet of roof surface, without the flashings.

Another Form of Flat Roof

The third problem gives another form of flat roof, and is shown by A B C D in Fig. 117. In this case the same rule is employed as that given in connection with Fig. 116. Multiply the width by the length in Fig. 117, thus: 18 × 60 feet equals 1,080 square feet if the roof is without breaks. Now deduct the chimney of 1 × 3 feet, or 3 square feet; deduct the shaft of 8 × 14 feet, or 112 square feet. The angle at the rear of the building measures 8 × 20 feet; this equals 160 square feet; from this deduct one-half, leaving 80 square feet. Now we have 3 + 112 + 80 feet, equaling 195 square feet, and to be deducted from 1,080 square feet, leaving 885 square feet of material required to cover a surface of the size given.

In diagram E the principle to be applied when figuring the deduction of angles is shown. The size of the rectangle is 8 × 20 feet and equals 160 square feet. By drawing the diagonal *a b*, we cut this amount in half, as shown by the shaded lines, making it 80 square feet, as noted above.

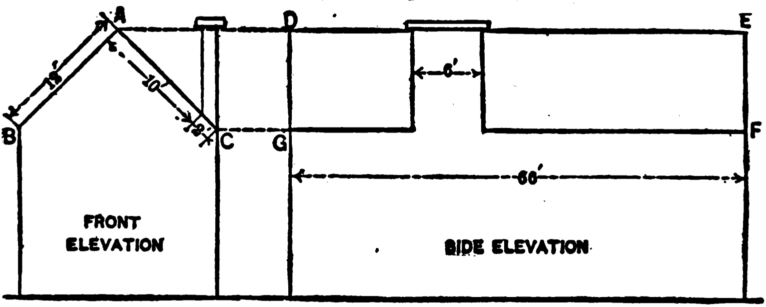


Fig. 118.—Simple Form of Pitched or Gable Roof

Pitched Roofs

In the fourth problem we begin with the simpler forms of pitched roofs. In Fig. 118 A B C shows the front elevation of the building and D E F G the side. The length of the rafter measures 12 feet, as shown from A to B in the front elevation, and the length from G to F in the side elevation measures 66 feet. Now 12 × 66 feet equals 792 square feet for one side. Double this and we have 1,584 square feet. Deduct the chimney, which is 6 feet wide by 2 feet, shown on the rake; 2 × 6 feet equals 12 square feet. This deducted from 1,584 square feet leaves 1,572 square feet for a plain pitched roof. Allowance must be made for the flashing of the chimney.

Hipped Roof of Equal Pitch

In the fifth problem, illustrated by Fig. 119, A B C shows the elevation of a pitched roof having four hips, and D E F G the plan of the hipped roof. The diagonal lines shown from D to F and E to G show the hip lines in plan. While it may appear difficult to figure the quantities in a hipped roof, it is very simple, if the rule is understood. The length of the rafter shown from A to C in elevation is 10 feet, and the width of the building at the eaves of the roof is 16 feet on each side. The hipped roof runs to an apex in the

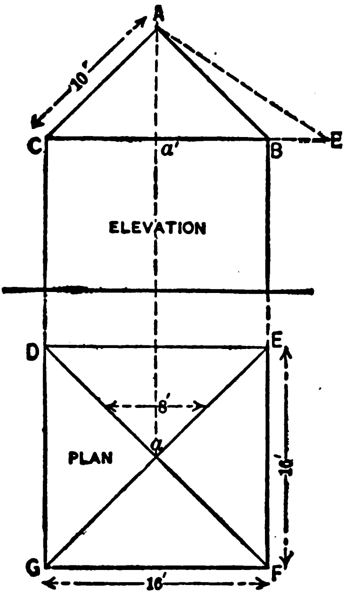


Fig. 119.—Pitched Roof with Four Hips

center, and the distance between the eave line D E and apex a in plan will measure one-half of 16 feet, or 8 feet, as shown. 8×10 feet equals 80 feet, this multiplied by 4 sides equals 320 square feet of roofing required on a building of the dimensions given. As the hips must be covered with a metal capping to avoid leakage, it is necessary to obtain the true length of the hip. This is accomplished by dropping a line from the apex A in elevation, cutting the line C B at a'. Extend the line C B as C E^1. Now take the distance of the diagonal a E in plan, and place it as shown from a' to E^1 in elevation, and draw a line from E^1 to A; this will represent the true length of the hip. Multiplying this amount by 4 will give the amount of capping or ridge roll required on a hipped roof of this size.

Hipped Roof with Sides of Unequal Pitch

The method of computing hipped roofs when the sides are of unequal pitch is explained in connection with Fig. 120. A B C D shows the plan of the roof, the ends measuring 14 feet and the sides 24 feet. The side elevation is indicated by E F G, showing the rafters of 14 feet length, and the end elevation by H I J, with rafters of 10 feet length. As the length of D C in plan is 24 feet, then the averaged distance between a and b is one-half of 24, or 12 feet; using the same rule the averaged distance between a and c is 7 feet. Multiplying the length of the rafter I H in the end elevation, which is 10×12 feet in plan, and equals 120 feet; twice this is 240 feet. In similar manner multiply the length of the rafter E G in the side elevation, which is 14×7 feet in plan, and equals 98 feet; twice this equals 196 feet, plus 240 feet equals 436 square feet. Deduct the chimney, which measures 2 feet 6 inches by 4 feet and equals 10 feet from 436 square feet, leaving 426 square feet of covering required. For the length of the hip take the distance from *a* to B in plan and place it on the line F G extended in the side elevation from *a'* to B¹. Then draw a line

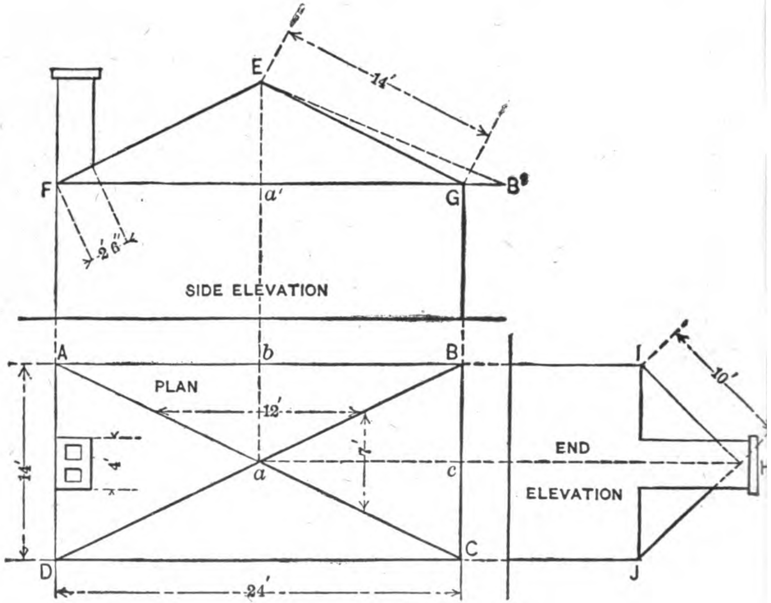


Fig. 120.—Diagram Showing Method of Computing Hip Roofs of Unequal Pitch

from B¹ to E; this is the true length of the hip for one corner. Multiply this length B¹ E by 4; the result will be the amount of hip roll for the four hips.

A Mansard and Deck Roof with Dormers

The seventh problem illustrates a deck and mansard roof with intersecting dormers. A B C D, Fig. 121, shows the side elevation and A¹ B¹ C¹ D¹ the end elevation. The plan of the mansard and deck roof is shown respectively by E F G H and I J K L; the dormers are indicated in the elevations and plan.

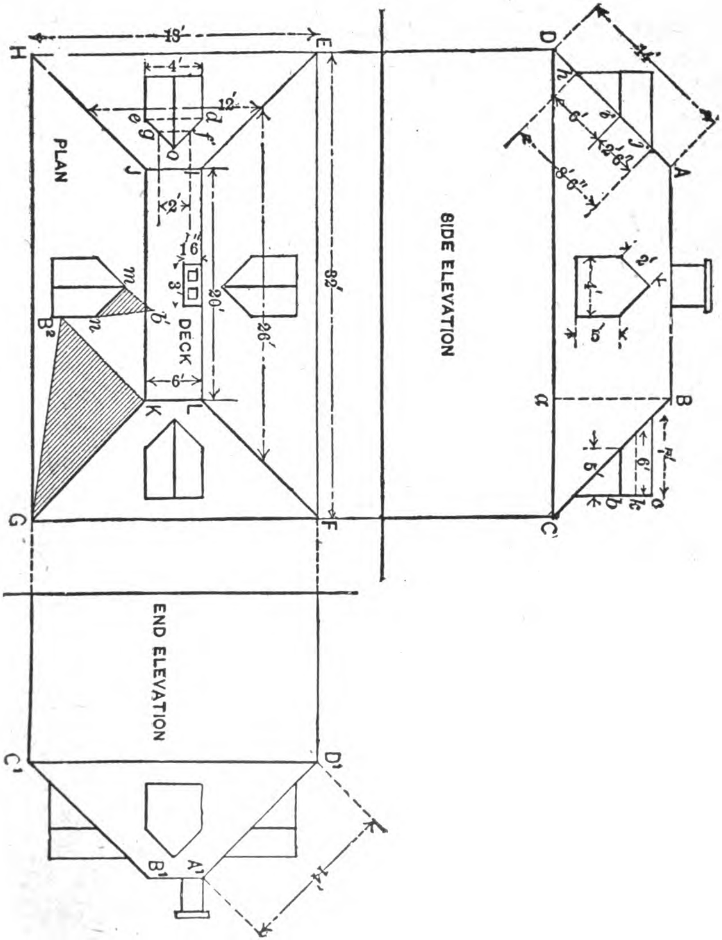


Fig. 121.—Plan and Elevations of Mansard Roof with Deck and Dormers

The roof measures at the eaves 18 × 32 feet, and at the deck 6 × 20 feet. Multiplying 6 × 20 feet equals 120 square feet; the chimney is 3 feet by 1 foot 6 inches, and equals 4 feet 6 inches. Deducting this from 120 will leave 115½ square feet of surface on the deck roof. Now average the distances between the eave lines E F and E H and deck lines L I and I J, as follows: 32 + 20 feet equals 52 feet, divided by 2 equals 26 feet. In similar manner average the end, obtaining the amount of 12 feet. As the length of the rafters in both end and side elevations measures 14 feet, multiplying 14 × 26 feet gives 364 feet; this multiplied by 2 sides gives 728 square feet. Then 14 × 12 feet equals 168 × 2 ends equals 336 square feet, making a total of 1,064 square feet. We now deduct the dormers. The length of the dormer cutting into the main roof from *h* to *j* in the side elevation is 8 feet 6 inches; the length of the cheek from *h* to *i* is 6 feet; the width of the dormer in plan is 4 feet. Multiplying 4 × 6 feet equals 24 feet; this for 4 dormers equals 96 square feet. The width of the pitched roof of the dormer cutting on the mansard roof on the rake is 2 feet 6 inches, as shown in the side elevation, while the averaged distance in the plan view of the dormer, between the line *d e* and the apex *o*, as shown from *f* to *g*, is one-half of 4 feet, or 2 feet. Thus 2 × 2 feet 6 inches equals 5 feet, multiplied by 4 dormers equals 20 feet. 96 feet and 20 feet equals 116 square feet to be deducted from 1,064 feet, leaving 948 square feet in the mansard roof minus the dormers. The covering for the cheeks and roofs of the dormers is as follows: The height of the cheek is 5 feet and the width of the cheek is 5 feet; 5 × 5 feet equals 25 feet, multiplied by 4 dormers equals 100 square feet. The pitch on the roof of the dormer equals

2 feet, while the averaged distance between the eave line b of the dormer and the ridge line c is $\frac{5+7}{2} = 6$ feet as shown by k. Then 6×2 feet equals 12 feet, multiplied by 8 roofs of dormers equals 96 square feet. We then have:

115½ square feet in deck roof,
948 square feet in mansard roof,
100 square feet in cheeks of dormers,
96 square feet in roofs of dormers, making a total of

1259½ square feet of material required for the mansard dormers and deck shown. In previous problems the length of the hip was obtained from the elevation; in this one we will show how it is obtained from the plan, either method being desirable. From the point B in the side elevation drop the vertical line B a, intersecting the line D C. Now take the vertical distance a B and place it at right angles to the hip K G in plan, as shown by K B^2. Draw a line from B^2 to G, which will be the true length of the hip ridge or rafter. Four times this amount will be required. In similar manner the length of the valley behind the dormer is obtained. Take the height of the roof of the dormer b c in the side elevation and place it at right angles to the valley line of the dormer m n in plan, as shown by m b'. Draw a line from b' to n. This is the true length of the valley. Eight times this amount will be required.

Hipped Roof with Wing

Fig. 122 shows a hipped roof with wing attached. In this problem we shall only give special attention to those parts which have not been previously explained. Assuming that the main building was minus the wing, it would be computed in the same way as Fig. 120. We would, however, in this case have to deduct the space occupied

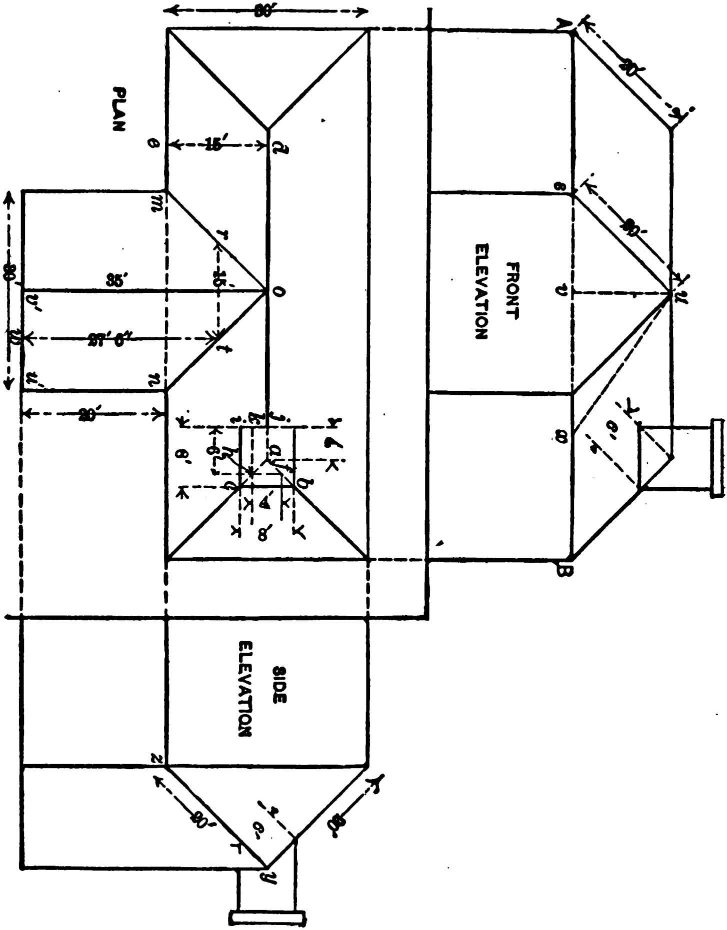


Fig. 122.—Plan and Elevations of Hip Roof with Wing Attached

on the roof by the chimney in Fig. 122, and deduct the space where the wing intersects the main roof. The chimney is 8 × 8 feet in size, and intersects the pitch of the roof a distance of 6 feet, as shown in the front elevation. Now average the distance in plan between the apex a and the side of the chimney $b\ c$, or $\frac{8}{2} = 4$ feet, as shown from f to h; then 4 × 6 feet equals 24 square feet. Now in the side elevation the chimney cuts into the pitch roof also a distance of 6 feet.

The line of the chimney in plan $c\ i$ equals 8 feet, and the ridge line, as far as chimney intersects it, from a to j, measures 4 feet. Then average the distance between $a\ j$ and $c\ i$, or $\frac{4 + 8}{2} = 6$ feet and is shown by $h\ k$. Then $6 \times 6 = 36$ feet, × 2 sides = 72 feet, + 24 feet = 96 square feet, which would be deducted from the main roof covering. The space to be deducted from the long side of the main roof to admit the intersection of the wing is obtained as follows: The width of the wing in plan is 30 feet. Now average the distance between the points $m\ n$ and the apex o; this will be one-half of 30 and measure 15 feet, as shown from r to t. Now multiply 15 feet by the length of the rafter $y\ z$ in the side elevation, or 20 feet; this equals 300 square feet, also to be deducted from the main roof. For the amount of roof surface in the wing only, take the length of the ridge from o to v', 35 feet, and the length of the eave from n to u', 20 feet. Thus $\frac{35 + 20}{2} = \frac{55}{2} = 27$ feet 6 inches, the averaged distance between the eave and the ridge, as shown from t to w. Now multiply this by the length of the rafter *u s* in the front elevation, which is 20 feet; thus 27 feet 6 inches × 20 feet = 550 square feet, × 2 sides equals 1,100 square feet of surface on the roof of wing. To obtain the length of the valley, *o n* in plan, drop a line from the apex *u* in the front elevation until it intersects the line A B at *v*; now take the distance *o n* in plan and place in the front elevation from *v* to *x* and draw a line from *x* to *u*; this will be the true length of the valley and at the same time the true length of the hip, because the end of the wing and the ends of the main building each measure 30 feet. Twice the length of *u x* will be the amount of valley required.

Amount to Be Deducted from Side of Main Roof to Allow for Wing Having a Different Pitch

The ninth problem, represented in Fig. 123, explains how much must be deducted from the side of the main roof to admit the intersection of the wing, whose pitch is different from that of the main roof. Referring to the elevation, the wing intersects the main roof a distance of 7 feet, as shown, and the width of the wing in plan is 10 feet. Now average the distance between the apex *b* and points of intersection *d* and *a* in plan; this will be $\frac{10}{2}$, or 5 feet, as shown from *f* to *h*. Then multiplying 5 × 7 feet equals 35 square feet, to be deducted from the side of the main roof. Taking the distance of the valley line *a b* in plan and placing it as shown from *a′* to *b′* in elevation and drawing the line *b′ c*, gives the true length of the valley for one side.

Finding the Quantities in a Turret or Tower

In the tenth problem, Fig. 124, the method of finding the quantities in a turret or tower whose base is either square, hexagon, octagon or any other shaped figure is indicated. Let A B C represent the elevation of the tower, whose plan on B C is shown by D E F G H I J K. Lines drawn to the center L in plan represent the hip

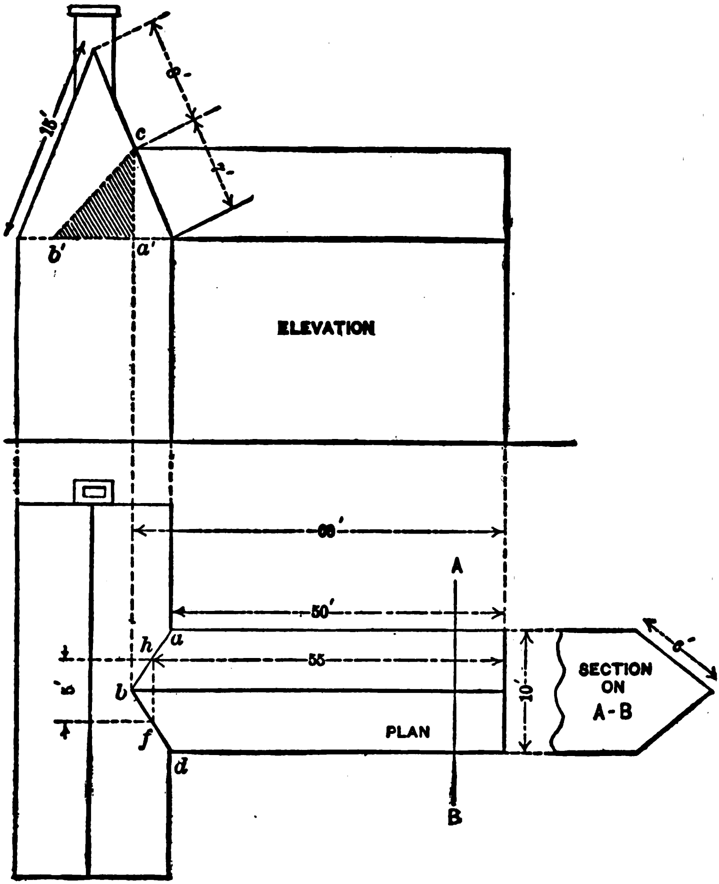


Fig. 123.—Diagram Showing Amount to Be Deducted from Side of Main Roof to Allow for Wing Having a Different Pitch

lines. Now, assuming that one side of the tower, J I in plan, measures 10 feet, then average the distance between J I and the apex L, which will be $\frac{10}{2}$, or 5 feet, as shown. The length of the rafter from A to B in elevation being 40 feet, then 40 × 5 feet = 200 feet × 8 sides = 1,600 square feet surface in the tower of the dimensions given. For the length of the hip draw the center line A L, intersecting the line B C in elevation at *a*; then take the distance of one of the hips in plan, as L D, and place it as shown from *a* to D^2 in elevation. Draw a line from D^2 to A; this gives the true amount of the hip, and must be multiplied by 8 for the full amount of the eight hips.

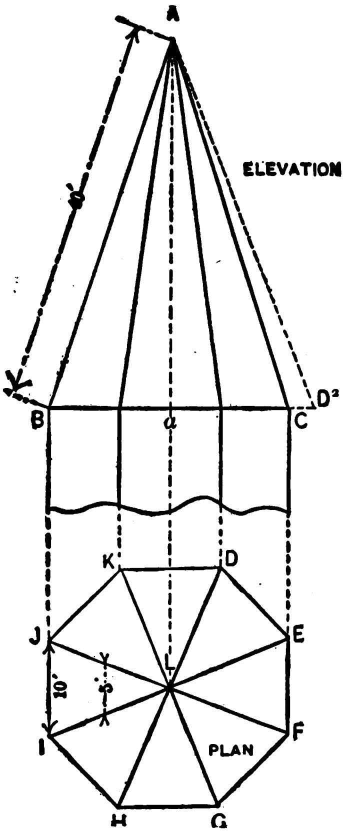


Fig. 124.—Finding Quantities in a Tower of Any Shaped Base

Octagon Tower with Square Base

A more difficult problem in computing roof surfaces is illustrated in Fig. 125. Here A B C D represents the square base of a tower or other object, from which a transition to an octagon takes place, as illustrated in plan by E F G H I

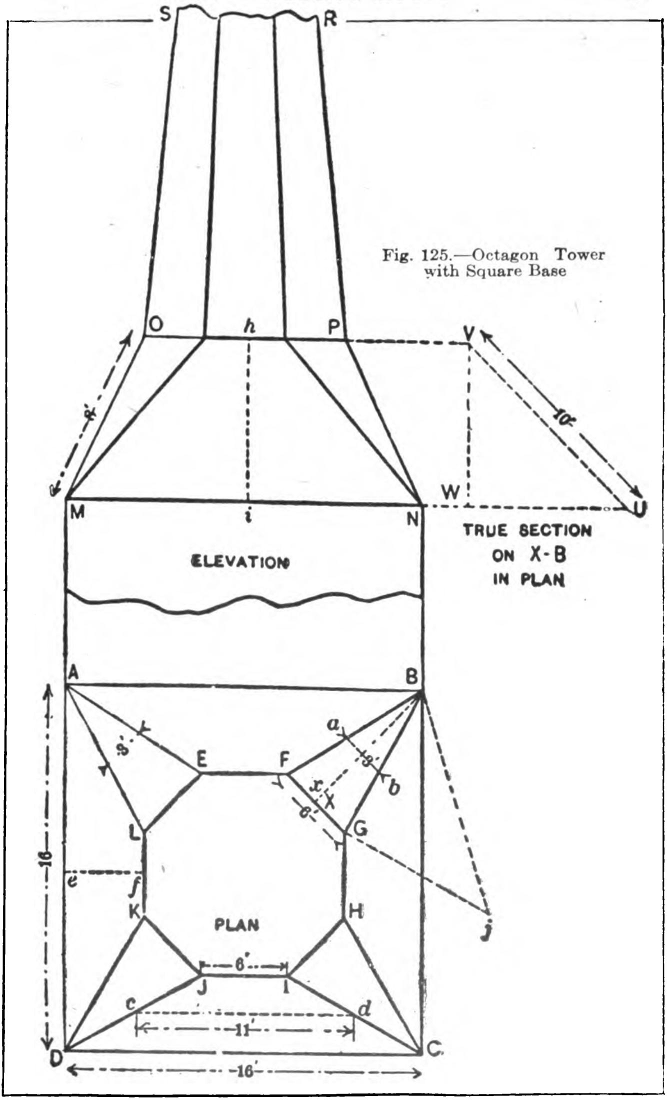


Fig. 125.—Octagon Tower with Square Base

J K L, the elevation being shown by M N O P R S. It is this portion M N P O, which forms the problem. The length of the rafter from O to M in elevation is 8 feet and is the true section on the line *e f* in plan. As the base line in plan is 16 feet and the top line in the octagonal plan is 6 feet, average the distance between the two as follows: 16 feet + 6 feet = 22 feet, ÷ 2 = 11 feet, as shown by *c d*. Now multiplying 8 × 11 feet equals 88 feet; this multiplied by 4 = 352 square feet for the four sides. For the gore piece F G B in plan it will first be necessary to find the true length of the rafter on X B in plan. This is accomplished by taking the distance X B and placing it on the line M N in elevation extended, as shown by W U.

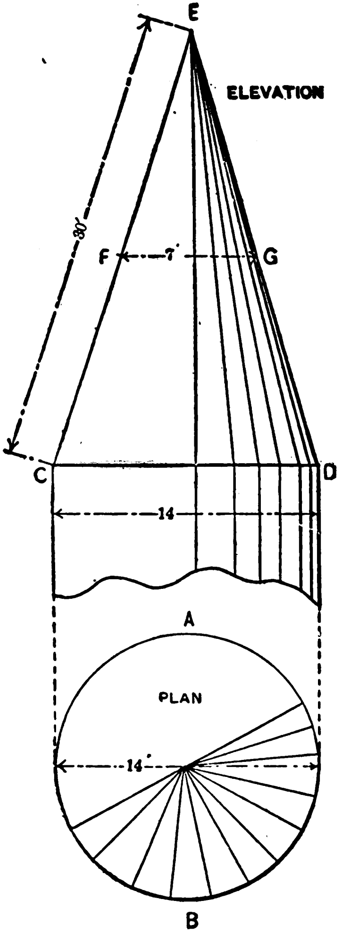


Fig. 126.—Plan and Elevation of Conical Spire

At right angles to W U draw the line W V until it meets the line O P extended, as shown. Draw a line from V to U, which will be the true section on X B in plan. The distance from F to G in plan measures 6 feet. Now average the distance between these points and the corner B; thus $\frac{6}{2}$ = 3, as shown by *a b*, which is 3 feet. Now, assuming that V U in elevation measures 10 feet, multiplying this by 3 feet = 30 feet, × 4 = 120 square feet for the gores. Add 352 square feet for sides, which will make 472 square feet of roof surfaces in the transition piece shown. The length of the hip is obtained by taking the vertical height in elevation *h i* and placing it in plan at right angles to B G from G to *j*; then draw a line from *j* to B; this will be the true length of the hip, and must be multiplied by 8 for the full amount for the eight hips.

Conical Spires or Towers

The next problem, shown in Fig. 126, gives the method employed when computing conical spires or towers. Assuming that the base of the spire, C D in elevation, is 14 feet, as shown by A B in plan, then average the distance between the base C D and the apex E in elevation by dividing 14 by 2, which will be 7 feet, as shown by F G. As the circumference of a circle is found by multiplying the diameter by 3.1416, or, as used in practice, 3 1/7, then multiplying 7 × 3 1/7 feet = 22 square feet. The length of the rafter being 30 feet, then 30 × 22 feet = 660 square feet of surface in a spire of the dimensions shown.

Finding Surface of Segmental Dome

To find the amount of sheet copper necessary to cover a segmental dome as shown in A, Fig. 127, proceed as in B, finding the area of the section of a sphere, as explained in connection with Fig. 128.

The area of either a hemisphere or segment of a sphere is equal to the diameter multiplied by 3.1416 and this product multiplied by the rise. As the radius of the segment shown in elevation is 6 feet, then 2 × 6 = 12, or the diameter. Thus 12 × 3.1416 =37.6992; 37.6992×3 (the rise) = 113.09 square feet of surface in B. Another

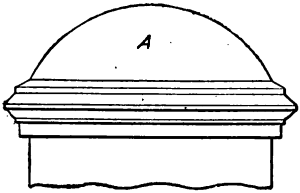


Fig. 127.—Segmental Dome

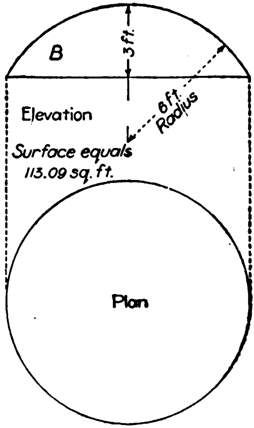


Fig. 128.—Finding Area of Surface of Segmental Dome

rule for computing the surface, is to find the entire surface of the sphere, dividing this sum by the fractional height of the sphere. The entire surface of a sphere is found by the rule given in connection with Fig. 23. Applying this rule to Fig. 128, we have 12 × 12 = 144; 144 × 3.1416 = 452.39 square feet for entire sphere. The rise of the segment being 3 feet, then the fractional height of the sphere is 4. Then 452.39 ÷ 4 = 113.09 square feet of surface, the same as the first solution.

CHAPTER XI

MEASURING FOR GUTTERS AND LEADERS

An adequate system of gutters and leaders is one of the essentials of the modern house, for leaks and discolorations to walls and ceilings are likely to ensue if proper attention is not paid to this important subject, which only too often is slighted.

The house shown in Fig. 129 is of the hip-roof type with a dormer in front, and the roof plan, Fig. 130, shows that there are no valleys for carrying off water. As seen by the outline of main roof, dormer, and deck, rain falling upon the dormer and adjacent parts of the roof finds its way to the front gutter E F, which pitches toward E. From here a slanting leader connects with the downspout D, as shown by the dotted lines. The back and left side of the roof pitch from A to the connection C, which leads to the downspout D, as shown by the dotted lines, but connects with the slanting leader D E, also shown in Fig. 129.

In many cases the dormer would be provided with a gutter pitched to a leader which would have an elbow at the bottom discharging on the main roof on either side of the dormers, and from there the rain would dribble down to the gutter. But when so placed there is apt to be discoloration of the roof shingles due to the action of the rain wash concentrated on the one line, whereas in the present job the fall is equally distributed over the dormer eave with a stainless result.

The gutter and leader connections at the opposite sides of the house, K, J, H, G in Fig. 130, are similar. Gutter K, J pitches to the outlet J, which connects by a slanting leader from J to I. Gutter G, H pitches to the outlet H, which connects to the downspout at I, the arrangement on this side of the house being practi-

Fig. 129.—Gutters and Leaders at F, E, D, C, B

cally the same as shown in Fig. 129. Gutter and leader sizes are usually figured from the roof plan, which in this case contains about 1,400 square feet. The various gutters and leaders take care of this surface about as follows:

Gutter E, F takes care of E, D, N, O, G, F, or about 517 square feet.

Gutter B, A takes care of the surface B, A, Q, P, or 175 square feet.

Gutter B, C takes care of B, C, N, P, or 245 square

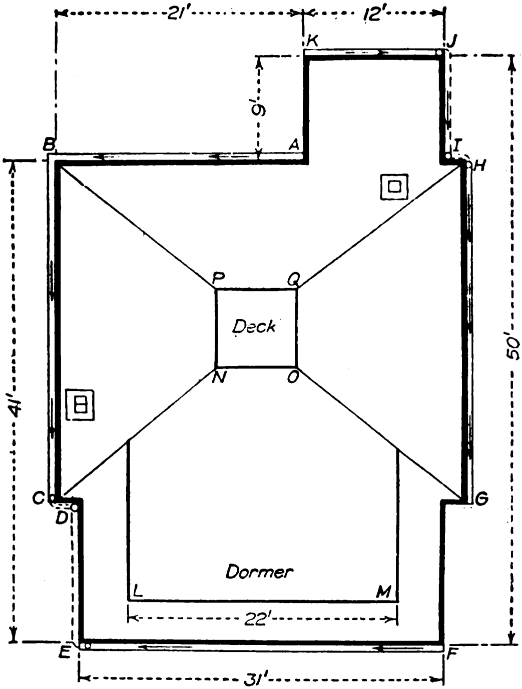


Fig. 130.—Plan Showing Pitch and Run of Gutters

feet, plus the flow from B, A of 175 square feet, which totals 420 square feet.

The downspout at D therefore takes care of the wash from all the roof to the left of the line A, Q, O, G, F, a total of about 937 square feet.

The other section of the roof, G, H, J, K, A, Q, O, is divided up as follows:

Gutter G, H takes care of G, O, Q, H, or about 245 square feet.

Gutter K, J takes care of K, A, Q, H, J, or about 142 square feet.

The downspout at I therefore carries off the wash from about 387 square feet.

The deck contains about 72 square feet, and pitches

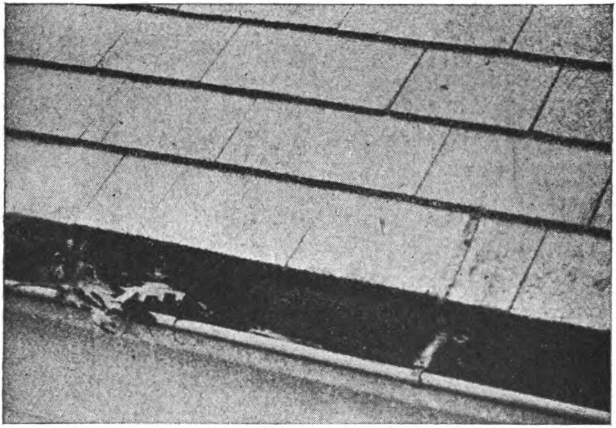


Fig. 131.—Type of Hanger Used to Support Gutters

equally in all directions. Its area is so comparatively small as to make it only necessary to make a slight allowance for it in the finished calculation, so it has not been included in the figures given above.

The rule used here in proportioning the leader is to allow 1 square inch of leader area for every 75 square feet of roof in plan. The calculation is done as follows:

There are 387 square feet on right side of roof which, divided by 75, equals about 5 square inches, the required area of the downspout. Divide 5 by 3.1416, to get the diameter of the pipe to use, which gives 1.59 inches. A 2-inch pipe would therefore be adequate, comparing the area for a 2-inch pipe has an area of 3.1416 × 2, which equals 6.2832 square inches. Although a 2-inch pipe would be large enough, a 3-inch leader pipe was used on this job at I in order that it would not be readily stopped by leaves or similar matter.

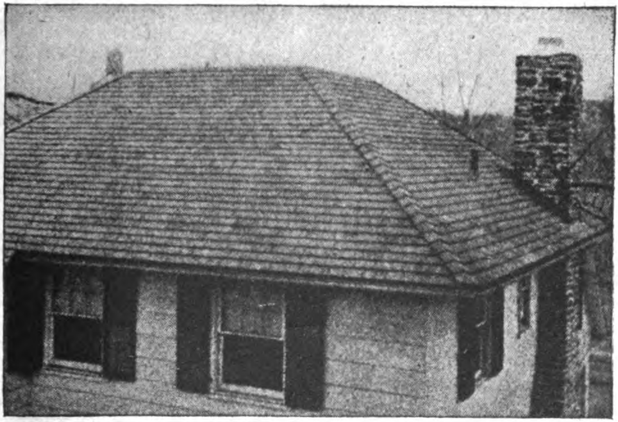


Fig. 132.—Gutter at Rear and Left Side of House

The other section of the roof contains about 937 square feet. Therefore a leader is required with an area of 937 divided by 75, or 12.5 square inches. Dividing 12.5 by 3.1416 gives 3.94 inches as the diameter of the required pipe. A 4-inch pipe would therefore be sufficient.

Galvanized iron half-round beaded eave trough or hanging gutter was used for collecting the roof water, and was 6½ inches wide at the top. An interesting feature in connection with the pitch is the manner in which the gutter inclination is concealed. It is so made that it is given sufficient capacity by being wide and shallow at outlet and narrow and deep at the opposite end, the bottom having a straight, continuous pitch, but

Fig. 133.—Slip Joint Connections at J and H in Fig. 130

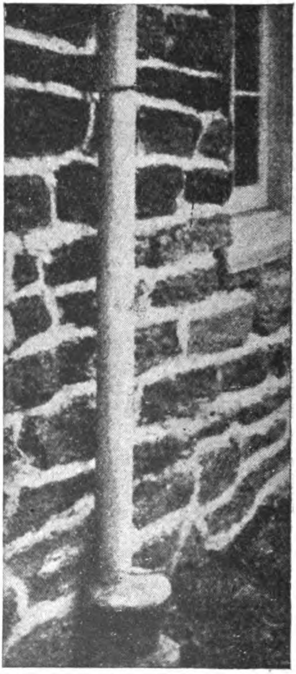


Fig. 134.—Hooks Fasten Leaders to Masonry and Connection to Sewer

without appearing out of alignment with the lines of the building.

The gutters are fastened to the roof shingles by adjustable galvanized iron hangers, as shown in Fig. 131. The rectangular notches in the roof strip permit of easy adjustment.

The view given in Fig. 132 shows the gutter at the rear of the house at A, B, C. The chimney flashings are also noticeable in this illustration.

In Fig. 133 is shown the gutter and leader connection at H in Fig. 130, and also the connection at J of Fig. 130. The leader is connected to the gutter by a slip joint.

The leaders are fastened to the wooden part of the structure by tin strips 1½ inches broad, and to the stone parts of the structure by galvanized iron drive hooks, as shown in Fig. 134, which also shows the sewer connection. The wall is drilled and wood plugs are inserted, into which the hooks are driven.

Now, comparing the measurements for leaders and gutter sizes determined above with the sizes arrived at in the following chapter, considerable differences will be found. This illustrates that the requirements often contained in specifications for work: *"Sufficient leaders and gutters of proper sizes are to be provided by the contractor"* is subject to a great difference in definition. Estimators, therefore, should be careful to specify in their estimates the sizes of gutters and sizes and numbers of leaders figured or proposed to install.

HOW TO PROPORTION DIFFERENT TYPES OF ROOF GUTTERS ON SCIENTIFIC BASIS

Gutters must be provided for gathering the rain or storm water from a roof so that it may be disposed of at a convenient point by outlets to conductor pipes or leaders sometimes called downspouts. The manner in which the size of these gutters of various types has been determined has not been generally understood

The base from which decision has been made for a method of reaching a conclusion on the size of gutters for any roof surface has not been known or defined as is needed by most makers of gutters. There has been considerable information given on the size of leaders or conductor pipes, but as to the size of gutters, in instances it may be truly said that these have been based on custom or practice of making them amply large. In consequence, most gutters show that they have been constructed without regard to what the proper size or proportion might be. A question as to the method of finding the size for a gutter led to a study of the subject and a treatment of the matter that is more comprehensive than anything to be found in libraries. To understand the conditions that also bear on gutter sizes, they must be considered with relation to conductor sizes before the solution offered can be presented.

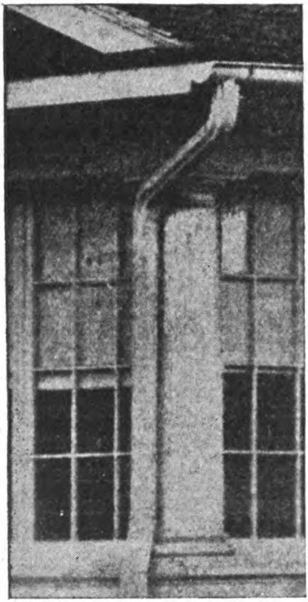


Fig. 135.—A Typical Corrugated Iron Leader Connection to Gutter

As in many of the piping systems that are installed in different classes of buildings, the sheet metal contractor finds that some of the work overlaps that of the heating man, who in turn discovers that some of his work is in the province of the plumber or some other trade. So it is with the subject of roof drainage. While the roofer or sheet metal man has been for years past the only mechanic to install gutters and rain water leaders, he now finds that considerable of this work especially on larger buildings and factories goes in part to the building contractor and in part to the plumber. For concrete, tile or brick roofs, the gutters are often formed as part of the building construction. As inside leaders are connected with the building drainage system, cast or wrought pipe is used and the plumber does the work.

Outside metal leaders, however, still predominate in all classes of buildings. Standard types of known roof constructions are also employed to a great extent. The residence type and smaller buildings are still the largest in number so that roof drainage work remains to be done mainly by the roofer or sheet metal worker and sometimes in part by the plumber, which accounts for the trades' more than passing interest in this subject.

To properly drain a roof of rain or storm water, gutters and leaders must be provided for the protection of the building, otherwise the outside walls may be damaged, or, still worse, the foundations may be affected. The gutters convey the water from the roof to outlets which connect the gutter with the leaders or conductor pipes. The leaders then carry the water to the drainage system, the sewer or other convenient place.

The size of gutter required for a given roof surface depends on several conditions. The main point is the amount of water to be handled, which is a factor entirely dependent on the weather conditions of the locality. The maximum amount of rain in a given time, or the rate of rain fall, is therefore the deciding factor. Government records show that there is a wide variation in the rate of rainfall for different months and different sections of the country. During two storms in Connecticut and Rhode Island, the rainfall reached the rate of 4.5 inches and during a storm in Maryland the rate was 4.6 inches. For California a downpour of 8.7 inches is recorded. While these figures show considerable variation, gutters and leaders must be made large enough for the maximum rainfall in such short periods as during violent thunder storms when the rate may even exceed the figures given above. As a general condition in proportioning roof drainage systems, a rate of 8 inches per hour will answer for practically all purposes.

With this information available, a scientific basis for proportioning the size of gutters or leaders is established. Then the problem becomes one of computation involving the laws of hydraulics.

At a rate of 8 inches rainfall during an hour, the quantity of water to be handled for 1,000 square feet of roof surface is 666.6 cubic feet per hour or 0.185 cubic feet per second, which is equal to 83 gallons per minute. Gutters and leaders of a size to safely carry away this water must therefore be provided for a satisfactory working system.

A Method Easy for the Practical Man to Understand

Without delving into the science relating to hydraulics or the flow of water, the practical considerations and results that will aid in solving roof drainage problems are here presented.

The size that a gutter should be for a given condition is influenced by the number of outlets provided to carry away the roof water in a period of time that will prevent the gutter filling to overflow. A gutter is virtually a trough or storage reservoir and receives the falling rain from the roof. The grade or fall at which the gutter is set or hung determines the velocity of flow and the more outlets that are provided, the quicker will the water be drained away.

Consider any gutter of a given length. If one leader were connected to this gutter for carrying off the water, it might serve the purpose. Now, then, if in that same length of gutter two conductors were used, it is quite clear that the rain water would be carried off at a more rapid rate and the gutter could then probably be of a smaller size. Also, for this reason, one size of gutter may be used for a building 30 x 40 feet and for a building 30 x 100 feet, or any other size. It is the number of leaders of the required size that will be used with these gutters in a given length that determines the size gutter necessary.

In the first case, or the smaller building, the roof area subject to rain is 1,200 square feet and the perimeter of the building or the total developed length combining all sides is 140 feet. In the larger building the roof area is 3,000 square feet and the perimeter or total developed length is 260 feet. Suppose then that a gutter of the same size is installed all around on the roofs of both buildings. Then if the leaders used to carry away the water cared for 50 feet of gutter length in each case, then three leaders would be required for the smaller building and five leaders for the larger building.

It should be understood, therefore, that the size of gutter is dependent on the number of leaders it is served by for a given length. The roof area does not enter into the problem except for the size of leaders which on the other hand are proportioned on a basis of roof area. Therefore, it becomes necessary to figure out the size and number of leaders required for a given condition before the gutter size is determined.

Minimum Size of Roof Gutters

In proportioning leaders there is a practical limit to the minimum size regardless of whether inside or outside conductors are employed. To prevent stoppage through roof dust, leaves or other debris that does collect on a roof, leaders of less than 3 inches diameter or equivalent size should not be installed. When 3-inch leaders are used, they should not be spaced more than 50 feet apart, no matter what type of building is being considered—factory or residence. The developed spacing may be greater but it should not exceed 75 feet and then leaders of 4-inch size should preferably be used.

Leader sizes are most easily proportioned on the basis of roof area, which is subject to and receives the falling rain water. Different authorities, including some building codes, give ratios varying from 75 to 250 square feet of roof surface to be served by 1 square inch of leader area. Satisfactory results are obtained in practice by allowing 1 square inch leader size to 160 square feet of roof. On this basis the accompanying tabulation has been computed and is presented as a guide in selecting proper leader sizes for roof drainage. These figures correspond closely with the hydraulic values employed in designing drains that are used separately for carrying rain water only and when these drains for such disposal are laid at a grade or fall of 1/8-inch to the foot. Knowing the roof area to be served, it is a simple matter to find the number and size of leaders required for the building.

Roof Area	Leader Size
1,120 square feet	3 inches
1,920 square feet	4 inches
3,040 square feet	5 inches
4,480 square feet	6 inches

The best results will be obtained by spacing the leaders not more than 50 feet apart as shown in the diagram Fig. 136. For a length of 50 feet a leader located centrally as indicated will serve 25 feet of roof on each side. Then if the roof space to be cared for is 20 feet wide as in the diagram, a 3-inch leader will be required for the 1,000 square feet of roof area.

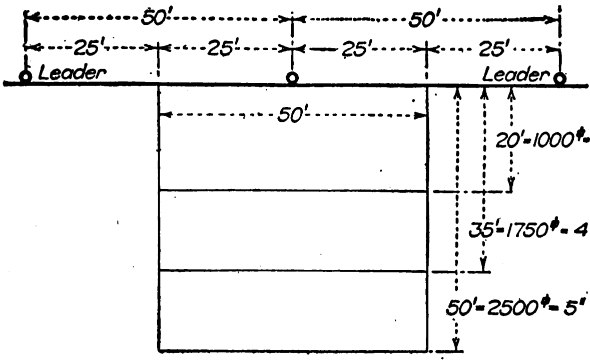


Fig. 136.—Proportioning Roof Leaders

If the building were 35 feet wide or the leader served a roof section 50 x 35 feet, which is 1,750 square feet, a 4-inch leader would be required. Then again, take a similar condition with a roof 50 x 50 feet, which is 2,500 square feet, and according to the figures in the tabulation, a 5-inch leader is required, all as indicated in Fig. 136.

Buildings or their roofs are not always regular in shape or of such size as to give a straight spacing of 50 feet between the leaders. In such cases the developed length or distance must be considered as shown in Fig. 137.

