

A HANDBOOK

FOR

SUPERINTENDENTS OF CONSTRUCTION, ARCHITECTS, BUILDERS, AND BUILDING INSPECTORS.

BY

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FIRST EDITION.

THIRD THOUSAND.



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GENERAL

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BY
H. G. RICHEY.

FIRST EDITION.
THIRD THOUSAND.



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PREFACE.

IN preparing this volume it has been the aim of the author to prepare a book that will be an every-day help to any one engaged in building construction.

Building construction, like everything else, advances and changes with the times, and the author has tried to make this work as complete and up to date as possible. He does not claim credit for all the formulas and information given in this volume, some of it having been compiled from various authors and sources, a list of which will be given, and due credit is given to all for anything that is found compiled in this book from any other work.

Still there is enough original matter and information to be found in the following pages to make the author think that it will prove a valuable addition to any mechanical or technical library, and taken altogether it is as its title represents: A handbook for any one engaged in any branch of building construction, and most especially superintendents of construction, and inspectors.

If by his past experience as carpenter, contractor, architect, and superintendent of construction, and through the medium of this volume, the author is able to render any information or assistance to those engaged in building construction, he will feel himself amply repaid for the labor expended in preparing the following pages.

H. G. RICHEY.

iii

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WORKS AND AUTHORS CONSULTED BY THE AUTHOR
IN PREPARING THIS VOLUME, AND OF WHICH
LIST ANY WILL PROVE A VALUABLE ADDITION
TO ANY LIBRARY.

- Building Construction, by F. E. Kidder.
Architects and Builders' Pocket Book, by F. E. Kidder.
Treatise on Foundations, by W. M. Patton.
Inspectors' Pocket Book, by Austin T. Byrne.
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Steam, by Babcock and Wilcox.
Masonry Construction, by I. O. Baker.

Magazines from which information has been derived:
*Architects and Builders' Magazine, Engineering News, Car-
pentry and Building, Brick Builder, Engineering Magazine,
Scientific American, National Builder, Cement and Engineer-
ing News, Cement.*

Also catalogues and trade publications of the various manu-
factures.

The dates of the various building codes from which extracts
have been taken are as follows:

| | |
|--|------|
| New York | 1901 |
| Philadelphia | 1903 |
| Chicago | 1903 |
| Baltimore | 1904 |
| Cleveland | 1904 |
| San Francisco | 1904 |
| National Board of Fire Underwriters..... | 1904 |

CONTENTS.

PART I.

| | PAGE |
|--|------|
| PERSONALITY AND DUTIES OF A SUPERINTENDENT. EXCAVATING, FOUNDATIONS, PILES, BUILDING-STONES..... | 1 |

PART II.

| | |
|--|----|
| STONE LAYING, SETTING, AND CUTTING, MARBLE AND SLATE WORK, BRICKWORK AND BRICKLAYING, PAVING, ETC..... | 46 |
|--|----|

PART III.

| | |
|---|-----|
| LIME, SAND, CEMENT, MORTAR, AND CONCRETE. CONCRETE CONSTRUCTION. FIRE-PROOF FLOOR CONSTRUCTION, PARTITIONS, ETC. ARCHITECTURAL TERRA-COTTA. FIRE-PROOF CONSTRUCTION AND FIRE PROTECTION OF BUILDINGS..... | 110 |
|---|-----|

PART IV.

| | |
|--|-----|
| LATHING AND PLASTERING. CARPENTRY; TIMBER. PLUMBING. TIN AND SHEET METAL WORK. PAINTING, GLAZING, AND PAPER-HANGING. IRONWORK, ELECTRIC WIRING, ETC. HEATING.... | 292 |
|--|-----|

PART V.

| | |
|---|-----|
| DRAWING. LAYING OUT WORK. MENSURATION. GEOMETRICAL MENSURATION. VARIOUS ENGINEERING FORMULAS..... | 533 |
|---|-----|

PART VI.

| | |
|---|-----|
| HYDRAULICS AND DATA ON WATER. STRENGTHS, WEIGHTS, ETC., OF MATERIALS. VARIOUS MATERIALS AND DATA..... | 634 |
|---|-----|

A HANDBOOK FOR SUPERINTENDENTS OF CONSTRUCTION.

PART I.



PERSONALITY AND DUTIES OF A SUPERINTENDENT.

EXCAVATING, FOUNDATIONS, PILES, BUILDING-STONES.

Personality and Duties of a Superintendent.—

A superintendent should be a man who can command the respect and obedience of those under him. In all his dealings he should be honest and just, demanding only what is right and insisting on what he demands being done. He should be a sober, upright, and intelligent man, well conversant with all the details of the work or structure which he will have under his supervision; he should study the work in advance so as to forestall any point or question which may come up for him to decide.

Before giving any decision or deciding any point he should study the matter carefully, be sure he is right, and then in a firm manner stick to it. Let a superintendent once give a decision and then by a little argument on the part of the contractor alter or change it and he will find the contractor will be sure to try to make him change others in the future.

At the commencement of any work or building the superintendent should be if anything a little more strict than necessary, for then he will have a chance to relax a little as the work progresses. This refers to both workmanship and material.

The superintendent should examine all material as it is brought to the work, and at once reject any that is of poor

quality or unfit for the work, and all rejected material he should have removed at once from the premises, for so long as any such material is at the job there is danger of some of it finding its way into the building or structure.

Regarding material the superintendent should be suspicious of any change or substitute advanced by the contractor, for it is of no advantage to a contractor to make a change unless it is to substitute something cheaper, and anything cheaper will be inferior in quality.

The superintendent should be at his post of duty at all hours when any work is being done, for there are some points of the work that in a few hours can be slighted enough to weaken the whole structure, and a building or any structure is only as strong as its weakest point.

In rejecting materials they should be marked and orders given to remove them at once. The superintendent should keep a record of all material rejected, giving the date and cause of rejection. He should be familiar with the tools used by the various trades and methods of using them, as he can then determine more quickly if a mechanic is doing good work or not. He should watch each and every workman employed so far as possible, and any whom he finds careless or unskilful, and whose work does not come up to the required standard, he should have removed.

The superintendent should keep a daily diary stating the condition of the work, state of the weather, materials received, or anything which has a bearing on the progress or completion of the work. He should see that the work progresses rapidly enough to insure its completion within contract time, and if there is any delay or suspicion of delay he should notify the contractor and report the same to his superiors.

On some work the superintendent is charged with the duty of making up the estimates due the contractor as the work progresses. To do this correctly it is advisable to obtain from the contractor at the commencement of the work a schedule of prices of the various parts of the work as he has estimated them. This should be given both in unit and in total. The superintendent in making up these estimates should be careful to do justice to both sides, being careful to give the contractor what is due him, but no more.

Of course on work where there are certain amounts to be paid at various stages of the work this schedule is not necessary,

as the amounts to be paid will be determined before the work is commenced.

If the superintendent would have a cost or price book and keep memoranda of the cost of the various works upon which he is engaged it will be a great help to him in making any estimate of work.

The superintendent should study the drawings and specifications carefully in advance of the work, so as to determine if everything is working out correctly, as there are often little changes or questions which will come up as the work progresses which the superintendent will be called upon to decide, and if he keeps on the lookout for such things he will have time to consult with his superiors before rendering a decision to the contractor.

Contractors in different localities have different methods of executing work, and it is advisable to leave the mode of execution to the contractor so long as the desired end is obtained, viz., a perfect and acceptable job.

The plans and specifications are his guide and he should insist on strict compliance with their meaning. He should avoid any arguments or controversy, as his duty is only to see that the work is carried out according to the meaning of the plans and specifications, and not to decide if any other method or material is better. When he has any complaint to make he should make it at once and in a firm, gentlemanly manner, and insist on its settlement immediately.

Any superintendent who acts in this manner and who has had experience enough to make himself familiar with good construction and methods of executing work should have no trouble with any one who is doing work under his supervision.

When the superintendent has cause to submit materials to a laboratory for testing, the following amount of each material should be submitted to make a complete test:

| | | |
|---------------------|----------------|-----------|
| Cement. | not less than | 15 pounds |
| White lead. | “ “ “ | 2 “ |
| Red lead. | “ “ “ | 2 “ |
| Varnish. | “ “ “ | 1 quart |
| Oil. | “ “ “ | 1 “ |
| Shellac. | “ “ “ | 1 “ |
| Tin. | 3 whole sheets | |
| Copper or zinc. . . | pieces | 6"×6" |

Laying Out for Foundations, etc.—The superintendent should have the contractor or his representative do all the laying out, so that he will be responsible for all errors, but the superintendent should go over all lines, angles, and measurements and verify them as to being correct.

In laying out work, turning angles, or running lines or levels it is advisable to do so with a transit and level, and if the superintendent does not possess or understand the use of one of these instruments he should engage the services of a civil engineer. A convertible architect's level, manufactured by Keuffel & Esser Co. of New York, is a good instrument for a superintendent to possess, as with it he can do all work such as running lines, giving levels, and bench-marks that may be desired.

Fig. 1 shows how the batter-boards should be set for the lines of a foundation; the boards should be long enough to catch the lines for both inside and outside of all walls and footings. The lines shown in the cut represent the lines in place for the walls and piers.

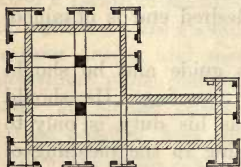


FIG. 1.

These boards should be put up firm and well braced and placed far enough back from the excavation to insure their being in solid ground; they should also be made high enough for the wall to be built up to the belt course, or ashlar course, without disturbing them. After the batter-boards are set the superintendent should have the main lines stretched and try the distance from opposite corners to prove if they are laid out square. A level or bench-mark should be put up on a solid stake or other solid object, giving the height of a certain point in the height of the walls or building; then all other heights can be measured from this point.

As the different grade heights are usually given in decimal parts of a foot from a given point a table giving the various fractions in feet and inches will be found very useful; such a table will be found on pages 608 and 609.

After the building is up, say to the belt course or any other level course, it is advisable to have the foreman of the building prepare a pole giving the heights of the various points or courses in the building, and set them all to this pole; in this way after the first course is set and levelled, if all the other courses are

set to this pole they will be correct for height and level. See Fig. 83, page 66.

The superintendent should go over the drawings as soon as possible after the work is commenced and see that all measurements are marked correct, as a little error in marking sometimes makes a lot of trouble afterwards. The author knows of an instance where the foreman of a building staked it out and built it two feet shorter in length than the plans called for, yet it was never noticed by the superintendent simply because he did not take the trouble to verify the foreman's measurements in laying out the building.

In laying out work where a series of points come on the same line the tape should be stretched the full length and the location of each point marked by adding together the various distances from the starting-point.

In giving any point, such as a bench-mark or height, or measurement of any kind, the superintendent should be very careful and be sure he is correct, for he can be held responsible for any error he may make.

In running walls, piers, etc., through from story to story the superintendent should always check them up at each floor-level to see if they are being carried up plumb.

Excavating.—When the excavating is being done the superintendent should see that all excavations, trenches, etc., are dug out at least six inches larger than the walls, so that there will be room for pointing or cementing, or when concrete is to be used, to have room for building the wood forms.

The superintendent should give height or bench-marks and see that the excavating is carried to the proper level, and if by chance any trench for a footing-course is dug too deep he should have it filled up with concrete or masonry, and not with loose earth.

If a stream of water or spring is encountered, provision must be made to take the water away; this can be done with a broken-stone or open tile drain as shown by Figs. 2 and 3.

As soon as the excavation is dug to the proper depth the superintendent should have the sewer to the building run in past the inside of the wall and a strainer put on so as to carry off any water which may gather from rain, snow, or damp soil.

The superintendent should pay strict attention to the work during the putting in of the foundation-footing and walls, for

there is a tendency on the part of some contractors to slight this work, thinking it will soon be covered up.

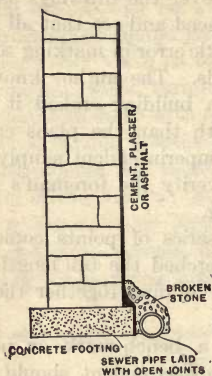


FIG. 2.

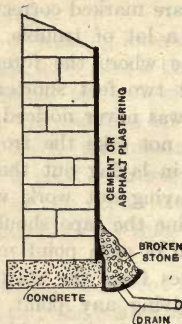


FIG. 3.

Shrinkage of Excavated Material.—All materials when first excavated will increase in bulk, but after laying a while will, with the exception of rock, shrink until they will occupy less space than when originally in the earth.

The shrinkage of various materials has been estimated as follows:

| | |
|----------------------------------|------------|
| Gravel..... | 8 per cent |
| Gravel and sand..... | 9 " |
| Clay and clay earths..... | 10 " |
| Loam and light sandy earths..... | 12 " |
| Loose vegetable soils..... | 15 " |
| Puddled clay..... | 25 " |

Foundations.—One of the first duties of a superintendent after taking charge of the erection of a building or other structure is to determine the stability of the ground upon which it will rest. The architect should ascertain if possible the nature of the ground before he makes his plans, as then his foundations can be made to suit the material it will rest upon. But often this is not done, and it devolves upon the superintendent to test the stability of the ground, and when it is found not to have a sufficient carrying capacity changes will have to be made in the foundation of the structure. If there is

any other like building in the immediate vicinity already erected the superintendent should make inquiry of the architect and builder of this building and find out all he can as to the nature and formation of the ground, and if any difficulty was experienced in putting in the foundations of the building.

Testing the Soil.—After the excavation is made, if the superintendent has any doubt as to the stability or carrying power of the ground on which the foundations will rest, he should test the same by boring holes or sinking a shaft, and if the bed is found insecure he should at once consult with his superiors and determine if the excavations are to be carried deeper or the plans of the foundation-walls changed so as to obtain a greater breadth or surface resting on the ground. There should be several borings made in different parts of the excavation to about the same depth (10 to 15 feet is deep enough for ordinary tests) and if the character of the soil is about the same in all the holes this test will be sufficient, but if there is a decided difference in the borings of any of the holes as to material, depth of stratas, etc., it is advisable to sink other holes to make a complete test.

It is better to have a little expense at the commencement of a building or other structure to determine the stability of the

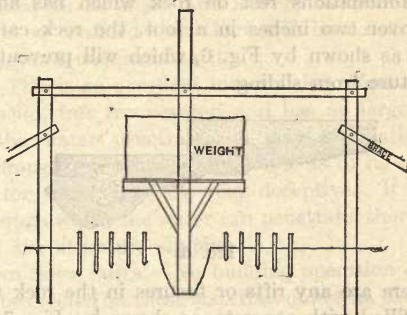


FIG. 4.

foundation than to go ahead and erect the structure and have the walls crack or perhaps worse from unequal settlement. Like a chain, a building is only as strong as its weakest point.

After testing the soil by borings as described, if there should be any doubt at all as to its carrying capacity it should be tested by an actual experiment as to what it will carry. This

can be done by digging a hole and setting up a mast as shown by Fig. 4.

The mast should be set up as shown and braced at the top to four posts which must be braced firm and secure as shown. A platform should be built on the mast to carry the load. Before loading, stakes should be driven radiating from the mast out about four feet, and the tops made perfectly level, and then a level should be taken from them to the mast. Now after the load is put on, a straight edge will show if the top of the stakes remains in line or if there has been any upheaval. Then a level should be taken of the mast to see if it has settled any.

Bed of Foundations.—The superintendent should see that the surface of the foundation-bed is dressed off at right angles to the thrust or weight which is to bear upon it. Where possible all foundations should be carried around at the same level, but where this is impossible and the footings have to be put in at unequal depths the difference in height of the different levels should be made in perpendicular steps as shown by Fig. 5.

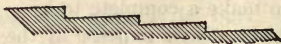


FIG. 5.

Where the foundations rest on rock which has an incline or dip of not over two inches in a foot, the rock can be cut or roughed off as shown by Fig. 6, which will prevent the building or structure from sliding.

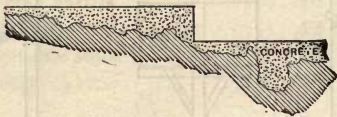


FIG. 6.

Where there are any rifts or fissures in the rock they should be entirely filled with concrete, as shown by Fig. 7, or if very deep, should be arched over with a masonry or concrete arch or with I beams bedded in the concrete.

Rock.—Where rock is used as a foundation-bed the superintendent should see if there is any seepage or water; as is often the case the water will follow along the top of the rock and come out in the excavation. In such cases care must be taken to collect the water and dispose of it, or by putting a drain

outside of the walls, catch the water and carry it away before it enters the excavation. Rock is of course the best foundation that can be had to build upon, as there will be no doubt of its carrying power, and as the crushing strength of the weakest

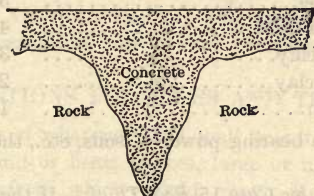


FIG. 7.

sandstone is about 3000 pounds to the square inch, a foundation of rock will carry all that is likely to be built on it.

GRAVEL.—This is one of the best materials to build on, but, like sand, has to be confined to a certain extent, especially if there is any water present, as there will be a tendency to wash out the sand and fine gravel, but if there is no water present and the gravel is packed solid it will carry the heaviest of structures.

SAND.—Sand makes a good foundation to build on only when it is confined on all sides, and is very dangerous to build on unless it is so confined that there will be no danger of water penetrating and undermining it.

CLAY.—This is an excellent material for a foundation providing it is solid, free from water, and has no large seams which will let the water penetrate. A clay foundation should be tested thoroughly if there is any doubt as to its not being solid and dry, for some clays are very deceptive. If there are any seams through which the water can penetrate, there will be great danger of the structure slipping.

SILT AND SOFT SOILS.—No building operation of any magnitude can be erected on these materials unless an artificial foundation is provided by driving piles, putting in footings of timbers or beams and concrete so as to cover a large surface and distribute the weight, or by sinking caissons and filling them with concrete.

The table given below will form a guide as to the bearing power of soils, etc. But, after all, there is no definite rule except by experience and testing.

| Name of Soil, etc. | Carrying Power per Square Foot. |
|-------------------------------------|------------------------------------|
| Rock, hard, on native bed | 250 tons |
| Ledge rock. | 36 " |
| Hard-pan. | 8 " |
| Gravel. | 5 " |
| Clean sand. | 4 " |
| Dry clay. | 3 " |
| Wet clay | 2 " |
| Loam. | 1 ton |

Regarding the bearing power of soils, etc., the Chicago Building Law says:

Sec. 75. *Load for Clay 15 Feet Thick.*—If the soil is a layer of pure clay at least 15 feet thick, without admixture of any foreign substance excepting gravel, it shall not be loaded more than at the rate of 3500 pounds per square foot. If the soil is a layer of pure clay at least 15 feet thick and is dry and thoroughly compressed, it may be loaded not to exceed 4500 pounds per square foot.

Sec. 76. *Load for Sand 15 Feet Thick.*—If the soil is a layer of dry sand 15 feet or more in thickness, and without admixture of clay, loam, or other foreign substance it shall not be loaded more than at the rate of 4000 pounds per square foot.

Sec. 77. *Load for Mixed Soil.*—If the soil is a mixture of clay and sand, it shall not be loaded more than at the rate of 3000 pounds per square foot.

Sec. 78. *Foundations in Wet Soil—Trenches to be Drained.*—In all cases where foundations are built in wet soil, it shall be unlawful to build the same unless the trenches in which the work is being executed are kept free from water by baling, pumping, or otherwise until after the completion of work upon the foundations.

Sec. 79. *Foundation—Where not Permitted.*—Foundations shall not be laid on filled or made ground, or on loam, or on any soil containing admixture of organic matter.

Piles for Foundations.—Piles are used to a great extent for the foundations of structures which rest on a soft or wet soil, and the superintendent should be familiar with the methods of driving and using them.

MATERIAL.—Oak is the best wood for piles, but is not used much on account of its scarcity in some localities and its value for other purposes, which makes the cost too excessive for piling. Spruce, Norway pine, and Oregon pine make good piles.

Cypress is sometimes used, but it is not hard enough to stand driving. The superintendent should inspect each and every pile as it is brought to the work and any rejected ones should be so marked and removed at once.

The following specifications for wood piles and timber were prepared by the American Railway Engineering and Maintenance of Way Association and is very complete.

SPECIFICATIONS FOR PILES AND TIMBER.

PILES.—All piles of whatever kind shall be cut from growing trees, free from wind or heart shakes, large or unsound knots, decay or other defects which would impair the strength or durability of the pile. Only butt cuts, cut about the ground swell of the tree, and with both ends cut square, will be accepted. They shall be peeled of bark and the knots trimmed, and the specified sizes shall be, after peeling, straight and uniformly tapering.

OAK PILES.—Shall be of the variety of white, burr, or post oaks, with wood of close, firm grain and with a sap ring not over 2 ins. thick. They shall be not less than 12 ins. diameter at 6 ft. from the butt, and when 23 ft. or less in length they shall be 10 ins. diameter at the top or small end, and where 30 ft. in length or longer shall be not less than 9 ins. at the top.

NORWAY PINE AND TAMARACK PILES.—These shall not be less than 14 ins. nor more than 18 ins. diameter at the butt, and where 36 ft. or less in length shall be not less than 10 ins. in diameter at the top, and where over 36 ft. in length shall not be less than 9 ins. at the top.

LONG-LEAF PINE PILES.—These shall be strictly long-leaf Southern or yellow pine, and no doubtful grades will be accepted. They shall be hewed square, with all the sap removed. They shall be not less than 12 ins. or more than 14 ins. square at the large end, or 8 ins. square at the small end, and must be smoothly hewed without large or deep score hacks.

CEDAR PILES.—These shall be of white or red cedar. White-cedar piles shall be not less than 14 ins. diameter at the butt and 9 ins. at the top where less than 30 ft. in length. Where over 30 ft. in length, they shall be not less than 8 ins. diameter at the top. Unsound butts will be accepted if the defect is not more than 5 ins. in diameter, and there must be at least 5 ins. of sound wood all around the defect. Red-cedar piles shall be not less than 12 ins. at the butt and 8 ins. at the top.

TIMBER.—All timber of whatever variety shall be cut from sound live trees, and shall be sawed full size, square in section and out of wind. It shall be free from wind shakes, large or unsound knots, pitch seams, decay or any other defects which would impair its strength and durability, and shall generally be free from sap.

LONG-LEAF PINE.—This shall be of the variety known as long-leaf Southern or yellow pine, and no loblolly or other doubtful grades will be accepted. The wood must be close, firm grained, and free from red heart or red-heart streaks; sound knots not over $1\frac{1}{4}$ ins. diameter will be allowed, but knots must not be in groups. Sap wood will be allowed on one or more of the four sides to an extent of not more than 15 per cent of the surface of any one side, and at any one point throughout the length of the piece.

FIR.—This shall be of the variety of Douglas fir, sometimes called Oregon or Washington fir, and may be the yellow or red variety, preferably the first. It shall not have at any point of its length and at any edge sap wood more than 2 ins. in width, and shall be free from knots over $1\frac{1}{2}$ ins. diameter, except that in long stringers sound knots not over $2\frac{1}{2}$ ins. diameter will not be cause for rejection if not more than 4 ft. from the end.

POINTING.—In silt and very soft soils, piles are usually driven with a square end, but in the harder soils they will have to be pointed, and in some cases provided with an iron shoe. There are several kinds of these shoes made, but those which are made with a socket and flat surface for the pile to set on will drive the best and not be so liable to split the pile as

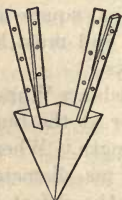


FIG. 8.



FIG. 9.

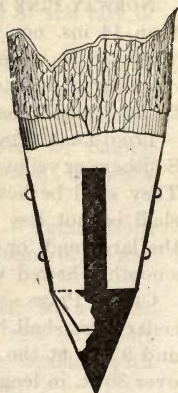


FIG. 10.

some others. Figs. 8, 9, 10 show very good styles of shoes and ones that will drive well.

DRIVING.—When the piles are being driven the superintendent should see that the large end is cut off square so that the hammer will strike it square and solid; he should see that rings are used on the head of the pile to keep it from splitting or brooming. It is customary in driving piles to lay the ring on the top of the pile and let the hammer at the first blow sink the ring into the wood. This is all right, providing the ring is nearly as large as the pile, but if a small ring is used in this way it causes large layers or splinters to split off the pile five or six feet in length. The superintendent should see that rings of different sizes are used or have the head of the pile chamfered off to suit the ring. A patent cap shown in Fig. 13 is now taking the place of rings in driving as shown. It is made to fit over the top of the pile *B* and is lifted with the hammer after the pile is driven. Before driving, the pile should be stripped of all the bark, as it has a tendency to promote decay.

The superintendent should see that the bottom end of the piles are perfectly square if they are being driven with a square end, or if pointed, see that the point is made true and in the centre of the pile; if the point is not true or the end not square it will cause the pile to glance when being driven.

Piles when driven in salt water should be thoroughly impregnated with creosote or some other preservative to protect

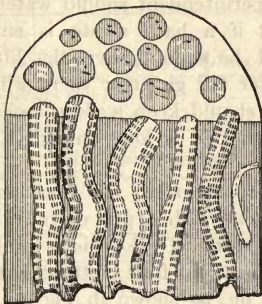


FIG. 11.

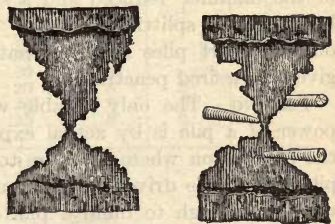


FIG. 12.

them from the ravages of the teredo. The life of a pile where exposed to these mollusks is from three to five years, and when

impregnated with a preservative it lengthens their life about three years. Fig. 11 shows the appearance of a pile eaten by the teredo, and Fig. 12 shows a pile eaten off by limnoria.

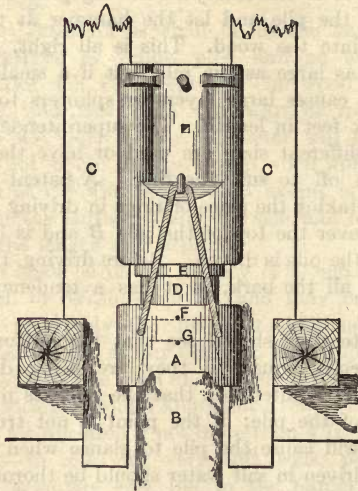


FIG. 13.

During the driving of piles the superintendent should watch the penetration at each blow, and if a hard strata is encountered and the pile drives hard he should have the lift of the hammer reduced and a shorter fall given or there will be danger of splitting the pile. He should keep a close look-out for short piles and see that each pile is long enough to give the desired penetration.

TESTING.—The only reliable way to ascertain the carrying power of a pile is by actual experiment with a pile driven in the foundation where they are to be used. To do this several piles should be driven in the foundation and four of them left up high enough to build a platform on, as shown in Fig. 14. The platform should then be evenly loaded with the desired weight or until the piles move. In this way a reliable test can be made, and where a structure of any importance is to rest on a foundation of piles the superintendent should insist on a complete test being made.

The following table and formula taken from *Engineering News* has been used by a number of engineers and has been pronounced

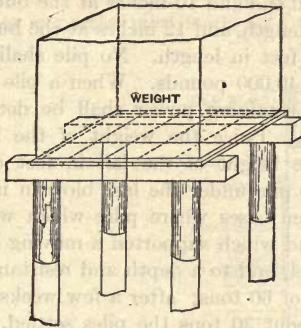


FIG. 14.

very reliable. The table is for spruce piles and average penetration during last five blows of a 1200-pound hammer dropping 15 feet.

BEARING VALUE OF PILES.

| Nature of Soil. | Length of Pile in Feet. | Average Diameter in Inches. | Penetration in Inches. | Load in Tons. |
|---|-------------------------|-----------------------------|------------------------|---------------|
| Silt..... | 40 | 10 | 6 | 2.75 |
| Mud..... | 30 | 8 | 2 | 6 |
| Soft earth with boulders and logs... | 30 | 8 | 1.5 | 7.2 |
| Moderately firm earth or clay with boulders and logs..... | 30 | 8 | 1 | 9 |
| Soft earth or clay..... | 30 | 10 | 1 | 9 |
| Quicksand..... | 30 | 8 | .5 | 12 |
| Firm earth..... | 30 | 8 | .5 | 12 |
| Firm earth into sand or gravel..... | 20 | 8 | .25 | 14 |
| Firm earth to rock..... | 20 | 8 | 0 | 18 |
| Sand..... | 20 | 8 | 0 | 18 |
| Gravel..... | 15 | 8 | 0 | 18 |

The formula is:

$$\text{Safe load in pounds} = \frac{2WH}{S+1},$$

in which *W* equals weight of the hammer in pounds, *H* its fall in feet, *S* average penetration in inches during last five blows.

The following from the New York building code will be a good guide for the superintendent:

"Sec. 25. No pile shall be used of less dimensions than 5 inches at the small end and 10 inches at the butt for short piles, or piles 20 feet in length, and 12 inches at the butt for long piles or more than 20 feet in length. No pile shall be loaded with a load exceeding 40,000 pounds. When a pile is not driven to refusal, its safe sustaining power shall be determined by the following formula: Twice the weight of the hammer in tons multiplied by the height of the fall in feet divided by least penetration of the pile under the last blow in inches plus one."

There have been cases where piles which were driven for a railroad trestle and which supported a moving load were driven in sand and gravel, and to a depth and resistance which figured an ultimate load of 60 tons; after a few weeks of use under an engine load of about 30 tons the piles settled. This no doubt was caused by the vibration, and the piles resting on a wet sand or gravel caused the water to collect and act something like a water jet, thus causing the piles to settle. Thus it will be seen that there are cases where no formula will give definite results, and this is where the superintendent must use good judgment in testing a pile and its foundation.

Concrete Piles.—Concrete piles are now being used with good success. One form of pile, Fig. 15, is made by casting the concrete and reinforcing it with steel. After they are thoroughly set and dry they are driven like an ordinary pile, except a special cap is used to prevent shattering the head of the pile. Another type called the Raymond, Fig. 16, has been used, which consists of a thin shell of metal with a strong core inside to take the shock of driving; after the shell and core are driven to the desired depth, the core, which is collapsible, is withdrawn and the shell filled with concrete. These piles are usually made with a large taper, as this gives them a large bearing area and permits the core to be taken out easily; about 6 inches at the bottom and 20 inches at the top is the usual size. By a test made in Chicago, one of these piles carried as much as three wooden ones having the same diameter at the point. And at Schenectady, N. Y., they were loaded with from 32,000 to 48,000 pounds per pile without settlement. The soil was a soft fill.

Figs. 17 and 18 show what is known as the Simplex Pile. A wrought-iron or steel cylinder with a concrete point is driven

like any ordinary pile, then the reinforcing is put inside the shell and it is filled with concrete, the shell being drawn as the concrete is filled up.

There have been used in the building of the wharves in San Francisco harbor concrete piles made by forcing down a shell

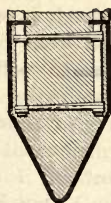
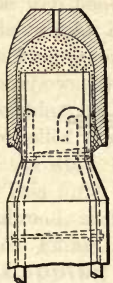


FIG. 15.

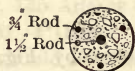


FIG. 16.

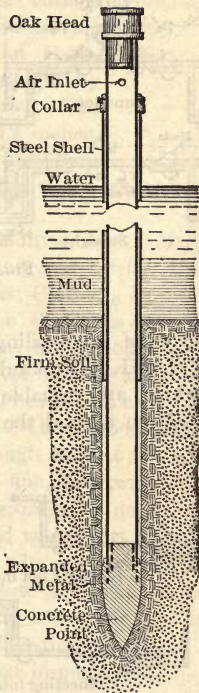


FIG. 17.



Expanded Metal

FIG. 18.

of wood 2 to 3 feet in diameter and after pumping it out filling it with concrete. The wooden shell is left on and by the time it decays or the teredo has destroyed it the concrete is hard and a concrete pile is the result. (See page 165 as to mixing concrete, etc.)

Steel Sheet-piling.—Fig. 19 shows a section of a sheet-piling made by the Friestedt Interlocking Channel Bar Co. of

Chicago; the piling is built up of channels and Z bars and locks together as driven.

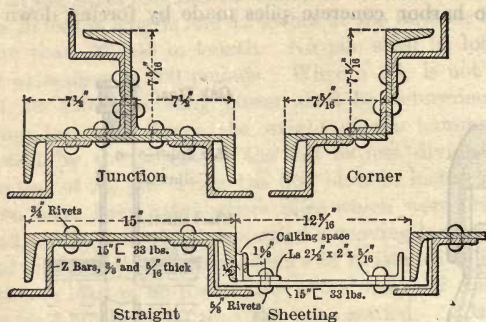


FIG. 19.

Another type of sheet-piling shown by Fig. 20 is manufactured by the H. Wittekind Interlocking Metal Piling Co. Piles of this kind are valuable for use in foundation-work, as they can be driven around the space to be excavated and the

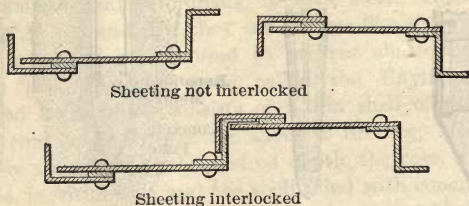


FIG. 20.

interior then taken out, the piling holding up the embankment and tending to keep out any water.

Fig. 21 shows a new style of steel sheet-piling which has recently been introduced, in which each pile is a single piece, complete in itself without rivets, bolts, or other attachments. The piles are of a special rolled section, consisting of a flat web with a cylindrical rib on each edge, the outer end of each rib

being slotted, as shown in the accompanying cut. The ribs are not of the same diameter, but the smaller rib of one pile fits easily within the larger rib of the adjacent pile, while the slot admits the web. This allows some flexibility in changing the direction of the line of piling, but for turning corners there is a special section of pile having the web bent in a curve or at an angle. The joints can be made water-tight by packing them with suitable material. The cut shows piles for a spacing of 12 inches, weighing 40 pounds per foot, but they are rolled in several sizes, according to the length and character of the work.

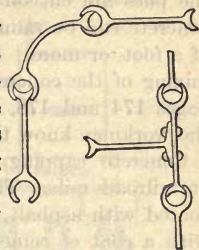


FIG. 21.

This form of sheet-piling is the invention of Mr. Samuel K. Behrend, and is manufactured and sold by the United States Steel Piling Co., 135 Adams Street, Chicago.

Capping of Piles.—After the piles are driven, the superintendent should see that they are cut off below low-water line. They should be cut off level and on a line so that the capping will have a true and equal bearing on each pile.

WOOD-CAPPING, OR GRILLAGE.—Where wood-capping is used the piles must be cut off low enough so that the timber in the grillage will be below low-water line, otherwise it will decay. The timbers are usually laid longitudinally on top of the piles and these timbers in turn crossed with short timbers, forming a floor to start the masonry on. In putting in these timbers the superintendent should pay close attention to see that the timbers have a bearing on each and every pile and are fastened to them with long drift bolts. The timbers should be strictly No. 1, free from any decay or other imperfection.

STEEL GRILLAGE.—Steel beams are used extensively for capping, being bedded in concrete; where they are used, the superintendent should see that the beams rest on each and every pile and that the beams are heavily coated with asphalt, or that concrete or cement mortar is put around them in such a manner that the beams will be thoroughly coated with cement, otherwise they will rust.

CONCRETE CAPPING.—Concrete, which is much used for capping of piles, is one of the best materials for this purpose, for when it is put in properly it forms one continuous stone having

a solid bed on all the piles. The superintendent should see that the piles are cut off square and the dirt cleaned away so the concrete can be rammed around the top of the pile to a depth of a foot or more. He should also pay strict attention to the mixing of the concrete and the ramming of it as described on pages 174 and 178, as this work is very often slighted unless the workmen know there is some person watching them.

Concrete capping is very often reinforced with steel beams or railroad rails. These should be free from rust or dirt and coated with asphalt, or close attention given to covering them with a coat of cement mortar or concrete. If the concrete is rammed solid enough around the beams it will in itself form a protection, but this takes much care and time and will require the strict attention of the superintendent. The New York building code says:

"The tops of all piles shall be cut off below the lowest water line. When required, concrete shall be rammed down in the interspaces between the heads of the piles to a depth and thickness not less than 12 inches and for 1 foot in width outside the piles. Where ranging and capping timbers are laid on the piles for foundations, they shall be of hard wood not less than 6 inches thick and properly joined together, and their tops laid below the lowest water line. Where metal is incorporated in or forms part of the foundation it shall be thoroughly protected from rust by paint, asphaltum, concrete, or by such materials and in such manner as may be approved by the Commissioner of Buildings. When footings of iron or steel for columns are placed below the water level, they shall be similarly coated or enclosed in concrete for preservation from rust."

When concrete is used for capping it should be allowed to harden before any additional weight is built upon it, or the ground may give between the piles and the piles will act like a series of punches forcing their way up through the concrete.

GRANITE CAPPING.—When granite capping is used the superintendent should see that the piles are driven in such a manner and the granite blocks are of such a size that a stone will not rest on more than three piles, as it is hard to get a stone to rest evenly on more, as shown by Fig. 22.

The superintendent should see that the bottom bed of the stones is cut true, and in setting them it is well to put a bed of strong cement mortar on top of the piles, as this will insure

a solid bearing on each pile. The granite blocks should be of such sizes that they will break joints as much as possible, as shown by Fig. 22. On top of this capping the footing-course

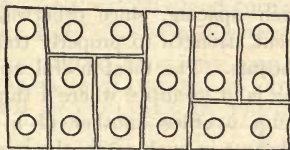


FIG. 22.

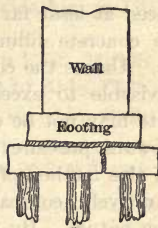


FIG. 23.

should be laid, each stone extending beyond the lines of the wall as shown by Fig. 23.

SPREAD FOOTINGS.—In many instances the footings of a structure have to be spread or extended out so as to cover ground enough to insure the carrying of the building, and in some cases the entire area of the foundation is covered with a grillage of steel or iron beams bedded in concrete. The superintendent should see that the surface of the foundation which it is intended to cover is carefully levelled off and the concrete laid in layers of not more than 8 inches in thickness, and that the beams are coated with asphalt or covered with cement. It has been demonstrated that iron or steel bedded in concrete, where the iron or steel was completely covered and the cement and iron in contact at all points, that the iron or steel will not rust. Only the best Portland cement and clean sharp sand should be used for this work. See page 168.

The Chicago Building Law says: "If steel or iron rails or beams are used as parts of foundations, they must be thoroughly imbedded in a concrete the ingredients of which must be such that after proper ramming the interior of the mass will be free from cavities. The beams or rails must be entirely enveloped in concrete, and around the exposed external surfaces of such concrete foundations there must be a coating of a standard cement mortar not less than 1 inch thick."

The foundation should be prepared by first laying a bed of concrete to a depth of from 4 to 12 inches and then placing upon this a row of I beams at right angles to the face of the wall. In the case of heavy piers the beams may be crossed in two directions. Their distances apart, from centre to centre,

may vary from 9 to 24 inches, according to circumstances, i.e., length of their projection beyond the masonry, thickness of concrete, estimated pressure per square foot, etc. They should be placed at least far enough apart to permit the introduction of the concrete filling and its proper tamping between the beams. Unless the concrete is of unusual thickness, it will not be advisable to exceed 20-inch spacing, since otherwise the concrete may not be of sufficient strength to properly transmit the upward pressure to the beams. The most useful application of this method of founding is in localities where a thin and comparatively compact stratum overlies another of a more yielding nature. By using I beams in such cases, the requisite spread at the base may be obtained without either penetrating the firm upper stratum or carrying the footing courses to such a height as to encroach unduly upon the basement room.

I Beams as Used in Foundations.—METHOD OF CALCULATION.—The following cuts and tables which have been prepared by The Carnegie Steel Co. give the strength and safe projection of beams used in foundations and footings. The same precautions should be taken with these beams as described on page 19.

The known quantities in this calculation are the load (L) on the column in tons, the allowable bearing capacity per square foot of ground in tons (b), and the projections p , p' , p'' in feet for the various tiers of beams.

Figure the separate areas covered by the successive tiers of beams and divide the load on the column by these areas. The quotients will give their respective pressures b , b' , b'' per square foot. Assume any spacing in inches, generally greatest for the lowest tier of beams and about 9 inches for the top course.

Find the corresponding figure for such spacing and pressure in the table on page 23 and multiply it by the corresponding projection. This product will give the modulus M .

In the table of moduli find the beam corresponding to this product.

For any other spacing or pressure than those given find M from the formula $M = p \sqrt{\frac{sb}{12}}$.

Example.—Let $L = 588$ tons $\left\{ \begin{array}{l} \text{Assume } p = 3 \text{ ft. 6 in.}, p' = 5 \text{ ft.} \\ \text{Let } b = 3 \text{ tons} \quad \left\{ \begin{array}{l} 3 \text{ in.}, p'' = 1 \text{ ft. 9 in.} \\ \text{Then } b' = 6 \text{ tons and } b'' = 24 \text{ tons.} \end{array} \right. \end{array} \right.$

Use 15 in. spacing for lowest tier of beams.

“ 12 “ “ “ 2d “ “ “

“ 9 “ “ “ 3d “ “ “

Now using the above method of calculation we have for the respective tiers:

$3.5 \times 1.937 = 6.78 = \text{mod. corresponding to 12-in. 31.5-lb. beam.}$

$5.25 \times 2.450 = 12.86 = \text{mod. corresponding to 20-in. 75-lb. beam.}$

$1.75 \times 4.243 = 7.43 = \text{mod. corresponding to 12-in. 40-lb. beam.}$

TABLES GIVING THE SIZE AND WEIGHT OF BEAMS FOR $s = 9, 12, 15, 18, 24$ INCHES, $b = 1$ TO 50 TONS PER SQUARE FOOT, AND $p = \text{VARIABLE IN FEET.}$

| Depth of Beam in Inches. | Weight per Foot. | Moduli. | Depth of Beam in Inches. | Weight per Foot. | Moduli. | Tons per Square Foot. | Spacing of I Beams. | | | | |
|--------------------------|------------------|---------|--------------------------|------------------|---------|-----------------------|---------------------|-------|-------|-------|--------|
| | | | | | | | 9" | 12" | 15" | 18" | 24" |
| 24 | 100 | 16.263 | 12 | 50.00 | 8.210 | 1 | 0.866 | 1.000 | 1.118 | 1.225 | 1.414 |
| 24 | 90 | 15.772 | 12 | 40.00 | 7.730 | 2 | 1.225 | 1.414 | 1.581 | 1.732 | 2.000 |
| | | | | | | 3 | 1.500 | 1.732 | 1.937 | 2.121 | 2.450 |
| 24 | 80 | 15.231 | 12 | 35.00 | 7.122 | 4 | 1.732 | 2.000 | 2.236 | 2.450 | 2.829 |
| 20 | 100 | 14.858 | 12 | 31.50 | 6.925 | 5 | 1.936 | 2.236 | 2.500 | 2.738 | 3.162 |
| | | | | | | 6 | 2.121 | 2.450 | 2.739 | 3.000 | 3.464 |
| 20 | 90 | 14.412 | 10 | 40.00 | 6.505 | 7 | 2.291 | 2.646 | 2.958 | 3.240 | 3.742 |
| 20 | 80 | 13.983 | 10 | 30.00 | 5.982 | 8 | 2.450 | 2.828 | 3.162 | 3.463 | 4.000 |
| | | | | | | 9 | 2.598 | 3.000 | 3.354 | 3.674 | 4.243 |
| 20 | 75 | 13.007 | 10 | 25.00 | 5.706 | 10 | 2.738 | 3.162 | 3.536 | 3.872 | 4.472 |
| 20 | 65 | 12.488 | 9 | 35.00 | 5.755 | 11 | 2.872 | 3.317 | 3.708 | 4.061 | 4.690 |
| | | | | | | 12 | 3.000 | 3.464 | 3.873 | 4.242 | 4.899 |
| 18 | 70 | 11.683 | 9 | 25.00 | 5.220 | 13 | 3.122 | 3.606 | 4.031 | 4.415 | 5.099 |
| 18 | 60 | 11.168 | 9 | 21.00 | 5.016 | 14 | 3.240 | 3.742 | 4.184 | 4.582 | 5.292 |
| | | | | | | 15 | 3.354 | 3.873 | 4.331 | 4.743 | 5.477 |
| 18 | 55 | 10.857 | 8 | 25.50 | 4.776 | 16 | 3.464 | 4.000 | 4.472 | 4.898 | 5.657 |
| 15 | 100 | 12.653 | 8 | 20.50 | 4.494 | 17 | 3.571 | 4.123 | 4.610 | 5.050 | 5.831 |
| | | | | | | 18 | 3.674 | 4.243 | 4.744 | 5.196 | 6.000 |
| 15 | 90 | 12.259 | 8 | 18.00 | 4.354 | 19 | 3.775 | 4.359 | 4.874 | 5.338 | 6.164 |
| 15 | 80 | 11.892 | 7 | 20.00 | 4.009 | 20 | 3.873 | 4.472 | 5.000 | 5.477 | 6.325 |
| | | | | | | 21 | 3.969 | 4.583 | 5.124 | 5.612 | 6.481 |
| 15 | 75 | 11.085 | 7 | 15.00 | 3.715 | 22 | 4.062 | 4.690 | 5.244 | 5.744 | 6.633 |
| 15 | 70 | 10.862 | 6 | 17.25 | 3.412 | 23 | 4.153 | 4.796 | 5.362 | 5.873 | 6.783 |
| | | | | | | 24 | 4.243 | 4.899 | 5.477 | 6.000 | 6.928 |
| 15 | 60 | 10.405 | 6 | 12.25 | 7.112 | 25 | 4.330 | 5.000 | 5.591 | 6.123 | 7.071 |
| 15 | 55 | 9.532 | 5 | 14.75 | 2.842 | 30 | 4.743 | 5.477 | 6.124 | 6.707 | 7.746 |
| | | | | | | 35 | 5.124 | 5.916 | 6.615 | 7.245 | 8.366 |
| 15 | 50 | 9.270 | 5 | 9.75 | 2.539 | 40 | 5.477 | 6.325 | 7.071 | 7.746 | 8.945 |
| 15 | 42 | 8.861 | 4 | 10.50 | 2.182 | 45 | 5.810 | 6.708 | 7.500 | 8.215 | 9.487 |
| | | | | | | 50 | 6.124 | 7.071 | 7.906 | 8.660 | 10.000 |

I Beams Used in Wall Foundations.—METHOD OF

CALCULATION:

Let $L =$ weight of wall per lineal foot in tons and

$b =$ assumed bearing capacity of ground per square foot (usually from 1 to 3 tons);

then $\frac{L}{b} = W =$ required width of foundation in feet;
 $w =$ width of lowest course of footing-stones;
 $p =$ projection of beams beyond masonry in feet;
 $s =$ spacing of beams centre to centre in feet.

Evidently the size of beams required will depend upon their strength as cantilevers of a length p sustaining the upward reaction, which may be regarded as a uniformly distributed load.

Thus $pb =$ uniformly distributed load (in tons) on cantilevers per lineal foot of wall

and $pbs =$ uniform load in tons on each beam.

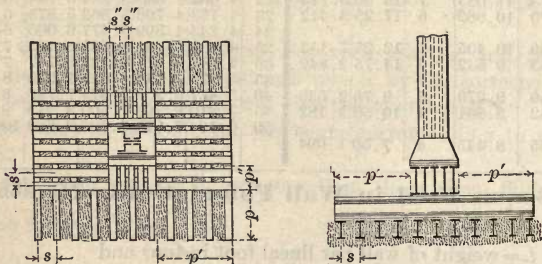
The table on page 25 gives the safe lengths p for the various sizes and weights of beams for $s = 1$ ft. and b ranging from 1 to 5 tons per square foot. For other values of s , say 15 in. or $1\frac{1}{4}$ ft., the table may be used by simply considering b increased in the same ratio as s (see example below). As regards the weight of beams, it is advantageous to assign to s as great a value as is warranted by the other considerations which obtain.

Example.—The weight of a brick wall together with the load it must support is 40 tons per lineal foot. The width of the lowest footing-course of masonry is 6 ft. Allowing a pressure of 2 tons per square foot on the foundation, what size and length of I beams 18 in. centre to centre will be required?

Answer.— $L = 40$, $b = 2$, $w = 6$, $s = 1\frac{1}{2}$.

Therefore $W = 40 \div 2 = 20$ ft., the required length of beams. The projection $p = \frac{1}{2} (20 - 6) = 7$ ft.

In order to apply the table calculated (for $s = 1$ ft.) we must consider b increased in the same ratio as s , i.e., $b = 2 \times 1\frac{1}{2} = 3$ tons.



In the column for 3 tons we find the length 7 ft. to agree with 20-in. I beams 65.0 lbs. per foot.

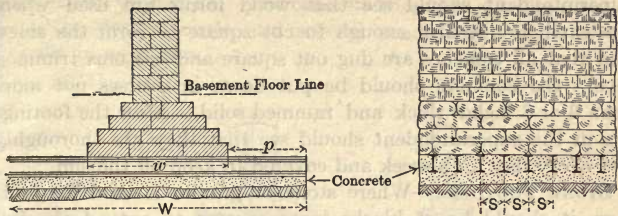


TABLE GIVING SAFE LENGTHS OF PROJECTIONS p IN FEET (SEE ILLUSTRATION) FOR $s=1$ FOOT AND VALUES OF b RANGING FROM 1 TO 5 TONS.

| Depth of Beam in Inches. | Weight per Foot. | b (Tons per Square Foot). | | | | | | | | | | |
|--------------------------|------------------|-----------------------------|-------|-------|-------|-------|------|------|------|------|------|------|
| | | 1 | 1½ | 1½ | 2 | 2½ | 2½ | 3 | 3½ | 4 | 4½ | 5 |
| 24 | 80.00 | 15.231 | 13.61 | 12.43 | 10.77 | 10.16 | 9.63 | 8.79 | 8.14 | 7.62 | 7.18 | 6.81 |
| 20 | 80.00 | 13.983 | 12.50 | 11.41 | 9.89 | 9.32 | 8.84 | 8.07 | 7.47 | 6.99 | 6.59 | 6.25 |
| 20 | 65.00 | 12.488 | 11.16 | 10.20 | 8.82 | 8.33 | 7.90 | 7.21 | 6.68 | 6.24 | 5.89 | 5.58 |
| 18 | 55.00 | 10.857 | 9.71 | 8.86 | 7.68 | 7.23 | 6.87 | 6.27 | 5.80 | 5.43 | 5.12 | 4.86 |
| 15 | 80.00 | 11.892 | 10.63 | 9.71 | 8.41 | 7.93 | 7.52 | 6.86 | 6.36 | 5.95 | 5.61 | 5.32 |
| 15 | 60.00 | 10.405 | 9.30 | 8.49 | 7.36 | 6.94 | 6.58 | 6.01 | 5.56 | 5.20 | 4.90 | 4.65 |
| 15 | 42.00 | 8.861 | 7.92 | 7.23 | 6.27 | 5.91 | 5.60 | 5.12 | 4.74 | 4.43 | 4.18 | 3.96 |
| 12 | 40.00 | 7.730 | 6.91 | 6.31 | 5.47 | 5.15 | 4.89 | 4.46 | 4.13 | 3.87 | 3.64 | 3.46 |
| 12 | 31.50 | 6.925 | 6.19 | 5.65 | 4.90 | 4.55 | 4.38 | 4.00 | 3.70 | 3.46 | 3.26 | 3.10 |
| 10 | 25.00 | 5.706 | 5.10 | 4.66 | 4.03 | 3.80 | 3.61 | 3.29 | 3.05 | 2.85 | 2.69 | 2.55 |
| 9 | 21.00 | 5.016 | 4.48 | 4.09 | 3.55 | 3.34 | 3.17 | 2.90 | 2.68 | 2.51 | 2.36 | 2.24 |
| 8 | 18.00 | 4.354 | 3.89 | 3.55 | 3.08 | 2.90 | 2.75 | 2.51 | 2.33 | 2.18 | 2.05 | 1.95 |
| 7 | 15.00 | 3.715 | 3.32 | 3.03 | 2.63 | 2.48 | 2.35 | 2.14 | 1.98 | 1.86 | 1.75 | 1.66 |
| 6 | 12.25 | 3.112 | 2.78 | 2.54 | 2.20 | 2.07 | 1.97 | 1.80 | 1.66 | 1.56 | 1.47 | 1.39 |
| 5 | 9.75 | 2.539 | 2.27 | 2.07 | 1.80 | 1.69 | 1.61 | 1.47 | 1.36 | 1.27 | 1.20 | 1.14 |
| 4 | 7.50 | 1.994 | 1.78 | 1.63 | 1.41 | 1.33 | 1.26 | 1.15 | 1.07 | 1.00 | 0.94 | 0.89 |

The size of beam for any other pressure is found by multiplying the projection by the square root of the assumed pressure and finding the beam having a projection corresponding to this product under the one-ton column.

Footing-courses.—Footing-courses are usually made of concrete or large flat blocks of stone or granite. If of concrete they should not be less than 12 inches in thickness, but this thickness should be governed by the width or area covered, and where stepped up, the offset should not be more than one-half the height of the respective course; if not reinforced with steel beams they should not be loaded with more than 8000 pounds per square foot. If reinforced by beams the load may be increased to from 12,000 to 16,000 pounds. The same precaution should be taken with the beams as described under Spread Footings. When concrete is used for footings the

superintendent should see that wood forms are used where the earth is not firm enough to cut square to form the sides, and that all trenches are dug out square and bottoms trimmed level; the concrete should be put down in courses not more than 6 or 8 inches thick and rammed solid. After the footings are in the superintendent should see that they are thoroughly wet every day for a week and covered to keep off the sun.

STONE FOOTINGS.—Where stone or granite is used for footings, it should be of blocks large enough to extend the full width of the footing, and from 4 to 8 feet in length; where it is not possible to obtain stone large enough to extend through the footing they may be jointed under the centre of the wall and a second course of single stone put on top, as shown by Fig. 24.

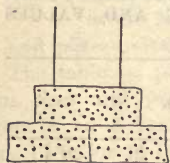


FIG. 24.

The stone should have uniform beds, and where two or more courses are used the offset should not be more than three-quarters of the height of the under course. The stone should be set in strong cement mortar and on a full bed under the entire stone; stone in footings should not be subject to a pressure of more than 10,000 to 14,000 pounds per square foot.

In setting stone footings the superintendent should see that each stone is squared off so they will fit close together, and no spalls used to fill up the joints; the top and bottom beds should be dressed off and set in a full bed of mortar and all vertical joints slushed full. Unless the superintendent is on the lookout the mason is liable in levelling the stone to raise it up and wedge it with a spall and then try to slush the mortar beneath the stone; this should not be allowed, but when a stone has to be raised any, have it lifted, a new bed of mortar spread, and the stone reset and beat down until it comes to a solid bearing.

BRICK FOOTING.—When brick is used for footings the bottom courses should be double, or composed of three separate courses, and the outside courses in a step footing should all be headers, so as to keep the joints back as far from the face of the footing as possible. The superintendent should see that only the hardest bricks are used, and that they are laid in the best of cement mortar, and that all joints are slushed full. In some cases where piers carrying a heavy weight rest on the footing-course it is advisable to turn inverted arches from pier to pier,

as shown by Fig. 25. The concrete should be put in and shaped to the desired circle and several concentric courses of brick built in as shown.

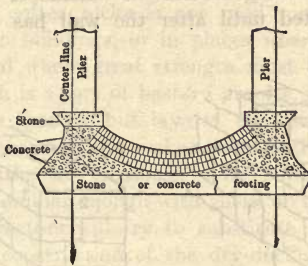


FIG. 25.

Foundation-walls.—**STONE.**—Where stone is to be used for foundation-walls, it should come from a quarry that is well known and the stone such as has been tested by use. It should be a hard compact stone and one which can be quarried in large blocks; care should be exercised at the quarry to get out the stone in such sizes as is desired, and so that they will lay in the wall on their natural bed.

The specifications usually mention how close headers or bond stone are to be built, as: "One-sixth of the face surface of the wall shall consist of bond stone or headers extending through the wall."

For ordinary structures the walls are usually built as shown in Fig. 26, 1, 1, 1 representing the bond stone and 2, 2, 2 the headers at a jamb or opening.

For large and more important structures the stone should be large blocks and laid in courses as shown by Fig. 27; every alternate course should have headers as indicated by 1, 1, 1. The superintendent should pay close attention to the mason when at work and see that every stone is set in a full bed of mortar and all joints slushed full. A mason usually if let alone will set a stone down and wedge up under with spalls until the stone will not rock, then plaster some mortar around it and call it set. The superintendent must also watch the filling of any cavities between the stone and see that they are filled solid with small stone and mortar. Wherever pipes of any kind are to pass through the wall, openings of a suita-

ble size should be left so that there will be no weight of the wall resting on the pipes. Or a better method is to build pipe-sleeves in the wall large enough for the pipe to pass through.

FILLING.—The filling around the outside of the wall should never be permitted until after the wall has been built long

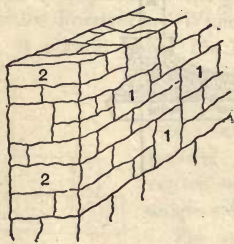


FIG. 26.

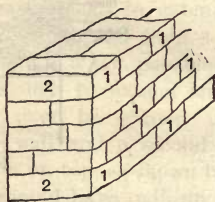


FIG. 27.

enough for the mortar to harden, and the beams of the first floor put in place, so as to prevent the walls from being shoved in by the pressure of the earth. In filling the superintendent should see that nothing but clean solid material is used and put in in layers of about 12 inches and well rammed, or, as is better, "puddled" into place. Where there is danger of dampness the walls should be plastered as shown and described on page 5.

Stonework.—**NATURAL STONES.**—The duty of selecting the stone or any other building material usually devolves upon the architect or engineer who prepares the plans and specifications, and unless the stone comes from a well-known and tried quarry it should be given thorough tests, and for a structure of any importance a new stone, or one that has not been in use any length of time, should not be used, unless by making severe tests the architect or the superintendent is convinced it will stand, as to strength and weathering qualities. Time and exposure to the elements are the best test for any stone.

Granite and Allied Rocks.—Granite as a rule can be quarried in any size that can be handled, and when coming from an old quarry the durability of it will be known, but if from a new quarry it should be tested. The usual color of granite is a light or dark gray, although different shades, from light

pink to red, are found in different localities. The color of granite is generally determined by the color of the feldspar in it, or by the color of the mica which it contains.

Granite, being so hard to work and thus being more expensive than the softer rocks, is not used much except for the more expensive buildings, or in places where other stones are not desired and where great strength must be had.

Gneiss, which is a sort of bastard granite, has much the same composition as granite, but lays in the quarry in layers. It can be easily quarried and makes good footings or foundations and street curbs or crossings. The superintendent should make himself familiar enough with gneiss to tell it from granite, for some contractors will try to substitute it for granite.

During the construction of the dry-dock at the Charleston, S. C., navy yard the United States Navy Department rejected the stone sent for constructing the dock, on account of it being gneiss, when granite was specified.

Syenite.—This is a rock which resembles granite, but contains no quartz. It is very little used, the principal quarries being in Arkansas.

Trap and Basalt.—These rocks are very hard, compact, and tough and are used for road-making and street-paving.

The principal granite quarries are found in the New England States. The table on page 30 will show the location of some of the best known quarries and buildings in which the granite was used.

A good granite should last from 75 to 200 years without showing any signs of discoloration or disintegration.

When using granite, the superintendent should examine all stones as they are brought to the building, both as to quality and workmanship, as granite is usually cut at the quarry and will come to the job ready to set. He should watch to see that there is not too much contrast in the color of the stones, as in some granites there is quite a difference in the color of the stone coming from different parts of the same quarry. He may find "knots" which are lumps of a different color from the body of the stone. They are usually much lighter or darker, and when found the stone should be rejected. "Sap," which is a stain in the stone, and "shakes," which are cracks or seams, should be sufficient cause to reject any stone containing them.

The table on page 31 shows the load per square inch at which

STRENGTH AND WEIGHT OF VARIOUS GRANITES.

| State. | Location. | Strength per Sq. Inch. | Weight per Sq. Foot. |
|----------------|----------------------------|------------------------|----------------------|
| Arkansas | Pulaski Co. (gray granite) | 14,000 | ... |
| " | Fourth Mountain (syenite) | 30,740 | 167 |
| California | Rocklin | 30,740 | 167 |
| Colorado | Gunnison | 12,976 | 165 |
| " | Platte Canyon (red) | 14,585 | 168 |
| Connecticut | Middleton | 21,460 | ... |
| " | Waterford | 23,510 | ... |
| " | Meriden (trap rock) | 34,920 | ... |
| " | Kirkland rocks | 35,000 | 166 |
| " | Lord's Island | 24,000 | ... |
| " | Mystic River | 22,250 | 164 |
| " | New Haven | 9,750 | ... |
| " | Millstown Point | 16,187 | 169 |
| " | Milford | 22,600 | ... |
| " | New London | 12,500 | 166 |
| Georgia | Lithonia | 25,630 | ... |
| Maine | Hurricane Isle | 19,538 | 167 |
| " | Jonesboro (red) | 24,507 | ... |
| " | Waldoboro (white) | 23,111 | ... |
| " | North Jay (red) | 22,367 | ... |
| " | Dix Island | 15,000 | 166 |
| " | Fox Island (blue) | 15,000 | 164 |
| " | Sharkey's Quarry | 22,125 | 170 |
| " | Vinalhaven (gray) | 17,000 | ... |
| Massachusetts | Cape Ann | 20,296 | 164 |
| " | Milford (pink) | 30,888 | ... |
| " | Milford (Norcross Bros.) | 20,883 | ... |
| " | Quincy (dark) | 17,750 | 166 |
| " | Quincy (light) | 14,750 | 166 |
| " | Fall River (gray) | 15,937 | ... |
| Michigan | Huron Island | 18,125 | 164 |
| Missouri | Graniteville | 24,181 | ... |
| Minnesota | East St. Cloud | 28,000 | 168 |
| " | Duluth (dark) | 17,631 | 175 |
| " | Duluth (light) | 19,000 | ... |
| New Hampshire | Troy | 17,950 | 168 |
| " | Keene (blue gray) | 12,000 | 166 |
| New York | Goshen | 23,500 | ... |
| " | Staten Island (blue) | 22,250 | 178 |
| " | Tarrytown | 18,250 | 162 |
| New Jersey | Scotch Plains (trap rock) | 17,950 | ... |
| " | Passaic Co. (gray) | 24,040 | ... |
| " | Jersey City | 20,750 | 189 |
| Rhode Island | Westerly (gray) | 17,500 | 165 |
| South Carolina | Carlisle | 29,150 | ... |
| Texas | Burnet Co. | 11,891 | 176 |
| Vermont | Barre (dark) | 19,975 | ... |
| " | Barre (light) | 17,856 | ... |
| Virginia | Peters | 25,100 | ... |
| " | Richmond | 25,520 | ... |

The argillaceous is a soft stone cemented with a clayey matter and disintegrates very easily.

The calcareous stone is cemented with carbonate of lime. This stone is soft and easy to work, but does not weather well.

In ferruginous stone the cementing material is composed of iron oxides, which cause the red or brown color. This stone is harder than the two last mentioned; does not work so easy, but stands the weather well.

CHEMICAL ANALYSIS OF GRANITES FROM VARIOUS QUARRIES.

| State. | Location. | Quarry. | Silica. | Oxide of Alumina. | Oxide of Magnesia. | Oxide of Sodium. | Oxide of Potassium. | Oxide of Iron. | Oxide of Calcium. |
|----------------|----------------|------------------------------|---------|-------------------|--------------------|------------------|---------------------|----------------|-------------------|
| California. | Exeter. | Rocky Point Granite Works. | 75.35 | 13.69 | .06 | 1.14 | 2.85 | 3.94 | 2.97 |
| Connecticut. | Waterford | Hurricane Isle Granite Co. | 68.11 | 14.28 | .68 | 6.57 | 5.46 | ..... | 1.86 |
| " | Meriden | (Trap rock). | 52.37 | 15.06 | 5.38 | 4.04 | ..... | ..... | 7.33 |
| Delaware. | Rockford. | Brandywine G't Co. (gneiss). | 67.98 | 16.14 | .53 | 4.32 | .45 | ..... | 5.89 |
| Maine. | Waldoboro. | Booth Bros. | 73.48 | 15.26 | .09 | 3.12 | 5.66 | ..... | .98 |
| " | North Jay. | Maine and N. H. Granite Co. | 71.54 | 14.24 | ..... | 3.39 | 4.73 | ..... | .94 |
| " | Blue Hill | Chase Granite Co. | 73.02 | 16.22 | ..... | 3.60 | 3.42 | ..... | .39 |
| " | " | Blue Hill Granite Co. | 74.64 | 14.90 | ..... | .41 | 6.88 | ..... | 3.73 |
| Maryland. | Point Deposit | M'Clenahan Bros. | 73.69 | 12.89 | .49 | 2.81 | 1.48 | 4.69 | 4.77 |
| Minnesota. | East St. Cloud | ..... | 65.12 | 16.96 | ..... | 5.25 | ..... | ..... | 1.10 |
| Massachusetts. | Cape Ann. | Rockport Granite Co. | 81.05 | 14.70 | ..... | 5.60 | 5.03 | ..... | ..... |
| " | Milford. | Shea Pink Granite Co. | 76.95 | 11.15 | ..... | 3.37 | 4.71 | ..... | ..... |
| " | " | Norcross Bros. | 76.07 | 12.67 | .10 | ..... | ..... | ..... | ..... |
| " | Monson. | (Trap rock). | 52.59 | 23.42 | .28 | 5.97 | ..... | 1.15 | ..... |
| " | " | Light granite. | 73.47 | 15.07 | ..... | ..... | ..... | 2 | ..... |
| " | " | Dark granite. | 69.35 | 18.23 | ..... | ..... | ..... | ..... | ..... |
| Nevada. | Reno. | Jno. Barret. | 58.67 | 14.89 | 1.79 | 3.78 | 2.69 | ..... | ..... |
| N. Hampshire. | Red Stone. | N. H. Granite Co. (red). | 71.44 | 14.72 | .96 | 7.66 | .89 | ..... | ..... |
| " | " | " (green) | 70.42 | 14.64 | 1.20 | 7.80 | .71 | ..... | ..... |
| " | Troy. | Troy Granite Co. | 73.15 | 17.04 | .30 | 2.05 | 5.74 | ..... | .81 |
| " | Mason. | Mason Granite Co. | 72.47 | 16.17 | .14 | 3.43 | 4.83 | ..... | 1.65 |
| New Jersey. | Little Falls. | Francesco Bros. (trap). | 50.81 | 13.25 | 6.97 | .76 | 10.96 | ..... | 10.96 |
| New York. | Stormy P't. | Daniel Donovan | 63.19 | 10.50 | 1.43 | 1.91 | 4.01 | ..... | 6.12 |
| Pennsylvania. | Birdsboro. | John T. Dyer Co. | 46.87 | 13.36 | 4.35 | 4.64 | 2.01 | ..... | 14.70 |
| Vermont. | Barre. | Wells, Lamson & Co. | 69.56 | 15.38 | ..... | 5.38 | 4.31 | ..... | 1.76 |
| Virginia. | Petersburg. | Petersburg Granite Co. | 64.12 | 20.91 | .66 | 4.57 | 4.82 | 2.96 | 1.98 |
| " | Richmond | P. Copeland. | 60.65 | 16.87 | 2.39 | 2.18 | 3.80 | ..... | 1.91 |
| Wisconsin. | Waushara Co. | Milwaukee Monument Co. | 76.62 | 13.02 | .05 | 2.24 | 6.38 | ..... | .51 |
| " | Berlin. | E. J. Nelson. | 73.65 | 11.19 | .51 | 3.74 | 1.86 | ..... | 2.78 |

PRODUCTION AND USE OF GRANITE IN U. S. DURING THE
YEAR 1901.

| State. | Sold in the Rough. | | | Dressed for Build- ing. | Dressed for Mon- umental Work. | Made into Paving Blocks. |
|-------------------|--------------------|------------------|---------|----------------------------------|---|-----------------------------------|
| | Build- ing. | Monu- mental. | Other. | | | |
| Arkansas..... | | | | | | \$2,627 |
| California..... | \$24,057 | \$38,755 | \$6,815 | \$358,832 | \$72,257 | 46,300 |
| Colorado..... | 45,650 | 7,562 | | 60,835 | 1,787 | 5,750 |
| Connecticut..... | 108,959 | 26,267 | 24,384 | 94,611 | 70,894 | 29,533 |
| Delaware..... | 9,069 | | 2,678 | 1,750 | 400 | 32,191 |
| Georgia..... | 54,321 | 22,315 | 2,725 | 57,207 | 14,526 | 328,087 |
| Idaho..... | 100 | 5,000 | | | | |
| Indian Territory. | | | | | | |
| Kansas..... | 2,340 | | | 7,800 | | |
| Maine..... | 407,418 | 24,475 | 27,447 | 1,501,797 | 76,276 | 401,189 |
| Maryland..... | 181,608 | 20,180 | 1,500 | 188,568 | 7,800 | 51,637 |
| Massachusetts.. | 333,047 | 236,327 | 118,567 | 455,535 | 236,273 | 364,721 |
| Michigan..... | | | | | | |
| Minnesota..... | 13,215 | 42,197 | 1,550 | 55,017 | 96,902 | 20,002 |
| Missouri..... | 550 | 17,406 | 2,095 | | | 40,651 |
| Montana..... | | | | | | |
| Nevada..... | | | | 15,600 | 3,500 | |
| New Hampshire. | 156,832 | 52,231 | 9,797 | 363,957 | 171,239 | 112,581 |
| New Jersey..... | 60,905 | 2,515 | | 19,888 | | 87,933 |
| New York..... | 24,312 | 1,325 | 6,150 | 97,350 | 6,283 | 33,025 |
| North Carolina.. | 27,464 | 4,105 | 2,212 | 68,975 | 6,813 | 10,862 |
| Oregon..... | 3,748 | 250 | 1,590 | 3,900 | 1,116 | |
| Pennsylvania.. | 63,568 | 1,050 | 4,538 | 18,916 | 227 | 15,712 |
| Rhode Island.. | 9,722 | 92,974 | 110 | 160,190 | 198,831 | 27,666 |
| South Carolina.. | 56,831 | 23,433 | 5,730 | 165,594 | 12,789 | 8,276 |
| South Dakota.. | 25,106 | | 2,159 | 1,650 | | 52,089 |
| Texas..... | 2,652 | 11,521 | | 243 | 10,400 | |
| Utah..... | 2,288 | 3,300 | | | | |
| Vermont..... | 208,825 | 534,755 | 101,779 | 16,343 | 354,563 | 16,304 |
| Virginia..... | 40,763 | 8,300 | 230 | 45,737 | 52,404 | 17,253 |
| Washington..... | 9,100 | 2,250 | | 3,000 | | 3,360 |
| Wisconsin..... | 3,575 | 79,175 | 28,015 | 17,999 | 62,277 | 113,682 |
| Wyoming..... | 2,810 | | | | | |
| Total..... | 1,878,835 | 1,257,668 | 350,071 | 3,781,294 | 1,457,557 | 1,821,431 |

The silicious stone, being cemented with silica, which has about the same composition as the grains of sand of which the stone is composed, makes a stone very hard and one which will weather well. The color of the stone is usually due to the amount of iron contained in it. The more iron the darker the stone. The iron oxides in the stone do no harm, but iron pyrites or sulphate of iron in light sandstones is sure to stain or rust the stone.

Sandstone being of a sedimentary formation, it is usually found in the quarry in layers, or there is a well-defined grain to the stone in the direction of its natural bed, which causes it to split readily. In working the stone, the superintendent should see that the stone is cut so it will set in the wall as it lay in the quarry, or on its natural bed. If it is set on edge it is sure to scale off as the frost and moisture penetrates it.

As nearly all the sandstones are very soft when first quarried

the superintendent should see that too much weight is not put on them until they have had time to season or harden after being taken from the quarry.

The defects usually found in sandstones are "drys" (seams which are not cemented together), and holes or cavities filled with sand or clay or uncemented material.

Sandstones are of great variety and color, and are found in all parts of the country, the different colors coming from different localities. Dark brown is found near Portland, Conn.; Hummelstown, Pa.; Marquette, Mich.; West Virginia; North Carolina; Indiana; Arizona, and Colorado. Red is found at East Longmeadow, Mass.; Potsdam, N. Y.; Fon du Lac, Minn.; Manitou, Col.; Glenrock, Wyoming, and Portage Entry, Mich. (Lake Superior sandstone). Perhaps the most extensively used sandstone comes from Ohio, near Cleveland, and is of a light buff or gray color.

Missouri has several quarries of a gray sandstone which has been used extensively in St. Louis and Kansas City.

The following table shows some of the principal quarries and buildings in which the stone has been used.

| State. | Location of Quarry. | Building Used in. | Color of Stone. |
|---------|----------------------------------|--|-----------------|
| Conn.. | Portland. | Technology Building, Boston. ... | Brown |
| " | " | Astor Library, New York City. .. | Brown |
| " | " | Music Hall, Buffalo, N. Y. | Brown |
| " | " | Union League Club B'd'g. Phila. | Brown |
| " | " | Savings Bank of Baltimore. | Brown |
| " | " | Residence of W. H. Vanderbilt, New York. | Brown |
| Colo. . | Fort Collins. . . | Grace Methodist Church, Denver | Dark red |
| " | " | Union Pacific Depot, Cheyenne, Wyoming. | Dark red |
| Mass. . | Longmeadow. . | Union League Club, Chicago. | Red |
| " | " | Trimmings Trinity C'ch, Boston.. | Red |
| Mich. . | Portage Entry (Lake Superior) | New Waldorf-Astoria Hotel, N.Y. | Red |
| " | Do. do. | U. S. Post-office, Rockford, Ill ... | Red |
| " | Marquette | Court House, Muskegon, Mich ... | Brown |
| Minn.. | Kettle River .. | Library Bldg., Univ. of Illinois. .. | Cream |
| " | Fond du Lac. . | Presbyterian Church, Minneap- olis, Minn. | Reddish brown |
| N. Y. . | Potsdam. | Parliament B'd'gs, Ottawa, Ont. | Red |
| " | " | Columbia College, New York City. | Red |
| " | Medina. | U. S. Government Building, Roch- ester, N. Y. | Pink |
| Ohio. . | Amherst. | Palmer House, Chicago. | Buff |
| " | " | State Capitol, Lansing, Mich | Buff |
| " | " | State Historical Library, Minne- apolis, Minn. | Buff |
| " | " | Wood Co., Ohio, Court House. ... | Gray |
| " | Berea. | U. S. Post-office, Minneapolis, Minn. | Blue-gray |
| Pa. ... | Hummelstown | U. S. Marine Barracks, League Island. | Brown |

The following table shows the value of the sandstone production in the United States from 1897 to 1901, inclusive, by States.

VALUE OF SANDSTONE PRODUCTION IN THE UNITED STATES
FROM 1897 TO 1901, INCLUSIVE, BY STATES.

| State. | 1897. | 1898. | 1899. | 1900. | 1901. |
|--------------------|-----------|-----------|------------------------|------------------------|------------------------|
| Alabama. | \$3,000 | \$27,882 | \$71,675 | \$7,132 | \$8,680 |
| Arizona. | 15,000 | 57,444 | 4,168 | 64,000 | 202,500 |
| Arkansas. | 3,161 | 24,825 | 73,616 | 104,923 | 62,825 |
| California. | 4,035 | 358,908 | 261,193 | 200,090 | 301,028 |
| Colorado. | 60,847 | 89,637 | 129,815 | 119,658 | 237,331 |
| Connecticut. . . | 364,604 | 215,733 | 271,623 | 192,593 | 146,814 |
| Georgia. | | | | 600 | |
| Idaho. | | | | 438 | 20,843 |
| Illinois. | 14,250 | 13,758 | 16,133 | 19,141 | 12,884 |
| Indiana. | 35,561 | 45,342 | 35,636 | 45,063 | 34,959 |
| Iowa. | 14,771 | 7,102 | 24,348 | 19,063 | 14,341 |
| Kansas. | 20,953 | 19,528 | 49,629 | 55,173 | 49,901 |
| Kentucky. . . . | 40,000 | 72,525 | 119,982 | 56,178 | 108,259 |
| Louisiana. | 8,000 | 200,500 | ¹ 226,503 | ² 118,192 | |
| Maryland. | | 13,646 | 24,426 | 6,655 | 4,546 |
| Massachusetts. . | 194,684 | 91,287 | 131,877 | 153,427 | 247,310 |
| Michigan. | 171,127 | 222,376 | 320,192 | 238,650 | 290,578 |
| Minnesota. | 158,057 | 175,810 | 294,615 | 267,000 | 246,685 |
| Missouri. | 57,583 | 48,795 | 57,662 | 53,401 | 42,170 |
| Montana. | 25,644 | 3,682 | 26,160 | 59,630 | 60,719 |
| Nebraska. | | | | | 515 |
| New Jersey. . . . | 190,976 | 257,217 | 147,768 | 198,234 | 244,512 |
| New Mexico. | | 3,500 | 1,829 | 2,500 | |
| New York. . . . | 544,514 | 566,133 | ³ 1,218,053 | ³ 1,467,496 | ³ 1,331,327 |
| N. Carolina. . . . | 11,500 | 9,100 | 10,300 | 27,210 | 11,682 |
| Ohio. | 1,600,058 | 1,494,746 | 1,775,642 | 2,233,596 | 2,576,723 |
| Oregon. | | 7,864 | 4,153 | 5,450 | 531 |
| Pennsylvania. . . | 380,813 | 478,451 | ³ 717,053 | ³ 1,050,248 | ³ 2,063,082 |
| South Dakota. . . | | 9,000 | 18,325 | 12,675 | 17,647 |
| Tennessee. | | | | 11,300 | 10,342 |
| Texas. | 30,030 | 77,190 | 35,738 | 37,038 | 111,568 |
| Utah. | 7,907 | 15,752 | 29,091 | 66,733 | 38,919 |
| Virginia. | | | 8,000 | 6,000 | 5,303 |
| Washington. . . . | 16,187 | 15,575 | 58,395 | 68,133 | 89,174 |
| West Virginia. . . | 47,288 | 14,381 | 33,860 | 72,438 | 106,710 |
| Wisconsin. | 33,620 | 80,341 | 132,901 | 81,571 | 90,425 |
| Wyoming. | 11,275 | 6,382 | 32,583 | 27,671 | 54,145 |
| Totals. . . . | 4,065,445 | 4,724,412 | 6,362,944 | 7,149,300 | 8,844,978 |

¹ Includes small amounts for Idaho and Nevada.

² Includes Mississippi.

³ Includes bluestone.

The following table gives the crushing strength per square inch and weight per cubic foot of sandstones found in various parts of the country.

The working strength of any stone should not be more than one-tenth of its crushing strength. The New York Building Code gives the working strength of sandstones at 400 to 1600 pounds per square inch, according to test.

STRENGTH AND WEIGHT OF SANDSTONES.

| State. | Location. | Color. | Strength per Sq. Inch. | Weight per Sq. Foot. |
|----------------|-------------------------------|---------------|------------------------|----------------------|
| Arizona | Flagstaff | Chocolate | 5,857 | 142 |
| California | Colusa | | 8,880 | ... |
| Colorado | St. Vrain | Red | 11,500 | 149 |
| " | Fort Collins | Gray | 11,707 | 140 |
| " | Manitou | Red | 11,000 | 140 |
| Connecticut | Portland | | 10,871 | 148 |
| " | Middletown | Brown | 6,950 | ... |
| " | Cromwell | | 16,890 | 156 |
| Indiana | Riverside | Gray | 6,000 | ... |
| " | " | Blue | 6,090 | ... |
| Iowa | La Grande | | 6,805 | ... |
| Kansas | Valley Falls | | 7,500 | 152 |
| Kentucky | Langford | | 15,160 | ... |
| Massachusetts | East Longmeadow | Red | 11,595 | 154 |
| Missouri | Warrensburg | Blue-gray | 9,687 | 149 |
| Minnesota | Kasota | Pink | 10,700 | 164 |
| " | Kettle River | Pinkish buff | 17,000 | 139 |
| " | Frontenac | Buff | 6,250 | 145 |
| Michigan | Redrock | | 6,019 | ... |
| " | Portage Entry (Lake Superior) | Red | 6,776 | 126 |
| " | Marquette | | 7,450 | 158 |
| New York | Potsdam | Red | 18,401 | 162 |
| " | Medina | Pink | 17,250 | 150 |
| " | Oxford | Blue | 12,677 | ... |
| " | Warsaw | Blue | 19,968 | 167 |
| " | Albion | Brown | 13,500 | 157 |
| " | Little Falls | Brown | 9,850 | ... |
| " | Haverstraw | Red | 4,350 | 133 |
| New Jersey | Belleville | Gray | 11,700 | 147 |
| " | " | Brown | 13,310 | 148 |
| North Carolina | Carthage | | 12,750 | ... |
| Ohio | Seneca | Reddish brown | 5,000 | 134 |
| " | Lancaster | | 5,950 | ... |
| " | Amherst | Buff | 9,450 | 133 |
| " | Berea | Dark drab | 9,510 | 134 |
| " | Cleveland | Olive-green | 6,800 | 140 |
| " | Vermillion | Drab | 8,850 | 135 |
| " | Massilon | Yellow-drab | 8,750 | ... |
| Pennsylvania | Hummelstown | Brown | 13,097 | ... |
| " | Laurel Run | | 22,250 | 166 |
| " | White Haven | | 29,250 | ... |
| South Dakota | Hot Springs | | 6,914 | ... |
| " | Rapid City | Gray | 11,452 | ... |
| " | " | Red | 6,116 | ... |
| Washington | Chuckanut | | 10,276 | ... |
| Wisconsin | Fon du Lac | Purple | 6,237 | 138 |
| Wyoming | Rawlins | | 10,883 | ... |

The table on the page opposite gives the chemical analyses of some of the principal sandstones.

Limestone.—The varieties of limestones used for building purposes are: Oolitic, limestones which are composed of small round grains that have been cemented together with lime to form a solid rock; magnesian limestones, which contain 10 per cent or more of carbonate of magnesia; dolomite, limestones which are an aggregation of the mineral dolomite; the latter is

usually of a light color and is generally much harder and heavier than the other limestones.

The most extensive quarries of limestone are near Bedford, Ind., from where stone is shipped to nearly all parts of the country. At Carthage, Mo., are several quarries of limestone of a coarse crystalline nature and which takes a good polish; this stone is found in layers, and the largest clear stone which

PRODUCTION OF LIMESTONE IN THE UNITED STATES IN
1900 BY STATES AND USES.

| State or Territory. | Building Purposes. | Paving and Road-making. | Riprap. | Made into Lime. | Stone Sold to Lime-burners. | Flux. | Other Purposes. | Total. |
|-------------------------|--------------------|-------------------------|----------|-----------------|-----------------------------|-----------|-----------------|------------|
| Ala. . . | \$83,380 | | \$14,697 | \$139,090 | | \$296,241 | \$200 | \$533,608 |
| Ariz. . . | 165 | | | | | | | 165 |
| Ark. . . | 5,994 | \$665 | | 64,038 | \$200 | | 510 | 71,407 |
| Cal. . . | 1,937 | 87,128 | 325 | 297,810 | 316 | 1,080 | 18,893 | 407,489 |
| Colo. . . | | 1,274 | | 96,055 | 75 | 62,413 | 770 | 160,587 |
| Conn. . . | | 25 | | 145,490 | | 2,545 | | 148,060 |
| Fla. . . | | 6,988 | 97,023 | 24,370 | | | | 128,381 |
| Ga. . . | 1,200 | 10,735 | | 39,492 | 2,000 | 1,024 | | 54,451 |
| Idaho . . | | 9,000 | | 25,587 | | | | 34,587 |
| Ill. . . | 499,739 | 859,602 | 96,900 | 246,575 | | 114,849 | 63,486 | 1,881,151 |
| Ind. . . | 1,639,985 | 239,913 | 11,451 | 227,343 | | 168,692 | 57,434 | 2,344,818 |
| Iowa. . . | 248,883 | 153,929 | 58,493 | 110,589 | 580 | | 13,936 | 586,410 |
| Kan. . . | 203,304 | 113,952 | 7,586 | 3,192 | 1,125 | | 10,307 | 339,466 |
| Ken. . . | 21,623 | 115,730 | 12,500 | 8,393 | | 17,728 | 2,278 | 178,252 |
| Maine . . | | | | 629,545 | 4,218 | 883 | 56,666 | 691,312 |
| Md. . . | 11,385 | 14,343 | 524 | 281,717 | 3,726 | 3,867 | 1,645 | 317,207 |
| Mass. . . | 8,175 | | | 199,645 | | 1,539 | | 209,359 |
| Mich. . . | 32,362 | 105,266 | 799 | 94,789 | 65,000 | 3,200 | 124,220 | 425,636 |
| Minn. . . | 323,688 | 27,778 | 32,912 | 42,480 | 400 | 300 | 13,996 | 441,554 |
| Mo. . . | 362,344 | 235,489 | 57,023 | 398,010 | | 8,285 | 18,189 | 1,079,343 |
| Mon. . . | 3,000 | 2,093 | | 19,000 | | 117,000 | | 141,093 |
| Neb. . . | 39,556 | 31,442 | 10,488 | 590 | 7,088 | 13,125 | 5,016 | 107,305 |
| N. J. . . | 6,955 | 1,299 | 1,000 | 105,902 | 286 | 54,564 | | 170,006 |
| N. Y. . . | 244,738 | 484,902 | 21,668 | 676,324 | 40,838 | 71,408 | 190,284 | 1,730,162 |
| Ohio. . . | 217,399 | 466,819 | 47,530 | 661,869 | 14,939 | 422,407 | 138,424 | 1,969,387 |
| Okla. . . | 2,672 | 22,914 | | | | | | 25,586 |
| Ore. . . | | | | 10,525 | 375 | | | 10,900 |
| Penn. . . | 128,997 | 684,933 | 660 | 910,903 | 21,799 | 1,949,859 | 103,117 | 3,800,318 |
| R. I. . . | | | | 16,715 | | 113 | | 16,828 |
| S. Car ¹ . . | | 500 | | 36,320 | | 1,595 | | 38,415 |
| S. Dak . . | 300 | | | 14,380 | | 33,082 | | 47,762 |
| Tenn. . . | 22,800 | 26,490 | 396 | 128,035 | 120 | 60,564 | 100 | 238,505 |
| Texas. . . | 15,681 | 9,821 | 250 | 79,659 | | 18,942 | 375 | 124,728 |
| Utah. . . | 11,979 | | | 770 | | | | 12,749 |
| Vt. . . | 193 | 32 | | 187,075 | | | 800 | 188,100 |
| Va. . . | 5,070 | 8,721 | | 151,687 | | 237,840 | | 403,318 |
| Wash. . . | | 240 | | 239,022 | | 6,643 | 3,258 | 249,163 |
| W. Va. . . | 9,391 | 40 | | 36,677 | 5,851 | 1,742 | | 53,701 |
| Wis. . . | 177,386 | 231,356 | 110,263 | 445,193 | 3,630 | 15,861 | 5,996 | 989,685 |
| Wy. . . | 425 | | | 2,640 | | | | 3,065 |
| Totals | 4,330,706 | 3,953,469 | 582,488 | 6,797,496 | 172,566 | 3,687,394 | 829,900 | 20,354,019 |

¹ Includes North Carolina.

can be got out is 20 inches in thickness. The United States Post-office at Joplin, Mo., was built of this stone, which gave very good satisfaction. The stone is very dense, heavy, and does not absorb moisture. At Lockport, N. Y., is quarried a gray limestone which is used much in the east for trimmings. Ohio, New York, Pennsylvania, Illinois, Minnesota, and Wisconsin also produce much limestone for building purposes.