This diagram shows a roof in plan which measures 20 x 30 feet. Half of the roof, therefore, measures 10 x 20 feet, which has a perimeter or total developed length of 10 + 30 + 10 = 50 feet as indicated. If two leaders were installed to take care of the rain water from the entire roof, each would serve one-half the roof area, and as half the developed length of the entire building is 50

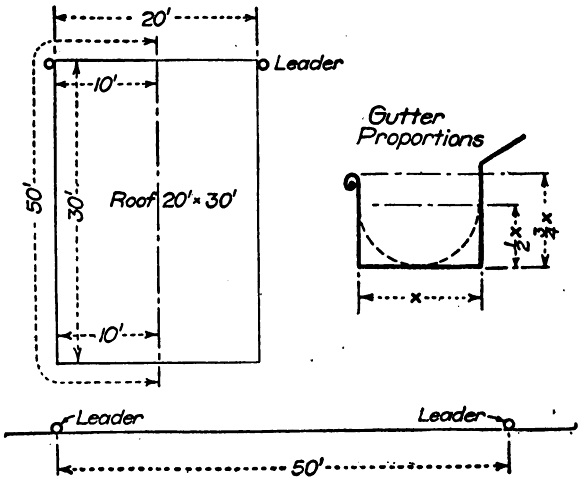


Fig. 137.—Gutter Design and Leader Spacing

feet, the spacing of the leaders is therefore equal to 50 feet, as shown in the diagram. In Fig. 137 is also shown a simple spacing or straight run of 50 feet, which is the equivalent of the developed length shown in the first part of the diagram.

A nominal spacing of 50 feet for leaders has been recommended for satisfactory service. This is especially important when the leaders are to carry away the water from peaked roofs. For serving flat roof surfaces, the leaders may have a nominal spacing of 75 feet. The closer spacing for peaked roofs as compared with flat roofs happily works out practically on the job. Residence type buildings, or independent houses such as country homes, are usually built with peaked roofs. They are usually of such shape and proportion that it becomes a necessity to space the leaders pretty closely as far as the developed length is concerned. Conditions in factory buildings and apartment houses and similar structures with flat roofs of large dimensions allow for the leaders to be readily spaced on the roof to suit the proportions and sizes that have been figured.

Closer spacing means smaller and possibly more leaders, depending on the size and shape of the roof. This may or may not be preferable, according to the type of building, but it insures a positive roof drainage which is the result that is sought and the effect that counts. This holds true for both inside and outside leaders.

A similar consideration applies to gutters that connect with the rain water conductors. Peaked roofs should be provided with larger gutters than flat roofs. This may be explained by the fact that roof areas which are inclined at a steep angle shed the water at a rapid rate. The rainfall striking the roof surface at such an angle is therefore led to the conductor pipes or leaders in a short space of time. For flat roofs and those with rough surfaces such as slag covering, smaller gutters may be employed.

It has been shown that when the number and size of leaders that drain the roof area are known the gutter size may be determined. In other words, with the leaders spaced a certain distance on the roof, the distance or unit of length is established for each roof outlet or leader which connects with the gutter.

To name the size of the gutter in terms of a single unit is not a simple matter when the different styles of gutters in use are considered. A few of the types that have been actually installed in various sections of the country are shown diagrammatically in Fig. 138-A. The dotted

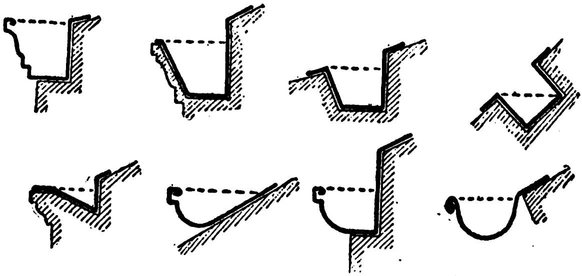


Fig. 138-A.—Various Types of Roof Gutters

lines in these illustrations show the maximum height of the water line, which is an indication of the amount of rain water each gutter can hold when filled to the point of overflow.

The size of gutter or its dimensions therefore depend on the style to be used. Some of them as shown in the illustration are not effective for their full depth, while some others are poor in the design cutting down the full effect of the width. The best type is a gutter proportioned so that its minimum depth is half the dimension of its width, the maximum depth not to exceed three-quarters of the width. This makes the width of gutter the deciding factor in proportioning its size and these features are shown in one of the diagrams in Fig. 137. In this illustration X is the width and $\frac{1}{2}$X or $\frac{3}{4}$X represents the recommended depth. For instance, take a gutter 6 inches wide and by making it ½X the depth will be 3 inches, and if this gutter were circular in section it would be the equivalent of an eaves trough or half-round gutter as indicated. Making this 6-inch gutter ¾X, it would then be 4½ inches deep. There is no material reason for a gutter deeper than obtained by this computation, except, perhaps, for purposes of ornamentation.

Using these features as a basis for general proportions, the gutter may be referred to as of a certain size in inches because the depth would then be understood. Combining this information with the figures given for leaders, the size of gutters may be proportioned for any condition by using the data which follows:

In general a gutter may be made the same size as the diameter of the leader which it serves, but never less. A gutter smaller than 4 inches is not recommended regardless of conditions. In common practice, a 4-inch gutter is seldom used because it makes work on the job, such as soldering, quite difficult. Eaves trough or half-round gutters are more economically made larger than 4 inches because the sheet of metal from which they are made then cuts up without waste, and this insures a gutter of fair proportions.

In figuring the size of gutters, distinction must be made between the character of roof, such as flat and peaked constructions. The basis for determining the size of gutter is the size of leaders and their spacing. If the gutter is longer than 50 feet for one leader connection or between leaders that have been proportioned in accordance with the foregoing tabulation of leader sizes, then add 1 inch to the leader diameter for every 20 feet additional spacing on peaked roofs in order to arrive at the size of gutter. For flat roof surfaces under the same conditions, add 1 inch to the leader diameter for every 30 feet of additional length in order to arrive at the size of the gutter. When the gutter is not more than 50 feet for the total developed length, it may be of a size equal to the leader with which it connects, but not less than 4 inches. These rules do not mean that the leader size is increased; the diameter of the leader is taken as a unit and the addition to this diameter gives the size of gutter required, as shown below.

For example, 50-foot length of gutter serves a 3-inch leader. In accordance with the rules given above, the gutter should be of 4-inch size. Again take a case of 4-inch leaders spaced 70 feet on a peaked roof. This is 20 feet more than the 50 feet of length which is taken as the basic unit and requires the addition of 1 inch to the leader diameter, which gives a gutter of 5-inch size. If this were a flat roof, the spacing of the leader for a 5-inch gutter could be made 80 feet.

The tabulation herewith has been computed according to the above rule. It shows the size gutters that are necessary for 4-inch leaders spaced at various distances for the conditions of a flat roof and a peaked roof. It will be seen that for a gutter 80 feet long with one leader spaced in this distance and installed on a flat roof, it should be of 5-inch size. On a peaked roof with the leaders spaced 90 feet apart, the gutter should be 6 inches.

Flat Roof			Peaked Roof		
Leader	Spacing	Gutter	Leader	Spacing	Gutter
4 inches	50 feet	4 inches	4 inches	50 feet	4 inches
4 "	80 "	5 "	4 "	70 "	5 "
4 "	110 "	6 "	4 "	90 "	6 "
4 "	140 "	7 "	4 "	110 "	7 "

In practical gutter work the arrangement of the leaders will of course determine the size of the gutter to be used. Take two buildings, as shown in Fig. 138-B, both having a roof measurement in plan of 50 x 60 feet. In the one case, as shown at the left, four leaders each of 3 inches diameter are provided. This peaked roof is pitched so that one-quarter of the area is taken care of by each leader. Two of these leaders are 50 feet apart and the other two are 60 feet apart, which gives an average

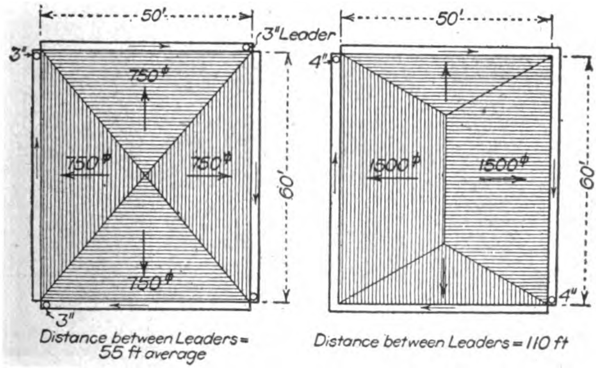


Fig. 138-B.—Proportioning Gutters for Roof Drainage

developed length for each of 55 feet. In this case a 4-inch gutter will give the desired service.

In the same size building, shown at the right of Fig. 138-B, only two leaders of 4 inches diameter have been installed. This gives a developed length or spacing between leaders of 110 feet, and the peaked roof is pitched to drain accordingly. On the basis of the rules given and the figures in the tabulation, a 7-inch gutter will be required for this condition. If this building had a flat roof only a 6-inch gutter would be required.

Finding the Pitch of the Sheets in Gutter

The question often arises in regard to the method of obtaining the pitch of various sheets without laying out full size lengths on the floor. For example, suppose a hanging gutter is to be placed around a roof (Fig. 140), the length to be 20 feet and the return 6 feet on each side. The gutter pitches both ways toward F and E, which are to be 4 inches below the highest point, H; in other words, the gutter is to have a fall of 4 inches at E and F. As

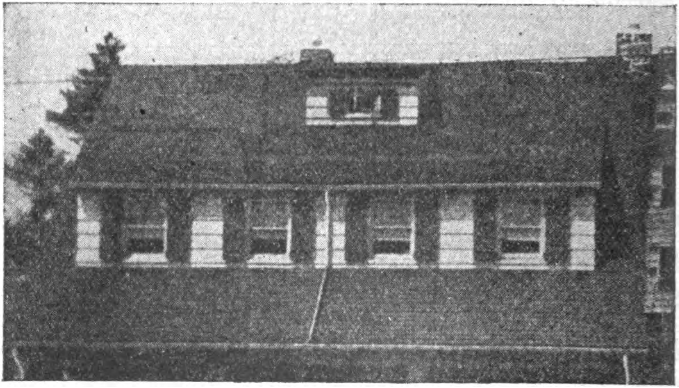


Fig. 139—Roof Drainage of a Country Home. Type of Roof Determines Gutter Size

the gutter is 20 feet long in front and H, the highest point, is in the center, we have a gutter whose length is 10 + 6 = 16 feet, with a fall of 4 inches. This will require a sheet of 8 feet and a piece 2 feet for the front, and a piece 6 feet for the return.

The usual method of obtaining the pitches for the various pieces previous to bending on the brake would be to strike a chalk line 16 feet long, as shown in diagram X, and to erect the perpendicular equal to the fall, or

4 inches, and draw a line from L to D, then to measure 8 feet from D to C, 2 feet from C to B, when the rest, from B to A, will measure 6 feet. The perpendicular C will then measure 2 inches and B 2½ inches; D will be the highest point, C will have a 2-inch pitch on an 8-foot sheet, B 2½ inches on the 2-foot piece and A L 4 inches pitch on the 6-foot piece.

All this labor can be avoided by using the short method of obtaining this pitch by computation: Given length, 16

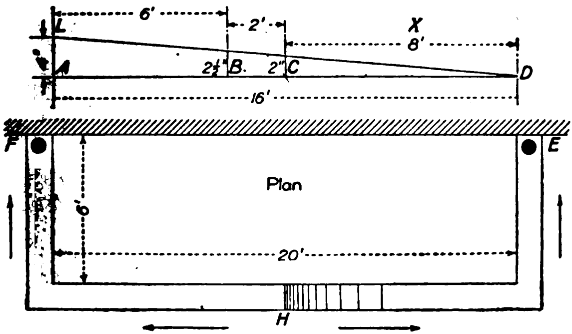


Fig. 140.—Plan of Roof, Showing Gutter

feet, given fall, 4 inches. If 16 feet has a fall of 4 inches, one foot will have 4 ÷ 16, or $\frac{4}{16} = \frac{1}{4}$ inch. Thus an 8-foot sheet equals 8 × ¼, or 2 inches fall; 10 feet, or front 10 × ¼, or 2½-inch fall, and 16 feet, 16 × ¼, or 4-inch, fall.

While ¼ inch gives the fall for each foot, the fall for an inch would be 1/12 of ¼, or 1/48 inch fall for each inch in length, and the various falls for the various inches could be found by referring to the following table.

FALL OF 1/4 INCH TO 1 FOOT (IN INCHES)

Length	Fall	Length	Fall
1 inch	= 1/48 inch	7 inch	= 7/48 inch
2 "	= 1/24 "	8 "	= 1/6 "
3 "	= 1/16 "	9 "	= 3/16 "
4 "	= 1/12 "	10 "	= 5/24 "
5 "	= 5/48 "	11 "	= 11/48 "
6 "	= 1/8 "	12 "	= 1/4 "

This rule can be applied to any length or fall, and a table worked out as above for the fall in inches.

CHAPTER XII

ESTIMATING COST OF SHEET METAL WORK ON SCIENTIFIC BASIS

It is not intended to go into a lengthy discussion of modern methods of "Cost Accountancy." It is considered necessary, however, to explain here those details appertaining to "Cost Accounting" and the underlying principals of it that are required to get the true cost in estimating sheet metal work.

It must be kept in mind that an "estimated" amount of cost is not the "actual" cost. The first term indicates "presumption," while the last term refers to "facts." Estimated cost is cost "presumed" before the work is done; actual cost is determined after completion of the work. The estimator is called upon to presume cost based on his knowledge of the technical and business conditions which will influence the cost of the work to be estimated. The "Accountant" will tell cost and profits made after the completion of a job or after elapse of a certain period in business.

The Elements of Cost

The estimator obtains the fundamental data for his work from the following mentioned sources:

A. From the plans and specifications relating to or from description or samples of the work to be done, he takes the quantities of material required for the job.

B. From the price lists, discount sheets, quotations, etc., issued by the manufacturer or dealer of material and from market publications in trade papers, the estimator obtains knowledge as to the amount of money required to purchase material necessary for the job.

D. From the payroll of the firm or his knowledge of prevailing wages he will be enabled to ascertain the value of labor required for the job.

His own practical knowledge of time required (if possible supported by records of previous jobs) will enable the estimator to determine the time necessary to do the job in question. Often it will be advisable to consult the work foreman in regard to time of labor.

The mentioned sources of information will permit the compiling of cost of "Material and Labor" and give in the aggregate the so-called "Prime Cost" of the job. These cost items do not, however, cover all costs of the job. To execute the job it will be required to furnish tools, machinery and other equipments; it will be necessary to lay out and supervise the work, to purchase transport, store and insure the material required for the job; it will be required to record the cost, or "keep books" and it will be necessary to do all that work in connection with the job on hand which is generally termed as "running the job" or "conducting the business." All these services have to be paid for and the business must be reimbursed for it, the same as it is to be reimbursed for the material and labor cost. It is therefore necessary to know the extent of such services relative to the job and there must be a source from which the estimator is able to obtain information as to the value of such services, which is generally termed "Overhead Expenses" and which include all cost items other than direct material and labor costs arising in executing the job. Often "Overhead Expenses" exceed labor and material cost.

Let it be clearly understood that "Overhead Expenses" not only include those expenditures which arise directly in connection with the job on hand, but also such expenses which are indirectly applicable to the job, as advertising expenses and all other general business expenditures, as cost of collecting, rents, insurances, in short any expenditure made in conducting the business, because same are made in the interest of the work handled and ultimately in the interest of the customer, who must be charged for all cost items arising in connection with his job.

No business is done without advertising, and if such advertising only consists of the fact of informing the public of the existence of the business. Store windows, show room, etc., are "advertisements," for the purpose of attracting the public or soliciting trade. Reasonable advertising expenses are therefore a just charge to the cost of doing business. Expenses also arise in rectifying errors made by workmen and looking after (often unjust) complaints of customers. "Profit" is only that amount which remains after all direct and indirect costs and expenses of the business are paid for. It is therefore essential to include same in the estimates and cost figures. The amount of overhead expenses will vary with different business, according to the manner of conducting same. On the other hand local conditions and the nature of the work itself will exert an influence upon the expenses. The estimator will therefore be required to know all such conditions relating to the business in question, and he will further have to be informed to what extent overhead expenses vary with different classes of work, so he may apply a just rate of overhead expenses to each job.

In the following pages the reader will find the cost of overhead expenses analyzed, as same occur in the business of the "Sheet Metal Worker." A method is shown by which the estimator is enabled to apply such expenses to each job.

Tabulation of Expenses

The difficulty generally arising in connection with overhead expenses is the proper apportioning of same to the individual jobs. In estimating a job the estimator must have a certain rate of overhead expenses to apply to the job. To illustrate one way by which this can be done, let us presume that the following figures are available for a sheet metal working shop:

Amount of business done during year		$17,000.00
Profit made during year		3,000.00
Net cost		$14,000.00
Cost of material used	$6,000.00	
Cost of labor (wages)	4,000.00	
Overhead expenses	4,000.00	$14,000.00

We would have a proportion of overhead expenses to labor and material cost as $4,000 is to $10,000 or 40 per cent. It then would be necessary to add this percentage to the cost of every job done to arrive at the total cost. For example, a certain job figures up as follows:

Material cost	$40.00
Labor cost	30.00
	$70.00
Overhead expenses, 40 per cent	28.00
Total cost	$98.00

This would be a very simple way and quite correct if all jobs would be of the same nature and all conditions concerning the different jobs would be alike, so that overhead expenses would be in the same proportion for every job. However, this is not the case in the different branches of sheet metal work. One job may be of simple nature, requiring comparatively little supervision not calling for special equipment; another job may be complicated, requiring special attention on the part of the management and the foreman, may necessitate the furnishing of special equipment, be of special risky character (scaffold work), etc. It is clear that the overhead expenses would not be alike for the different jobs. Charging all kinds of jobs with the same rate of overhead would result in over-rating one job and favoring the other job. The fundamental principle of proper cost finding is to charge to each particular job the value of every service that actually goes into it, to the extent it was rendered for the benefit of this job on the same principal as only so much labor and material cost is to be charged as was actually consumed for this job.

A plain roofing repair job, for which no special endeavor is required in managing the job, where no facilities and equipments are required but small hand tools, would certainly carry a lower amount of overhead expenses than, for example, a complicated cornice job, for which large machinery is required, for which a number of miter patterns have to be laid out, where a careful supervision of the job is required from the time it reaches the shop till it is fastened to the building, a dangerous undertaking, putting great responsibility upon the proprietor. This job should be figured with the value of all these special services added (responsibility is also a service—often more costly than labor service). The question, however, arises at what rate the charge for overhead expenses should be made to the job. In order to arrive at such rate, it is necessary to enumerate and classify the expense items of the business. To illustrate the practical side of this subject we shall here describe a typical system for a business, which is a combination sheet metal, plumbing and heating shop, with the following departments:

1. Plumbing contract department.
2. Sheet metal contract department (architectural work).
3. Plumbing jobbing department.
4. Sheet metal jobbing department (outside repair work).
5. Sheet metal shop work department.
6. Furnace heating and ventilating department.
7. Steam and hot water heating department.

These are distinct work-operating departments. The business has the following mentioned commercial departments:

A. SELLING DEPARTMENT. This department takes care of selling the services of the business, that is, obtaining work. It handles the necessary advertisements; it takes care of collections, estimating and everything else in connection with selling.

B. MERCHANDISE DEPARTMENT. In this department all material used for the work is looked after, as buying, storage and handling of material to and from job and shop, etc.

C. GENERAL BUSINESS ADMINISTRATION. This is the proprietors' or managers' department, where the general business affairs are being attended to, including financial matters, etc.

One can see at a glance that each department is of equal importance in conducting the business. The operating departments cannot "operate" unless work is obtained through the selling department, material obtained through the merchandise department and—somewhere somebody must run the business (administration). On the other hand, it would be useless to obtain work unless the equipment and men are there to do the work; but not each department contributes the same amount and value of service to each individual job. Certain kinds of work will require very little selling endeavor, but a very large amount of operating services (labor), another class of work will require little labor and comparatively much material, or will require much selling service, etc.

We have the following data regarding the business here in question:

The business employed on the average during the preceding year four to five workmen at an average of 8 hours per day, with a total of 1,343 productive working days or 10,750 productive working hours. The expenditures for productive labor were $5,950, and the cost of material used on jobs was $9,400. The entire business done amounted to $27,500, and all expenses (besides labor and material) amounted to $7,698. An itemized tabulation of all cost items is as follows:

	Total Amount Business	Material Cost	Labor Cost	Productive Working Hours
Plumbing contracts	$5,500	$2,500	$1,000	1,600
Architectural sheet metal contracts	5,500	2,500	1,500	2,500
Plumbing jobbing	3,300	500	1,000	2,000
Sheet metal outside repair work	3,300	1,800	800	1,700
Sheet metal shop work	3,300	1,000	750	1,500
Furnace heating and ventilating	3,300	1,500	500	850
Steam and hot water heating	3,300	1,600	400	600
Total	$27,500	$9,400	$5,950	10,750

The business overhead expenses were as follows:

Fire insurance	$50.00
Accident insurance	225.00
Liability insurance	50.00
Light	60.00
Heat	80.00
Fuel and motive power	28.00
Not productive labor	675.00
Office help	800.00
Postage, telegrams, etc	100.00
Telephone	70.00
Petty expenses	100.00
Stationary	30.00
Sales advertisements	100.00
Holidays, paid for	30.00
Donations	50.00
Store keeper	200.00
Collection and losses	350.00
Attorney's fees	25.00
Not classified expenses	150.00
Bonds	25.00
Operating and office supplies	220.00
Rent	600.00
Furniture and fixtures	165.00

Besides these cost items other services were performed partly by the proprietors. (It was a partnership of two proprietors.) The value of these services was agreed upon to be as follows:

General management	$500.00
Purchasing merchandise	100.00
Salesman's work	400.00
Foreman and superintendent of shop	1,500.00

There are still other items to be considered which are of the utmost importance, but which are often overlooked by persons less experienced in business management. Every machine and equipment loses in value as time goes by (it depreciates), machines become obsolete (old-fashioned); machines and equipment require repairs and upkeep attention; small hand tools being lost and used up. A reasonable amount should also be figured for the financing of the business (interest on investment and to banks for funds to run contracts, discounts for notes, etc.) There is an unaccountable loss of merchandise (larceny, thievery, etc.); there are errors made by workmen and material is being spoiled. All these items are cost to the business, and only after such cost expenditures are paid for can there be a "profit," and these cost items must be figured in the estimates to arrive at the exact and real cost of a job. For the business here in question we have for such cost items during the preceding year the amounts as follows:

Depreciation and obsoletion of machinery and equipment	$185.00
Interest and discounts	350.00
Upkeep and repair of machinery and equipment	200.00
Unaccountable loss of material	100.00
Errors and spoiled work	180.00
Total of expenses	$7,698.00

It should be born in mind that above cost items are put here in round figures for convenience, but nevertheless same were generally based on actual facts as the writer found same. If called upon to figure cost and overhead rates for a business where no figures from previous business periods are available, it would be required to estimate such cost items based on business experience and knowledge of the peculiarities of the business or local conditions. Then through keeping of records during a year or any other suitable period the correctness of the estimated cost items may be controlled and then the overhead expense rates, if necessary, changed accordingly.

APPORTIONING OF OVERHEAD EXPENSES

No.	Items	Total	Selling Dept.	Merchandise Dept.	General Expenses	Administration	Operating Departments Dept. 1	Dept. 2	Dept. 3	Dept. 4	Dept. 5	Dept. 6	Dept. 7
1	Fire insurance	$50.00		$22.00		$5.00	$3.00	$3.00	$3.00	$3.00	$5.00	$3.00	$3.00
2	Accident insurance	225.00		10.00			30.00	50.00	40.00	40.00	30.00	12.50	12.50
3	Liability insurance	50.00			50.00								
4	Light	60.00	9.00	12.00	3.00	3.00	3.00	3.00	3.00	3.00	18.00	1.50	1.50
5	Heat	80.00	12.00	16.00	4.00	4.00	4.00	4.00	4.00	4.00	24.00	2.00	2.00
6	Fuel and motive power	28.00					6.00	8.00		2.00	4.00		8.00
7	Non-productive labor	675.00	25.00	100.00	75.00	20.00	75.00	75.00	100.00	75.00	40.00	50.00	40.00
8	Foreman and superintendent	1500.00					450.00	750.00	75.00	75.00	50.00	50.00	50.00
9	Office salaries	800.00	300.00			500.00							
10	Postage, telegrams, etc.	100.00	40.00	10.00		50.00							
11	Telephone	70.00	28.00	7.00	35.00								
12	Petty expenses	100.00			100.00								
13	Stationary	30.00	15.00			15.00							
14	Sales advertisement	100.00	100.00										
15	Depreciation and obsoletion	185.00					35.00	40.00	20.00	20.00	30.00	20.00	20.00
16	Int. on invest. and borrowed money	350.00		100.00		140.00	10.00	30.00	10.00	18.00	18.00	14.00	10.00
17	Upkeep and repair	200.00					38.00	44.00	21.00	21.00	32.00	22.00	22.00
18	Unaccountable loss, material	100.00		100.00									
19	Errors and spoiled work	180.00					18.00	38.00	59.00	9.00	10.00	23.00	23.00
20	Holidays	30.00			30.00								
21	Donations	50.00	25.00		25.00								
22	Stockkeeper	200.00		200.00									
23	Collection and losses accounts	350.00	150.00		200.00								
24	Attorney's fees	25.00				25.00							
25	Not classified expenses	150.00			150.00								
26	Bonds	25.00	10.00			15.00							
27	General management	500.00				500.00							
28	Purchasing merchandise	100.00		100.00									
29	Operating and office supplies	220.00	10.00		50.00	10.00	30.00	30.00	18.00	18.00	18.00	18.00	18.00
30	Rent (total $600.00)												
a	Productive space for machinery	150.00					10.00	10.00	20.00	20.00	70.00	10.00	10.00
b	Productive space for benches	50.00							5.00	5.00	40.00		
c	Productive space for tools, etc.	45.00			15.00						30.00		
d	Not productive space	155.00			155.00								
e	Showroom	20.00	20.00										
f	Office	50.00	25.00			25.00							
g	Stockroom	130.00		130.00									
31	Salesman	400.00	400.00										
32	Furniture and fixtures	165.00	35.00			40.00	8.00	20.00	5.00	15.00	25.00	10.00	7.00
		$7698.00	$1204.00	$807.00	$892.00	$1352.00	$720.00	$1105.00	$383.00	$328.00	$444.00	$236.00	$227.00

After having a tabulation of all cost items, it is necessary to apportion same over the different service departments of the business, as is shown in our tabulation on page 198.

To make this subject perfectly clear, it is required to add the following explanatory remarks:

Item 1. Fire insurance is based on value of equipment, etc., in the different departments. The inventory of the business showed a total value of $5,000. The insurance rate was $1 per $100. The average value of merchandise carried, including value of racks and shelves, was $2,200. Therefore the proportionate amount of insurance to be charged to the merchandise department is $22. In the same manner the apportioning of fire insurance cost was carried through for the other departments.

Item 2. Accident insurance was based on the average number of working men employed in the different departments.

Item 3. Liability insurance figures as "General Expenses" and is then distributed with other items placed under this heading over the jobs handled.

Items of light, heat, fuel and motive power are distributed over the different departments, which benefit through these expenditures. The floor space used for the departments gives a base for the distribution of heat expenses, with due consideration of any conditions which may warrant the proportionate heavier or lighter burdening of any department. Fuel (gas) is being used for soldering, etc.

Item 7. Not productive labor. This is to represent all such labor which cannot be directly charged to jobs. Putting machines in order, arranging the tools, cleaning shop, labor used in stock (merchandise) department, fixing up the showroom, etc., are items under this heading. Due consideration must be given to the amount and the nature of work handled in each operating department. There is as a rule much not-productive labor in the jobbing departments.

Item 8. Foreman and superintendent. This is distributed on number of working hours in each department and nature of work, which will require more or less of the foreman's or superintendent's attention.

The item "obsoletion and depreciation of machinery and equipment" requires some explanation. Strictly speaking, each machine, each tool, each piece of equipment in any part of the business is there for the purpose of rendering service. The fact of its possession and its use produces "cost." From this standpoint the following enumerated items have to be considered with each piece of equipment:

1. Interest on the investment (or the value) at the commercial and legal rate of 6 per cent.

2. Depreciation and obsoletion. The business here in question figured 10 per cent of the value of each machine to be charged off each year. If the purchase price or the value of a machine is $560, then every year 10 per cent, or $56 is figured as depreciation and obsoletion into the business expenses. While it is true that the machine in question may not lose its entire value in 10 years, it is nevertheless found by experience that 10 per cent for depreciation and obsoletion is a fair and, *in the average*, correct rate.

The attached floor plan furnishes sufficient explanation about the distribution of rent expenses over the different departments. While it is not possible to always

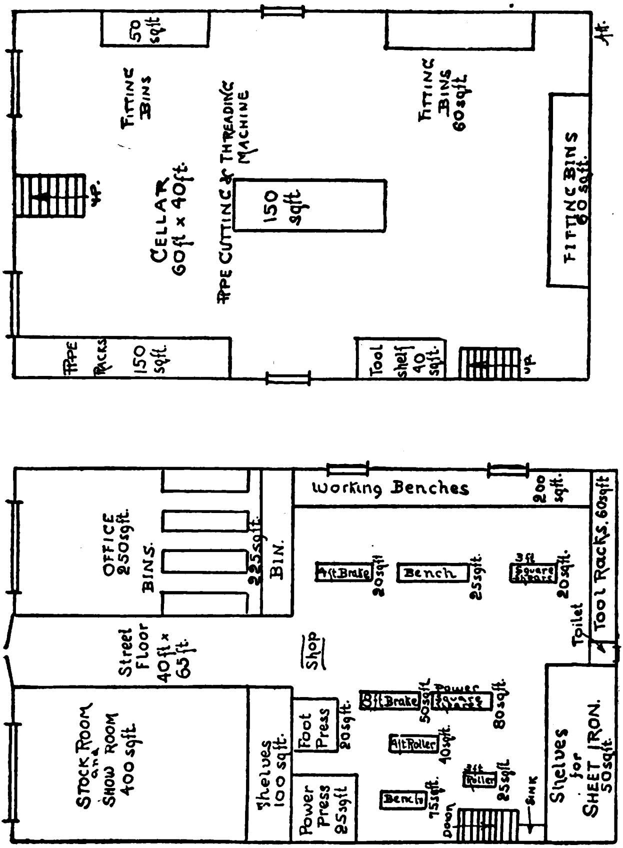


Fig. 141—Distribution of Floor Space.

keep exactly apart the floor space allotted to each department, an equitable manner was used in this case by judging and estimating the approximate proportion of rent to be charged for each department.

The floor space used as showroom benefits the sales department and the cost of this space is therefore charged as sales expenses. In the same manner the other space is allotted to the administration department (office), merchandise department (space for storage of merchandise) and operating departments (shop space). The remaining not-productive space is figured into "General Expenses."

The monthly rent of $50 is apportioned: to the store floor $40; to the cellar $10. The entire floor space is as follows:

Store floor (40 x 60 feet).....	2,600 square feet	Value per year.....	$480.00
Cellar......................	2,400 "	Value per year.....	120.00
Total....................	5,000 square feet		$600.00
Therefore, store floor value per square foot........................			18½ cts.
Cellar floor value per square foot........................			5 cts.

A word of explanation must be given regarding the item "Operating Supplies." This item includes small tools, as hammers, screwdrivers, wrenches, drills, chisels, shovels, picks, brushes, etc. Such articles are really investment items, but their duration of life is generally short and they are often lost. Therefore they should be treated as expense items, distributed mainly over operating departments, burdening same in proportion to the rate at which such supplies are being used in the different departments. The balance is charged to "General Expenses." Here also belong oil, greases, kerosene, soldering fluxes, etc. Such items cannot very well be charged to individual jobs and are therefore charged as a whole to the departments in proportion to consumption of such supplies in the different departments.

The item "Furniture and Fixtures" includes office equipment, shelving, bins, etc. Such equipment undergoes changes in a comparatively short time on account of constant changes in their arrangement necessitated by business requirements; the rate of depreciation and obsoletion is therefore to be figured for such equipment at a much higher rate than for regular working machinery. In our overhead expense tabulation we found this item taken care of under No. 32. It appears not necessary to go here lengthy in the explanation of each item, as the matter should be clear enough to enable the reader to apply the principles involved intelligently to his own business. Common sense must certainly be exercised. The most important point is that all possible cost items are included in making up "Overhead Expense" rates and that local and individual conditions are taken in consideration.

A word of explanation appears in place regarding the charge for the proprietors' services. From the standpoint of business there appears no doubt that the proprietors' service must be charged as "cost." Hereby is meant (and let this be understood very clearly) not the sum which the proprietors draw for living expenses, but the value of their services to the business. The following tables will explain how the rates for the proprietors' services were arrived at for the business here in question.

These sums do not represent the amount they will draw for the living expenses, but are only a measure of value to the business for their enumerated services. "Cost of running the business" cannot be influenced by the fact that the proprietor draws $50 or $10 per week,

Partner 1:	
As general office manager	$250.00
As salesman and estimator	300.00
As collector	100.00
As purchasing agent	100.00
As superintendent of outside (architectural) and jobbing sheet metal work	500.00
As associate general manager	250.00
	$1,500.00
Partner 2:	
As general shop superintendent	$250.00
As stock (merchandise) keeper	150.00
As draftsman, etc	100.00
As superintendent of plumbing work	300.00
As superintendent of heating and ventilating work	200.00
As salesman and estimator	150.00
As associate general manager	100.00
As his part of superintending outside sheet metal work	150.00
	$1,400.00

or decides to draw nothing in order to raise the available funds of the business. Only the value of the services has any influence on cost. The fact that the amounts above stated for the value of services are not the same for both proprietors does in itself not indicate that the entire services of partner No. 2 will be worth less than the services of partner No. 1, because the enumerated services do not take up the entire time of the proprietors. Either may render as occasion arises any other service, or probably practical labor on the jobs. In the latter case it is directly charged to the jobs. In making up the above schedules the requirements for the business management were taken in consideration, and certain duties were allotted to each partner and these duties valued in accordance to the ability of the partners to perform such duties, the same as the ability of a hired man is measured and expressed in his salary. With the growth of the business and the growth of the proprietors with it, their services may become more valuable, and then an accordingly changed valuation should be placed on their services. As mechanics, their value may be worth $3,000 per year or more; as business managers, the value of their services had to be measured by their ability as such, and the requirements of the business.

Determining of Overhead Rates

Based on the figures obtained, it is now only a matter of plain arithmetic to arrive at the proper rates to be applied to the individual jobs:

A. Selling Expenses:	
Amount of business done	$27,500.00
Net cost of business done	23,048.00
Selling expenses	1,204.00
Ratio of expenses to net cost about	5%
B. Merchandise Expenses:	
Merchandise sold or used on jobs	9,400.00
Expenses	807.00
Ratio of expenses to value of merchandise about	8½%
C. Administration Expenses:	
Productive labor hours	10,750
Total expenses	1,352
Ratio of administration expenses to productive labor about	12 cents
D. General Expenses:	
Productive labor hours	10,750
Total expense	892.00
Ratio of general expenses to productive labor hours	8 cents
E. Operating Expenses:	
Productive labor hours	10,750
Total expenses for all operating departments	3,443.00
Rate of operating expenses to productive labor hours	32 cents

The above figures summarized would give the following rates:

Operating, general and administration expenses (collectively called "Work Overhead Expenses") per hour	52 cents
Merchandise expenses	8½%
Selling expenses	5%

If there was only one operating department, or if all operating departments were of such nature that same bear approximately the same rate of overhead expenses above rates may be applied as stated. For the business here in question, however, we have seven departments of somewhat different conditions governing each department. Therefore we figure the operating expenses for each department separately, according to the amount of expenses and number of working hours in each department, as follows:

	Expenses	Productive Hours	Rate per Hour
Plumbing Contract Department	$720.00	1,600	45 cts.
Architectural sheet metal contract work	1,105.00	2,500	44 "
Plumbing jobbing	383.00	2,000	19 "
Sheet metal jobbing (outside)	328.00	1,700	19 "
Sheet metal shop work	444.00	1,500	30 "
Furnace heating and ventilating	236.00	850	28 "
Steam and hot water heating	227.00	600	40 "
	$3,443.00	10,750	32 cts.

It is remarkable how the rates for the different departments vary for the business here in question. One must keep in mind that under other conditions and for another firm in this line of business the rates may differ considerably from the above stated rates. The rates for plumbing contract and architectural sheet metal work, as well as steam and hot water heating are comparatively high; same may be reduced if a larger amount of business for these departments would be obtained.

The rates above stated would now be the correct ones to be applied as overhead expenses in estimating, if the conditions and facts underlying our computations remain the same. The business outlook, however, warrants the expectation of some changes. It is now a matter of sound business judgment to fairly correctly foretell business developments, and from this point of view it is estimated that the amount of business in the following year will be $30,000.00 instead of $27,500.00, and that correspondingly merchandise used on jobs (or sold) will amount to $10,500.00 instead of $9,400.00; further, that the expected expansion will be mainly in the Architectural Sheet Metal Department and the Sheet Metal Shop Work, but that all other departments will be approximately the same as in the previous year. It is estimated that the advance will reflect itself as follows:

	Productive Hours
Architectural Sheet Metal Department....	3,000 (instead 2,500)
Sheet Metal Shop Work Department......	3,000 (instead 1,500)

With the expected larger volume of business corresponding larger expenses will arise. A careful study of list of expenses from the previous year and expected developments warrant the conclusion that Selling Expenses and Merchandise Expenses will rise in proportion to the amount of sales and value of merchandise sold, so that the rates of 8½% for Merchandise Expenses and 5% for Selling Expenses will remain the same, but that Operating Expenses in the two affected departments will change as follows:

Architectural Sheet Metal Department............................	from	$1,105.00	to	$1,260.00
Sheet Metal Shop Work Department.	from	444.00	to	630.00

It should not be required to go here further into details than to state that each item of operating expenses was carefully gone over, the estimated changes noted and then the above mentioned totals computed. The details of these computations cannot interest here directly, as the main object here is to illustrate the principal involved. It is certainly required that a thorough and practical knowledge of local and general business conditions are possessed by the business management in order to be able to estimate expected changes in volume of business and in expenses. Above stated changes would influence rates of operating expenses as follows:

	Expenses	Productive Hours	Rate per Hour
Architectural Sheet Metal Department....	$1,260.00	3,000	42 cts.
Sheet Metal Shop Work Department.....	630.00	3,000	21 cts.

We now have the complete rates to be added as overhead expenses in estimating. In the following chapters we will illustrate the practical application of these rates on practical examples. It must naturally be understood that the estimates shown cannot be considered as giving "Standard Cost or Charge Prices." Only the procedure of preparing the estimates and the manner of applying overhead expenses are illustrated. The rates of expenses will vary locally and individually with different business.

General Expenses, Administrative Expenses and Operating Expenses may be combined into one figure by adding 20 cents (12 cents Administrative and 8 cents General Expenses) to the Operating Expenses for the different departments, thereby arriving at the following rates respectively:

65 cents, 62 cents, 39 cents, 39 cents, 41 cents, 48 cents and 60 cents. (Compare with table on Page 206.)

Our explanations should be, however, illustrative enough to make the subject matter clear.

Charges for Special Risks

Extra charges are to be made as the occasion may arise for special dangerous work or voluminous articles to be handled. Such special charges should be based on an equitable base in proportion to the amount of any special insurance carried for such risks or the proper value of such insurance. Example would be:

Handling of glass and earthenware, for breakage risk	10% of cost
Solder, copper and brass goods, etc., for thievery risk	2 to 5% of cost
Street openings for liability risk	25 cts. per hour
Use of scaffolding, for liability risk	25 cts. per hour

A Differential Charge Table of Overhead Expenses

The writer used the following table for a sheet metal shop, in which work was done for the trade only, and no outside work at all. The rates stated here were charged to cost as "Operating Expenses."

Stock Work

This includes work done for stock, as making stove and smoke pipes, chimney caps, leader heads, etc., which articles were then sold to the trade. This was all plain work, done in quantities and needed very little supervision after the men were once instructed and accustomed to the work.

	Per Hour
Class A. Bulky work, requiring much working space	35 cts.
Class B. Small work	30 "

Work Done to Order for Customers

Work of simple nature, requiring little supervision	
Class C. Very bulky or heavy (smoke stacks, large boxes, etc.)	50 cts.
Class D. Bulky or heavy work (skylight of medium sizes, etc.)	45 "
Class E. Small, light work	40 "
Out of the ordinary, but not very complicated work, needing more than ordinary supervision.	
Class F. Very bulky or heavy	65 "
Class G. Bulky or heavy	60 "
Class H. Small, light work	55 "
Special complicated work (making models, etc.)	
Class I. Very bulky or heavy	85 "
Class J. Bulky or heavy	80 "
Class K. Small, light work	75 "

This schedule is here referred to for illustration only, and is not being used for the figures in this book. Nevertheless it shows an interesting example of graduating the overhead expense rates to work of different nature.

Charges for Truck Deliveries

Regarding cost of transportation of material, tools and equipment from and to shop and job, it is optional to either charge each job with the value of cartage done for the job, or to include the entire cost of automobile or team expense in the general overhead tabulation and distribute the expense over the different departments in the same manner as other service expenses are allotted and divided. The manner of charging to the jobs direct is the most just one and comparatively easy, when cartage is contracted for to be done by an outside man as necessity for it arises.

The practical application of all explanations and basic figures explained regarding overhead expenses will be found in the estimates shown in the corresponding chapters of this book.

CHAPTER XIII

THE COST OF MERCHANDISE

As in all walks of life it is not of less importance in the conduct of the sheet metal working and plumbing business to spend one's money wisely and economically, which applies here in a great measure to the "right" buying of material used on jobs. Material is often the greatest part of the cost of a job. One must be versed on market conditions and the rules of buying and selling merchandise in order to be able to buy at the right time, at the right place, and at the right prices. A man with little or no technical knowledge (or rather practical trade experience) will often outdo in business the "first class mechanic" through his knowledge of business rules and customs In order to be successful, the mechanic must acquire certain fundamental business knowledge; that is, he must try not to depend mainly on his good reputation as a "first class mechanic." Market reports and price publications in trade papers will be of great assistance to the man who runs a business, but they are most essential to the "estimator," who must also know the best sources of supplies. He must be familiar with standard price lists, base prices and differentials, current discounts, etc. We therefore append to this book a list of current standard price lists with explanations of "differentials" and of the customs in buying the different kinds of merchandise in quantities.

Waste Material as an Item of Cost

In concluding this chapter attention is called to the importance of figuring waste material in the estimates. It is not sufficient to know the exact quantity of sheet metal, etc. directly to be used for the article, but also to take in consideration the size of the sheet, etc., from which the piece is to be cut and the size of the remaining piece left, which, if of odd shape or small, must be figured at its full value in the estimate. Otherwise, cut-offs are often included at half value in the estimate. Where much material is being cut up, it is of greatest importance to give due consideration to the waste material, as otherwise it will be found that a large portion of the profit is buried in the waste material. Often *considerable* quantities of valuable waste material (copper, brass, etc.) will be obtained. Such is to be deducted from the cost at its salvage price.

CHAPTER XIV

PRACTICAL AIDS FOR THE ESTIMATOR

As in other straits of human activities so are for the work of estimating certain mechanical aids available which to some degree "lighten the burden and shorten the path." Numerous adding and calculating machines, calculating devices of different other kinds, charts for discount figuring, etc., will be found of great help to the busy estimator, and their cost will practically in every case be earned in a comparatively short time by the saving of time and the avoidance of errors in figuring. Nevertheless the size of a business must warrant the expenditures for such mechanical helps. It would, for example, not pay to purchase an electrical dish-washing machine for a small household, although such machine will be an essential for a large restaurant. The successful business man will examine with an open mind and a favorable inclination all labor-saving devices, weighing carefully the possibilities of adapting such to his own business.

There are, however, "kinks" for the estimator, which are developed through experience and necessity, and deserve to be adapted generally. All estimators of standing advise the use of schedules, enumerating all items to be included. For example, for figuring skylights the following schedule would be made up, which is referred to item by item when estimating this kind of work.

Schedule for Skylight Estimating

Sheet iron or copper for
- curb
- bars
- ventilator
- louvres
- turrets
- clips

Glass, plain, ribbed, wire (¼-inch thick or 3/16-inch thick) for
- skylight
- turret

Solder
Putty
Rivets
Opening device or gearing (¾, ½, ⅜ inch) consisting of:
- lifting powers
- brackets
- arms
- collars
- hinges
- handles
- pole hooks
- poles
- extensions
- mitre gears
- gas pipe or rod

Bolts
Screws
Wood (to fill in posts for turrets)
Nails

This list can be extended or more fully itemized to suit requirements.

A similar list can be made up for labor. Sometimes estimators will figure the labor cost as a lump sum for the entire article (here the skylight), as follows:

Labor for skylight
Labor for turret
etc.

At other times it may be advisable to specify the labor items for each part of the article and then summarize, as follows:

Labor for curb
bars
ventilators
assembling, etc., etc.

Often it is advisable (and in many cases it is the safest way) to analyze the labor items into operations:

Labor for laying out
cutting and marking sheets for curb
forming curb
assembling curb
cutting sheets for bars
forming bars
cutting sheets for ventilators
final assembling of skylight, etc., etc.,

so going through the entire list of labor operations. Either system may be applied as the case suggests. The main purpose is not to overlook any item of material or labor, and not to rely solely on the good memory of the estimator.

In order to correctly figure material and labor items the estimator will picture in his mind the article to be estimated, but it will always add a large degree of certainty if sketches are made of the article and its parts, if not sufficient detailed drawings are furnished with the invitation for the bids. We can again here comment favorably on the detailed specifications and blueprints furnished by the Board of Education of the City of New York, as referred to in the chapter "Estimating Ventilating Work."

Card Index Files

The writer prefers a card index file, having one card for each item of material required for the job, and marking on the different cards the prevailing prices, or last purchase prices, the sources of supplies, reference to catalogues and any other information of importance for estimating. The items to be considered for the estimate are then noted on the estimate sheets as same appear on the cards, so that no item can be forgotten in figuring.

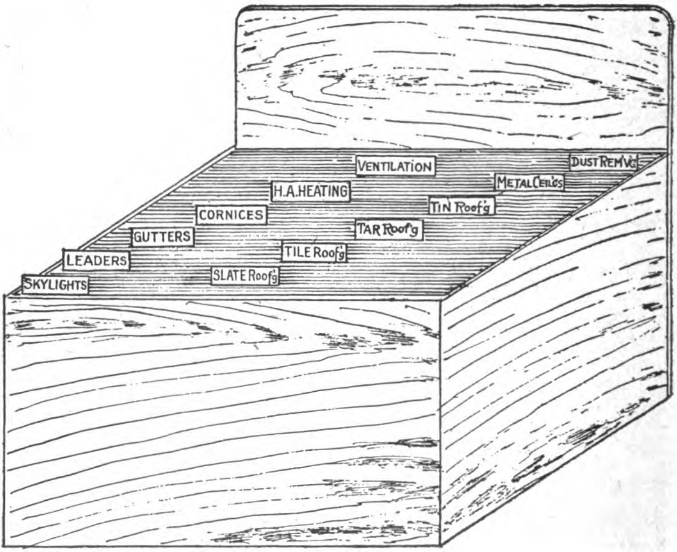


Fig. 143-A

Conductor pipe, corrugated, steel, round.