All limestones should be set with non-staining mortar made of non-staining cement, as other cements will generally stain right through the stone or stain dark around the joint.

In some limestones are found pieces of flint, and when these are of any size and appear on an exposed surface of the stone, the stone should be rejected. The other defects of limestone are about the same as those found in sandstones and require the same inspection.

The table on page 38 shows the value of the limestone production in 1900 by States and uses.

The following table gives the crushing strength per square inch and the weight per cubic foot of limestones from various parts of the country.

| State. | Location. | Strength per Sq. Inch. | Weight per Cu. Foot. | State. | Location. | Strength per Sq. Inch. | Weight per Cu. Foot. |
|----------|---------------------|------------------------|----------------------|-----------|--------------------|------------------------|----------------------|
| Ark. . . | Johnston. | 15,500 | 165 | Mich. | Lime Island. . . . | 18,000 | 185 |
| Ill. . . | Kankakee. | 13,544 | 160 | Mo. . . | Carthage (white) | 14,950 | 141 |
| " . . . | Joliet (white) . . | 14,775 | 160 | " . . . | Cooper Co. (dark | 6,650 | 168 |
| " . . . | Quincy. | 9,687 | 154 | " . . . | drab). | 6,650 | 171 |
| " . . . | Grafton. | 17,000 | 156 | N. Y. | Glens Falls. . . . | 11,475 | 169 |
| Ind. . . | Bedford. | 6,000 | 156 | " . . . | Lake Champlain | 25,000 | 168 |
| " . . . | Bloomington. . . | 4,100 | 156 | " . . . | North River. . . . | 11,475 | 168 |
| " . . . | Salem. | 9,000 | 156 | " . . . | Canajoharie. . . . | 20,700 | 165 |
| " . . . | Stinsville | 5,600 | 136 | " . . . | Erie Co. (blue). . | 12,250 | 168 |
| Iowa. . | La Grande. | 10,825 | 168 | " . . . | Kingston | 13,900 | 165 |
| " . . . | Stone City. . . . | 11,250 | 168 | " . . . | Garrison | 18,500 | 150 |
| Kan. . . | Marion. | 12,364 | 168 | Ohio. | Marble'h'd (w'e). | 12,600 | 174 |
| Ky. . . | Warren Co. | 6,795 | 160 | Wis. . . | Sturgeon Bay | | |
| " . . . | Bardst'n (da'k). . | 16,250 | 160 | " . . . | (blue). | 21,500 | 160 |
| Minn. . | Winona. | 16,250 | 172 | " . . . | Waukesha | 8,880 | 160 |
| " . . . | Stillwater. | 15,000 | 162 | Pa. . . . | Avondale (gray) | 18,000 | 160 |
| " . . . | Redwing. | 23,000 | 162 | " | " (light) | 12,112 | 160 |
| | | | | " | Conshohocken. . . | 15,000 | 160 |

The following table gives the chemical analysis of the limestone from some of the various quarries.

CHEMICAL ANALYSIS OF VARIOUS LIMESTONES.

| State. | Location. | Quarry. | Carbonate of Calcium. | Carbonate of Magnesia. | Ox. Iron & Alumina. | Silica. | Oxide of Calcium. |
|-------------|-------------------------|-------------------------------|-----------------------|------------------------|---------------------|---------|-------------------|
| Ill. . . . | Quincy. | F. W. Menke Stone Co. . | 92.77 | 6.75 | .27 | 15.90 | ..... |
| " | Lemont. . . . . | ..... | 45.80 | ..... | 9.30 | 15.90 | ..... |
| " | Joliet. . . . . | ..... | ..... | ..... | ..... | ..... | ..... |
| Ind. . . . | Bedford | Bedford Quar. Co. | 98.20 | .39 | .39 | .63 | ..... |
| " . . . . | ..... | ..... (blue) | 97.26 | .37 | .49 | 1.69 | ..... |
| " | Spencer. . . . . | ..... | 96.80 | .11 | .91 | .70 | ..... |
| " | Clear Creek. | Acme Stone Co. | 97.37 | .78 | .13 | .84 | .10 |
| " | Peru. | J. N. Hurtz | 52.90 | 38.94 | 1.25 | 4.05 | ..... |
| Iowa. . . . | Monmouth. | L. B. Stewart Co. | 57.54 | 41.51 | ..... | .42 | ..... |
| Kan. . . . | Marion. | I. Kuhn & Co. | 91.50 | 1.62 | 1.24 | 5.51 | ..... |
| Ky. . . . | Warren Co. | Caden Stone Co. | 54.80 | ..... | .22 | .76 | ..... |
| " | Bowling Green . . . . . | ..... | 95.31 | 1.12 | .39 | 1.42 | ..... |
| Mich. . . . | Trenton | Sibly Quarry Co | 98.53 | .53 | .06 | .60 | ..... |
| Minn. . . . | Kasota. . . . . | ..... | 49.16 | 37.53 | 1.09 | 13.06 | ..... |
| " | Stillwater. . . . . | ..... | 50.22 | 37.39 | .78 | 8.74 | ..... |
| " | Frontenac. . . . . | ..... | 54.78 | 42.53 | .67 | 2.73 | ..... |
| Mo. . . . | Carthage. | Myers Stone Co | 98.57 | .65 | .21 | .69 | ..... |
| N. Y. . . . | Cobleskill | Cobleskill Quarry Co. | 41.90 | 1.65 | .97 | 4.31 | 51.05 |
| " | Amsterdam. . . . . | ..... | 42.64 | ..... | 1.08 | 3.82 | 52.46 |
| Ohio. . . . | Cold Springs. | Casparis Stone Co | 54.05 | 44.94 | .23 | .49 | ..... |
| " | Tiffin. . . . . | ..... | ..... | 40.36 | .10 | 1.61 | 57.44 |
| " | Dayton. . . . . | ..... | 92.40 | 1.10 | .58 | 1.70 | ..... |
| " | Springfield. . . . . | ..... | 54.70 | 44.93 | .20 | .10 | ..... |
| Pa. . . . | Youngstown. | Carbon Limestone Co. | 96.43 | .40 | 1.60 | 1.50 | ..... |
| " | Norristown. | Wm. Rambo. | 53.49 | 45.76 | ..... | .70 | ..... |
| R. I. . . . | Lime Rock. | Herbert Harris | 88.23 | 8.79 | .32 | 2.74 | ..... |
| W. Va . . . | Marlow. | G. C. Ditto. . . . . | ..... | .98 | .26 | .18 | 98.44 |
| Wis. . . . | Hamilton. | Hamilton Stone Co. | 54.25 | 44.48 | .10 | .67 | ..... |

Marble.—Marble, which is a crystallized limestone, or a pure form of carbonate of lime, is an earlier formation of limestone which was formed with a pressure, and which retained the carbonic acid. Marble is the name usually given to any limestone which will take a good polish. The marble quarries of the U. S. are fast being developed, and are now furnishing the larger part of the marble used in this country. The table on page 41 will show the value and purposes for which produced, of the various marble-producing States for the year 1901.

The most used marbles of this country are the white, blue-grays, and greenish grays of Vermont, used mainly for interior and monumental work; the red or chocolate and white-mottled dolomitic varieties ("Winooski" marble), which come from Mallet's Bay, Vt. A white granular dolomitic marble from Lee, Mass., is used for building purposes. The United States Capitol at Washington is built of this marble. A coarse "snowflake" marble comes from Westchester County, N. Y., and is

PRODUCTION AND USE OF MARBLE QUARRIED IN THE U. S.
DURING 1901.

| State. | Rough | Build- ing. | Orna- m'tal. | Ceme- tery. | Inter- ior. | Other. | Total. |
|--------------------|---------|----------------|-----------------|----------------|----------------|----------|-----------|
| Alaska..... | \$1,500 | ..... | ..... | ..... | ..... | ..... | \$4,500 |
| Arizona..... | 300 | ..... | ..... | ..... | ..... | ..... | 300 |
| Arkansas..... | 200 | ..... | \$100 | ..... | ..... | ..... | 300 |
| California..... | 3,280 | \$1,550 | 1,812 | ..... | ..... | ..... | 6,642 |
| Georgia..... | 268,761 | 241,683 | 16,500 | \$207,305 | \$166,305 | \$36,000 | 936,549 |
| Maryland..... | 8,100 | 45,000 | ..... | 15,000 | ..... | ..... | 68,100 |
| Massachusetts..... | 63,556 | 26,220 | 3,700 | 9,560 | 15,051 | 8,459 | 126,546 |
| Missouri..... | ..... | ..... | ..... | 2,100 | ..... | ..... | 2,100 |
| Montana..... | ..... | ..... | ..... | 1,500 | ..... | ..... | 1,500 |
| New Mexico..... | 4,200 | 3,000 | 300 | 3,100 | ..... | ..... | 10,600 |
| New York..... | 2,367 | 132,943 | 4,900 | 204,289 | 28,000 | 6,660 | 379,159 |
| Oregon..... | ..... | ..... | ..... | 500 | ..... | ..... | 500 |
| Pennsylvania..... | 18,078 | 111,069 | ..... | 25,060 | 400 | 2,940 | 157,547 |
| Tennessee..... | 162,513 | 13,000 | ..... | 14,000 | 305,124 | ..... | 494,637 |
| Utah..... | 320 | ..... | ..... | ..... | ..... | ..... | 320 |
| Vermont..... | 53,892 | 659,200 | 94,450 | 1,452,434 | 493,607 | ..... | 2,753,583 |
| Washington..... | 1,600 | 2,358 | 4,814 | 14,044 | ..... | ..... | 22,816 |
| Totals..... | 591,667 | 1,236,023 | 126,576 | 1,948,892 | 1,008,482 | 54,059 | 4,965,699 |

much used for building. Pink, gray, and chocolate-brown and white-mottled varieties are found in Tennessee, and are used much for interior work. A coarse white and white-clouded marble comes from Georgia, which is used much for building and inside work. A black marble is quarried at Glens Falls, N. Y.

Georgia Marble.—The Georgia marble known as “Kennesaw” is a white marble whose separate crystals are nearly transparent.

The “Etowah” marble is formed of very small crystals, but in other respects has quite a similar structure to the “Kennesaw” marble. Every crystal in it, however, instead of being white is tinted a faint shade of amethyst, making a tinted marble.

The “Creole” is a banded or gray marble.

The following table gives the composition, strength, and weight of some of the various marbles.

Onyx.—Onyx is the name given to a stone of the same composition as marble, but which was formed by chemical deposits.

The name is given on account of the resemblance to the true onyx, which is a variety of agate. This stone is found in Mexico, Arizona, and California, and is of various shades and colors. It is used entirely for ornamental purposes.

Testing Stone.—When a stone comes from a well-known quarry, and the stone is known by its past use to be what is

CHEMICAL COMPOSITION, WEIGHT, AND CRUSHING STRENGTH
OF VARIOUS MARBLES.

| State. | Location. | Car- bonate of Lime. | Iron. | Car- bonate of Mag- nesia. | Insol- uble. | W'ght per Square Foot. | Crush- ing Str'ng'h per Square Inch. |
|---------------|----------------------------|-------------------------------|-------|--|-----------------|---------------------------------|---|
| Cal. . . . | Inyo. | 78.36 | .017 | 21.79 | 2.6 | ..... | 29,000 |
| " | Colton. | 92.9 | ..... | 4.5 | 2.6 | ..... | 9,350 |
| " | Beulah. | 98.00 | .04 | .05 | .06 | ..... | ..... |
| Ga. | Cherokee. | 98.96 | ..... | .13 | .61 | 171 | 10,970 |
| " | Creole. | 98. | ..... | .26 | .50 | 172 | 12,078 |
| " | Etowah. | 97.32 | .26 | 1.60 | .62 | 169 | 10,642 |
| Ill. | Mill Creek. . . . . | ..... | ..... | ..... | ..... | 172 | 9,687 |
| Md. | Cockysville. . . . . | ..... | ..... | ..... | ..... | 178 | 23,500 |
| Mass. | Lee. | 69.64 | ..... | 27.98 | 1.00 | ..... | 18,047 |
| " | Westfield. | 79.68 | ..... | 19.68 | .20 | ..... | 21,820 |
| " | Great Barrington. | 98.34 | .14 | .50 | .38 | ..... | 10,910 |
| " | Hastings. | 52.82 | ..... | 45.78 | ..... | ..... | 18,941 |
| N. Y. | South Dover | 77.29 | ..... | 20.25 | .90 | ..... | 18,836 |
| " | East Chester . . . . . | ..... | ..... | ..... | ..... | 179 | 13,500 |
| " | Pleasantville. | 54.12 | ..... | 45.04 | .10 | ..... | 12,692 |
| " | Sing Sing. | 53.24 | ..... | 45.89 | ..... | ..... | ..... |
| Pa. | Annville. | 95.10 | .23 | 3.96 | 1.07 | ..... | 12,210 |
| " | Montgomery (blue). | 98.15 | .54 | .50 | .77 | 180 | 18,000 |
| Tenn. | East Tennessee. | 98.78 | .26 | .67 | .08 | ..... | 15,750 |
| Vt. | Proctor. | 98.37 | .03 | .77 | .63 | ..... | ..... |
| " | Rutland (white). | 97.73 | .59 | ..... | 1.68 | 166 | 10,746 |
| " | Rutland (green) | 85.45 | 14.55 | ..... | ..... | ..... | ..... |
| " | Dorset. . . . . | ..... | ..... | ..... | ..... | 165 | 7,612 |
| Va. | Montgomery . . . . . | ..... | ..... | ..... | ..... | ..... | 8,950 |
| Wis. | North Bay. . . . . | ..... | ..... | ..... | ..... | 175 | 20,025 |

desired, there is no need of a test, but if it is from a new quarry, or is a stone that has not been tested, by use, it should be tested thoroughly before being used in any extensive work. This can be done by analysis, to find its composition, but some of the more simple tests are given below which will be of much benefit to the superintendent. As a rule the most dense and compact stones will prove the best for building purposes and to withstand the effects of the weather. If the stone absorbs much moisture, then it will be subject to the effect of frost or freezing. To ascertain the absorption powers of a stone, take cube specimens of the stone which have been thoroughly dried and weighed; immerse them in clear water for three or four days, then take them out, wipe them dry, and re-weigh them. The increased weight indicates the amount of water absorbed.

EFFECT OF FREEZING.—Take cube specimens of the stone, dry and weigh them, and then repeatedly saturate them with water and freeze them. The loss in weight will indicate the loss of stone by integration. A test can be made by immersing

RATIO OF ABSORPTION.

| Kind of Material. | Maximum. | Minimum. | Average. | Kind of Material. | Maximum. | Minimum. | Average. |
|-------------------|-----------------|-----------------|-----------------|-------------------|----------------|-----------------|----------------|
| Granites. | $\frac{1}{150}$ | 0 | $\frac{1}{750}$ | Sandstones. . . | $\frac{1}{15}$ | $\frac{1}{240}$ | $\frac{1}{24}$ |
| Marbles. | $\frac{1}{150}$ | 0 | $\frac{1}{800}$ | Bricks. | $\frac{1}{4}$ | $\frac{1}{50}$ | $\frac{1}{10}$ |
| Limestones. . . | $\frac{1}{20}$ | $\frac{1}{500}$ | $\frac{1}{88}$ | Mortars. | $\frac{1}{2}$ | $\frac{1}{10}$ | $\frac{1}{4}$ |

the stone in a concentrated boiling solution of sulphate of soda, and hanging them up in the air for a few days. The salt crystallizes in the pores of the stone and acts about the same as frost or freezing. The stone is to be weighed before immersing and after drying, and the difference indicates the amount lost by integration.

To see if a stone will withstand the atmosphere and gases of cities, soak a sample several days in a solution of water containing 1 per cent of sulphuric and hydrochloric acids. If there is any composition in the stone that will be dissolved by the atmosphere the water will become discolored.

To see if a stone contains clay, or earthy matter, pulverize a piece, put the powder in a bowl of clear water, and shake well; if the water becomes discolored it indicates the presence of clay or earthy matter in the stone.

A fresh fracture of a stone should show bright and clean. A dull-looking fracture indicates a "dry" or a stone that is liable to decay. The superintendent should notice all stone when being worked, and by the sound can usually tell if the stone is sound; if there is a clear ring when the stone is struck it is sound, but a dull sound indicates cracks or seams. In some stone are found "crowfeet," which are veins running through parallel to its bed, but which are not cemented tight, being filled with a sort of earthy material, the stone being held together by the "dove-tail" nature of the seam. This is the main fault found with the limestone quarried at Carthage, Mo.

The superintendent should examine all stone before being set and reject any that contains seams or cracks. Where stone is quarried by blasting, the superintendent must be on the lookout for "powder" cracks, or shakes, as they do not show up very distinctly at first, and are hard to find.

The following regarding testing of stone is taken from the annual report of the United States Geological Survey for 1898-99.

Tests and Analyses of Stone.—In the selection of all kinds of material for structural use it is becoming more and more customary to test such material, and to make the final selection on the basis of results so secured. It is, of course, unnecessary to state that if a given material has already demonstrated its fitness for a certain use by years of experience with it in that capacity, no results of scientific test should be considered as in any way capable of offsetting these results of actual experience; but in a country as young as the United States enough time has not yet elapsed in the use of stone as a building material to afford, in more than a few cases, a sufficient amount of such knowledge as results from long-continued use. As an example of a stone already sufficiently well known not to require further special tests, Quincy granite may be cited. This stone, by its hardness and susceptibility to high polish, and the contrast offered between polished and hammered surface, has demonstrated its fitness for use as a monumental stone. Similar statements might be made in regard to Westerly granite and other long-quarried and well-known materials.

When, however, a new material comes up for consideration it is desirable to learn of its qualities by quicker processes than those which depend upon actual use. There have, therefore, been devised a number of methods of testing stone which may be quickly carried out and which are of various degrees of value, according to the nature of the stone tested and the use to which it is to be put. The practice of making these tests of stone is of such comparatively recent date that it can hardly be said that the particular tests are so well understood as to be beyond criticism either in regard to the nature of the test itself or in the method of carrying it out. There is, moreover, a great lack of agreement among testing experts, both as to what tests should be applied to a given stone and as to details in the methods of applying these tests. In some cases physical tests seem to be all that are necessary to furnish the needful information without any chemical analysis whatever. In other cases it is quite generally conceded that physical tests should be supplemented by more or less complete chemical analyses. At the present time the uses to which stone is put are quite different from those involving it as a structural material. Thus, limestone is used in enormous quantities for burning into lime and as a flux in metallurgical operations. Limestone for such uses may be taken from the same quarry that furnishes building

stone, and is thus quarried by the same methods as apply to the production of the building stone. It cannot therefore well be considered apart from that which is devoted to structural use. If limestone is to be burned into lime, it is of course evident that the physical strength of the stone so used is of no moment whatever, but a knowledge of the chemical composition is absolutely essential. The same idea applies to limestone to be used as a blast-furnace flux.

Again, although a stone to be used for structural purposes may show great physical strength, it may, nevertheless, contain minerals which, by decomposition from atmospheric agencies, may develop in the entire mass weaknesses that would in course of time make the use of the stone undesirable. To detect the presence of such minerals chemical analysis may be resorted to in some cases, or, better still, this, together with a microscopical examination of thin sections, by which it is possible to detect minerals as such, even though the amount present may be extremely minute. The application of microscopical examination as a means of studying stone in relation to its technical applications is of recent date and as yet is used only to a limited extent.

Among the tests most commonly applied to stone which is to be used for structural purposes is the crushing-strength test. This gives in general a good idea not only of the power of the stone to support without fracture the superstructure that may rest upon it, but also of the homogeneity and all-round durability of the material. Other tests of value include transverse strength, porosity, corrodibility, specific gravity, and resiliency.

PART II.

STONE LAYING, SETTING, AND CUTTING, MARBLE AND SLATE WORK, BRICK- WORK AND BRICKLAYING, PAVING, ETC.

Stone Laying, Setting, and Cutting.—**RUBBLE-
WORK.**—This is the cheapest and most common of stonework, but
is only used for foundation-, or cellar-walls, retaining-walls, and
such like; stone suitable for this work can be obtained in almost
any locality. Fig. 28 shows a piece of random rubblework
in which there is no attempt made to lay the stone in courses.

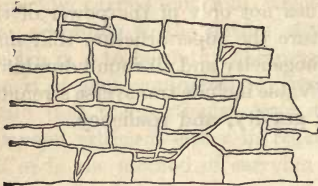


FIG. 28.—Random or Broken
Rubble.

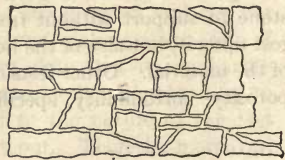


FIG. 29.—Rubblework Laid in
Courses.

Fig. 29 shows a style of random rubble laid in courses
from 16 inches to 30 inches in height. This is a good way
to have a mason build any rubble wall where much weight is
to rest on it, as he will have to level up at the top of each
course, and start anew, and in this way he will build the wall
more solid, and get more headers or bond-stones; also at each
course he is sure to get level beds.

Fig. 30 shows a rubble wall laid in courses, with a bonding
course AA between each course of wall; this makes a very

strong wall, as the bond course extends through the wall and ties it together.

Fig. 31 shows random-range work laid in level and broken courses. This is an improvement on the ordinary rubble wall;



FIG. 30.—Broken Rubble, with Bond Courses AA Extending through the Wall, Makes a Very Strong Wall.



FIG. 31.—Random Range Laid in Level and Broken Courses.

in this the stones are dressed nearly square and with level beds, and do not require spalls for filling out the joints, as in ordinary rubble.

Fig. 32 shows the same work, but laid in courses, as in coursed rubble.

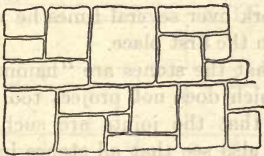


FIG. 32.—Coursed Random Ranged.

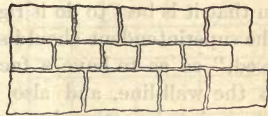


FIG. 33.—Block Coursed.

Fig. 33 shows block-coursed work, which makes the strongest of stone walls, as all the stones must be dressed to a given thickness and with level beds.

Fig. 34 shows a wall built of stone dressed in irregular form, with close joints, giving the wall a sort of rustic appearance; this is used only in dwellings or places where something "odd" or unusual is desired; it is expensive and requires great care in working, so that the joints will all have different directions, and not more than three to five centre at one place. The stone should all be about the same area on the face, and dressed so that all joints will be the same size. This is

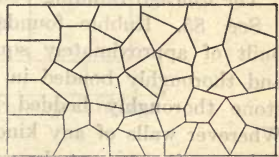


FIG. 34.—Stone of Irregular Form and Dressed to Make Joints.

one of the hardest designs of stonework to build, and will require the strict attention of the superintendent to get a satisfactory job.

Rubblework is often specified as "one-man" or "two-man" rubble, according to the size of the stone desired to be used and the number of men required to handle them.

In all rubble- or range-work the superintendent should see that a through stone or header is used to every six superficial square feet of wall, or one-fourth the face of the wall, consisting of bond-stone extending two-thirds of the distance through the wall from opposite sides and overlapping each other. The superintendent should watch the masons to see that each stone is bedded in a full bed of mortar, and that all cavities and spaces are filled solid. The way a mason usually fills up these holes is to gather up the spalls and dirt at his feet, throw this in the hole, and spread a little mortar on top. The only way to prevent this will be for the superintendent to pay close attention to the work, and as soon as he catches a mason at this have him take down that part of the wall and build it over again. When the mason has to do his work over several times he will learn that it is best to do it right in the first place.

The superintendent should see that the stones are "hammer-dressed," so as to have a face which does not project too far from the wall-line, and also see that the joints are such as can be pointed neatly; he should also see that all stones have a flat top and bottom bed, and that no round boulders or "nigger heads" are built in the wall. In building rubble the mason often tries to set the stone on edge, and fill in between with spalls, as he can build faster in this way than if he took the time to lay every stone on its flat. This way of building should never be permitted, as it makes a very poor wall.

The Chicago Building Code says:

Sec. 85. Rubble foundations and rubble walls must be built of approximately square and flat bedded stones, well and thoroughly bonded in both directions of the walls, each stone thoroughly bedded in mortar under its entire area. Wherever walls of any kind are used as curb walls, their exterior surfaces must be rendered approximately water-tight by a coating of a standard cement mortar.

Cut-stone Work.—ASHLAR.—The facing of a wall in stone, without any regard to the design or style of cutting, is

called ashlar. The following cuts show the most common methods of laying the stone.

Fig. 35 is regular coursed ashlar, in which the stones are all the same height. In all coursed ashlar-work the specifications should mention if the joints are to be carried plumb or not,

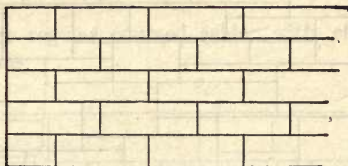
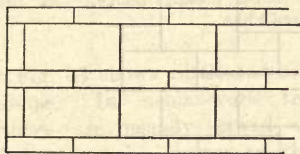


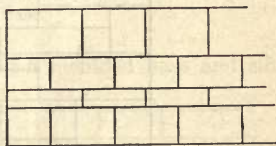
FIG. 35.—Regular Coursed Ashlar.

for, if it is not specified, there is a chance for argument on the part of the contractor. He may insist on the vertical joints being placed at random, as it is much cheaper, but does not make as nice a looking wall as when the joints are kept plumb.



Coursed Ashlar, two sizes

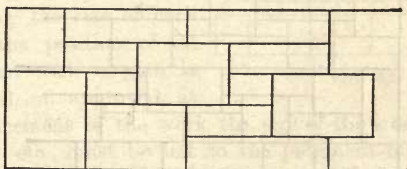
FIG. 36.



Irregular coursed ashlar

FIG. 37.

Fig. 36 shows coursed ashlar of two sizes. This is one of the cheapest methods of ashlar, as the large courses are usually but



Level and Broken Ashlar. Three sizes of stones.

FIG. 38.

4 inches in thickness and the small courses 8 inches, so as to get 4 inches bond in the wall.

Fig. 37 shows ashlar of irregular courses.

Fig. 38 shows level and broken courses. In this style of ashlar, care should be taken to keep the horizontal joints as short as possible; they should not be more than 3 or 4 feet in length.

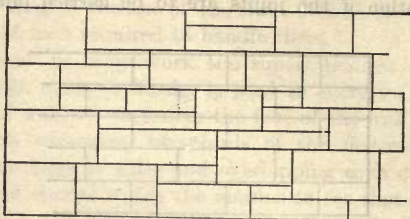


FIG. 39.—Random Ashlar.

Fig. 39 shows random ashlar, in which the plumb joints are set at random.

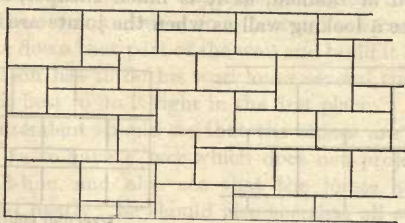


FIG. 40.—Random Ashlar, Plumb Joints.

Fig. 40 shows the same work improved by keeping the vertical joints plumb.

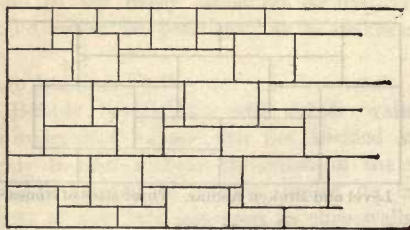


FIG. 41.—Random Ashlar in Courses.

Fig. 41 shows the ashlar divided into courses, 16 or 20 inches in height. To get a nice appearing wall in all random ashlar-

work, the superintendent must see that the different sizes of the stone are scattered through the wall as much as possible, and not have a lot of small-size stones or a lot of large ones built in at one place and adjoining each other. In all ashlar there should be a bond-stone to every 6 square feet of face of wall, or in coursed work every alternate course should be a bond course.

Fig. 42 shows regular coursed ashlar with chamfered and rusticated quoins.

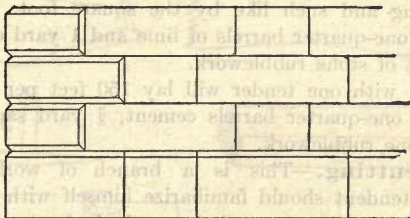


FIG. 42.—Regular Coursed Ashlar, with Chamfered and Rusticated Quoins and Chamfered Base.

Fig. 43 shows rusticated ashlar with moulded base and sill course. In ashlar-work the stones are usually sawed or dressed at the quarry to the different heights or thicknesses, leaving them to be cut to length at the job. Where the ashlar is in courses, it is customary in large work to have a working plan showing the size of each stone and the position of all joints. When such a plan is not provided or approved at the commencement of the work the size of the stone, location of the joints, etc., must be left to the judgment of the superintendent.

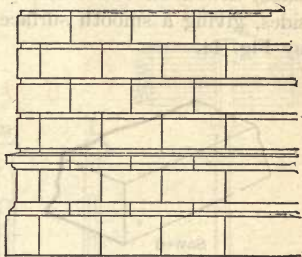


FIG. 43.

MEASUREMENT OF STONEWORK.—Rubble stonework is usually done by the perch, which is $24\frac{3}{4}$ cubic feet, or, as is more convenient, 25 feet; however, in some localities custom has made it a rule to call any number of feet from 16 to 25 a perch, according to the custom of the locality; so it is best when work

is done by the perch to have an understanding at the commencement how many feet are to be considered a perch. It is also well to have an understanding as to what openings are to be counted as solid or what are to be left out in measuring the wall.

In measuring stonework always measure from the outside, thus measuring all the angles twice.

All walls under 18 inches are counted same as 18 inches.

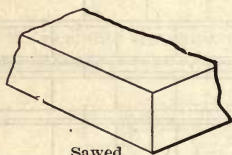
Ashlar and dimension or block stone are usually measured by the cubic foot; mouldings, belt courses, etc., by the lineal foot; flagging and such like by the square foot.

One and one-quarter barrels of lime and 1 yard of sand will lay 100 feet of stone rubblework.

One man with one tender will lay 150 feet per day.

One and one-quarter barrels cement, $\frac{3}{4}$ yard sand, will lay 100 feet stone rubblework.

Stone-cutting.—This is a branch of work in which the superintendent should familiarize himself with the various tools used by the cutters, and the method of using them, so to more readily determine between good and bad work, and also to know what tools should be used to produce the result desired. The stone when cut at the job will usually come in slabs, sawed on two sides, or perhaps in lengths, sawed four sides, giving a smooth surface to the beds and face, as shown by Fig. 44.



Sawed

FIG. 44.

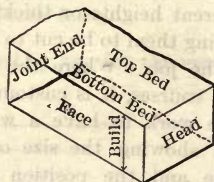


FIG. 45.

Fig. 45 shows the names of the different faces of the stone. Fig. 46 shows the various tools used by masons and cutters in dressing stone. *B* is the mason's or spalling hammer and is used to roughly square or dress a stone for rubblework. *C* is the mash-hammer used by cutters when using the point in roughing off and in working the harder rocks such as granite. *D* is the peen-hammer, which is used to smooth off the surface of a stone after using the point; it is sometimes used on

granite in place of patent hammer, but does not give as desirable a finish. *E* is the pick, which is used for dressing off stone for rough work, such as rubble or block course work

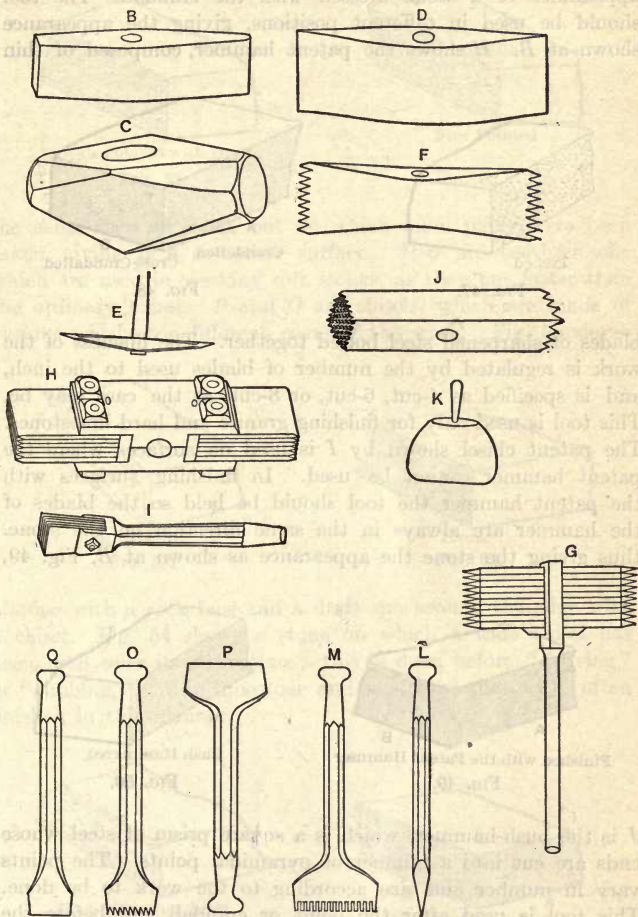


FIG. 46.

(Fig. 47). *F* shows the tooth-axe, which is used to bring the rough surface of soft stones to the desired plane, ready for the crandall, or tool; it is used also for dressing the beds of

stones. *G* is the crandall, which has a series of points fastened in a handle with a key; this is used on sandstones after the tooth-axe, and gives a smoother surface. Fig. 48 shows the appearance of a stone dressed with the crandall. The tool should be used in different positions, giving the appearance shown at *B*. *H* shows the patent hammer, composed of thin

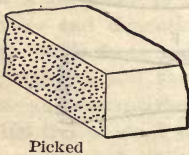


FIG. 47.

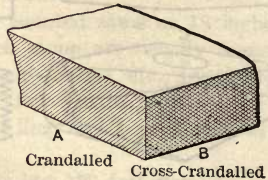
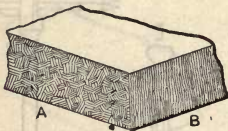


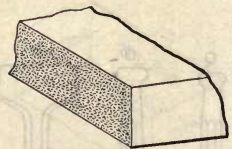
FIG. 48.

blades of sharpened steel bolted together. The fineness of the work is regulated by the number of blades used to the inch, and is specified as 4-cut, 6-cut, or 8-cut, as the case may be. This tool is used only for finishing granite and hard limestones. The patent chisel shown by *I* is used on surfaces where the patent hammer cannot be used. In finishing surfaces with the patent hammer the tool should be held so the blades of the hammer are always in the same direction on the stone, thus giving the stone the appearance as shown at *B*, Fig. 49,



Finished with the Patent Hammer

FIG. 49.

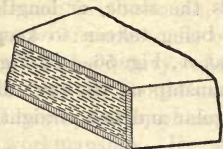


Bush Hammered

FIG. 50.

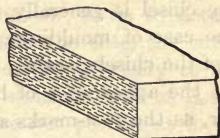
J is the bush-hammer, which is a square prism of steel whose ends are cut into a number of pyramidal points. The points vary in number and size according to the work to be done. This tool is used after the point or crandall and before the chisel in "drove" or "tooled" work. Fig. 50 shows the appearance of a stone after being bush-hammered. *K* is the mallet, which is used on the point or chisel when working limestone, sandstone, or any other soft stone. *L* is the point, which is

used to roughly dress off a stone, and is also sometimes used to dress the face of a stone as shown by Fig. 51. Fig. 52 shows



Rough Pointed with Draft

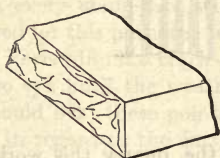
FIG. 51.



Fine Pointed

FIG. 52.

the same style of finish but on which more pains have been taken, giving it a smoother surface. *M-O* are tooth-chisels, which are used in working soft stones, as they cut faster than the ordinary chisel. *P* and *Q* are chisels, which are made of various widths for different parts of the work. Fig. 55 shows



Rock Face

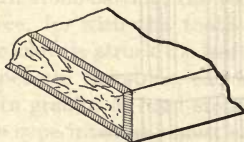
FIG. 53.



Tooled

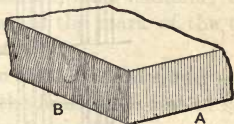
FIG. 54.

a stone with a rock face and a draft run around the edge with a chisel. Fig. 54 shows a stone on which a wide chisel has been used over its entire face; this is done before "droving" or "rubbing," and in limestone and sandstone the face is often finished in this manner.



Rock Face with Draft

FIG. 55.



Drove Work

FIG. 56.

Fig. 56 shows what is called "drove" work and is done with a wide chisel after the stone has been tooled and the char-

acter or fineness of the work regulated by the number of "bats," or blows, given the chisel to each inch in the length of the stone, usually 4.

The chisel is generally used across the stone, or lengthwise in the case of mouldings, etc., care being taken to keep the cuts of the chisel parallel, as shown at *A*, Fig. 56. *B*, Fig. 56, shows the appearance of bad workmanship on the part of the cutter, as the tool-marks are all irregular and not straight and parallel.

Fig. 57 shows a piece of drove-work, showing the cuts of the

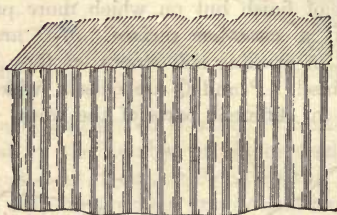


FIG. 57.

tool. Where the cutting is done at the quarry this work is usually done on a machine, and is always regular, but when done by hand requires great care.

Parallel lines should be marked out on the stone, as a guide to hold the chisel; one line to each two "bats" is sufficient. A template made of sheet iron or zinc is shown in Fig. 58,

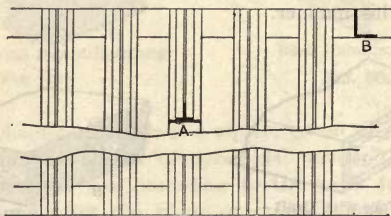


FIG. 58.

and is a very convenient tool for marking the stone for this kind of work. It is made, as shown, of a series of bars, *A*, sol-

dered or riveted to an angle, *B*, and is laid on the stone like a square and the lines marked off.

Where possible to do so, the superintendent should examine the stone in the rough, before being cut, so as to detect any flaws or imperfections, but, as is often the case, the cutting is done at the quarry, and the stone shipped ready to set; in such cases he should examine the stone as soon as it arrives, and promptly reject any which are not perfect as to quality or workmanship. He should see that the stones are being cut to the desired shape and size, and all mouldings and projections are cut as per detail.

In cutting mouldings, the cutter will very often change the shape or contour of the mould a little so as to make it easier to cut, and the superintendent must be on the lookout for anything of this kind. He should examine the stone for cracks or "drys" which may have been cemented up by the cutter, or patches cemented on where a corner has been knocked off. In every stone-yard will be found a bottle of shellac which is used for this purpose; in some of the white stones a little plaster of Paris will fill a crack or hole so that it is hardly discernible to the eye until the weather eats it out, and the superintendent should bear these points in mind when inspecting stone.

In regard to the cutting he should see that the finished face of the stone does not show marks from the tools used in roughing out the stone previous to finishing, for if the stone is not gradually brought to the desired finish by using the proper tools in succession, the marks of the rough tools will show through the finished face. In tooled work, if it is tooled without using the bush-hammer, the marks of the point, tooth-axe, or crandall will show, and in droved work, if it is not tooled before being drove, the marks of the bush-hammer will show.

In stone-cutting, the tools all should be used with moderate force, for with the tooth-axe, crandall, bush-hammer, etc., if the blow is struck too heavy, it causes the mark of the tool to penetrate the stone, causing a "sting."

In granite or hard stones, where the patent hammer is used, the superintendent must see that the finish is as fine or smooth as is desired. Often coarse work done with a coarse patent hammer, or with a peen-hammer, is sent to the job in place of fine patent-hammer work, and the superintendent should be able to readily judge between the two. He should examine all stones and see that the beds are cut at right angles to the

face; the tendency of the cutter is to cut the beds slack on the back, sometimes half an inch or more. This should not be allowed for the mortar-joint will then be one-fourth of an inch at the face and an inch and a quarter at the back of the stone, and will make a poor wall, for there will be more shrinkage in one and a quarter than in one-quarter inch of mortar.

The workmanship on all stone should be uniform, but at times the contractor will employ a poor workman, so the superintendent must see that all stones have a uniform appearance, and reject any not found perfect.

The superintendent should see that all stones, where required, are cut with the proper wash, and where necessary have a drip cut to throw off the water. In Fig. 59 at A, by undercutting, as shown, the arris will form a drip so all water will drop off at this point; if this is not done, the water will course down over the face of the stone to B before dropping off, and will always keep the stone covered with dirt and stain.

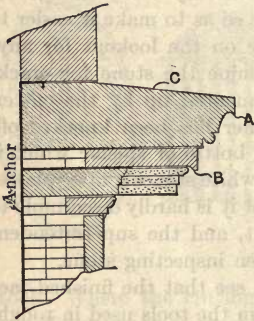


FIG. 59.

The wash on top of the stone, as shown at C, Fig. 59, while it need not be rubbed, as is the case with washes where exposed to view, it should be cut comparatively smooth, so that the dirt will not accumulate to be washed off with the rain, and if a wind is blowing, blow it against the face of the wall.

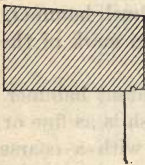


FIG. 60.

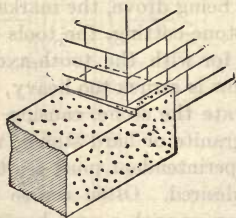


FIG. 61.

Figs. 60 and 61 show how the wash and drip should be cut on window-sills.

In ordinary work the wash is run the full length of the stone, as the work can then all be done with the saw, but on good work it should stop at the jamb as shown, having the top of the stone level, thus giving a level seat for the brickwork, which is not obtained when the wash runs the full length of the sill.

Figs. 62 and 63 show how the wash should be cut on a sill

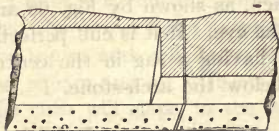


FIG. 62.

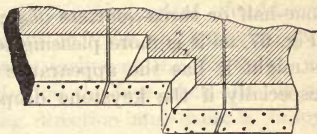


FIG. 63.

or belt course where the projections vary. These washes, where exposed to view, should always be rubbed smooth.

LINTELS.—In forming lintels over wide windows or other openings, it is advisable instead of using one long stone to use

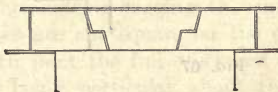


FIG. 64.

three stones, as shown by Fig. 64, which forms a sort of an arch. Or the stone can be notched over and hung on an I beam,



FIG. 65.

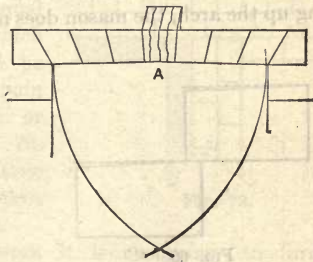


FIG. 66.

as shown by Fig. 65. Over very wide openings the stone should be cut to form a jack-arch, as shown by Fig. 66.

In cutting stone for an arch of any kind, or any stone on which a great pressure will be exerted, the stone should be cut so that the vein or natural bed of the stone will be at right angles to the pressure, as shown by Fig. 66 at A.

If the stone is cut with the vein parallel with the direction of the pressure, it is liable to split or scale off. In cutting stone for a jack-arch, the under side or soffet should be cambered one-half or three-quarters of an inch, as shown by Fig. 66 and Fig. 67, as it is more pleasing to the eye. If it is cut perfectly straight it has the appearance of having a sag in the centre, especially if the keystone drops below the arch-stone.

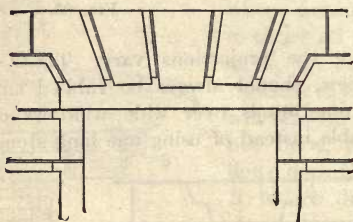


FIG. 67.



FIG. 68.

In springing a jack-arch over a lintel, as shown by Fig. 67, the arch-stone should be notched over the lintel, as shown by Fig. 68, thus leaving the lintel free and nothing to carry but its own weight.

The superintendent should watch when this is done, that, in backing up the arch, the mason does not fill up the space between

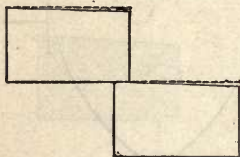


FIG. 69.

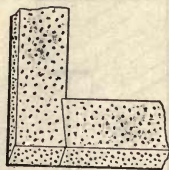


FIG. 70.

the arch and the lintel with mortar. If this should happen and there should be a slight settlement in the arch, the lintel would be broken.

STEPS.—Steps should be cut with a droop or wash of one-eighth or three-sixteenths of an inch, as shown by Fig. 69; this prevents the water from laying on them and makes them much easier to ascend than if they were level.

AREA COPING.—In cutting area coping, or any cap where there is any pressure from the side, it should be cut at the angle, as shown by Fig. 70, as this prevents the stone from moving.

CURBS.—In cutting curbing, the superintendent should see that the proper bevel or wash is cut on them, so that when set, the top of curb will have the same incline as the sidewalk. If cut square and set with an incline on the face, then the top of the curb will slope in the wrong direction and cause a valley to hold the water, as shown by Fig. 71.



FIG. 71.



FIG. 72.

FLAGGING.—When cutting flagging, the superintendent should see that the stones are cut square on the edges, so there will be the same width joint the full thickness of the stone. At times, instead of being particular about this, the cutter will pinch off the stone to the line and the stone will have a feather edge, as shown by Fig. 72.

In cutting stone for and building walls, such as area walls, buttresses, etc., which will not carry a weight, or have a pressure exerted upon them equal to that on the main wall, which they adjoin, they should be built independent of the main wall and set in a chase or recess, as shown by Fig. 73. If built in this way the stone in the angle will not be broken by any unequal settlement.

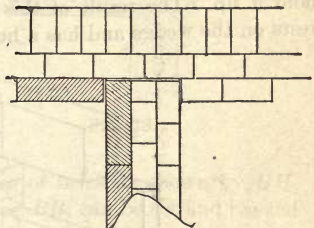


FIG. 73.

CARVING.—In carved work it is customary to furnish a model for the carver to work to, and it is the duty of the superintendent to see that the carving in the stone is a strict duplicate of the model. The carver will usually try to offer suggestions whereby he will claim he can improve the work, but as

a rule it will be a change for his own benefit, or so the work can be done quicker. He should be held strictly to the model and plans, unless, of course, in the judgment of the superintendent the work will be benefited or improved by a slight change. The superintendent must see that all arrises are cut sharp and all projections or cavities given their full dimension. The work should be brought out bold and well undercut to show a bold relief, and cavities cut so as to throw a shadow. This is the work the carver always tries to get out of doing, and will require the close attention of the superintendent.

Stone-setting.—This branch of work will require more attention from the superintendent of to-day than in former years, for by the rules of the trades unions nearly all stone setting is done by brick-masons who never learned the art of handling or setting stone. Accustomed as they are to slushing up joints in brickwork, they usually try to set stone by using three or four wedges to level up the stone and then try to slush mortar under it. Wedges are something a superintendent should not permit to be used, unless occasionally, when the mortar is soft, to keep a stone from settling too low, and then he will have to keep a sharp lookout,

for if the stone happens to be a little low, the mason will just lift the stone a little with his bar and shove in the wedge to hold it up. The result of this is shown in Fig. 74; the stone rests on the wedge and has a hollow joint under half its bed.

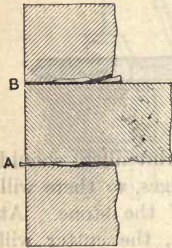


FIG. 74.

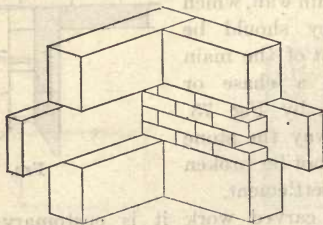


FIG. 75.

Fig. 74 at *B* shows a stone which has been cut with a slack bed, and the mason has wedged it up with a spall, leaving the

stone with no bed under the centre. The superintendent should insist on each and every stone being set in sufficient mortar so that the stone will have to be beat down to its bearing. In setting stone the mason will try to set three or four courses at a time, running in a course of brick to hold up the bond course, as shown by Fig. 75.

This will leave a vertical joint in the wall between the stone and the backing. The superintendent should not permit more than two courses of stone set in advance of the backing up; first a bond course and then a thin or ordinary course, as AA, Fig. 76; then he should have the wall backed up to this

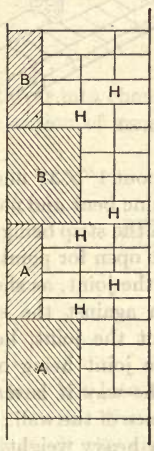


FIG. 76.

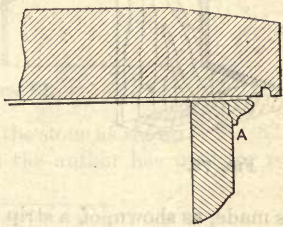


FIG. 77.

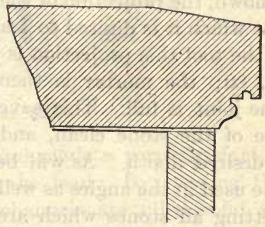


FIG. 78.

height, running in a header courses of brick as shown by HH, Fig. 76. Then the next two courses, BB, can be set and backed up in the same manner. In this way the ashlar and the brick work are firmly bonded together.

In setting stone the superintendent should see that all joints are raked out about three-quarters of an inch deep for pointing, and when a stone sets on top of a moulded projection, as shown by Fig. 77, the mortar should be kept back of the projection, if the joint is filled to the face of the moulding,

and should there be a little settlement the moulding is liable to be broken off as shown at *A*.

It is better to have such projection cut on the top stone, as shown by Fig. 78.

Fig. 79 shows a tool which the author has used with much success in slushing up vertical joints in stonework.

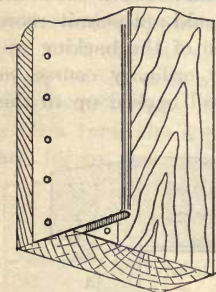


FIG. 79.

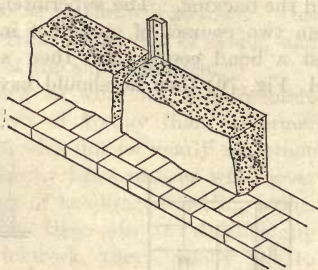


FIG. 80.

It is made, as shown, of a strip of wood about 1"×3" and as long as desired, with a piece of sheet iron or zinc bent and nailed on as shown, the projection of the metal from the strip being the depth at which it is desired to leave the joint open for pointing. To use the tool this projection is inserted in the joint, as shown by Fig. 80; the mortar is then slushed in against the strip until the joint is full. This saves raking out the joint, keeps the face of the stone clean, and insures the joint being open to the desired depth. As will be seen by the way it is made, it can be used in the angles as well as on the face of the wall.

In setting all stones which are to carry a heavy weight, the mortar should be kept back far enough from the face of the stone so that there will be no danger of the corner being chipped off by the pressure on the stone.

The joint in cut-stone work should not be more than one-fourth inch, and for rock-face work not over three-eighths inch.

In setting projecting courses, such as cornices, etc., the stone when being set should be bedded but little beyond the face of the wall, as shown by Fig. 59, page 58, the balance of the joint being filled when the pointing is done; in this way every stone is responsible for its own weight and leverage, and the lower courses do not have to carry the weight of

the top stone. The stone in a cornice should always extend back in or through the wall, so that there will be weight enough in that part of the stone in the wall to overbalance the overhang or projection; then the top stone should be anchored as shown.

The top of the joints in the cap course of a cornice or other wide projection should be covered with lead, as shown by Fig. 81, the lead extending down into the joint about 2 inches,

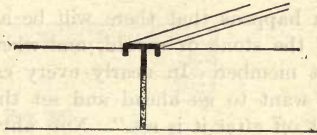


FIG. 81.

and over into channels cut in the stone as shown. Fig. 82 shows the section of a mould which the author has used for running

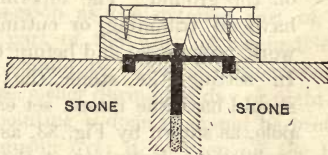


FIG. 82.

the lead hot into the joints, and made a very satisfactory job, much better than cementing the lead. By running the lead in hot, all the crevices and channels are filled solid and the lead takes hold of the rough surface of the stone and cannot get loose or come out.

It sometimes happens that after a stone is set it has to be moved a little; when this has to be done the superintendent must see that the stone is lifted and reset, for by shifting the stone it changes its position on the bed of mortar, and will not rest solid. As the stones are being set the superintendent should see that all joints are of the desired size. When a stone is a little long, and not room enough left for the vertical joint, the mason will likely say, "We will dress it off when we come to point it." The superintendent should never pay any attention to an assertion of this kind. It is much easier to cut

a little off the stone before it is set than to cut the joint out when it comes to pointing. When there is any cutting to be done to a stone it should be done before it goes into the wall.

The superintendent should have the stones, as they are being set, brushed clean, and wet with water so that the mortar will take hold of the stone. If the stones have been sawed on all sides, or on the top and bottom bed, he should have them gone over with the point or tooth-axe so as to roughen the surface a little to catch the mortar. He should see that all stones in a course member with each other, and that all mouldings join perfectly. It often happens that there will be a little difference in the shape of the stone or mould, and when the stones are set they will not member. In nearly every case of this kind the mason will want to go ahead and set the stone, saying, "We will dress it off after it is set." Now any promise of this kind is made with the idea that this little thing will be forgotten, and nothing more said about it, for it is two or three times costlier to do trimming of this kind when a man has to work from a ladder or scaffold than if he had the stone

on the ground. The superintendent should have all trimming or cutting done as the work progresses, and before the stone is set. In setting the stone the superintendent should have the mason set each course to a pole, as shown by Fig. 83, as this will insure each course being set at the correct height and level.

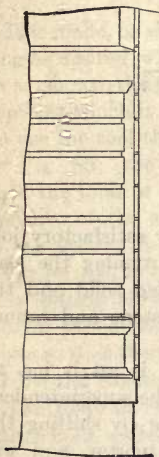


FIG. 83.

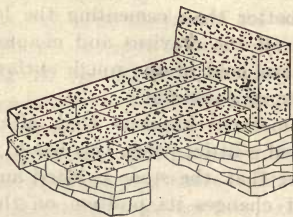


FIG. 84.

STEPS.—Steps should be set as shown by Fig. 84, being carried on the wall at each end; in this way there will be no danger of breaking, in case there is any settlement, as would happen if the steps were bedded their entire length.

FLAGGING.—Stones for flagging or sidewalks should be set on a bed of broken stone or cinders extending below the frost-line, or a better method is to set them on dwarf walls, as shown by Fig. 85. After being set, the joints should be thoroughly filled with strong cement mortar, and the stone gone over and any irregularities at the joints dressed off.

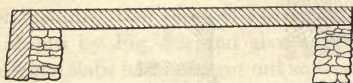


FIG. 85.



FIG. 86.

In setting a curb, it should be set on a bed of broken stone, and the curb itself be wide enough to extend below the frost-line, as shown by Fig. 86

Pointing Stonework.—The pointing of stonework is usually done as soon as the exterior part of the building is up, unless this part of the work is reached in cold weather, as no pointing should be allowed during weather when the mortar will freeze, either during the day or night. In extremely hot weather, if pointing is done it should be protected by hanging canvas or muslin over it to keep off the hot rays of the sun, as the heat will dry it too fast and the cement will lose its strength. All joints before pointing should be raked out at least three-quarters of an inch deep. The superintendent should have this done as the walls are built, as it can be done better while the mortar is soft than after the walls are up and the mortar set and hardened.

The superintendent should see that the mortar for pointing is mixed as desired, and all the joints filled and packed solid, and that they are thoroughly wet before the mortar is packed in them. The mortar for pointing should be mixed with cement and fine sand or marble-dust, so that the mortar will dress off smooth under the jointing tool.

Fig. 87 shows some of the different styles of pointing; with the designs AA the corner of the stone acts as a guide for the tool, but with raised designs the tool should be held against a straight edge; an ordinary short, straight edge with a couple of blocks tacked on the side to hold it up off the finished

joints answers the purpose, and the joints will all be made straight.

Before pointing the superintendent should have the work brushed off and washed down.

There are some stones which are damaged by acids, and the superintendent must determine this before having the walls washed. If acid does not damage the stone, a solu-

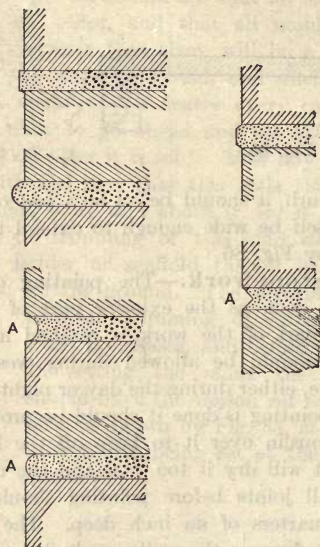


FIG. 87.

tion of dilute muriatic acid will neutralize the dirt and surplus mortar on the stone, and take it off very quickly. If there is any danger of acid affecting the stone, pure water must be used. Lye, pearline, etc., are also good for cleaning down some stone. As the stones are set, the superintendent should see that all moulds, etc., member, and the joints are kept the right size for pointing; this will save lots of trouble when the pointing is being done.

Marble Cutting, Finishing, and Setting.—Marble being but a high grade of limestone, the working or cutting of it is similar, the finished surface of marble usually being droved, tooled, or polished. Rock face, or any of the rougher finishes,

are seldom employed. In polishing marble, it is first rubbed with coarse sand on a rubbing-bed, then with fine sand and grit, then with pumice-stone, followed with Scotch bone, and last with putty-powder, which is used to give a gloss to the marble; oxalic acid is sometimes used with this powder, but a more durable polish is obtained without its use. Water is used in all the different steps of polishing.

Marble, when used for wainscoting, window-sills, water-closet partitions, etc., should be selected when got out so that the slabs will harmonize with each other in color and veining. For instance, two slabs of nearly the same veining are put up, as shown by Fig. 88, and give a very bad appearance; but if the same slabs had been got out so that they would have been put up as shown by Fig. 89, the heavy part of the veining would have come together and made a much more pleasing appearance.

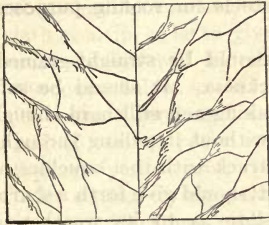


FIG. 88.



FIG. 89.

The superintendent should watch the marble as it is being set, and have it set so as to obtain as much harmony as possible; he should examine the marble to see if the polish is what is desired and all slabs are polished alike; he should also watch for cracks and stains. Marble when set against a wall is usually set in plaster of Paris and fastened with wire hold-fasts or anchors; these should be of heavy copper wire. The superintendent must see that a sufficient number of these are used to hold the marble firm and rigid, and that the slab is backed up with plaster of Paris so as to make it solid at each anchor. Where marble is fastened with bolts or screws they should be of brass and heavily plated with nickel or silver, as an iron screw will rust or stain the marble. Marble in floorwork should be set in Portland cement mortar.

In some colored marbles there are small cavities which have

to be filled with a wax when polished, and the superintendent should see that this is neatly done, so as not to be noticeable.

Marble Mosaic.—In this work the superintendent should see that the pieces of marble used are of nearly a uniform size and the cement joints between them show about the same. After the cement has set, the floor should be rubbed to a smooth surface and polished.

Terrazza.—In laying Terrazza floor the marble chips used should be small and nearly uniform in size and should be mixed with just enough neat Portland cement to fill the voids in the stone. As the chips will vary a little in size, the superintendent should see that the various sizes are evenly distributed throughout the floor and not have spots in the floor containing all large chips or all small ones. He should see that the floor is rubbed down sufficiently to show the chips uniformly throughout the floor.

Slate.—The principal use of slate is for roofing purposes, stair treads, urinal partitions, etc.

The slate for roofing purposes should be straight-grained, evenly split, and of a uniform thickness. It should be soft enough to cut or punch without breaking and still hard enough to firmly hold the head of the nail without it pulling through.

A good slate, when held up and struck with the knuckles of the hand or some metallic instrument, should give forth a sharp, clear, ringing sound. To test a slate as to its weathering qualities, especially in large cities where there is much smoke and gases, take a piece of the slate and immerse it in dilute sulphuric acid in a closed vessel for two or three days; at the end of that time if the slate is poor it will be softened and easily broken up, while a good slate will preserve its hardness. Another simple test for the absorptive power of slate is to stand a piece of the slate in a vessel of water for twelve hours and note the distance the water is absorbed up the slate from the water-level; in good slate the water will not rise more than one-eighth of an inch.

The presence of clay can be detected by breathing on a fresh piece of slate and observing if any clayey odor arises; the best slate will give out no odor whatever.

Some slates contain streaks of a hard material running through them which are called "ribbons"; this slate is usually sold as "ribbon slate," and at a reduced price. Any slate supposed to be No. 1 and containing any ribbons should be rejected.

PRESENCE OF LIME.—This can be determined by the application of cold dilute hydrochloric acid to the edges of a freshly quarried slate. Rapid effervescence implies presence of lime; slow, that of a lesser quantity of it or dolomite—carbonate of lime and magnesia.

COLOR AND DISCOLORATION.—The color of freshly quarried slate should be noted and compared with pieces exposed for several years to the weather. A good slate should retain its original color and not fade.

A good slate will have a fine grain, and the block from which the slates are split should be got out at the quarry, and split so that this grain will run lengthwise of the slate, so that should the slate ever crack with this grain it will be divided so there will be a nail in each piece.

The superintendent should see that the slates are all full size and have no broken corners. In putting them on he should see that the first course is doubled, and the bottom edge laid on a lath or strip, so as to give the slate the proper pitch so that the next courses will lay solid; each course should lay solid on the course below, so that the wind and weather cannot get under. To make a good roof it is advisable to lay the slate in a thin bed of cement paste or mortar; this costs a little more, but makes a perfect roof.

In slating up hips, etc., where there is no saddle to be used, the superintendent must see that the slater makes the proper lap with the slate and putties up each course with slaters' cement as he goes along. When finishing at the ridge or comb of the roof the slate should be cut, and not laid in a "stretcher" course, as is often done. In laying slates which are rough or of an uneven thickness it is hard to get each succeeding course to lay solid, and the slater will wedge up with a nail or small piece of slate; this should never be permitted, for the wedge is liable to work out and leave the slate loose.

Where slate is laid with a close valley, that is, where the slates are mitred in the valley and flashed each course, the superintendent must see that no broken or cracked ones are used, and that the flashing is large enough to insure a tight valley: such valleys should not be used on roofs under one-half pitch, for the rain or snow will be liable to blow up under the flashing.

The following table gives the strength, weight, etc., of some of the various slates.

STRENGTH, WEIGHT, ETC., OF SLATE.

| State. | Location. | Crushing Strength per Sq. Inch. | Weight per Cubic Foot. | Porosity. | Per Cent of Loss by Corroding. |
|-----------------|------------------|---------------------------------|------------------------|-----------|--------------------------------|
| Maine..... | Monson..... | 19.510 | ..... | ..... | ..... |
| Maryland..... | Peachbottom..... | 11.250 | ..... | ..... | ..... |
| Pennsylvania .. | Albion..... | 7.150 | 173 | .338 | .547 |
| " .. | Old Bangor..... | 9.810 | 173 | .145 | .446 |
| " .. | Peachbottom..... | 11.260 | 180 | .224 | .226 |
| Vermont | Rutland Co. | 10.975 | ..... | .260 | .350 |

Slate for wainscoting, stair-treads, etc., should receive the same attention as described for marble in like places.

TABLE SHOWING SIZES OF SLATES, THE NUMBER OF PIECES IN A SQUARE, AND HOW MUCH SHOULD BE EXPOSED TO THE WEATHER ON THE ROOF, ALLOWING 3 INCHES LAP

| Size of Slate. | Number in Each Square. | Exposed When Laid. | Distance of Lath. | Size of Slate. | Number in Each Square. | Exposed When Laid. | Distance of Lath. |
|----------------|------------------------|--------------------|-------------------|----------------|------------------------|--------------------|-------------------|
| Inches. | | Inches. | | Inches. | | Inches. | |
| 24×14 | 98 | 10½ | 10½ | 16×10 | 222 | 6½ | 6½ |
| 24×12 | 115 | 10½ | 10½ | 16×9 | 247 | 6½ | 6½ |
| 22×12 | 126 | 9½ | 9½ | 16×8 | 277 | 6½ | 6½ |
| 22×11 | 138 | 9½ | 9½ | 14×10 | 261 | 5½ | 5½ |
| 20×12 | 142 | 8½ | 8½ | 14×8 | 327 | 5½ | 5½ |
| 20×10 | 170 | 8½ | 8½ | 14×7 | 374 | 5½ | 5½ |
| 18×12 | 160 | 7½ | 7½ | 12×8 | 400 | 4½ | 4½ |
| 18×10 | 192 | 7½ | 7½ | 12×7 | 457 | 4½ | 4½ |
| 18×9 | 214 | 7½ | 7½ | 12×6 | 533 | 4½ | 4½ |
| 16×12 | 185 | 6½ | 6½ | | | | |

To determine the number of pieces to a square of any size slate not given, first deduct 3 inches from the length; divide this by 2; multiply by the width of slate and divide the result into 14,400.

An example—20×10 would be calculated thus: 20-3=17; divided by 2=8½; 8½×10=85; 85 divided into 14,400=169¼/100 pieces.

The weight of the various thicknesses of slate per square foot is as follows:

| Thickness of slate in inches..... | ⅛ | ¼ | ⅜ | ½ | ⅝ | ¾ |
|---------------------------------------|------|------|------|------|------|-------|
| Weight per square foot in pounds..... | 1.81 | 2.71 | 3.62 | 5.43 | 7.25 | 10.88 |

The above is the weight of the slate of the thickness given. To find the weight when the slate is laid, the lap and surface exposed to the weather must be considered.

TABLE SHOWING QUANTITY OF NAILS NEEDED TO LAY ONE SQUARE OF SLATE.

(The quantity given is from actual count.)

| Sizes of Slate. | No. to Square, 3-inch Lap. | Weight of Nails to a Square. | | | | | | | | | | | | | |
|-----------------|----------------------------|------------------------------|-----|------|-----|----------------------|-----|----------------|-----|------|-----|------|-----|----------------------|-----|
| | | 3d. | | | | | | | | 4d. | | | | | |
| | | Gal. | | Tin. | | Copper & Steel Wire. | | Aluminum Wire. | | Gal. | | Tin. | | Copper & Steel Wire. | |
| | | lbs. | oz. | lbs. | oz. | lbs. | oz. | lbs. | oz. | lbs. | oz. | lbs. | oz. | lbs. | oz. |
| 24×14 | 98 | 1 | 2 | ... | 15 | ... | 14 | ... | 6 | 1 | 6 | 1 | 2 | 1 | 4 |
| 24×12 | 115 | 1 | 5 | 1 | 2 | 1 | 1 | ... | 7 | 1 | 10 | 1 | 5 | 1 | 7 |
| 22×12 | 126 | 1 | 7 | 1 | 4 | 1 | 3 | ... | 8 | 1 | 12 | 1 | 7 | 1 | 9 |
| 22×11 | 138 | 1 | 9 | 1 | 5 | 1 | 4 | ... | 9 | 1 | 15 | 1 | 9 | 1 | 11 |
| 20×12 | 141 | 1 | 10 | 1 | 6 | 1 | 5 | ... | 9 | 2 | ... | 1 | 10 | 1 | 12 |
| 20×10 | 170 | 1 | 15 | 1 | 11 | 1 | 9 | ... | 10 | 2 | 6 | 1 | 15 | 2 | 2 |
| 18×12 | 160 | 1 | 13 | 1 | 9 | 1 | 8 | ... | 10 | 2 | 4 | 1 | 13 | 2 | ... |
| 18×10 | 192 | 2 | 3 | 1 | 14 | 1 | 12 | ... | 11 | 2 | 11 | 2 | 3 | 2 | 6 |
| 18×9 | 214 | 2 | 7 | 2 | 1 | 1 | 15 | ... | 12 | 3 | 8 | 2 | 7 | 2 | 11 |
| 16×12 | 184 | 2 | 2 | 1 | 12 | 1 | 11 | ... | 11 | 2 | 9 | 2 | 2 | 2 | 5 |
| 16×10 | 222 | 2 | 8 | 2 | 2 | 2 | ... | ... | 12 | 3 | 1 | 2 | 8 | 2 | 12 |
| 16×8 | 277 | 3 | 2 | 2 | 11 | 2 | 8 | ... | 15 | 3 | 14 | 3 | 2 | 3 | 8 |
| 14×10 | 261 | 3 | ... | 2 | 8 | 2 | 6 | ... | 14 | 3 | 10 | 3 | ... | 3 | 4 |
| 14×8 | 327 | 3 | 12 | 3 | 2 | 3 | ... | 1 | 2 | 4 | 9 | 3 | 12 | 4 | 2 |
| 14×7 | 374 | 4 | 4 | 3 | 10 | 3 | 7 | 1 | 4 | 5 | 3 | 4 | 4 | 4 | 11 |
| 12×8 | 400 | 4 | 9 | 3 | 14 | 3 | 10 | 1 | 6 | 5 | 9 | 4 | 9 | 5 | ... |
| 12×7 | 457 | 5 | 3 | 4 | 6 | 4 | 2 | 1 | 9 | 6 | 6 | 5 | 3 | 5 | 11 |
| 12×6 | 533 | 6 | 1 | 5 | 2 | 5 | 14 | 1 | 13 | 7 | 6 | 6 | 1 | 6 | 11 |

Bricks and Brick-laying.—The quality of a brick depends on the material used, the care in its manufacture, and the manner in which it is burned. With the machinery that is in use at the present time it is possible to use different materials and make better brick than in former days when clay was the only material used and the bricks were moulded by hand.

For common bricks, a shale rock makes perhaps the best brick, and when burned with gas, as quite a number are now burned, they make a very hard brick and of uniform size and color.

The chemical compounds contained in the material used determines the color and quality of the brick to a great extent; if there is much silicate of lime in the material used, it renders the clay too fusible and causes the brick to soften and warp or twist in burning. A small amount of sand is beneficial, as it tends to prevent shrinkage from the heat in burning.

Iron gives hardness and strength to the brick, and also causes the red color in burning, the color depending a great deal on the amount of iron contained.

In face or front brick iron or mineral pigments are sometimes added to the clay so as to color the brick as desired.

Where the bricks are exposed to excessive heat in burning, the iron fuses and produces a dark-blue or purple color, as shown by the "arch" or clinker brick next to the fire in the kiln.

When the clay contains much magnesia with the iron it produces a yellow color.

NAMES OF BRICK.—All brick not hard enough to stand in the outside of buildings are known as "salmon" or "soft" brick.

All brick hard enough for the outside of buildings, but not selected or graded, are known as "hard kiln run."

All brick set in the arches or benches of the kiln, and which are discolored, broken, or twisted in the burning are known as "arch brick."

All common brick selected for the outside of buildings are known as

| | | |
|--------------|---|-----------------------|
| Front brick. | { | No. 1 light-burned. |
| | | No. 2 medium-burned. |
| | | No. 3 hardest-burned. |

All brick used for sidewalks are known as "sidewalk brick."

All the brick in the kiln not strictly soft taken together are known as "merchantable brick."

All brick that are set in the kiln when burned are known as "kiln-run brick."

Bricks moulded either by hand or machinery in rough, coarse sand and repressed without rubbing, so as to give the brick a rough sand finish, are known as "stock" or "sand-struck" brick.

All brick other than square are known as "ornamental brick."

All brick made either by the repress or dry-press process, and selected for fronts of buildings, are known as "press brick," which are: No. 1, light shade; No. 2, medium; No. 3, dark.

SIZES OF BRICKS.—The sizes of bricks vary much in different parts of the country, and when brick and stone are worked together the architect should know what brick he is going to use, so as to know its size and in preparing the drawings make the sizes of stone to suit the brick. The author has known of cases where the contractor had to ship brick several hundred miles, just because the brick which were made near the work was not of a suitable size to work with the stone as laid out and figured for the building. This is in regard to the face

brick, although the common brick should work with the stone so as to get the correct bonding. In English bond and English cross bond there is often trouble to get brick of a suitable size to work the bond correctly.

WEIGHT OF BRICK.—The weight of brick vary, according to size and their density, from $4\frac{1}{2}$ to $5\frac{1}{2}$ pounds; in the wall a cubic foot of brickwork will weigh about 115 pounds.

QUALITY.—The superintendent should examine the brick as brought to the work, and see that they are of the desired quality; they should be uniform in size and color and hard and well burned. When two bricks are struck together they should give forth a clear ringing sound. When broken with a hammer they should break across the brick, dividing it into two "bats," and produce a clean fracture showing a compact, hard structure, having a bright surface free from cavities and air-holes. A soft brick when broken will usually fly into several pieces.

The brick should have square edges and parallel surfaces, and not be twisted or warped by burning.

A brick should not absorb more than one-tenth of its weight of water.

As a rule the darkest bricks are the strongest and best burned, while the light-colored ones are usually soft and will not stand much crushing strain or the weather. A good test for a brick is to heat it red-hot and then pour cold water on it; if it does not crack or break it is of excellent quality.

**SPECIFIC GRAVITY, WEIGHT, AND CRUSHING STRENGTH
OF BRICK.**

| Name. | Specific Gravity. | Weight per Cubic Foot in Pounds. | Crushing Strength per Square Inch in Pounds. |
|--------------------|-------------------|----------------------------------|--|
| Best pressed. | 2.4 | 150 | 5000 to 14973 |
| Common hard. | 1.6 to 2.0 | 125 | 5000 to 8000 |
| Soft | 1.4 | 100 | 450 to 600 |

The New York Building Code gives the working strength of brickwork as follows:

| | Pounds per Square Inch. |
|--|-------------------------|
| Brickwork in Portland-cement mortar; cement, 1; sand, 3. | 208 |
| Brickwork in lime and cement mortar; cement, 1; lime, 1; sand, 6. | 160 |
| Brickwork in lime mortar; lime, 1; sand, 4. | 111 |

A good brick supported at each end on supports 6 inches apart should withstand a pressure at the centre of 2000 pounds without breaking.

In a test made by Norcross Bros. of Boston the crushing strength of brick ranged as follows: 2720 pounds for light hard, the poorest; up to 8000 pounds per square inch for the best quality to produce the first crack; while the ultimate strength ran from 3149 up to 10,532 pounds per square inch.

FIRE-BRICK.—Fire-brick are made by a similar process to making ordinary brick, but from different material. The clay used is known as fire-clay. This clay is composed of hydrated silicates of alumina, associated with silica and alumina in various states or subdivisions and sufficiently free from alkalis, iron, and lime to resist vitrification at high temperature.

Oxide of iron or sulphate of iron in the clay is very injurious, and when found in the brick in a quantity of more than 5 per cent they should be rejected. Lime, soda, potash, and magnesia, are also injurious and any fire-brick containing over 3 per cent of either should be rejected.

Good fire-clay should contain 50 to 80 per cent of silica and 18 to 35 per cent of alumina; it should be of a uniform texture and have a greasy feel between the fingers.

Fire-brick which are to be exposed to heat should be laid in fire-clay, and should be thoroughly wet before laying; the mortar should be used very thin and the joint made as tight as possible.

VITRIFIED BRICK are brick burned to a hard glossy consistency so as to be impermeable to water and fit for damp-proof work, paving, and such purposes.

BRICK-LAYING.—This is one of the branches of work that will require the close attention of the superintendent, as it is one that can be slighted at any time and a defect covered up in a moment. If in making his rounds of the building the superintendent should notice a brick-mason hurriedly spreading mortar over the top of the wall or a course of brick just laid, he should regard it with suspicion, and it would be well for him to examine this particular part of the wall. The strength and stability of a wall depends, in addition to the quality of the materials used, upon the manner in which it is built. The superintendent should first see that the bricks are hard, sound, and of correct shape, and that they are all thoroughly wet before being laid in the wall, so that they will not absorb the water out of the mortar, thus causing it to lose its strength. The mason will often complain that wetting the brick makes

them hard to lay, or that they will "creep." The superintendent should pay no attention to this, for a brick will have to be soaked in water until it will absorb no more before it is too wet to use. When the bricks are being laid the superintendent should see that they are all laid on a full bed of mortar, and where possible should be shoved or rubbed into position, and he should also see that all vertical joints are filled solid with mortar.

It is the custom of masons to spread the mortar, then lay on the brick, exerting no pressure on the brick except its own weight. The superintendent should watch for this and compel the mason to shove or force each brick down to a solid bed and close joint.

The vertical joints should all be completely filled with mortar and the brick kept at least $\frac{1}{4}$ inch apart for this purpose, as shown by Fig. 90 at A. Fig. 90 at B shows how the mason will want to lay the brick tight against each other with a dry joint.

The face of a wall where the mason has his own way will usually be laid as shown in Fig. 91. He will spread the mortar and with his trowel gather up the overhanging mortar and scratch it off on the end of the brick already laid, then lay the next brick against this mortar. Often there will only be enough mortar to fill the joint half an inch deep, and this will be all it will ever get unless the superintendent compels the mason to fill it. The superintendent must see that these joints are completely filled and not left as shown in Fig. 91.

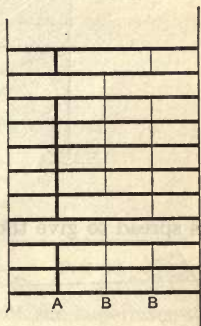


FIG. 90.



FIG. 91.

In spreading mortar for the outside courses, the mason will stretch it along the top of the brick already laid, and then run the point of his trowel through the centre, leaving it as shown by Fig. 92.

Unless the superintendent watches to see that enough mortar

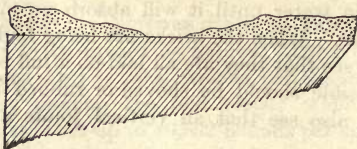


FIG. 92.

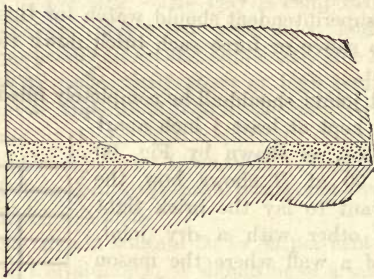


FIG. 93.

is spread to give the brick a full bed, the chances are that the brick will be bedded only a little on each side, as shown by Fig. 93. This is often a defect in laying front brick with "butter" joints; the mortar is placed on the brick to be laid in the manner shown by Fig. 94, and when laid the result is shown by Fig. 95, leaving the centre of the brick without any bed.

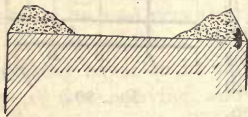


FIG. 94.

The author has seen work of this kind where the weight of the wall had caused pieces of brick to spall off, as shown at *A*, Fig. 95, just because the brick did not have a full bed of mortar.

The bed joints for common brickwork should be about $\frac{3}{8}$ inch, but depend a great deal on the mortar used. The superintendent can tell by watching a few bricks laid, and noticing the pressure required to get a solid bearing, what size joint should be used. In "stock" or "sand-struck" brick for outside work the joint should be $\frac{1}{4}$ inch, and for "press" brick $\frac{1}{8}$ or $\frac{3}{16}$ inch.

The superintendent should see that the bricks, as laid, are

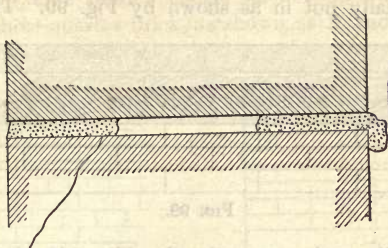


FIG. 95.

set level. The custom of masons is to set the brick with a slight incline, as shown by Fig. 96, as this gives them a projection on the lower course to guide the trowel in striking the joint. The face of the bricks should be kept as near plumb as possible and no unnecessary projections made to catch the water.

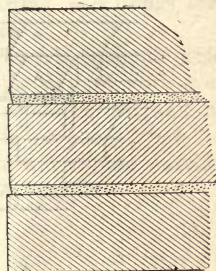


FIG. 96.

Bond is another point in brick-work that requires the close attention of the superintendent. It is usually specified that every fifth or sixth course, as the case may be, shall be a header, and it is the duty of the superintendent

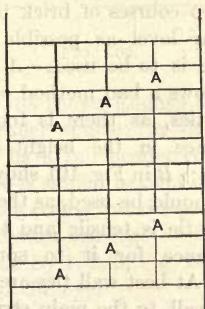


FIG. 97.

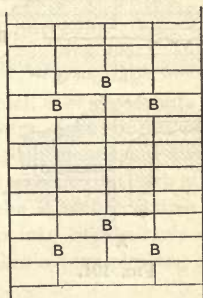


FIG. 98.

to see that this is strictly carried out, and that each header course is lapped through the wall, as shown by Fig. 97 or Fig. 98.

In facework, where it is not desired to show the headers, they are usually put in as shown by Fig. 99. This is called

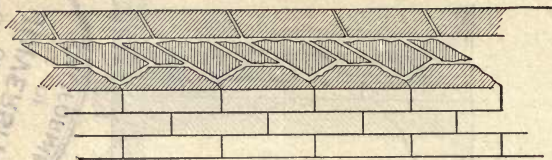


FIG. 99.

clipped or diagonal secret bond. Fig. 100 shows another style of secret bond; the stretcher course is clipped to half its width, and a three-quarter bond course laid behind, as shown.

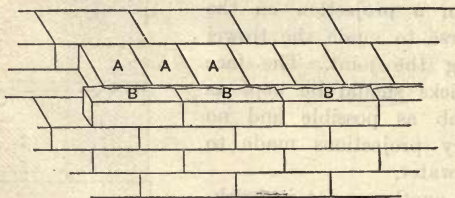


FIG. 100.

Metal wall ties of various kinds are also used for bonding the face brick to the main wall.

When these are used the superintendent should see that they are used in sufficient numbers, and the two courses of brick brought as near level as possible where the tie is to be used. *A* in Fig. 101 shows a bad method of using these ties, as there is too much difference in the height of the courses; *B* in Fig. 101 shows how they should be used, as the strain on the tie is tensile and there is no chance for it to spring or give. At best wall ties are a very

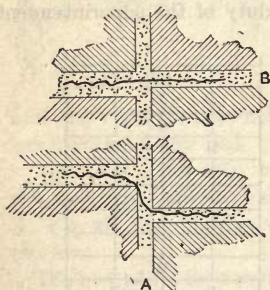


FIG. 101.

poor method of tying the face of a wall to the main structure, and the author cannot recommend their use.

The strongest wall is obtained when header courses are used in the face of the wall. Fig. 102 shows the common form of

bond in which a header course is run at intervals of, say, every six courses. This header course should be started with a quarter or three-quarter brick, as shown at *A* and *B*, of which that at *A* looks the best.

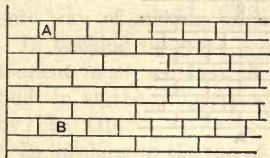


FIG. 102.

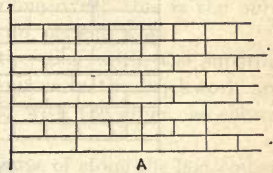


FIG. 103.