				List	Disct	F.O.B	
11/3	19	J. J. Shaw & Co, City quoted		St'd	50%	shop	
12/2	19	J. J. Shaw & Co, City bought		"	50%	"	
12/30	19	F. Billins, Philadelphia quoted		"	55%	Pha.	
1/5	20	F. Billins, Philadelphia		"	55-5%	"	

Fig. 143-B

STANDARD LIST PRICES—PER FOOT
Adopted August 15, 1912

Round Corrugated Pipe—Per Foot in 10-ft. Lengths

Sizes Ins.	No. 29 Gauge		No. 28 Gauge		No. 26 Gauge		No. 24 Gauge		Sizes Ins.
	Per foot	Pounds per 100 ft.	Per foot	Pounds per 100 ft.	Per foot	Pounds per 100 ft.	Per foot	Pounds per 100 ft.	
2	$ .13	47	$ .15	51	$ .19	59	$.....	....	2
3	.15	58	.17	63	.21	74	.27	95	3
4	.20	76	.23	82	.28	96	.35	123	4
5	.25	94	.28	102	.34	119	.44	152	5
6	.30	111	.33	121	.40	141	.52	180	6

Fig. 143-C

Preparing the Estimate

In the chapters immediately following here, the reader will find the manner of taking off material from plans, and in conclusion of each chapter a summarized form of estimate for the work treated in each chapter. There are many different forms used for the summarizing of estimates; each having its advantages and disadvantages. This is, however, mostly a matter of personal convenience to the estimator. The principal idea with all forms used is to present the estimate in such shape that the items are clearly set forth, so that the figures can be readily checked off as to their correctness and allow easy reference to them at any future date. The writer prefers a sheet which has a margin at the left, which is used for arithmetic work, so that the broad space at the right is used only for itemizing cost items and computed figures.

Splendid estimate forms have been compiled, especially for heating work, and we refer the reader to other publications on estimating, in which numerous scheduled estimate blanks adaptable for the sheet metal worker are reprinted.*

How ever valuable any information may be that the reader is able to gather from this book and other works on "Estimating," an essential requirement for estimating work is a thorough knowledge of elementary arithmetic and accuracy in figuring, which can be acquired only by diligent practice. Estimates should never be considered correct before same have been checked in all items, preferably by someone else than the person who prepared the estimate.

Uniform estimate sheets (not necessarily printed) should be used, and all basic information regarding the job should be set forth on the sheet, so that the estimate can be easily checked. The estimate is a fundamental part of successful business, and should be treated with all due regard of its importance.

*"How to Make the Business Pay," by Edwin L. Seabrook.

Standard Selling Prices

For many kinds of work "standard" or "graduated" prices are the custom. For example, skylights are often sold by the square foot of surface. Following such trade customs without controlling estimate-figuring will often result in serious losses. While it is true that often trade customs dictate or dominate selling prices, an exact figuring of cost will guide in refusing work at accustomed prices that are too low. The writer once used the following list for skylight, thereby deviating from the then customary manner of a uniform skylight price of 60c. per square foot surface.

Standard selling prices for plain hip vent skylights made of No. 26 gauge galvanized steel with plain (puttyless) bars, ¼ inch thick ripped glass. Prices do not include delivery and erection.

Basic skylight (20 square feet surface of curb), per square foot, 60 cts.	$12.00
Add or deduct for each square foot more or less than 20 square feet	40 cts.

Skylights of more than 45 square feet at special prices.

These figures were based on allowing for more or less material used in different sizes of skylights, and also allowing for any difference in labor for a smaller or larger skylight. Due regard was given to the fact that the difference in labor is only in assembling, while the labor in cutting and bending the parts is practically the same for any size skylight up to 8 feet length of the parts. Larger skylights than 45 square feet, however, as a rule require more labor, also extra material for bracing, etc., and are therefore excluded from the "standard" list.

A skylight of 5 x 4 feet or of any other dimension comprising 20 square feet would sell at		$12.00
A skylight 2 x 2 feet (4 square feet) would sell at	$12.00	
Less 16 x 40 cts)	6.40	5.60
A skylight of 6 x 7 feet (42 square feet) would sell at	$12.00	
Plus 22 x 40 cts	8.80	20.80

While it is seen that the average price of 60 cents per foot is correct, small skylights cost up to $1.40 per foot and larger ones can be made for 50 cents per foot.

Taking Measurements for Estimating

In large sheet metal concerns the usual procedure in going out estimating is about as follows: The general contractor or architect sends out postals asking the sheet metal worker to bid upon a certain job. A number of these invitations to bid are received almost every morning. These cards are given to the estimator and form an introduction as well as an admittance to the contractor's or architect's office. The estimator should have a 3½-inch dividers, as shown in Fig. 144-D, with a small cork pressed over the points of the dividers to prevent tearing the pockets. He should also have a 6-inch flat boxwood scale having the ⅛, ¼, ½ and 1-inch scales on same as shown in Fig. 144-E.

When the scale calls for ¼ inch to the foot this means that every ¼ on the architect's drawing equals 12 inches when taking off quantities. In other words, the scale drawing is 4 × 12 or one-forty-eighth full size. If ¼ inch equals 12 inches, ⅛ inch will equal 6 inches, 1/16 inch will equal 3 inches, and so on. Should the scale be drawn to ½ inch to the foot, then ½ inch will equal 12 inches, ¼ inch 6 inches, ⅛ inch 3 inches and 1/16 inch 1½ inches. ½ inch to the foot indicates that the drawings are 2 × 12 or one-twenty-fourth full size. Whatever the scale may be, multiply this by 12 and it will give the reduced size of the blueprint or scale drawing. The dividers, scale, pencil, note book and small pieces of tracing paper can be carried in one's pocket. The tracing paper is used for making tracings of any stamped metal ornamentation shown on the scale drawing, which can then be submitted to the metal stampers for an estimate in making up the final bid.

Application of Examples

Fig. 144-A shows how the girth of molds, cornices, gutters, skylights or any other ornamental piece of sheet metal work is found. Assuming that the set of drawings to be figured from are drawn to a scale of ¼ inch to the

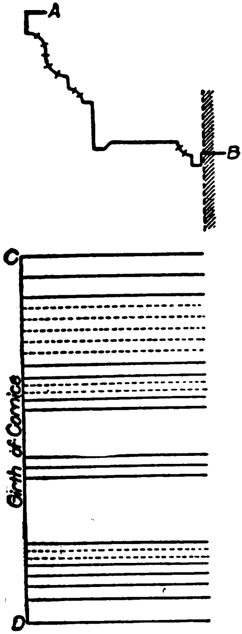


Fig. 144-A.—Finding Girth of Molding

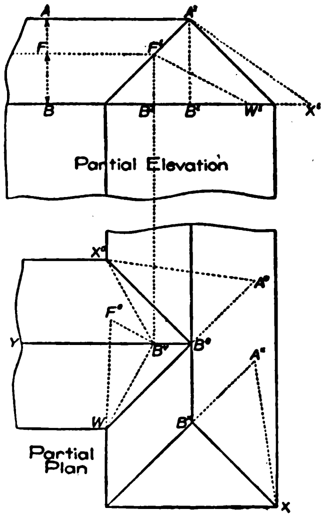


Fig. 144-B.—Finding True Lengths of Hips and Valleys

foot, then set the dividers to 1 inch, found on the quarter scale, and start to measure the girth of the cornice shown from A to B. As the steppings are being made they are counted to know the number of inches in the girth, or, they can be placed on any vertical line, as shown by C D. Further hints on this subject will be given later when taking off quantities from plans.

The principles applicable to finding the true lengths of hips and valleys are given in connection with Fig. 144-B, where two methods are shown. The cut shows a partial plan and elevation of a hipped roof with connecting wing. To find the true length of the hip X Bx in plan, take the vertical height B A in elevation and set it off at right

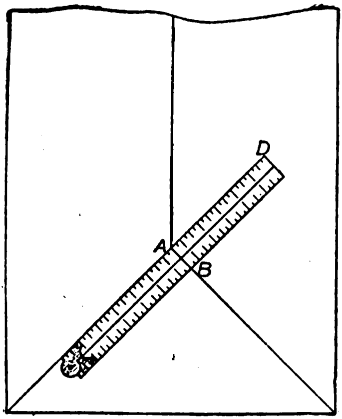


Fig. 144-C.—Squaring the Height on Hip in Plan

angles to Bx X in plan as shown by Bx Ax. A line drawn from Ax to X will give the true length of the hip.

Great care must be taken that the line Ax Bx in plan is drawn at right angles to Bx X. Some estimators can erect this line with accuracy by using the eye, but the proper way to proceed is illustrated in Fig. 144-C. Take an ordinary 2-foot rule and place it so that the inch lines or fractional inch lines at A and B will come directly over the hip line A C and then draw the line A D. D A C will then be a right angle, and on the line A D the desired height may be set off. This is a quick method, and avoids mistakes in measuring up the true lengths.

The same true length shown by Ax X in plan in Fig. 144-B could be found by taking the length of the hip Bx X in plan and setting it off in elevation from the vertical line dropped from the apex A^1 from B^1 to X^1.

Fig. 144-D.—Dividers

X^1 A^1 will then be the same length as Ax X in plan. The length of the valley B° X° in plan is found in a similar manner; the height A B in elevation is set off at right angles to the valley line X° B° in plan as shown by B° A°; then the distance from A° to X° will be the true length of the valley.

This same valley length could be found in the elevation, setting off the distance X° B° in plan as shown from

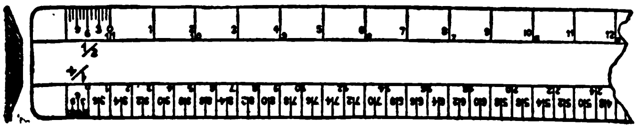


Fig. 144-E.—Flat Boxwood Scale

B^1 to X^1 in elevation, when the desired length is indicated by A^1 X^1.

When both the valley and hip lines in plan have similar lengths, and the vertical heights are similar in elevation, then the true lengths of the hips and valleys will be similar. If the roof of the wing Y in plan were lower than the roof of the main building, that is, if the vertical height was equal to F B in elevation, then the true length of the valley would be found similar to that already explained. In other words, a horizontal line would be projected from F in elevation until it intersects the main roof at F^1, from which point a perpendicular line is dropped, cutting the ridge Y B° in plan at B*v*. X° B*v* and B*v* W then represent the valley lines in plan.

Its true length may now be found in two ways. The first, by taking the vertical height F B in elevation and setting it off at right angles to the valley line W B*v* in plan, as F°, thus obtaining the true length F° W. The second way is to drop a perpendicular line from F^1 in elevation until it intersects the base of the valley at B^2.

From B^2 set off the distance B^2 W^1 equal to B*v* W in plan, and the distance from W^1 to F^1 in elevation will equal W F° in plan. Knowing both rules, the estimator can use either as occasion demands.

The Micrometer Caliper

The sheet metal worker is often called upon to furnish estimates for work other than from plans and specifications. Especially articles for commercial use, made of sheet metal, have to be estimated from samples, when no further information is given as to the thickness of material to be used. It is often impossible to conclude from the weight of the article the thickness of material, as the article may be made in some parts of different thickness, while on the other hand certain parts attached to the sample (as wooden handles, castings, etc.) would not permit to obtain the weight of the sheet metal used. In such cases often the use of an instrument, which is too little known and still less used by the sheet metal worker, will be of great assistance, and often cannot be done without. This is the "Micrometer Caliper," by means of which thickness of material can be measured by the thousandths of an inch. If, for example, it is found by the means of the micrometer caliper that copper is 159 thousandths of an inch thick, we can easily see from a corresponding list that the material is No. 26 Brown & Sharpe (B. & S.) gauge, which weighs .722 pounds per square foot. After finding the amount of material in square inches or square feet in the customary manner and knowing the gauge of the material, it is a matter of plain arithmetic to arrive at the total weight of the material required.

How to Use a Micrometer Caliper

We present here an illustration (Fig. 144-G) and description of the micrometer caliper with directions for using

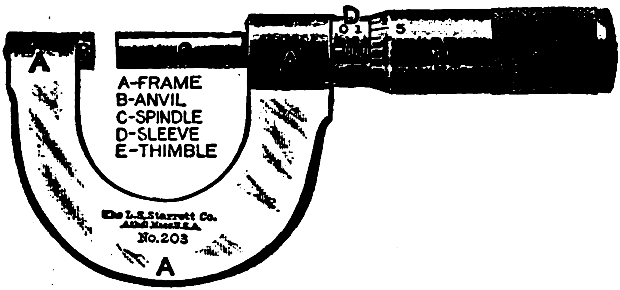


Fig. 144-G.—Micrometer Caliper

it, which will sufficiently explain the construction and usefulness of this highly interesting appliance, which is typically called the "tool with a soul."

The spindle C is attached to the thimble E at the point H. The part of the spindle which is concealed within the sleeve and thimble is threaded to fit a nut in the frame A. The frame being held stationary, the thimble E is revolved by the thumb and finger, and the spindle C being attached to the thimble revolves with it, and moves through the nut in the frame, approaching or receding from the anvil B. The article to be measured is placed between the anvil B and the spindle C. The measurement of the opening between the anvil and the spindle is shown by the lines and figures on the sleeve D and the thimble E.

The pitch of the screw threads on the concealed part of the spindle is 40 to an inch. One complete revolution of the spindle therefore moves it longitudinally one-fortieth (or twenty-five thousandths) of an inch. The sleeve D is marked with 40 lines to the inch, corresponding to the number of threads on the spindle. When the caliper is closed, the beveled edge of the thimble coincides with the line marked 0 on the sleeve, and the 0 line on the thimble agrees with the horizontal line on the sleeve. Open the caliper by revolving the thimble one full revolution, or until the O line on the thimble again coincides with the horizontal line on the sleeve; the distance between the anvil B and the spindle C is then one-fortieth or (.025) of an inch, and the beveled edge of the thimble will coincide with the second vertical line on the sleeve. Each vertical line on the sleeve indicates a distance of one-fortieth of an inch. Every fourth line is made longer than the others, and is numbered figure 0, 1, 2, 3, etc. Each numbered line indicates a distance of four times one-fortieth of an inch, or one-tenth.

The beveled edge of the thimble is marked in twenty-five divisions, and every fifth line is numbered, from 0 to 25. Rotating the thimble from one of these marks to the next moves the spindle longitudinally one-twenty-fifth of twenty-five thousandths, or one-thousandth of an inch. Rotating it two divisions indicates two-thousandths, etc. Twenty-five divisions will indicate a complete revolution, .025 or one-fortieth of an inch.

To read the caliper, therefore, multiply the number of vertical divisions visible on the sleeve by .25, and add the number of divisions on the bevel of the thimble, from 0 to the line which coincides with the horizontal line on the sleeve. For example, as the tool is represented in the engraving, there are seven divisions visible on the sleeve. Multiply this number by 25, and add the number of divisions shown on the bevel of the thimble, 3. The micrometer is open one hundred and seventy-eight thousandths. $(7 \times 25 = 175 + 3 = 178.)$

The Engineer's Slide Rule

The Estimator will encounter difficulties in making certain arithmetical calculations, especially in extracting roots, unless he has had considerable practice. Even the experienced mathematician finds the extracting of roots by the common methods troublesome. When much work of this nature is to be done, an instrument known as the "Engineer's Slide Rule" will save time. The Estimator will find it to his advantage to make himself acquainted with this instrument, by means of which many arithmetical manipulations are solved without any figuring. Dealers in engineer's instruments will furnish, as a rule free of charge, detailed description and explanation of the use of the Engineer's Slide Rule.

Extracting of Roots by Means of Logarithms

In any book on advanced arithmetic will be found a thorough explanation of the principles underlying the meaning and use of "Logarithms." A brief outline of the methods used in employing logarithms will be given here.

The principle of logarithms is that each number has another number as its exponent. This exponent is called the logarithm of the number. A table of logarithms will give the exponents (or logarithms) for the different numbers.* By means of logarithms many calculations (even such which cannot be done at all by the regular methods of arithmetic are made easy.) At any rate much drudgery in arithmetic work will be saved through the intelligent use of logarithms. The estimator will in his practical work find the use of logarithms especially useful for the extraction of roots, as well as the multiplication and division of large numbers.

Dividing the logarithm of a number by 2 will give the logarithm of its square root.

Dividing the logarithm of a number by 3 will give the logarithm of its cube root.

Dividing the logarithm of a number by 4 will give the logarithm of its fourth root, etc.

Examples:

Find the square root of 7,058 (as on page 11)

Logarithm of 7,058 (see table of logarithms) is.. 3.8485

Divide this by 2 gives........................ 1.9243

1.9243 is the logarithm (see table of logarithms) of............................ 84

Therefore, 84 is the square root of 7,058 (same as on page 11.)

* Smoley's Five Place Logarithmic and Trigonometrical Tables, Price $1.00, will give all the data usually required.

Find the cube root of 42,875 (as on page 43.)

Logarithm of 42,875 (see table of logarithms) is 4.6323

Divide this by 3 gives 1.5441

1.5441 is the logarithm (see table of logarithms) of 35

Therefore, 35 is the cube root of 42,058 (same as on page 43.)

Multiply 568 *by* 348.

The logarithm of 568 is (see table of logarithms) 2.7543

The logarithm of 348 is (see table of logarithms) 2.5416

adding together gives 5.2959

5.2959 is the logarithm of 197,664

Therefore, 568 x 348 is 197,664, which can be proven by plain arithmetic.

CHAPTER XV

ESTIMATING SKYLIGHT QUANTITIES AND COST

Many shops, in figuring skylights, have a graded schedule of the prices per square foot for different size skylights in either flat, double pitched or hipped, glazed with rough, ribbed or wire glass, made up in either galvanized iron or copper of various gauges. Assuming that a skylight measuring 8 x 8 feet in size, and containing 64 square feet, made of galvanized iron and glazed with 3/16-inch ribbed glass, could be made and erected for 55 cents per square foot, a smaller size, say 4 x 4 feet, containing 16 square feet, could not be made for the same price, because the amount of labor for either one is nearly the same; for instance, in so far as the bending is concerned it takes just as long to bend up a curb 4 feet long as to bend one 8 feet long, as the bending leaf must be lifted in either case, assuming that an 8-foot brake is in use. The same applies to the skylight bars; it makes no difference if the bars are a little longer, the operations and time being similar.

To obtain an accurate estimate of the amount of material, glass, putty, etc., required for flat, double pitched or hipped skylights when no graded schedule of prices for the various size skylights are at hand, is to take off the quantities of metal, glass and putty and then add to this labor, expenses, etc. All skylight makers have standard sets of patterns for the curb and bars in either style of skylights, so that the girth of the material required is known at once. It then only becomes a matter of simple computation to figure the length required of the various curbs and bars, as well as the square feet of glass, and the weight of putty.

As an example assume that the quantities are required in making up a flat, a double pitched or a hipped skylight 5 x 8 feet in size, to be made of 16-ounce cold-rolled copper, glazed with ¼-inch wire glass well bedded in putty. In taking off the quantities of any skylight it is necessary that the estimator be familiar with the rules and regulations of the National Board of Fire Underwriters for the construction and installation of skylights. One of the fire underwriters' rules is as follows:

Glass—"For all skylights, plane or inclined not over 45 degrees, to be either of standard wired glass not less than ¼ inch thick or ½ inch thick glass protected with approved wire screens. Panes not to be over 18 or 20 inches wide and not to exceed 720 square inches in area." In other words, if the light or pane of glass required were greater than 18 x 40 inches, or 720 square inches in area, two lights of glass would have to be used.

Figuring Quantities for a Flat Skylight

In Fig. 145-A is shown a sectional and plan view of a flat skylight 5 x 8 feet in size, the rafters or bars running the 5-foot way, as shown in the sectional view. As the Board of Fire Underwriters do not allow the panes of glass to be more than 20 inches, the length of 8 feet or 96 inches has been spaced in six lights. As the shoulder at A in the sectional view is ½ inch wide, and is formed around the entire curb, then 1 inch is deducted from the length of 96 inches; then 95 ÷ 6 = 15 5/6 inches, the width of the bar spacings to receive the glass. As the Board of Fire Underwriters do not allow a pane of glass to have more than 720 square inches, and as the pane required for the flat skylight above referred to would contain 15 5/6 × 59, or 934 square inches, then the light would be made of two panes of glass with a 2-inch lapped joint as indicated in the plan.

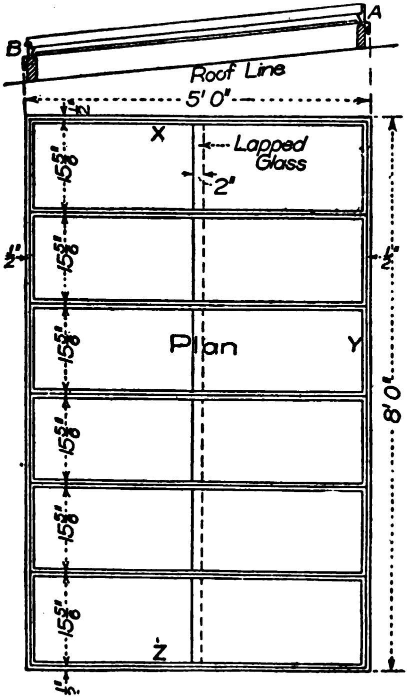


Fig. 145-A.—Section and Plan of Flat Skylight

In Fig. 145-B is shown the one-half full size sections of the skylight curb and bars for the flat skylight shown in Fig. 145-A. It will be noticed that the girth of the bar in Fig. 145-B takes 6½ inches and the cap 2 inches, making a total of 8½ inches. The girth for the curb is 8 inches and the cap 2 inches for the three sides marked X Y and Z in plan in Fig. 145-A, making a total of 10 inches for these three sides. The lower side, marked B in the sectional view, does not require a cap, as the water flows off at that end, the standing edge of the curb being bent over at right angle, at the dot marked B in the curb section in Fig. 145-B. This dot B is always placed so that it will be flush with the upper surface of the thickness of glass used.

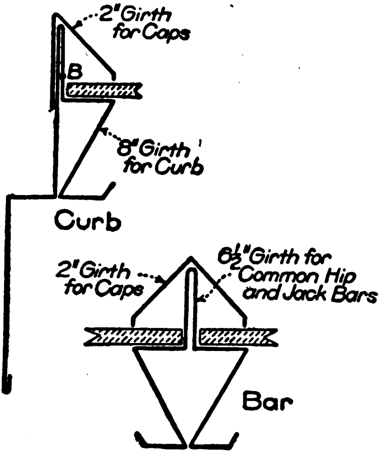


Fig. 145-B.—One-half Full Size Section for Flat Skylights

Knowing the girth, the quantities are now in order. As the girth of the lower curb B in the sectional view in Fig. 145-A measures 8 inches, as shown in Fig. 145-B, and as the length of this lower curb is 8 feet, or 96 inches, as shown in Fig. 145-A, then $8 \times 96 = 768$ square inches. As the length of the three sides, X, Y and Z in plan, measure 5, 8 and 5 feet, respectively, or 216 inches, and as the girth required for these three sides is 10 inches, including the caps, as shown in Fig. 145-B, then $10 \times 216 = 2,160$ square inches. The girth for the bars and caps combined require 8½ inches. The length of each bar is 5 feet, minus 1 inch for curb shoulders, or 59 inches, as shown in plan in Fig. 145-A. Then $8.5 \times 59 = 501.5$ square inches for each bar; as there are five bars then $5 \times 501.5 = 2507.5$ square inches total. There are then:

Lower curb	768	square inches
Top and two side curbs	2160	"
Five bars	2507.5	"
Making a total of	5436	square inches

As 144 square inches equal 1 square foot, then $\frac{5436}{144} = 38 +$ square feet.

As the skylight is to be made of 16-ounce cold-rolled copper, which means that each square foot is to contain 16 ounces, then 38 pounds of copper will be required. To this an approximate amount is added for solder, copper clips and copper rivets, as well as brass screws for screwing curb to roof frame. ½ pound of solder, 1 pound for copper clips to fasten caps, including copper rivets, and one dozen brass screws 1¼ inches long will be sufficient.

The amount of glass and putty is found as follows: All glass widths come in even numbers; that is, if glass were ordered 14¼ inches this would be cut from 16-inch widths. There are two panes in each light, as shown in plan, and the length is 59 inches, plus 2 inches for lap. The width of the glass is 15 5/6 – ¼ inch for play, and would be cut from 16-inch wide glass. Then $16 \times 61 = 976$, $\times$ 5 lights $= 4880$. $\frac{4880}{144} = 34 +$ square feet ¼-inch wire glass.

An approximate rule to find the number of pounds of putty is to allow 1 pound for good imbedding for every 2 feet of bar on both sides. Thus we have two long runs of 8 feet each; two runs of 5 feet each, and five double runs of 5 feet each for the bars. Then $8 + 8 + 5 + 5 + (5 \times 10) = 76$ feet single imbeddings $\frac{76}{4} = 19$ pounds putty.

The entire flat skylight, 5 × 8 feet in size, would require 38 pounds copper, ½ pound of solder, 1 pound copper clips and rivets, 1 dozen brass screws, 34 square feet ¼-inch wired glass, and 19 pounds putty, to which must be added cost for labor, expenses, etc. Knowing the price of the skylight, divide it by 40, the number of square feet in the skylight, and obtain price per square foot. These prices should be kept for future reference, and in this way a graded schedule is obtained for the various sizes. (See estimate on page 245.)

Figuring Quantities for Double Pitched Skylights

When the skylight is of the gable or double pitch style, as shown in Fig. 146, the method used in computation is as follows: In this case assume the pitch to be one-third, which means one-third the span. In other words, the span, or width, A A° in the sectional view, is 60 inches; 1/3 of 60 is 20, and gives the vertical rise between A° and B.

The length of the rafter on the glass line from A to B is 36 inches as scaled. This can be further proven by assuming A B to be the hypothenuse of a triangle whose base is ½ of 60, or 30 inches, and whose altitude is 20 inches, then the $\sqrt{20^2 + 30^2} = 36$ inches, or the length of the pitched bars. The girth of the bars will be 8½ inches, including the cap, as shown in Fig. 145-B. As each bar in Fig. 146 is 36 inches long, then $36 \times 8.5 = 306$ square inches, × 10 bars, or 3,060 square inches. The girth of the curb is 7½ inches, as shown in Fig. 147. As there are two runs of curb, as shown in plan in Fig. 146, of 96 inches each, then 96 × 7.5 = 720 square inches × 2 = 1,440 square inches.

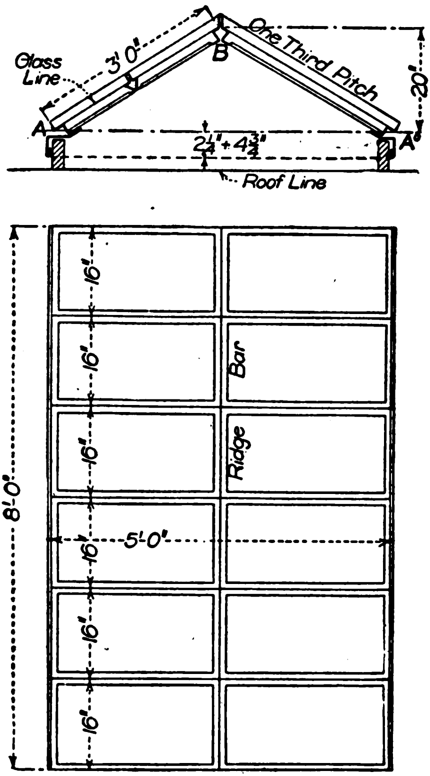


Fig. 146.—Section and Plan of Double Pitched Skylight

The ends of the double pitched skylight are flat with a curb attached to the bottom to set on the roof frame, as indicated from C to D in Fig. 147, whose girth is 4¾ inches.

To find the quantity of copper in the two triangular heads in the sectional view in Fig. 146 multiply the base of the triangle A A° by one-half the vertical height. Thus 60 × 10 = 600 square inches for one end, 600 × 2 = 1,200 square inches for both ends. Below the base of the triangle A A° in the sectional view, 2¼ inches of material is required, as shown by A B in the curb section

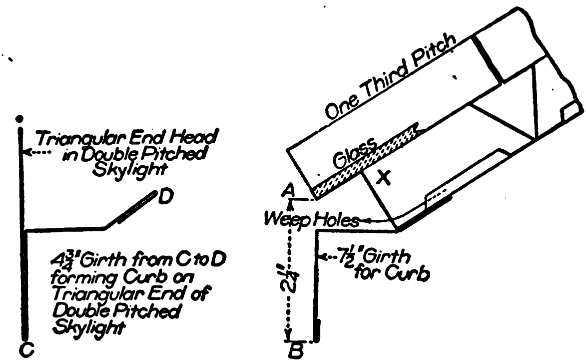


Fig. 147.—One-third Full Size Section of Curb for Double Pitch and Hipped Skylights

in Fig. 147. To this must be added the girth of 4¾ inches from C to D in the curb on triangular end, making a total of 2¼ + 4¾, or 7 inches.

The width of the skylight is 60 inches, as shown in Fig. 146. Then 7 × 60 = 420 square inches for one end. Multiply by 2 and obtain 840 square inches for two ends. The length of the ridge bar is 96 inches, while the girth of the ridge bar shown in Fig. 148, including the cap, is 10¾ or 11 inches. 96 × 11 = 1,056 square inches. All the material for the copper work in the double pitched skylight in Fig. 146 can be summed up as follows:

10 skylight bars....................	3,060 square inches
Lower curbs....................	1,440 "
Triangular ends....................	1,200 "
Curb on ends....................	840 "
Ridge bar....................	1,056 "
Making a total of.............	7,596 square inches

$\frac{7596}{144} = 52\frac{1}{2}$ square feet. As the gauge copper is 16 ounces or 1 pound to the square foot, then $52\frac{1}{2}$ pounds of copper will be used. To this is added for copper clips and rivets about 1 pound and about 1 pound of solder, 1 dozen brass screws, etc.

The plan of the skylight in Fig. 146 has been spaced in six divisions of 16 inches each. The run of the bar on the glass line is 36 inches, as shown in the sectional view; $36 \times 16 = 576$ square inches, which is safe in area, as called for in the rules for glass of the Fire Underwriters' regulations. As twelve lights of glass will be required, then $12 \times 576 = 6{,}912$ square inches. $\frac{6912}{144} = 48$ square feet of ¼-inch wired glass required. Following the rule previously given for the amount of putty required, 4 runs of 8 feet = 32 feet, 24 runs of 3 feet each of the bars = 72 feet, making a total of 104 linear feet to be puttied, $\frac{104}{4} = 26$ pounds of putty required. To this must be added labor, time and expenses, and this saved for future use and reference towards a schedule.

(See estimate on page 246.)

Quantities for Hipped Skylight

Finding the quantities in a hipped skylight is a little more difficult, the plan of which is shown in Fig. 149. The girth of the curb is similar to that shown by X in Fig. 147, which is 7½ inches. As this curb is placed around the four sides in Fig. 149, then 96 + 60 + 96 + 60 = 312 inches; 312 × 7.5 = 2,340 square inches. The true length of the ridge bar is found by deducting the narrow side from the wide side of the curb, thus: 96 – 60 = 36 inches. As the profile of the ridge bar is similar to that shown in Fig. 148, which requires 10¾ inches girth, including the cap, which in figuring is called 11, then 11 × 36 = 396 square inches in ridge bar. The girth of the common, hip and jack bars in Fig. 149 equals 8½ inches, including the caps, as shown in Fig. 145-B.

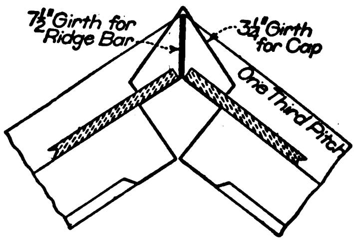


Fig. 148.—One-third Full Size Section of Ridge Bar for Hipped and Double Pitched Skylights

As the hipped skylight shown in Fig. 149 is also to have one-third pitch, the same as the sectional view in Fig. 146, then the length of the common, common jack and center jack bars shown in Fig. 149 will be 36 inches long, as previously computed. All told, there are eight bars. Then 36 × 8.5 × 8 = 2,448 square inches.

If the length of the common bar has a 36-inch pitch on a run of 30 inches, as shown in the sectional view in Fig. 146, then the pitch on a run of 1 inch would be $\frac{36}{30} = 1.2$.

This gives us the factor for finding the true length of the jack bars in Fig. 149. As the division of the jack bar is 15 inches, then $15 \times 1.2 = 18.0$, the length of the jack bar on the glass line. As the girth of the jack bar is 8½ inches, then $8.5 \times 18 = 153$ square inches, and 8 jacks being required would require 8×153 or 1,224 square inches of material.

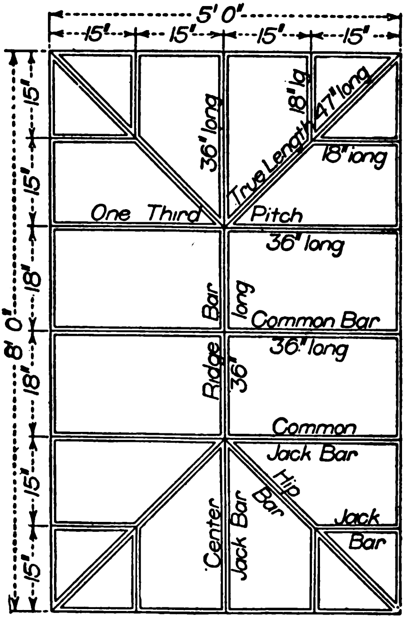


Fig. 149.—Plan of Hipped Skylight with Ridge Bar

As the hip bar forms a diagonal in a square whose base is 2 feet 6 inches by 2 feet 6 inches, as shown in plan, then this diagonal length in plan will equal $\sqrt{30^2 + 30^2} = 42.42$. As the rise at one-third pitch is 20 inches, as shown in the sectional view in Fig. 146, then the true length of the hip bar will equal $\sqrt{42.42^2 + 20^2}$ or $\sqrt{30^2 + 30^2 + 20^2} = 46.9$ or 47 inches on the glass line. As the girth of the hip bar is also 8½ inches, then 8.5 × 47 × 4 hip bars = 1,598 square inches.

The total square inches of copper in the hipped skylight in Fig. 149 can now be added as follows:

Curb	2,340	square inches
Ridge bar	396	"
Common, common jack and center jack	2,448	"
Jack bars	1,224	"
Hip bars	1,598	"
Making a total of	8,006	square inches

Then $\frac{8006}{144} = 56 +$ square feet of copper at 16 ounces per square foot would require 56 pounds. To this would be added solder 1¾ pound, cleats and rivets 1½ pounds, 1 dozen brass screws, etc.

The accurate amount of wired glass is computed as follows: The width of the panes of glass in Fig. 149 are 15 and 18 inches. As the glass comes in even numbers, 16 and 18 are used in this computation. The length of the common bars is 36 inches long and those of the jack 18 inches long, as shown on plan and previously computed. Four rectangular lights will be required, 18 x 36 inches. Then 18 × 36 × 4 = 2,592 square inches. Eight irregular lights will be required, 15 inches wide, 36 inches at one side and 18 at the other side.

The rule to follow in finding the area is take one-half the sum of the sides and multiply by the width, thus

$\frac{36+18}{2} = \frac{54}{2} = 27$; 27×16 (stock width) $= 432$; 432×8 lights $= 3{,}456$ square inches. The eight triangular lights have an area of $\frac{16 \times 18}{2} = 144$; $144 \times 8 = 1152$ square inches.

The amount of glass may now be summed up as follows:

4 rectangular lights	= 2,592 square inches
8 irregular lights	= 3,456 square inches
8 triangular lights	= 1,152 square inches

or a total of 7,200 square inches. $\frac{7200}{144} = 50$ square feet ¼-inch wired glass.

The amount of putty would be 26 feet on curb, 6 feet on ridge bar, 48 feet on common bars, 24 feet on jack bars, 32 feet on hip bars, making a total of 136 feet of linear puttied surface. Figuring 4 feet to the pound, then $\frac{136}{4} = 34$ pounds putty.

In this manner quantities are obtained to which must be added expenses for time and labor for construction and erection, which vary in different parts of the country.

(See estimate on page 248.)

All estimating blanks should be saved, as they form valuable information, which is referred to time and again when similar size skylights come up for figuring, and from which a schedule can be made.

If the skylights are to contain ventilators, this is computed in a similar manner. When a ventilator is used less glass will be required, varying according to the width of ventilator used.

Practical Examples for the Estimating of the Cost of Skylights

Many sheet metal working shops make a specialty of the building of skylights and have this branch of the trade developed to such perfection that they are able to turn out skylights at a very much lower cost than in an ordinary shop, where skylights are built only occasionally and no special attention is paid to this branch. Therefore, sheet metal workers will often find it more economical to give work out to these "specialty shops." There are now machines in use by means of which a skylight bar can be turned out by a few press operations in less than a minute's time. Nevertheless, the ordinary shop will still be able to handle the making of skylights if this work is somewhat systematized, especially if men are on hand who are accustomed to the work, where the necessary patterns for the cutting out of bars, curb, ventilator, etc., are prepared and if the shop is equipped with the necessary plain machinery usually found in a sheet metal shop. The cost of making skylights (and as far as this goes, of any other article as well) will naturally vary in the different shops under otherwise equal conditions of equipment, depending upon the more or less economical and efficient manner work is generally handled in the shop. The estimator must be acquainted with the conditions that have any influence on cost of the particular business for which he is estimating. We shall here illustrate the manner of figuring the work in accordance with our explanations in the previous chapters of this book, and show the cost of the work in the shop in which the conditions prevail as we have described. The time of labor stated in the estimate is certainly subject to change, nevertheless the principle will be sufficiently understood by our examples. The same is true of the cost of material, which will depend upon efficiency in buying. In our examples it is presumed that the skylights are built complete in the shop with the glass put in, and so delivered to the building, ready to be put in place. It may often be advisable to put in the glass after the skylight is placed in position. This is, however, immaterial as far as it concerns the practical illustration of preparing and figuring estimates. The estimator shall either receive or prepare a sketch of the work (a general lay-out) and have all information (specifications, etc.) regarding details of the work, so he may be able to fairly correctly figure material and estimate labor required. Only so a dependable estimate can be prepared.

In many shops standard sketches or drawings are kept for the different kind of skylights and then same are referred to by number or other mark; for example, "Skylight, our style No. 6," etc.

The profit of 25 per cent, as figured in our estimates, is certainly optional.

It is also to be noted that in the estimates no allowance is figured for waste of copper, because the pieces of copper as specified are cutting well from full commercial sheets, 60 inches or 96 inches long. There is a small waste in cutting the 59-inch long pieces. This waste, however, will be used for the clips.

Sharp & Brown Co.
Trestenville, N. Y.

ESTIMATE No. 20 — Nov. 26 /19

for 1-flat skylight, 5 feet x 8 feet, as per sketch attached.
for Mr. . . . .
to be delivered to and erected at . . . .
Specification: 16 ounces cold-rolled copper, ¼-inch wire glass.

NOTE
Use this space for figuring.

Material:			
Copper (from stock):			
Lower curb:			
1 piece 8 inches x 96 inches	768 square inches		
Sides and caps:			
2 pieces 10 inches x 60 inches	1,200 "		
1 piece 10 inches x 96 inches	960 "		
Bars and caps:			
5 pieces 8½ inches x 59 inches	2,508 "		
	5,436 square inches		
= 38 square feet at 1 pound = 38 pounds,			
Base price	33½ cents		
Extra for cold-rolled	1½ "		
Total for 38 pounds at	35 cents		$13.30
Solder, ½ pound			.20
Copper clips and rivets			.40
Glass: (quoted by Hirsh & Co.)			
5 pieces 16 inches x 61 inches, 34 square feet at	30 cents		10.20
Putty (from stock):			
19 pounds, at	6¼ "		1.19
Total material			$25.29
Labor:			
Making skylight in shop:			
9 hours, at			7.00
Total prime cost			$32.29
Overhead expenses:			
Operating, administration and general expenses:			
9 (hours), x 41 cents		$3.69	
Merchandise expenses:			
8½% of $25.29		2.15	
Glass risk:			
10% of $10.20		1.02	
Solder and copper risk:			
2% of $13.90		0.28	7.14
			$39.43
Selling expenses: 5%			1.97
Total cost of making skylight			$41.40
Erecting skylight:			
Material:			
Screws, 1 dozen			$0.10

Labor:	
Hoisting to roof and fastening to curb, including time traveling from shop to job and return: 2 men, each 3 hours, at 70 cents	$4.20
Delivery to job	2.00
Carfares	.30
Total prime cost	$6.50
Overhead expenses:	
6 (hours) x 62 cents	3.72
	$10.22
Selling expenses: 5%	.51
Total cost of erecting skylight	$10.73
Cost of making skylight	41.40
Total cost	$52.13
Profit, 25%	13.03
	$65.16

Estimated by........................
Checked by........................
Quote, $66.00.
Approved by........................

Statistical remarks:
Cost of making, per foot, $1.04.
Total cost, per foot, $1.30.
Total selling price, per foot, $1.63.

Sharp & Brown Co.
Trestenville, N. Y.

ESTIMATE No. 21 Nov. 26/19

for 1-double pitched skylight, 5 feet x 8 feet, as per plan and specification attached.

Architect..

for Mr..

to be delivered to and erected at..............................

Specification: 16 ounces cold-rolled copper, ¼-inch wire glass.

Material:	
Copper (from stock):	
Bars: 10 pieces 8½ inches x 36 inches	3,060 square inches
Lower curb:	
2 pieces 7½ inches x 96 inches	1,440 "
Triangular ends:	
2 pieces 10 inches x 60 inches	1,200 "
Curbs on ends:	
2 pieces 7 inches x 60 inches	840 "
Ridge bar, 11 inches x 96 inches	1,056 "
	7,596 square inches

=52½ square feet at 1 pound = 52½ pounds, base price	33½ cents	
Extra for cold-rolled	1½ "	
Total for 52½ pounds at	35 cents	$18.38
Solder, 1 pound		.40
Copper clips and rivets		.40
Glass: (quoted by Hirsh & Co.)		
12 pieces 36 inches x 16 inches = 48 square feet at	30 cents	14.40
Putty (from stock)		
26 pounds, at	6½ "	1.69
Total material		$35.27
Labor:		
Making skylight in shop:		
15 hours at	70 cents	10.50
Total prime cost		$46.77
Overhead expenses:		
Operating, administration and general expenses:		
15 (hours) x 41 cents	$6.15	
Merchandise expenses:		
8½% of $35.27	3.00	
Glass risk:		
10% of $14.40	1.44	
Solder and copper risk:		
2% of $19.18	0.38	$10.97
		$57.74
Selling expenses, 5%		2.89
Total cost of making skylight		$60.63
Erecting and delivery of skylight, same as in estimate No. 20		10.73
Total cost of erected skylight		$71.36
Profit, 25%		17.84
		$89.20

Estimated by........................
Checked by........................
Quote, $90.00.
Approved by........................

Statistical remarks:
Cost of making, per foot, $1.52.
Total cost, per foot, $1.80.
Total selling price, per foot, $2.23.

CHAPTER XVI

ESTIMATING SHEET METAL WORK FOR BUILDINGS

A One-family Brick Residence

To give the reader a practical idea of how quantities are estimated, the method of procedure in an actual instance will be demonstrated. For this purpose the case of the one-family brick residence, shown in the accompanying illustrations, together with details, will be taken and the quantities will be taken off. The usual method followed is to take off the quantities in the order in which they occur in the specifications. The following is a typical specification for the job in question, when first class work is desired:

Specifications

Specifications for the roofing, cornice, gutters, leaders and skylights on the brick residence to be erected for John Smith, according to the plans and specifications prepared by James Doe, architect.

Tin Roofing

The roof of the main building, also the roof over the rear porch, to be covered with 14 x 20-inch flat seam roofing (M. F. brand) with 32 pounds coating to the box, each sheet to be secured with three cleats, using 1-inch tinned roofing nails, and to have 3/8-inch edge. Before laying the tin plates, the roofer should see that the sheathing boards underlying the roofing tin are closely fitted and notify the carpenter to remedy any defect before laying the tin roofing. After the roof has been properly sheathed, give the sheathing boards and side walls under flashings one coat of red lead in boiled linseed oil and do not lay the roofing until the boards are thoroughly dried. Paint the under side of each sheet with the same paint, avoiding that part of the folded edge which locks into the sheet, so that the fusion of the locks between the two sheets is not interfered with when soldering. Use no acid as a flux in soldering the tin work, only clean rosin and half and half solder, composed of 50 tin and 50 lead, new metals. Where the tin roofing joins the galvanized iron work, the flux should be made of muriatic acid and zinc clippings, known as "killed acid." All flashings against scuttle and skylight curbs and brick walls should be painted in similar manner and should be turned up not less than 8 inches from the roof line and should be "base flashed."

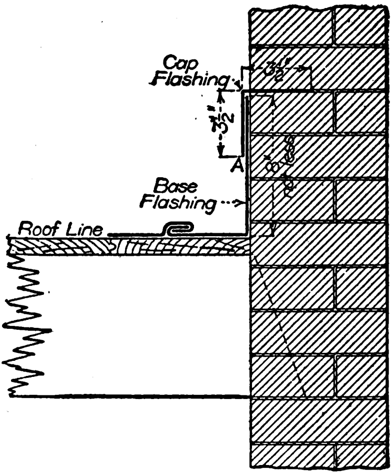


Fig. 150.—Cap and Base Flashing on Main Roof

Cap flashings should be cut not less than 7 inches wide and bent through the center at right angles, so that 3½ inches will set on the wall and 3½ inches over the wall (as indicated in Fig. 150). These cap flashings should be furnished to the mason in 8 or 10-foot lengths, painted two coats of red lead in oil, and thoroughly dried before delivery. The roofer shall see that these cap flashings are set on the wall as the work progresses, so that they can be built in not less than 8 inches above the roof line.

They should be lapped not less than 3 inches and where the pitch of the roof requires the cap flashing to be "stepped," the upper cap should project over the lower not less than 6 inches. Care should be taken that the cap flashing lays snug against the wall (as indicated at A in Fig. 150.) All upright soldering on the base flashings to be thoroughly sweated and on completion of the tin work all rosin is to be removed from the seams and the roof painted with a good coat of red lead in oil. Four weeks after putting on first coat the second coat is to be applied.

Galvanized Iron Spanish Tile Roofing

The pitched roof over the main cornice and the roof over the first story sun parlor to be covered with galvanized iron Spanish tile roofing, the metal to be not less than No. 24 gauge, finishing tiles to be used on the last course. The tile as well as the hip rolls at the corner are to be painted one coat of red lead in oil on both sides and allowed to dry before laying. Where the tile butts against the brick wall at the top, a No. 24 galvanized iron cap flashing should be built in the wall as the mason work progresses, not less than 3 inches above the highest point of the Spanish roll. The flashing around piers over sun parlor must extend 8 inches under the tile and 8 inches up against the walls. All flashings are to be painted as mentioned in connection with the tin cap flashing. The finishing color of the tile roof will be done by the painter contractor. All parts of all roofs shall throw the water sharply to the outlets.

Galvanized Iron Cornices, Gutters and Leaders

The cornice on the front and side of main building, including the brackets and paneled soffit, the gutters on the rear of main roof, rear porch and over the first story sun parlor, the return moulds forming the wash at sides of sun parlor, the raking moulds at the ends of the Spanish tile roofs over main cornice and sun parlor, the leaders from the main roof, rear porch and sun parlor are all to be made of No. 24 galvanized sheet iron, with all joints closely riveted with 2-pound tinned rivets and thoroughly sweated with solder, or the leaders are to be grooved and the seams thoroughly sweated by means of soldering after they are made of galvanized iron, or galvanizing after they are made of black sheets.