Fig. 103 shows the wrong way of starting, and brings three vertical joints over each other, as shown at *A*.

Fig. 104 shows what is known as Flemish bond, in which every alternate brick is a header. In this style of work every alternate course should have headers of full brick, and not "bats." The mason will try to work in as many "bats" as possible so as to save face brick, and it will require watching on the part of the superintendent to prevent it.

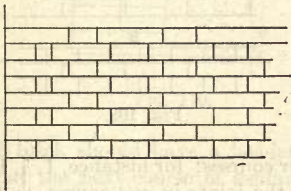


FIG. 104.

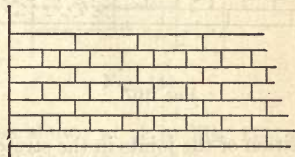


FIG. 105.

Fig. 105 shows English bond in which every alternate course is a header course; in this work every sixth course of brick should be a full header course. English cross-bond shown by Fig. 106 is similar to the English bond, except that each alternate stretcher course breaks joints with the stretcher course below. This divides the face of the wall up into St. George's crosses, as shown by 1, 2, 3, Fig. 106, and makes a very pleasing appearance to the eye.

Fig. 107 shows how this work should be carried around quoins, etc. In all facework it will be the duty of the superintendent to see that the mason keeps his joints plumb and in

line. Fig. 108 at *A* shows the distorted appearance of a wall laid in English cross-bond, in which the joints were not kept plumb. Fig. 108 at *B* shows the work as it should be.

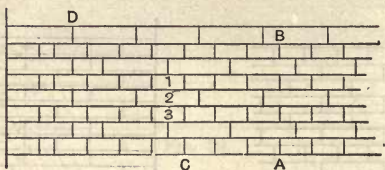


FIG. 106.

The author has often found it necessary to have the mason mark out a pole, as shown by Fig. 109, and mark on it the

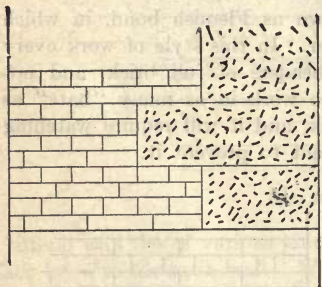


FIG. 107.

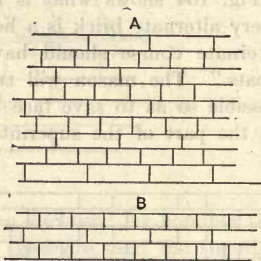


FIG. 108.

position of the joints in the stretcher courses; for instance, 1, 1, 1 on the pole will be the position of the joints in one course, and 2, 2, 2 will be the position of the joints in the next stretcher

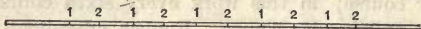


FIG. 109.

course. The pole should be made so that one end of it can be held at the corner of the wall or pier, so that it will always be held in the same position. After the header course is laid the pole should be used and each joint of the stretcher course marked off; after the stretcher is laid the header course can be centred with the eye; then repeat the operation for the next stretcher.

The joints should line up, as shown at *AB*, Fig. 106, and form a true diagonal step, as shown from *C* to *D*.

The superintendent should instruct the foreman of the work how he desires to have the work done, and any work not done correctly, have it taken down and done over; this is the only sure way of making brick-masons do perfect work.

In backing up stone ashlar or other like work, the superintendent must see that the bond courses in the brickwork are built in at the proper place to bond with the stone, as shown by Fig. 110.

In finishing to the top of a thin course of stone the last course

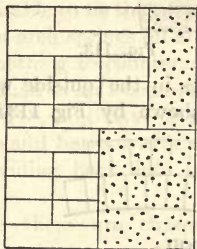


FIG. 110.

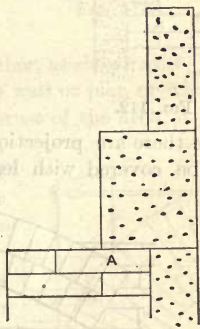


FIG. 111.

of brick should have a header, as shown at *A* in Fig. 111, so that the next course of ashlar will lap onto it and form a bond with it.

The superintendent should never allow more than two courses of stone set ahead of the brick-mason; first a thick or bond course, and then a thin one, as shown by Fig. 111. Then the mason can back up these two courses, as shown by Fig. 110, when the wall will be ready to set two more courses of ashlar.

Unless the superintendent cautions the mason against it, they will run up three or four courses of ashlar by filling in a course of brick, as shown by Fig. 112. This should never be permitted, as it makes a vertical joint through the wall, as shown from *A* to *B*.

The superintendent should occasionally, as the walls are being built, sight along and down the face of them, to see if they are

being built straight and plumb; some masons will keep working "hard" against the line until they have the wall considerably out of plumb.

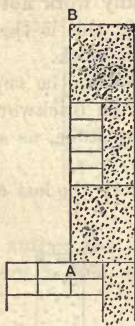


FIG. 112.

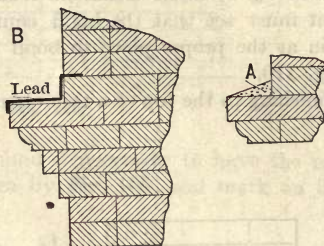


FIG. 113.

Where there are projection courses in the outside wall, they should be covered with lead, as shown by Fig. 113B; some-

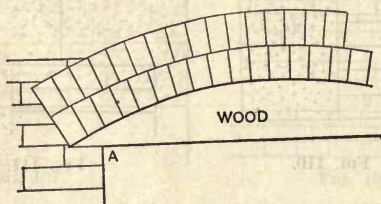


FIG. 114.

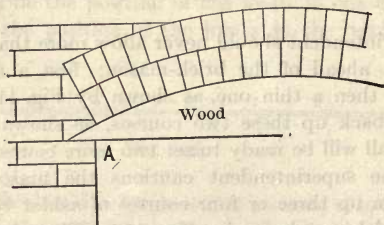


FIG. 115.

times they are covered with cement mortar, as shown by Fig. 113A; this is not so reliable as the lead, for the cement may crack and work loose.

In turning arch lintels over door or other openings, it is customary to use a wood centre, as shown by Fig. 114. The superintendent should see that the arch is started at the end of the wood centre, as shown by Fig. 114, and not as shown by Fig. 115, as this throws the weight onto the wood.

Arches are usually built of concentric rings or header courses, as shown by Fig. 116. Where the arch is to carry a heavy load

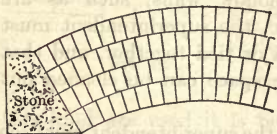


FIG. 116.

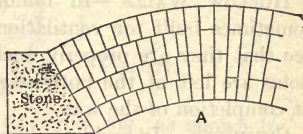


FIG. 117.

it is advisable to tie the courses together, as shown at A, Fig. 117. When an arch springs off an outside wall or pier, or where there will be nothing to counteract the thrust of the arch, it is advisable to build in an I beam, as shown by Fig. 118, and have it anchored solid top and bottom with a bolt or rod extending back into the main wall.

Where there are chases or recesses for pipes or vent flues to be built in the wall, the superintendent should see that they are located correctly, and that they are built straight and plumb; these chases or recesses should be shut off at each floor level after the pipes are in place, and before plastering, so as to prevent any egress from floor to floor in case of fire.

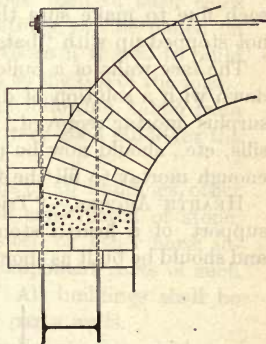


FIG. 118.

Where walls are built to any great height or length with nothing to brace them, the superintendent should have them braced temporarily until the mortar hardens, or until the floor-beams are put in place.

In narrow buildings where an engine and elevator are used for hoisting the superintendent should see that the strain from the platform to the engine is lengthwise of the building. The author saw a case where a six-story building had to be taken

down when the walls reached the sixth floor, because the engine and elevator had been set crosswise of the building, and the strain and vibration caused the walls to "creep" until they were 6 inches out of plumb.

The superintendent should see that all walls are protected from the weather as they are being built, and covered every night, especially front or outside walls.

HOLLOW WALLS.—In building hollow walls, such as are sometimes built for ventilation, etc., the superintendent must see that they are properly anchored or tied together, and that holes are left at the bottom so the space can be cleaned out at completion of the wall.

CHIMNEYS.—In building chimneys the superintendent must see that the flues are built straight and with as few bends as possible, and that all joints in the brickwork are slushed full of mortar, and where flue-lining is not used, see that the inside of the flue is plastered smooth. The top of a chimney above the roof should be laid in cement mortar. When the chimney is completed, the superintendent should have a weight dropped down each flue to make sure that it is open its entire length, and not stopped up with "bats" and mortar.

The face walls of a building at completion should be washed down with a solution of diluted muriatic acid and all dirt and surplus mortar removed; all open joints left under window-sills, etc., should now be pointed, care being taken to use just enough mortar to fill the face of the joint.

HEARTH ARCHES.—"Trimmer" or "hearth" arches for the support of a hearth stone or tile are usually built of brick and should be built as shown by Fig. 119; this throws the weight

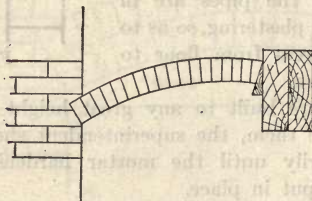


FIG. 119.

and thrust nearly all on the chimney and not on the wood joist. A flat wood centre is often used in frame houses, as shown

by Fig. 120; but the author does not consider this a good method, for the wood in the recess in the brickwork is but $2\frac{1}{2}$ or 3 inches away from the flue, which is too close for safety. Where centres



FIG. 120.

FIG. 121.

of this kind are used it is better to corbel out, as shown by Fig. 121; this will give 4 inches of brick between the wood and the flue.

BRICK NOGGING.—In wooden partitions it is often specified for a course of brick to be built in at the bottom of the story, and also at half height, resting on the bridging; this is to prevent the passage of vermin and also act as a fire-stop. The superintendent should see that the brick used in such cases are not wider than the studs, so the lathing can be nailed on straight; where the joist rests on a partition it is well to build “nogging” from the top of this partition to the top of the joist.

WALLS, PIERS, AND PARTITIONS.—The following, taken from the New York Building Code, 1901, is a very good guide for the superintendent:

Sec. 27. Materials of Walls.—The walls of all buildings, other than frame or wood buildings, shall be constructed of stone, brick, Portland-cement concrete, iron, steel, or other hard, incombustible material, and the several component parts of such buildings shall be as herein provided. All buildings shall be inclosed on all sides with independent or party walls.

Sec. 28. Walls and Piers.—In all walls of the thickness specified in this code, the same amount of materials may be used in piers or buttresses. Bearing walls shall be taken to mean those walls on which the beams, girders, or trusses rest. If any horizontal section through any part of any bearing wall in any building shows more than 30 per centum area of flues and openings, the said wall shall be increased 4 inches in thickness for every 15 per centum, or fraction thereof, of flue or opening area in excess of 30 per centum.

The walls and piers of all buildings shall be properly and

solidly bonded together with close joints filled with mortar. They shall be built to a line and be carried up plumb and straight. The walls of each story shall be built up the full thickness to the top of the beams above. All brick laid in non-freezing weather shall be well wet before being laid. Walls or piers, or parts of walls and piers, shall not be built in freezing weather, and if frozen, shall not be built upon.

All piers shall be built of stone or good, hard, well-burnt brick laid in cement mortar. Every pier built of brick, containing less than 9 superficial feet at the base, supporting any beam, girder, arch or column on which a wall rests, or lintel spanning an opening over 10 feet and supporting a wall, shall at intervals of not over 30 inches apart in height have built into it a bond-stone not less than 4 inches thick, or a cast-iron plate of sufficient strength and the full size of the piers. For piers fronting on a street the bond-stones may conform with the kind of stone used for the trimmings of the front. Cap-stones of cut granite or bluestone, proportioned to the weight to be carried, but not less than 5 inches in thickness, by the full size of the pier, or cast-iron plates of equal strength, by the full size of the pier, shall be set under all columns or girders, except where a 4-inch bond-stone is placed immediately below said cap-stone, in which case the cap-stone may be reduced in horizontal dimensions at the discretion of the Commissioner of Buildings having jurisdiction. Isolated brick piers shall not exceed in height ten times their least dimensions. Stone posts for the support of posts or columns above shall not be used in the interior of any building. Where walls or piers are built of coursed stones, with dressed level beds and vertical joints, the Department of Buildings shall have the right to allow such walls or piers to be built of a less thickness than specified for brickwork, but in no case shall said walls or piers be less than three-quarters of the thickness provided for brickwork.

In all brick walls every sixth course shall be a heading course, except where walls are faced with brick in running bond, in which latter case every sixth course shall be bonded into the backing by cutting the course of the face brick and putting in diagonal headers behind the same, or by splitting the face brick in half and backing the same with a continuous row of headers. Where face brick is used of a different thickness from the brick used for backing, the courses of the ex-

terior and interior brickwork shall be brought to a level bed at intervals of not more than ten courses in height of the face brick, and the face brick shall be properly tied to the backing by a heading course of the face brick. All bearing walls faced with brick laid in running bond shall be 4 inches thicker than the walls are required to be under any section of this Code.

Sec. 29. *Ashlar*.—Stone used for the facing of any building, and known as ashlar, shall be not less than 4 inches thick.

Stone ashlar shall be anchored to the backing and the backing shall be of such thickness as to make the walls, independent of the ashlar, conform as to the thickness with the requirements of sections 31 and 32 of this Code, unless the ashlar be at least 8 inches thick and bonded into the backing, and then it may be counted as part of the thickness of the wall.

Iron ashlar plates used in imitation of stone ashlar on the face of a wall shall be backed up with the same thickness of brickwork as stone ashlar.

Sec. 30. *Mortar for Walls and Ashlar*.—All foundation-walls, isolated piers, parapet walls and chimneys above roofs shall be laid in cement mortar, but this shall not prohibit the use in cold weather of a small proportion of lime to prevent the mortar from freezing. All other walls built of brick or stone shall be laid in lime, cement, or lime and cement mortar mixed.

The backing up of all stone ashlar shall be laid up with cement mortar, or cement and lime mortar mixed, but the back of the ashlar may be pargeted with lime mortar to prevent discoloration of the stone.

Sec. 31. *Walls for Dwelling-houses*.—The expression "walls for dwelling-houses" shall be taken to mean and include this class walls for the following buildings:

Dwellings, asylums, apartment-houses, convents, club-houses, dormitories, hospitals, hotels, lodging-houses, tenements, parish buildings, schools, laboratories, studios.

The walls above the basement of dwelling-houses not over three stories and basement in height, nor more than 40 feet in height, and not over 20 feet in width, and not over 55 feet in depth, shall have side and party walls not less than 8 inches thick, and front and rear walls not less than 12 inches thick. All walls of dwellings exceeding 20 feet in width and not exceeding 40 feet in height shall be not less than 12 inches thick. All walls of dwellings 26 feet or less in width between bearing-walls which are hereafter erected or which may be altered to be used

for dwellings, and being over 40 feet in height and not over 50 feet in height, shall be not less than 12 inches thick above the foundation-wall. No wall shall be built having a 12-inch-thick portion measuring vertically more than 50 feet. If over 50 feet in height and not over 60 feet in height the wall shall be not less than 16 inches thick in the story next above the foundation-walls and from thence not less than 12 inches to the top. If over 60 feet in height, and not over 75 feet in height, the walls shall be not less than 16 inches thick above the foundation-walls to the height of 25 feet, or to the nearest tier of beams to that height, and from thence not less than 12 inches thick to the top. If over 75 feet in height, and not over 100 feet in height, the walls shall be not less than 20 inches thick above the foundation-walls to the height of 40 feet, or to the nearest tier of beams to that height, thence not less than 16 inches thick to the height of 75 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top. If over 100 feet in height, and not over 125 feet in height, the walls shall be not less than 24 inches thick above the foundation-walls to the height of 40 feet or to the nearest tier of beams to that height, thence not less than 20 inches thick to the height of 75 feet, or to the nearest tier of beams to that height, thence not less than 16 inches thick to the height of 110 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top. If over 125 feet in height and not over 150 feet in height, the walls shall be not less than 28 inches thick above the foundation-walls to the height of 30 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 65 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 100 feet, or to the nearest tier of beams to that height; thence not less than 16 inches thick to the height of 135 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top. If over 150 feet in height, each additional 30 feet in height or part thereof, next above the foundation-walls, shall be increased 4 inches in thickness, the upper 150 feet of wall remaining the same as specified for a wall of that height.

All non-fireproof dwelling-houses erected under this section, exceeding 26 feet in width, shall have brick fore-and-aft partition-walls. All non-bearing walls of buildings hereinbefore in

this section specified may be 4 inches less in thickness, provided however, that none are less than 12 inches thick, except as in this Code specified. 8-inch brick partition-walls may be built to support the beams in such building in which the distance between the main or bearing walls is not over 33 feet; if the distance between the main or bearing walls is over 33 feet the brick partition-wall shall be not less than 12 inches thick; provided, that no clear span is over 26 feet. No wall shall be built having any one thickness measuring vertically more than 50 feet. This section shall not be construed to prevent the use of iron or steel girders, or iron or steel girders and columns, or piers of masonry, for the support of the walls and ceilings over any room which has a clear span of more than 26 feet between walls, in such dwellings as are not constructed fire-proof, nor to prohibit the use of iron or steel girders, or iron or steel girders and columns in place of brick walls in buildings which are to be used for dwellings when constructed fireproof. If the clear span is to be over 26 feet, then the bearing-walls shall be increased 4 inches in thickness for every $12\frac{1}{2}$ feet or part thereof that said span is over 26 feet, or shall have, instead of the increased thickness, such piers or buttresses as, in the judgment of the Commissioner of Buildings having jurisdiction, may be necessary.

Whenever two or more dwelling-houses shall be constructed not over 12 feet 6 inches in width, and not over 50 feet in height, the alternating centre wall between any two such houses shall be of brick not less than 8 inches thick above the foundation-wall; and the ends of the floor-beams shall be so separated that 4 inches of brickwork will be between the beams where they rest on the said centre wall.

Sec. 32. *Walls for Warehouses.*—The expression “walls for warehouses” shall be taken to mean and include in this class walls for the following buildings:

Warehouses, stores, factories, mills, printing-houses, pumping-stations, refrigerating-houses, slaughter-houses, wheelwright-shops, cooperage-shops, breweries, light- and power-houses, sugar-refineries, office-buildings, stables, markets, railroad buildings, jails, police-stations, court-houses, observatories, foundries, machine-shops, public assembly buildings, armories, churches, theatres, libraries, museums. The walls of all warehouses 25 feet or less in width between walls or bearings shall be not less than 12 inches thick to the height of 40 feet above

the foundation-walls. If over 40 feet in height, and not over 60 feet in height, the walls shall be not less than 16 inches thick above the foundation-walls to the height of 40 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top. If over 60 feet in height, and not over 75 feet in height, the walls shall be not less than 20 inches thick above the foundation-walls to the height of 25 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches thick to the top. If over 75 feet in height, and not over 100 feet in height, the walls shall be not less than 24 inches thick above the foundation-walls to the height of 40 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 75 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches thick to the top. If over 100 feet in height, and not over 125 feet in height, the walls shall be not less than 28 inches thick above the foundation-walls to the height of 40 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 75 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 110 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches thick to the top. If over 125 feet in height, and not over 150 feet the walls shall be not less than 32 inches thick above the foundation-walls to the height of 30 feet, or to the nearest tier of beams to that height; thence not less than 28 inches thick to the height of 65 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 100 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 135 feet, or to the nearest tier of beams to that height; and thence not less than 16 inches thick to the top. If over 150 feet in height, each additional 25 feet in height, or part thereof next above the foundation-walls shall be increased 4 inches in thickness, the upper 150 feet of wall remaining the same as specified for a wall of that height.

If there is to be a clear span of over 25 feet between the bearing-walls, such walls shall be 4 inches more in thickness than in this section specified, for every $12\frac{1}{2}$ feet, or fraction thereof, that said walls are more than 25 feet apart, or shall have instead of the increased thickness such piers or buttresses as, in the judgment of the Commissioner of Buildings, may be necessary.

The walls of buildings of a public character shall be not less than in this Code specified for warehouses with such piers or buttresses, or supplemental columns of iron or steel, as, in the judgment of the Commissioner of Buildings having jurisdiction, may be necessary to make a safe and substantial building.

In all stores, warehouses, and factories over 25 feet in width between walls there shall be brick partition-walls, or girders supported on iron, steel, or wood columns, or piers of masonry.

In all stores, warehouses, or factories, in case iron, steel, or wood girders, supported by iron, steel, or wood columns, or piers of masonry, are used in place of brick partition-walls, the building may be 75 feet wide and 210 feet deep, when extending from street to street, or when otherwise located may cover an area of not more than 8000 superficial feet. When a building fronts on three streets it may be 105 feet wide and 210 feet deep, or if a corner building fronting on two streets it may cover an area of not more than 12,500 superficial feet; but in no case wider nor deeper, nor to cover a greater area, except in the case of fire-proof buildings. An area greater than herein stated may, considering location and purpose, be allowed by the Board of Buildings when the proposed building does not exceed three stories in height.

Sec. 33. *Increased Thicknesses of Walls for Buildings more than 105 feet in Depth.*—All buildings, not excepting dwellings that are over 105 feet in depth, without a cross-wall or proper piers or buttresses, shall have the side or bearing-walls increased in thickness 4 inches more than is specified in the respective sections of this Code for the thickness of walls for every 105 feet, or part thereof, that the said buildings are over 105 feet in depth.

Sec. 34. *Reduced Thickness for Interior Walls.*—In case the walls of any building are less than 25 feet apart, and less than 40 feet in depth, or there are cross-walls which intersect the walls, not more than 40 feet distant, or piers or buttresses built into the walls, the interior walls may be reduced in thickness in just proportion to the number of cross-walls, piers, or buttresses, and their nearness to each other; provided, however, that this clause shall not apply to walls below 60 feet in height, and that no such wall shall be less than 12 inches thick at the top, and gradually increased in thickness by set-offs to the bottom. The Commissioner of Buildings having jurisdiction is hereby authorized and empowered to decide (except

where herein otherwise provided for) how much the walls herein mentioned may be permitted to be reduced in thickness, according to the peculiar circumstances of each case, without endangering the strength and safety of the building.

Sec. 35. *One-story Brick Buildings*.—One-story structures not exceeding a height of 15 feet may be built with 8-inch walls when the bearing-walls are not more than 19 feet apart, and the length of the 8-inch bearing-walls does not exceed 55 feet. One-story and basement extensions may be built with 8-inch walls when not over 20 feet wide, 20 feet deep, and 20 feet high to dwellings.

Sec. 36. *Inclosure Walls for Skeleton Structures*.—Walls of brick built in between iron or steel columns, and supported wholly or in part on iron or steel girders, shall be not less than 12 inches thick for 75 feet of the uppermost height thereof, or to the nearest tier of beams to that measurement, in any building so constructed, and every lower section of 60 feet, or to the nearest tier of beams to such vertical measurement, or part thereof, shall have a thickness of 4 inches more than is required for the section next above it down to the tier of beams nearest to the curb-level; and thence downward, the thickness of walls shall increase in the ratio prescribed in section 26, this Code.

Sec. 37. *Curtain-walls*.—Curtain-walls built in between piers or iron or steel columns and not supported on steel or iron girders, shall be not less than 12 inches thick for 60 feet of the uppermost height thereof, or nearest tier of beams to that height, and increased 4 inches for every additional section of 60 feet or nearest tier of beams to that height.

Sec. 38. *Existing Party Walls*.—Walls heretofore built for or used as party walls, whose thickness at the time of their erection was in accordance with the requirements of the then existing laws, but which are not in accordance with the requirements of this Code, may be used, if in good condition, for the ordinary uses of party walls, provided the height of the same be not increased.

Sec. 39. *Lining Existing Walls*.—In case it is desired to increase the height of existing party or independent walls, which are less in thickness than required under this Code, the same shall be done by a lining of brickwork to form a combined thickness with the old wall of not less than 4 inches more than the thickness required for a new wall corresponding with the total height of the wall when so increased in height. The

said linings shall be supported on proper foundations and carried up to such height as the Commissioner of Buildings having jurisdiction may require. No lining shall be less than 8 inches in thickness, and all lining shall be laid up in cement mortar and thoroughly anchored to the old brick walls with suitable wrought-iron anchors, placed 2 feet apart and properly fastened or driven into the old walls in rows alternating vertically and horizontally with each other, the old walls being first cleaned of plaster or other coatings where any lining is to be built against the same. No rubble wall shall be lined except after inspection and approval by the Department.

Sec. 40. *Walls of Unfinished Buildings.*—Any building, the erection of which was commenced in accordance with specifications and plans submitted to and approved by the Department of Buildings prior to the passage of this Code, if properly constructed, and in safe condition, may be completed, or built upon in accordance with the requirements of law, as to thickness of walls, in force at the time when such specification and plans were approved.

Sec. 41. *Walls Tied, Anchored, and Braced.*—In no case shall any wall or walls of any building be carried up more than two stories in advance of any other wall, except by permission of the Commissioner of Buildings having jurisdiction, but this prohibition shall not include the inclosure walls for skeleton buildings. The front, rear, side and party walls shall be properly bonded together, or anchored to each other every 6 feet in their height by wrought-iron tie anchors, not less than $1\frac{1}{2}$ inches by $\frac{3}{8}$ inch in size, and not less than 24 inches in length. The side anchors shall be built into the side or party walls not less than 16 inches, and into the front and rear walls, so as to secure the front and rear walls to the side, or party walls, when not built and bonded together. All exterior piers shall be anchored to the beams or girders on the level of each tier. The walls and beams of every building, during the erection or alteration thereof, shall be strongly braced from the beams of each story, and when required, shall also be braced from the outside, until the building is inclosed. The roof tier of wood beams shall be safely anchored, with plank or joist, to the beams of the storly below until the building is inclosed.

Sec. 42. *Arches and Lintels.*—Openings for doors and windows in all buildings shall have good and sufficient arches of stone, brick, or terra-cotta, well built and keyed with good

and sufficient abutments, or lintels of stone, iron, or steel of sufficient strength, which shall have a bearing at each end of not less than 5 inches on the wall. On the inside of all openings in which lintels shall be less than the thickness of the wall to be supported, there shall be timber lintels, which shall rest at each end not more than 3 inches on any wall, which shall be chamfered at each end, and shall have a suitable arch turned over the timber lintel. Or the inside lintel may be of cast iron, or wrought iron or steel, and in such case stone blocks or cast-iron plates shall not be required at the ends where the lintel rests on the walls, provided the opening is not more than 6 feet in width.

All masonry arches shall be capable of sustaining the weight and pressure which they are designed to carry, and the stress at any point shall not exceed the working stress for the material used, as given in section 139 of this Code. Tie-rods shall be used where necessary to secure stability.

Sec. 43. *Parapet Walls*.—All exterior and division or party walls over 15 feet high, excepting where such walls are to be finished with cornices, gutters, or crown mouldings, shall have parapet walls not less than 8 inches in thickness and carried 2 feet above the roof, but for warehouses, factories, stores, and other buildings used for commercial or manufacturing purposes the parapet walls shall be not less than 12 inches in thickness and carried 3 feet above the roof, and all such walls shall be coped with stone, terra-cotta, or cast iron.

Sec. 44. *Hollow Walls*.—In all walls that are built hollow the same quantity of stone, brick, or concrete shall be used in their construction as if they were built solid, as in this Code provided, and no hollow wall shall be built unless the parts of same are connected by proper ties, either of brick, stone, or iron, placed not over 24 inches apart.

Sec. 45. *Hollow Bricks on Inside of Walls*.—The inside 4 inches of all walls may be built of hard-burnt hollow brick, properly tied and bonded into the walls, and of the dimension of ordinary bricks. Where hollow tile or porous terra-cotta blocks are used as lining or furring for walls, they shall not be included in the measurement of the thickness of such walls.

Sec. 46. *Recesses and Chases in Walls*.—Recesses for stairways or elevators may be left in the foundation- or cellar-walls of all buildings, but in no case shall the walls be of less thickness than the walls of the fourth story, unless reinforced by

additional piers with iron or steel girders, or iron or steel columns and girders, securely anchored to walls on each side. Recesses for alcoves and similar purposes shall have not less than 8 inches of brickwork at the back of such recesses, and such recesses shall be not more than 8 feet in width, and shall be arched over or spanned with iron or steel lintels, and not carried up higher than 18 inches below the bottom of the beams of the floor next above. No chase for water or other pipes shall be made in any pier, and in no wall more than one-third of its thickness. The chases around said pipe or pipes shall be filled up with solid masonry for the space of 1 foot at the top and bottom of each story. No horizontal recess or chase in any wall shall be allowed exceeding 4 feet in length without permission of the Commissioner of Buildings having jurisdiction. The aggregate area of recesses and chases in any wall shall not exceed one-fourth of the whole area of the face of the wall on any story, nor shall any such recess be made within a distance of 6 feet from any other recess in the same wall.

Sec. 47. *Furred Walls*.—In all walls furred with wood the brickwork between the ends of wood beams shall project the thickness of the furring beyond the inner face of the wall for the full depth of the beams.

Sec. 48. *Light and Vent Shafts*.—In every building hereafter erected or altered, all the walls or partitions forming interior light or vent shafts, shall be built of brick, or such other fire-proof materials as may be approved by the Commissioner of Buildings having jurisdiction. The walls of all light or vent shafts, whether exterior or interior, hereafter erected, shall be carried up not less than 3 feet above the level of the roof, and the brick walls coped as other parapet walls. Vent shafts to light interior bathrooms in private dwellings may be built of wood filled in solidly with brick or hard-burnt clay blocks, when extending through not more than one story in height, and carried not less than 2 feet above the roof, covered with a ventilating skylight of metal and glass.

Sec. 49. *Brick and Hollow-tile Partitions*.—Eight-inch brick and 6-inch and 4-inch hollow-tile partitions, of hard-burnt clay, or porous terra-cotta, may be built, not exceeding in their vertical portions a measurement of 50, 36, and 24 feet respectively, and in their horizontal measurement a length not exceeding 75 feet, unless strengthened by proper cross-walls, piers, or buttresses, or built in iron or steel framework. All such partitions shall

be carried on proper foundations, or on iron or steel girders, or on iron or steel girders and columns or piers of masonry.

Sec. 50. *Cellar Partitions in Residence Buildings.*—One line of fore-and-aft partitions in the cellar or lowest story, supporting stud partitions above, in all residence buildings over 20 feet between bearing-walls in the cellar or lowest story, hereafter erected, shall be constructed of brick, not less than 8 inches thick, or piers of brick with openings arched over below the under side of the first tier of beams, or girders of iron or steel and iron columns, or piers of masonry may be used; or if iron or steel floor beams spanning the distance between bearing-walls are used of adequate strength to support the stud partitions above in addition to the floor load to be sustained by the said iron or steel beams, then the fore-and-aft brick partition, or its equivalent, may be omitted.

Stud partitions which may be placed in the cellar or lowest story of any building shall have good solid stone or brick foundation-walls under the same, which shall be built up to the top of the floor-beams or sleepers, and the sills of said partitions shall be of locust or other suitable hard wood; but if the walls are built 5 inches higher of brick than the top of the floor-beams or sleepers, any wooden sill may be used on which the studs shall be set.

Sec. 51. *Main Stud Partitions.*—In residence buildings where fore-and-aft stud partitions rest directly over each other, they shall run down between the wood floor-beams and rest on the top plate of the partition below, and shall have the studding filled in solid between the uprights to the depth of the floor-beams with suitable incombustible materials.

Sec. 52. *Timber in Walls Prohibited.*—No timber shall be used in any wall of any building where stone, brick, or iron is commonly used, except inside lintels, as herein provided, and brace blocks not more than 8 inches in length.

POINTING.—Fig. 122 shows different styles of pointing used in face brickwork, that shown at *I* being the most common, or what is known as the struck joint; it is made with the point of the trowel, using the lower course of brick to rest the trowel on, and the top course as a guide for drawing the trowel along.

Some architects object to this style of joint, claiming the small projection on the lower course forms a table to catch the water, and preferring that shown at *K*, which is just the reverse of that at *I*. The author has used both, and for looks prefers

that shown at *I*, for this reason: A person standing on the ground and looking up at a wall with joints struck as shown at *K*, the eye will catch the little projection on every course of brick and cause the wall to look rough, but with the method

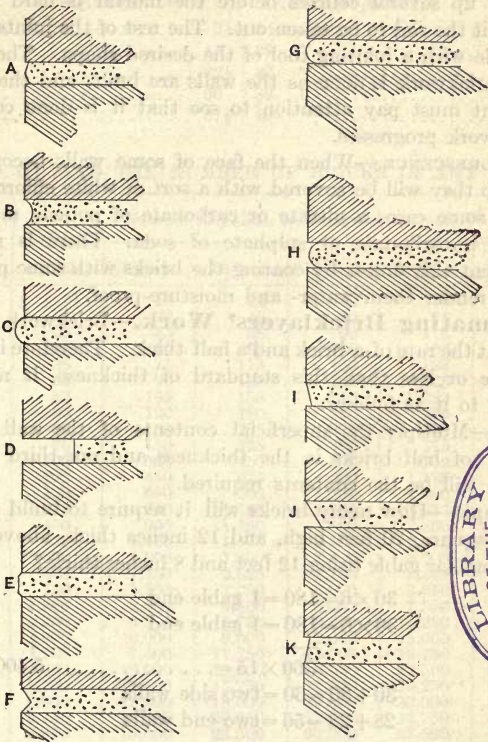


FIG. 122.

shown at *I*, the projections cannot be seen and the wall looks perfectly smooth to the eye.

One point the superintendent must watch in striking the joints is to see that the mason holds his trowel at the right angle and does not strike the joint as shown at *J*. The method shown at *A* is much used in press-brick work, being a combination of the methods shown at *I* and *K*. The joint shown at *D* is



made by using an iron rod the thickness of the joint; this is laid on the face edge of the brick already laid and the mortar spread out to it; after the bricks are laid and the mortar has sufficiently hardened the rod is taken out and the mortar smoothed, if necessary, with a tool. It takes several rods, as the mason will lay up several courses before the mortar is hard enough to permit the rod to be taken out. The rest of the joints shown are made with a jointing tool of the desired shape. The pointing of brickwork is done as the walls are built, and the superintendent must pay attention to see that it is done correctly as the work progresses.

EFFLORESCENCE.—When the face of some walls become wet or damp they will be covered with a sort of white efflorescence; it is in some cases a nitrate or carbonate of potash, more frequently a carbonate or sulphate of soda. There is no way to prevent this unless by coating the bricks with some preparation to render them water- and moisture-proof.

Estimating Bricklayers' Work.—Brickwork is estimated at the rate of a brick and a half thick. Therefore if a wall be more or less than this standard of thickness, it must be reduced to it as follows:

Rule.—Multiply the superficial contents of the wall by the number of half bricks in the thickness and one-third of that product will be the contents required.

Example.—How many bricks will it require to build a house 30 feet square, 20 feet high, and 12 inches thick, above which is a triangular gable rising 12 feet and 8 inches thick ?

$$\begin{array}{r}
 30 \times 6 = 180 = 1 \text{ gable end} \\
 30 \times 6 = 180 = 1 \text{ gable end} \\
 \hline
 360 \times 15 = \dots\dots\dots 5,400 \\
 30 + 30 = 60 = \text{two side walls} \\
 28 + 28 = 56 = \text{two end walls} \\
 \hline
 116 \\
 20 = \text{height} \\
 \hline
 2320 \times 22\frac{1}{2} = \dots\dots\dots 52,200 \\
 \hline
 57,600 \text{ (Ans.)}
 \end{array}$$

One barrel lime will lay 1000 to 1200 bricks.

One man with one tender will lay 1800 to 2000 bricks per day.

One thousand bricks closely stacked occupy 56 cubic feet.

One thousand old bricks cleaned and loosely stacked occupy about 70 cubic feet.

Six hundred bricks, 1 cubic yard in wall.

TABLE OF NUMBER OF BRICKS REQUIRED IN A WALL PER SQUARE FOOT OF FACE OF WALL.

| | | | |
|---------------|-----|----------------|-----|
| 4 inches..... | 7½ | 24 inches..... | 45 |
| 8 "..... | 15 | 28 "..... | 52½ |
| 12 "..... | 22½ | 32 "..... | 60 |
| 16 "..... | 30 | 36 "..... | 67½ |
| 20 "..... | 37½ | 40 "..... | 75 |

TABLE TO FIND THE NUMBER OF BRICKS IN ANY WALL.

| Superficial Feet of Wall. | Number of Bricks to Thickness of Wall. | | | | | |
|---------------------------|--|---------|----------|----------|----------|----------|
| | 4-inch. | 8-inch. | 12-inch. | 16-inch. | 20-inch. | 24-inch. |
| 1 | 7½ | 15 | 23 | 30 | 38 | 45 |
| 2 | 15 | 30 | 45 | 60 | 75 | 90 |
| 3 | 23 | 45 | 68 | 90 | 113 | 135 |
| 4 | 30 | 60 | 90 | 120 | 150 | 180 |
| 5 | 38 | 75 | 113 | 150 | 188 | 225 |
| 6 | 45 | 90 | 135 | 180 | 225 | 270 |
| 7 | 53 | 105 | 158 | 210 | 263 | 315 |
| 8 | 60 | 120 | 180 | 240 | 300 | 300 |
| 9 | 68 | 135 | 203 | 270 | 338 | 405 |
| 10 | 75 | 150 | 225 | 300 | 375 | 450 |
| 20 | 150 | 300 | 450 | 600 | 750 | 900 |
| 30 | 225 | 450 | 675 | 900 | 1,125 | 1,350 |
| 40 | 300 | 600 | 900 | 1,200 | 1,500 | 1,800 |
| 50 | 375 | 750 | 1,125 | 1,500 | 1,875 | 2,250 |
| 60 | 450 | 900 | 1,350 | 1,800 | 2,250 | 2,700 |
| 70 | 525 | 1,050 | 1,575 | 2,100 | 2,625 | 3,150 |
| 80 | 600 | 1,200 | 1,800 | 2,400 | 3,000 | 3,600 |
| 90 | 675 | 1,350 | 2,025 | 2,700 | 3,375 | 4,050 |
| 100 | 750 | 1,500 | 2,250 | 3,000 | 3,750 | 4,500 |
| 200 | 1,500 | 3,000 | 4,500 | 6,000 | 7,500 | 9,000 |
| 300 | 2,250 | 4,500 | 6,750 | 9,000 | 11,250 | 13,500 |
| 400 | 3,000 | 6,000 | 9,000 | 12,000 | 15,000 | 18,000 |
| 500 | 3,750 | 7,500 | 11,250 | 15,000 | 18,750 | 22,500 |
| 600 | 4,500 | 9,000 | 13,500 | 18,000 | 22,500 | 27,000 |
| 700 | 5,250 | 10,500 | 15,750 | 21,000 | 26,250 | 31,500 |
| 800 | 6,000 | 12,000 | 18,000 | 24,000 | 30,000 | 36,000 |
| 900 | 6,750 | 13,500 | 20,250 | 27,000 | 33,750 | 40,500 |
| 1,000 | 7,500 | 15,000 | 22,500 | 30,000 | 37,500 | 45,000 |

Example.—Find the number of bricks in a wall 8 inches thick, 5 feet high, and 10 feet long; five multiplied by ten equals 50 feet of wall 8 inches thick. Under 8 inches and opposite 50 you will find 750, the number of bricks in the wall.

The above tables are based on the usual sizes of Eastern brick; Western brick are made some larger and will take a slight percentage less than in the above tables.

Paving, etc.—As a guide for street-paving, etc., the following specifications are given which form a good guide for such work:

SPECIFICATIONS.

CITY OF CHICAGO, BOARD OF LOCAL IMPROVEMENTS.

COMBINED CURB AND GUTTER. STREET-PAVING. PORTLAND-CEMENT FOUNDATION. WEARING SURFACE, EITHER BRICK OR ASPHALT.

COMBINED CURB AND GUTTER.—In making the combined curb and gutter Portland cement shall be used and ordinarily will be subjected to the following inspection and tests:

Fineness.—It shall be so ground that nine-two (92) per cent will pass through a standard No. 100 sieve having 10,000 meshes per square inch.

Soundness.—It shall meet the requirement of the "boiling" test.

Setting.—The cement when mixed with twenty (20) per cent of water, by measure, shall take initial set in not less than forty-five (45) minutes.

Strength.—Briquettes one (1") inch square in section shall develop the following ultimate tensile strength:

Neat—one day in air and 6 days in water, 400 pounds.

One (1) part cement to two (2) parts fine granite screenings—one day in air and 6 days in water, 200 pounds; and shall show a gradual increase in strength of fifteen (15) per cent at the end of twenty-eight (28) days.

Samples of cements which it is proposed to use in the work shall be submitted to the Board of Local Improvements in such quantities and such time and place as to make all the required tests.

The Board of Local Improvements reserves the right to reject without recourse any cement which is not satisfactory, whether for reasons mentioned in these specifications or for any good and sufficient cause.

All cement to be used in the combined curb and gutter must be delivered on the work in approved packages bearing the name, brand, or stamp of the manufacturer. It shall be thoroughly protected from the weather until used, in such manner as may be directed.

The granite screenings used in making the concrete shall be clean, dry, free from dust, loam, and dirt, and when delivered on the street shall be deposited on flooring and kept clean until used.

The crushed granite shall be clean, free from dust and dirt, broken so as to measure not more than one (1") inch in any dimension, and when delivered on the street shall be deposited on a flooring and kept clean until used.

The granite concrete combined curb and gutter shall be constructed at the established grade and in a continuous line on each side of the street (..') feet from and parallel with the centre line thereof, except at all intersections of streets and alleys, where it shall be returned to the street line, and at such intersections there shall be formed the necessary circular stones built to such radii as the engineer may direct. All grades and lines will be given by the engineer. The combined curb and gutter shall rest on a foundation of cinders which must be six (6") inches in thickness after being thoroughly flooded and compactly rammed to an even surface.

The curb and gutter shall be made of concrete formed by intimately mixing one (1) part of cement with two (2) parts of fine granite screenings; to this mixture shall be added four (4) parts of crushed granite and the whole thoroughly mixed together, after which just sufficient water to wet the mass shall be added, so that when it is rammed in place a film of moisture shall appear on top. All exposed surfaces shall be covered with a finishing coat of mortar three-eighths ($\frac{3}{8}$ ") inch in thickness, composed of one (1) part of the cement thoroughly mixed with one and one-half ($1\frac{1}{2}$) parts of the fine granite screenings. Before the concrete sets, the curb and gutter shall be cut into sections not exceeding six (6') feet in length.