Fasten Cornices, Gutters, Leaders

The main cornice to be supported to band iron braces, spaced 3 feet apart, made of 1/4 x 1 1/4-inch black band iron, bolted to the cornice with 1/4 x 3/4-inch flat head stove bolts. All gutters to be supported by gutter braces made of 1/4 x 1 1/4-inch band iron, galvanized after they are made. These gutter braces to be spaced 30 inches apart. Leaders to be secured with galvanized malleable iron hinged fasteners, 1 inch off the wall, spaced not over 4 feet apart. All leader openings to be protected with galvanized wire basket strainers. All galvanized iron work, braces, hooks, etc., to receive one coat of red lead in oil on both sides, and allowed to dry thoroughly before being put in position.

Where seams are to be joined together at the building, the painting should be omitted 2 inches from the end at each seam, to allow the seam to be riveted and soldered, after which the seam should be painted. The finishing color on the above galvanized iron work will be done by the painter contractor.

Galvanized Iron Skylights

The skylight on main roof over hall to be of the hipped pattern without a ventilator. The bars and lower curb to be provided with condensation gutters to carry any condensation or leakage to the outside. The skylight over bathroom to be a hipped ventilating skylight, with ridge ventilator and fixed or stationary louvres 15 inches high. These skylights are to be made of No. 24 galvanized sheet iron painted one coat of red lead in oil both in and outside before setting. They are to be glazed with ¼-inch ribbed glass, the ribs placed toward the inside and the glass is to be well set in white lead putty. All puttied joints between the glass and metal to be capped in a manner according to best practice (shown in Fig. 151), using brass bolts which can be easily removed in case of breakage of glass. After the completion of the skylight work, the outside is to receive another coat of red lead.

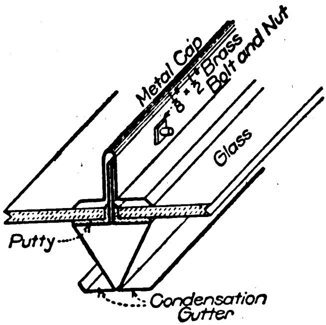


Fig. 151.—Capping Puttied Joint of Skylight

Guarantee

There shall be executed and delivered to the architect, before his signing of the final payment, a written guarantee that all sheet metal work covered by this specification, is free from all defects, both as to workmanship and material, and that should any such defects develop within the space of one year from the date of completion and acceptance of the building, the same shall be made good free of charge to the owner of the building, as witnessed by the signature of the architect to the final payment.

Taking Off the Quantities

Having read over the specifications carefully it is now time to proceed with the taking off of the quantities from the roof plan, front, side and rear elevations in the order in which they occur in the given specifications, the first being tin roofing.

Architects' plans are usually drawn to a scale of ¼ inch to the foot, and scale details are furnished from which accurate measurements can be obtained. The rule usually followed in estimating metal roofing is to make no deduction for openings (chimneys, skylights, ventilators or other objects) if less than 50 square feet in area; if between 50 and 100 square feet, one-half the area is deducted; if over 100 square feet the entire opening is deducted. Flashings for around these openings are figured extra.

The roof plan in Fig. 152 shows that none of the skylights or scuttle opening is over 50 square feet in area, so that the roof will be measured as if it contained no openings at all. Using the scale indicated below the plan, find that the distance from inside to inside of wall measures 18 feet 6 inches. The specification calls for the flashing to turn up not less than 8 inches against walls. As the roof runs on a slope to shed the water, the flashings may average about 12 inches high.

Twelve inches on each side would add 2 feet to width of 18 feet 6 inches, shown in Fig. 152, making the width

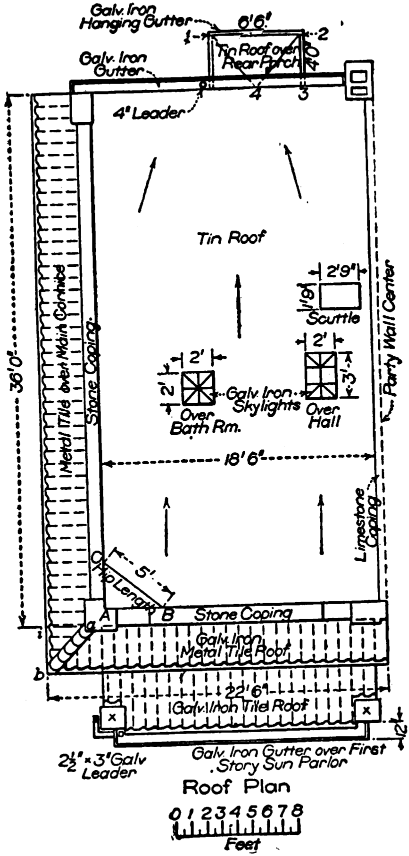


Fig. 152.—Roof Plan

20 feet 6 inches. The length of the roof cannot be accurately obtained from the roof plan, as the slope will add more surface.

The side elevation, Fig. 153, shows the roof line from the inside of the front wall to the edge of the gutter and measures 35 feet; add to this 1 foot for flashing up at the front wall, thus making 36 feet. Then 36 × 20.5 = 738 square feet for main roof. The rear porch roof is hipped and the pitch is 4 feet 3 inches in the side elevation. The plan is given in Fig. 152 by 1 2 4. The distance from

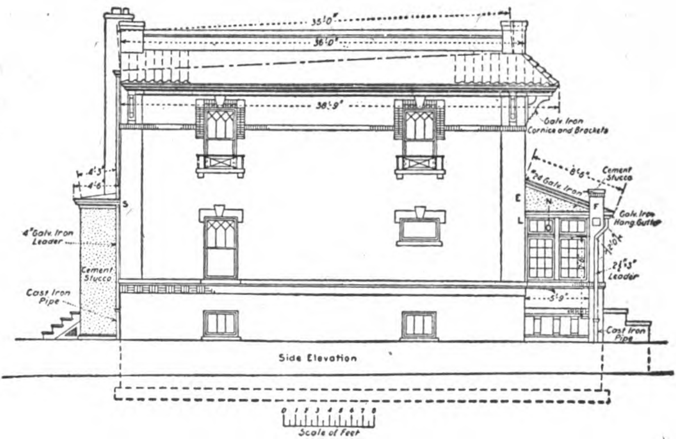


Fig. 153.—Side Elevation

1 to 2 measures 6 feet 6 inches. The area of the front part of this hipped roof is figured as follows:

$\frac{1}{2}$ of $6.5 \times 4.25 = 27.62$. $\frac{27.62}{2} = 13.81$ square feet.

In practical work the fractions are omitted and whole numbers taken, as 14 in this case. The area of the two sides shown by 2 3 4 would be found by scaling the pitch of the sides of the roof shown over the door in Fig. 154, which indicates 3 feet 6 inches.

Again referring to Fig. 152, the sides from 2 to 3 scale

4 feet. Then $4 \times 3.5 = 14$. $\frac{14}{2} = 7$ square feet for each side, or 14 square feet for the two sides. Then 14 square feet for the sides + 14 square feet for the front = 28 square feet of tin roofing on rear porch. To this must be added the flashing which turns up and against the wall. Figuring the two slopes shown, $2 \times 3.5 = 7$ feet, and allowing 1 foot for the width of the flashing, then a flashing 7 feet x 12 inches would be required. Sometimes when the pitch of the roof is not very steep, the area of the roof is found by squaring the dimensions shown in the roof plan. Again the tape measure is run over roof where the measurements will be the longest, as the extra surface will not pay for the extra labor. While this may be quicker, it is not accurate and it is better to do it right.

The specifications call for cap flashing 7 inches wide, 3½ inches on each side. As the length of the roof is 35 feet, the length of the flashing for two walls will be 2×35, 70 feet plus the width of the roof, which is 18 feet 6 inches, or a total of 88 feet 6 inches. The specification calls for the cap flashings to be lapped 3 inches, and where they are stepped they are to project 6 inches over the lower one. Assuming that the cap flashing is made up of five 20-inch sheets, each length of five sheets would average 96 inches with the edges deducted, or 8 feet. As 88 feet 6 inches of cap flashing is required, an average of 11 lengths of 8 feet each would require 11 times 3 inches lap, or 33 inches. The slope of the roof may require 3 stepping of 6-inch projection each, on both sides, or $3 \times 6 \times 2$, or 36 inches. $33 + 36 =$ a total of 69 inches in laps, which would have to be added to the previous length obtained of 88 feet 6 inches. Instead of adding

69 inches for laps, add 72 inches, or 6 feet. Then 6 + 88.5 = 94½ linear feet of cap flashing. Although small roof openings are not allowed for, but as same necessitate cutting up of material.

The flashings around same are figured extra. The skylight curbs measure 2 feet × 2 feet and 2 feet × 3 feet. The average height of this flashing is 9 inches, as shown at the small skylight in Fig. 154. Allowing 1 inch for nailing this flashing to the top of the curb it would be 10 inches high and in length equal to the girth of the skylights, or 19 feet. The scuttle frame is also to be flashed 6 inches high, or 7 inches with nailing flange, and the length or girth is 9 feet 7 inches wide.

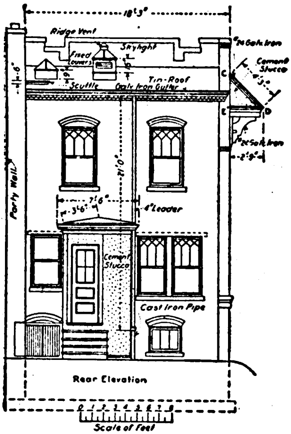


Fig. 154.—Rear Elevation

Quantities for the Tin Roofing

The quantities for the tin roof are therefore as follows: Painting roof boards and side walls under flashing one coat red lead in oil; main and porch roofs, total 766 square feet; and painting tin roofing one coat red lead on under side and two coats on top. There would also be required 94½ feet of 7-inch cap flashing painted with two coats of red lead; 18 feet of 10-inch curb flashing, 9 feet of 7-inch scuttle flashing, and 7 feet of 12-inch rear porch flashing for the job.

Taking Off the Spanish Tile

Reading the specification, the next quantity to be found is the galvanized Spanish tile roofing over the main cornice and sun parlor roof. The sectional view shown at the left of the front elevation in Fig. 155 gives the pitch of the roof over the cornice as 4 feet 6 inches. The extreme length of the front of the metal tile roof is

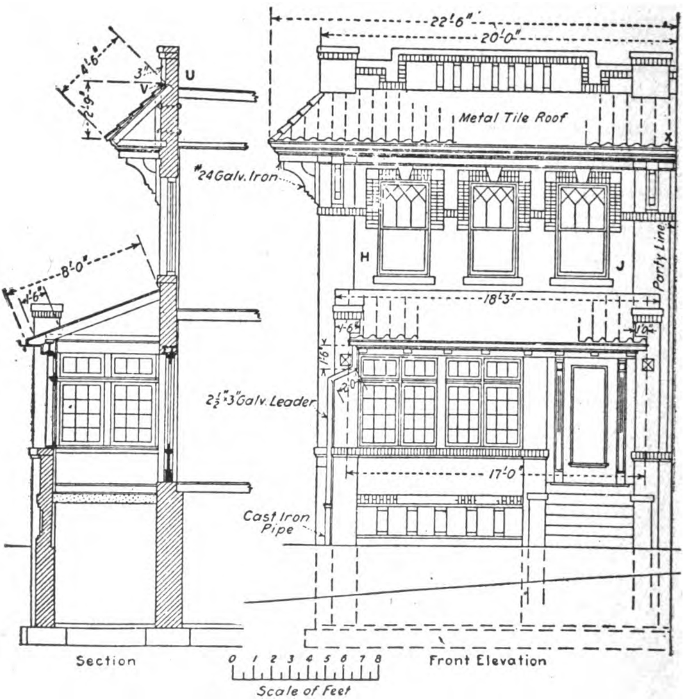


Fig. 155.—Elevation of Front Showing Points from Which Measurements Are Taken

given in Fig. 152 as 22 feet 6 inches, while the outer length of the tile roof on the side is 36 feet to a line drawn from *a*. The reason the measure is taken from *i* or *a* is that the front is measured to the outer corner at *b*, and by multiplying this length of 22 feet 6 inches by the slope of the roof will be the same as if the triangle *a i b* was added to it. To obtain the area of the roof over the main cornice multiply the slope by the length of the front and side roofs, 4.5 × 22.5 = 101.25 square feet and 4.5 × 36 = 162 square feet, and the total is 101.25 + 162 = 264 square feet. To obtain the number of feet of hip roll take the distance *a b* in angle of the roof plan and set it off from any right angle corner in the roof plan as A B. Take the vertical height of the tile roof shown in the section in the front elevation in Fig. 155 as 2 feet 9 inches, and place it on the right angle in roof plan in Fig. 152 from A to C. Scale B C and it will measure 5 feet, the amount of hip roll required.

As the two brick piers X and X at the corners of the roof over the sun parlor occupy a space of less than 50 square feet, no deduction will be made in finding the area of this roof. The section in Fig. 155 gives the slope of the sun parlor roof as 8 feet; the length in the front elevation is 18 feet 3 inches, and 8 × 18.25 = 146 square feet area. The specifications call for a 3-inch galvanized iron flashing over the highest portion of the Spanish tile, so that an 8-inch flashing is safe.

The length of the sun parlor flashing is 18 feet 3 inches, the front cornice flashing 20 feet, and the side cornice flashing is 36 feet. The amount of the recess of the corner piers shown over the roof of the main cornice is 3 inches, as indicated in the sectional view in Fig. 155 at U. This recess cutting the sloping roof at V would measure 4½ inches, or 6 inches in practice. As there are three recesses in the front elevation and two in the side elevation in Fig. 153, then 5 × 6 = 30 inches of flashing. The recess of the pier is 2 inches. This same amount of recess also takes place at H and J in Fig. 155, and its intersection with the sloping line of the sun parlor roof will measure 3 inches. In practice nothing less than 6 inches is figured for small offsets. Then $2 \times 6 = 12$ inches. For the various lapped joints in the flashings just figured 2 feet 6 inches will be allowed. Two more flashings are required around the brick piers over the sun parlor roof. The slope of the roof against the pier measures 1 foot 6 inches as shown in the section, and two times that would be 3 feet. The rear face of the pier shown in the front elevation scales 1 foot 6 inches. Then $2 \times 1.5 = 3$ feet. The front face of the pier is flashed a distance of 1 foot as marked on the right pier in front elevation, $2 \times 1 = 2$ feet. Following the specification, this flashing around the piers must extend up under the tile 8 inches and up against the brick wall 8 inches; allowing the flashing to enter the brick joints, say 2 inches, then 18 inches girth will be required.

Quantities of Tiles and Flashing

The quantity of tile and flashing for the tile roofs can now be summed up as follows: Tile over main cornice, 264 square feet; tile over sun parlor roof, 146 square feet, making a total of 410 square feet. There will also be required 5 feet of hip roll. Flashing having 8 inches girth, of galvanized iron and painted, will be as follows: Over sun parlor roof, 18 feet 3 inches; over front cornice, 20 feet; over side cornice, 36 feet; lapped joints, 2 feet 6 inches; recesses over main cornice, 2 feet 6 inches; recesses over sun parlor, 1 foot, making a total of 80 feet 3 inches. There will also be required 8 feet galvanized iron flashing around piers on sun parlor roof having 18 inches girth.

Taking Off Cornice

The next in order is finding the quantities of the galvanized iron cornice shown on the front and side elevation in Figs. 155 and 153 respectively. In finding the girth of any cornice the dividers are set to a fractional part of an inch of the scale in use, and stepped off along the entire profile to find the true length as previously explained. To obtain an accurate girth from a quarter scale drawing is a very difficult matter when the moldings are complicated and close together, for sometimes the thickness of a line will almost scale one inch.

When accuracy is essential, scale details of the cornice and other ornamental work should be furnished by the architect, from which the quantities are obtained. The scale detail of the main cornice is given in Fig. 156, and shows all that is required to accurately determine the amount of material, that must be known to avoid loss.

Set the dividers equal to ½ inch on the scale from *a* to *b*, and starting from C on the main cornice step off to D. It will be found to contain 114 half-inch steps, or 57 inches, the girth of the main cornice from C to D. In measuring length of cornice the rule is to include the miters. In Fig. 155 the extreme length of the main cornice is 22 feet 6 inches, and in Fig. 153 the side cornice is 38 feet 9 inches, making a total of 61 feet 3 inches. As the girth of this cornice in Fig. 156 is 4 feet 9 inches, then $4.75 \times 61.25 = 290.94$ square feet of No. 24 gauge galvanized iron. There is a return to this cornice shown by E D in the rear elevation in Fig. 154, and this return is 2 feet 9 inches long. There is also a similar return on the right side in the front elevation in Fig. 155 at X. These two returns take up as much material as is indi-

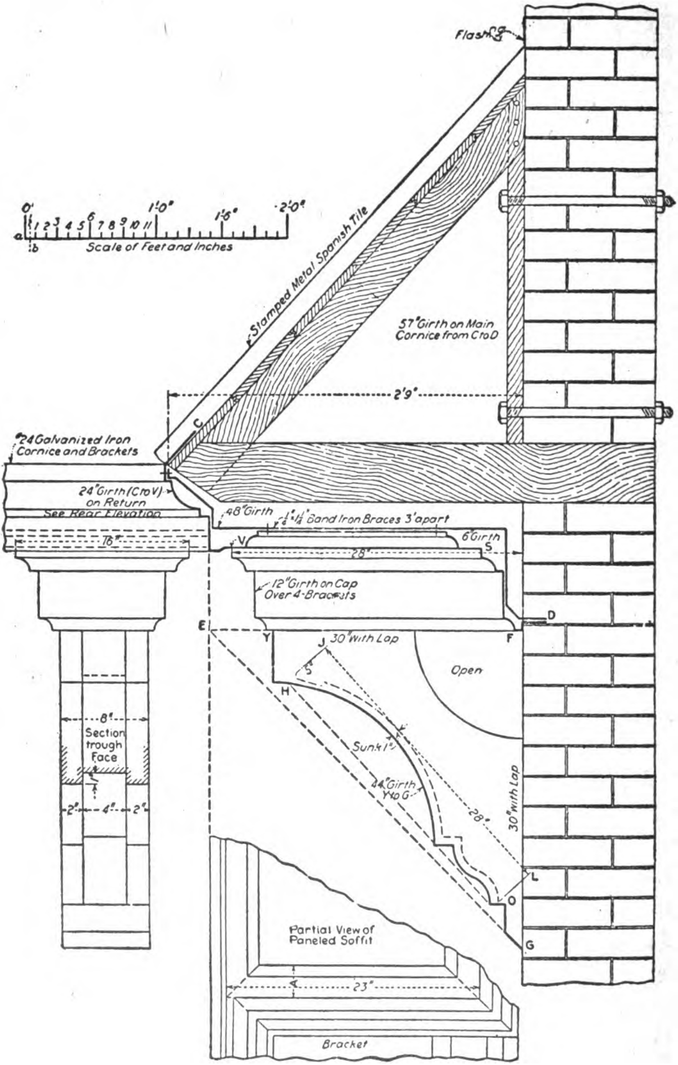


Fig. 156.—Large Details of Main Cornice, Brackets and Paneled Soffit

cated in the detail in Fig. 156 from C to V, and when measured require 21 inches, or 1 foot 9 inches. As the return is 2 feet 9 inches long, then 1 foot 9 inches × 2 feet 9 inches × 2, or in decimals, 1.75 × 2.75 × 2 = 9.62, or 10 square feet of metal.

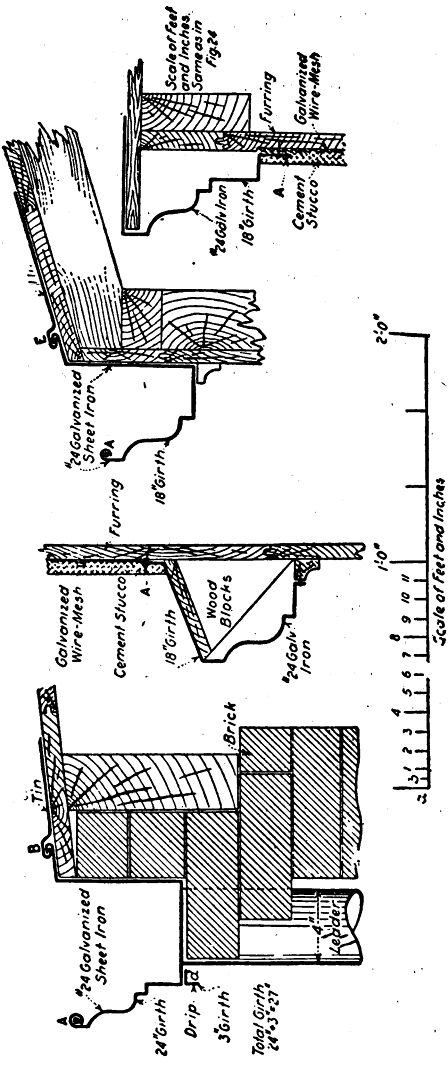
The cornice has a paneled soffit, which is mitered alongside of each bracket as indicated by A. The width of this panel or miter is 23 inches, or in practice 24 inches, or 2 feet. The girth of this panel miter is 6 inches, as shown at S in the sectional detailed view. Two brackets in the side elevation and two in the front elevation and a panel miter are required on each side of the bracket, then 4 × 2 = 8 miters. As each miter is 2 feet long, with a 6-inch girth, then 2 × 0.5 = 1.0 and 8 × 1 = 8 square feet for the panel miters.

The next items to be taken off are the caps and brackets. The girth of the cap from S to F in the detail in Fig. 156 is 12 inches. The extreme length of the cap is 28 inches at the sides and 16 inches on the front. Two sides will be 2 × 28 = 56; 56 + 16 (front) = 72 inches, or 6 feet; as the girth of the cap is 12 inches, then 6 square feet will be required for each bracket cap, multiplied by four brackets, equals 24 square feet. The width of the bracket face is 8 inches and its girth from Y to G is 44 inches, and 8 × 44 = 352 square inches; 4 × 352 = 1,408 square inches, or 9 112/144, or about 10 square feet, for bracket faces.

In estimating the amount of material in the bracket sides, it is always arranged so that two sides can be cut from one piece of metal. Therefore, a diagonal line is drawn from E to G in the section so that it will give a little play outside of the profile to allow for any laps. If these dimensions E F and F G are multiplied by each other, the sum will be the square feet required for two sides. Allowing for laps for riveting and nailing purposes, E F and F G measure 30 inches each. Then $2.5 \times 2.5 = 6.25$ square feet for each bracket, and as there are four brackets, $4 \times 6.25 = 25$ square feet total. The sink strip shown from H to O is cut from one rectangular piece of metal whose dimensions would be 5 x 28 inches, as indicated by H J L O. $5 \times 28 = 140$. As there are two sink strips to each bracket, and there are four brackets, then $8 \times 140 = 1{,}120$ square inches area, $\frac{1120}{144}$ = almost 8 square feet. The total number of square feet of No. 24 gauge galvanized iron required for the main cornice may now be summed up as follows: Main cornice, 290.94 square feet; returns, 10 square feet; panel miters, 8 square feet; bracket caps, 24 square feet; bracket faces, 10 square feet; bracket sides, 25 square feet; sink strips, 8 square feet, making a total of 375.94, or 376 square feet material required.

Gutter and Mold Quantities

Next in order in the specifications is the gutter on main roof. This detail is shown in Fig. 157. Set the dividers say to ½ inch on the scale as from *a* to *b* and step off along the profile and it will be found to require 24 inches girth from A to B. An angular drip is soldered to the bottom of the gutter at *d*; this prevents the water from running back into the brick joints, should the gutter overflow from stoppage of leader by rubbish or ice. Including the drip, 27 inches girth is required for the gutter. The length of the gutter is 18 feet 3 inches. As the girth of the gutter requires 2 feet 3 inches then $18.25 \times 2.25 =$ 41 square feet galvanized iron for rear gutter.



Figs. 157, 158 and 159

Fig. 157.—Detail of Gutter on Main Roof. Figs. 158 and 159.—Details of Gutters and Raking Molds Over Sun Parlor Near Porch and Main Cornice

The specification calls for gutters on rear porch and on roof over sun parlor. This gutter detail is shown in Fig. 158. Again setting the dividers, say to ½ inch as *a b* on the scale, step off the girth from A to E which will measure 18 inches. The length of the gutter over the sun parlor is 17 feet, as shown in Fig. 155, and there is also a return on each side of 1 foot 0 inch as shown in the roof plan in Fig. 152, which makes 19 feet. As the girth required is 1 foot 6 inches then $1.5 \times 19 = 28.5$ square feet galvanized iron. The front of the rear porch gutter measures 7 feet 6 inches. The side of the rear porch gutter is 4 feet 6 inches. As there are two sides, then $2 \times 4.5 = 9 + 7.5$ (front gutter) = 16 feet 6 inches. As this gutter has a girth of 18 inches, as shown in the detail in Fig. 158, then $1.5 \times 16.5 = 24.75$ square feet metal.

The quantity of the return molds at the sides of the sun parlor shown by N O in the side elevation in Fig. 153 are the next to be estimated. This detail is shown in Fig. 158 and has a similar mold as the gutter to the right, but forms a wash and flange under the cement stucco as shown. This mold has an 18-inch girth and is 5 feet 9 inches long scaled from L to F in Fig. 153. As there is a return on each side, then 2 × 5 feet 9 inches = 11 feet 6 inches. As the girth is 18 inches, then $1.5 \times 11.5 = 17.25$ square feet of material is required.

The quantity in the raking molds at the ends of the Spanish tile roofs over main cornice and sun parlor are next to be estimated. The detail of this mold is shown in Fig. 159. Scaling it the girth measures 18 inches. The length of the raking mold over the sun parlor is 8 feet 6 inches, no deduction being made for the brick pier on account of the waste in trimming. There is a mold on each side, thus making the lengths twice 8 feet 6 inches or 17 feet. 17 × 1.5 = 25.5 square feet of metal. The other raking mold over the cornice having the same girth is 4 feet 3 inches long, as shown in Fig. 154, from C to D. This same rake mold will be placed on the opposite end of the main cornice as at X in Fig. 155. Thus 2 × 4 feet 3 inches = 8 feet 6 inches × the girth = 8.5 × 1.5 = 12.75 square feet metal.

Leader Quantities

The amount of leaders required are next in order. Referring to the roof plan in Fig. 152 a 4-inch diameter leader is required from the main roof gutter, and to this leader the gutter on the rear porch is connected. There is also a 2½ × 3-inch leader required from the gutter over the sun parlor. Referring to Fig. 154 the amount of leader required scales 21 feet. Allow 6 inches for laps and connection to the cast-iron drain pipe which is put in by the plumber.

In measuring the 2½ × 3-inch leader from the sun parlor gutter, all elbows should be measured from their extreme points and extras charged for time and labor where considerable fitting is required as in this case. Referring to Fig. 155, the two arms of the elbow scale 1 foot 6 inches and 2 feet, respectively, and Fig. 153 shows another elbow of 2 feet and a vertical length connecting to the cast-iron pipe of 7 feet 6 inches. The total then is 1 foot 6 inches + 2 + 2 + 7 feet 6 inches = 13 feet of 2½ × 3 inches galvanized iron leader of No. 24 gage.

Amount of Band Iron Braces and Leader Hooks

Finding the number of linear feet of band iron braces for the cornices is next in order. The cornice detail in Fig. 156 shows that band iron braces inside of the cornice are to be used and made from $\frac{1}{4} \times 1\frac{1}{4}$-inch band iron. They will be spaced 3 feet apart, and each brace requires a girth of 4 feet. As there is 56 feet of cornice requiring bracing then $56 \div 3 = 19$ or 19 braces. As each brace is 4 feet long, then $19 \times 4 = 76$ feet band iron.

The gutter braces are to be spaced 30 inches apart. Then seven gutter braces 12 inches long will be required for the main gutter shown in Fig. 154; ten braces for the gutter on the rear porch, three on each side and four in the front and seven braces across the gutter of sun parlor, each 8 inches long. Four 4-inch malleable iron galvanized hinged hooks will be required for the main leader and two $2\frac{1}{2} \times 3$-inch hinged hooks for the leader for the sun parlor roof.

Three 4-inch galvanized wire basket strainers will also be needed, one for the main outlet, one for the porch outlet and another for the sun parlor outlet.

Summary of Gutter, Mold and Leader Quantities

The materials just estimated can be summed up as follows:

For gutter on main roof, 41 square feet; sun parlor, 28.50 square feet; rear porch, 24.75 square feet; molded wash on sun parlor, 17.25 square feet; raking molds on sun parlor, 25.50 square feet; raking molds on main cornice, 12.75 square feet, making a total of 149.75 square feet. The sum of the leaders required are 21 feet 6 inches of 4-inch galvanized iron leaders of No. 24 gauge; 13 feet of $2\frac{1}{2}$ x 3-inch galvanized iron leaders of No. 24 gauge.

Braces and hooks required are 76 feet of $\frac{1}{4}$ x $1\frac{1}{4}$-inch band iron for cornice braces. Seven gutter braces for main gutter, 12 inches long. Seventeen gutter braces for porch and sun parlor, 8 inches long. Four 4-inch galvanized iron hinged leader hooks. Two 2½ x 3-inch galvanized iron hinged leader hooks. Three 4-inch galvanized wire baskets over leaders.

Amount of Skylights

The last item to be estimated are the skylights shown on the roof plan Fig. 152. The one over the hall is 2 x 3 feet and contains 6 square feet of hipped skylight without any ventilator or louvers, as indicated in Fig. 154. The skylight over the bathroom measures 2 x 2 feet, as shown in Fig. 152, and contains 4 square feet of hipped skylight with a ridge ventilator, as shown in Fig. 154. It will be noticed that this skylight has fixed louvers 15 inches high. As each side of the skylight is 2 feet, then $4 \times 2 = 8$ and $8 \times 1.25 = 10$ square feet of louver surface.

A summary of the entire quantities for the job in question follows:

Tin Roofing Summary

M. F. Brand, 14 ×20 inches tin; cleated, 32 pounds coating; one coat of red lead on under side, two coats on top. Main building and rear porch, 766 square feet. As this roofing is to be edged ⅜ inch, each sheet of 14 × 20-inch tin will have an exposing surface of 243 square inches. As each square foot contains 12 × 12 or 144 square inches, then 766 square feet will contain $766 \times 144 = 110{,}304$ square inches. As one sheet of ⅜-inch edged tin covers 243 square inches of surface, then to cover 110,304 square inches will require $\frac{110{,}304}{243} = 454$ sheets. There are further required 766 square feet of painting of roof sheathing, 94½ linear feet of cap flashing, 7 inches girth, painted two coats of red lead in oil on both sides, 18 linear feet of skylight curb flashing, 10 inches girth, one coat red lead on under side, two on top, 9 linear feet of scuttle flashing, 7 inches girth and 7 linear feet of rear porch flashing—12 inches girth—painted as above.

It will be found that 42 sheets are required for flashing and 6 sheets for cleats, making a total of 502 sheets.

Summary of Galvanized Iron Tile Roofing

410 square feet of No. 24 galvanized iron stamped tile painted one coat of red lead on under side and one coat on top.

5 linear feet of galvanized iron hip roll painted same as above.

The prices per square foot of the stamped metal tile can be obtained from dealers.

$80\frac{1}{4}$ linear feet of No. 24 gauge galvanized iron flashing, having 8 inches girth, painted two coats on both sides.

8 linear feet of flashing, 18 inches girth, painted as above.

The flashing above mentioned would contain $80\frac{1}{4}$ feet $\times$ 12 inches or 963 linear inches; this multiplied by the girth of 8 inches would be $963 \times 8 = 7{,}704$ square inches. 8 feet $\times$ 12 inches $= 96$ linear inches. $96 \times 18 = 1{,}728$ square inches. $1{,}728 + 7{,}704 = 9{,}432$ square inches. Divide this by 144, the number of square inches to the foot, then $\frac{9432}{144} = 66$ square feet. As each square foot of No. 24 gauge galvanized iron weighs 18.5 ounces, then $66 \times 18.5 = 1{,}221$ ounces. Divide this by 16: thus, $\frac{1221}{16} = 76$ pounds of metal.

Summary of Molds, Main Cornice and Gutters

376 square feet of No. 24 gauge galvanized iron cornice painted one coat of red lead on each side.

41 square feet of similar material on main gutter, painted as above.

28.50 square feet of similar material (painted) on sun parlor gutter.

24.75 square feet of similar material (painted) on rear porch gutter.

17.25 square feet of similar material (painted) on returns on sun parlor.

25.50 square feet of similar material (painted) on rake molds for sun parlor.

12.75 square feet of similar material (painted) on rake molds for cornice.

Adding this together is 525.75 square feet. Multiply this amount by 18.5, the number of ounces in a square foot of No. 24 gauge galvanized iron. Then $525.75 \times 18.5 = 9{,}727$ ounces. Divide this by 16 thus, $\frac{9727}{16} =$ 608 pounds of galvanized iron.

Summary of No. 24 Gauge Galvanized Iron Leaders

21 feet x 6 inches of 4-inch round leader from main building.

13 feet of 2½ x 3-inch leader from sun parlor roof.

Four 4-inch galvanized iron hinged leader hooks.

Two 2½ x 3-inch galvanized iron hinged leader hooks.

Three 4-inch galvanized wire basket strainers.

Summary of Cornice and Gutter Braces

76 linear feet of band iron ¼ x 1¼ inches for cornice braces (black).

7 linear feet of band iron $\frac{1}{4}$ x $1\frac{1}{4}$ inches for main gutter (galvanized).

12 linear feet of band iron $\frac{1}{4}$ x $1\frac{1}{4}$ inches for porch and sun parlor (galvanized), making a total of 95 linear feet. As each foot of $\frac{1}{4}$ x $1\frac{1}{4}$-inch band iron weighs 1.04 pounds, then $95 \times 1.04 = 99$ pounds of metal.

Summary of Hipped Skylights

6 square feet hipped galvanized iron skylight, No. 24 gauge, glazed with $\frac{1}{4}$ ribbed glass.

4 square feet of hipped skylight with ridge ventilator of similar material and glazing.

10 square feet area of louvers (stationary). All above skylight work painted one coat red lead on both sides and on completion of the glazing another coat on the outside.

Having found all the quantities from the plans and elevations according to the specifications, the prices must be made to suit different locations. Wages vary in different parts of the country and the ability to turn out work quickly depends upon the facilities at hand.

Compiling the Estimate

After having summarized the material required, it would be necessary to ascertain the waste material to be expected, by comparing the required sizes with the obtainable commercial sizes, and price the material. It must also be determined by the estimator which parts are to be bought and which are to be made in the shop. This refers to leader pipe, gutter, cornice parts, etc. The necessary price quotations must be obtained and all details which have bearing on the final pricing of the job must be clearly set forth in the estimate, so that the estimate may easily be refigured for any of the items, if it should be necessary to revise the estimate. The next step, after having disposed of cost of material, would be to estimate the labor cost. In order to do so, the estimator must in his mind picture the manner in which the job would have to be handled efficiently, also determine which part of the work would better be handled and prepared in the shop, and which parts must be done at the building. For some jobs it is most economical to provide in or near the building a separate shop, where the necessary machinery is installed (break, rollers, square-shear, etc.), while in other cases this may not be practical. The same principal which was followed in taking off and summarizing the amount of material required, must be applied in "taking off labor cost." For this purpose the estimator must analyze labor operations, that is, he must make a list of all labor items for the different parts of the work and then summarize the labor items. For this purpose the estimator must possess a thorough practical knowledge of the work. If necessary, however (and this is probably advisable in every case), the estimator should consult his partner or foreman as to the manner the job is to be handled and the number of working hours required for the different items. If possible, the estimator should visit the site of the building and thereby obtain knowledge of local conditions, which may have an influence upon the more or less smooth handling and executing of the job. There is often much time lost through delays by other mechanics. The estimator should take in consideration the reputation of the general contractor and all other sub-contractors to be employed at the building as to their manner in executing work. For any difficulties or delays to be expected, a special risk allowance should be included in the estimate. In our sample estimates all these points are illustrated. It will be noticed that the labor items are minutely analyzed. In practice it may often not be necessary to do this to such extent. The time set in the sample estimates for labor is only illustrative. The object here is to show how to include the figures in the estimate, without intending to set a certain standard rate of labor time for any work. The same applies to the rates of wages figured. If in our sample estimates a wage rate of 65 cents is figured, this is presumed to be the approximate average rate paid on this job.

ESTIMATE No. 34

for roofing, cornice, gutters and leaders, as per plans and specifications prepared by architect..................................

....

for Mr. John Smith..................at....................

Tin Roofing

Material:		
M. F. brand tin, 32 pounds coating Total required 502 sheets (See Page 271)		
One box of 112 sheets covers net 189 square feet, therefore required 4½ boxes, quoted by Bergerson Co., at $13.00....................................		$58.50
2,000 1-inch tinned nails, about 7 pounds, from our stock, per pound 15 cents........................		1.05
Paint for roof boards and side walls, roofing and flashing (one gallon covers about 325 square feet); total surface to be painted about 4,000 square feet therefore required: 12 gallons, quoted by M. C. Michals at $2.50.......		30.00
Solder (there is about 1,500 feet soldering to be done), 2 pounds per 100 feet soldering, therefore total required: 30 pounds 50/50% grade, from our stock at 40 cents..		12.00
Total material for tin roofing and flashing........		$101.55
Labor:		
Shopwork:		
Notching and edging sheets..............	5 hours	
Making cleats..........................	4 "	
Bending flashing, including soldering, into suitable lengths......................	5 "	
Painting flashing and sheets..............	6 "	
Total shop work......................	20 hours	

At 65 cents		13.00
Building work:		
Painting roof boards and side walls	7½ hours	
Laying sheets	15 "	
Attending having cap flashing put on by mason	2½ "	
Laying flashing	4 "	
Soldering sheets and flashing seams	10 "	
Cleaning roof	1½ "	
Painting roof, first coat	4 "	
Painting roof, second coat	5 "	
Total building work	49½ hours	
At 65 cents		32.18
Total prime cost		$146.73
Cartage from shop to job and return		5.00
		$151.73

Overhead expenses:

Operating, administration and general expenses:		
Shop work, 20 hours at 41 cents	$ 8.20	
Building work, 49½ hours at 62 cents	30.69	
Merchandise expense:		
8½% of $101.55	8.63	
Extra for solder risk:		
2% of $12.00	.24	$47.76
		$199.49
Selling expenses:		
5% of $199.59		9.97
Total cost of tin roofing and flashing		$209.46

Main Cornice, Molds and Gutters

According to schedule on page 273 there are required for the main cornice	376	square feet
and for the gutters, returns and molds	149¾	"
Total	525¾	square feet

of No. 24 gauge galvanized iron. In checking up sizes it will be found that it would be necessary to use:

Material:

Sheet iron for the cornice:		
19 sheets 30 x 96 inches, totaling	380	square feet
3 sheets 24 x 96 inches, totaling	48	"
For the main gutter:		
3 sheets 30 x 96 inches, totaling	60	"
For the other gutters, returns and mold:		
5 sheets 36 x 96 inches, totaling	120	"
	608	square feet
Net requirements as above	525¾	"
Leaving waste of	82¼	square feet

which we shall charge to the job at half its value.

Cost of sheet iron, as per quotation from Bergerson Co., at 7 cents per pound (608 square feet, weighing 703 pounds)	$49.21
Less waste 82¼ square feet = 95 pounds, at 3½ cents	3.32
net	$45.89
Paint (total surface to be covered about 1,050 square feet); 1 gallon for 325 square feet; 3¼ gallons at $2.50	8.10
Band iron, black, 1¼ x ¼ inch, 95 feet = 99 pounds, quoted by Ericson Co. at 4 cents	3.96
Solder (50/50% quality). There are about 275 feet of soldering to be done. Required about 1 pound for 5 feet soldering, 55 pounds at 40 cents	22.00
100 flat-head brass bolts, ¾ x ¼ inches	1.25
1,000 tinned nails, about 3½ pounds, at 15 cents	.53
Galvanizing 20 pounds of band iron for gutter hangers, quoted by J. P. Garret	2.00
Total material	$83.73

Labor.

Shopwork:

On main cornice:			
Cutting sheets	2	hours	
Cutting mitres	2½	"	
Bending sheets (10 sections)	10	"	
Assembling cornice into sections	26	"	
Cutting bracket caps	5	"	
Bending bracket caps	3	"	
Cutting brackets	4	"	
Cutting soffit panels	8	"	
Assembling caps brackets and soffits	24	"	
Cutting and bending braces	2	"	
Adjusting braces to cornice	5	"	
Painting cornice	3	"	
On main gutters:			
Marking sheets and bending same	2½	"	
Marking and bending drip	½	"	
Cutting and putting together mitre and flat ends; Setting gutter together into 2 sections	3½	"	
Painting gutter	1½	"	
Making and putting in leader tube	1	"	
On sun parlor and rear porch gutter:			
Marking and cutting sheets and cutting mitres	2½	"	
Bending (8 sections)	4	"	
Putting together into 3 sections; Making and putting in leader tubes and 4 flat ends	9	"	
Painting gutter	2½	"	
Return molds for sun parlor:			
Marking sheets, bending and painting	3	"	
Rake moulds:			
Marking sheets, bending and putting together	4	"	
Painting	1½	"	
Total shopwork	130	hours	
At 65 cents			$84.50

Building work:

Hanging cornice and joining seams	24	hours	
Hanging gutters	7	"	
Putting on returns and rake moulds	6	"	
	37	hours	
At 65 cents			$24.05

Summary

Material	$83.73
Shop labor	84.50
Building labor	24.05
Total prime cost	$192.28
Transportation from shop to building and return	8.00
Overhead expenses:	
Operating, administration and general expenses:	
Shopwork, 130 hours at 41 cents	53.30
Building work, 37 hours at 62 cents	22.94
Merchandise expenses:	
8½% of $83.73	7.12
Extra for solder risk:	
2% of $22.00	.44
Extra risk for hanging cornice and rake moulds on same, 27 hours at 25 cents	6.75
	$290.83
Selling expenses, 5%	14.54
Total cost of cornice, gutters and moulds	$305.37

Spanish Tile Roofing

As preliminary information regarding the Spanish Tile Roofing, the manufacturer of the tile states that 150 tiles are required to cover 1 square (109 square feet) of roof surface. The hip roll is made in 18-inch lengths, to be laid 12 inches to the weather. The cost for No. 24 gauge tile is as follows:

150 tiles, sufficient to cover 100 square feet	$30.00
Therefore, per square foot covering	.30
Hiproll, per piece, covering 1 foot	.35

Material:		
Tile for main cornice roof	264 square feet	
sun-parlor roof	146 "	
	410 square feet	
At 30 cents per foot		$123.00
Hiproll for main cornice roof, 5 feet at 35 cents		1.75
Flashing over main cornice, 80¼ feet, 8-inch girth	54 square feet	
Flashing over sun parlor, 8 feet, 18-inch girth	12 "	
	66 square feet	
76 pounds, at 7 cents		5.32
Paint for tile and hiproll, both sides one coat	2 gallons	
flashing, both sides two coats	1 "	
	3 gallons	
At $2.50		7.50
Solder, for flashing, 3 pounds at 40 cents		1.20
Nails, 6 pounds at 15 cents per pound		.90
Roof cement, 12½ pounds, tin		1.25
		$140.92
Freight and cartage of tile to shop and to building		5.00
Total cost of material		$145.92

Labor:		
Shop work:		
Cutting and bending flashing	2 hours	
Painting flashing both sides, two coats	2 "	
Painting tile and hip roll (dipping into paint)	3 "	
	7 hours	
At 65 cents		4.55
Building work:		
Putting on flashing	8 hours	
Putting on tiles and hiprolls	12 "	
	20 hours	
At 65 cents		13.00
Total prime cost		$163.47
Overhead expenses:		
Operating, administration and general expenses:		
Shop work, 7 hours at 41 cents	$2.87	
Building work, 20 hours at 62 cents	12.40	
Merchandise expenses:		
8½% of $145.92	12.51	
Extra risk for building work on slanting roof over main cornice, 7 hours at 25 cents	1.75	29.53
		$193.00
Selling expenses, 5%		9.65
Total cost of Spanish tile roofs		$202.65

Leaders

Material: There are required, as per schedule, 21½ feet 4-inch grooved, and galvanized after made, round leader pipe. This can be bought to best advantage ready made. It is purchasable in 10-foot lengths. The missing 1½ feet can be made up in the shop. This piece will be made grooved and soldered. There are further needed 13 feet 2½ x 3-inch square leader, which is of odd size and must be made in the shop. (The regular commercial size is 2¼ x 3¼ inches). The girt of this leader is about 12 inches, therefore required 13 square feet.

Material:		
13 square feet, about 15 pounds gauge No. 24 galvanized iron, at 7 cents		$1.05
20 feet 4-inch round grooved leader, No. 24 gauge, list price per foot, 35 cents	$7.00	
Current market discount, 50 and 10%	3.85	3.15
2 pounds galvanized iron for 1½ feet additional round leader at 7 cents		.14
4 4-inch galvanized iron hooks, hinged, quoted by Bergerson Co		.60
2 2½ x 3 inch square hinged hooks, quoted by Bergerson Co		.36
3 wire baskets, quoted by Bergerson Co		.75
4 pounds galvanized iron for leader tubes at 7 cents		.28
6 pounds 50/50 solder for leader and tubes at 40 cents		2.40
¼ gallon paint for leader		.60
Total material for leader		$9.33

Labor:	
Shop work:	
Making 1½ feet round and 13 feet of square leader, including painting, 3½ hours at 65 cents.........	2.28
Building work:	
Putting in hooks, making elbows and connections for and hanging of leader pipes, 8 hours at 65 cents....	5.20
Total prime cost..............................	$16.81
Overhead expenses:	
Operating, general and administration expenses:	
Shopwork, 3½ hours x 41 cents....................	1.44
Building work, 8 hours x 62 cents..................	4.96
Merchandise expenses:	
8½% of $9.33..................................	.80
Extra risk on solder:	
2% of $2.40..................................	.05
	$24.06
Selling expenses, 5%.............................	1.20
Total cost of leaders...........................	$25.26
(Transportation to building disregarded, as this charge will be nominal.)	
Summary of entire work on building without skylights:	
Tin roof..	$209.46
Cornice, molds and gutters.........................	305.37
Spanish tile......................................	202.65
Leaders..	25.26
	$742.74
Add profit.	

The figuring of cost of the skylights shown on the plans is here omitted. The reader is referred to the previous chapter, where the method of estimating skylights is sufficiently explained.

Soldering flux of any kind and charcoal are here not figured in Prime Cost, but are taken care of in Overhead Expenses under Heading "Operating Supplies."

CHAPTER XVII

ESTIMATING SHEET METAL WORK FOR BUILDINGS

Second Example: A Hipped Roof Frame and Stucco Building

In this part, which will cover illustrations from Figs. 160 to 174 inclusive, will be shown how quantities are estimated when the roofs are hipped and are to be covered with either standing seam or batten roofing or when they are to be covered with slate or tile.

When the roofs are to be covered with either standing seam or batten roofing, it is only necessary to find the various areas. If the roofs are to be covered with slate or tile, the areas of the roofs must be obtained, as well as the true lengths of the hips, ridges and valleys.

In finding the various quantities from the drawings which will follow, assume that three alternate bids are required. The first, when the roof is to be covered with standing seam roofing; the second, when batten roofing is desired, and the third, when the roof is to be covered with either slate or tile, and the ridges, valleys and hips are to be covered with metal.

The following is a typical specification for the job in question.

Specifications

Specifications of material and labor required in the erection and completion of the sheet metal work and roofing on building for John Smith, in strict accordance with the accompanying drawings and these specifications. The drawings and these specifications are intended to co-operate with, and form part of, these specifications. The figures and dimensions shown on drawings shall be taken in preference to measurements by scale, and when two drawings of the same part on different scales disagree, the preference shall be given to the drawing on the larger scale.

The work shall be under the supervision of the archi-

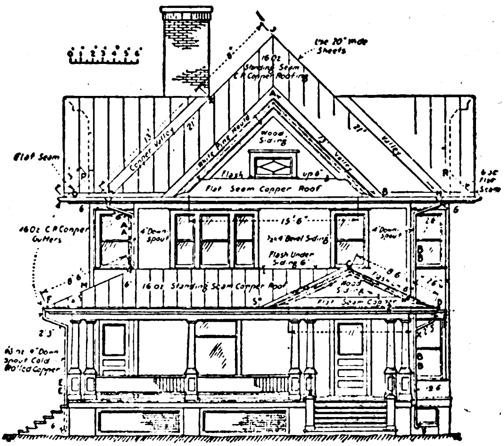


Fig. 160.—Front Elevation for Taking Off Material Quantities

tect who will have the power to order the removal of any defective work or material.

The contract shall provide a sufficient force of skilled mechanics and proper materials to insure the completion of the work at the time specified in the contract. Each contractor is to furnish his own scaffolding.

Cover the roofs of the main building, extension and porch with double-locked standing seam copper roofing laid as to show 1 inch of finished standing seam. All cross seams are to be locked ½ inch, being careful to tin the edges on both sides 1½ inches wide before edging. All copper sheets to be 20 x 96 inches in size, of 16 ounce cold rolled copper, cleated every 18 inches on the standing seam and two cleats in every cross seam, absolutely no nails are to be driven through the copper sheets. The steep part of all roofs under all gables on the entire building to be laid flat seam as indicated in the elevations. All locks are to be ½ inch wide, the sheets tinned 1½ inches on both sides before edging. All sheets are to be cleated 12 inches apart with 1 x 1½-inch cleats fastened with 1-inch copper nails. Flash up not less than 6 inches under all siding, which abuts roofing all as indicated on the elevations. The flat sheets to be laid 24 inches wide by the full depth of the wash. In other words, no horizontal seams are to show, except where connection is made to the gutter.

The saddle behind the chimney to be covered with flat copper of the same quality and weight. Where flashings adjoin chimney, flash up not less than 12 inches.

All eave gutters to be made of 16-ounce cold-rolled copper not less than 5 inches in diameter, as will be shown on scale details. The gutter to have a ⅜-inch beaded edge, with a tinned lock at the back, cleated every 18 inches and supported every 3 feet with ⅛ x 1-inch band brass braces. The lower brace is to be countersunk into the roof board as indicated on the detail of that part, and supported by an upper brass brace, as will be shown on the scale detail. The brass braces to be secured with No. 14 brass screws and bolts and all joints in the copper gutters to be riveted with 1-pound copper rivets, spaced 2 inches apart.

Sweat all copper joints with one-half and one-half solder, composed of 50 tin and 50 lead, new metals. Use "killed acid" as a flux for the hanging gutters and leader work, and rosin as a flux for the roofing, valleys and flashing.

All down spout and leaders to be 4 inches in diameter, made of 16-ounce cold-rolled copper, corrugated.

The leaders to have a copper wire strainer over each

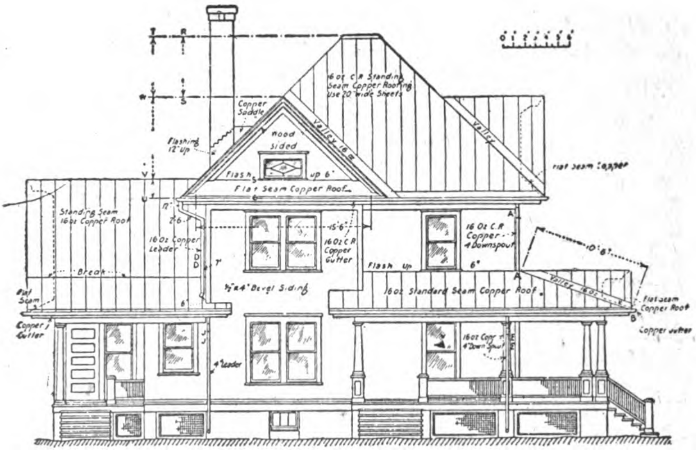


Fig. 161.—Left Side Elevation of Building

inlet and secured with hinged bronze fasteners of the design to be shown on the detail. Space the leader fasteners so that two fasteners will be required on each run of leader on the second story, three fasteners to each run on the first story and four fasteners on the long run from the main roof gutter to the ground, as shown on the right side elevation. Grade all gutters to the leader outlets as shown on the roof plans.

Procedure for Taking Off the Quantities

Before proceeding to take off the quantities the estimator should be familiar with the plans he is to figure on. The roof plan should be laid in the center of the table and the various elevations placed toward the proper sides shown on the plan. A glance at the various elevations and plan at once forms a mental picture of the general outline of the work on which a bid is to be given.

This part of the estimating series shows the plans and elevations of a country residence having hipped roofs, gables and sloping porch roofs. The various plans and elevations will be as follows: The front elevation, the left side elevation, the rear elevation, the right side elevation, the second-story plan showing roofs over porch and kitchen, the roof plan of the main building, and the various details to be explained.

Taking Off the Gutter Quantities

The first quantities to be taken of the plans will be the gutters on the porch roof, kitchen roof and main roof. Referring to the front elevation in Fig. 160 it will be noticed that the hanging gutter runs through the entire width of the main and porch roofs, passing under the gables and connecting to the flat seam roofing over the wash at the foot of the gables. The left side elevation in Fig. 161 also shows the run of the gutters, with their projections over the building line at the end of the porch and kitchen roofs. The right side elevation in Fig. 162 shows the main roof gutter, also the gutters on the returns of the front porch roof and rear kitchen roof. The rear elevation in Fig. 163 shows the main roof gutter intersecting the kitchen roof, also the gutter along the wash under the foot of the gable over kitchen. Measurements will be taken from the roof plans over porch, kitchen and main roofs. The original plans of this residence were drawn to a scale of ¼ inch to the foot, the usual scale employed from which measurements are taken. The drawings shown herewith have been reduced to the scale shown on each elevation.

Using the scale rule according to the scale in use, as

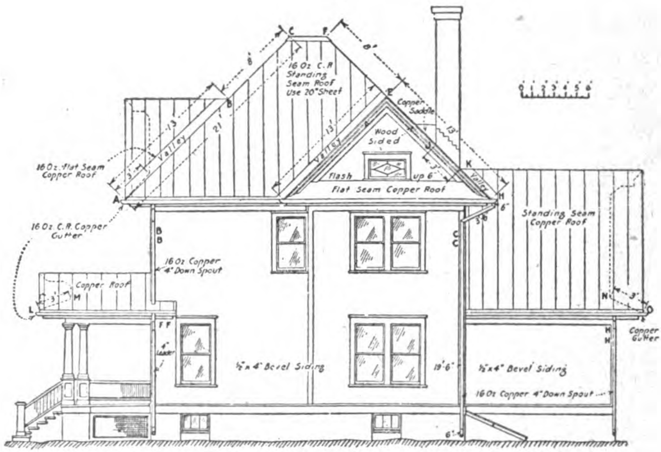


Fig. 162.—Right Side Elevation of Building

shown on the various elevations, measure the lengths of the various gutters shown on the plan in Fig. 164, as from A to B, which scales 11 feet 6 inches; B to C, 35 feet 0 inch; C to D, 26 feet 6 inches; always measuring to the extreme projection of the gutter, as shown, which makes up for the flat heads which must be placed at the ends of the gutter. There are 11 feet 6 inches + 35 feet + 26 feet 6 inches = 73 feet of gutter on porch roof.

Scaling the gutter over the kitchen roof, there are 19 feet from E to F; 32 feet from F to G, and 16 feet 6 inches from G to H. Then 19 feet + 32 feet + 16 feet 6 inches = 67 feet 6 inches of gutter over kitchen roof.

Referring to the roof plan in Fig. 165, and using the scale there indicated, there are 31 feet 6 inches on the front from A to B; 14 feet from B to C; 3 feet 6 inches from C to D; 20 feet from D to E; 17 feet from E to F; 17 feet from G to H; 20 feet from H to J; 3 feet 6 inches from J to L; and 14 feet from L to A. This makes total for the gutter for main building of 140 feet 6 inches, as follows:

A to B	31	feet	6	inches
B to C	14	"	0	"
C to D	3	"	6	"
D to E	20	"	0	"
E to F	17	"	0	"
G to H	17	"	0	"
H to J	20	"	0	"
J to L	3	"	6	"
L to A	14	"	0	"
Or	140	feet	6	inches

The entire amount of gutter may now be summed up as follows:

73 feet 0 inch on porch roof
67 feet 6 inches on kitchen roof
140 feet 6 inches on main roof

or 281 feet in all.

Construction of Gutters

All of these gutters are to be put up and constructed as shown in the details in Figs. 166 and 167, the former showing the detail of the gutter on the main roof, and the latter the detail of the gutter over the porch roof and extension, or kitchen roof. As shown in Figs. 166 and 167, and as called for in the specifications, the lower edge of the roof boards is cut out to accommodate the braces, ⅛ inch deep by 1 inch wide, spaced 36 inches apart, as specified. The lower braces, A, in either diagram, are first screwed to the roof boards, as shown, using two No. 14 1-inch brass wood screws, being careful to countersink

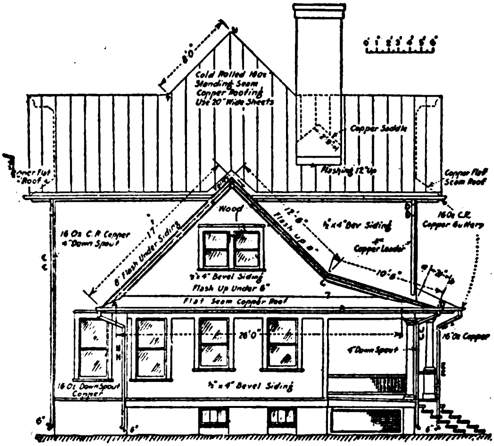


Fig. 163.—Rear Elevation of Country Residence

the top of the brass brace so that a smooth, flat surface on the top results.

After these braces are screwed in their proper positions, and graded properly to the leader outlets, the copper gutter is set in as shown, with a lock at *b*, to which the standing seam is locked, being careful (specified) to fasten all locks with cleats, driving no nails whatever through any metal work.

The copper gutters being in position, the top brace, indicated in both Figs. 166 and 167 by B, is placed in position, bolting with a brass bolt through the metal gutter to the outer brace at C, and fastening to the roof

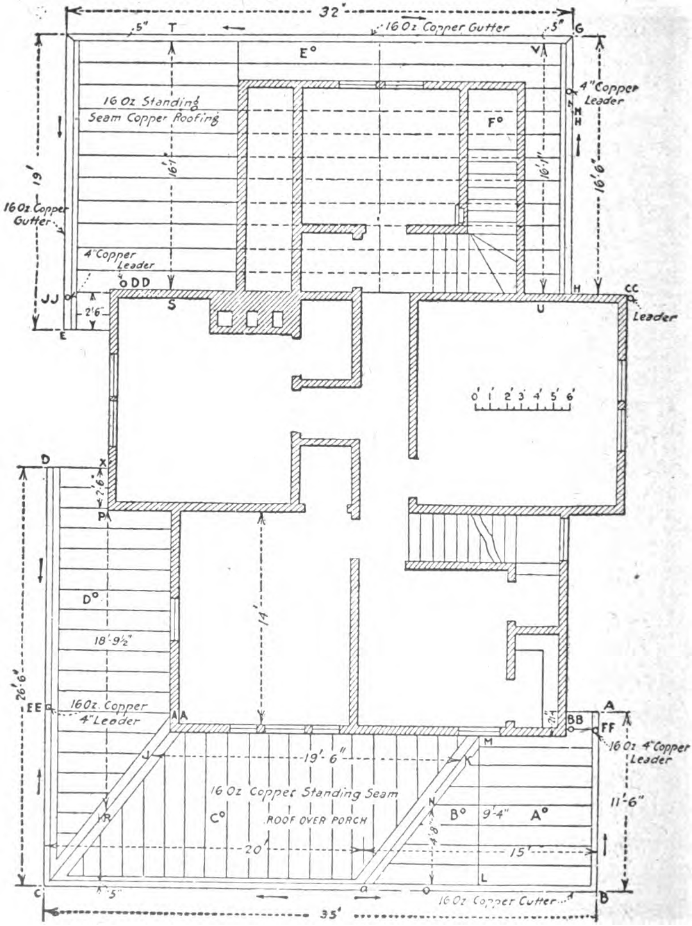


Fig. 164.—Roof Plan of Porch and Kitchen

boards with a No. 14 1¼-inch brass wood screw, the screw passing through a hole previously punched in the lower brace before securing it to the roof board. The hole in the top brace at D is also countersunk. On the top brace, at B, in both Figs. 166 and 167, a twist is made

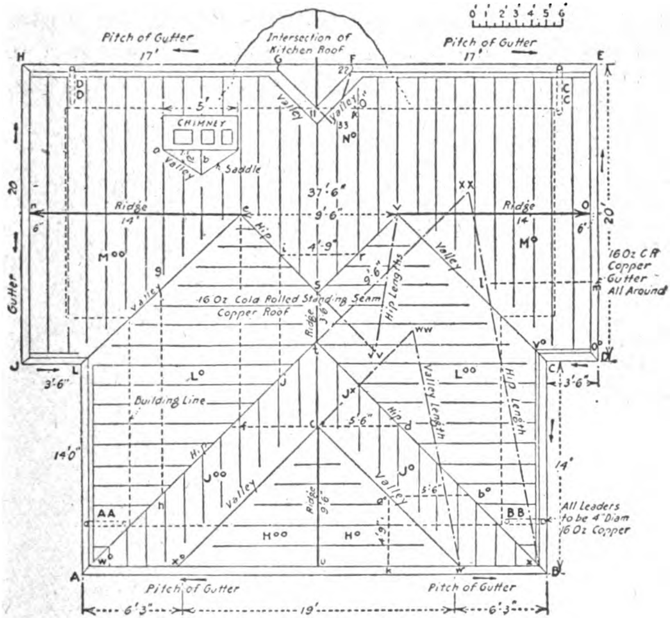


Fig. 165.—Roof Plan of Main Building

as indicated, which serves two purposes—the first to strengthen the upper brace, and second, to prevent the water, when running down the roof, following the brace and running over the front edge of the gutter. By having the twist in the brace the water is led into the gutter.

Obtaining Weight of Gutter

In scaling the detailed sections in Figs. 166 or 167, the copper gutter will require a girth of 1 foot 6 inches from *a* to *b*. As there is a total of 281 feet of gutter, then 281 × 1.5, or 1 foot 6 inches = 421.5 square feet of copper for gutters. Assuming that the gutters will be made in 8-foot lengths, then, computing each of the gutter lengths in the plans in Figs. 164 and 165, it will require 29 laps of 1 inch each. In estimating, call it 36, or 3 feet.

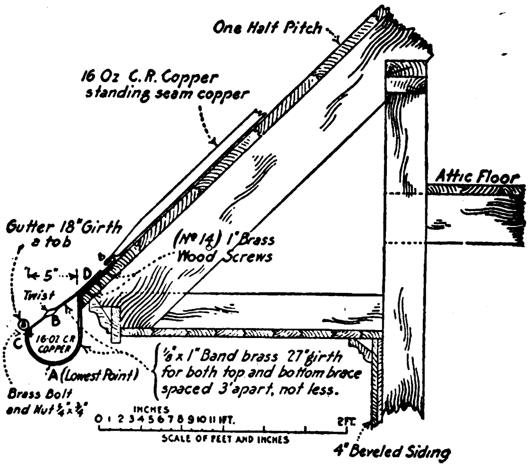


Fig. 166.—Detail of Gutter of Main Roof

As the girth of the gutter is 18 inches, as shown in the details in either Figs. 166 or 167, then 3 × 1.5 = 4.5. Then 421.5 + 4.5 = 426 square feet of gutter, including laps. As 16-ounce copper is called for, then 426 pounds of cold-rolled copper will be required for all gutters. As there are 29 seams and 18 miters and heads in the gutter, this makes a total of 47 joints to be riveted, 2 inches apart. As the girth of the gutter is 18 inches, then $\frac{18}{2}$ = 9, the amount of rivets in each seam. $9 \times 47 = 423$ rivets required for all gutters and miters.

Amount of Braces

The brass top and bottom braces of the gutter are to be spaced 3 feet apart. As there are 281 feet of gutter,

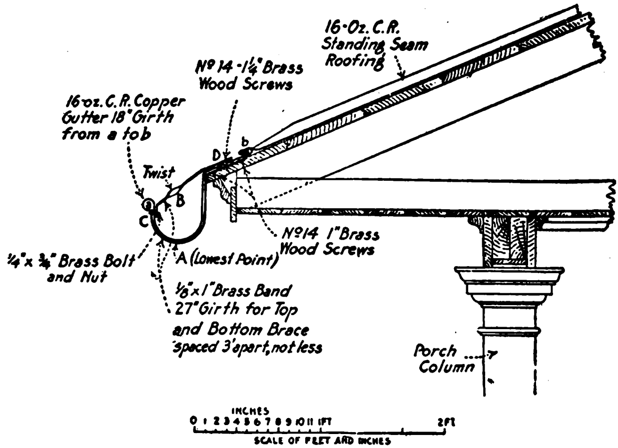


Fig. 167.—Detail of Gutters Over Extension and Porch Roofs

then $\frac{281}{3} = 94$ braces; but this would not give the true amount, because the 281 feet does not run in one length.

The true number of braces are obtained as follows: Referring to the porch and kitchen roof plan in Fig. 164, the length of A B, or 11 feet 6 inches, divided by 3 feet, would give 4 spaces, but 5 braces. In other words, the total amount could be noted as follows:

A B	= 11	feet	6	inches	÷ 3 =	4 spaces	=	5 braces
B C	= 35	"	0	"	÷ 3 =	12 spaces	=	13 braces
C D	= 26	"	6	"	÷ 3 =	9 spaces	=	10 braces
E F	= 19	"	0	"	÷ 3 =	6 spaces	=	7 braces
F G	= 32	"	0	"	÷ 3 =	11 spaces	=	12 braces
G H	= 16	"	6	"	÷ 3 =	6 spaces	=	7 braces
						Or a total of		54 braces

Referring to the main roof plan in Fig. 165:

A B	= 31	feet	6	inches	÷ 3 =	10 spaces	=	11 braces
B C	= 14	"	0	"	÷ 3 =	5 spaces	=	6 braces
C D	= 3	"	6	"	÷ 3 =	1 space	=	2 braces
D E	= 20	"	0	"	÷ 3 =	7 spaces	=	8 braces
E F	= 17	"	0	"	÷ 3 =	6 spaces	=	7 braces
G H	= 17	"	0	"	÷ 3 =	6 spaces	=	7 braces
H J	= 20	"	0	"	÷ 3 =	7 spaces	=	8 braces
J H	= 3	"	6	"	÷ 3 =	1 space	=	2 braces
L A	= 14	"	0	"	÷ 3 =	5 spaces	=	6 braces
						Making a total of		57 braces

Then 54 braces for porch and kitchen gutter, and 57 braces for main roof gutter, makes a total of 111 brass band braces ⅛ inch x 1 inch.

As Figs. 166 and 167 show that 27 inches of girth are required for each top and bottom brace combined, then 111 braces are multiplied by 27 inches, thus: 111 × 2.25 feet = 249.75, or 249¾ linear feet of brass band. As each foot of ⅛ x 1-inch band brass weighs 0.48, or ½ pound per linear foot, then say 250 × 0.5 = 125 pounds of brass for gutter braces. As the top and bottom braces are bolted together with ¼ x ¾-inch round-head stove bolts, then 111 brass bolts will be required. As the lower braces require two wood screws and the upper brace one, then 222 No. 14 1-inch brass wood screws and 111 No. 14 1¼-inch brass wood screws will be required.

Amount of Cleats

As the gutters are to be cleated every 18 inches with cleats 1 inch wide by 2 inches long, requiring 2 square inches of copper, and as there are 281 feet of copper gutter to be cleated, then $\frac{281}{1.5} = 187$ cleats, or say approximately 200. 200×2 inches $= 400$ square inches. $\frac{400}{144} = 3$ square feet, or say 3 pounds of copper for cleating gutters, and 200 1-inch copper nails. As there are 47 joints or seams in the gutter work, and assuming that each joint will require ¼ pound of solder, then $\frac{47}{4} = 12$ pounds of half and half solder. Add thereto 5 pounds solder for tinning roof lap of gutters, 1½ inches wide.

The amount of material for the construction and erection of all the gutters may now be summed up as follows:

426	pounds of 16-ounce cold-rolled copper on gutters
3	pounds of 16-ounce cold-rolled copper on gutters, cleats
125	pounds of band brass ⅛ inch x 1 inch, cold-rolled
16¾	pounds of half and half solder
423	1-pound copper rivets
111	round-head brass stove bolts, ¼ x ¾ inches
111	flat-head brass wood screws, No. 14, 1¼ inches long
222	flat-head brass wood screws, No. 14, 1 inch long
200	1-inch long copper nails.

Finding Quantities of Leaders

The next quantity to be estimated will be the leaders, which are to corrugated, 4 inches in diameter, made of

20

16-ounce cold-rolled copper. Referring to the main roof plan in Fig. 165, four leaders are shown, marked A A, B B, C C and D D. These same leaders are also shown in the roof plan in Fig. 164, as shown by similar letters. The location of the porch and kitchen roof leaders are indicated by E E, F F, H H and J J. To obtain the amount of leader at A A, refer to the front elevation in Fig. 160, where the side view of the leader, A A, is shown, and scales 6 inches + 2 feet 6 inches + 5 feet 6 inches, which equals 8 feet 6 inches.

The leader indicated in the roof plan in Fig. 164 by B B can also be measured in the front elevation in Fig. 160, where its side view is indicated by B B, where it scales 6 inches + 2 feet 6 inches + 19 feet 6 inches + 6 inches, making a total of 23 feet. The porch gutter is connected to this leader, B B, by means of the branch, F F, at X. This branch, F F, is also shown in the roof plan in Fig. 164, at F F, and is scaled from the front elevation in Fig. 160, which measures 9 inches + 2 feet 3 inches, or 3 feet in all.

The leader shown by C C in the roof plan in Fig. 164 can be measured from the right side elevation in Fig. 162, where it is indicated by C C, and scales 6 inches + 3 feet 6 inches + 19 feet 6 inches + 6 inches, the last 6 inches being the shoe shown in the rear elevation in Fig. 163, at the bottom of the leader marked C C. The total for the leader C C amounts to 24 feet.

The leader shown by D D in the roof plan in Fig. 164 can be measured from the left side elevation in Fig. 161, where it is indicated by D D, and scales 1 foot + 2 feet 6 inches + 7 feet + 6 inches, making a total of 11 feet.

The porch leaders indicated in the roof plan in Fig. 164 by E E, H H, and J J, are all similar in length, and are shown by similar letters in the three elevations in Figs. 161, 163 and 162. One length can be measured, and then multiplied by 3 for the total.

The true length can be obtained from the side view of the leader, E E, shown in the front elevation in Fig. 160, where it scales 9 inches + 2 feet 3 inches + 10 feet + 6 inches, making a total of 13 feet 6 inches. 3 × 13 feet 6 inches = 40 feet 6 inches, the amount required for the three leaders, E E, H H and J J.

The total amount of leaders can now be summed up as follows:

Leader A A =	8	feet	6	inches
Leader B B =	23	"	0	"
Leader C C =	24	"	0	"
Leader D D =	11	"	0	"
Leader E E =	13	"	6	"
Leader F F =	3	"	0	"
Leader H H =	13	"	6	"
Leader J J =	13	"	6	"

Making a total of 110 feet 0 inches of 4-inch cold-rolled corrugated leader, which can be bought from sheet metal supply houses.

As there are a total of 8 leader inlets, then 8 copper strainers will be required. There will also be required 8 copper tubes 6 inches long and 3¾ inches diameter, thus making connections between the gutter and leader.

The amount of copper in the tubes can be computed as follows: Multiply the length of the tube by its circumference, thus 3.75 × 3.1416 = 11.78, or 12 inches; 1 foot × 0.5 = 0.5 square feet × 8 = 4 square feet of copper for tubes, or 4 pounds, using 16-ounce copper.

The number of hinged bronze fasteners is next in order, and are shown detailed in Fig. 168. A shows a perspective view of the hook in question, it being hinged at C with two hooks turned outward at D, which are closed by twisting with copper wire. In putting up the leaders, they are to stand off the wall 2 inches, as shown in the cut; *a* and *b* showing the small hooks.

The specifications call for two fasteners on all runs of leader on second story. This would mean the leaders shown on the roof plan in Fig. 164 by A A, B B and D D, and would total 6 fasteners. Three fasteners are required for each run of leader on the first floors; this would take in the leaders marked E E, the continuation of the leader, B B, also H H and J J, or a total of 12 fasteners. The remaining run, C C, would require four fasteners, as called for in specifications. The total fasteners may now be summed up as follows:

Leader A A = 2 fasteners
Leader B B = 5 fasteners
Leader C C = 4 fasteners
Leader D D = 2 fasteners
Leader E E = 3 fasteners
Leader H H = 3 fasteners
Leader J J = 3 fasteners

Making a total of 22 fasteners.

The total materials for leaders for the entire building may now be summed up as follows:

110 feet 4-inch corrugated 16-ounce cold-rolled copper leader
8 copper wire strainers
4 pounds 16-ounce copper on 8 tubes
22 cast bronze or brass hinged fasteners as per detail shown in Fig. 168.

Finding Quantities of Flashing for Chimney

Flashing will be required where the brick chimney passes through the main roof, as shown on the roof plan in Fig. 165. A saddle is placed behind the chimney which sheds the water and prevents a pocket for snow. The width of the chimney scales 5 feet and the flashing along this width turns up 12 inches, as shown in the rear elevation in Fig. 163. Thus 1 × 5 = 5 square feet. The pitch of each side of the saddle is 2 feet 9 inches, as shown

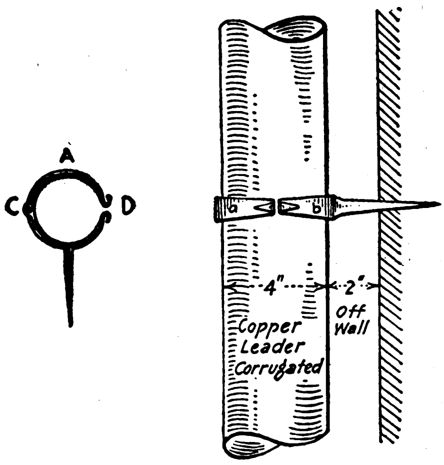


Fig. 168.—Hinged Cast Bronze Leader Fasteners

on the rear elevation, and the width of the saddle in plan in Fig. 165 is determined by scaling the distance midway between the apex *a* and ridge line of the saddle *b*, which is 1 foot. Then 2.75 × 1 = 2.75 × 2 = 5.5 square feet for the saddle proper.

The flashing above the saddle will also turn up 12 inches, and as the double pitch of the saddle will be 5 feet 6 inches, as indicated in the rear elevation in Fig

163, then $1 \times 5.5 = 5.5$ square feet. The amount of pitch where the chimney passes through the roof is 3 feet, as shown by J K in the right side elevation in Fig. 162. As this flashing will also turn up 12 inches then $1 \times 3 = 3 \times 2$ sides $= 6$ square feet.

The amount of flashings around the chimney are as follows:

Front of chimney	5	square feet
Back of chimney	5½	"
Saddle of chimney	5½	"
Two sides of chimney	6	"
Making a total of	22	square feet

As 16-ounce copper is to be used, this flashing will then require 22 pounds copper.

To solder the joints at the corners and ridge of the saddle, figure one pound of solder. About 16 wall hooks will be required for flashing to brick joint of chimney and about 5 pounds of paint-skin.

There will also be required 16 feet 6 inches of cap flashing using 6-inch girth. That means 5 feet for the width of the chimney shown in plan in Fig. 165, 6 feet for the two sides shown in the right-side elevation in Fig. 162, and 5 feet 6 inches for over the pitch of the saddles shown in the rear elevation in Fig. 163. Then $16.5 \times 0.5 = 8.25$ square feet, or 8¼ pounds of 16-ounce cold-rolled copper.

The amount of material for the chimney flashing may now be summed up as follows:

Base flashing around chimney, 22 pounds; cap flashing around chimney, 8¼ pounds; solder for soldering flashing around chimney, 1 pound; paint-skin, 5 pounds, and 16 brass wall hooks, 2½ inches long.

Finding Amount of Copper for Gable Washes

The amount of copper required for covering the washes at the foot of the gables is estimated as follows: All told there are five gables—two on the front elevation as shown in Fig. 160, one on the left side elevation in Fig. 161, one over the kitchen on rear elevation in Fig. 163, and one on the right side elevation in Fig. 162.

Starting with the gable over the porch in front elevation in Fig. 160, average the distance between the upper line of the wash marked 1 and the lower line marked 2; in other words, bisect the distance between 1 and 2 and where this bisecting line meets the lines of the gable mouldings, measure its length, which in this case scales 11 feet. Allow to this 6 inches on either side for flashing under the gable mouldings, making the length 12 feet.

As the specifications call for these slopes to be covered with copper 24 inches wide, then 12 feet $\div$ 2 = 6 sheets, or 5 locks of ½-inch width. As each ½-inch lock takes up 3 times ½ inch or 1½ inches, then $5 \times 1\frac{1}{2} = 7\frac{1}{2}$ inches for locks, which will be 9 inches or 0.75 feet, thus making the entire net length 12.75 feet.

The slope of the wash can be measured from the right side elevation in Fig. 162, where it scales from L to M 3 feet. To this must be added 6 inches for flashing up under the weatherboards, thus making the girth 3 feet 6 inches. Then $3.5 \times 12.75 = 44.625$ square feet.

To obtain the quantity of copper on the wash of the gable shown over the roof in the front elevation, Fig. 160, average the distance between the upper line of the wash (3) and the lower line and this will be found to measure 15 feet 6 inches as shown. To this add 6 inches on either side for flashing up under the gable mouldings making the length 16 feet 6 inches. Then 16 feet 6 inches ÷ 2 feet, the width of copper sheets employed, equals 8 full and one fractional sheet, indicating 8 cross locks. As each lock takes up 1½ inches, then $8 \times 1.5 = 12$ inches, thus adding 1 foot to 16 feet 6 inches, or 17 feet 6 inches in all. The amount of pitch in this wash is obtained from the right side elevation in Fig. 162 where the pitch from A to X scales 3 feet. To this amount add 6 inches for flashing under the siding, making a total of 3 feet 6 inches. Then $3.5 \times 17.5 = 61.25$ square feet of material.

As the gables on the right and left side elevations are similar in size to the gable on the front, then the amount of covering on the wash will be the same; in other words, the wash at the foot of the gable on the left side elevation in Fig. 161 and on the right side elevation in Fig. 162 will each contain an area of 61.25 square feet.

The long wash at the foot of the gable over the kitchen is shown in the rear elevation in Fig. 163, here again the distance between the lines of the wash 7 and 8 are averaged and when scaled will measure 26 feet. To this amount is added a total of 1 foot for flashing under the gable moulds, making the length 27 feet. 27 feet ÷ 2, the width in feet of the sheets used, equals 13 full and a fractional sheet, thus indicating 13 locks. As each lock takes up 1½ inches in all, then $13 \times 1.5 = 19.5$ inches, or 1.75 feet in practice. Adding this amount to 27 feet gives 28.75.

The amount of pitch which this rear wash has is indicated in the right side elevation in Fig. 162, where the distance from N to O scales 3 feet. Add to this 6 inches for turning up under the siding, making the total 3 feet 6 inches. Then $28.75 \times 3.5 = 100.625$ square feet area.

The entire amount for the gable wash coverings may now be summed up as follows:

On gable over porch in Fig. 160...	44.625	square feet
On gable over main roof in Fig. 160	61.250	"
On gable over main roof in Fig. 161	61.250	"
On gable over kitchen in Fig. 163..	100.625	"
On gable over main roof in Fig. 162	61.250	"
Making a total of.............	329	square feet

In the previous figuring of the amount of copper required for the eave gutters over main roof, porch and kitchen, a 6-inch flange was figured to lie on the roof, as shown in Figs. 166 and 167. This amount must now be deducted from the total of the gable wash coverings, whenever the gutter joins to the gables, as these coverings were measured down to the eave line. Thus the length of the gutter joining the gable over porch in front elevation in Fig. 160 scales 15 feet, as shown on the roof plan in Fig. 164. The length of the gutter joining the gable over kitchen in rear elevation in Fig. 163 scales 32 feet, as shown in plan in Fig. 164. The length of the gutter joining the gable over roof in front elevation in Fig. 160 scales 19 feet, as shown on the roof plan in Fig. 165, while the length of the gutters joining the gables on roof in the right and left elevations in Figs. 162 and 161 respectively, are shown on the main roof plan in Fig. 165 and scale 20 feet each. The total amount of gutters joining to gable washes are $15 + 32 + 19 + 20 + 20 = 106$ feet. Then 106×0.5 (the width of the gutter flange) = 53 square feet, to be deducted from the area of the wash coverings. These coverings amounted to 329 square feet − 53 = 276 square feet of wash coverings, or 276 pounds of 16-ounce cold-rolled copper.

To this should be added an approximate amount for solder, copper cleats and copper nails. As the entire covering of the washes under gables takes up 42 cross seams of 3 feet each, making a total of 126 feet, also 106 feet of seam joining to gutter, then $126 + 106 = 232$ feet of soldered seam. Assuming that ¼ pound of solder will be used for each one foot of thorough sweating in of the seam, then $\frac{232}{4} = 58$ pounds of solder.

The copper cleats are to be cut 1 inch × 1½ inches and contain 1½ square inches of copper each. As these cleats are called for 12 inches apart, then 126 feet of seams will require 126 cleats, $126 \times 1.5 = 189$ square inches. $\frac{189}{144} = 1.3$ or say 1½ square feet of copper.

There will be required 126 copper nails 1 inch long for fastening the cleats.

The entire amount of material for the five washes at the foot of the gables is summed as follows:

276 square feet net on five gable washes; 1½ square feet net for cleats, making a total of 277½ square feet, or 277½ pounds 16-ounce cold-rolled copper. Also 58 pounds half and half solder and 126 1-inch copper wire nails.

Of course rosin, acid and coal should be added which, however, does not make a large item. Finding the quantity of the amount of copper for the standing seam roofs are next in order. These quantities will be divided in three divisions: The first for the porch roof, second the kitchen roof, and third the main roof.

Obtaining Areas of Roof Parts

Referring to the roof plan of the porch shown in Fig. 164, page 288, the various slopes have been lettered A°, B°, C° and D°. To find the area of A° find the length of the slope in the front elevation in Fig. 160 where the slope from C to D scales 8 feet 6 inches to the eave line, and multiply it by the length of the roof in plan in Fig. 164, which scales 9 feet 4 inches from M to L. Add 6 inches flashing for turning up under siding to 9 feet 4 inches, making this 9 feet 10 inches or 10 feet in practice. Then $10 \times 8.5 = 85$ square feet area.

A small distance of this porch roof projects over the building line, as indicated by B B in plan, which scales 1 foot 9 inches. The slope of this short piece scales 2 feet 6 inches, as shown in the front elevation in Fig. 160. Add 6-inch flashings to turn up, to the 2 feet 6 inches. Then 2 feet 6 inches + 6 inches = 3 feet. $3 \times 1.75 = 5.25$ square feet.

The slope of the roof B° in plan in Fig. 164 is shown from C to S° in front elevation in Fig. 160 and scales down to the eave line the same as C D, or 8 feet 6 inches. As M L *a* in plan in Fig. 164 of the roof part B° is in the form of a right angle triangle, then take one-half of 9 feet 4 inches, the distance of M L or 4 feet 8 inches, which will indicate the length of N O the center line between points L and *a* and which call 4 feet 9 inches. Then 8 feet 6 inches × 4 feet 9 inches will equal 8.5×4.75 or 40.375 square feet of area.

The length of the roof C°, Fig. 164, from valley line to hip is 19 feet 6 inches. The slope of this roof is indicated in the left-side elevation in Fig. 161 where the distance from the building line A to the eave line B scales 10 feet 6 inches plus 6 inches for turning up under the siding against building, thus making a distance of 11 feet. Then 11 feet × 19.5 (the length) = 214.5 square feet, the area of C° in Fig. 164.

To find the area of D° the averaged distance must be found from P to R. This is done as follows: The length of the gutter from C to D is 26 feet 6 inches to the bead line of the gutter. The projection of the gutter to the bead line is 5 inches. 26 feet 6 inches – 5 inches = 26 feet 1 inch. The projection of the porch roof over the building line from P to X scales 2 feet 6 inches, which deducted from 26 feet 1 inch = 23 feet 7 inches. The length at the top of the sloping roof at the building line is 14 feet. Add 23 feet 7 inches to 14 feet, which equals 37 feet 7 inches; divide this by two will give the length from P to R, or 18 feet 9½ inches, which is called 19 feet in practice.

The slope of this roof D° is indicated in the front elevation in Fig. 160 at F, which scales 8 feet 6 inches to the eave line, to which is added 6 inches for flashing under siding, or 9 feet all told. Then $9 \times 19 = 171$ square feet copper covering for the roof D° in plan in Fig. 164. That part of D° projecting over the building line from P to X measures 2 feet 6 inches and has a slope shown in the front elevation in Fig. 160, from F to M, which scales 4 feet 3 inches + 6 inches for flashing, or 4 feet 9 inches. Then $4.75 \times 2.5 = 11.875$ square feet of surface.

The entire areas of the porch roof are as follows:

Area in A°	85	square feet
Area in A° (projecting slope)	5.25	"
Area in B°	40.375	"
Area in C°	214.5	"
Area in D°	171	"
Area in D° (projecting slope)	11.875	"
Making a total of	528.	square feet

From this amount deduct the 6-inch gutter flange which has already been added to the gutter girth. Referring to the plan in Fig. 164, the run of gutters around the porch roof is 11 feet 6 inches + 20 feet + 26 feet 6 inches, which equals 58 feet. As the gutter flange is 6 inches wide and as the roofing was measured to the eave line, then 58 feet × 6 inches = 29 square feet of copper to be deducted from 528 square feet, leaving the net roofing for porch 499 square feet.

To this amount must be added the area of the ½-inch cross locks and the 1-inch finished double locked standing seams. The amount of these locks may be approximately determined by the following rule: Refer to Fig. 169, which shows the full size measurements of a bent 20-inch wide sheet. As the finished seam is to be 1 inch when completed as shown in the cut, then 1¼ inches will be bent up on one side and 1½ inches on the other, thus leaving 17¼ inches between the standing seams as shown. This standing seam then requires 2¾ inches of metal. As there will be a 20-inch cross lock on every sheet of 8 feet length, requiring 1½ inches in girth, or an area of 30 square inches for every cross lock, and to avoid the tedious computation in finding the number of cross locks, add ¼ inch to the 2¾ inches above obtained for the standing seams girth, making the girth 3 inches to be deducted from the 20-inch sheet. ¼ inch times the length of the 96-inch sheet will equal but 24 square inches, while the cross lock requires 30 square inches. approximation will be as close as desired.

Rule for Finding the Area of Seams

To make clear the rule which will be used in determining the approximate area of the seams, the roof diagram in Fig. 169 has been drawn. This shows a perspective of a roof 9 feet wide by 10 feet pitch, and covers an area of 90 square feet. So that the number may be an even one assume the width between the sheets to be 1 foot 6 inches. 9 feet would then require 6 of these widths, also 6 standing seams. Figuring each seam to take a 3-inch girth, 6 seams would require 6 × 3 or 18 inches in girth or 1 foot 6 inches. Multiply 1 foot 6 inches × 10 feet, the pitch of the roof, and obtain 15 square feet of standing seams.

As the entire roof has an area of 90 square feet, divide

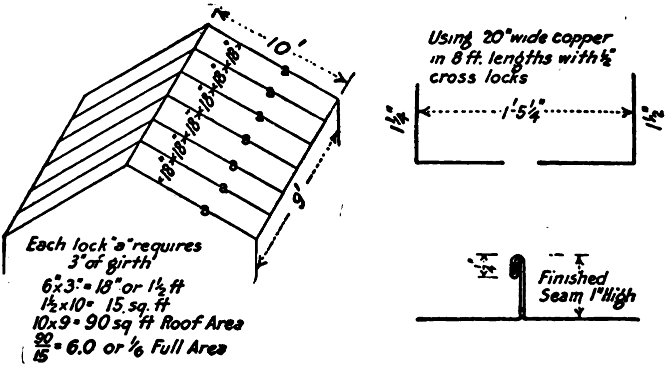


Fig. 169.—Material Required and Dimensions for Standing Seams

this by 15 and obtain the number 6. This number indicates that the standing and cross seams take up one-sixth the area of the entire roof, when the sheets are spaced 18 inches between the standing seams. Even though the job now being figured has the sheets but 17¼ inches between seams, 6 can be safely taken.

If, however, absolute accuracy were desired, the width of 17.25 inches could be divided by 3, when a divisor of 5.75 would be obtained in place of using the number 6. No matter what the size of the seams or the width between them may be, the above rule holds good for finding the divisor. As the full area of the roof minus the gutter flange was 499 square feet, then $\frac{499}{6} = 83+$ square feet to be added.

Then $499 + 83 = 582$ square feet.

Determining Number of Cleats for Standing and Cross Locks

To find the approximate number of cleats for the standing and cross locks, the following rule can be used: Two cleats 1 inch × 1½ inches will be used for every cross lock and will contain 3 square inches. The cleats at the standing seams will be spaced 18 inches apart as called for in specifications so that 6 will be required for each 8-foot long sheet. These cleats will be cut 1 inch wide by 2¾ inches long and will contain 2.75 square inches in area. As 6 are required, then $6 \times 2.75 = 16.5$ square inches. $16.5 + 3 = 19.5$ square inches for the 8 cleats on each 20 x 96-inch sheet. Each 20 x 96-inch copper sheet contains 1,920 square inches. Divide this by 144, the number of square inches per foot, then $\frac{1920}{144} = 13\frac{1}{3}$ square feet.

Divide 13⅓ into the full area of the copper sheets required and the result multiplied by 8 will give the number of cleats required.

The total area of copper roofing was 582 square feet. $\frac{582}{13\frac{1}{3}} = 45+$. Then $45 \times 8 = 360$ cleats, as well as 360 copper nails 1-inch long. As every 8 cleats contained 19.5 square inches, then $45 \times 19.5 = 877.5$ square inches. $\frac{877.5}{144} = 6.1$ square feet copper.

Amount of Solder Required

Every sheet of copper laid has a 20-inch cross seam, and as $\frac{1}{4}$ pound of solder has been allowed for every linear foot for the thorough sweating of seams, then 20 inches or 1 foot 8 inches will require $6\frac{2}{3}$ ounces. As 45 sheets will be required, then $45 \times 6\frac{2}{3} = 300$ ounces $\div$ 16 $= 18\frac{3}{4}$ pounds of half and half solder.

Where the gutter lining locks to the standing seam roofing, this requires a long seam to be soldered as shown in plan in Fig. 164, which measures as follows: 26 feet 6 inches + 20 feet + 11 feet 6 inches, making a total of 58 feet. Using $\frac{1}{4}$ pound of solder for each foot $\frac{58}{4}$ $= 14\frac{1}{2}$ pounds of solder.

The total material for the roof over porch may be summed up as follows:

582 square feet of copper roofing.

6 square feet of copper cleats, making a total of 588 square feet of copper, or 588 pounds of 16-ounce copper. Also 360 1-inch copper nails and $33\frac{1}{4}$ pounds of half and half solder.

Quantity of Material Necessary for Roof Over Kitchen

The area of the roof over the kitchen, shown in plan in Fig. 164, is now in order. This roof has been marked E° and F° and is 16 feet 1 inch wide, as shown from S to T and U to V, plus 8 inches for flashing up against wall under siding, making a total of 16 feet 9 inches. The pitch of this roof is scaled from the rear elevation in Fig. 163, and is 17 feet from A to B, 12 feet 6 inches from B to C, and 10 feet 6 inches from C to D, measuring from eave lines. The top of the gable at B intersects the main roof as shown on main roof plan in Fig. 165 from F to G. While this intersection decreases the area of the kitchen roof somewhat, it is not taken in consideration on account of the extra material required in cutting same up for the valley.

Adding together the various slopes of the kitchen roof as $17 + 12.5 + 10.5 = 40$ feet. 40×16.75 (the width) = 670 square feet. A small portion of the kitchen roof projects over the building line a distance of 2 feet 6 inches as indicated in the roof plan in Fig. 164 at E. This projecting roof has a slope as indicated in the rear elevation in Fig. 163 from *a* to *b* which scales 2 feet plus 6 inches flashing under siding. Then $2.5 \times 2.5 = 6.25$ square feet. Then $670 + 6.25 = 676.25$ square feet from which the gutter flange of 6 inches must be deducted at the eave line. The lengths of these two eave gutters are shown in Fig. 164, from E to F and G to H, a total of 35 feet 6 inches. 6 inches × 35 feet 6 inches = $0.5 \times 35.5 = 17.75$ square feet. $676.25 - 17.75 = 658.50$ square feet, actual standing-seam area.

Divide 658.5 by 6 to find the amount of copper taken up by the standing and cross locks as previously described which gives 109.75 square feet to be added. Then $658.5 + 109.75 = 768.25$ square feet of copper roofing. Divide 768.25 by $13\frac{1}{3}$ so as to find the number of sheets thus: 768.25, the number of square feet in roof, $\div 13\frac{1}{3}$, the number of square feet in each sheet, gives 58 + sheets. As each sheet takes up 8 cleats, then 58×8, the number of cleats to each sheet = 464 cleats and 464 1-inch copper nails. As every 8 cleats contain 19.5 square inches, then $58 \times 19.5 = 1{,}131$ square inches, which divided by 144, the number of square inches to the square foot, equals 8 square feet of copper for cleats.

As every sheet of copper of the size here used requires $6\frac{2}{3}$ ounces of solder, as previously computed, then $58 \times 6\frac{2}{3} = 386$ ounces, or 24 pounds of solder.