The gutter flag must be eighteen (18") inches wide and five (5") inches thick; the curb must be seven (7") inches thick throughout, except at the upper face corner, which is to be rounded to a radius of one and one-half ($1\frac{1}{2}$ ") inches. The height of the curve above the gutter flags will be of varying dimensions, averaging not less than (..") inches.

The contractor or contractors shall build without extra charge all "inlets" necessary to properly connect the combined curb and gutter with the catch-basins and such steps on the gutter flags at the crossings as the engineer may direct.

The curb and gutter shall be back-filled to the top, and filling

at that point shall be four (4') feet wide and shall have a slope of one and one-half ($1\frac{1}{2}$) horizontal to one (1) vertical. The full quantity of filling shall be put in front and back of each section of curb and gutter as it is built, and must be thoroughly rammed with a proper rammer at the same time so that the curb and gutter will be firmly held in place.

CONCRETE FOUNDATION.—After the sub-grade is prepared a foundation of Portland-cement concrete to a uniform thickness of six (6") inches shall be laid.

CEMENT.—In making the concrete, Portland cement shall pass same specifications as for cement used in curb and gutter work.

SAND.—The sand used in making the concrete shall be clean, dry, free from dust, loam, and dirt, of sizes ranging from one-eighth ($\frac{1}{8}$ ") inch down to the finest, and in such proportion that the voids as determined by saturation shall not exceed thirty-three (33) per cent of the entire volume, and it shall weigh not less than one hundred (100) pounds per cubic foot.

No wind-drifted sand shall be used.

The sand when delivered on the street shall be deposited on flooring and kept clean until used.

CRUSHED STONE.—The crushed stone used in making the concrete shall be of the best quality of limestone, clean, free from dirt, broken so as to measure not more than two (2") inches and not less than one (1") inch in any dimension.

The stone when delivered on the street shall be deposited on flooring and kept clean until used.

MIXING AND LAYING OF CONCRETE.—The concrete shall be mixed on movable tight iron platforms of such size as shall accommodate the manipulations hereinafter specified.

The cement, sand, and stone shall be mixed in the following proportions: One (1) part of cement, three (3) parts of sand, and seven (7) parts of crushed stone. The sand and cement shall be thoroughly mixed, dry, to which sufficient water shall be added and then made into a stiff mortar. The crushed stone shall then be immediately incorporated in the mortar and the mass thoroughly mixed, adding water from time to time as the mixing progresses, until each particle of stone is covered with mortar.

The concrete shall be removed from the platform with shovels and deposited in a layer on the roadway in such quantities that after being rammed in place it shall be of the required thickness

and the upper surface shall be true and smooth and (..") inches below and parallel with the top of the finished pavement.

During the progress of the work the sub-grade must be kept moist.

The concrete shall be sprinkled so as to prevent checking in hot weather, and shall be protected from injury at all times, and shall lay at least seven days before being covered with the wearing surface, or a longer time if deemed necessary.

SAND CUSHION.—Upon the concrete foundation shall be spread a layer of sand in such quantity as to insure, when compacted, a uniform thickness of one (1") inch.

On surfacing said layer of sand the contractor or contractors shall use such guides and templets as the engineer may direct.

WEARING SURFACE.—Upon the layer of sand as above specified shall be placed the brick of such quality and in such manner as hereinafter specified.

QUALITY OF BRICKS.—The brick to be used shall be of the best quality of vitrified paving brick. Salt-glazed bricks will not be received.

The dimensions of the brick used shall be the same throughout the entire work in any particular case, and shall be not less than eight (8") inches in length, four (4") inches in depth, and two and one-half ($2\frac{1}{2}$ ") inches in thickness, with rounded edges to a radius of one-quarter ($\frac{1}{4}$ ") of an inch.

Said brick shall be of a kind known as repressed vitrified paving brick and shall be repressed to the extent that the maximum amount of material is forced into them. They shall be free from lime and other impurities, shall be as nearly uniform in every respect as possible, shall be burned so as to secure the maximum hardness, so annealed as to reach the ultimate degree of toughness, and thoroughly vitrified so as to make a homogeneous mass.

The bricks shall be free from all laminations caused by the process of manufacture, and free from fire-cracks or checks of more than superficial character or extent.

Any firm, person, or corporation bidding for the work to be done shall furnish specimen brick, which shall be submitted to a "water-absorption" test, and if such brick show a water absorption exceeding three (3) per cent of their weight when dry, the bid of the person, firm, or corporation so furnishing the same shall be rejected. Such "water-absorption" test shall be made by the Board of Local Improvements of the City of

Chicago, in the following manner, to wit: Not less than three (3) bricks shall be broken across, thoroughly dried, and then immersed in water for seventy-two (72) hours. The absorption shall then be determined by the difference between the weight dry and the weight at the expiration of said seventy-two (72) hours.

Twenty or more specimen bricks shall also be furnished by each bidder for submission to the "abrasion" test by the Board of Local Improvements. Such test shall be made in the following manner, to wit: Such specimen brick or a sufficient number to fill 15 per cent of the volume of the rattler shall be submitted to a test for one hour in the machine known as the "rattler," which shall measure twenty (20'') inches in length and twenty-eight (28'') inches in diameter, inside measurement, and shall be revolved at the rate of thirty (30) revolutions per minute. If the loss of weight by abrasion during such test shall exceed twenty (20) per cent of the original weight of the brick tested, then such bid shall be rejected.

All brick shall have a specific gravity of not less than two and one-tenth ($2\frac{1}{10}$), as determined by the formula specific gravity equals $\frac{W}{W'W''}$; where W equals weight of brick dry, W' equals weight of brick after being immersed in water for seventy-two (72) hours, and W'' equals weight of brick in water.

All brick used must be equal in every respect to the specimen submitted by the bidders to the Board of Local Improvements for test.

How Laid.—All brick shall be delivered on the work in barrows, and in no case will teams be allowed on the street before the wearing surface is rolled.

Broken bricks can only be used to break joints in starting courses and in making closures, but in no case shall less than half a brick be used.

The bricks shall be laid on edge, close together, in straight lines across the roadway, between gutters, and at right angles to the curbs and perpendicular to the grade of the street. Gutters shall be constructed as directed by the engineer.

The joints shall be broken by a lap of not less than three (3'') inches.

On intersections and junctions of lateral streets the bricks shall be laid at an angle of forty-five (45°) degrees with the line of the street unless otherwise ordered by the engineer.

The bricks when set shall be rolled with a roller weighing not less than five (5) tons until the bricks are well settled and made firm. Or, if the engineer shall direct, the bricks, when set, shall be thoroughly rammed two or more times, the ramming to be done under a flatter, with a paving rammer weighing not less than thirty (30) pounds, the iron of the rammer face in no case to come in contact with the pavement.

After rolling and ramming, all broken brick found in the pavement must at once be removed and replaced by sound and perfect brick.

PITCHING OR GROUTING AND TOP-DRESSING.—When the bricks are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the brick shall be completely filled with a paving pitch which is the direct result of the distillation of "straight-run" coal-tar, and of such quality and consistency as shall be approved by the Board of Local Improvements. The pitch must be used at a temperature of not less than 280 degrees Fahrenheit.

When the brick are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the bricks shall be filled with a cement grout filler composed of limestone 65 per cent, furnace slag 25 per cent, and potters' clay 10 per cent, to be made as follows: The above materials in the proportions stated shall be mixed together and ground into an impalpable powder and then burned in kilns until reduced to clinker, after which it shall again be ground into an impalpable powder. Equal portions of said grout and clean, sharp sand shall then be thoroughly mixed, and sufficient water added to bring the mixture to such a consistency as will allow it to run to the bottom of the joints between the brick. After said joints are filled to the top, the surface shall be finished off smoothly with steel brooms.

After the spaces between the brick have been filled with the pitch or grout as above specified, the surface of the pavement shall then receive a one-half ($\frac{1}{2}$ ") inch dressing of sand, evenly spread over the whole surface.

Where cement grout is used as a filler the pavement must be kept clear of traffic for a period of four (4) days—or as much longer as the engineer may direct—after the application thereof.

ASPHALTIC CEMENT.—The asphaltic cement hereinafter speci-

fied shall be made of refined Trinidad Lake asphalt, obtained from the island of Trinidad, or of an asphalt of equal quality for paving purposes, and heavy petroleum-oil. The oil shall be mixed with the asphalt in such proportions as are suitable to the character of the asphalt used.

BINDER COURSE.—Upon the concrete foundation as above specified shall be laid a "binder" course, composed of clean broken limestone of a size known as "small concrete," and asphaltic cement. The stone shall be heated and thoroughly mixed with asphaltic cement in the proportion of fifteen (15) gallons of asphaltic cement to one (1) cubic yard of stone; the mixing shall be continued until each particle of stone is thoroughly coated with the asphaltic cement. This binder shall be spread on the base above described, and, while in a hot and plastic condition, shall be rolled with a five (5) ton steam-roller until it has a uniform thickness of one and one-half ($1\frac{1}{2}$ "') inches. The upper surface shall be parallel with and two (2"') inches below the final surface of the pavement.

Binder that has been burned or has become chilled shall be removed from the line of the work.

WEARING SURFACE.—Upon this binder course shall be laid a wearing surface, which shall be composed of asphaltic cement seventeen (17) parts, sand seventy-three (73) parts, and pulverized carbonate of lime ten (10) parts. The sand and asphaltic cement shall be heated separately to a temperature of three-hundred (300°) degrees Fahrenheit. The pulverized carbonate of lime shall be mixed with the sand, and these ingredients then mixed with the asphaltic cement at the above temperature, in an apparatus which shall effect a perfect mixture.

The mixture at a temperature of not less than two hundred and fifty (250°) degrees Fahrenheit shall then be carefully spread by means of hot iron rakes in such a manner as to give a uniform and regular grade, and on such a depth that after having received its ultimate compression it will have a thickness of two (2"') inches. The surface shall be compressed by rollers, after which a small amount of hydraulic cement shall be swept over it, and it shall then be thoroughly compressed by a fifteen (15) ton steam-roller, the rolling being continued as long as it makes an impression on the surface.

Where necessary to make the gutters impervious to water, a width of twelve (12"') inches next to the curb shall be coated

with hot pure asphalt and smoothed with hot smoothing-irons in order to saturate the pavement with excess of asphalt.

HEADERS.—At the end of each intersecting street and alley wing there shall be placed a "header," extending from curb to curb, and so dressed as to conform to the crown of the pavement. The "header" shall be constructed of three by twelve (3"×12") inch oak plank, properly supported by six (6") inch split cedar posts, three (3') feet in length, firmly set in the ground and spaced not more than five (5') feet apart.

All "headers" shall be constructed by the contractor or contractors without extra charge.

CROSSWALKS.—Unless otherwise directed by the engineer there shall be formed in the pavement four (4) crosswalks at each street intersection, three (3) at each half intersection, and one (1) near the middle of each long block. A gutter nine (9") inches in the clear width shall be constructed at the ends of the crosswalks by setting sandstone curbing in the roadway nine (9") inches from and parallel with the curb line. The sandstone curbing must be four (4") inches thick and twenty-four (24") inches deep, and the length of the curbing shall be within two (2') feet of the width of the abutting sidewalk space; provided, however, that the minimum length of said curbing shall be six (6') feet.

The crosswalks, gutters, and their appurtenances shall be formed and constructed where and as directed by the engineer, and without extra cost over and above the price paid per square yard for the pavement.

PART III.

LIME, SAND, CEMENT, MORTAR, AND CON- CRETE. CONCRETE CONSTRUCTION. FIRE-PROOF FLOOR CONSTRUCTION, PARTITIONS, ETC. ARCHITECTURAL TERRA - COTTA. FIRE - PROOF CON- STRUCTION AND FIRE PROTECTION OF BUILDINGS.

Lime, Sand, and Cement.—Mortar is one of the principal materials used in construction, and upon which the strength and stability of the structure depends to a great extent; hence the different materials and proportions used in making the mortar must receive particular attention from the superintendent. He must be so familiar with the different materials used that he will be able to judge the quality of them so as to determine any worthless material and reject it at once.

SAND.—Sand, which enters largely into the composition of all mortars, should be sharp and angular and comparatively free from any dirt or loam. Recent experiments have shown that a slight percentage of clay in the sand used for cement mortar does not affect its strength, but there should not be more than 5 per cent of clay in the sand. For rough stone or common brick work the sand should be coarse, but for "press" brick and setting ashlar it should be fine, so as to get a close joint. Marble dust is often used in place of sand where a close joint is desired in the work.

By taking a small amount of sand and spreading it over the hand or examining it with a magnifying-glass the superintendent can readily determine its quality.

When ocean sand is used for plastering or any work where the salt is liable to come to the surface and show, it should be thoroughly washed.

For concrete or any rough work, the salt does not affect it.

LIME.—Lime is obtained by burning limestone. When carbonate of lime is calcined the carbonic acid is thrown off and lime is obtained. It is then known as caustic lime or quicklime; if it then be mixed with water it will throw out great heat, swell to several times its original bulk, and finally falls to a powder. In this state it is known as slaked or a hydrate of lime.

The quality of lime depends on the composition of the limestone from which it is made. Those stones which are nearly pure carbonate of lime make the best lime, while those which contain much impurities, such as silica, clay, magnesia, and alkalis, make the poorest lime according to the amount of impurities contained.

Good lime should be free from cinders or unburned stone, and not contain a large per cent of impurities; over 10 per cent of impurities makes poor lime and it should be rejected.

Lime should be in large hard pieces and contain little dust. When wet with water it should slake readily into a smooth, fine paste or putty. The lime should slake by simply immersing it in the water, although stirring it will hasten it somewhat.

The superintendent should see that the lime used is freshly burned and has not been exposed to the air, which will cause it to "air slake" and make it unfit for use; he should also see that proper provisions have been made to keep and protect the lime at the work, for lime exposed to a damp atmosphere for a day will absorb dampness enough to cause it to slake.

WHAT ONE BARREL OF LIME WILL DO.

- | | | | | | | | | | |
|---|--------|----|------|------|---------|-----------------|---------|------|-----------------|
| 1 | barrel | of | lime | will | make | 2 $\frac{3}{4}$ | barrels | of | paste. |
| 1 | " | " | " | " | lay | 3 | perch | of | stone rubble. |
| 1 | " | " | " | " | " | 1000 | to | 1200 | bricks. |
| 1 | " | " | " | " | plaster | 28 | yards | of | 3-coat work. |
| 1 | " | " | " | " | " | 40 | " | " | 2- " " |
| 1 | " | " | " | " | equals | 3 | bushels | of | 80 pounds each. |

HYDRAULIC LIME.—Hydraulic lime is made from calcareous rock containing 12 to 30 per cent of silica, alumina, iron, and

magnesia; when calcined at a low temperature it will slake and will set and harden in water in from one to ten days to five or six months, depending on the amount of silica and alumina contained. Hydraulic lime is not used much in this country, as natural cement takes its place. The following is an average of French hydraulic lime:

| | |
|----------------------|----------------|
| Silica. | 22.0 per cent |
| Alumina. | 2.0 “ |
| Oxide of iron. | 1.0 “ |
| Lime. | 63.0 “ |
| Magnesia. | 1.5 “ |
| Sulphuric acid. | 0.5 “ |
| Water. | 10.0 “ |
| | <hr/> |
| | 100.0 per cent |

Cements.—Natural cements are generally called Rosendale cement, from the name of the town in New York where it was first made in this country. It is made from a natural rock containing about 60 per cent of lime and magnesia to about 40 per cent of silica and alumina, with a little iron or potash. This cement sets and attains its limit of strength much quicker than Portland, and is used where extreme strength is not necessary. Portland cement, because the price is becoming cheaper than in former days, is now fast taking the place of Rosendale cement.

Rosendale cement is usually a dark brown; a light color indicates an inferior cement.

WEIGHT AND CHEMICAL ANALYSIS.—*Weight.*—The average weight of Louisville or Rosendale cement is as follows:

| | |
|----------------------------|-------------|
| 1 cubic foot, loose. | 55½ pounds. |
| 1 cubic foot, packed. | 74 “ |

Therefore a barrel of 265 pounds contains 4.77 cubic feet of loose cement and 3.58 cubic feet of packed cement.

Louisville cement is shipped in three kinds of packages: barrels, weighing 285 pounds gross; paper bags, 82 pounds each; and jute sacks, weighing 133 pounds each.

Chemical Analysis.—The following is a characteristic analysis of Louisville or Rosendale cement:

| | | |
|------------------------------------|-------|-----------------|
| Silica..... | 26.40 | per cent |
| Alumina..... | 6.28 | “ |
| Iron oxide..... | 1.00 | “ |
| Lime..... | 45.22 | “ |
| Magnesia..... | 9.00 | “ |
| Potash and soda..... | 4.24 | “ |
| Sulphate lime..... | 0.00 | “ |
| Carbonic acid, water, and loss.... | 7.86 | “ |
| | <hr/> | |
| | | 100.00 per cent |

The following specifications for natural cements have been prepared and are used by the United States Engineer Department;

SPECIFICATIONS FOR NATURAL CEMENT.

(1) The cement shall be a freshly packed natural or Rosendale, dry and free from lumps. By natural cement is meant one made by calcining natural rock at a heat below incipient fusion and grinding the product to powder.

(2) The cement shall be put up in strong, sound barrels, well lined with paper so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer.

Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established brands of high-grade natural cement which have been in successful use under similar climatic conditions to those of the proposed work.)

(5) The average net weight per barrel shall not be less than 300 pounds. (West of the Allegheny Mountains this may be 265 pounds.) . . . Sacks of cement shall have the same weight as 1 barrel. If the average net weight, as determined by test weighings, is found to be below 300 pounds (265) per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply free of cost to the United States an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, time of setting, and tensile strength of the cement.

(7) **FINENESS.**—At least 80 per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) **TIME OF SETTING.**—The cement shall not acquire its initial set in less than twenty minutes and must have acquired its final set in four hours.

(9) The time of setting is to be determined from a pat of neat cement mixed for five minutes with 30 per cent of water by weight and kept under a wet cloth until finally set. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(10) **TENSILE STRENGTH.**—Briquettes made of neat cement shall develop the following tensile strengths per square inch, after having been kept in air for twenty-four hours under a wet cloth and the balance of the time in water:

At the end of seven days, 90 pounds; at the end of twenty-eight days, 200 pounds.

Briquettes made of one part cement and one part standard sand by weight shall develop the following tensile strengths per square inch:

After seven days, 60 pounds; after twenty-eight days, 150 pounds.

(11) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(12) The neat cement for briquettes shall be mixed with 30

per cent of water by weight, and the sand and cement with 17 per cent of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar is to be placed in the briquette mould in four equal layers, each of which is to be rammed and compressed by thirty blows of a soft brass or copper rammer three-fourths of an inch in diameter (or seven-tenths of an inch square with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. Upon completion of ramming the surplus cement shall be struck off and the layer smoothed with a trowel held nearly horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(13) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of the bids. Any cement showing, by sample, higher tests than those given must maintain the average so shown in subsequent deliveries.

(14) A cement may be rejected which fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner above specified. All expenses of such tests shall be paid by the contractor, and all such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Portland Cement.—Portland cement is what is known as a tri-calcic cement and is composed of lime, silica, alumina, iron oxide, and magnesia artificially blended together into a scientifically correct mixture and burned at a white heat. The process varies greatly with the character of the raw materials used.

By the heat of the kiln the silica, lime, alumina, and oxide of iron become silicate of lime and alumina, and aluminate of lime and ferrite of lime. If the composition of these compounds is brought about in the right proportions in the molecule and in the mass, their nature is to crystallize when wet with water, and then harden till they become as rocks

When any lime leaves the kiln uncombined and is not changed to hydrate of lime, or carbonate of lime by exposure to the air, the uncombined lime will act as a deleterious ingredient, and is the cause of the swelling of cement in barrels and the checking and blowing found in finished cement-work; if the cement contains any of this uncombined lime it will generally show in the tests made for soundness or expansion.

Nearly all the Portland cement made in this country is produced artificially. The name "Portland" is given the cement on account of its color when hardened, which resembles the color of a stone found on the Isle of Portland, off the coast of England.

The quality of Portland cement depends on the raw materials used, their proportion, and fineness to which it is ground. Portland cement sets much slower than the natural cements and requires a much longer time to reach its limit of strength, but attains a much greater strength than the natural cement.

The color of Portland cement is a dark bluish or drab color. It should weigh at least 375 pounds per barrel and 4 sacks should equal a barrel. A cement which is lighter in weight than this is liable to be poor.

CHEMICAL COMPOSITION.—The ordinary composition of a good Portland cement varies as follows:

| | |
|-----------------------------|------------------------|
| Lime. | from 60 to 64 per cent |
| Silica. | from 20 to 24 " |
| Alumina and iron oxide. . . | from 8 to 12 " |
| Magnesia. | from 1 to 3½ " |
| Alkalies. | from trace to 2 " |
| Sulphuric acid. | from 1 to 2 " |

Cement containing over 3½ per cent of magnesia and 2 per cent of sulphuric acid should be avoided.

The manufacturers of Portland cement will usually sell their cement under the following guarantee:

1st. The cement will stand a minimum tensile strain of 600 pounds to the square-inch section of neat briquettes kept one day in air and six days in water. 2d. The cement will stand a minimum tensile strain of 175 pounds per square-inch section, 3 parts of sand and 1 part of cement, the briquettes kept one day in air and six days in water, standard crushed quartz used in testing. 3d. The cement will stand what is known as the

boiling test. 4th. 85 per cent of this cement will pass through a No. 200 sieve. 96 per cent will pass through a No. 100 sieve. All of the barrel cement will be put up in tight packages of great strength and uniformity. The bag cement will be put up in cotton bags of superior quality, and all the weights are strictly guaranteed.

The following are the specifications used by the United States Engineering Department for Portland cement.

SPECIFICATIONS FOR AMERICAN PORTLAND CEMENT.

(1) The cement shall be an American Portland, dry and free from lumps. By a Portland cement is meant the product obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime, by weight, as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions for the purpose only of regulating certain properties of technical importance to be allowable to not exceeding 2 per cent of the calcined product.

(2) The cement shall be put up in strong, sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not established itself as a high-grade Portland cement and has not for three years or more given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established

brands of high-grade Portland cement which have been made by the same mill and in successful use under similar climatic conditions to those of the proposed work for at least three years.)

(5) The average weight per barrel shall not be less than 375 pounds net. Four sacks shall contain one barrel of cement. If the weight, as determined by test weighings, is found to be below 375 pounds per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) FINENESS.—Ninety-two per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) SPECIFIC GRAVITY.—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 3.10 and 3.25.

(9) SOUNDNESS.—To test the soundness of the cement, at least two pats of neat cement, as taken from the package, mixed for five minutes with about 20 per cent of water by weight, shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the centre, tapering thence to a thin edge. The pats are to be kept under a wet cloth until finally set, when one is to be placed in fresh water for twenty-eight days. The second pat will be placed in water which will be raised to the boiling-point for six hours, then allowed to cool. Neither should show distortion or cracks. The boiling test may or may not reject at the option of the engineer officer in charge.

(10) TIME OF SETTING.—The cement shall not acquire its initial set in less than forty-five minutes and must have acquired its final set in ten hours.

(The following paragraph will be substituted for the above in case a quick-setting cement is desired:

The cement shall not acquire its initial set in less than twenty nor more than thirty minutes, and must have acquired its final set in not less than forty-five minutes nor in more than two and one-half hours.)

The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being

appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(11) TENSILE STRENGTH.—Briquettes made of neat cement, after being kept in air for twenty-four hours under a wet cloth and the balance of the time in water, shall develop tensile strength per square inch as follows:

After seven days, 450 pounds; after twenty-eight days, 540 pounds.

Briquettes made of 1 part cement and 3 parts standard sand, by weight, shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(In case quick-setting cement is desired, the following tensile strengths shall be substituted for the above:

Neat briquettes: After seven days, 400 pounds; after twenty-eight days, 480 pounds.

Briquettes of 1 part cement to 3 parts standard sand: After seven days, 120 pounds; after twenty-eight days, 180 pounds.)

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes well-dried cement and sand will be used; neat cement will be mixed with 20 per cent of water by weight, and sand and cement with $12\frac{1}{2}$ per cent of water by weight. After being thoroughly mixed and worked for five minutes, the cement or mortar will be placed in the briquette mould in four equal layers, and each layer rammed and compressed by thirty blows of a soft brass or copper rammer three-quarters of an inch in diameter (or seven-tenths of an inch square, with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed, the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work

under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deem it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner herein specified. All expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Puzzolan Cement.—This was originally an imported cement, made from a natural burned material of volcanic origin, but the slag cements now being made are really Puzzolan cement and should be classed under that head.

The so-called slag cement is the product obtained by pulverizing, without calcination, a mixture of granulated basic blast-furnace slag and slaked lime. This product, though in reality a member of the class of Puzzolanic cements, is usually marketed as "Portland cement," in spite of the fact that it differs from a true Portland cement in method of manufacture, ultimate and rational composition and properties.

Some recent tests made with slag cement in the municipal laboratory at Vienna, gave the following results: The mortar was mixed one to three. After seven days hardening, tensile strength, 383 pounds per square inch; strength of compression, 3880 pounds per square inch. After twenty-eight days hardening, tensile strength, 551 pounds per square inch; strength of compression, 5411 pounds per square inch.

The following regarding Puzzolan or slag cement is taken from the professional papers of the United States Engineer Corps:

SLAG CEMENT.—This term is applied to cement made by intimately mixing by grinding together granulated blast-furnace slag of a certain quality and slaked lime, without calcination subsequent to the mixing. This is the only cement of the Puzzolan class to be found in our markets (often branded as Portland), and as true Portland cement is now made having

slag for its hydraulic base, the term "slag cement" should be dropped and the generic term *Puzzolan* be used in advertisements and specifications for such mixtures not subsequently calcined.

Puzzolan cement made from slag is characterized physically by its light lilac color; the absence of grit attending fine grinding and the extreme subdivision of its slaked-lime element; its low specific gravity (2.6 to 2.8) compared with Portland (3 to 3.5); and by the intense bluish-green color in the fresh fracture after long submersion in water, due to the presence of sulphides, which color fades after exposure to dry air.

The oxidation of sulphides in dry air is destructive of Puzzolan cement mortars and concretes so exposed. Puzzolan is usually very finely ground, and when not treated with soda sets more slowly than Portland. It stands storage well, but cements treated with soda to quicken setting become again very slow-setting from the carbonization of the soda (as well as the lime) element after long storage.

Puzzolan cement properly made contains no free or anhydrous lime, does not warp or swell, but is liable to fail from cracking and shrinking (at the surface only) in dry air.

Mortars and concretes made from Puzzolan approximate in tensile strength similar mixtures of Portland cement, but their resistance to crushing is less, the ratio of crushing to tensile strength being about 6 or 7 to 1 for Puzzolan and 9 to 11 to 1 for Portland. On account of its extreme fine grinding Puzzolan often gives nearly as great tensile strength in 3 to 1 mixtures as neat.

Puzzolan permanently assimilates but little water compared with Portland, its lime being already hydrated. It should be used in comparatively dry mixtures well rammed, but while requiring little water for chemical reactions, it requires for permanency in the air constant or continuous moisture.

PROPER USES OF PUZZOLAN CEMENT.—Puzzolan cement never becomes extremely hard like Portland, but Puzzolan mortars and concretes are tougher or less brittle than Portland.

The cement is well adapted for use in sea-water, and generally in all positions where constantly exposed to moisture, such as in foundations of buildings, sewers, and drains, and in underground works generally, and in the interior of heavy masses of masonry or concrete.

It is unfit for use when subjected to mechanical wear, attrition, or blows. It should never be used where it may be exposed for

long periods to dry air, even after it has well set. It will turn white and disintegrate, due to the oxidation of its sulphides at the surface under such exposure.

Sulphuretted hydrogen, which is often evolved upon decomposition of the sulphides in Puzzolan cement, is injurious to iron and steel.

Such metals, if used in connection with Puzzolan cement should be protected, or an allowance be made for deterioration by increase of section."

Some more recent tests of slag cements show that they contain very little sulphur and analyses show their composition to be practically the same as the best brands of Portland cements.

SPECIFICATIONS FOR PUZZOLAN CEMENT.

PREPARED BY THE U. S. ENGINEER DEPARTMENT.

(1) The cement shall be a Puzzolan of uniform quality, finely and freshly ground, dry, and free from lumps, made by grinding together without subsequent calcination granulated blast-furnace slag with slaked lime.

(2) The cement shall be put up in strong sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed, and for any brand from cement works that do not make and test the slag used in the cement,

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor.

No cement will be allowed to be used except established brands of high-grade Puzzolan cement which have been in

successful use under similar climatic conditions to those of the proposed work and which come from cement works that make the slag used in the cement.

(5) The average weight per barrel shall not be less than 330 pounds net. Four sacks shall contain 1 barrel of cement. If the weight as determined by test weighings is found to be below 330 pounds per barrel, the cement may be rejected or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) FINENESS.—Ninety-seven per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) SPECIFIC GRAVITY.—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 2.7 and 2.8.

(9) SOUNDNESS.—To test the soundness of cement, pats of neat cement mixed for five minutes with 18 per cent of water by weight shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the centre, tapering thence to a thin edge. The pats are to be kept under wet cloths until finally set, when they are to be placed in fresh water. They should not show distortion or cracks at the end of twenty-eight days.

(10) TIME OF SETTING.—The cement shall not acquire its initial set in less than forty-five minutes and shall acquire its final set in ten hours. The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to one-fourth pound weight. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to 1 pound weight.

(11) TENSILE STRENGTH.—Briquettes made of neat cement, after being kept in air under a wet cloth for twenty-four hours and the balance of the time in water, shall develop tensile strengths per square inch as follows:

After seven days, 350 pounds; after twenty-eight days, 500 pounds.

Briquettes made of one part cement and three parts standard sand by weight shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes neat cement will be mixed with 18 per cent of water by weight, and sand and cement with 10 per cent of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar will be placed in the briquette mould in four equal layers and each layer rammed and compressed by thirty blows of a soft brass or copper rammer, three-quarters of an inch in diameter or seven-tenths of an inch square, with rounded corners, weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized testing laboratory in the manner herein specified, all expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Silica Cement, or Sand Cement.—This is a patented article manufactured by grinding together silica or clean sand

with Portland cement, by which process the original cementing material is made extremely fine and its capacity to cover surfaces of concrete aggregates is much increased.

The sand is an adulteration, but on account of the extreme fineness of the product it serves to make mortar or concrete containing a given proportion of pure cement much more dense, the finer material being increased in volume.

The increase in cementing capacity due to the fine grinding of the cement constituent offsets, in great degree, the effects of the sand adulteration, so that sand cement made from equal weights of cement and sand approximates in tensile strength to the neat cement, and the material is sold as cement.

The extreme fine grinding also improves cement that contains expansives, but nevertheless sand cement should not be purchased in the market, but should be made on the work from approved materials if used for other purposes than for grouting, for which it is peculiarly adapted.

SPECIFICATIONS FOR CEMENTS.

NATURAL CEMENT.—All natural cement must have a specific gravity of not less than 2.70, must be of such fineness that 80 per cent will pass through a No. 100 standard sieve, and briquettes made of such neat natural cement, after exposure to the air for one day and immersion in water for six days, must show a tensile strength of 90 pounds to the square inch. Pats $\frac{1}{2}$ inch thick must stand same test hereinafter specified for Portland cement.

PORTLAND CEMENT.—All Portland cement must have a specific gravity of not less than 3.10, must be of such fineness that 90 per cent will pass through a No. 100 standard sieve, must not contain more than 2 per cent anhydrous sulphuric acid, nor 3 per cent magnesia, and briquettes made of such neat Portland cement, after exposure to the air for one day and immersion in water for six days, must show a tensile strength of 350 pounds to the square inch. One-half-inch pats exposed to the air for seven days or immersed in water for the same time after hard set shall show no blotches, discolorations, checks, or signs of disintegration.

NON-STAINING CEMENT.—Non-staining cement must be of a brand that has been in use for at least two years to test its

non-staining qualities, have a specific gravity of not less than 2.75, contain not more than 2 per cent sulphuric acid, nor more than 3 per cent magnesia, be of such fineness that 85 per cent will pass through a No. 100 standard sieve, and briquettes of the neat cement, tested as specified for Portland cement, shall have a tensile strength of 200 pounds per square inch.

All cement must be of uniform quality and when delivered must be in original packages with the brand and maker's name marked thereon, and must be kept dry.

Tests, etc., of Cement.—In ordinary work the superintendent can be guided as to the quality of the cement by the brand and name of the manufacturer; unless the cement is of a standard brand and make, and which has been thoroughly tested in the past by use, etc., the superintendent should not permit any of it to be used until it has been tested. This is best done at some laboratory equipped for the purpose.

The following rules have been adopted by the U. S. Engineer Corps for testing cement, and should be a good guide for the superintendent.

GENERAL CONSIDERATIONS.—The constructing engineer is confronted by no problem more difficult than to decide whether a certain cement, when placed in a work, will behave in a predetermined way. This is especially true of Portlands. Other cements are much more reliable under conditions of exposure for which they are suited.

The difficulties arise from the fact that tests for acceptance or rejection must be made on a product not in its final stage. A cement, when incorporated in masonry, undergoes for months chemical changes in the process of setting, so that the material subjected to strains in the work is not the material tested, but a derivative of it. The object of tests is to establish two probabilities: First, that the product of the given cement will develop the desired strength and hardness soon enough to enable it to bear the stresses designed for it; second, that it will never thereafter fall below that strength and hardness. Up to the present time it appears that the relation between the chemical and physical properties of raw cement and of its partially indurated derivatives, determined by tests, and the physical properties of the same cement or its derivatives, after complete hydration and induration in the work, can be stated only within rather wide limits.

The most useful tests of cements are those, first, which connect themselves definitely with some serious defect to which cements are subject, or with some merit which they should possess; second, which can be made with the least apparatus and manipulation, and which give their indications in the shortest time; and, third, which are freest from personal equation and from influences of local surroundings. These criteria, applied to the customary tests of cements, give indications as to their relative value and the best methods of making them.

TEST OF GRINDING.—This test derives importance from the fact, apparently well established, that, other things being equal, the finer the cement the greater will be its sand-carrying capacity; that is, it will show greater strength with the same charge of sand, or equal strength with a greater charge. According to the best information the Board can obtain, the cementitious value of this material is believed to reside principally, if not wholly, in the very fine part. It follows that a grinding test should be directed to determining the proportion which it very fine rather than the residue above a certain size. The Board does not propose any change in the accepted grinding test of Portland cement, but favors for natural cement the use of the same size screen as for Portland, No. 100, with the requirement that 80 per cent shall pass through it. The screen should be frequently examined, magnified, if practicable, to see that no wires are displaced, leaving apertures larger than the normal.

TEST FOR SPECIFIC GRAVITY.—This test is made with simple appliances, and its result is immediately known. It appears to connect itself quite definitely with the degree of calcination which the cement has received. The higher the burning, short of vitrification, the better the cement and the higher the specific gravity.

This test has another value, in that the adulterations of Portland cement most likely to be practised and most to be feared are made with materials which reduce the specific gravity. The test is therefore of value in determining a properly burned, non-adulterated Portland. If underburned, the specific gravity may fall below 3; it may reach 3.5 if the cement has been overburned. No other hydraulic cement is so heavy in proportion to volume, natural cement having a specific gravity of about 2.5 to 2.8 and Puzzolan (slag) of about 2.7 to 2.8. Properly burned Portland, adulterated with slag, will fall below 3.1.

TEST OF ACTIVITY.—This test, made by gauging the cement with water and observing the times of initial and permanent set, is partly direct and partly indirect. It is direct in so far as its limits relate to the time necessary to get the cement in place after mixing, which must not be greater than the time of initial set, and to the time within which the cement product must take its load, which must not be less than the time of permanent set. It is indirect in so far as its limits relate to the probable final strength, elasticity, and hardness of the cement mixtures. In the latter respect it appears to be reasonably well established that cements exhibiting great activity give, after long periods, results inferior to those with action less rapid.

The test for activity is easily made with simple appliances, and its results are known in a few hours at most. Variable results in the test are caused by different local conditions of moisture and temperature and by the different judgments of observers as to whether the needles penetrate or not. Generally speaking, both periods of set are lengthened by increase of moisture and shortened by increase of temperature. Some manufacturers claim that their cements show their best results when gauged with particular percentages of water. It is not considered good policy to encourage these peculiarities at the expense of the uniformity of tests which is so greatly desired. It is better to adopt a definite proportion of water for gauging and require all cements of the same class to stand or fall on their showing when so gauged. Such a percentage, adopted and known, will probably be used by manufacturers in testing goods sold to the Engineer Department, and a greater harmony between mill and field tests of the same cement will result.

In gauging Portland cement the samples should be thoroughly dried before adding water. This precaution is not deemed necessary with natural cement. Sufficient uniformity of temperature will result if the testing-room be comfortably warmed in winter and the specimens be kept out of the sun in a cool room in summer and under a damp cloth until set.

TEST FOR CONSTANCY OF VOLUME.—This test results from observations made on the pats or cakes used in the setting test. It derives its value from its connection with the quantity of expansives in the cement.

The test is easy to make, and its results are relatively free

from personal error, though there is room for a difference of judgment as to the appearance of the cakes. As they may be preserved and the decision reviewed at any time on the original data, such differences are immaterial.

TESTS OF STRENGTH.—These may be subdivided into compressive and tensile tests, the latter including the transverse test made by breaking a beam of the cement. The compressive test need not be further considered, as it is less easily made than the tensile test and gives no surer indications. The ratio of compressive to tensile strength of the same class of cements is quite uniform.

Of the tensile tests the direct pull is preferable to the flexure test.

The tensile test is theoretically a perfect index of the quality of the cement at the periods of test, and a comparison at different periods gives the best obtainable indication of what its subsequent conduct will be. In the opinion of the Board the two periods most generally adopted, seven and twenty-eight days after mixing, are, on the whole, the best. The one-day test, though of some value in a discriminating sense, should not be placed in the same category as the other periods named.

The apparatus for tensile tests is somewhat elaborate and delicate, but is of standard manufacture and readily obtainable at relatively small cost.

In respect of uncertainties due to the personal equation of the tester and to the influence of local conditions this test presents greater difficulties than any of the others considered. The most scrupulous care must be observed in the manipulations, and the tester should possess natural aptitude for such work. The object is to determine the greatest stress per square inch which the cement can be made to stand under given conditions without rupture. If the conditions have been carefully observed and several discrepant results are obtained, the highest may be right, but the others are certainly wrong. No averaging should be done.

The remarks made above under the activity test as to the relation between early hydraulic intensity and the final excellence of a cement product are equally applicable to the indications from tensile tests. A cement which tests moderately high at seven days and shows a substantial increase to twenty-eight days is more likely to reach the maximum strength slowly

and retain it indefinitely with a low modulus of elasticity than a cement which tests abnormally high at seven days with little or no increase at twenty-eight days.

ACCELERATED TESTS.—The rules recommended by the committee of the American Society of Civil Engineers in 1885 have been substantially accepted here and abroad as to tests of setting qualities and soundness; more rapid tests for soundness are, however, proposed and practised, though no accelerated test has been generally accepted.

Accelerated tests proposed for the speedy detection of the presence of expansives in cement usually consist in the application, after gauging, of dry heat or of immersion in warm or boiling water or steam. The immersion tests are most in vogue. They vary from immersing freshly gauged pats on glass plates in water at 115° F. for twenty-four hours, or at higher temperatures for various periods, to steaming or boiling cakes or cylinders of the material to be tested at 212° F. for varying times.

In France and Germany the swelling or expansion of boiled cylinders is measured directly by calibration. Usually change of volume not accompanied by visible evidences of it—i.e., distortion or disruption—is not observed in American tests prescribed in specifications for the reception of cements. Of all these tests the boiling test is the simplest, requires only apparatus everywhere available, and is recommended by the Board. It has been the experience that this test detects material that is unsound by reason of the presence of active expansives; but in some cases it rejects material that would give satisfactory results in actual work and will reject material that would stand this test after air slaking.

The great value of the test lies in its short-time indications and in at once directing attention to weak points in the cement to be further observed or guarded against. Of two or more cements offered for use or on hand, the cements that stand the boiling tests are to be taken preferably; it should be constantly applied on the work among other simple tests to be noted, for although the boiling test sometimes rejects suitable material, it is believed that it will always reject a material unsound by reason of the existence of active expansives. Sulphate of lime, while enabling cements to pass the boiling tests, introduces an element of danger.

This test is proposed as suggestive or discriminative only.

Except for works of unusual importance it is not recommended that a cement passing the other tests proposed shall be rejected on the boiling test.

TESTS TO BE MADE.—For selecting Portland and Puzzolan cements from among the brands offered, the Board recommends that the following tests be made:

1. For fineness of grinding.
2. For specific gravity.
3. For soundness or constancy of volume in setting.
4. For time of setting.
5. For tensile strength.

For natural cement we recommend the omission of the specific-gravity and soundness tests.

On the works the Board recommends simple tests when the more elaborate tests cannot well be made.

In determining the minimum requirements for cements given in the subjoined specifications we recognize that many cements that attain only fair strength neat and with sand in a short time and show marked gains of strength on further time will fulfil the requirements of the service, and that unusually high tensile strength attained in a few days after gauging is often coupled with a small or negative increase in strength in further short intervals. Unusually high tests in a short time after gauging should be regarded with suspicion, although some well-known brands of American cements show great strength in short-time tests and, so far as observed, are reliable in air and fresh water. Cements offered under such known brands should show their characteristic strength and other qualities or be suspected as spurious or adulterated, if not rejected, even though the minimum requirements of the specifications are met. The practice of offering a bonus or free gift of money in addition to the contract price for cement testing above a fixed high point should be prohibited as unnecessary, for cements so obtained are likely to be unsound in a manner not easily detected in the time usually available in testing.

It is believed that most of the very high-testing Portland cements have lime in excess, the effect of which is temporarily masked by the use of sulphate of lime. Overlined cements so treated are unfit for use in sea-water. For such uses a chemical analysis should be required, and the quantity of sulphuric acid, as well as magnesia, be limited to a low per-

centage.¹ It is not yet known that sulphate of lime in quantity less than 2 per cent is injurious to cements to be used in fresh water or in air. It masks expansives that might ultimately cause the destruction of the work, but it is not known whether this effect is permanent. Its addition is now deemed necessary to control time of setting. It makes a quick-setting cement slow setting, at the same time increasing tensile strength acquired in a short time.

MANIPULATION OF CEMENTS FOR TESTS.—*I. Fineness.*—Place 100 parts (denominations determined by subdivisions of the weighing-machine used) by weight on a sieve with 100 holes to the linear inch, woven from brass wire No. 40, Stubb's wire gauge; sift by hand or mechanical shaker until cement ceases to pass through.

The weight of the material passing the sieve plus the weight of the dust lost in air, expressed in hundredths of the original weight, will express the percentage of fineness. In order to determine this percentage the residue on the sieve should be weighed.