The length of the soldered seam between the eave gutter and roofing is figured ¼ pound to every foot. As there are 35 feet 6 inches of gutter, as shown on the plans in Fig. 164, then $\frac{35.5}{4} = 9$ pounds solder. Then $24 + 9 = 33$ pounds of solder for the kitchen roof.

The entire quantities for the kitchen roof may now be summed up as follows:

768.25 square feet copper roofing } = 776.25 pounds 16-
8 square feet copper cleats } ounce copper.
464 one-inch copper nails.
33 pounds solder.

Quantities for Main Roof

The method of figuring the quantities when the roof is cut up by hips and valleys is explained in connection with Fig. 165 which shows the main roof plan.

The various portions of the roof have been marked H°, J°, L°, M° and N°, those parts marked J°°, L°° and M°° are similar in size to those marked J°, L° and M°, respectively. The roof plan of the gable marked H° measures 9 feet 6 inches along the ridge, and has the form of a right angle triangle *c u w*. To obtain the area of this surface divide 9 feet 6 inches by 2, which will leave 4 feet 9 inches, the distance from $a°$ to k. Multiply this distance of 4 feet 9 inches by the length of the rafter, or pitch, as indicated in the right side elevation in Fig. 162, from A to B, which scales 13 feet. Then $13 \times 4.75 = 61.75$ square feet for H° in Fig. 165. As H°° is similar in size, then $2 \times 61.75 = 123.50$ square feet for the front gable roof. That part of the front pitched roof indicated by J° in plan is in the form of a rhomboid *c d x w*, and its distance on a line parallel to the eave scales 5 feet 6 inches, as shown fom *a*° to *b*°. The pitch of this portion is again obtained from the right side elevation in Fig. 162, where it scales 13 feet from A to B. Then $13 \times 5.5 = 71.5$. As J°° in plan in Fig. 165 is similar in size to J°, then $2 \times 71.5 = 143$ square feet for front slope J° and J°°.

The triangular portion indicated by J*x* is in the form of an isosceles triangle shown by *d f t*. Its area is found by drawing a line from the apex *t* at right angles to *f d* until it intersects the base line of the triangle *f d* at *c*. The distance *c d* will scale 5 feet 6 inches, and is the same as *a*° *b*°. The slope or pitch of the roof on *c t* is found on the right side elevation in Fig. 162, from B to C, where it scales 8 feet. Then $8 \times 5.5 = 44$ square feet of surface in the roof portion J*x* in Fig. 165.

That part of the roof marked L° is indicated by the irregular figure L *e s t* A, and must be divided into two geometrical shapes by drawing a line from *e* parallel to the eave line, until it intersects the hip line *t* A at *f*. L *e f* A will then represent a rhombus and *e f t s* an isosceles trapezoid. As the length of the eave line is 14 feet then the distance through the center as *g h* will also be 14 feet.

The slope or pitch of the roof between the lines L A and *e f* is found by referring to the front elevation in Fig. 160, where the distance from L to X scales 13 feet. Then $13 \times 14 = 182$ square feet of surface in the one portion of L° in Fig. 165.

The averaged length through that part of the roof shown by *e f t s* is found by adding together the sum of *e f* and *s t* and dividing by 2. *e f* is 14 feet and the ridge *s t* scales 3 feet 6 inches; 14 feet + 3 feet 6 inches = 17 feet 6 inches ÷ 2 = 8 feet 9 inches. The slope of this part of the roof is indicated in the front elevation in Fig. 160, where it scales 8 feet from X to J, or in the rear elevation in Fig. 163, where it also scales 8 feet from T to U. Then 8 × 8.75 = 70 square feet, the area of the surface *e f t s* in plan in Fig. 165. Adding together the two areas in L° will be 182 + 70 = 252 square feet for the entire surface L°; 252 × 2 = 504 square feet for L° on the left and L°° on the right side.

That part of the roof shown by M° or *v o v*° *o*° is in the form of a trapezoid, and its averaged length through the center *l m* is found as follows: The length of the ridge from *v* to *o* scales 14 feet; the length of the eave is 3 feet 6 inches; 14 feet + 3 feet 6 inches = 17 feet 6 inches ÷ 2 = 8 feet 9 inches, the distance from *l* to *m*. The slope or pitch of this roof M° is shown on the right side elevation in Fig. 162, where it scales 13 feet, as shown at the left of E. Then 13 × 8.75 = 113.75 × 2 = 227.5 square feet of surface in both M° and M°° in roof plan in Fig. 165.

The rear part of the roof is indicated by N°, and forms an outline indicated by H E *o v s e n*. Where the chimney and kitchen roof intersect this main roof no deductions will be made for these intersections, as they are too small to consider.

In figuring this part the roof will be divided into two geometrical figures, H E *o n* forming a rectangle and *e v s* an isosceles triangle. The length of the rectangle from *n* to *o* scales 37 feet 6 inches, and its pitch is 13 feet, as shown in the right side elevation in Fig. 162 from H to E; 13 × 37.5 = 487.5 square feet for the rectangular part N° in plan in Fig. 165. The base of the triangular portion *e v* scales 9 feet 6 inches ÷ 2 = 4 feet 9 inches, the distance from *i* to *r*. The pitch of this triangular portion N*x* is shown from F to E in the right side elevation in Fig. 162, and scales 8 feet; $8 \times 4.75 = 38$ square feet surface; $38 + 487.5 = 525.5$ square feet in the rear portion of roof N° in Fig. 165. The entire area of the main roof may now be summed up as follows:

H° and H°°	contain	123.5	square	feet
J° J°° and J*x*	contain	187	"	"
L° and L°°	contain	504	"	"
M° and M°°	contain	227.5	"	"
N° and N*x*	contain	525.5	"	"

Making a total area of 1567.5 square feet on main roof. From this amount the area of the 6-inch gutter flange must be deducted, as the roof has been measured down to the eave line.

The lengths of the gutters joined to the main roof are shown in the roof plan in Fig. 165, and are as follows:

From *w*° to *x*°	6	feet	3	inches
From *w* to *x*	6	"	3	"
From B to C	14	"	0	"
From C to D	3	"	6	"
From E to F	17	"	0	"
From G to H	17	"	0	"
From J to L	3	"	6	"
From L to A	14	"	0	"
Making a total of	81	feet	6	inches

Then $81.5 \times 0.5 = 40.75$ square feet of area; $1567.5 - 40.75 = 1526.75$ square feet. To this amount of 1526.75 must be added the extra amount of copper taken up by the standing seams and cross locks. This is done as explained in connection with the porch roofs by dividing the area of the roof covering by 6, as the seams take up one-sixth of the full area of the roof covering. Thus $\frac{1526.75}{6} = 254.46$ square feet additional material. Then $1526.75 + 254.50 = 1781.25$ square feet of copper. Divide 1781.25 by $13\frac{1}{3}$ so as to find the number of sheets thus. $\frac{1781}{13\frac{1}{3}} = 134 +$ sheets of copper required.

As each sheet takes up 8 cleats, then $8 \times 134 = 1{,}072$ cleats, also 1,072 1-inch copper nails. As every 8 cleats contain 19.5 square inches then $134 \times 19.5 = 2{,}613$ square inches. $\frac{2613}{144}$ or 18 square feet. As every sheet of copper requires $6\frac{2}{3}$ ounces of solder, then 134 sheets will require $134 \times 6\frac{2}{3}$ or 893 ounces $\div 16 = 56$ pounds solder.

The solder required for the lock between the gutter and roofing is computed as follows: As there are 81 feet 6 inches of gutter and each linear foot is allowed ¼ pound of solder then $\frac{81.5}{4} = 20\frac{1}{2}$ pounds solder.

The materials used for the main roof will be as follows:

1781.25 square feet copper on roofs
18 square feet copper on cleats
76½ pounds solder
1,072 1-inch copper nails

making a total of 1,799¼ pounds of 16-ounce cold-rolled copper required for main roof only.

The total amount of all the materials required for the entire job can be figured together by referring to the various parts of the roofs previously estimated.

Batten Roofing Quantities

The specifications call for an alternate bid if batten roofing is employed. In this bid the porch roof, extension roof and main roof are to be covered with batten roofing, but all other quantities remain as previously figured. It is assumed in this case that the cleats will be nailed on top of the wood battens and locked to the flanged upright seams, in which case 1 inch wide × 2¾ inches long cleats would be sufficient, the same as used in the standing seam roofing. It will be noticed that the battens in Fig. 170 are spaced 1 foot 6 inches on centers

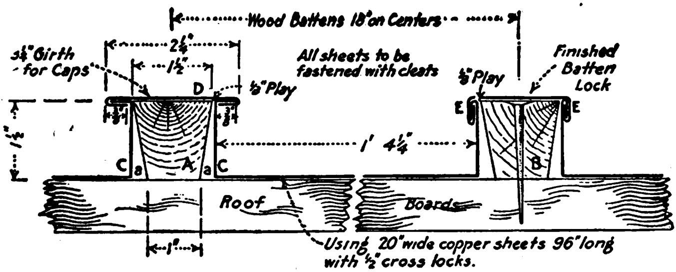


Fig. 170.—Sectional View of Batten Roofing with Full Size Measurements

to take up 20-inch wide sheets as follows: space between copper bends 1 foot 4¼ inches, two uprights of 1½ inches each equal 3 inches; two horizontal flanges of ⅜ inch each equals ¾ inch, making a total of 20 inches. The wood battens A and B are 1½ × 1½ inches as shown, cut tapering down to 1 inch at the bottom. This gives a ¼-inch space on each side as indicated by *a a*, which allows room for the expansion and contraction of the metal. After the battens have all been nailed in position, the sheet C is laid in position, fastened with cleats and over the flange of the standing horizontal edge and cleat, the cap D is locked as shown, after which the locks are turned down as indicated at E E.

In finding the amount of material for a roof of this kind simply divide the area of the actual roof covering surface as previously obtained from the plans, and divide the sum by the extra amount of copper required for the batten seams. The extra amount of copper required for the batten seams is as follows: Two vertical heights of 1½ inches each and six ⅜-inch locks, making a total of 5¼ inches, which is divided into the width of a finished sheet as measured from center to center, thus: Width of finished sheet from center to center of battens 18 inches, as shown in Fig. 170. Extra amount of copper required, 5.25 inches on each width of 18 inches; 18 ÷ 5.25 = 3.43. 3.43 is then the number which must be divided in the actual area of the roof surface, and the result obtained must be added to the actual roof area, the same as was explained in connection with the double locked standing seam roofing.

Alternate Slate Roofing Bid

When the roof of the residence for which a sheet metal roof has been estimated is to be covered with slate, and have copper valleys and ridges, an example of alternate bid is given herewith.

Cover all roofs on main building with 8 x 16 x ¼-inch slate laid 6½ inches to weather, each slate to be nailed with two-penny yellow metal composition slaters' nails. Lay all valleys 18 inches wide, 16-ounce soft copper. All hip and ridge rolls to be covered with 16-ounce cold-rolled copper secured to wooden cores with hard brass clamps ⅛ x 1 inch in thickness, spaced not over 30 inches apart on centers. Use one-ply tar paper under all slating of the weight to be given by architect. Where slates abut the hip ridges and chimney, shingle flashings are to be used laid in with courses of slate not less than 9 inches long and 6 inches wide, bent 3 inches each way, as will be shown on details.

In making this alternate bid, all previous quantities figured for the porch and extension roofs remain the

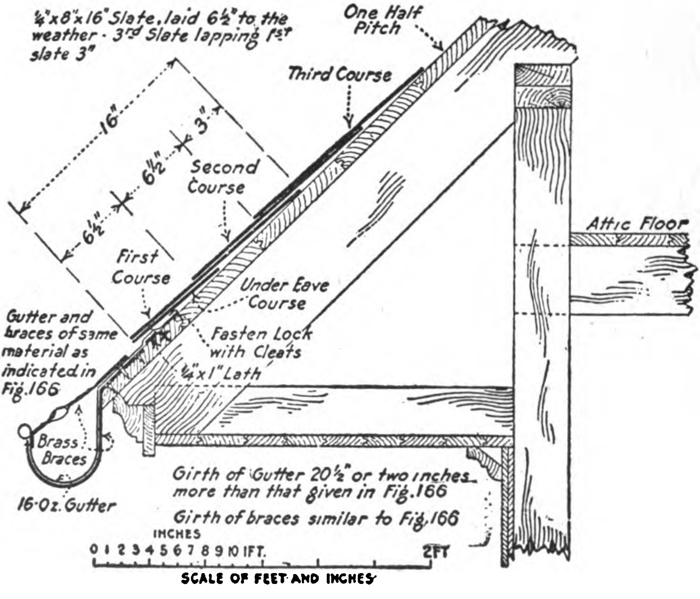


Fig. 171.—Detailed Section of Copper Gutter Under Slate or Tile Roof

same. All leaders, tube fasteners and strainers remain the same. The length of the gutters on main roof are similar with the exception that 20½ inches of girth will be required, as shown in Fig. 171, instead of 18 inches, as previously estimated for the copper roofs. This means that the length of the main gutters must be multiplied by 2½ inches and the extra number of square feet thus obtained, added to the previously figured quantity for main gutters. The girth for the top and bottom brass braces remain the same as before.

Before hanging the copper gutters when a slate roof is employed a wood cant strip or lath ¼ inch thick by 1 inch wide is nailed to the roof as indicated in Fig. 171 by X and over this the gutter flashing is turned, as indicated, being careful that the lath is nailed so that the slates will project down 2 inches below the lower lath line and that 8 inches of copper will flash under the slates. This lath then tips up the under eave or starting course of slate, as shown in the illustration. The slates being laid 6½ inches to the weather, and 16-inch long slates being used, the third course will overlap the first courses 3 inches, as shown, because 6½ + 6½ + 3 = 16 inches, all as indicated.

Figuring the Quantities of Slate

In figuring the quantity of slates required the same rule is employed as explained in connection with the copper roof, with the exception that an additional foot is added for each hip and valley on an additional foot for the extra eave course. This is made clear in connection with Fig. 165. Assuming that the surface marked L° or *e f* A L is being figured, then as *g h* scales 14 feet, 16 feet would be used, thus allowing 1 foot for extra cutting on the valley L *e* and the hip A *f*. In similar manner an extra foot would be allowed for the under eave course along L A; thus 14 × 1 = 14 square feet extra. Where a measurement is 4 feet 9 inches, as in H°, this would be called 5 feet 9 inches, thus allowing 1 foot for the extra cutting of slate at the valley.

Having found the number of squares required, the number of slate to each square can be computed as follows: As the slates are laid 6½ inches to the weather each exposed part on a slate 8 inches wide will be $6\frac{1}{2} \times 8$ or 52 square inches. Each square contains 100 square feet or 100×144 or 14,400 square inches, divided thus: $\frac{14,400}{52} = 277$ slates to a square. As each slate will require two yellow metal nails, then 554 nails will be used for each square.

The number of square feet of one-ply tar paper for under slating will be similar to the number of square feet of slating just obtained.

Find Amount of Ridging

Where the slating finishes at the ridge a finishing course of slate is placed, as indicated in Fig. 172. Over these finishing courses a copper ridge is set with sufficient flange, so as to cover the head of the nails used to secure the slates. This metal ridge has a wood core, over which the metal ridge is set and secured by means of brass clamps ⅛ x 1 inch in thickness.

The number of feet of ridge is found by scaling these measurements on the main roof plan in Fig. 165. Here there are four ridges, as shown, two of 14 feet each, one of 9 feet 6 inches and one of 3 feet 6 inches; then $14 + 14 + 9.5 + 3.5 = 41$ feet. Scaling the profile of the ridge, shown in Fig. 172, 14 inches girth or 1⅙ feet are required. Then $1\frac{1}{6} \times 41 = 48$ square feet of 16-ounce cold-rolled copper are required.

As the clamps are to be spaced 2 feet 6 inches apart, then two clamps will be required from *t* to *s*, in Fig. 165, five clamps from *c* to *u*, seven clamps from *v* to *o* and seven from n to e, making a total of 21 clamps. As each clamp requires a girth of 13 inches, as shown on the detail in Fig. 172, then $13 \times 21 = 273$ inches or 23 linear feet of $\frac{1}{8}$ x 1 inch band brass. As each linear foot weighs 0.48 pound, or say $\frac{1}{2}$ pound, then $0.5 \times 23 = 11\frac{1}{2}$ pounds of brass. Each clamp is secured to the ridge pole with two No. 14 $1\frac{1}{4}$-inch brass screws, thus requiring 21×2 or 42 brass wood screws.

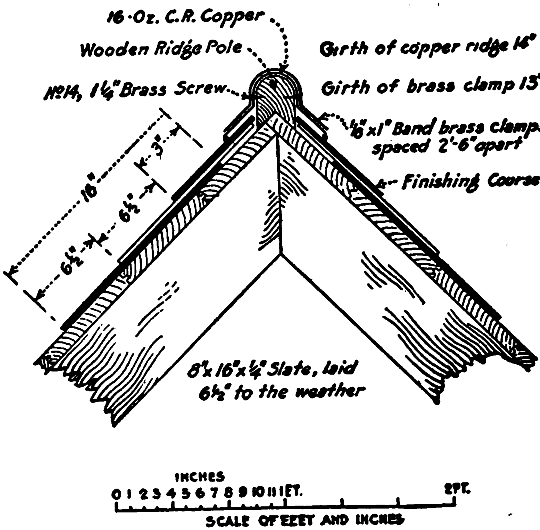


Fig. 172.—Detail of Copper Ridge Over Slate Roof

The total amount of material for main ridge is summed as follows: 48 pounds of 16-ounce cold-rolled copper; $11\frac{1}{2}$ pounds of $\frac{1}{8}$ x 1-inch band brass; 42 No. 14 $1\frac{1}{4}$-inch brass screws.

The same detail shown in Fig. 172 is used for the hip ridges. To obtain the various lengths of the hip ridges, refer to the main roof plan in Fig. 165. There are four hips, the true lengths of which are obtained as follows: To obtain the true length of the hip line $t\ x$, take the vertical height of this hip indicated in the left side elevation in Fig. 161 from T to U and place it at right angles to the hip line $t\ x$ in plan in Fig. 165, as shown from t to xx. A line measured from xx to x will scale 25 feet 6 inches, as indicated.

As there are two of these hips, then $25.5 \times 2 = 51$ feet.

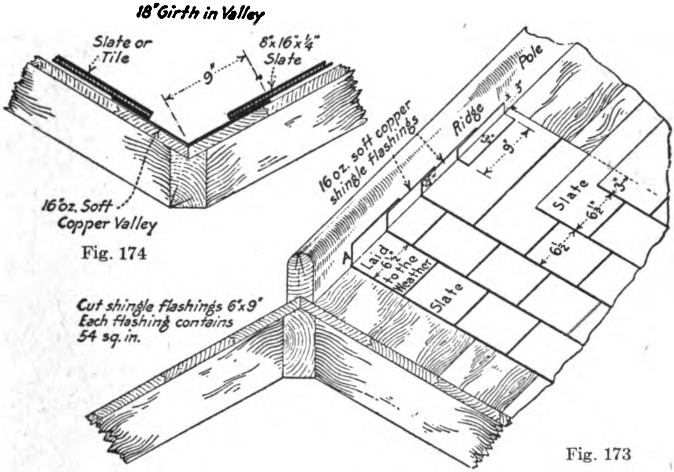


Fig. 173.—Section Through Hip Showing Flashings Laid in with Roof Covering
Fig. 174.—Section Through Copper Valley on Slate Roof

The length of the hip from s to v is found by taking the vertical height of this hip, shown in the left side elevation in Fig. 161, from R to S, and placing this distance at right angles to $s\ v$ in plan in Fig. 165, as shown from s to vv. The distance from v to vv will then scale 9 feet 6 inches. As there are also two of these hips, then $2 \times 9.5 = 19$ feet. Then 19 feet + 51 feet = 70 feet of hip ridge, whose girth is also 14 inches or $1\frac{1}{6}$ feet; $70 \times 1\frac{1}{6}$

= 82 square feet of ridging or 82 pounds of copper required.

As the clamps on the hip ridges are also spaced 2 feet 6 inches apart, then 11 clamps will be used on the 25 feet 6 inch length and five clamps on the 9 feet 6 inch length or a total of 16; $16 \times 2 = 32$ clamps required. As each clamp takes up 13 inches of girth, then $13 \times 32 = 416$ inches or say 35 linear feet of brass band ⅛ inch x 1 inch. Figuring ½ pound to each linear foot, then 35×0.5 = 17½ pounds of brass; 32 clamps will require 64 No. 14 1¼-inch brass wood screws.

The total amount of material for hip ridges is as follows: 82 pounds of copper on ridge (16-ounce); 17½ pounds of band brass ⅛ x 1 inch; 64 No. 14 1¼-inch brass wood screws.

Finding Quantity of Shingle Flashings

Wherever the slates abut the hip ridges and chimney, shingle flashings should be laid in with the courses, as shown in Fig. 173. They are laid under the lower end of the first slate, as shown in the cut, and are cut about 2½ inches longer than the slates are laid to the weather. The part turned up at A should never be nailed, for the reason that the wood work will settle or warp and cause the flashing, if nailed, to tear up or break the slate.

As the slates are laid 6½ inches to the weather and a 2½-inch overlap is allowed, and as the flashings will be turned up 3 inches and turn under slate 3 inches, then 6 inches x 9 inches will be the size to cut these shingle flashings.

As the hip ridges require single flashings on each side, then every 6½ inches of ridging will require 18 inches of flashings; in other words, two shingle flashings containing 108 square inches will be required for every 6½ inches of hip ridge. As there are 70 feet of hip ridging required, then reducing 70 feet to inches is 840 inches. $\frac{840}{6.5} = 130+$. $130 \times 108 = 14{,}040$ square inches. $\frac{14{,}040}{144} =$ 98 + square feet or 98 pounds of 16-ounce soft copper.

Amount of Valleys

The last item to take off is that of the valleys. The roof plan in Fig. 165 shows four valleys from *e* to L, *v* to v°, *w* to *c* and *c* to x°. As they are all similar the true length of the one will answer for all four.

To find the true length of the valley *c w* take its vertical height, shown in the left side elevation in Fig. 161, from W to U, and place it at right angles to *w c* in plan in Fig. 165, as shown from *c* to *w w*. The distance scaled from *w w* to *w* will measure 16 feet. 4×16 feet = 64 feet of valley 18 inches wide, as indicated in the detail in Fig. 174. Where the kitchen roof intersects the main roof, as shown in plan in Fig. 165, by G 11, F, take the vertical height of this valley, as shown in the left side elevation in Fig. 161 from U to V and place it at right angles to 11 22 in plan in Fig. 165, as shown from 11 to 33. The distance scaled from 22 to 33 will measure 4 feet and 2×4 will be 8 feet to be added to the 64 feet previously obtained, making a total of 72 linear feet of valley 18 inches wide; $72 \times 1.5 = 108$ square feet of 16-ounce soft copper or 108 pounds.

This completes the entire quantities which must be carefully arranged and prepared in submitting the alternate bids. While this article may seem lengthy, it should be understood that it takes less time to do this actual figuring in practice than it takes to describe it here.

Preparing Estimate for Gutters, Leaders and Roofing

In preparing the estimate it is presumed that as much work as possible will be done in the shop and delivered to the building by a hired expressman, whose charges are included in the estimate.

Leader elbows and shoes will be bought ready made.

The labor cost per hour is figured for shopwork at an average of 65 cents, for building work at 70 cents.

Regarding the provision in the estimate that each contractor has to furnish his own scaffolding, no charge is to be figured in our estimate for this item, as it was agreed with the carpentry contractor to let our mechanics use his scaffolding without any cost to us.

All material (other than copper for main roof, which will be bought from the mill and arrive at the freight station) will be delivered by local dealers to the shop without delivery charges.

Sharp & Brown
Trestenville, N. Y.

ESTIMATE No. 30

for furnishing and erecting gutters, leaders and roofing as per plans and specifications, dated.......................................
prepared by architect.......................................
for Mr. John Smith....................Address............
to be erected at.......................................

A. Gutters. Required 284 feet, including seams. **Girt of gutter,** 18 inches.
Material required for gutters and cleats: (see **Page 295**).
18 sheets cold rolled copper, 16 ounces **per foot, 36 x 96** inches, weight per sheet 24 pounds, **total weight 432** pounds. (Actual requirement 429 pounds.)

Base price, per pound................	**33⅓ cents**	
Extra for cold rolled.................	**1⅔ "**	
Total per pound.................	**35 cents**	**$151.20**

500 1-pound copper rivets* quoted by Hunter Co.....		.50
125 pounds 1/8 x 1 inch brass band, quoted by Hunter Co., per pound	.40 cents	50.00
12 pounds half and half solder (market price) per pound	.38 cents	4.56
120* 1/4 x 3/4 inch stove bolts, brass, quoted by Barley Bro.		1.50
120* 1 1/4-inch No. 14 flat-head brass wood screws, quoted by Barley Bro.		1.20
250* 1-inch No. 14 flat-head brass wood screws, quoted by Barley Bro.		1.40
200 1-inch long copper nails, quoted by Hunter Co....		.60
5 pounds half and half solder for tinning roof lap of gutter, 1 1/2 inches wide on each side, as per specification, per pound	.38 cents	1.90
Total material for gutters		$212.86

B. Leaders, 4-inch corrugated, 16 ounces, cold rolled copper. Required including 15 bends and 6 shoes, 110 feet. After deducting lengths of bends and shoes the net requirements are:

86 feet, quoted by Hunter Co., per foot	.55 cents	$47.30
15 bends, quoted by Hunter Co., each	$1.35	20.25
6 shoes, quoted by Hunter Co., each	1.50	9.00
8 copper strainers, quoted by Hunter Co. each	.40 cents	3.20
4 pounds cold-rolled copper for tubes, per pound	.35 cents	1.40
22 brass fasteners for leaders, quoted by Hunter Co., each	.50 cents	11.00
Solder for tubes, seams, etc. and wire for brass fasteners		.55
		$92.70

Labor:

Shopwork:

Making gutters

Cutting sheets in 18-inch wide strips...	3/4	hours
Marking and punching strips	1	"
Cutting miters	2	"
Bending gutters	15	"
Cutting and putting in heads	4	"
Making 200 cleats	1 1/2	"
Making braces:		
Cutting brass strips and filing off burrs made in cutting	2 1/2	"
Punching and countersinking holes for screws	4 1/2	"
Bending strips	6	"
Making leader tubes	1 1/2	"
Tinning edge of gutter both sides	6	"
Total	44 3/4	hours

Shop work, 44 3/4 x 65 cents $29.08

Work on building:

Cutting roof boards for lower braces	20	hours
Putting on lower braces	5	"
Laying gutter and fastening cleats, including riveting and soldering seams	25	"
Putting in upper braces	7	"
Putting in leader tubes	2	"
Cutting leader in required lengths	2 1/2	"
Putting leader together	5	"
Fastening hooks and hanging leader	10	"
Total	76 1/2	hours

Total labor at building, 76 1/2 x 70 cents $53.55

Recapitulation

Material for gutters			$212.86
Material for leaders			92.70
Shop work 44¾ hours			29.08
Work on building, 76½ hours			53.55
Total prime cost			$388.19
Delivery of material to building			4.00
			$392.19
Overhead expenses:			
Operating expenses:			
Shopwork, 44¾ hours at 21 cents		$ 9.40	
Building work, 76½ hours at 42 cents		32.13	
Administration and general expenses: 121¼ hours at 20 cents		24.25	
Merchandise expenses: 8½% of $305.56		25.97	
Extra for copper, brass and solder risk: 2% of $305.56		6.12	97.87
			$490.06
Selling expenses, 5%			24.50
Total cost of gutters and leaders			$514.56

C. Flashings

Chimney flashing, required 22 square feet (cut 12 inches wide)

Cap flashing, required 8¼ square feet (cut 6 inches wide)

Note: Both widths cut well out of 24 inch wide sheets.

There are needed 2 sheets 24 x 96 inches, totaling 32 square feet, weight 32 pounds.

Base price	33½ cents	
Extra for cold rolled	1½ "	
32 x 35	cents	$11.20

(Net requirements are 30¼ pounds, therefore waste 1¾ pounds, which, as being small we shall disregard).

D. Covering of washes below gables.

Note: The length of material for all 5 slopes to be covered is 36 inches and the width of the pieces is 24 inches. Therefore 36 inches wide sheets will cut to advantage.

Required: 12 sheets 16 ounce cold-rolled copper, 36 x 96 inches, totaling 288 square feet, weighing 288 pounds.

Base price	33½ cents	
Extra for cold rolled	1½ "	
288 x 35	cents	100.80
		$112.00
(Net requirements are 277½ pounds (see Page 304), therefore waste is 10½ pounds, which is deducted from the total at 15 cents per pound		1.58
		$110.42
1 pound solder for flashing		.38
58 pounds solder for washes		22.04
5 pounds paint-skin for flashing		.50
16 brass wall hooks, 2½ inches long, quoted by Hunter Co.		1.92
150 copper nails, 1 inch long, quoted by Hunter Co.		.45
Total material for flashing and wash covering		$135.71

E. Standing seam roofing:

As the copper required for this roofing is not of commercial size (20 inches wide) it is presumed in this estimate that the copper of required width will be ordered as a mill shipment, for which a quotation was received from Hunter Co. at 32 cents per pound, F. O. B. mill, with a freight charge of 50 cents per hundred pounds.

Total amount of copper sheets required is:		
For porch covering	45 sheets	
For kitchen roof covering	58 "	
For main roof covering	135 "	
Total	238 sheets	
Each sheet weighs 13⅓ pounds, therefore total weight 3,173 pounds at 32 cents		$1015.36
Actual requirements are (see Pages 310, 312, 316.)		
For porch roof	588.00 pounds	
For kitchen roof	776.25 "	
For main roof	1,799.25 "	
Total	3,163.50 pounds	
There is a difference of 9½ pounds purchase above actual requirements, which being small is disregarded.		
Freight for 3,163 pounds at 50 cents per hundred		15.87
Cartage from railroad to shop		2.25
Solder for porch roof	33¼ pounds	
kitchen roof	33 "	
main roof	76½ "	
Extra solder for tinning edges	18 "	
	160¾ pounds	
At 38 cents		61.09
Copper nails, for porch roof	360	
kitchen roof	464	
main roof	1,072	
	1,896 pounds	
In round number 2,000 nails, quoted by Hunter Co.		6.00
Total material for roof covering		$1,100.57

Labor:

Shopwork:		
Cutting and bending chimney flashing and cap flashing	1½ hours	
Cutting and edging wash coverings	10 "	
Notching and bending sheets for roofs	50 "	
Tinning edges on both sides	24 "	
Making 2,000 cleats	8 "	
Total	93½ hours	
Shop work, 93½ x 65 cents		$60.78
Work on building:		
Cutting sheets into proper lengths and bending cross seam edges	20 hours	
Laying sheets and putting on cleats	125 "	
Putting flashing on to chimney	3 "	
Laying and soldering washes	35 "	
Soldering seams on roofs	35 "	
Unforeseen time and on various items not enumerated	20 "	
Total	238 hours	
Work on building, 238 x 70 cents		$166.60

Recapitulation

Material for flashing and wash coverings	$135.71
Material for main roof covering	1,100.57
Shop work, 93½ hours	60.78
Work on building, 238 hours	166.60
Total prime cost	$1,463.66
Delivery of material from shop to building	8.00
	$1,471.66
Overhead expenses:	
Operating expenses:	
Shopwork, 93½ hours at 21 cents	19.64
Building work, 238 hours at 42 cents	99.96
Administration and general expenses: 231½ hours at 20 cents	46.30
Merchandise expenses: 8½% of $1,236.28	105.07
Extra for copper brass and solder risk: 2% of $1.236.28	24.72
Extra risk for work on slanting roof (same risk as scaffold work).	
Actual work on roof about 175 hours, at 25 cents per hour	43.75
	$1,811.10
Selling expenses, 5%	90.55
Total cost of flashing, wash and roof covering	$1,901.65

Summary

Cost of gutters and leaders	$514.56
Cost of flashings and roof coverings	1,901.65
	$2,416.21
Profit, 20%	483.24
Total	$2,899.45

Bid, $3,000.00
Estimated by........................
Checked by........................
Approved by........................

*Screws, bolts, etc. should for obvious reasons always be figured slightly in excess of actual requirements.

Although the specification calls for alternate bids for Batten roofing and Slate roofing, it appears not necessary here to figure in detail the cost of these alternate bids The examples shown in our sample estimates should be illustrative enough to enable the reader to apply the principals to bids of any other kind of work in the sheet metal line.

If, as is often done, the slate roofing will be sub-contracted to a regular slate roofer, then the bid from the slate roofer should be used as a base for our estimating and the regular selling expenses added to his bid. For example:

Total cost of sheet metal work	$900.00
Slate roofing as per estimate from Franklin Roofing Co.	550.00
Selling expenses on Slate roofing bid 5%	27.50
Total cost	$1477.50
Profit, 20%	295.50
Total	$1772.00

CHAPTER XVIII

ESTIMATING FURNACE HEATING WORK

In this branch of sheet metal work several problems present themselves to the estimator which have a marked influence upon the manner of preparing the estimate. In other branches of sheet metal work, as a rule, fundamental facts and requirements are specified, which give a positive base for figuring of quantities of material and value of labor. For example, plans and specifications for leader, gutters, skylights, etc., will as a rule give all information as to sizes, kind and grade of material so that it will be necessary only to measure from the plans and figure the weights, etc., of material to arrive at quantities. In heating work, however, specifications and plans often state merely the results to be obtained. A typical specification for heating, for example, will state that "the contractor is required to install a certain kind of heating system, by means of which it shall be possible to heat the building in all its part to 70 degrees Fahrenheit in zero weather," without specifying the manner of design of the heating plant. Such specifications will neither state the size of furnace or boiler, nor the size of registers, pipes, ducts, etc. Under these conditions the contracting sheet metal worker must solve problems of a branch of engineering which is far from a state of highest development, and there exists no certain set of rules, which are universally applied, as to the figuring of sizes of furnaces, pipes, etc., to arrive at standard results. It is not within the scope of this book to solve technical heating problems, nor the intention to enter the controversy concerning the superiority of one or another heating system, or the correctness of figuring pipe and register sizes, etc., according to either of the numerous methods in use. We must refer the reader who desires information regarding the design of heating and ventilating systems to the scores of books written on these subjects; here we shall deal only with

Fig. 175.—View of House Used as Basis of Estimate

those phases of the subject which have direct bearing on estimating after the design of the system is completed, either by the estimator or somebody else competent to do so. For our purpose, we shall use the layout of a system of "Furnace Heating" in detail described by Alfred G. King* and illustrate therefrom the manner of preparing the estimate.

*Progressive Furnace Heating," by Alfred G. King, New York, 1914.

The first step would be "Taking Off Quantities," which is followed by "Tabulating of Labor Cost," "Figuring of Overhead Expenses," and "Summarizing of Cost."

On the floor and basement plans we find marked the exact locations of the registers, the furnace and chimney,

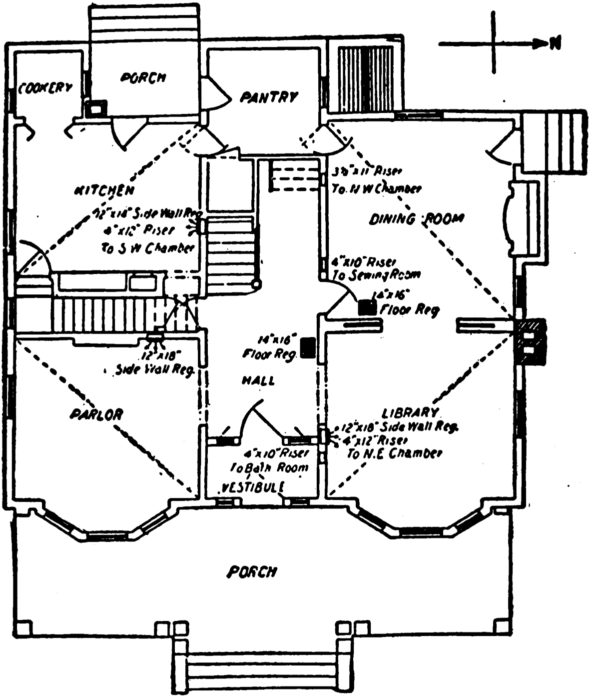


Fig. 176.—First Floor Plan

as well as cold air inlet, the sizes of cold air duct, etc. If this information is not furnished with the plans prepared by the architect (and it seldom is), it should be ascertained by the furnace contractor and the corresponding entries made on the plans in order to serve as a record and to give the proper base for figuring the estimate.

For the purpose of estimating, we shall observe here the following specifications concerning the job:

All hot air pipes are to be made of IX charcoal tin.

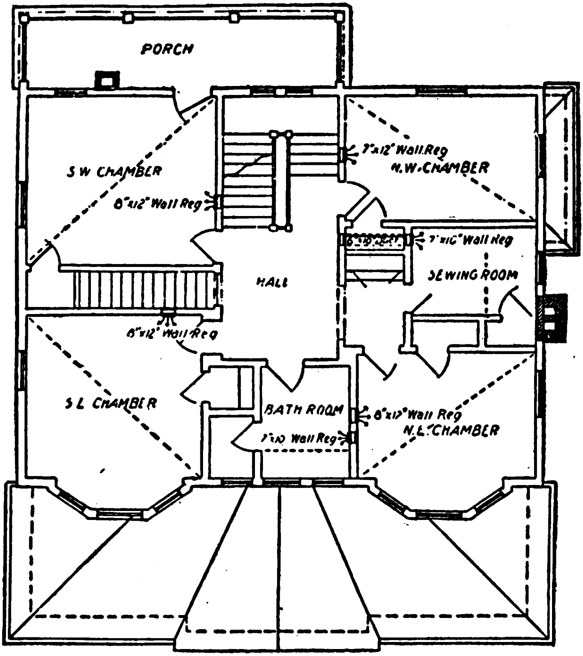


Fig. 177.—Plan of Second Floor

Cellar leader pipes to be covered with 2-ply air cell asbestos paper and to be supplied with individual dampers. Vertical flues to be of single wall type. The studdings facing the flues are to be covered with tin and the facing to be covered from stud to stud with metal lath. All flues to be run in inside partitions.

The furnace to be of the portable style. Hood of furnace to be provided with 1-inch high rim to be filled in with fine sand. The side of hood (or bonnet) to be covered with 1-inch thick plastic asbestos cement. Furnace is to be set on concrete base, to be built by mason contractor. Smoke pipe between furnace and

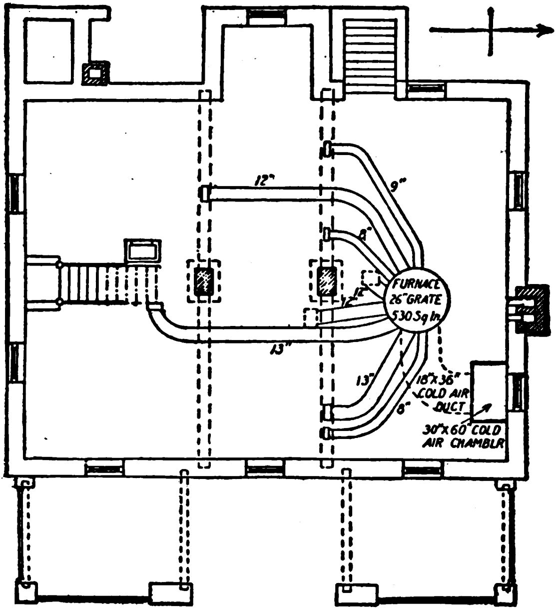


Fig. 178.—Plan of Basement

chimney to be made of No. 24 gauge galvanized steel and supplied with cast iron damper.

The cold air duct to be made of No. 24 gauge galvanized steel and to be connected by the heating contractor to a cold air chamber which will be built by another contractor. Bends in cold air duct are to be made in the long sweep style.

All elbows on hot air pipes and smoke pipe to be of the 4-piece pattern, except connections of hot air pipes at furnace, which are to be made with collars at side of bonnet and 45-degree elbows. Connections between vertical ducts and cellar leaders are to be made by means of "frictionless" starters (Fig. 185). Where one riser supplies more than one floor, the lower floor register is to be of the extended pattern type (side wall registers), Fig. 196. All registers are to be black japanned with cast iron or pressed steel facing.

For the purpose of estimating we have the following data on hand.*

*These schedules are reprinted from "Progressive Furnace Heating," by Alfred King, where the rules for arriving at these figures are explained in detail.

TABLE OF EXPOSURES

First Floor	Size	Cubic Contents	Glass Surface	Exposed Wall
Parlor	15 x15 x10	2,250	72	228
Library	15 x15 x10	2,250	72	198
Dining room	16 x16 x10	2,560	64	256
Kitchen	12 x15 x10	1,800	64	100
Reception hall	9 x22 x10	.....	..	...
Second floor hall	9 x21 x10	3,870	81	...
Second Floor				
S. E. chamber	14 x15 x 9	1,890	72	189
N. E. chamber	14 x12 x 9	1,512	72	162
Sewing room	7 x 9¾x 9	621	18	45
N. W. chamber	10 x15 x 9	1,350	36	189
S. W. chamber	13 x15 x 9	1,755	64	188
Bath room	7 x 9 x 9	567	..	...
Toilet	3½x 5 x 9	155	46	...

TABLE OF SIZES

Room	Diam. of Cellar Pipe	Size Vertical Flue	Size Register	Notes
Parlor	13 inches	7 x22	12x18	Side wall reg.
Library	13 "	7 x22	12x18	Side wall reg.
Dining room	12 "	Floor reg.	14x16	Floor reg.
Kitchen	12 "	7 x16	12x14	Side wall reg.
Reception hall	12 "	Floor reg.	14x16	Floor reg.
S. E. chamber	(See parlor)	4 x12	8x12	Wall reg.
N. E. chamber	(See library)	4 x12	8x12	Wall reg.
Sewing room	8 inches	4 x10	7x10	Wall reg.
N. W. chamber	9 "	3½x11	7x12	Wall reg.
S. W. chamber	(See kitchen)	4 x12	8x12	Wall reg.
Bath and toilet	8 inches	4 x10	7x10	Wall reg.

Total area of basement pipes: 768 square inches.
Size of furnace required: 3½ square feet of grate surface (or about 25½ inches in diameter.)

Taking Off Quantities

The floor plans and the basement plan are reproduced here at a scale of 1/16 inch to 1 foot (being 1/4 size of original plans which were drawn at the scale of 1/4 inch to 1 foot).

Smoke Pipe.—A galvanized smoke pipe of 9 inches diameter is required. The distance between the furnace

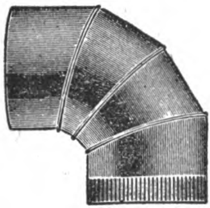


Fig. 179

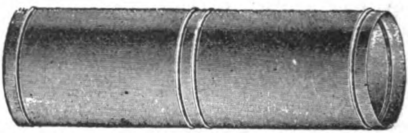


Fig. 182

and the chimney, as shown in the basement plan, is 5 feet. The smoke pipe collar in the furnace is 4 feet from the floor, while the chimney flue opening is 5½ feet from the floor. It will therefore be necessary to use two 4-piece elbows (Fig. 179) and 2 lengths of 9-inch galvanized

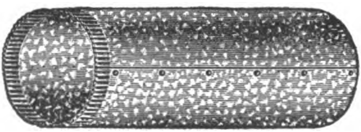


Fig. 180

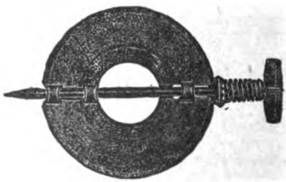


Fig. 181

pipe (Fig. 180) No. 24 gauge, also one cast iron damper (Fig. 181).

Measurements for pipes and ducts can be taken from plans as follows:

A. Pipes in cellar (Fig. 182)	13-inch	12-inch	9-inch	8-inch
For parlor..........	20 feet	......	......	......
For library..........	14 "	......	......	......
For dining room.....	......	2 feet	......	......
For kitchen.........	......	20 "	......	......
For reception hall....	......	6 "	......	......
For S. E. chamber....	(Connected with parlor pipe)			
For N. E. chamber...	(Connected with library pipe)			
For sewing room.....	......	......	......	7 feet
For N. W. chamber...	......	......	12 feet	......
For S. W. chamber...	(Connected with kitchen pipe)			
For bathroom........	......	......	......	14 "
	34 feet	28 feet	12 feet	21 feet

These pipes are made in 20-inch lengths, and require 2 inches lap for each length. The net available length is therefore 18 inches (1½ feet). By dividing the total required length by 1½, we find the number of 20-inch sections necessary, as follows:

13-inch diameter pipe	(34 ÷ 1½)..........	23 sections
12 " " "	(28 ÷ 1½)..........	19 "
9 " " "	(12 ÷ 1½)..........	8 "
8 " " "	(21 ÷ 1½)..........	14 "

From this should be deducted the length which is taken up by elbows, allowing for each 4-piece adjustable elbow 1½ of its diameter, disregarding however, the 45-degree elbows at the furnace collars, as the length taken up by same will be little and be offset by the additional length required on account of the running of the pipes at a pitch.

13-inch diameter pipe
(23 sections less 6 sections for 6 elbows)... 17 sections
12-inch diameter pipe
(19 sections less 4 sections for 4 elbows)... 15 "
9-inch diameter pipe
(8 sections less 3 sections for 4 elbows)... 5 "

8-inch diameter pipe
(14 sections less 4 sections for 6 elbows)... 10 sections

Fig. 183
Casing Collar for
Side of Bonnet

Fig. 184

B. Furnace collars (Fig. 183). (One for each pipe.)

2—13 inches diameter
3—12 " "
1— 9 " "
2— 8 " "

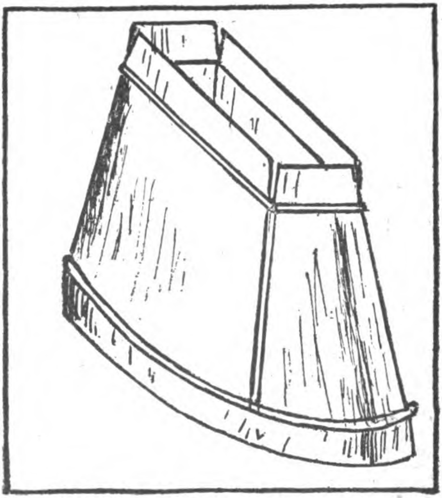


Fig. 185

C. Dampers (Fig. 184.) (One for each pipe.)

2—13	inches	diameter
3—12	"	"
1— 9	"	"
2— 8	"	"

D. Starters (Fig. 185). (One for each pipe.)

2—7	x 22	inches	by	13	inches	round
1—7	x 16	"	"	12	"	"
1—4	x 10	"	"	8	"	"
1—3½	x 11	"	"	9	"	"
1—4	x 10	"	"	8	"	"

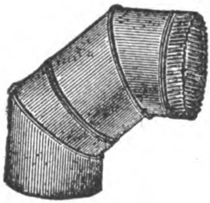


Fig. 186

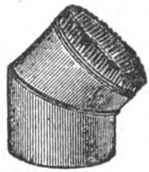


Fig. 187

E. 90-degree 4-piece elbows (Fig. 186).

(Besides those shown on the basement plan, one elbow will be required at the end of each pipe to connect with the starter and the floor register boxes.)

6—13	inches	diameter
4—12	"	"
4— 9	"	"
6— 8	"	"

F. 45-degree elbows (Fig. 187). (One for each furnace collar.)

2—13	inches	diameter
3—12	"	"
1— 9	"	"
2— 8	"	"

G. Floor register boxes (Fig. 188).

2—14 x 16 inches, with 12-inch collar.

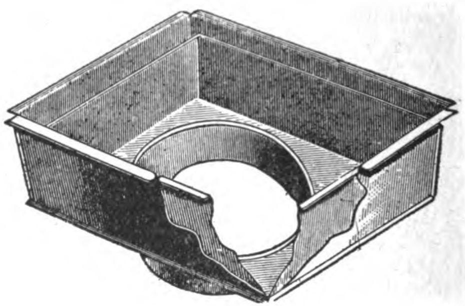


Fig. 188

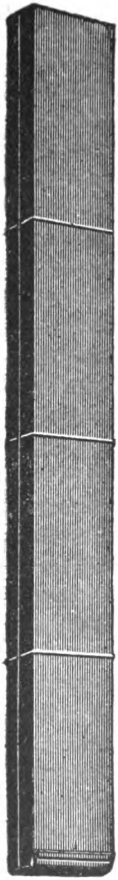


Fig. 189

H. Vertical flues (Fig. 189).

3 sections of 10 feet, each 4 x 12 inches, for S. E. chamber, N. E. chamber and S. W. chamber starting above side wall registers of library, parlor and kitchen. Total, 30 feet.

2 sections of 12 feet, each 4 x 10 inches, for sewing room and bathroom, starting above starter fitting in basement, total: 24 feet.

1 section of 12 feet, 3½ x 11 inches, for N. W. chamber, starting above starter fitting in basement. Total, 12 feet.

I. Combination side wall register boxes and reducers (Fig. 190).

2—7 x 22 inches reducing to 4 x 12 inches, with-12 x 18 inches register outlet (for parlor and library).

1—7 x 16 inches reducing to 4 x 12 inches, with 12 x 14 inches register outlet (for kitchen).

J. Wall register boxes (Fig. 191.)

2—4	x 10 inches	with	8 x 12	inches	register	outlet
2—4	x 10 "	"	7 x 10	"	"	"
1—3½	x 11 "	"	7 x 12	"	"	"
1—4	x 12 "	"	8 x 12	"	"	"

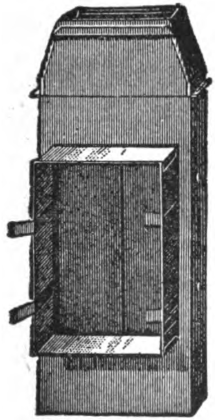


Fig. 190

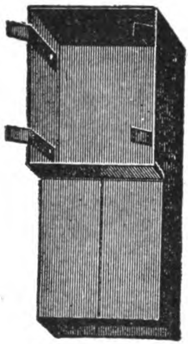


Fig. 191

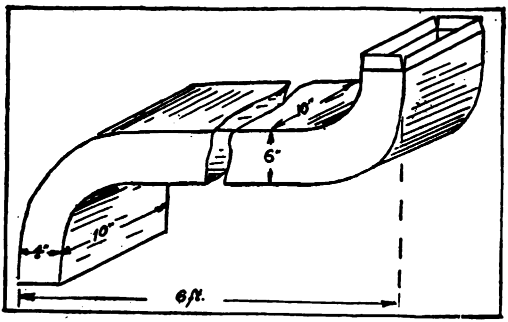


Fig. 192

K. There is further required a duct running below floor of upper story to the sewing room (as shown on second floor plan).

5 feet 6 x 10 inches duct and 2 elbows (Fig. 192).

L. I. C. Terne for covering of studding, beams around starters and around duct below floor on second story. 20 sheets 20 x 28 inches.

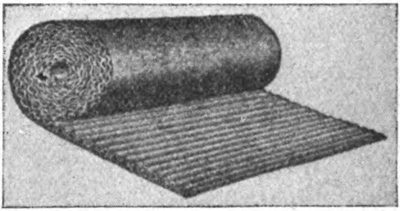


Fig. 193

M. 2-ply air cell asbestos paper (Fig. 193).

119 square feet for covering 34 feet pipe 13 inches diameter
98 square feet for covering 28 feet pipe 12 inches diameter
30 square feet for covering 12 feet pipe 9 inches diameter
53 square feet for covering 21 feet pipe 8 inches diameter

300 square feet.

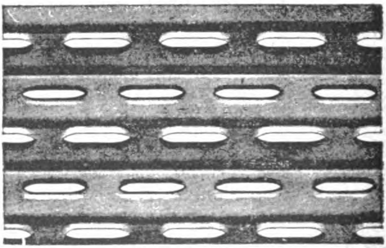


Fig. 194

N. Metal lath, black (Fig. 194), to run from stud to stud (16 inches apart).

180 square feet to cover 6 flues of 10 feet each on both sides.
11 square feet to cover ceiling below duct on second floor.

---

191 square feet, or 12 sheets of 2 x 8 feet.

O. Asbestos cement.

100 pounds.

P. Furnace cement, nails, wire for fastening pipes and other miscellaneous supplies.

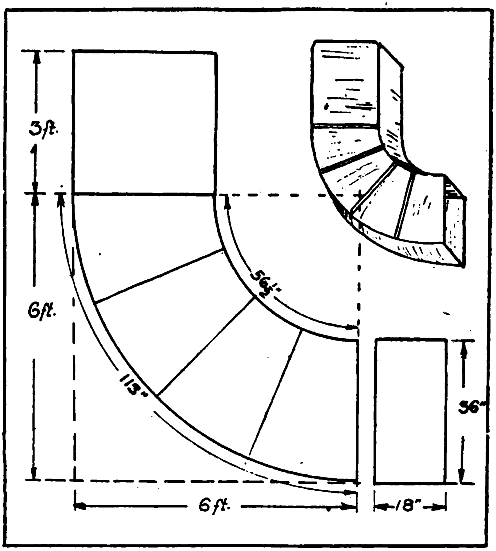


Fig. 195-A

Q. Cold air duct (Figs. 195A and 195B).

The basement plan shows the cold air duct to be 36 inches by 18 inches. In order to use economically 36-inch wide sheets and allowing enough for double seam-ing, the exact measurements of the duct will be 35 inches by 17½ inches. Referring to the sketch of the duct it will be found that there will be required:

For top and bottom of elbow..	2	sheets 36 x 96 inches
For top and bottom of 3-foot straight piece............	¾	"
For sides (113, 36, 56½, 36 inches) 241 inches by 18 inches, or 30 square feet, equal to..................	1¼	"
For furnace shoe to connect duct with casing and flange on other end for connection with cold air chamber.....	½	sheets 36 x 96 inches

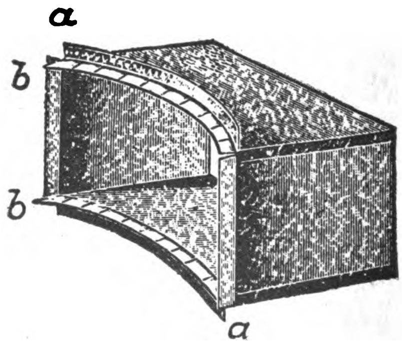


Fig. 195-B

Total..................	4½	sheets 36 x 96 inches

which is equal to 108 square feet, weighing 125 pounds, of No. 24 gauge galvanized steel.

R. Registers, as per schedule on page 335 (Figs. 196 to 198).

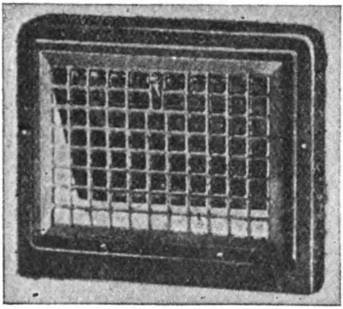


Fig. 196.—Side Wall Register

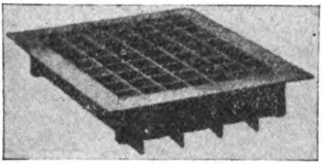


Fig. 197.—Floor and Wall Register

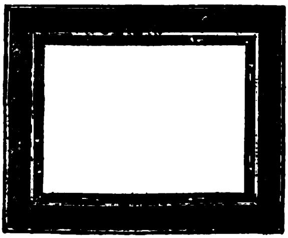


Fig. 198.—Floor Border

ESTIMATE No. 00

Date....................

for installing Hot Air Heating
as per plans and specifications prepared by Architect Mr........
....................................which are here attached.
for Mr..
at..

Material:

Furnace No. 00, 25-inch grate, quoted by Robinson Furnace Co..................................	$125.00
(This price includes casing, bonnet and 1-inch high sand ring on bonnet)	
Smoke pipe:	
2 lengths of 2 feet each 9-inch diameter No. 24 gauge smoke pipe, galvanized........................	1.40
2—9-inch 4-piece adjustable elbows, No. 24 gauge, galvanized..................................	1.50
1—9-inch cast iron damper......................	.45
(All quoted by Bergerson Bros.)	
Round hot air pipe:	
17 sections 20 inches long, 13-inch diameter.........	12.00
15 " 20 " " 12 " "	9.00
5 " 20 " " 9 " "	2.25
10 " 20 " " 8 " "	4.00
(Quoted by Hunter Bros.)	
Collars on furnace bonnet:	
These are made in the shop and the following listed material will be needed:	
For 2—13-inch collars. 1½ sheets 20 x 28 inches	
For 3—12- " " . 2 (+) " 20 x 28 "	
For 1— 9 " " . ½ (+) " 20 x 28 "	
For 2— 8 " " . 1 (−) " 20 x 28 "	
1 x charcoal tin...... 5 sheets 20 x 28 inches	
(Per box of 112 sheets quoted by Bergerson Bros. $26.75).	
Cost per sheet, 24 cents............................	1.20

+ or — mark are to indicate that slightly more or less will be needed than specified. The total requirement, however, will be 5 sheets, as can easily be ascertained.

Dampers:	
2—13 inches diameter at 40 cents................	.80
3—12 " " " 30 "	.60
1— 9 " " " 22 "	.22
2— 8 " " " 22 "	.44
(Quoted by Bergerson Bros.)	
Starters:	
2—7 x 22 inches by 13 inches	
1—7 x 16 " " 12 "	
1—4 x 10 " " 8 " } at $1.20..........	$7.20
1—3½ x 11 " " 9 "	
1—4 x 10 " " 8 "	$166.06
(Quoted by Bergerson Bros.)	

Tin elbows, 4-piece, adjustable:		
6—13 inches diameter, each	75 cents	4.50
4—12 " " "	68 "	2.72
4— 9 " " "	45 "	1.80
6— 8 " " "	42 "	2.52
Tin elbows, 2-piece:		
2—13 inches diamete, each	50 cents	1.00
3—12 " " "	45 "	1.35
1— 9 " " "	35 "	.35
2— 8 " " "	30 "	.60
(Quoted by Bergerson Bros.)		
Floor register boxes:		
2—14 x 16 x 12 inches, each	$1.00	2.00
(Quoted by Bergerson Bros.)		
Vertical flues:		
30 feet 4 x 12 inches, per foot	30 cents	9.00
24 " 4 x 10 " " "	28 "	6.72
12 " 3½ x 11 " " "	27 "	3.24
(Quoted by Bergerson Bros. to be furnished in 20-inch sections, each section to be figured 18 inches net lengths.)		
Register boxes:		
3 combination register boxes and reducers		6.00
6 regular boxes, each		6.00
Duct 5 feet 6 x 10 inches, with 2 elbows (Fig. 192)		7.00
(Quoted by Bergerson Bros.)		
Registers and borders:		
2—12 x 18 inches side wall registers		11.00
2—14 x 16 " floor registers		6.40
2—14 x 16 " cast iron borders		6.40
1—12 x 14 " side wall register		4.50
3— 8 x 12 " wall registers		3.00
2— 7 x 10 " " "		1.70
1— 7 x 12 " " "		.95
(Quoted by F. B. Jennison, Inc.)		
I. C. Terne plates:		2.65
20 sheets 20 x 28 inches		
(From our stock.)		
Asbestos paper, 2 ply:		
300 square feet at 6 cents		18.00
(Quoted by Hirsh & Son)		
33 bands for same at 10 cents		3.30
Metal lath:		
12 sheets 2 x 8 feet, totaling 21⅓ yards at 40 cents		8.60
(Quoted by Bensen Co.)		
Asbestos cement:		
1 bag (100 pounds), Grade B		2.25
(Quoted by Hirsh & Son)		
Furnace cement, nails, wire, etc		1.50
Galvanized iron, gauge No. 24, for cold air duct:		
4¼ sheets 36 x 96 inches (approximately 125 pounds) at 8½ cents		10.63
(From our stock)		
Total cost of material		$301.74
Freight and cartage for asbestos and registers (estimated)		5.00
(All other material will be delivered by the different jobbers, F.O.B. building or shop.)		
Total cost of material		$306.74

Labor:

Shop work:

Making collars for furnace bonnet:		
2 hours at 70 cents		$1.40
Making cold air duct:		
5 hours at 70 cents		3.50
2 hours at 50 cents		1.00
Work on job:		
Furnace:		
Setting of same and cementing seams, etc., 2 men, each 4 hours, total	8 hours	
Smoke pipe:		
Fitting and connecting same	1 "	
Bonnet collars:		
Adjusting same to bonnet	1½ "	
Vertical flues:		
Putting same together into suitable lengths and fastening into place, also covering studs with tin and applying metal lath, 2 men, each 12 hours	24 "	
Cellar hot air pipes and elbows:		
Putting same together into suitable lengths, adjusting dampers connecting pipes and fastening same, including putting floor register boxes into place, 2 men, each 7 hours	14 "	
Asbestos:		
Covering bonnet with asbestos cement and applying sheet asbestos to pipes, also covering bonnet of furnace with sand, 2 men, each 6 hours	12 "	
Cold air duct:		
Putting same in place and connecting to cold air box and furnace, including connecting shoe to casing, 2 men, each 2½ hours	5 "	
Registers:		
Setting same	4 "	
Testing furnace and heating plant, 2 men, each 2 hours	4 "	
Total	73½ hours	
Average rate of pay, 70 cents		51.45
Total labor		$57.35

Summary:

Material		$306.74
Labor*		57.35
Prime cost		$364.09
Overhead expenses:		
Operating, general and administrative expenses:		
Shop work, 9 hours at 41 cents		3.69
Building work:		
73½ hours at 48 cents		35.28
Material expense:		
8½% of $306.74		26.07
		$429.13
Selling expense, 5%		21.46
		$450.59

Total carried	$450.59
Cartage of materials and tools from shop to building and return	$ 5.00
Total cost	$455.59
Add profit.	

*It should be noticed that the time here set for labor is not for the purpose to set a standard rate, nor should it be suggestive as to the average rate of time required; it is here simply used for the purpose to illustrate the method of compiling the estimate.

In submitting an estimate for heating work, where the heating contractor has to design the plant and is to guarantee certain results as to efficiency of the plant, it should be made a point of condition that the building will be so constructed that the presumed facts underlying the estimate (as changes of air per hour, chimney construction, etc.) will be established in the finished building. There are good "standard" estimate and contract forms containing these clauses available for heating work. Such forms are, as a rule, distributed by the trade associations and advertised in trade papers.

Before setting the amount of profit for a heating job, which is to be designed and guaranteed by the heating contractor, a corresponding allowance should be made in the cost figuring to cover the value of this risk.

CHAPTER XIX

ESTIMATING VENTILATING WORK

In this branch of the business probably more profits can be anticipated and on the other hand more often money is lost and disappointment met by the sheet metal contractor than in any other branch of the business. If a ventilating job of small size is undertaken, no special difficulties may be encountered, but "ventilating work" in its broader meaning is a special branch which requires special experience and training, so that the regular sheet metal contractor should hesitate in soliciting and accepting work of this nature unless he has a "justified" feeling of confidence as to his ability to handle such work successfully. "Ventilating" is an engineering problem "pure and simple." Therefore, unless the sheet metal contractor has the principals of ventilating at "his fingertips" he should better let modesty be his virtue and admit his inability to design the system. Often ventilating work is done by concerns who specialize in this work and employ trained "ventilating engineers" for the design of the work. The sheet metal worker is then simply "filling the ventilating engineer's prescription", shoulders only the responsibility for the proper execution of the work and is not liable for the "scientific lay-out or design of the plant and its efficiency." As "sheet metal worker" one should not endeavor (and could not be expected) to do higher engineering work. Considering the importance of ventilation for the welfare of human beings the design of ventilating plants should rightly not be permitted to be designed by a contractor of sheet metal work, the same as a pharmacist is not permitted to make prescriptions for medicine. Ventilating is surely not less important than sanitary plumbing. Rules and regulations governing plumbing cover all details as to design of plumbing installation and direct minutely even the grade and kind of all materials to be used. When legislature will regulate and standardize ventilating work to the same extent as it does plumbing work, the field of ventilating work will be safer for the contractor as well as for the public.

The "Standard Specifications for Ventilating," adapted by the Board of Education of the City of New York, leave very little beyond the practical execution of the mechanical work to be solved by the sheet metal contractor and the specifications give all details as to design and sizes of ducts and branches, dampers, deflectors, branch connections, registers, hangers, etc., also as to kinds of seams, manner of bracing ducts, even sizes and kinds of bolts and rivets to be used. Such close specifications require from the sheet metal contractor only conscientious and careful observance of the specifications to insure a perfect job and an efficient ventilating plant. From the standpoint of the estimator such complete design of the ventilating system is a prerequisite for the preparation of the estimate, and for our purpose we shall presume that a job is to be figured for which plans and specifications give all measurements and details of the completely laid-out ventilating system, leaving nothing to solve but the mechanical execution of the job. At the end of this chapter we reprint the major part of the "Standard New York City Specifications" above referred to and have set in italic type those sections and phases which deserve special attention on the part of the estimator, on account of the influence these provisions have upon cost of the job, or which bring about uncertainties as to cost. For example, the provision:

"all ducts shall be run close up to ceilings, *unless otherwise necessary and approved to clear piping, etc.*" may make it necessary to build elbows and offsets in the duct work which cannot at a certainty be estimated beforehand. The same applies to the provision:

"the right is reserved to *change shape or run of ducts and flues to suit local conditions.*"

The manner of "taking off quantities from plans" has been broadly covered in the previous sections of this book and the writer feels that it would be repetition of what has been already sufficiently explained. We shall therefore explain here only those points which deserve special consideration in connection with duct work and then prepare an estimate, in which we include the cost of certain quantities of material presumed to be necessary for the job, also presume certain labor cost and then show the manner of figuring of "overhead expenses" typical for this class of work.

For any fair size ventilating job it is most economical (and sometimes this is a requirement by the architect) to make and fit all parts, as straight lengths of ducts, bends, offsets, etc., at the job. For this purpose a "transient shop" is to be erected in some suitable part of the building, where the necessary machinery (square shears, break, etc.) is installed. In such case the estimator is confronted with the problem of figuring the correct rate of overhead expenses for the job, which will differ from the rate for regular shop work or building work. In our example in Chapter XII we have established overhead rates for furnace heating and ventilating work. Conditions are different, however, in the case of the transient shop, and we shall show here the manner of arriving at correct overhead rates for the case in question. The cost of transporting machinery to and from the job and erecting machinery, etc., in the transient shop, as well as making necessary enclosures for same, are charged directly to the job, as shown in our estimate for the work in addition to the regular rates for ventilating work.

We presume that the following machinery will be used in the transient shop:

8-foot square shears
8-foot brake
3-foot square shears
3-foot brake
1 punch
1 band and angle iron cutter

We may further presume that the firm doing the work in order to carry through the job and in expectation of other jobs of the same nature has these machines especially bought and regularly reserved for ventilating work in transient shops, transporting same from job to job or placing it in storage when no job is on hand.

We have the following data:

Value of	8-foot square shears	$300.00
	8-foot brake	225.00
	3-foot square shears	65.00
	3-foot brake	55.00
	Punch	35.00
	Band and angle iron cutter	65.00
		$745.00

In connection with these machines we have to consider the following expense items:

Interest on investment, 6% of $745.00........	$45.70
Upkeep and repair per year (estimated or from previous years' records)..................	*110.00
Depreciation and obsoletion 10% of value....	74.00
Insurance ($1.50 per $100 per year)..........	11.18
Cost of storage place, when machinery is not in use on the job..........................	60.00
Total expense..............................	$300.88

It will be noticed that in our schedule on page 198 we have included as overhead items for "Furnace Heating and Ventilating Work" certain amounts for interest on investment, upkeep and repair, depreciation, insurance and rent. These amounts, however, are not for machinery as we have same in the transient shop, but for other appliances regularly used on this class of work. We are therefore justified in adding the full amount of $300.88 as "special" overhead expenses.

We now presume, based on previous experience and judging the future amount of business expected, that we will be able to use this machinery during 8 months (240 days) of the year, while during the remaining time the machinery will be in storage. In order to arrive at a rate per day we divide $300.88 by 240, which gives $1.25 per day, or (the working day figured at 8 hours) approximately 16 cents per hour.

This rate is probably higher than it would be for a firm which does ventilating work regularly, and bidding against such firm may result in losing the job. But,

*This will be higher than in a regular shop where equipment is under better control. The frequent transporting of the machines will also influence upkeep and repair cost.

nevertheless, the truth remains that the cost of the job to our firm would be the amount specified. The only way we may be able to obtain the contract (if the price is a deciding factor) would be to figure a smaller profit than the competitor does. This to decide, however, is a matter of business policy, with which the estimator as such is not concerned. The estimator has to present the figures of cost as they "are." It may happen that the amount of a competitor's bid is so much lower, that to meet same would leave no profit for our firm, although the competitor may have figured a substantial profit. This would only illustrate our assertion at the beginning of this chapter that ventilating work offers prospects of good profits as well as chances for serious losses and disappointments. Knowledge of correct cost arrived at by a scientific method in preparing the estimate will be the effective "stop—look—listen" sign of warning.

In making up the list of material it should be remembered that considerable waste of material has to be expected in duct work if regular size stock sheets of galvanized iron has to be used. For example, a duct 32 inches wide and 20 inches high would cut un-economically from any of the regular stock widths 24, 30 or 36 inches. If time and other condition permit, sheets should be ordered in required widths and "re-squared" from the mill. The re-squaring is essential, because otherwise considerable difficulties will be encountered in using the sheets to full advantage. Nothing but the best grade of sheet steel is economical for duct work. The low grades of sheets are brittle at the edges. This causes the metal to break when being worked at the edges for the lock-seams. Therefore, soft (preferably charcoal iron) sheets should be used for this work.

We may proceed with preparing the estimate for which we presume the cost of material required to be $250.00

Freight and carting of material to job 12.00

The tabulated estimate would then be as follows:

ESTIMATE No. 00

Date ....

for ventilating duct work

as per plans and specifications prepared by ....

for ....

Work to be done by ....

Material: (summarized)		$250.00
Freight and carting		12.00
Labor: (summarized) 3 men, each 22 days of 8 hours, total (3 x 22 x 8) 528 hours, at (average) 70 cents....		369.60
Prime cost		$631.60
Overhead expeuses:		
Regular operating expenses for ventilating work	28 cents	
Special rate for transient shop	16 "	
General and administration expenses	20 "	
528 (hours) x	64 cents	337.92
Material burden:		
8½% of $250.00		21.25
Transportation of machinery and equipment		10.00
Cost of enclosure for building shop and lockers		10.00
		$1010.77
Cost of mason work (building up brickwork where ducts pass through walls) estimated		35.00
		$1045.77
Selling expenses, 5%		52.28
Total cost		$1098.05

In reproducing here Figs. 199 to 209, which are part of the drawings of the "Standard Details for Duct Work" prepared by J. J. McCann of the Building Bureau of the Board of Education of the City of New York, we intend to indicate the value of such detailed design for purposes of estimating as well as economical execution of the work. Such designs furnished with the invitation for bids will also assure a uniform base for estimating and eventually result in standardizing the highest grade of design and mechanical execution of ventilating systems.

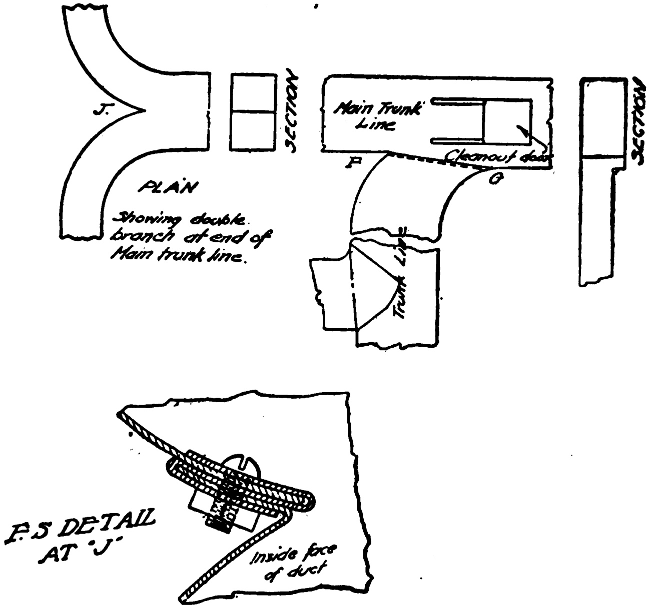


Fig. 199

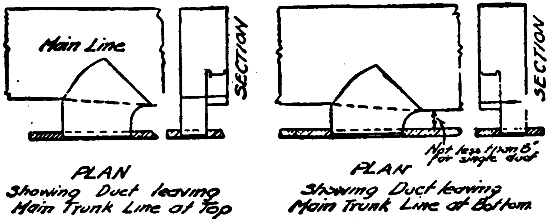
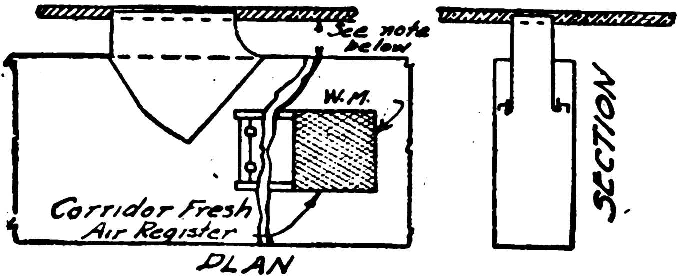
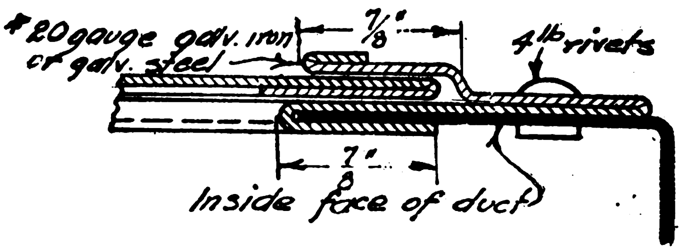


Fig. 200



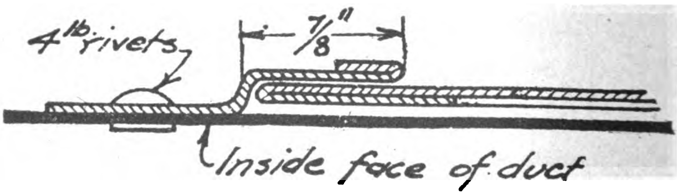
Showing Duct leaving Main Trunk Line between Top and Bottom.

Fig. 201



F.S. DETAIL ON LINE "B-B"

Fig. 202



F.S. DETAIL ON LINE "C-C"

Fig. 203

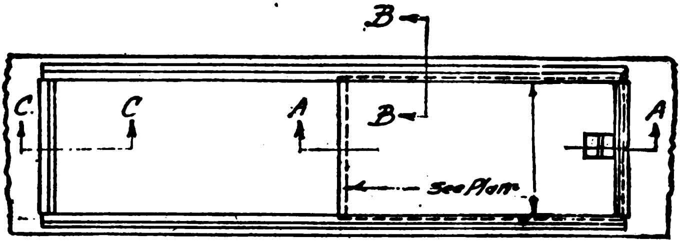


Fig. 204

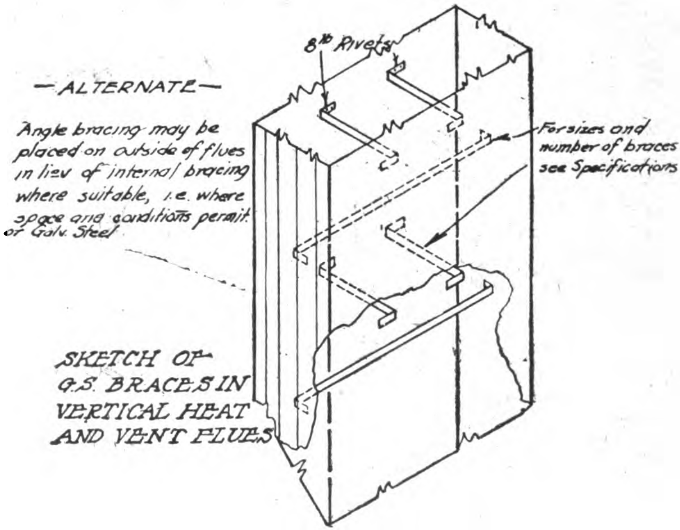


Fig. 205

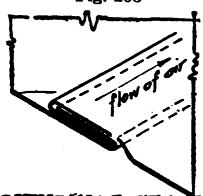


Fig. 206

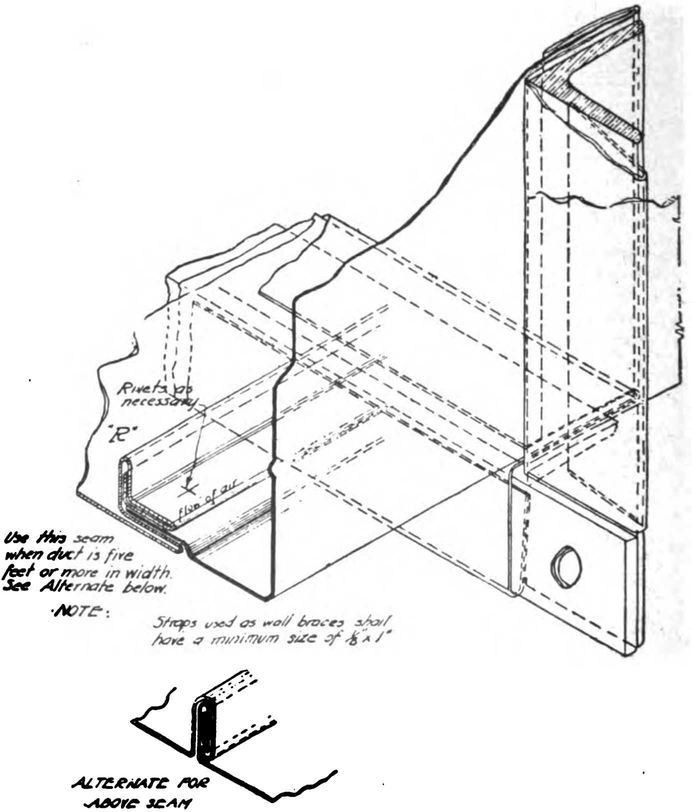

Rivets as necessary
"R"
flow of air
Use this seam when duct is five feet or more in width. See Alternate below.
NOTE:
Straps used as wall braces shall have a minimum size of ⅛" x 1"
ALTERNATE FOR ABOVE SEAM

Fig. 207

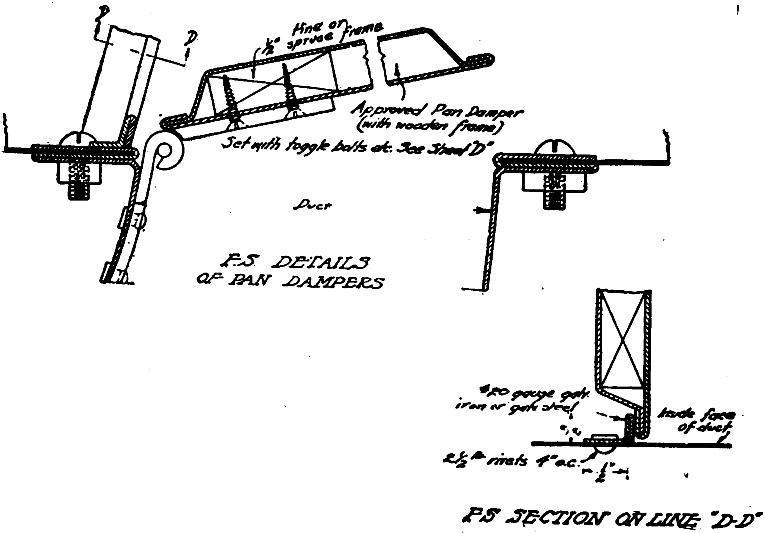


Fig. 208

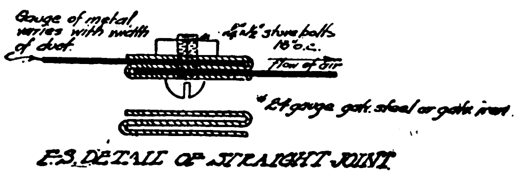


Fig. 209

STANDARD SPECIFICATIONS FOR DUCT WORK

As Adopted by the Board of Education of the City of New York

(A) All sheet-metal work of heat and vent flues and ducts, including all fresh-air ducts and flues, sheet-metal ducts connecting the cold-air intakes, blowers, tempering stacks or heaters and reheaters, together and to the up-takes, also all vent flues and ducts and ventilating hoods, together with all necessary dampers, deflectors, clean-out slides, braces, hangers, etc., etc., all as shown on drawings and as specified herein, shall be completely installed under this contract.

(B) The steel framing, terra-cotta blocks, plastering, etc., of furred ceilings and partitions enclosing such flues and ducts and to support same, will be installed by the General Contractor, but this Contractor shall work *in harmony with General Contractor and his Sub-contractors,* and shall install ducts and flues *as rapidly as progress of other work will permit.* This Contractor shall also brace and support ducts and flues independent of framing for furring, etc., and so as not to interfere with the erection of such enclosing work; all ducts shall be run *close up to ceilings,* unless otherwise necessary and approved, to clear piping, etc.

(C) Sizes and runs of ducts, flues, etc., shall be *approximately* as shown on drawings, but the *right is reserved to change shape or run of ducts and flues* to *suit local conditions.*

(D) All ducts, flues, etc., shall be made of the best bloom galvanized sheet-steel, unless otherwise herein specified. The ducts, flues, etc., shall be put together and erected throughout in a workmanlike manner and in strict accordance with "*Standard G. I. Details 'C,' 'D' and 'E,'*" and all ducts and flues, doors, etc., shall be mechanically air-tight. Ducts, etc., shall be braced from walls, etc., as necessary, to prevent sagging and vibration. Where one duct is run below another duct of greater width, the lower duct shall be hung from the braces of the upper duct by means of strap hangers bolted to the braces of upper duct. Strap hangers of all ducts shall each be made of a continuous single piece of galvanized metal extending down one side of duct and bent and rivetted under same.

(E) There shall be no acute angles in the forming of ducts and flues, but all ducts and flues shall be gradually *curved and run to suit requirements of location.*

(F) Suitable size *anemometer**-reading and clean-out openings shall be formed in bottom or sides of ducts and flues, including branches, and shall be provided with slides for air-reading or clean-out purposes (see Standard Details and drawings). Such openings in concealed ducts and flues shall be located to correspond with doors in partitions or ceilings, etc., furnished in place by other parties. (See drawings.)

(G) *The Contractor shall do all required cutting and repairing* in connection with the running of these ducts and flues through walls, etc., already in place. All such new openings shall be provided with cast or wrought iron lintels, *full-width of walls and sufficiently strong to carry the weight above same. The jambs shall be built up square and plumb and finished to match adjoining work.*

(H) *Where ducts pass through openings in walls,* whether such openings *are cut by this Contractor or left open by other parties,* this Contractor *shall neatly brick*

*Anemometer is an instrument for measuring the velocity of air currents.

up such openings underneath and at both sides of ducts close up to ducts, and a 1¼-inch steel angle shall be rivetted to duct each side of wall to close space between duct and wall practically air-tight. Open spaces above ducts shall be filled in practically air-tight to ceiling and walls with No. 22 gauge galvanized sheet-steel secured to steel angles rivetted to ducts and properly fastened and fitted to ceiling.

(I) *Where steam and other pipes, columns, etc., pass through ducts or flues, the ducts or flues shall be increased in size at these places to allow for obstruction;* air-tight oblong sleeves shall be inserted through ducts or flues, with rivetted flanges for pipes, etc., to pass through. *Before running ducts, plumbers' drawings should be consulted in regard to location of plumbing pipes, etc.* This Contractor shall consult Contractor for Item 2 as to location of humidifiers, etc., and shall leave proper openings therefore.

(J) Where flues come adjacent to offsets in brick walls, they shall splay back full-size to face of wall above offset. All vent flues and ducts shall be connected mechanically air-tight with ventilators and air pumps on roof.

(K) For ducts and flues from heating chambers or tempering stacks to blowers and from blowers to the bases of vertical uptakes in each case, and also for the ducts from vent uptakes to exhausters and from exhausters to ventilators, the gauge of sheet-metal shall be No. 24 gauge for ducts and flues not more than 36 inches in either dimension, No. 22 gauge for ducts and flues 36 to 54 inches in larger dimension, No. 20 gauge for ducts and flues 54 to 72 inches in larger dimension, and No. 18 gauge for ducts and flues exceeding 72 inches in either dimension. Large indirect stack casings, connections between stacks, and extension from stacks to fresh-air downtakes and blowers shall be as hereinbefore specified. Dampers shall be as hereinafter specified.

(L) For all other ducts and flues up to roof line, the gauge of metal shall be No. 24 throughout, except for dampers. For vent flues above roof line and for all ventilator heads, except air pumps, the gauge of metal shall be No. 22.

(M) All joints shall be constructed as shown by accompanying Standard G. I. Details, or as otherwise approved; overlaps, sleeves, guides, etc., shall be of No. 24 gauge, angles and straps shall be used for cross bracing and stiffening, spaced not to exceed 4 feet on centers, secured and rivetted *as and where shown, and as and where directed* to properly secure and stiffen the ducts and flues.

(N) Below roof line all rivets shall be tinned rivets and all bolts shall be button-head stove bolts, ¼ x ¾-inch minimum size and rivetted to prevent loosening. Above roof line all rivets and bolts shall be tinned; they shall be soldered over after being driven and shall be provided with tinned protecting washers.

(O) The numbers of gauges of metal herein specified shall be taken to mean U. S. Standard Steel Gauge.

(P) For all ducts (*i.e.*, all air conduits except vertical flues), the braces shall be 1-inch standard angles for ducts not exceeding 36 inches in either dimension, and 1¼-inch standard angles for ducts larger than 36 inches in either dimension.

(Q) All vertical flues shall be put together with slip-joints made mechanically air-tight and shall be braced with galvanized steel flats set on edge. These braces shall be made of ⅛ x 1-inch flats for braces up to 30 inches between surfaces braced, and $\frac{3}{16}$ x $1\frac{1}{4}$-inch flats for longer braces. These braces shall be set staggered on width and length of flue, not more than 4 feet apart in height for each set of braces and not more than 2 feet apart in width of flue. (Every flue larger than 12 inches on either side shall have cross braces in both directions.) Suitable angles on outside of flues may be used in place of flats inside.

(R) The Assembly Room and Playroom Reheaters shall be encased in galvanized sheet-steel removable casings, constructed to agree in every respect with duct work herein specified.

(S) The sheet-metal vent ducts and flues from Toilets and Motion Picture Booth, etc., extending to air pumps, vent hoods or exhaust fans, and also the air pumps and vent hoods in connection therewith, as indicated on drawings, shall be constructed throughout of special galvanized sheet iron; the highest grade of American Ingot Iron, Inland Steel Company Vismera Iron, Newport Rolling Mill Co. Genuine Open Hearth Iron, or Toncan metal, or other equal thereto, will be approved. Such flues, etc., where enclosed in terra-cotta partitions shall be constructed and erected similar in all respects to other sheet-metal work herein specified; exposed flues in Toilets, etc., shall be constructed as hereinafter specified, and as per Standard G. I. Details.

(T) All exposed ducts and flues in all Toilets in entire building shall be double-seamed, with sections put together with slip joints, made as per "Straight Joint Detail" (G. I. Detail D), and properly secured with iron loops, as directed. Exposed ducts and flues shall be tightly connected to enclosures at rear of seats, etc., and to ducts and flues enclosed in partitions at ceilings (see drawings). A neatly fitting collar shall be provided for each connection to enclosures at rear of seats.

(U) The inside of all ducts and flues connecting water-closet seats with vent hoods on roof shall be painted BEFORE ERECTION with two coats of black asphaltum varnish or Bitumastic paint; all exposed surfaces shall be painted two coats of radiator enamel, color as selected.

(V) The fresh-air inlets near ceiling in Gymnasiums which are supplied from blowers supplying classrooms, and also in Open-Air Rooms and in adjoining Food Preparation Rooms shall be provided with wire screen registers, adjustable blade deflectors, etc.; and the volume of air through each fresh-air register shall be tested, blade deflectors adjusted, etc., similar in all respects to ventilating system in remainder of building. After damper settings have been approved by the Superintendent, this Contractor shall blank off these fresh-air inlets, also the vent outlets, with No. 22 galvanized steel plates securely fastened in position at back of registers. Such plates, where exposed to view, shall be painted similar to other exposed sheet-metal work as hereinafter specified.

(W) DEFLECTORS.—A deflector made of No. 24 galvanized steel, with ends wired with No. 6 B. & S. gauge half-hard wire, shall be furnished and installed at each fresh-air inlet throughout building. The symbol or note at each inlet indicates type of deflector which shall be installed in each case.

(X) Where the symbol "B. D." is placed in horizontal inlets, Special Board of Education Pattern Adjustable Multiple Blade Deflectors (with shelves) shall be installed. All necessary stops, guides, rods, set-screws, etc., shall be provided and deflectors shall be made strictly as per Standard Detail 108. In certain rooms where the symbols "S. B. D.," or "B. D. K.", etc., are placed in inlets (see drawings), these deflector blades shall be especially constructed to suit size and location of respective inlet. (See Standard Detail 108.)

(Y) The Adjustable Deflectors shall be put in place prior to setting of dampers, hereinafter specified, which shall include adjusting of the deflectors to give uniform flow of air throughout registers.

(Z) DAMPERS, DEFLECTING PLATES, ETC., made as shown on Standard G. I. Details shall also be furnished and installed where shown on drawings *and as necessary to obtain the proper distribution* of air in entire building. In this connection adjustable dampers shall be provided for all main and branch heat and vent ducts and flues.

(AA) All single thick dampers shall be made of No. 16 gauge sheets with reinforced edges. Pan dampers shall be made of No. 20 gauge sheets nailed with galvanized nails to suitable clear pine or spruce frames.

(BB) All set-dampers shall have suitable clamps for small ducts and quadrants for large ducts for setting same. Damper rods, when ends are exposed to view, shall be sawed across ends in exact line with damper blades for ease in setting same. All SET-SCREWS used in this work shall be steel-cup-pointed. Dampers over large ducts shall be arranged to be operated by means of heavy chains and pulleys, with "OPEN" and "SHUT" indicators.

(CC) Where dampers are set in flues enclosed in terra-cotta partitions or plastered ceilings, the work shall be carefully done, *and all damage shall be made good*; exposed damper rods shall be provided with set-screw clamps, etc., as per Standard G. I. Details.

(DD) Each damper, excepting those dampers operated in the room controlled thereby, shall have a neatly stenciled BRASS TAG about 1½ x 3 inches in size screwed onto woodwork surrounding damper, or rivetted onto ducts at dampers in ducts not enclosed. This tag shall give in large plain letters and figures, the number of room or story controlled by the damper in each case.

(EE) ADJUSTING SET-DAMPERS.—Owing to the difference in length and position of the fresh-air and vent ducts and flues leading to and from the several rooms, etc., from the blowers and to the exhausters and fans, the HEATING CONTRACTOR shall adjust the flow of air by partly closing the dampers, adjustable deflectors, etc., in the ducts and flues to equalize the volume of air to be discharged into and withdrawn from each room, and in this connection the speed of air shall be measured with an anemometer at the opening or openings of the fresh-air ducts and vent flues or ducts in each room, including Auditorium, playrooms, etc., and also as necessary in the various trunk ducts and flues.

(FF) NOTE.—The exhausters and exhaust fans shall be tested for required air delivery, and the amount of air exhausted through each vent opening or register by respective exhaust fan, shall be tested in each case, with all windows of rooms vented thereby WIDE OPEN and with supply fans not in operation. Supply fans (or blowers) shall be tested for required air delivery, and the amount of air delivered through each fresh-air opening or register shall be tested in each case with corresponding exhaust fans in operation (after being tested as above), and with windows TIGHT SHUT. Where two or more supply fans discharge into same main fresh-air duct, all such fans shall be operated simultaneously during above test.

(GG) Adjustable deflecting plates shall be provided for and placed in ducts or flues where necessary and where shown, so as to obtain the required amount of air through each register.

(HH) The amount of air passing through each opening shall be not less than that marked on drawing for each case, nor shall it exceed such amount by more than ten (10) per cent in any case. (Individual readings at any portion of the opening shall not vary from the required velocity by more than twenty (20) per cent.) After damper settings have been approved by the Superintendent, the Contractor shall MARK POSITIONS OF DAMPERS with painted lines as directed.

(II) TELL-TALE STREAMERS 18 inches long by 2 inches wide, made of approved dark brown silk ribbon shall be furnished; one streamer shall be attached at opening of each fresh-air inlet throughout the building in an approved manner and at height as directed; streamers shall not be put in position until dampers have been adjusted. Streamers need not be placed on fresh-air inlets at Auditorium window sills.

(JJ) CANVAS NECKS.—Portions of fresh-air and vent ducts, about 2 feet in length, where shown on drawings, shall be formed of 10-ounce canvas (see drawings). The seams in these portions of ducts shall be tightly sewed and made air-tight, and the canvas shall be properly fastened in an approved manner to galvanized steel ducts by clamp joints extending entirely around duct. Such canvas shall be painted to leave same air-tight.

(KK) COVERING OF DUCTS.—All exposed portion of Auditorium fresh-air and vent ducts in Boiler Room, etc., and elsewhere where so indicated on drawings, shall be covered with asbestos air-cell covering of thickness equal to projecting leg of angle framing around ducts, properly and neatly secured in place with 8-ounce canvas sewed on, with seams on top. Portions of such ducts in Coal Room shall also be covered with air-cell covering as above specified, and then shall be encased in a No. 24 galvanized steel casing. Coverings (canvased and steel encased) shall finish tight to adjoining ceiling and walls. Air-cell covering and canvas shall in all respects be similar to materials specified for pipe covering, and canvas and casings shall be painted as specified in Section 65.

(LL) VENTILATORS.—Sheet-metal ventilators or vent hoods shall be erected over vent uptakes, and exhauster and fan discharges. Except for Air Pumps hereinafter specified, these hoods or ventilators shall be made in strict accordance with Standard G. I. Details and preceding paragraph (L) as to general details and of dimensions as given in each case on Roof Plan. All necessary framing for ventilators proper shall be furnished by this Contractor and securely bolted to framing furnished in place by other parties. Curb, *i.e.*, terracotta blocks, outside sheet-metal covering, roof flashing, etc., will be furnished by other parties in each case, but this Contractor shall flash over top of curb and shall extend main vent flue up through curb and make all work air and water-tight to ventilator and curb in each case.