It is only the impalpable dust that possesses cementitious value. Fineness of grinding is therefore an essential quality in cements to be mixed with sand. The residue on a sieve of 100 meshes to the inch is of no cementitious value, and even the grit retained on a sieve of 40,000 openings to the square inch is of small value. The degree of fineness prescribed in these specifications (92 per cent) for Portland through a sieve of 10,000 meshes to the square inch is quite commonly attained in high-grade American cements, but rarely in imported brands. On the Pacific Coast, where foreign cements mainly are in the market, this requirement may be lowered for the present to 87 per cent on No. 100 sieve.

II. Specific Gravity.—The standard temperature for specific-gravity determinations is 62° F., but for cement testing temperatures may vary between 60° and 80° F. without affecting results more than the probable error in the observation.

Use any approved form of volumometer or specific-gravity bottle, graduated to cubic centimeters with decimal subdivisions. Fill instrument to zero of the scale with benzine, turpentine, or some other liquid having no action upon cements.

¹ Not more than 3 per cent, by weight, of magnesia, 1 per cent of sulphuric anhydride, or 2 per cent of sulphate of lime should be allowed in any case. In sea-water not exceeding one-half these quantities.

Take 100 grams of sifted cement that has been previously dried by exposure on a metal plate for twenty minutes to a dry heat of 212° F., and allow it to pass slowly into the fluid of the volumometer, taking care that the powder does not stick to the sides of the graduated tube above the fluid and that the funnel through which it is introduced does not touch the fluid.

Read carefully the volume of the displaced fluid to the nearest fraction of a cubic centimeter. Then the approximate specific gravity will be represented by 100 divided by the displacement in cubic centimeters.

The operation requires care.

III. Setting Qualities and Soundness.—The quantity of water and the temperature of water and air affect the time of setting. The specifications contemplate a temperature varying not more than 10° from 62° F. and quantities of water given herein:

For Portland cements use about 20 per cent of water.

For Puzzolan cements use about 18 per cent of water.

For natural cements use about 30 per cent of water.

These quantities are for the cements as taken from the packages.

Mix thoroughly for five minutes, vigorously rubbing the mixture under pressure; time to be estimated from moment of adding water and to be considered of importance.

Make on glass plates two cakes from the mixture about 3 inches in diameter, $\frac{1}{2}$ inch thick at middle, and drawn to thin edges, and cover them with a damp cloth or place them in a tight box not exposed to currents of dry air. At the end of the time specified for initial set apply the needle $\frac{1}{16}$ inch diameter weighted to $\frac{1}{4}$ pound to one of the cakes. If an indentation is made the cement passes the requirement for initial setting, if no indentation is made by the needle it is too quick-setting. At the end of the time specified for "final set" apply the needle $\frac{1}{16}$ inch diameter loaded to 1 pound. The cement cake should not be indented.

Expose the two cakes to air under damp cloth for twenty-four hours. Place one of the cakes, still attached to its plate, in water for twenty-eight days; the other cake immerse in water at about 70° temperature supported in a rack above the bottom of the receptacle; raise the water gradually to the boiling-point and maintain this temperature for six hours and then let the water with cake immersed cool. Examine the

cakes at the proper time for evidences of expansion and distortion. Should the boiled cake become detached from the plate by twisting and warping or show expansion cracks the cement may be rejected, or it may await the result of twenty-eight days in water. If the fresh-water cake shows no evidences of swelling, the cement may be used in ordinary work in air or fresh water for lean mixtures. If distortion or expansion cracks are shown on the fresh-water cake, the cement should be rejected.

Of two or more cements offered, all of which will stand the fresh-water-cake test for soundness, the cements that will stand the boiling tests also are to be preferred.

IV. Tensile Strength.—*Neat Tests:* Use thoroughly dried unsifted cements.¹ Place the amount to be mixed on a smooth, non-absorbent slab; make a crater in the middle sufficient to hold the water; add nearly all the water at once, the remainder as needed; mix thoroughly by turning with the trowel, and vigorously rub or work the cement for five minutes.

Place the mould on a glass or slate slab. Fill the mould with consecutive layers of cement, each when rammed to be $\frac{1}{4}$ inch thick. Tap each layer 30 taps with a soft brass or copper rammer weighing 1 pound and having a face $\frac{3}{4}$ inch diameter or $\frac{7}{16}$ inch square with rounded corners. The tapping or ramming is to be done as follows: While holding the forearm and wrist at a constant level, raise the rammer with the thumb and forefinger about $\frac{1}{2}$ inch and then let it fall freely, repeating the operation until the layer is uniformly compacted by 30 taps.

This method is intended to compact the material in a manner similar to actual practice in construction, when a metal rammer is used weighing 30 pounds, with circular head 5 inches in diameter falling about 8 inches upon layers of mortar or concrete 3 inches thick. The method permits comparable results to be obtained by different observers.

After filling the mould and ramming the last layer, strike smooth with the trowel, tap the mould lightly in a direction parallel to the base plate to prevent adhesion to the plate, and

¹ The hot clinker is often suddenly chilled by steam or water in order to reduce the work of grinding by first cracking it. This water, as well as that absorbed from the air, should always be expelled or its percentage ascertained and deducted from the amounts prescribed for briquettes. Sand, also, should be similarly treated.

cover for twenty-four hours with a damp cloth. Then remove the briquette from the mould and immerse it in fresh water, which should be renewed twice a week for the specified time if running water is not available for a slow current. If moulds are not available for twenty-four hours, remove from the moulds after final set, replacing the damp cloth over the briquettes. In removing briquettes before hard set great care should be exercised. Hold the mould in the left hand and, after loosening the latch, tap gently the sides of the mould until they fall apart. Place the briquettes face down in the water trough.

For neat tests of Portland cement use 20 per cent of water by weight.

For neat tests of Puzzolan cement use 18 per cent of water by weight.

For neat tests of natural cement use 30 per cent of water by weight.

Nearly all this water is retained by Portland cement, whereas only about one-third of the gauging water is retained by Puzzolan or natural cements; from this it follows that an apparent condition of plasticity or fluidity that ultimately little injures Portland paste, very seriously injures Puzzolan or natural mortars and concretes by leaving a porous texture on the evaporation of the surplus water.

Sand Tests.—The proportions 1 cement to 3 sand are to be used in tests of Puzzolan and Portland, and 1 cement to 1 sand in tests of natural or Rosendale cements. Crushed quartz sand, sifted to pass a standard sieve with 20 meshes per linear inch and to be retained on a standard sieve with 30 meshes to the inch, is to be used.

After weighing carefully, mix dry the cement and sand until the mixture is uniform, add the water as in neat mixtures, and mix for five minutes by triturating or rubbing together the constituents of the mortar. This may be done under pressure with a trowel or by rubbing between the fingers, using rubber gloves. The rubbing together seems necessary to coat thoroughly the facets of the sand with the cement paste.

It is found that prolonged rubbing, when not carried beyond the time of the initial set, results in higher tests. Five minutes is the time of mixing quite generally adopted in European specifications. The briquettes are to be made as prescribed for neat mixtures.

Portland cements well dried require water from 10 to 12½ per cent by weight of constituent sand and cement for maximum ultimate strength in tested briquettes.

Puzzolan, about 9 to 10 per cent.

Natural, about 15 to 17 per cent.

Mixtures that at first appear too dry for testing purposes often become more plastic under the prolonged working required herein.

In general, about four briquettes constitute the maximum number that may be made well within the time required for initial setting of moderately slow-setting cements.

Three such batches of sand mixtures should be made, and one briquette of each batch may be broken at seven and twenty-eight days, giving three tests at each period. At least one batch of neat cement briquettes should be made.

If the first briquette broken at each date fulfils the minimum requirement of these specifications it is not necessary to break others which may be reserved for long-time tests.

If the first briquette does not pass the test for tensile strength, then briquettes may be broken until six briquettes, two from each batch, have been broken at seven days, and the remaining six reserved for twenty-eight-day tests. The highest result from any sample is to be taken as the strength of the sample when the break is at the least section of briquette.

If, on the twenty-eight-day tests, the cement not only more than fulfils the minimum requirements of these specifications, but also shows unusual gain in strength, it may still be accepted if the other tests are satisfactory, notwithstanding a low seven-day test, if early strength is not a matter of importance. Such cements are likely to be permanent.

For a batch of four briquettes, the following quantities are suggested as in accord with these specifications. Water is measured by fluid-ounce volumes, not by weight, temperature varying not more than 10° from 62° F.

Portland Cement.—Neat: 20 ounces of cement, 4 ounces of water. Mix wet five minutes.

Sand: 15 ounces sand, 5 ounces cement, 2½ ounces water. Mix thoroughly dry; then mix wet five minutes.

Puzzolan Cement.—Neat: 20 ounces cement, 3¼ ounces water. Mix wet five minutes.

Sand: 15 ounces sand, 5 ounces cement, 2 ounces water. Mix thoroughly dry; then mix wet five minutes.

Natural Cement.—Neat: 20 ounces cement, 6 ounces water. Mix wet five minutes.

Sand: 10 ounces cement, 10 ounces sand, $3\frac{1}{2}$ ounces water. Mix dry; then wet for five minutes.

For measuring tensile strength, a machine that applies the stress automatically at a uniform rate is preferable to one controlled entirely by hand.

These specifications for tensile strength contemplate the application of stress at the rate of 400 pounds per minute to briquettes made as prescribed herein. A rate so rapid as to approximate a blow or so slow as to approximate a continued stress will give very different results.

The tests for tensile strength are to be made immediately after taking from the water or while the briquettes are still wet. The temperature of the water during immersion should be maintained as nearly constant as practicable; not less than 50° nor more than 70° F.

The tests are to be made upon briquettes 1 inch square at place of rupture. The specifications contemplate the use of the form of briquette recommended by the committee of the American Society of Civil Engineers, held when tested by close-fitting metal clips, without rubber or other yielding contacts. The breaks considered in the tests are to be those occurring at the smallest section, 1 inch square.

SIMPLE TESTS.—Tests of cement received upon a work in progress must often be of much simpler character than prescribed herein.

Tests on the work are mainly to ascertain whether the article supplied is genuine cement, of a brand previously tested and accepted, and whether it is a reasonably sound and active cement that will set hard in the desired time, and give a good, hard mortar. Simple tests may give this information, and such should be multiplied whether or not more elaborate tests be made. Pats and balls of cement and mortar from the storehouse and mixing platform or machine should be frequently made. The setting or hardening qualities, as determined roughly by estimating time and by pressure of the thumb-nail, should be observed; the hardness of the set and strength, by cracking the hardened pats or cakes between the fingers, and by dropping the balls from the height of the arm upon a pavement or stone and observing the result of the impact.

By placing the pats in water as soon as hardened sufficiently

and raising the temperature to the boiling-point for a few hours and observing the character and color of the fracture after sufficient immersion, information as to the character of the material, whether hydraulic, a Portland, or Puzzolan, whether too fresh or possibly "blowy," may be speedily and quite well ascertained without measuring instruments.

Many engineers and users of cements regard such simple tests, taken in connection with the weight and fineness of the cement and the apparent texture and hardness of the mortars and concretes in the work, sufficient field tests of a material of known repute. The more elaborate tests, described above, should be made in well-equipped laboratories by skilled cement testers.

CLASSIFICATION OF TESTS.—The tests to be made are two classes.

(1) Purchase tests on samples furnished by bidders to ascertain whether the bidder may be held on the sample to the delivery of suitable material, should his offer be accepted.

(2) Acceptance tests on samples taken at random from deliveries, to ascertain whether the material supplied accords with the purchase sample, or is suitable for the purpose of the work, as stated in the specifications for cement supplies.

(1) *Purchase tests.*—Under these specifications bids for Portland cements will be restricted to brands that have been approved after at least three years' exposure in successful use under similar conditions to those of the proposed work. This specification limits proposals to manufacturers of cement of established repute, and in so far lessens the dependence to be placed upon tests of single samples of cement in determining the probable quality of the cements offered, that sample packages may not be required with the proposals when the brand is known to the purchaser. When the cement is not known to the purchasing officer by previous use, a barrel of it should be required as representing the quality of cement to be supplied. A full set of tests should be made from this sample, and subsequent deliveries be required to show quality at least equal to the sample.

In this connection it is advisable in districts where well-equipped laboratories have been established, that sample packages of the cements in use in that territory, as sold in the open market, be obtained and tested as occasion offers to ascertain the characteristic qualities of the brands as commer-

cial articles, the information to be used in subsequent purchases of cements.

When purchase samples are waived, acceptance tests should be based upon the known qualities of the brand, as shown by previous tests.

The sample barrel should not be broken further than to take therefrom the necessary samples for testing. Afterwards it should be put away in a dry place and kept for further testing, should the results obtained be disputed.

(2) *Acceptance tests.*—The tests to be made on cements delivered under contract depend not only on the extent, character, and importance of the work itself, but also on the time available between the delivery and the actual use of the material.

(a) On very important and extensive works, equipped with a testing laboratory and adequate storehouses, where cement may be kept at least thirty days before being required for use, full and elaborate tests should be made, keeping in view the fact that careful tests of few samples are more valuable than hurried tests of many samples.

(b) On active works of ordinary character, when time will not permit full tests, and on small works where the expenses of a laboratory are not justified, the tests must necessarily be limited to such reasonable precautions against the acceptance and use of unfit material as may be taken in the usually short interval between the receipt and use of the material.

Such conditions were in view in formulating the specification that proposals will be received from manufacturers of such cements only as have been proved by at least three years' use under similar conditions of exposure. Of the tests named in the specifications, those for fineness, activity or hydraulicity, specific gravity, weight of packages, and accelerated tests for indications as to soundness, may be made within two days after the receipt of the material and with a very small outlay for instruments.

Cement of established repute, shown by specific gravity and fineness to be properly burnt and ground, or normal for the brand, that will set hard in reasonable time, the cakes snapping with a clean fracture when broken between the fingers, and standing the tests above named, may be accepted and used with reasonable certainty of success. Nevertheless, packages taken at random from the deliveries should occasionally be set aside and samples taken therefrom sent to a testing

laboratory for the more elaborate tests for tensile strength (and for soundness should the boiling tests not be conclusive). The final acceptance and payment for such cement as may not have been actually placed in the work should, by agreement, be made to depend upon such tests.

In all cases where cement has been long stored it should be carefully tested before use to ascertain whether it has deteriorated in strength.

Should the simple tests give unsatisfactory or suspicious results, then a full series of tests should be carefully made.

When Portland cement is in question the specific-gravity and fineness tests should be made to guard against adulteration, and in all cases test weighings should be made to guard against short weights.

In cases where the amount of cement or the importance of the work will not justify the purchase of the simple apparatus required for the specific gravity, fineness, and boiling tests, the cement can be accepted on the informal tests mentioned herein, which require no apparatus whatever, but in such cases cements well known to the purchaser by previous use should be selected and purchased directly from the manufacturer or his selling agent in order that responsibility for the cement may be fixed.

Certified tests by professional inspectors made as prescribed herein on samples taken from the cement to be shipped to the work, in a manner analogous to that customary among engineers in the purchase of structural steel and iron, may be required in such cases.

SAMPLING.—The entire package from parts of which tests are to be made is to be regarded as the sample tested. It should be marked with a distinctive mark that must also be applied to any part tested. The package should be set aside and protected against deterioration until all results from tests made from it are reached and accepted by both parties to the contract for supplies.

Cement drawn from several sample packages should not be mixed or mingled, but the individuality of each sample package should be preserved.

In testing it should be borne in mind that a few tests from any sample, carefully made, are more valuable than many made with less care.

The amount of material to be taken for formal tests is indicated herein where weights of the constituents of four briquettes are given, to which should be added the amount necessary for the tests for specific gravity, activity, and soundness.

In extended tests the material should be taken from the sample package from the heads and centre of barrel, and from the ends and centre of bag, by such an instrument as is used by inspectors of flour. All material taken from the same sample package may be thoroughly mixed or mingled and the tests be made therefrom as showing the true character of the contents of the sample package.

In making formal tests at the work for acceptance of cement sample packages should be taken at random from among sound packages. The number taken must depend upon the importance and character of the work, the available time, and the capacity of the permanent laboratory force. For tensile strength the tests with sand are considered the more important and should always be made. Tests neat should be made if time permits.

It is not necessary in any case on a large work to test more than 10 per cent of the deliveries, even of doubtful cement, and a much less number of samples may be taken should no cause for distrust be revealed by the tests made. In very important work of small extent each package may be tested. A cement should be rejected if the samples show dangerous variation in quality or lack of care in manufacture and resulting lack of uniformity in the produce without regard to the proportion of failures among samples tested.

In all cases in the use of cements the informal or simple tests of the character named herein should be constantly carried on. These constitute most valuable tests. Whenever any faulty material is indicated by such tests, elaborate tests should be at once instituted and should the fault be confirmed, the cement delivered and not used should be rejected and the use of the brand be discontinued.

TESTS FOR WEIGHT.—From time to time packages should be weighed in gross and afterwards the weight of neat cement and tare of the packages determined. If short weight of neat cement is indicated, a sufficient number of packages should be weighed and the average net weight per package ascertained with sufficient certainty to afford a satisfactory basis of settlement.

The superintendent may make some simple tests to determine the quality of the cement as follows:

SOUNDNESS.—To test the soundness of the cement, take a lamp-chimney with a large swell to it and stand it on end; fill it with dry cement and then pour water on the cement; if the glass cracks the cement is unfit for use in any damp place.

The cement can be tested as to the time the initial set takes place; as a rule the longer it takes the cement to set the stronger it will be.

A simple test can be made by mixing some cement with just enough water to make it plastic, and roll it into a ball about the size of a walnut; after it sets in the air for about two hours, place it under water for three or four days. If it gradually becomes harder with no cracks it is an indication of good cement.

EXPANSION.—A cement that will expand should not be used. To test this make a cake of cement and let it remain in the air until it sets, then put it under water for a few days; if any cracks appear around the edge of the cake it indicates expansion and should be rejected. This sometimes happens with newly made cement, and age will overcome it. The test for soundness will also generally show if the cement will expand.

NON-STAINING CEMENT.—In setting or pointing marble or limestones or other porous stones a reliable brand of a non-staining cement should be used, as Portland or Rosendale cement will stain the stone enough to disfigure it. This is a patent cement called La Farge, which is usually made from a limestone having hydraulic qualities. Some of the foreign Puzzolan cements also possess this non-staining feature.

Notes Regarding Cement.

NUMBER AND MESH OF SIEVES FOR TESTING CEMENT.

| | |
|--------------|----------------------------------|
| No. 50..... | 2500 meshes to the square inch |
| No. 74..... | 5476 meshes to the square inch |
| No. 100..... | 10,000 meshes to the square inch |
| No. 200..... | 40,000 meshes to the square inch |

The porosity of mortar and cement, according to recent tests made by Prof. Lang, shows that when wet Portland-cement

concrete is impermeable to air. By measuring the amount of air which passes a layer of given thickness, under a certain pressure, in a unit of time, the following values for the degree of permeability were obtained:

| | Dry. | Wet. |
|--------------------------------|------|------|
| Portland cement, neat. | 0.05 | 0.00 |
| Portland-cement concrete. | 0.40 | 0.00 |

The specific gravity of Portland cement is between 3.10 and 3.25.

The specific gravity of cement is the figure which denotes the density of a sample or the number of times a given volume of it is weightier than the same volume of water.

For cement pipe use the following proportions: one part cement to three parts of sand and gravel. After the pipe is removed from the mould it should be coated with a wash of neat cement and water, of the consistency of paint, applied with a brush, to prevent seepage of water when in service.

Neat cement reaches a greater strength at short periods than sand mixtures. Concrete, however, gains in strength gradually, and ultimately surpasses neat cement in strength.

The compressive strength of cement is usually from eight to twelve times the tensile strength.

Quick-setting cement requires more water than slow-setting cement.

Temperature of water and atmospheric conditions naturally affect setting time.

Saline water retards setting.

A sand mixture of a cement which does not stand the neat pat test perfectly may show no imperfections whatever. Sand tends to diminish the ill effects of some inferior qualities.

Finely ground cement has greater capacity for sand, ages more rapidly, sets quicker, gets ultimate strength quicker, requires more water, is lighter in color, shows lower tensile strength in neat briquettes, shows greater tensile strength in sand briquettes, than the same cement not so finely ground. The finer the grinding, the more active the cement.

Aged cement as a rule sets slower, shows lower tensile strength in early breaks (one, three, and seven days especially), shows greater tensile strength in later breaks, is more liable to withstand pat tests, has smaller capacity for sand, than the same cement when tested fresh.

WHAT A BARREL OF PORTLAND CEMENT WILL DO.

A barrel of Portland cement weighs about 380 pounds net.

A barrel of Portland cement weighs about 400 pounds gross.

A barrel of Portland cement contains about 3.40 cu. ft. packed.

A barrel of Portland cement contains about 4.25 cu. ft. loose.

A barrel of Portland cement contains about 2.73 bushels packed.

A barrel of Portland cement contains about 3.61 bushels loose.

A barrel of Portland cement will make about 3.15 cu. ft. of neat mortar.

A barrel of Portland cement will make about 5.4 cu. ft. of mortar mixed 1 to 1.

A barrel of Portland cement will make about 8.5 cu. ft. of mortar mixed 1 to 2

A barrel of Portland cement will make about 10.7 cu. ft. of mortar mixed 1 to 3.

A barrel of Portland cement will make about 13.5 cu. ft. of mortar mixed 1 to 4.

A barrel of Portland cement will make about 23 cu. ft. of concrete mixed 1, 3, 5.

A barrel of Portland cement will make about 26 cu. ft. of concrete mixed 1, 3, 6.

A barrel of Portland cement will make about 29 cu. ft. of concrete mixed 1, 3, 7.

A barrel of Portland cement will make about 30 cu. ft. of concrete mixed 1, 3, 8.

A barrel of Portland cement (neat) will cover about 40 sq. ft. 1 in. thick.

A barrel of Portland cement to 1 sand will cover about 65 sq. ft. 1 in. thick.

A barrel of Portland cement to 2 sand will cover about 92 sq. ft. 1 in. thick.

A barrel of Portland cement to 3 sand will cover about 128 sq. ft. 1 in. thick.

A barrel of Portland cement to 2 sand will lay about 750 brick with $\frac{3}{8}$ -in. joint.

A barrel of Portland cement to 2 sand will lay about 1050 brick with $\frac{1}{4}$ -in. joint.

A barrel of Portland cement to 3 sand will lay about 900 brick with $\frac{3}{8}$ -in. joint.

A barrel of Portland cement to 3 sand will lay about 1350 brick with ¼-in. joint.

A barrel of Portland cement to 3 sand will lay about 2 perches of rubble stonework.

ANALYSIS OF VARIOUS BRANDS OF CEMENT.

| Brand of Cement. | Lime. | Silica | Clay and Iron Oxide | Magnesia. | Sulphuric Acid. | Analysis Made by |
|------------------|-------|--------|---------------------|-----------|-----------------|--|
| Alpha. | 63.93 | 20.68 | 10.60 | 2.86 | ..... | Manufacturer. |
| Atlas. | 62.22 | 21.48 | 10.44 | 2.95 | 1.03 | Department of Public W'ks, Brooklyn, N. Y. |
| Alpena. | 63.35 | 20.52 | 10.50 | 1.93 | 1.24 | Manufacturer's guarantee. |
| Buckeye. | 63.50 | 22.25 | 9.75 | 1.75 | .75 | Manufacturer. |
| Colton. | 63.05 | 23.00 | 11.50 | .18 | 1.63 | Adolph New, chemist, Colton, Cal. |
| Catskill. | 63.21 | 23.44 | 10.34 | 1.15 | 1.25 | Manufacturer. |
| Diamond. | 63.40 | 20.60 | 12.18 | 1.44 | .79 | Superintendent of Construction, U. S. P. O., Clevel'd. |
| Golden Gate. . | 60.00 | 23.10 | 12.12 | 1.15 | 1.84 | Adolph New, chemist, Colton, Cal. |
| Hudson. | 62.98 | 21.60 | 12.07 | 1.27 | 1.33 | Manufacturer. |
| Iroquois. | 62.20 | 23.70 | 10.39 | 1.21 | 1.70 | Manufacturer's guarantee. |
| Ideal. | 64.20 | 23.30 | 8.40 | .72 | 1.90 | Adolph New, chemist, Colton, Cal. |
| Iron clad. | 63.50 | 21.50 | 10.50 | 1.80 | 1.50 | Manufacturer. |
| Lehigh. | 62.96 | 22.42 | 9.18 | 2.76 | 1.05 | Booth, Garret & Blair, Philadelphia, Pa. |
| Medusa. | 64.78 | 23.30 | 9.44 | .97 | 1.21 | Manufacturer. |
| Marquette. | 64.26 | 21.80 | 10.81 | 1.76 | .96 | Manufacturer's guarantee. |
| Napa Junction | 61.00 | 22.50 | 11.50 | 1.08 | 2.00 | Adolph New, chemist, Colton, Cal. |
| Old Dominion. | 63.47 | 20.65 | 9.69 | 2.76 | 1.34 | Booth, Garret & Blair, Philadelphia, Pa. |
| Peninsula. | 64.10 | 22.00 | 10.50 | .60 | 1.60 | Manufacturer. |
| Saylors. | 64.51 | 19.67 | 12.34 | 1.16 | .... | Manufacturer. |
| T. A. Edison.. | 62.71 | 20.14 | 10.84 | 2.34 | 1.64 | Lathbury & Spackman, Philadelphia, Pa. |
| Universal. | 61.92 | 23.62 | 11.92 | 1.78 | 1.32 | Robt. Hunt & Co., Chicago. |
| Average. . | 63.10 | 21.98 | 10.65 | 1.61 | 1.37 | |

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS BRANDS OF PORTLAND CEMENT.

| Brand of Cement. | Twenty-four Hours. | | Seven Days. | | Twenty-eight Days. | | Six Months. | | Initial Set in Minutes. | Final Set in Minutes. | Per Cent through No. 100 Sieve. | Test Made by |
|-------------------------|--------------------|---------|-------------|---------|--------------------|---------|-------------|---------|-------------------------|-----------------------|---------------------------------|---|
| | Neat. | 1 to 3. | Neat. | 1 to 3. | Neat. | 1 to 3. | Neat. | 1 to 3. | | | | |
| Alpha..... | ..... | ..... | 513 | 160 | 699 | 206 | ..... | ..... | ..... | ..... | ..... | U. S. Engineer Corps. |
| Atlas..... | ..... | ..... | 585 | 252 | 760 | 475 | 818 | 497 | 26 | 288 | 98 | City Engineer, Youngstown, Ohio. |
| Alsen (German)..... | 439 | ..... | 653 | 214 | 703 | 282 | ..... | ..... | 155 | 335 | 80.5 | U. S. Engineer, San Francisco. |
| Alpena..... | 510 | ..... | 704 | 275 | 871 | 379 | ..... | ..... | ..... | ..... | 95.3 | Department of Public Works, St. Paul, Minn. |
| Buckeye..... | ..... | ..... | 330 | 193 | 518 | 291 | ..... | ..... | ..... | ..... | ..... | Champion Iron Works, Kenton Ohio. |
| Catskill..... | 346 | ..... | 654 | ..... | 736 | ..... | ..... | ..... | ..... | ..... | 86.4 | Metropolitan Sewerage Works, Boston. |
| Castle (Belgian)..... | 235 | 65 | 336 | 121 | 387 | 176 | ..... | 59 | 290 | 86 | ..... | Department of Public Works, Philadelphia. |
| Colton..... | 312 | 110 | 730 | 250 | 900 | 375 | ..... | ..... | ..... | ..... | ..... | Adolph New, chemist, Colton, Cal. |
| California..... | 137 | ..... | 618 | 119 | 719 | 342 | ..... | ..... | ..... | ..... | 86.9 | U. S. Engineer, San Francisco, Cal. |
| Cannon..... | ..... | ..... | 212 | ..... | 260 | ..... | ..... | ..... | ..... | ..... | 94 | U. S. Engineer, San Francisco, Cal. |
| Comet..... | 305 | ..... | 573 | 158 | 667 | 230 | ..... | ..... | ..... | ..... | 81.7 | U. S. Engineer, San Francisco, Cal. |
| Condor..... | 165 | ..... | 610 | 162 | 695 | 261 | ..... | ..... | ..... | ..... | 85.4 | U. S. Engineer, San Francisco, Cal. |
| Chicago AA..... | ..... | ..... | 674 | 264 | 775 | 463 | 889 | 606 | 120 | 345 | 94 | H. L. Bailey Laboratory, Chicago. |
| Dexter..... | 302 | ..... | 771 | 296 | 841 | 361 | ..... | 270 | 420 | 99.3 | ..... | Lathbury & Spackman, New York. |
| Dragon..... | 316 | 107 | 572 | 273 | 744 | 359 | ..... | ..... | ..... | ..... | 96 | Illinois Central R. R. Co. |
| Dykerhoff (German)..... | 249 | ..... | 481 | 252 | ..... | ..... | ..... | 300 | ..... | ..... | 92 | U. S. Engineer Department, Washington. |
| Diamond..... | ..... | ..... | 682 | 199 | ..... | ..... | ..... | 50 | ..... | ..... | 95 | Superintendent of Construction, U. S. P. O., Cleveland. |
| Elk..... | 300 | ..... | 650 | 200 | 800 | 275 | 900 | 450 | 120 | 300 | 95 | Manufacturer. |
| English..... | 330 | ..... | 575 | 159 | 710 | 205 | ..... | ..... | ..... | ..... | ..... | City Surveyor, Charleston, S. C. |
| Egypt..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | U. S. Engineer Department, Washington. |

| | | | | | | | | | | | | |
|------------------------------|-------|-----|-------|-------|-------|-------|-------|-------|-------|-------|--|---|
| Giant..... | 424 | 87 | 669 | 227 | 719 | 309 | 786 | 329 | 70 | 359 | 90.3 | Board of Public Works, Philadelphia. |
| Germania (German)..... | 202 | 594 | 198 | 745 | 246 | 180 | 329 | 180 | 180 | 91 | U. S. Engineer Department, Washington. | |
| Golden Gate..... | 260 | 626 | 283 | 741 | 460 | ..... | ..... | ..... | ..... | 96.1 | U. S. Engineer, San Francisco. | |
| Gillingham..... | 237 | 489 | 194 | 523 | 241 | ..... | ..... | ..... | ..... | ..... | City Engineer, Los Angeles, Cal. | |
| Green Island (Oriental)..... | 177 | 452 | 119 | 564 | 197 | ..... | ..... | ..... | ..... | 84.2 | U. S. Engineer, San Francisco. | |
| Hilton's (English)..... | 243 | 625 | 143 | 713 | 209 | ..... | ..... | ..... | ..... | 89.9 | U. S. Engineer, San Francisco. | |
| Helderberg..... | 250 | 700 | 302 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Manufacturer. | |
| Heyen (German)..... | 396 | 543 | 234 | 614 | 288 | ..... | ..... | ..... | 108 | 416 | 92.3 | Board of Public Works, Philadelphia. |
| Hemmoor (German)..... | 221 | 84 | 466 | 191 | 502 | 263 | ..... | ..... | 2 | 21 | 95.1 | Board of Public Works, Philadelphia. |
| Hercules..... | 209 | 47 | 314 | 90 | 425 | 135 | 687 | 265 | 3 | 21 | 77.9 | Board of Public Works, Philadelphia. |
| Henry..... | 164 | 159 | ..... | 159 | 188 | ..... | ..... | 319 | ..... | ..... | ..... | Engineering Department, District of Columb. |
| Hanover..... | ..... | 205 | ..... | 205 | 244 | ..... | ..... | 315 | ..... | ..... | ..... | Engineering Department, District of Columb. |
| Hudson..... | ..... | 657 | 223 | 726 | 354 | ..... | ..... | ..... | 198 | 328 | 92.4 | U. S. Engineer, Tuscaloosa, Ala. |
| Iron Clad..... | 176 | 792 | 302 | 819 | 370 | 861 | 496 | ..... | ..... | ..... | ..... | Aqueduct Commission, New York. |
| Iola..... | 178 | 834 | ..... | 904 | ..... | ..... | ..... | ..... | 150 | 300 | 93 | Denver Union Water Co. |
| Iroquois..... | 368 | 688 | 272 | 776 | 336 | 986 | 544 | ..... | 180 | 345 | 95 | Manufacturer. |
| Ideal..... | 346 | 710 | 237 | 847 | 276 | 843 | 497 | ..... | 146 | 374 | 97.03 | City Engineer, Los Angeles. |
| Iron Crown..... | ..... | 251 | 68 | 478 | 100 | ..... | ..... | ..... | ..... | ..... | 79.3 | U. S. Engineer, San Francisco. |
| Josson..... | 235 | 606 | 202 | 702 | 264 | ..... | ..... | ..... | ..... | ..... | 89.9 | U. S. Engineer, San Francisco. |
| Lehigh..... | 302 | 598 | 220 | 685 | 300 | ..... | ..... | ..... | 120 | 300 | 95 | U. S. Engineer, Buffalo, N. Y. |
| Lagerdorfer..... | ..... | 436 | 150 | 534 | 223 | 546 | 384 | ..... | 165 | ..... | 90.3 | Colorado Iron Works, Pueblo, Col. |
| Medusa..... | ..... | 731 | 196 | 810 | 300 | ..... | ..... | 363 | 183 | 278 | 93.70 | U. S. Engineer Corps. |
| Mannheimer (German)..... | 211 | 74 | 483 | 177 | 585 | 237 | ..... | ..... | 90 | 295 | 93 | Board of Public Works, Philadelphia. |
| Marquette..... | 310 | 47 | 799 | 238 | 845 | 367 | ..... | ..... | ..... | ..... | 94.5 | Illinois Central R. R. Co. |
| Nazareth..... | 275 | 654 | 225 | 765 | 238 | ..... | ..... | ..... | 120 | 210 | 97.3 | Board of Public Works, Philadelphia. |
| Napa Junction..... | 225 | 630 | 208 | 670 | 345 | ..... | ..... | ..... | ..... | ..... | ..... | Adolph New, chemist, Colton, Cal. |
| Owl..... | 154 | 611 | 209 | 791 | 304 | 937 | 387 | ..... | ..... | ..... | 98 | Illinois Central R. R. Co. |
| Old Dominion..... | 467 | 878 | 294 | 684 | 270 | ..... | ..... | ..... | ..... | ..... | 93.4 | U. S. Engineer Commission. |
| Omega..... | ..... | 611 | 202 | 684 | 270 | ..... | ..... | ..... | ..... | ..... | 98.75 | Robert Hunt & Co., Chicago. |
| Peninsula..... | 196 | 354 | ..... | 566 | 277 | ..... | ..... | ..... | ..... | ..... | 95.05 | Watertown Arsenal. |
| Phoenix..... | ..... | 702 | ..... | 679 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | City Engineer, Minneapolis. |

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS BRANDS OF PORTLAND CEMENT—(Continued).

| Brand of Cement. | Twenty-four Hours. | | Seven Days. | | Twenty-eight Days. | | Six Months. | | Initial Set in Minutes. | Final Set in Minutes. | Per Cent through No. 100 Sieve. | Test Made by |
|---------------------------|--------------------|---------|-------------|---------|--------------------|---------|-------------|---------|-------------------------|-----------------------|---------------------------------|---|
| | Neat. | 1 to 3. | Neat. | 1 to 3. | Neat. | 1 to 3. | Neat. | 1 to 3. | | | | |
| | | | | | | | | | | | | |
| Porta. .... | ..... | ..... | 580 | 209 | 628 | 243 | 543 | 105 | ..... | ..... | ..... | U. S. Engineer, San Francisco. |
| Peerless. .... | ..... | ..... | 451 | 182 | 630 | 253 | ..... | ..... | 250 | ..... | ..... | City Engineer, Minneapolis. |
| Saylor's "Red Ring" .. | ..... | ..... | 685 | 177 | 773 | 212 | ..... | ..... | ..... | ..... | ..... | City Engineer, Minneapolis. |
| St. Louis "Red Ring" .. | 124 | ..... | 790 | 244 | 876 | 300 | ..... | ..... | ..... | ..... | ..... | Washington University Laboratory. |
| Steel. | 128 | 55 | 405 | 224 | 511 | 278 | ..... | 72 | 127 | 98.47 | ..... | City Engineer, Chicago. |
| Star. | 437 | 77 | 721 | 219 | 746 | 298 | ..... | 75 | 299 | 91.7 | ..... | Board of Public Works, Philadelphia. |
| Shiffardicker (German) .. | 272 | ..... | 446 | 175 | 590 | ..... | ..... | ..... | ..... | 86.9 | ..... | City Engineer, Peoria, Ill. |
| "Sampson" (Canadian) .. | 132 | ..... | 428 | ..... | 463 | ..... | ..... | ..... | ..... | ..... | ..... | City Engineer, Port Huron, Mich. |
| Sandusky. | 162 | ..... | 694 | ..... | 903 | ..... | ..... | ..... | ..... | ..... | ..... | City Engineer, Port Huron, Mich. |
| Stettin (Anchor). .... | ..... | ..... | 471 | 168 | 630 | 255 | ..... | ..... | ..... | ..... | ..... | City Engineer, Youngstown, O. |
| Struthers. | 71 | ..... | 630 | 230 | 709 | 532 | ..... | ..... | ..... | ..... | ..... | Pittsburg, Carnegie & Western R. R. |
| Scales (English) .. | 171 | ..... | 622 | 212 | 795 | 268 | ..... | ..... | ..... | ..... | ..... | U. S. Engineer, San Francisco. |
| Teutonia (German). .... | ..... | ..... | ..... | 241 | ..... | 273 | ..... | 210 | 300 | 93.6 | ..... | U. S. Engineer, San Francisco. |
| Thomas A. Edison. | 325 | ..... | 676 | 255 | ..... | 331 | ..... | 120 | 390 | 99.8 | ..... | Lathbury & Spackman, Philadelphia. |
| Toltec (slag) .. | 196 | 69 | 472 | 154 | 477 | 200 | ..... | 138 | 345 | 99 | ..... | Department of Public Works, Philadelphia. |
| Universal. | 559 | 129 | 536 | 248 | 628 | 368 | 937 | 390 | 420 | 93.90 | ..... | Robert W. Hunt & Co., Chicago. |
| Vulcanite. | 290 | 45 | 748 | 226 | 767 | 287 | 740 | 330 | 108 | 439 | 89.90 | Board of Public Works, Philadelphia. |
| Victor ("Invincta"). | 372 | ..... | 486 | 170 | 562 | 226 | ..... | ..... | ..... | ..... | ..... | Barber Asphalt Co., Long Island. |
| Wayland. | 187 | 42 | 456 | 220 | 565 | 337 | ..... | 78 | 240 | 88.4 | ..... | City Engineer, Chicago. |
| Whitehall. | 328 | 79 | 855 | 339 | 991 | 459 | ..... | 180 | 360 | 95.75 | ..... | U. S. Navy, Annapolis, Md. |
| White's (English) .. | ..... | ..... | 356 | ..... | 268 | 110 | 256 | 15 | 45 | 94.03 | ..... | Colorado Iron Co., Pueblo, Col. |

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS NATURAL OR ROSENDALE CEMENTS.

| Brand of Cement. | Twenty-four Hours. | | Seven Days. | | Twenty-eight Days. | | Six Months. | | Percentage thro' No. 100 Sieve. | Test made by |
|----------------------------|--------------------|---------|-------------|---------|--------------------|---------|-------------|---------|---------------------------------|--|
| | Neat. | 1 to 2. | Neat. | 1 to 2. | Neat. | 1 to 2. | Neat. | 1 to 2. | | |
| | | | | | | | | | | |
| Akron Star-brand..... | 172 | 259 | 352 | 475 | ..... | ..... | ..... | ..... | ..... | City Cement Inspector, Philadelphia, Pa. |
| "Banner" Louisville, | 104 | 113 | 160 | 140 | ..... | ..... | ..... | 88 | ..... | Chicago Drainage Canal Board. |
| Beaches..... | 115 | 190 | 367 | 93 | ..... | ..... | ..... | 80 | ..... | U. S. Engineer, Fort Delaware. |
| Ft. Scott "Double Star.".. | 46 | 137 | 327 | ..... | ..... | ..... | ..... | ..... | ..... | Manufacturer. |
| Improved Anchor, | 164 | 271 | 378 | ..... | ..... | ..... | ..... | ..... | ..... | City Cement Inspector, Philadelphia, Pa. |
| Louisville Star, | 79 | 135 | 210 | 124 | ..... | ..... | ..... | 76.2 | ..... | Osborn Engineering Co., Cleveland. |
| Lehigh Improved, | 145 | 235 | 352 | ..... | ..... | ..... | ..... | ..... | ..... | City Cement Inspector, Philadelphia, Pa. |
| Milwaukee, | 97 | 141 | 259 | ..... | ..... | ..... | ..... | 93 | ..... | Company's Laboratory. |
| Mankato, | 142 | 179 | 267 | ..... | ..... | ..... | ..... | ..... | ..... | City Engineer, St. Paul, Minn. |
| Norton's Rosendale, | 107 | 141 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Northern Central R. R. Co. |
| Northern Hydraulic, | 200 | ..... | 300 | 200 | ..... | ..... | ..... | 96 | ..... | Manufacturer's guaranteee. |
| Shield Improved, | 170 | 239 | 298 | 220 | ..... | ..... | ..... | 95 | ..... | Booth, Garret & Blair, Philadelphia. |
| Utica, ..... | ..... | 207 | 230 | 225 | ..... | ..... | ..... | 91 | ..... | Sanitary District, Chicago. |
| Union Improved, | 155 | 209 | 316 | ..... | ..... | ..... | ..... | ..... | ..... | City Cement Inspector, Philadelphia. |

Mortar.—The following extract from an article on mortar was taken from the *Irish Builder*:

“Like all other compounds, mortar depends for its quality upon that of its constituents, and also upon the proportions in which they are used, and the method by which they are mixed. To all intents and purposes it is an exceedingly fine concrete, composed of an aggregate and a matrix mixed with water, its purpose being to fill up the interstices in the joints between the bricks or stones of which a wall is composed, so as to provide an even bedding surface, and render the wall water-tight, adherent properties being rather valuable for securing this than needed to prevent the bricks from being pulled apart.

“Thus it comes about that the more close is the jointing of a wall, the finer should be the grain of the mortar, and of its aggregate. A coarse rubble wall having wide, irregular mortar joints would be best with a mortar made of a fine gravel or crushed stone, or, at least, with one which contained a considerable amount of pea-sized lumps as well as finer sand amongst the aggregate, to assist in filling up the larger hollows without undue liability to settlement. On the other hand, for well-dressed ashlar masonry, the finest sharp-grained sand obtainable should be used, there being only very small cavities to fill up, and the very thinnest possible joint being required.