(MM) AIR PUMPS.—Where shown on drawings, this Contractor shall furnish air pumps over vent stacks from Toilets, Motion Picture Booth, etc. Air pumps of the very highest grade of Autoforce Ventilating System, The Bicalky Fan Co. (Roof Fan Ventilators), or Century Ventilating Co., or other equal thereto, will be approved. Each of these air pumps and the transition or base piece, connecting same to the respective flue shall be made of No. 20 U. S. Standard gauge galvanized steel, properly stiffened and braced. Each ventilator base shall be fitted over and flashed and secured to vent curb, etc., left by other parties. Inside of air pumps shall be heavily painted with the very highest grade of asphaltum of Bitumastic paint; the exterior shall be painted as hereinafter specified, to match standard ventilators.

(NN) Unless ventilators, air pumps, etc., are installed prior to starting of plastering, all such openings shall be temporarily made weather-proof as follows: For all vent flues projecting through roofs, water-tight water sheds of sheet metal shall be securely fastened in place over curbing, and such sheds shall be kept in place until permanent ventilators, air-pumps, etc., are built ready for immediate installation. *Tarpaulins* shall be used to keep out moisture while ventilators are in course of erection.

(OO) Each vent flue leading to ventilators and air pumps (except Motion Picture Booth vent flue which shall have no damper), shall be equipped with a damper made in one or more sections, as per standard G. I. Details and supported in special bearings all complete, as shown on Standard G. I. Details. The bearings for these dampers shall be securely bolted to angles and tees furnished for this purpose by other parties, or by this Contractor when so required.

(PP) All the dampers in all ventilators and air pumps shall be provided with operating chains accessible in respective Exhauster Room on roof, or from other approved accessible locations. Each chain or hook shall be provided with suitable "OPEN" and "SHUT" indicating tag or label. Where doors (furnished by other parties) in ventilator curbs do not permit access to all dampers in each stack, this Contractor shall form an approved weather-tight door in base of each such ventilator for access to dampers. These doors shall be 12 x 16-inch, (or of size as directed for small hoods).

(QQ) The dampers and all galvanized steel-work in connection therewith in the vent flues from Toilets and Motion Picture Booths shall be covered with two heavy coats of black asphaltum varnish or Bitumastic paint.

(RR) AUDITORIUM AND PLAYROOM MAIN VENT AND RECIRCULATION DAMPERS.—Easily operatable and closely fitting hinged dampers, constructed with materials, special bearings, etc., similar to ventilator dampers, bearings, etc., hereinbefore specified and provided with counter-balances, etc., shall be furnished and installed in the Auditorium and Playroom main heat and vent ducts or flues, and in connection between heat and vent ducts or flues, as shown on drawings. Dampers shall each be equipped with rod extension for connection by Contractor for Item 2. *A detail drawing shall be furnished and delivered for approval of the Superintendent before commencing work on dampers.*

(SS) REGISTER GRILLES AND SCREENS.—Except for special register faces in Auditoriums, noted on drawings as being furnished by other parties, all registers and wire screens in fresh-air and vent openings shall be furnished and installed all complete together with galvanized steel register boxes, etc., by this Contractor, in openings left by other parties. For sizes of registers and screens, see drawings. NOTE that no registers are required for vent outlets occurring in wardrobes.

(TT) ALL CAST-IRON REGISTERS furnished under this contract shall be cast-iron black japanned register faces or grilles (with strengthening bars and frames when set in floor). These grilles shall have all surfaces faced and shall be free from burrs and inequalities, and shall have no valves or wheel slots, but shall have countersunk screw holes. Cast-iron registers and grilles of the very highest grade of American Register Co., W. G. Creamer & Co., "Kernan," or Tuttle & Bailey Mfg. Co., or other equal thereto, will be approved. Register grilles set in side walls shall be painted to match wall finish.

(UU) All cast-iron registers shall be secured in place by channels or angles and screws so that they may be removed without disturbing the plaster work or disfiguring the moldings; one section of each vertical vent register shall be hinged with 3 x 2½-inch plain loose pin cast-brass butts and secured with an approved rim deadlock at least 3½ inches wide by 2½ inches high and ⅝-inch thick, with heavy bolt having at least ½-inch throw and fitted with tinned malleable or steel key; all keys shall be interchangeable and six (6) keys shall be furnished. Each lock shall have a suitable striking plate.

(VV) WIRE SCREEN REGISTERS shall be made of No. 10 Brown & Sharpe Wire Gauge half-hard wire, 2-inch diagonal mesh framed in ¾-inch steel channel frames with ¾ x ⅛-inch flat covering strips rivetted into place on all edges. Each wire screen register shall be hinged with at least two 3 x 2-inch plain loose pin (not ball tipped) butts, screwed to wooden trim. All screens in fresh-air inlets shall be provided with approved heavy square case bolts (two to each screen wider than 24 inches in either dimension), as shown on Standard G. I. Details. Approved heavy spring snap catches rivetted into ducts may be used in place of case bolts.

(WW) All screens in vent outlets in side walls shall be made and hinged same as fresh-air registers, but shall be hinged at side (with three hinges each if longer than 48 inches in either dimension and otherwise with two hinges each), and shall each be equipped with a mortise dead-lock at least 1¾ inches high, 2 inches wide, and exactly $\frac{9}{16}$-inch thick with ¾ x 3-inch front, and tinned malleable or steel key; all keys shall be interchangeable. (Six (6) keys shall be furnished.) The tumblers for these locks shall have at least ½-inch throw and shall be at least ¼-inch thick. Each lock shall be countersunk through frame of screen and shall be bolted to frame and rivetted to neatly formed sheets of galvanized steel (one on each side of screen mesh), all as per sample in Office. Each lock shall have a suitable striking plate, and each screen shall have at least two suitable stops.

(XX) Screen registers in ceilings shall be made as above and shall be hinged and provided with cup-board turns of approved design properly installed.

(YY) Screens of ¾-inch mesh of No. 12 galvanized iron wire cloth in ½-inch round iron frames shall be furnished in place across outlets of all vent hoods above the roof, all securely fastened to framework with hinges and snap latches as per Standard G. I. Details.

(ZZ) All surfaces of sheet-metal and framework exposed to weather or to view, also all wire and grille registers in side walls and ceilings, also all dampers and blanking sheets (in Gymnasiums, etc.) visible from rooms, also the insides of connections between heaters and blowers and between blowers, tempering stacks or heaters and reheaters, so far as may be furnished under this contract, shall be painted as hereinafter specified under "PAINTING."

CHAPTER XX

MANUFACTURING OF SHEET METAL ARTICLES

Now, more than ever, the American sheet metal worker is confronted with the possibility of entering the field of manufacturing sheet metal articles of a commercial character, and more than ever, the trend of the time is now to use machines to take the place of human hands. In sheet metal working the "power press" is the king of manufacturing machines. Often, what would require days and weeks of tedious work by the trained mechanic and hours by the means of other sheet metal working machines, and more often work that cannot be done at all by hand, can be completed by the power press in a second, attended by untrained workers.

In order to estimate sheet metal stamping a thorough knowledge of the practical side of the subject is required. The estimator must often consult the "die-maker" before he is able to complete his figures. It is beyond the scope of this book to present an exhaustive treatise on sheet metal stamping. A practical example of an estimate for sheet metal stamping and drawing may suffice here to show the principals involved and create the desire for, as well as point the way to a deeper study of the subject matter.

In order to estimate sheet metal stamping certain preliminary information must be obtained by the estimator. We shall consider here the stamping of a certain round copper bowl, for which the following basic information is on hand:

Quantity required, 10,000 pieces or 50,000 pieces (the estimator is to show the cost per piece).

Net weight of sample, 10 ounces.

Press operations required to draw the article in question:

First operation: blanking.

Second operation: forming partly to the desired shape.

Third operation: final forming to the desired shape.

Fourth operation: trimming.

Between the second and third operations the metal has to be annealed (softened) to prevent tearing when being drawn.

Cost of dies, $300.00.

As the blanks for this article are circular, there will be a certain amount of waste material, which must be included in the estimate. From the table on page 000 we know that the area of a circle is .7854 of the area of a square from which it is cut. For example, a square of 10 inches has an area of 100 square inches, while a circle of 10 inches diameter has an area of 78.54 square inches. The same proportion will be in the weight of the square and the circle of equal measurements. If a circular disk weighs 78.54 pounds, then the square from which this circle is cut will weight 100 pounds; therefore to this net weight of circular disk a waste of (100 less 78.54) 21.46 pounds must be added, or for 100 pounds net weight of the disk $\frac{(100 \times 21.46)}{78.54}$ 27.32% pounds waste.

A certain amount of waste material must also be figured for trimming the drawn article (fourth operation) and a reasonable amount, based on judgment, for spoilage in drawing through tearing of the material.

It requires extensive experience in this line to be able to judge fairly correctly the number of operations required to draw or stamp a certain article. Often, however, the best die designer will not be able to tell in advance positively how many operations may be required. It is always advisable for the sheet metal worker to consult the die designer as to the number and kinds of drawing operations required and the approximate cost of the dies to enable the estimator to prepare a fairly safe estimate.

Metal, when drawn into shape, will not retain its thickness evenly. It would therefore be unsafe to measure the thickness of a drawn metal article by the micrometer calibre and conclude from it the gauge of material required for the article. It is safer for the estimator to compute the amount of material required from the weight of the sample submitted and add the waste as indicated above.

When the requirements for a certain article to be drawn are such that the article is to be made of material of certain thickness in the blank, then it would be required for the estimator to ascertain the size of the blank necessary for the work. As a rule this cannot be done correctly before the dies are made. From actual test with the finished die the size of blank is found. If estimating before the dies are finished, the estimator must make proper allowance for this uncertainty.

Occasionally it is required to produce an article, which, when completed, should be of certain thickness at a certain part of the article. In such case the thickness of the blank is not known beforehand and the estimator must make a safe allowance for the drawing qualities of the metal to be used. In many cases the die designer will not be able to state in advance the size or the thickness of the blank material.

In the following page we show a typical sample estimate for metal stamping.

ESTIMATE No. 00

Dated November 20, 19. .

Article: Bowl as sample, net weight 10 ounces.
Material: copper.
For. . . . .
Quantity required: 10,000 or 50,000 pieces.

Use this space for figuring

Required per 1,000 pieces			
Material:			
10,000 ounces, or	625 pounds		
Waste (6.25 x 27.32)	170¾ "		
Trimming waste	40 "		
Total	835¾ pounds		
At 35 cents			$292.51
Less value of waste, 210 pounds at 16 cents			33.60
Net cost			$258.91
Labor:			
Press operations:			
Blanking 800 per hour	1¼ hours		
Forming 600 per hour	1⅔ "		
Forming 600 per hour	1⅔ "		
Trimming 600 per hour	1⅔ "		
Total	6¼ hours		
At 50 cents			3.25
Cost of annealing between second and third operations			5.00
Total prime cost			$267.16
Overhead expenses:			
Operating expenses, 6¼ x 21 cents		$1.31	
Administration and general expenses, 6¼ x 20 cents		1.25	
Merchandise expenses: 8½% of $292.51		24.86	27.42
			$294.58
Selling expenses, 5%			14.73
			$309.31
Add for spoilage, 1%			3.09
Total cost per 1,000 pieces			$312.40
Cost of dies $300.00, distributed over 10,000 pieces, per 1,000			30.00
Total cost including dies in 10,000 lots			$342.40
Cost per piece, 34.24 cents.			
If 50,000 pieces are made cost would be			$312.40
Cost of dies $300.00 ÷ 50			6.00
Total cost, including dies in 50,000 lots			$318.40
Cost per piece, 31.84 cents.			

Estimated by. . . . .
Checked by. . . . .
Quote: 20% profit.
Approved by. . . . .

The cost of doing metal stamping and drawing will vary considerably in accordance to the equipment of the plant. There are automatic feed attachments in use which eliminate human labor. Some presses have a capacity of 1,500 stampings per hour, while other presses will stamp up to 7,000 pieces per hour of the same article. Any attempt to standardize cost for an article produced in different shops will be futile when such things are taken in consideration.

In connection herewith it may also be mentioned that in many manufacturing plants special rates of manufacturing expenses are set for different machines or presses. In the same manner as we have set different rates for the different branches of the business (sheet metal jobbing, sheet metal shop work, hot air heating, etc.), for the reason that each branch carries a different rate of overhead expenses, the metal stamping department should be considered separately, if a considerable amount of work is expected in this branch of the business.

In our case we have only one power press and one foot press, both of comparatively small value; we therefore have included same in the general overhead. There are presses in use which cost $5,000.00 or considerably more. Such presses would certainly cost much more per working hour than a small press of $500.00 value. Therefore, in larger plants each press is figured separately and a certain rate set for same, which is charged as operating expense for each hour such press is used for a job. It has been found that some machines carry an hourly operating expense of $3.00 and more, while other machines will only carry 25 cents per hour charge.

CHAPTER XXI

TRADE CUSTOMS, STANDARD PRICE LIST, ETC., FOR PRODUCTS GENERALLY BOUGHT BY THE SHEET METAL WORKER

It is of great importance to the estimator, that he be acquainted with the prevailing trade customs relating to material. This will not only enable him to set correct prices, but also to determine the standard quantities which have to be purchased and the amount of waste to be considered. For example, if 85 feet of corrugated leader pipe is required for a certain job, the estimator should know that same is sold in 10-foot length and that therefore 90 feet are to be bought and a waste of 5 feet has to be considered. Furthermore he will be able to indicate to manufacturers and dealers in the proper trade names the material required and will more intelligently understand price quotations received. Using proper trade terms indicates experience and often inquiries for prices are judged by the experience the inquirer reveals in the wording of his inquiry, and this often leads to special considerations on the part of manufacturers and dealers. Ignorance of trade customs has resulted in serious losses. If, for example, copper is quoted at 35 cents base price and it is overlooked to add the differentials for cold rolling, polishing, or for widths of sheets, the difference on a few hundred pounds of copper may be considerable. The list and schedules printed in this chapter do not cover the entire field of merchandising concerning the sheet metal worker, but the most important articles are covered. As a rule one will not experience any difficulty in obtaining prevailing list prices and information of trade customs, price differentials, etc., from the manufacturers and dealers. A careful study of catalogs and market reports in trade papers are essential to the estimator.

Sheet Iron and Steel in Sheets

This material is manufactured according to the U. S. Standard Gauge, regulated by Legislature, as follows:

An Act Establishing a Standard Gauge for Sheet and Plate Iron and Steel

Be it enacted by the Senate and House of Representatives of the United States of America in Congress Assembled, that for the purpose of securing uniformity the following is established as the only standard gauge for sheet and plate iron and steel in the United States of America, namely:

Number Gauge	Approximate Thickness in Fractions of an Inch	Approximate Thickness in Decimal Parts of an Inch	Weight per Square Foot in Ounces Avoirdupois	Weight per Square Foot in Pounds Avoirdupois
6	13-64	.203125	130	8.125
7	3-16	.1875	120	7.5
8	11-64	.171875	110	6.875
9	5-32	.15625	100	6.25
10	9-64	.140625	90	5.625
11	1-8	.125	80	5.
12	7-64	.109375	70	4.375
13	3-32	.09375	60	3.75
14	5-64	.078125	50	3.125
15	9-128	.0703125	45	2.8125
16	1-16	.0625	40	2.5
17	9-160	.05625	36	2.25
18	1-20	.05	32	2.
19	7-160	.04375	28	1.75
20	3-80	.0375	24	1.50
21	11-320	.034375	22	1.375
22	1-32	.03125	20	1.25
23	9-320	.028125	18	1.125
24	1-40	.025	16	1.
25	7-320	.021875	14	.875

Number Gauge	Approximate Thickness in Fractions of an Inch	Approximate Thickness in Decimal Parts of an Inch	Weight per Square Foot in Ounces Avoirdupois	Weight per Square Foot in Pounds Avoirdupois
26	3–160	.01875	12	.75
27	11–640	.0171875	11	.6875
28	1–64	.015625	10	.625
29	9–640	.0140625	9	.5625
30	1–80	.0125	8	.5
31	7–640	.0109375	7	.4375
32	13–1280	.01015625	6½	.40625
33	3–320	.009375	6	.375
34	11–1280	.00859375	5½	.34375
35	5–640	.0078125	5	.3125
36	9–1280	.00703125	4½	.28125
37	17–2560	.006640625	4½	.265625
38	1–160	.00625	4	.25

And on and after July first, eighteen hundred and ninety-three, the same and no other shall be used in determining duties and taxes levied by the United States of America on sheet and plate iron and steel. But this act shall not be construed to increase duties upon any article which may be imported.

SEC. 2. That the Secretary of the Treasury is authorized and required to prepare suitable standards in accordance herewith.

SEC. 3. That in the practical use and application of the standard gauge hereby established a variation of two and one-half per cent, either way, may be allowed. Approved March 3, 1893.

We have omitted here that part of the schedule relating to sheets up to gauge No. 5, as same is of no interest to the sheet metal worker.

Sheets are sold in bundles weighing approximately 150 pounds, and at prices in accordance with the schedules here following. The "base price" varies according to market conditions. No. 28 gauge sheets up to 30 inches wide are sold at the base price. For other gauges and

28-gauge sheets wider than 30 inches a "differential" is charged as stated in the schedules, which were adopted voluntarily by the American sheet manufacturers.

SHEETS—GALVANIZED

Size in Inches	Wt. per Sheet	Net Extra for Size
No. 10x30x 96	116	−1.00
36x 96	139	−1.00
36x120	173	−1.00
48x 96	185	−.80
No. 12x30x 96	91	−.90
36x 96	109	−.90
36x120	136	−.90
48x 96	145	−.70
No. 14x30x 96	66	−.90
36x 96	79	−.90
36x120	98	−.90
48x 96	105	−.70
No. 16x24x 96	43	−.75
24x120	53	−.75
30x 96	53	−.75
30x120	66	−.75
36x 96	64	−.75
36x120	80	−.75
48x 96	85	−.55
No. 18x24x 96	35	−.60
24x120	43	−.60
30x 96	43	−.60
30x120	54	−.60
36x 96	52	−.60
36x120	65	−.60
48x 96	69	−.40
No. 20x24x 96	27	−.60
24x120	33	−.60
28x 72	23	−.60
28x 84	27	−.60
28x 96	31	−.60
28x108	35	−.60
28x120	39	−.60
30x 72	25	−.60
30x 84	29	−.60
30x 96	33	−.60
30x108	37	−.60
30x120	41	−.60
36x 96	40	−.60
36x120	50	−.60
48x 96	55	−.20
48x120	63	−.20
No. 22x24x 96	23	−.45
24x120	28	−.45
28x 72	20	−.45
28x 84	22	−.45
28x 96	26	−.45
28x108	28	−.45
28x120	33	−.45
30x 72	21	−.45

Size in Inches	Wt. per Sheet	Net Extra for Size
No. 22x30x 84	25	−.45
30x 96	28	−.45
30x108	30	−.45
30x120	35	−.45
36x 96	34	−.45
36x120	42	−.45
No. 24x24x 96	19	−.45
24x120	23	−.45
26x 96	20	−.45
28x 72	17	−.45
28x 84	19	−.45
28x 96	22	−.45
28x108	25	−.45
28x120	27	−.45
30x 72	17	−.45
30x 84	20	−.45
30x 96	23	−.45
30x108	26	−.45
30x120	29	−.45
36x 96	28	−.45
36x120	35	−.45
No. 26x24x 96	15	−.30
24x120	18	−.30
28x 72	13	−.30
28x 84	15	−.30
28x 96	17	−.30
28x108	19	−.30
28x120	21	−.30
30x 72	14	−.30
30x 84	16	−.30
30x 96	18	−.30
30x108	20	−.30
30x120	23	−.30
36x 96	22	−.30
36x120	27	−.30
No. 28x24x 96	13	Base
24x120	16	"
26x 96	14	"
28x 72	11	"
28x 84	13	"
28x 96	15	"
28x108	16	"
28x120	18	"
30x 96	16	"
30x120	20	"
36x 96	19	+.20
36x120	23	+.20
No. 30x24x 96	11	+.50
30x 96	13	+.50

SHEETS, ONE PASS, COLD ROLLED (BLACK)

Size in Inches	Wt. per Sheet	Net Extra for Size	Size in Inches	Wt. per Sheet	Net Extra for Size
No. 18x24x 96	32.64	−.20	No. 22x24x 96	20.40	−.15
24x120	40.80	−.20	24x120	25.50	−.15
26x 96	35.36	−.20	26x 96	22.10	−.15
28x 96	38.08	−.20	28x 72	17.85	−.15
30x 96	40.80	−.20	28x 84	20.83	−.15
30x120	51.00	−.20	28x 96	23.80	−.15
36x 96	48.96	−.20	28x108	26.77	−.15
36x120	61.20	−.20	30x 96	25.50	−.15
40x 96	53.60	−.15	30x120	31.87	−.15
40x120	67.97	−.15	36x 96	30.60	−.15
42x 96	57.12	−.15	36x120	38.25	−.15
42x120	71.40	−.15	No. 24x24x 96	16.32	−.15
48x 96	65.28	−.15	26x 96	17.68	−.15
48x120	81.60	−.15	28x 72	14.28	−.15
No. 20x24x 96	24.48	−.20	28x 84	16.66	−.15
24x120	30.60	−.20	28x 96	19.04	−.15
26x 96	26.52	−.20	28x108	21.42	−.15
28x 72	21.42	−.20	30x 96	20.40	−.15
28x 84	24.99	−.20	36x 96	24.48	−.15
28x 96	28.56	−.20	No, 26x24x 96	12.24	−.10
28x108	32.12	−.20	28x 72	10.71	−.10
30x 96	30.60	−.20	28x 84	12.50	−.10
30x120	38.25	−.20	28x 96	14.28	−.10
36x 96	36.72	−.20	28x108	16.06	−.10
36x120	45.90	−.20	30x 96	15.30	−.10
40x 96	40.79	−.05	36x 96	18.36	−.10
40x120	50.16	−.05	No. 28x24x 96	10.00	Base
42x 96	42.84	−.05	26x 96	10.83	"
42x120	53.56	−.05	28x 96	11.67	"
48x 96	48.96	+.05	30x 96	12.5	"
48x120	61.20	+.05	36x 96	14.70	+.10
			No. 30x24x 96	8.00	+.20
			30x 96	10.00	+.20

To find the present price of No. 28 gauge galvanized sheets, 36 inches wide, 96 inches long, if the base price is, for example, known to be $6.00, add to the base price .20, therefore the net price would be $6.20 per hundred pounds. No. 24 gauge black sheets 30 inches wide, 96 inches long would cost (if the base price for black sheets is $5.00) $5.00 less .15 = $4.85, and No. 30 gauge sheets 30 inches wide at the same base price would cost $5.00 plus .20 = $5.20 per hundred pounds. Base prices are set for

black sheets of steel
galvanized sheets of steel

black sheets of charcoal iron
galvanized sheets of charcoal iron.

Sizes generally kept in stock are as enumerated in above schedules. Extra sizes are made upon special order.

Jobbers generally charge 50 cents per 100 pounds extra for sheets if bought in less than bundle lots.

In asking for base prices the inquirer must state if shipment from mill or warehouse is wanted, as for mill shipments a lower base price will be quoted.

Corrugated sheets are charged 30 cents per 100 pounds above flat sheet prices.

For re-squaring sheets at the mill an extra charge of 5% of price.

Copper

Copper is generally designated according to its weight per square foot. For example, "16-ounce copper" means 16 ounces weight per square foot. Copper is generally kept in stock in the following thicknesses: 32-ounce, 24-ounce, 16-ounce, 14-ounce, 12-ounce, 10-ounce. From the mill copper can be ordered in any thickness of a fraction of an inch.

Copper is sold at base prices and differentials as per list following;

HOT ROLLED STEEL COPPER—PLAIN BOTH SIDES (January 7, 1920.)

SIZE OF SHEETS: Widths	Lengths	64 oz. to ⅜ in.	Inc. 48 oz. to 64 oz.	Inc. 32 oz. to 48 oz.	Inc. 24 oz. to 32 oz.	Inc. 20 oz. to 24 oz.	Inc. 16 oz. to 20 oz.	15 oz.	14 oz.	13 oz.	12 oz.	11 oz.	10 oz.	9 oz.	8 oz.	Ligt'r than 8 oz.
		CENTS PER POUND OVER BASE PRICE														
Not wider than 20 ins.	Not longer than 72 ins.	Base	Base	Base	Base	½	¾	1	1½	2½	3½	4½	5½	7	9	Prices Quoted Upon Application
	Longer than 72 ins. Not longer than 96 ins.	Base	Base	Base	Base	½	¾	1	1½	3	4½	6½	8½	11	14	
	Longer than 96 ins. Not longer than 120 ins.	Base	Base	1½	1	1½	2	3	4	6	8	10½	13	16	20	
	Longer than 120 ins. Not longer than 200 ins.	Base	Base	1	1½	2½	3	4	5½	7½	10	12½	15	19	24	
Wider than 20 ins. but not wider than 30 ins.	Not longer than 72 ins.	Base	Base	Base	Base	¾	1	1½	2½	4	5½	7½	10	13	16	
	Longer than 72 ins. Not longer than 96 ins.	Base	Base	Base	Base	¾	1	1½	2½	5	7½	10	13	16	19	
	Longer than 96 ins. Not longer than 120 ins.	Base	Base	1	1½	2½	3½	5	7	9	11	14				
	Longer than 120 ins. Not longer than 200 ins.	Base	1	1½	3	4	5	7	9	12	15					
Wider than 30 ins. but not wider than 36 ins.	Not longer than 72 ins.	Base	Base	Base	1½	2¼	3	4½	6	8	10	12	14½	17	20	
	Longer than 72 ins. Not longer than 96 ins.	Base	Base	Base	1½	3½	4½	5½	7½	10	13	16	20			
	Longer than 96 ins. Not longer than 120 ins.	Base	1	2	3	4½	5½	7½	11	15	19	23				
	Longer than 120 ins. Not longer than 200 ins.	Base	1½	3	4	6½	8	11	14	18	22					
Wider than 36 ins. but not wider than 48 ins.	Not longer than 72 ins.	Base	Base	1	2	3½	4½	6	8	11	14	17	20	23	27	
	Longer than 72 ins. Not longer than 96 ins.	Base	Base	1½	3	4½	6½	9	12	15	18	21	25			
	Longer than 96 ins. Not longer than 120 ins.	Base	1½	3	4½	7	9	12	15	18	21					
	Longer than 120 ins. Not longer than 200 ins.	2	3	4	5	7½	10½	14	18	21	24					
Wider than 48 ins. but not wider than 60 ins.	Not longer than 72 ins.	Base	2	4	6	8½	12	15	18	21	25	30				
	Longer than 72 ins. Not longer than 96 ins.	Base	3	5	7	10	13	16	20							
	Longer than 96 ins. Not longer than 120 ins.	2	4	7	10	13	16									
	Longer than 120 ins. Not longer than 200 ins.	3	6	9	12	15	18									
Wider than 60 ins. but not wider than 72 ins.	Not longer than 96 ins.	2	3½	6	9	12	15									
	Longer than 96 ins. Not longer than 120 ins.	3	6	9	12	15	18									
	Longer than 120 ins. Not longer than 200 ins.	5	8	12	15	18										
Wider than 72 ins. but not wider than 108 ins.	Not longer than 96 ins.	3	5½	8	12	15	18									
	Longer than 96 ins. Not longer than 120 ins.	5	8	12	15	18										
	Longer than 120 ins. Not longer than 200 ins.	7	10	15	18											

The longest dimension of any sheet shall be considered its length.

Sheets over 200 inches long, special prices.

ALL COLD OR HARD-ROLLED COPPER, 14 ounces per square foot and heavier, 2 cents per pound over the prices as per list.

ALL COLD OR HARD-ROLLED COPPER, lighter than 14 ounces per square foot, 3 cents per pound over the prices as per list.

COLD-ROLLED AND ANNEALED COPPER SHEETS AND CIRCLES take the same price as cold or hard-rolled copper of corresponding dimensions and thickness.

COLD-ROLLED COPPER, prepared suitable for polishing, same prices and extras as polished copper.

ALL POLISHED COPPER, 20 inches wide and narrower, 5 cents per square foot advance over the price for cold-rolled copper.

ALL POLISHED COPPER, over 20 inches wide, 7½ cents per square foot advance over the price for cold-rolled copper.

PLANISHED COPPER, 1½ cents per square foot more than polished copper.

CIRCLES 8 INCHES DIAMETER AND LARGER, SEGMENTS AND PATTERN SHEETS, 5 cents per pound advance over prices of sheet copper required to cut them from.

CIRCLES LESS THAN 8 INCHES DIAMETER, prices quoted upon application.

Example: If the base price for copper is 32 cents, then 16-ounce cold-rolled, polished sheets, 36 inches wide, 120 inches long would cost:

All lists of differentials and standard price lists carry the date of their adoption. One should always refer to or inquire about the date of schedules and lists when receiving quotations When, for example, a certain article is quoted "25% off list," date of list should be asked.

Base price	32	cents
Extra for 36 inches wide and 120 inches long	5½	"
Extra for cold-rolled	2	"
Total per pound	39½	cents

with an additional 7½ cents per square foot for "polishing."

Prices are for 100 Pounds or More per Item in One Order

ROLL AND SHEET BRASS, COMMERCIAL BRONZE AND GILDING

BASE PRICES QUOTED UPON APPLICATION

Issued Sept. 1, 1918

Extras Over Base Prices, Cents per Pound

			In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	Wider than		2	8	12	14	16	18	20	22	24	26	28	30	32	34	36
	and including		8	12	14	16	18	20	22	24	26	28	30	32	34	36	38
	No. 20 (.0319) and thicker		Base	½	2	3	5	7	9	11	14	17	20	24	28	33	38
	21	.0284	½	1	2½	4	6	8	10	12	15	18	21	25	29	34	39
	22	.0253	½	1	2½	4	6	8	10	12	15	18	21	25	29	34	39
	23	.0225	1	1½	3	5	7	9	11	13	16	19	22	26	30	35	
	24	.0201	1	1½	3	5	7	9	11	13	16	19	22	26	30	35	
	25	.0179	1½	2	4	6	8	10	12	14	17	20	23				
Brown	26	.0159	1½	2	4	6	8	10	12	14	17	20	23				
and	27	.0142	2	3	5	7	9	11	13	15	18						
Sharpe's	28	.0126	2	3	5	7	9	11	13	15	18						
Gauge	29	.0112	2½	4	6	8	10	12	14								
the	30	.0100	2½	4	6	8	10	12	14								
Standard	31	.0089	3	5	7	9											
	32	.0079	4	6	8	10											
	33	.0071	5	7	9												
	34	.0063	8	10	12												
	35	.0056	11	14													
	36	.0050	14	18													

Sheet Metal thinner or wider than listed above, special prices quoted upon application.

All metal heavier than No. 4 gauge, listed and charged as Sawed Metal, whether sheared, slit or sawed.

Copper in rolls are quoted at special prices.

The extras charged for tinning and polishing are often changed according to the changes in cost of tin and labor.

Brass

At the time of this writing the following schedule was in force for brass (see Page 392).

Metal between gauges takes price of nearest gauge.

Circles cut from above metal, over 6 inches and not exceeding 12 inches diameter, No. 10 gauge and thinner, 6 cents advance

Circles cut from above metal over 6 inches and not exceeding 12 inches diameter, thicker than No. 10 gauge, 10 " "

Circles cut from above metal, 6 inches and smaller, and larger than 12 inches diameter, special prices are quoted upon application.

Segments, pattern sheets, and irregular shape blanks, special prices quoted upon application.

Embossed metal.................... 4 cents advance

Polishing sheet from above metal, special prices are quoted upon application.

Sheet metal over 2 inches, but not wider than 14 inches, cut to uniform specific lengths, add the following advances:

Shorter than 12 Inches	Inc. 1 Foot to 4 Feet	Inc. 4 Feet to 6 Feet	Inc. 6 Feet to 8 Feet	Inc. 8 Feet to 10 Feet	10 Feet and Over
Special prices, not less than 1 cent.	1 cent	2 cents	4 cents	6 cents	Special prices, not less than 6 cents.

Sheet metal wider than 14 inches cut to uniform specific lengths, special prices are quoted upon application, not less than the prices for cutting metal 14 inches wide.

WEIGHT OF SHEET BRASS, BROWN & SHARPE'S GAUGE

No.	Pounds per Square Foot	No.	Pounds per Square Foot
0000	20.37	19	1.589
000	18.14	20	1.415
00	16.15	21	1.260
0	14.39	22	1.122
1	12.81	23	.9995
2	11.41	24	.8901
3	10.16	25	.7927
4	9.047	26	.7059
5	8.057	27	.6286
6	7.175	28	.5598
7	6.389	29	.4985
8	5.690	30	.4439
9	5.067	31	.3953
10	4.512	32	.3521
11	4.018	33	.3135
12	3.578	34	.2792
13	3.187	35	.2486
14	2.838	36	.2214
15	2.527	37	.1972
16	2.251	38	.1756
17	2.004	39	.1564
18	1.785	40	.1393

Thickness in Inches

Inch	Pounds per Square Foot	Inch	Pounds per Square Foot
1/16	2.768	1 1/16	47.05
1/8	5.535	1 1/8	49.82
3/16	8.303	1 3/16	52.59
1/4	11.07	1 1/4	55.35
5/16	13.84	1 5/16	58.12
3/8	16.61	1 3/8	60.89
7/16	19.37	1 7/16	63.66
1/2	22.14	1 1/2	66.42
9/16	24.91	1 9/16	69.19
5/8	27.68	1 5/8	71.96
11/16	30.44	1 11/16	74.73
3/4	33.21	1 3/4	77.49
13/16	35.98	1 13/16	80.26
7/8	38.75	1 7/8	83.03
15/16	41.51	1 15/16	85.80
1	44.28	2	88.56

Variations from these weights must be expected in practice.

We reprint here the information given by a prominent brass mill for ordering brass.

RULES TO OBSERVE IN ORDERING BRASS

General Information Desired

In meeting all requirements of the trade, so many different alloys, tempers and anneals must necessarily be used, that it is not practicable to outline in a price list, the kind or quality of material best suited for a particular purpose.

Therefore, in addition to information regarding thickness, width, length and temper which should invariably appear on each order it is essential that initial orders should *state plainly the purpose for which the material is intended* and so far as possible how it is to be worked. A sample or blue print will aid in determining the proper materials required.

Gauge

The adoption of the micrometer caliper (see footnote) to determine the thickness of metal or the size of wire in decimal parts of an inch, and the abolition of all gauge numbers when ordering is strongly recommended. This will prevent confusion, expense and loss of time.

The price lists are based on the gauge numbers most frequently used by the trade, but material may be ordered to sizes between gauges if desired.

All gauge numbers applying to orders for brass, bronze and nickel silver in the form of *sheet wire, rod and brazed tubes,* will be intrepreted according to the *American or Brown & Sharpe's* Standard unless otherwise ordered.

*The use of the micrometer is explained on page 225.

Diameter Measurements

When ordering *brazed tubes* state whether the diameter given is "*inside*" or "*outside*" otherwise it will be considered that outside measurements are required.

Anneals and Tempers

All of the materials before named are produced annealed to various degrees of softness and rolled or drawn to various tempers, to meet special requirements.

The character of either the anneal or the temper should always be specified, but in the absence of any instructions, *sheet brass* will be shipped *annealed* suitable for drawing. The tempers commonly ordered for sheet brass are "half hard," "hard" and "spring."

Wire, rods and brazed tubes will be shipped *commercially hard* unless otherwise ordered, with the exception of nickel silver wire which is commonly supplied annealed.

When there is uncertainty as to what quality of material is wanted, additional instructions will be requested.

Published prices for brass are for items of 100 pounds or more in one order.

For less quantities add as follows:

Items Less than	To and Including	Extra per Pound
100 pounds	75 pounds	2 cents
75 "	50 "	5 "
50 "	25 "	10 "
25 "	10 "	25 "
10 "		35 "

The above extras do not apply to standard size of brass rods.

When orders for brass call for stock lengths, such as 6-foot, 8-foot, etc., it is meant that the specified length is the maximum, a certain percentage must however be accepted in shorter length than specified. As a rule between 20 per cent and 40 per cent may be less than the specified length. If wanted in uniform specific length the order must expressly state so and then an extra charge will be made, unless the order also states: "with end pieces included" and "with random lengths included."

Tin and Terne Plates

Much confusion exists as to the customs relating to tin plates. Roofing tin and other kinds of tin plates are steel sheets or charcoal iron sheets (called "the base") covered with a layer of pure tin, or a layer of a mixture of lead and pure tin (called "the coating").

Terne plates (used mainly for roofing purposes) are the sheets coated with the mixture of lead and tin.

Tin plates (mainly used for cooking utensils, etc.) are the sheets coated with pure tin. According to the thickness of the coating, tin plates are designated as "coke plates" or "charcoal plates." It must be kept in mind that the name "charcoal plate" does not indicate that the base is "charcoal iron." The two names "coke plates" and "charcoal plates" are simply commercial terms adapted for the purpose of indicating the thickness of the tin coating.

The basic size of Terne and tin plates is 14 inches by 20 inches, packed in boxes containing 112 sheets. This is called the "base box." 112 sheets of the size 20 inches by 28 inches make a "case." According to the amount of coating used per case the grade of the Terne plate is determined.

The specified coating of a Terne plate is usually from 8 to 40 pounds per case in the following weights of coating: 8, 12, 15, 20, 25, 30 and 40 pounds, with variations between these numbers. When, for example, the term "8-pound terne plate" is used it is meant that the coating is 8 pounds of lead and pure tin per case.

The thickness of the base is denoted as follows:

No. 30½	gauge	as	ICL
No. 30	"	"	IC
No. 28	"	"	IX
No. 27	"	"	2X
No. 26	"	"	3X
No. 25	"	"	4X
No. 24	"	"	D2X
No. 23	"	"	D3X
No. 22	"	"	D4X

Terne plates are generally specified with the base of ICL, IC or IX.

The following table gives the weight of different grades of Terne plates of 112 sheets, 14 inches by 20 inches:

8-pound	coating	ICL,	100	pounds,	8-pound	coating	IC,	107	pounds
12	"	"	IC,	115	"	12	"	"	IX,	143	"
15	"	"	IC,	118	"	15	"	"	IX,	146	"
20	"	"	IX,	151	"	25	"	"	IX,	156	"
30	"	"	IX,	161	"	35	"	"	IX,	166	"
40	"	"	IX,	171	"	etc.					

In the process of coating the Terne plates a "mottle" appears on the face of the plate. This mottle is visible as blotches. The heavier the coating the more distinct are the mottles. Eight-pound coating has no mottles. To the accustomed eye the amount of coating can therefore be judged by the appearance of the mottle. The size of the mottle, however, has no bearing on the amount of coating.

There are different trade names known for Terne plates, as "old style, "old method," etc. These names indicate nothing in themselves. The grade and thickness of the base and the amount of coating are the only measures of quality. The style of finish of Terne plates as "bright dry," "blue finish," "streaky finish," etc., have also no bearing on quality, but indicate simply different finishes for appearance, reached by the more or less use of palm oil. Marks like "MF" or "Taylor's Old Style" are trade names of different manufacturers. Besides the standard sizes of 14 inches by 20 inches and 20 inches by 28 inches, Terne plates are obtainable in any other size, called "odd sizes." The price of Terne plates is designated by the cost of the "base box" (14 inches by 20 inches, containing 112 sheets, with an aggregate area of 217.77 superficial feet). The prices of other sizes are in proportion to their larger area. For example, if the price is quoted "$9.00 base box" it is meant that a box of 112 sheets 14 inches by 20 inches costs this amount. A case of 112 sheets 28 inches by 20 inches would then be twice this amount, etc.

All these customs apply also to coke and charcoal tin plates. The distinction between coke and charcoal plates is as follows: Tin plates with a coating of up to 2 pounds per base box are called "coke." Plates with heavier coating, up to 7 pounds, are called "charcoal" or "bright charcoal." There are also the following terms in use to distinguish between the different coating of charcoal plates:

1-A (or A)	denotes	a	coating	of	3	pounds	per	base	box
2-A (or AA)	"	"	"	"	3½	"	"	"	"
3-A (or AAA)	"	"	"	"	4	"	"	"	"
4-A (or AAAA)	"	"	"	"	5	"	"	"	"
5-A (or AAAAA)	"	"	"	"	6	"	"	"	"
6-A (or AAAAAA)	"	"	"	"	7	"	"	"	"

Plates with a coating of 7 to 14 pounds are called "dairy stock." Perfect plates are designated as "prime plates." Special prices are quoted for "waste plates" (with some defects either in the coating or the base of the plate) and for "waste-waste plates" (with pronounced defects, as large patches, holes in the plate, badly bent, etc.). A typical order or inquiry would be worded: "Box—15 pounds I. C. Prime Ternes," which would mean: Box of Perfect Terne plates (or roofing tin), containing 112 sheets of 14 inches by 20 inches with a coating of 15 pounds per case, No. 30 gauge base.

"20 x 28 XXX AAAA Charcoal" would indicate: Tin plate in size 20 inches by 28 inches, No. 26 gauge base, with a coating of 5 pounds per box.

STOVE BOLTS are sold in packages containing 100 bolts and nuts according to the following standard price list, which is subject to a varying discount:

FLAT AND ROUND HEAD STOVE BOLTS

Per 100
List Adopted March 1, 1907

Size		3/8	1/2	5/8	3/4	7/8	1	1 1/8
5/32 and 3/16		$0.85	$0.85	$0.85	$0.85	$0.90	$0.90	$0.95
1/4		1.20	1.20	1.20	1.20	1.25	1.30	1.35
Size		1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2
5/32 and 3/16		$1.00	$1.05	$1.10	$1.15	$1.20	$1.25	$1.30
1/4		1.40	1.45	1.50	1.55	1.60	1.70	1.80
Size	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2
5/32 and 3/16	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00	$2.10
1/4	1.90	2.00	2.10	2.20	2.30	2.40	2.50	2.60
Size	4 3/4	5	5 1/4	5 1/2	5 3/4	6	6 1/4	6 1/2
5/32 and 3/16	$2.20	$2.30	$2.40	$2.50	$2.60	$2.75	$2.90	$3.05
1/4	2.70	2.85	3.00	3.15	3.30	3.45	3.60	3.75

RIVETS are bought in packages of 1,000. There is no generally adapted standard price list for rivets in vogue. Prices for rivets should therefore be asked net. A more economical way to purchase rivets is in bulk of 25, 50 or 100 pounds.

NAILS are sold by the keg, containing 100 pounds, or loose by weight.

LEADER HOOKS and commercial gutter hangers are sold at net piece prices and quoted single, by the dozen or by the hundred.

LEADER PIPE, corrugated or plain seamed (lock seamed) and half round eave trough (gutter) are sold in 10-foot lengths per foot, according to standard list, with a discount on same.

The following named articles are also sold according to standard list, subject to discount:

Conductor elbows,
Conductor shoes,
Conductor wire strainers,
Hot air registers.

(Manufacturers and dealers as a rule will supply the prevailing standard list prices and quote discounts on same.)

TAR PAPER is sold in large quantities per ton, otherwise in single rolls of varying sizes, as "containing one square," "two square," etc., which is to indicate that the contents will be sufficient to cover "one square" (100 square feet) of roof. One square of tar paper is considered to be 107 square feet.

ROSIN is sold wholesale in barrels containing 300 to 500 pounds or retail loose by weight.

MURIATIC ACID is sold by weight, wholesale in carboys, containing about 125 pounds, with a deposit of $5.00 for the carboy, or retail in bottles or jugs by the gallon or by the weight (one gallon weighs approximately 10 pounds.)

PUTTY is sold in tubs or blotters containing about 100 pounds or in 5 to 25-pound tins, by weight.

WIRE is sold in coils of about 65 pounds or in stones of about 12½ pounds, by weight.

METAL LATH is sold in bundles weighing about 150 pounds or single sheets by the square foot.

METAL SHINGLES by the sheets or by the square (containing sufficient pieces to cover 100 square feet.)

METAL TILE (Spanish) is sold by the square.

SKYLIGHT GLASS is made in widths of even numbers of inches, as 12 inches, 14 inches, 16 inches, etc., and sold in straw-packed cases of about 400 square feet. A charge of $3.00 is made for the case. If glass is specified at certain lengths it is packed in random lengths not to exceed the specified length. Skylight glass bought to measure in unvarying lengths is charged for extra. When cut to fit an extra charge of 2 to 5 cents per square foot is made and the "cut-off" is charged as waste at full price.

ROOF CEMENT is sold by weight in tubs containing about 100 to 135 pounds, or in tins of 5, 10 or 25 pounds.

SOLDER is sold by weight in single bars or by the case of 100 or 250 pounds. Commercial names for solder as "half and half," "warranted half and half," "refined," etc., do not indicate the correct grade. The proper manner of purchasing solder is to indicate the mixture as follows:

50-50, which means 50% blocktin and 50% lead
45-55, which means 45% blocktin and 55% lead
40-60, which means 40% blocktin and 60% lead

or any other mixture required.

If solder is bought in large quantities the manufacturer will furnish upon request a certified chemical analysis of the solder as to its ingredients.

ZINC in sheets is sold by the cask, weighing about 600 pounds.

The base price is changeable according to market conditions. "Differentials" are charged according to the following schedule:

SHEET ZINC

Packed in Casks Containing About 600 Pounds
Extras Over Base Price
In Cents per 100 Lbs.

Size	No. 5	No. 6	No. 7	No. 8	Nos. 9 to 20
32 to 40 x 84	100	50	20	15	Base
24 x 84	135	50	20	15	Base
26 x 84	260	85	40	15	Base
28 x 84	210	90	60	50	Base
30 x 84	165	70	50	40	Base
48 x 84	135	50	35	15	Base
50 x 84	210	50	35	15	Base
52 x 84	340	135	40	15	Base
58 and 60 x 84	340	210	100	90	80
36 x 96	165	135	100	70	25
48 x 96	260	210	100	70	25
36 x 108	210	155	100	65	30
48 x 108	...	210	135	65	30
62 x 84		Extras given on application.			

EXTRA CHARGES FOR SMALL PACKAGES

100 lb. casks (all Nos. up to No. 12 inclusive)............Add 15c per 100 lbs.
200 and 300 lb. casks (all Nos. up to No. 14 inclusive)......Add 10c per 100 lbs.
Orders for a less quantity than 400 lb. are subject to an extra charge of 20c per 100 lbs.

It should be kept in mind that schedules of base prices and differentials (for brass, copper, zinc, etc.) are here reprinted for general information only. Same are subject to change. As a rule differentials are kept constant, but base prices are changed frequently according to market conditions. During the last few years rapid changes in basic business conditions made it necessary to accordingly change differentials quite often. For example, the difference for polished copper over 20 inches wide used to be 4 cents per square foot, during the preparation of this book, however, it was changed to $7\frac{1}{2}$ cents per square foot. In these days of uncertain business conditions the estimator should be very watchful as to changes in base prices and differentials. Manufacturers and jobbers will generally supply the latest lists upon request.

THE END

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