“Beyond this, it is necessary in all cases that the aggregate should, under a magnifying-glass, display either sharp edges or a roughened surface or both, in order that the matrix may adhere to it; for, while there is little necessity to stick the bricks of a wall together, if they be properly laid, it is quite necessary that the mortar should form in itself a homogeneous substance, else it will crumble into dust or wash out of the joints.”

LIME MORTAR.—Lime mortar is made by slaking the lime and adding sand in the desired proportion. The slaking is usually done by putting the lime in a water-tight box and covering with water. The lime is then stirred with the hoe so as to let the water get to all sides of the lumps of lime, and thus cause it to slake more readily. Enough water is added to make the mixture about the consistency of thick cream. It is then run off through a sieve into a larger box, where the sand is added and the mortar allowed to cool a little and thicken. The amount of sand used is regulated by the quality

of the lime used, as some limes will take more sand than others.

The "mortar-man" by experience can usually tell when he has enough sand added to the lime as he "runs it off," but if it is a little "rich," as it usually is, he will add more sand when he tempers it up for use. The mortar should have just enough sand in it to make it work nicely and not stick to the trowel.

The superintendent, by a little experience with, and watching, the mortar, will be able to tell at a glance if the mortar is "rich" or "poor." Mortar should be run off at least three days before using, so that the lime will have time to cool off and there will be no small particles of lime left unslaked and which may slake after being built in the wall.

Lime mortar should not be used in freezing weather, although if it is frozen hard and dry without any thawing it hardly ever affects it much, but, if it is alternately frozen and thawed, the mortar will lose its strength and be destroyed; so, to be on the safe side, it is well to follow the rule of using no lime mortar in freezing weather.

When the lime is being slaked the superintendent should see that it is of a good quality, as described on page 168, and that the sand is up to the requirements.

In making mortar for laying "press" brick or brick with a close joint, a fine white sand or marble-dust is generally used.

The New York Building Code requires that lime mortar be made of 1 part of lime and not more than 4 parts of sand.

SUGAR IN MORTAR.—Sugar has been used for centuries in India in the making of lime mortar and is said to add greatly to its strength. Experiments were made some years ago to ascertain the effect of sugar on Portland cement, and an addition of from $\frac{1}{8}$ to 2 per cent of pure sugar added to Dyckerhoff's German Portland cement was found to considerably increase its strength after three months. The sugar was said to "retard its setting," and thus permit the chemical changes in the cement to take place more perfectly, but more than 2 per cent of it rendered the cement useless. As sugar is soluble in water it should never be used in mortar which is to be used under water.

PORTLAND CEMENT-LIME MORTAR.¹—"There are many kinds of work which require a quick-hardening mortar, but for which

¹ Extracts from "Das Kleine Cement-Buch."

the great strength of a mixture of 1 of cement with 1 to 4 of sand is unnecessary. The cost of such mortar is also for many purposes too high. A mixture of cement with 5 or more parts of sand would give abundant strength, but such mortars work too 'short' and adhere too imperfectly to the stone or brick; it cannot therefore be safely used. In such cases the addition of slaked lime or hydraulic lime will correct the faults of poor mixtures of cement and sand, and will produce a cheap mortar, suitable for a great variety of uses. Used in this manner, Portland cement may be used with economy for the most ordinary purposes. The advantages of Portland cement-lime mortar are its cheapness in comparison with other hydraulic materials, its rapid hardening, marked hydraulic properties, great strength on exposure to air, and remarkable resistance to weather.

"The following mixtures for cement-lime mortar have been found by experience to be most suitable:

| | | | | | |
|--------|---------|------|---------------|------------|-----------------------|
| Cement | 1 part, | sand | 5 parts, | lime paste | $\frac{1}{2}$ part. |
| " | 1 " | " | 6 to 7 parts, | " | 1 " |
| " | 1 " | " | 8 parts, | " | $1\frac{1}{2}$ parts. |
| " | 1 " | " | 10 " | " | 2 " |

"The above proportions are to be taken by measure. Hydraulic lime may be used in the place of ordinary slaked lime.

"Cement-lime mortar is prepared by making a dry mixture of the required quantities of cement and sand; milk of lime is then made with the necessary quantities of lime paste and water and this milk of lime thoroughly mixed and worked in with the mixture of sand and cement."

In laying face brick in cement mortar it is advisable to add a little lime "putty" to the mortar, as it makes the mortar work smooth, and the mason can do a neater job. Mixtures of cement with three parts or more of sand are found to work too "short" for rapid and easy work in laying brick or stone. The addition of lime paste removes this defect, and makes the mortar smooth and plastic. The adhesion of the mortar to brick or stone, and also its impermeability to water, are also greatly increased by the addition of slaked lime. As to strength, it will be found that a mixture of Portland cement 1, lime paste 1, sand 6, is as good in every respect as a mixture of Portland cement 1, sand 3; or in other words, that one-half

the cement may be replaced by lime paste without loss of strength.

Compared with mortar made with Louisville, the Portland cement-lime mortar will be found immensely stronger, and little or no more expensive.

CEMENT MORTAR.—In making cement mortar, the strength of it depends on the quality of the cement and sand, the proportions used, and the manner of mixing. The sand should be sharp and irregular, as described on page 168, the finest depending on the nature of the work in which the mortar is to be used.

For mortar for laying brick or for grouting, it should be comparatively fine, while for concrete or coarse mortar it should range from fine to coarse. A small amount of pure clay in the sand used for cement mortar will not affect its strength.

Proportions.—The proportions of cement and sand for cement mortar varies according to the cement used, and the strength of the mortar desired.

The most common mixture is 1 to 3 for Portland cement and 1 to 2 for natural cements. There must be enough cement to more than fill all the voids in the sand, and make a compact tree.

For masonry and brickwork, use 1 part cement to 2, 3, or 4 parts of sand, according to the strength required and the purposes for which the mortar is to be used; for some special purposes 5, or even 6, parts of sand may be used.

Cement mortar for face brickwork is usually composed of 1 part cement and 2 parts sand; for backing and in ordinary masonry foundations, it is not necessary to use a richer mortar than 1 part cement to 3 of sand. When large quantities of sand are used, the mortar is "short" and brittle, and will not work well.

In some cases lime paste is added to the cement mortar to give it the required plasticity. The proportions are about one-half part lime paste added to the mortar.

Stone dust and fine screenings have been used as a substitute for sand and gave as strong a mortar as if sand had been used. The table on page 171 shows the average strength of cement mortars of different proportions and age.

WATER-TIGHT MORTAR.—For the lining of cisterns and reservoirs, and also in some cases for the protection of underground conduits and piping, a mortar which is impermeable to water

is required. According to Dykerhoff, the following mixtures will be found water-tight as soon as set:

| | | | | | |
|------------------|----|-------|----|----|-----------------------------|
| Portland cement, | 1; | sand, | 1; | | |
| “ | “ | 1; | “ | 2; | lime paste, $\frac{1}{2}$. |
| “ | “ | 1; | “ | 3; | “ “ 1. |
| “ | “ | 1; | “ | 5; | “ “ $1\frac{1}{2}$. |

From the above mixtures the one may be chosen which offers the required strength and hardness.

A solution of 1 pound of concentrated lye, 5 pounds of alum, and 2 gallons of water mixed with cement in the proportion of 1 pint of the solution to 5 pounds of cement and applied with a brush and well rubbed in will make cement walls water-proof.

MIXING.—At the commencement of the work the superintendent should decide what shall be used as a unit of measure in making the mortar or concrete. The wheelbarrow is most commonly used, and if this is decided upon the superintendent should have a barrel of cement measured by the barrow so as to ascertain how many barrows of sand or aggregate are to be used to a barrel of cement.

The cement and sand should be put in the mortar-box dry and thoroughly mixed until they become a uniform color. The mass should then be drawn to one end of the box and the water added at the other end, and the mortar wet and mixed in just such quantities as can be used before the initial set begins. A common fault on most work is that the cement will be mixed up in large quantities in the morning and some of it will be four or five hours old before it is used. The superintendent should never permit any mortar over three hours old to be used, and any that attains this age in the mortar-box should be thrown away. He will not have to do this more than once or twice until the mortar will be made in such quantities as he desires. At night he should see that the mortar-box is left clean and if any mortar is not used have it thrown out to prevent it from being remixed again in the morning. He should also see that the mortar is mixed with just enough water to make it soft enough to allow the brick or stone to bed into it readily and fill all joints.

COLORING OF CEMENT MORTAR, ETC.—The following coloring materials are usually used for coloring cement mortars. Usually coloring materials will lessen the strength of the mortars

so no more than necessary should be used; this is especially so of the ochres. To color

Gray, use 2 pounds of Germantown lampblack to a barrel of cement.

Black, use 45 pounds of manganese dioxide to a barrel of cement.

Blue, use 19 pounds of ultramarine to a barrel of cement.

Green, use 23 pounds of ultramarine to a barrel of cement.

Red, use 22 pounds of iron oxide to a barrel of cement.

Bright red, use 22 pounds of Pompeian or English red to a barrel of cement.

Violet, use violet oxide of iron 22 pounds to a barrel of cement.

Yellow and brown, use 22 pounds of ochres to a barrel of cement.

Ultramarine is one of the best coloring materials, as it does not affect the strength of the cement. Germantown lampblack is also good on account of the small quantity necessary to give a good color.

TEMPERATURE AND CEMENT.¹—"The effect of cold is to stop the setting of cement. Most cements set very slowly, if at all, below a certain temperature, which is usually between 30° and 40° F. When the temperature is raised the cement sets, unless in the mean time the water has evaporated sufficiently to leave an insufficient quantity for the chemical action, so that the freezing of work laid in cement mortar usually has the effect simply of delaying the hardening of the mass. If too much water is used in the mortar, the expansion of the water in freezing may disintegrate the mortar by the mechanical action of the ice in forming. Either of these effects is most apparent near the surface of the mass of masonry, and often requires pointing up of the joints of brick or stone masonry, while the remainder of the work will be found in good condition. Alternate freezing and thawing increases the danger of injury. Portland cement is seldom injured by freezing, but many natural cements are more or less injured, and mortar of natural cement is the more liable to disintegrate even under the best conditions if the temperature is long enough or often enough below freezing-point before it has had an opportunity to set. In a few instances some setting of mortar frozen for a long time has been observed, but as a rule the setting is delayed until the temperature again

¹ *National Builder.*

rises above the freezing-point. The first method of aiding the setting of mortar which suggests itself is to delay the time of reaching the freezing-point by heating the stone or brick, the sand, the cement, and the water. The amount of heat required depends upon the temperature of the air and the rapidity with which the work can be done after heating stops. This method is seldom entirely satisfactory unless very quick-setting cements are used. Slow-setting cements will evidently give more trouble than those which set as quickly as can be permitted under the conditions of time necessary to get the mortar into the work after the water is added. Mortar should be made richer than for use at ordinary temperatures, say one to one and a half, instead of one to two, and other mixtures in the same proportion. As little water as possible should be used, although this will increase the probability of requiring pointing of joints or the crumbling of outer surfaces of concrete. It is frequently possible to delay freezing by covering the work with straw or even tarpaulins. If stable manure can be kept in place in sufficient quantities to keep up its fermentation it is the most efficient material for covering. Perhaps the most common method of preventing the freezing of mortar is the use of a solution of common salt for mixing. The usual rule is to add 1 per cent of salt to the water for every degree of temperature below freezing, using the minimum temperature to which the masonry will be subjected for the computation. The cold delays the setting of the cement, but there is no mechanical action from freezing, and the results of this method are usually quite satisfactory, the pointing of joints being the only additional operation expected. It is evident that work to be placed upon concrete laid in freezing weather must be delayed until the setting of the cement makes the mass sufficiently stable to carry the weight. Laying of masonry, especially of massive stone masonry, in freezing weather is quite easy, but the placing of masses of concrete in exposed situations, or of small sections of concrete, is not so easy nor so certain of success."

The author has used mortar and concrete made of Portland cement in freezing weather and never experienced any trouble, the mortar or concrete made and used in cold weather being equal in strength in a few months to that made in warm weather. The main point in using cement mortar or concrete in freezing weather is to not use too much water, and to keep it from freezing until it is well set.

Natural cements should not be used in freezing weather, as they will not stand freezing.

Sidewalks should not be laid or any plastering or finishing done with cement in freezing weather; the finished surface may be affected by the moisture in the mortar freezing and expanding, causing blisters, making the finished surface scale off.

In using cement in hot weather, where the heat or the rays of the sun will strike it, care must be taken to protect it, for heat in such cases dries the cement too quick, drawing out the water before the proper action of the cement takes place, and thus decreasing its strength to a great extent. The small cracks like those in dry mud, sometimes seen in pavements, are the results of the cement being dried too fast by the heat.

When laying sidewalks, plastering walls, pointing or finishing any surface with cement, it must be well protected from the heat, and should be wet two or three times a day for about four days after being laid.

The following paper, by C. S. Gowen, M. Am. Soc. C. E., giving the result of experiments made by him while resident engineer of the New Croton Dam, N. Y., was read before the Cement Section of the American Society for Testing Materials, July 3, 1903:

Tests of Portland-cement Mortar Exposed to Cold.—The following experiments were made with a view to getting some definite information on the effect of frost on Portland-cement mortar, under the different conditions in which it may be desired to use it in cold weather. No facilities existed for maintaining a prolonged cold or uniform temperature and the briquettes were accordingly exposed to the open air, and so kept until it was evident that the tendency to "dry out" unduly was reducing their proper strength and creating a condition by which no basis of comparison with ordinary results could be had.

The briquettes were accordingly placed in water in July, at the end of the first six months of the tests, and the author is inclined to the opinion that if this had been done earlier, at the end of the three months' tests, the twelve months' results would have showed much nearer the average twelve months' results of tests made in the ordinary way of briquettes kept

BREAKING WEIGHTS OF 2 : 1 MORTAR BRIQUETTES, POUNDS PER SQUARE INCH, EXPOSED TO COLD AT NEW CROTON DAM.

(Cement used, Giant Portland; sand used, crushed quartz—Lot 209, 1476 bbls. Each breaking weight given is the mean of eight breakings.)

| Temperature Intended. | | Twenty-eight Days. | | |
|-----------------------|--------------|--|--------------------------------|--------------------------|
| | | Breaking Weight, Pounds per Square Inch. | Temperature Exposure, Degrees. | Time to Take Heavy Wire. |
| 24 to 32° | ..... | 370 | 22 r. | 4 hrs. ² |
| 24 to 10° | ..... | 458 | 24 f. | Night |
| 24 to 32° | ..... | 371 ¹ | 28 f. | 65 min. |
| 20 to 10° | ..... | 272 | 16 r. | 6 hrs. |
| 20 to 10° | ..... | 255 | 18 s. | 35 min. |
| 24 to 32° | Three months | 474 | 27 r. | 4½ hrs. ² |
| 24 to 10° | | 455 | 22 s. | Night |
| 24 to 32° | | 413 | 28 f. | 65 min. |
| 20 to 10° | Six months | 360 | 16 f. | 4 hrs. r.* |
| 20 to 10° | | 246 | 18 s. | 35 min. ³ |
| 24 to 32° | | 366 | 34 f. | ..... |
| 24 to 10° | Six months | 347 | 12 r. | 15 min. ³ |
| 24 to 32° | | 314 | 28 f. | 65 min. |
| 20 to 10° | | 287 | 14 r. | 2½ hrs. r†* |
| 20 to 10° | Nine months | 300 | 18 s. | 35 min. ³ |
| 24 to 32° | | 553 | 28 r. | 4½ hrs. ² |
| 24 to 10° | | 381 | 14 r. | 15 min. ³ |
| 24 to 32° | Twelve mos. | 452 | 28 f. | 65 min. |
| 20 to 10° | | 567 | 20 r. | 5½ hrs.† |
| 20 to 10° | | 437 | 18 s. | 35 min. ³ |
| 24 to 32° | Twelve mos. | 553 | 26 r. | 7 hrs. s. |
| 24 to 10° | | 586 | 16 r. | 45 min. ⁴ |
| 24 to 32° | | 510 | 28 f. | 45 min. |
| 20 to 10° | Twelve mos. | 602 | 26 f. | 2½ hrs. ^{3*} |
| 20 to 10° | | 512 | 16 s. | 35 min. ³ |

¹ This set was broken on a day when the temperature was 16°; a ninth briquette was thoroughly thawed on same day and broke at 210 pounds.

² Did not appear frozen when it took heavy wire.

³ Frozen at end of time noted, and took wire.

⁴ Froze slowly and took heavy wire.

* Had not set at end of time noted.

† Some signs shown of freezing.

‡ One briquette made with fresh water froze and took heavy wire in 20 minutes.

Remarks.—24 to 32°: Placed in cold air at temperature noted immediately after mixing; fresh water used. 24 to 10°: Placed in cold air at temperature noted immediately after mixing; fresh water used. 24 to 32°: Took heavy wire before being placed in cold air; fresh water used. 20 to 10°: Placed in cold air at temperature noted immediately after mixing; brine used. 20 to 10°: Placed in cold air at temperature noted immediately after mixing; fresh water used. In column of "Temperature Exposure" r. indicates a rising temperature, f. a falling temperature, and s. a steady temperature. All briquettes were left in open air in a dry but not sunny place until the three months' break was made (about April 15); then they were put in a damp place until the six months' break was made (about July 15); and then they were placed in water until finally broken. The brine used was a solution strong enough to float a potato, about 10 per cent by weight of salt to weight of water.

in water continuously until broken. In the table given below each breaking weight given is the mean of eight briquettes broken, and it may be said that each set of breakings showed marked uniformity in the strength of the briquettes.

AVERAGE BREAKING WEIGHTS OF 2 : 1 MORTAR BRIQUETTES.
GIANT PORTLAND CEMENT, BROKEN AT NEW CROTON
DAM IN 1896, 1897, 1898.

| | | Lot 209, 1476 bbls. |
|--|---------|------------------------|
| Time..... | 28 days | .. |
| Number of breakings..... | 690 | 10 |
| Average breaking weight, pounds per square inch. ... | 441 | 483 |
| Time..... | 3 mos. | .. ¹ |
| Number of breakings..... | 215 | .. |
| Average breaking weight, pounds per square inch. ... | 563 | .. |
| Time..... | 6 mos. | .. |
| Number of breakings..... | 185 | .. |
| Average breaking weight, pounds per square inch. ... | 657 | .. |
| Time..... | 9 mos. | .. |
| Number of breakings..... | 155 | .. |
| Average breaking weight, pounds per square inch. ... | 671 | .. |
| Time..... | 12 mos. | .. |
| Number of breakings..... | 165 | .. |
| Average breaking weight, pounds per square inch. ... | 663 | .. |

¹ Normal test of this lot not continued after 28 days. Time of taking heavy wire, mean of seventy tests (2 : 1), briquettes, 63 min.; mean of seventy tests, neat briquettes, 71 min.; average breaking weight, mean of seventy tests (2 : 1), briquettes, 1 week, 344 pounds.

The results are from experiments made by the author while acting as resident engineer for the Aqueduct Commissioners of the City of New York, in charge of the New Croton Dam, and to them the author wishes to make proper acknowledgment for the use of these data.

EFFECT OF COLD UPON SETTING.—In the case of this lot of cement, which was moderately quick-setting (taking heavy wire in sixty-three minutes, 2 to 1 briquettes, and taking heavy wire in seventy-one minutes, neat briquettes, under normal conditions of testing in laboratory), moderate cold, 22° and upward, delays setting but does not freeze. This is shown by the set of tests made for the intended temperature, 24° to 32°, of exposure.

The second set of tests (intended temperature of exposure 24° to 10°) show in the case of the twenty-eighth day and three months' breakings (temperature 24° and 22°, respectively) a

delayed setting which resulted in freezing during the night. The other breakings, six, nine, and twelve months, show, at lower temperatures, quick freezing.

The third set of tests (intended temperature of exposure 24° to 32°) was exposed to moderate cold after having taken heavy wire in laboratory.

The fourth set, a mixture with brine (intended temperatures of exposure 20° to 10°), shows clearly the influence of the cold in delaying the set, as well as the effect of the brine in delaying freezing.

At temperature of exposure $16^{\circ}+$, the set occurred in six hours; $16^{\circ}-$, no set in four hours and no sign of freezing; $14^{\circ}+$, no set in two and three-quarter hours and no sign of freezing; $20^{\circ}+$, a set in five and one-half hours with some indications of freezing; $26^{\circ}-$, no set in two and one-half hours and no sign of freezing.

The fifth set of briquettes was exposed at a steady temperature of $18^{\circ}\pm$, and all froze in thirty-five minutes.

Conclusion.—A moderately quick-setting cement can be used in temperatures about 20° , without freezing, with a 2:1 mixture.

The use of brine delays freezing, at least at temperatures of about 15° , if it does not wholly prevent it before the set has occurred.

EFFECT OF COLD UPON BEAKING STRENGTH.—It is apparent that the general falling off at the end of six months is due to air exposure, the rise for nine and twelve months after being placed in water being marked, and the author is of the opinion that had briquettes enough been made for fifteen and eighteen months' breakings there would have been a uniform increase in strength, comparing favorably with general results from laboratory tests, a summary of which has been added to the tabular statements. The six months' breakings of the various sets show a much greater uniformity than those of one month and three months, as might have been expected, the extremes being 287 and 366 pounds.

At nine months sets 1 to 4 agree closely,
 " " " " 3 to 5 agree closely,

while set 2 is lower in its breaking weight than either of the others.

At twelve months sets 2 to 4 agree closely,
 “ “ “ “ 3 to 5 agree closely,

while set 1 comes between these extremes, which vary between 510 and 602 pounds, an extreme variation, not much greater than indicated by the six months' breakings, and much less than that shown by the nine months' results.

Conclusion.—The general result is favorable to the use of brine at low temperatures; also there is no indication that freezing reduces the ultimate strength of the mortar, although it delays the action of setting.

In this particular example the frozen set No. 2 shows better at twelve months than frozen set No. 5, but not so well at nine months, where the relative difference is the other way.

At twelve months sets Nos. 2 and 4 (“frozen at low temperature” and “brine”) agree closely.

Set No. 1 comes next (“mixed at moderate temperature”), and sets Nos. 3 and 5 follow.

There seems to be nothing in the results shown in set No. 3 to indicate an advantage in securing a set before exposure to freezing temperature.

The above results are relative rather than conclusive, as it is impossible to say what would have been the results at the end of the year, and how they would have compared with the general average given for briquettes tested under normal conditions if they had not been exposed to the varying temperatures of spring and early summer and to “drying out.”

These briquettes were mixed in February, 1897, as opportunity and the required temperatures occurred, and the records of the time of setting were made as carefully as was practicable under the circumstances.

The temperatures of the air at the time of the final test for the set were not taken, but as a rule the temperature rose or fell, as indicated, steadily during the time that elapsed while the observation was made. These results are submitted for what they may be worth, as the author does not know of any series of tests extending over so long a time and at the same time covering such extremes and variations of temperature.

The following, showing the results obtained by tests made under ordinary laboratory conditions, when brine was used, are added here, and the conclusion seems to be plain that the effect of brine is to delay setting temporarily, while not affecting the ultimate strength of the mortar materially.

Giant Portland 2 to 1 briquettes.

Per cent of water used to weight of cement, 40.

Time to take heavy wire, fresh-water briquettes, 241 minutes;
salt-water briquettes, 306 minutes.

| | One Week. | One Month. | Three Months. | Six Months. | Nine Months. | Twelve Months. |
|-----------------------|-----------|------------|---------------|-------------|--------------|----------------|
| Fresh water used..... | 236 | 289 | 414 | 549 | 554 | 572 |
| Salt water used..... | 126 | 231 | 294 | 424 | 452 | 576 |

Giant Portland 3 to 1 briquettes.

Per cent of water used to weight of cement, 50.

Time to take heavy wire, fresh-water briquettes, 350 minutes;
salt-water briquettes, 407 minutes.

| | One Week. | One Month. | Three Months. | Six Months. | Nine Months. | Twelve Months. |
|-----------------------|-----------|------------|---------------|-------------|--------------|----------------|
| Fresh water used..... | 112 | 183 | 268 | 335 | 351 | 458 |
| Salt water used..... | 68 | 131 | 215 | 266 | 301 | 413 |

Standard sand used (crushed quartz).

The brine used was strong enough to float a potato, about a 10 per cent solution by weight.

Each of the above results is the mean of ten breakings, in pounds per square inch.

The briquettes were placed in air twenty-four hours and then immersed in water until broken.

The following shows the result of tests for freezing and thawing of cement, made by H. W. Parkhurst, Engineer of Bridges and Buildings, Illinois Central Railroad Company.

“Briefly described, these were made as follows: Sets of briquettes were made, one-half of which were put on the flat roof of our office-building, where they were exposed to all the changes of weather, commencing in December, 1902. The other half of the briquettes were treated in the usual way—being put in pans of water kept at pretty nearly uniform temperature (between 60 and 70 degrees F.), and sets of ten were taken from each of these lots at the age of twenty-eight days, two months, three months, four months, five months, and six months. Column headed “Frozen” contains results of those that were out of doors exposed to the weather. Column headed

"Warm" shows results of those that were kept in the house at uniform temperature. The column headed "Per Cent" shows percentage of strength of briquettes exposed to freezing as compared with those of the same date and age which were not so exposed. You will note that in the case of the "one-to-three" mortar, the briquettes that were exposed to the weather came out considerably stronger at four, five, and six months' age than those which were kept in the water all the time. This speaks well for the probable condition of concrete under the usual exposure."

The freezing and thawing tests are shown in the following tabular statement:

AA PORTLAND CEMENT—1902-1903.

FREEZING AND THAWING.

Sieves: No. 50, 100 per cent; No. 100, 99.8 per cent.

| Age. | One to Two. | | | | One to Three. | | | | Re- marks. |
|---------|-------------------------|--------|------|--------------|-------------------------|--------|------|--------------|---------------|
| | Date Brok'n 1903. | Frozen | Warm | Per Cent. | Date Brok'n 1903. | Frozen | Warm | Per Cent. | |
| 28 days | 1/23 | 233 | 425 | 55 | ..... | 189 | 290 | 65 | 1/27 |
| 2 mos. | 2/26 | 334 | 535 | 62 | 2/28 | 259 | 348 | 74 | 2/28 |
| 3 mos. | 3/26 | 363 | 572 | 63 | 3/30 | 331 | 381 | 87 | .. |
| 4 mos. | 4/26 | 395 | 595 | 66 | 4/30 | 453 | 325 | 139 | .. |
| 5 mos. | 5/26 | 462 | 611 | 76 | 5/30 | 441 | 373 | 118 | .. |
| 6 mos. | 6/26 | 628 | 531 | 118 | 6/30 | 563 | 363 | 155 | .. |

Grouting.—Grout is a thin mortar usually made of sand and cement, and is generally used in brickwork, by building up the two outside courses of the wall, then laying the inside brick and pouring the thin mortar over them, working it well into all the joints. The grouting should be done every course, so that all the joints will be filled.

Brick wet and laid with ordinary mortar and the mortar slushed into all the joints makes just as strong a wall as grouting, but because it is hard to get brick-masons to lay brick as they should be, grouting is often resorted to when a strong wall is desired.

Concrete.—Concrete is a mixture composed of broken stone, gravel, or similar material held together by cement mortar. The theory of concrete is that enough cement mortar should be used to fill all the voids between the stones.

On large engineering works, the proportions of cement, sand, and broken stone or gravel should be accurately determined

and specified. For general purposes it is possible to state approximate proportions, as the sand, broken stone, and gravel vary in size and proportions of voids according to their source and preparation.

The proportion of sand and stone must also be adapted to the character of the work in which the concrete is to be used and the strength required. The superintendent can tell when the first batch of concrete is rammed in place if the proportions of mortar and aggregate are such that the concrete will ram well and all the voids will be filled solid.

Concrete is being used more and more every day and is now one of the most used building materials, and as it is one most easily slighted, will require the closest attention from the superintendent. When any concrete work is being done the superintendent should be present at all hours while the work is in progress, and see that each batch of concrete is made of the correct proportions and mixed thoroughly, and that it is put in place as soon as mixed.

Any time he sees any of it slighted he should reject it at once, or have it mixed over. He should also see that no concrete is used after initial set has commenced; any concrete over three hours old should be rejected.

WET AND DRY CONCRETE.—There is quite a difference of opinion among engineers and architects as to just what amount of water should be used in mixing concrete to get the best results. Some claim that it should be mixed with as little water as possible, others think that a very plastic or wet concrete is best. It is the opinion of the author that either according to the conditions under which it is to be used is better than the other. For instance, in a large foundation or any place where the concrete can be spread in thin layers and where no trouble will be experienced in ramming, a mixture that when rammed enough to make it a solid and compact mass with no voids, and which at the end of this ramming shows just a little water at the top, will make as good a concrete as it is possible to obtain. On the other hand, in narrow walls or foundations, between beam grillage, and all places where any difficulty will be had in ramming, then a wet concrete will work the best.

The author has used concrete in such places, mixed so it would just carry the man ramming, and which when he walked or tamped on it, caused it to "quake," which gave excellent results, and contained no cavities. Where a concrete is to be

made water-tight a mixture of this kind will give the best results.

Tests have been made which show while the dry concrete becomes much stronger in a short period of time, the wet mixture if allowed to harden for a long period will ultimately become stronger than the dry mixture.

The superintendent must decide, according to the work to be done, just how wet the concrete should be mixed, and he can determine this after a little of it has been put in place and rammed.

Where a wet concrete is to be used the forms or moulds should be nearly water-tight.

MIXING CONCRETE.—This is another point in concrete work where engineers and architects differ in opinion, some even preferring hand-mixing to that done with a machine. There are a number of ways or methods employed for mixing concrete by hand, and they will nearly all give good results providing enough labor is expended.

This is where the contractor usually tries to save a little, turning the mass once or twice, when it should be turned four or five times. Then experience is a factor in turning concrete by hand; a man who has had experience in turning will mix better with two or three turnings than a man with no experience will do in four or five. It is the duty of the superintendent to examine the first batch after it is mixed and see if it is satisfactory; if not, he should have it turned and mixed until it is, and then see that all subsequent batches are mixed the same.

It is well to let the contractor use his own method of mixing provided it gives the desired results.

A method which the author has used for hand-mixing and which gave excellent results as to cost of labor and result of mixing is subjoined:

Make a tight platform about 30 feet long and 14 feet wide. On one end of this platform mix the sand and cement dry in the following manner: Have a bottomless box of sufficient size and depth to measure the exact proportion of sand, place it on the platform as shown at *A*, Fig. 123, and fill it with sand, using a straight-edge to strike it level full. On top of this set another bottomless box of the correct depth to measure the correct proportion of cement and fill it in like manner; now lift the two boxes and thoroughly mix the sand and cement until it is of a uniform color.

While the cement and sand are being mixed by part of the "gang," let the rest prepare the aggregate. Place a bottomless box on the platform close to the pile of cement and sand as shown by *B*, Fig. 123, the box to be of a depth to measure the

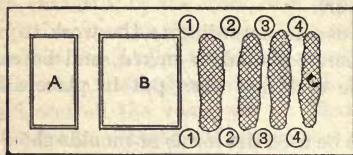


FIG. 123.

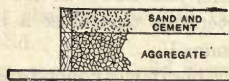


FIG. 124.

aggregate; fill it level full and set on top another box to measure the combined cement and sand; fill this box level full, as shown by Fig. 124; now remove the boxes and the mass is left in a flat pile with the cement and sand spread uniformly over the aggregate. Now let two men, as 1, 1, Fig. 123, start turning the pile toward the vacant end of the platform, and as they turn keep the new pile about the same width and depth as the one made by the boxes.

After they have started turning start two more men as shown at 2, 2, giving the second turning; but as it is turned and spread in the pile have a man with the hose and sprinkler (or a good plan is to tie the nozzle of the hose on a shovel-blade so the blade will spray the water) and wet the mass as it is spread in the pile. Then give it two more turnings by men at 3, 3 and 4, 4, and when it reaches the pile *C*, as shown in Fig. 123, it is thoroughly mixed. With a little experience the man with the water will be able to regulate it so that each batch will have about the same amount of water.

The author has also used three boxes as described, on top of each other, one for the aggregate, one for the sand, and one for the cement; then turning and mixing the mass as described, it gave a very uniform mixture. In mixing by hand the men should be provided with long-handled, square-bladed shovels, as they can reach the centre of the pile better and will not tire themselves as with a short-handled shovel. In large work the concrete can be mixed very rapidly as described; as one batch is being finished another one can be got ready, and thus a continuous stream of concrete can be turned out. The author has seen concrete mixed in this way in competition with a

machine where the amount mixed by hand in a day was equal to that done by the machine with the same amount of labor.

On small work where it would not pay to go to the trouble as described above, a good method is to mix the sand and cement dry, then add the water, making a wet mortar; spread this out and add the aggregate which has already been wet and washed; now turn and mix until a uniform mass is obtained.

Where machine-mixing is done, the superintendent must see that the proper proportions are used, and it is well for him to have the sand and cement mixed dry by hand before going into the machine. Some machines are so arranged with a spiral feed that they are supposed to feed themselves. When a machine of this kind is used, the superintendent should have a batch of concrete measured out in the desired proportions and run through the machine to see if it feeds correctly. After the concrete comes through he should examine it and see if it is thoroughly mixed and if too wet or dry. If not mixed right, he should have it run through again or mixed by hand.

AGGREGATE.—The aggregate for concrete is usually broken stone, gravel, or cinders, or two or all of them combined. Along the seashore and rivers gravel is often used because it can be obtained much cheaper than the broken stone, and makes very good concrete, but on account of the smooth surface of the stones does not make quite as strong a concrete as broken stone, which with its rough angular surfaces and corners causes the mortar to take a better hold.

Broken stone from $\frac{1}{2}$ to 2 inches makes the best concrete and does not require quite as much mortar, the voids not being so large as if the stone were all of the 2-inch size.

Cinder aggregate is usually used for fireproofing of floors, etc.

When broken stone is used it should be cleaned from dust and dirt, by passing it over a $\frac{3}{8}$ -inch mesh sieve.

Gravel can usually be cleaned by washing it to take out the clay or earthy matter. It should vary from $\frac{1}{4}$ to 2 inches in size.

Cinders for concrete should be nearly all clinkers which will pass through a 1-inch mesh sieve, and if very dirty, they should in addition be passed over a $\frac{3}{8}$ -inch mesh sieve. They should not contain more than 5 per cent of ash or unburned coal. Specifications usually call for rolling-mill slag or good,

clean, crushed vitrified clinkers, and the superintendent should see that such material is used, as the ordinary cinders are not fit for fire-proof work.

CRUSHED STONE should be clean and free from dust or dirt, and should not exceed $1\frac{1}{2}$ to 2 inches in size. The best results are obtained from strong, hard, durable rocks, with fracture into sharp angular fragments, such as trap-rock or limestone. Soft, porous, friable rocks, or rocks of a slaty fracture, should be avoided. For some purposes certain kinds of slag make an excellent concrete. Dust in crushed stone weakens the concrete. The best concrete is obtained from crushed stones of various sizes. In some cases the stone is screened to separate the different sizes, which are then remixed in the proper proportions.

SAND FOR CONCRETE.—Sand should be clean, coarse, and sharp. A quartz sand gives the best results. Loamy sand or that containing much clay should not be used; it will give poor results and retard the set. Organic matter and dirt are objectionable in any sand. A very fine sand or gravel is not good, as it weakens the work. A very coarse sand gives the greatest strength in concrete, but when the proportions of sand exceed 2 parts to 1 of cement, a sand of mixed grains, fine to coarse, with the coarse predominating, is preferable, as the fine sand helps to fill the voids in the coarse sand and makes a more dense and less absorbent mortar.

PROPORTIONS AND STRENGTH.—The proportion of the mortar to the aggregate should be such that it will a little more than fill all the voids of the aggregate, the strength of the concrete depending a great deal on the proportion of sand to the cement.

For all ordinary purposes, such as heavy foundations, machinery foundations, reservoirs, cisterns, retaining-walls, sub-surfaces of sidewalks, cellars, and street-paving, 1 part of cement, 2 or 3 parts of sand, with 5 parts of broken stone, will give the best results; for footings and subwork 1 part of cement, 3 parts of sand, and 7 parts of broken stone will give excellent results.

The superintendent should see that the proportions are such that the mortar will fill all the voids in the aggregate, and the mass will tamp solid. The proportion of cement and sand to the aggregate depends a great deal on the nature of the aggregate; if it is of coarse stone with large voids then it will require more mortar to fill them than if the aggregate was of a

finer stone or gravel. To determine the voids in any aggregate, take a box containing a cubic foot and fill it with the aggregate, which should already be soaked with water, then pour water in the box until it is full; now pour off the water and measure it, which will show the voids contained in a cubic foot of the aggregate.

A good method of determining the voids in concrete materials is to fill a box of exactly 1 cubic foot capacity, or a convenient fraction thereof, with the substance and weigh the contents. A solid block of quartz or limestone, measuring exactly 1 cubic foot, will weigh 165 pounds; a cubic foot of sand, gravel, or broken stone, considerably less: and the difference will represent the voids. For example, if 1 cubic foot of gravel weighs 95 pounds, the difference is $165 - 95 = 70$. The percentage of voids is then $70 \times 100 \div 165 = 42.4$.

The following table shows the percentage of voids found in some common concrete materials:

| | | |
|---|------|----------------|
| Sand, not screened. | 32.3 | per cent voids |
| Gravel, $\frac{1}{4}$ - to $\frac{1}{8}$ -inch. | 42.4 | “ “ |
| Broken stone, 1- to 2-inch. . . . | 47.0 | “ “ |

Mixed materials, which contain the greatest variety of sizes from fine to very coarse, will be found to have the least voids. With any two materials, one fine and one coarse, there is one mixture, and only one, which will give the greatest possible density. This may be determined by calculation; for example, taking the gravel given above, since it contains 42.4 per cent voids, we must fill these by adding sand to the amount of 42.4 per cent of its volume. For this we require 42.4 measures of sand to 100 measures of gravel, or 1 to $2\frac{1}{3}$. For the stone, 47 measures to 100 will be required, or 1 to 2.13. With mixed materials, such as are generally met with in practice, in which no sharp division between sand and gravel can be made, practical test will be found more satisfactory than calculation. The sand and gravel or stone should be mixed in the calculated proportion, and also in other proportions, and the weight per cubic foot of each mixture taken, until that giving greatest density is found. With favorable materials it will be found possible to make a mixture weighing 140 pounds per cubic foot, corresponding to 15 per cent voids. If the greatest weight obtainable is less than this, the materials are not the best.

The proportion of cement to be used depends upon the per cent of voids in the mixture of sand and gravel or stone, and also upon the purpose for which the concrete is required. In general it may be said that an amount of cement sufficient to fill the voids in the mixture will give a first-class concrete. With mixed materials weighing 140 pounds per foot and containing 15 per cent voids, cement to the amount of 15 per cent, by measure, or 1 to 6 $\frac{2}{3}$, will theoretically be required. Greater compression strength may be obtained by increasing the proportion of cement, and for the foundations of engines or other heavy machinery as high a proportion as 1 to 5 may well be used. On the other hand, for foundations of buildings, filling of abutments, and other purposes requiring less strength, mixtures of 1 to 10 or 1 to 12 will be found fully satisfactory.

It should be remembered that the strength of the concrete will depend on its density. A mixture of cement and sand, 1 to 3, will usually be found weaker than a 1 to 7 mixture, rightly proportioned, of cement, sand, and gravel or stone. Mixtures of cement and sand are greatly *strengthened* by the addition of a suitable amount of coarse material, though the proportion of cement is thus decreased. It is, therefore, well worth while to give careful study to the concrete materials which it is proposed to use.

The following table, showing the result of tests of cement mortar of different proportions and age, was made at the United States Arsenal, Watertown, Mass. The cement used was Peninsula Portland cement.

COMPRESSIVE STRENGTH OF PORTLAND-CEMENT MORTAR
IN POUNDS PER SQUARE INCH.

| Age in | | | Neat. | 1 Cement, 1 Sand. | 1 Cement, 2 Sand. | 1 Cement, 3 Sand. | 1 Cement, 4 Sand. |
|--------|--------|-------|-------|----------------------|----------------------|----------------------|----------------------|
| Air. | Water. | Air. | | | | | |
| 7 | ..... | ..... | 4970 | 2350 | 1370 | ..... | 473 |
| 1 | 6 | ..... | 6260 | 2330 | 1440 | ..... | 557 |
| 30 | ..... | ..... | 6140 | 3400 | 1490 | ..... | 656 |
| 1 | 29 | ..... | 8870 | 4680 | 2750 | ..... | 950 |
| 92 | ..... | ..... | 6080 | 3410 | ..... | ..... | ..... |
| 1 | 91 | ..... | 9560 | ..... | ..... | ..... | ..... |
| 1 | 91 | 2 | ..... | 7570 | ..... | ..... | ..... |
| 1 | 90 | 2 | ..... | ..... | 4990 | ..... | ..... |
| 93 | ..... | ..... | ..... | ..... | 2635 | ..... | ..... |
| 100 | ..... | ..... | ..... | ..... | ..... | ..... | 1030 |
| 101 | ..... | ..... | ..... | ..... | ..... | 1510 | ..... |
| 1 | 96 | 4 | ..... | ..... | ..... | 3140 | ..... |
| 1 | 95 | 4 | ..... | ..... | ..... | ..... | 1970 |
| 1 | 70 | ..... | ..... | ..... | ..... | 2570 | ..... |

The following tests of the tensile strength of Portland-cement mortar of different proportions and age were made by the New York State Canal Commission. The cement used was Glens Falls "Iron Clad."

NEW YORK STATE CANALS.

DEPARTMENT OF CEMENT TESTS.

Record of cement tests made with the Glens Falls "Iron Clad" Portland cement, showing tensile strength in pounds per square inch. All briquettes kept in air twenty-four hours, balance of time in water. Figures below represent in each case the average of five briquettes. Quartz was used in mixing all briquettes.

| Kept in Water. | Amount of Water Used. | | | | | |
|------------------|-----------------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| | 2½ oz. | 1½ oz. | 1½ oz. | 1½ oz. | 1½ oz. | 1 oz. |
| Number of Days. | Proportions Used in Mixing. | | | | | |
| | Neat. | 1 Sand, 1 Cement. | 2 Sand, 1 Cement. | 3 Sand, 1 Cement. | 4 Sand, 1 Cement. | 5 Sand, 1 Cement. |
| 6 | 516 | 549 | 237 | 210 | 162 | 133 |
| 12 | 609 | 569 | 349 | 242 | 186 | 150 |
| 18 | 651 | 651 | 423 | 267 | 222 | 169 |
| 24 | 671 | 660 | 435 | 277 | 227 | 169 |
| 30 | 715 | 665 | 446 | 285 | 233 | 171 |
| Number of Months | | | | | | |
| 3 | 776 | 714 | 549 | 347 | 225 | 184 |
| 6 | 784 | 651 | 540 | 441 | 217 | 189 |
| 9 | 744 | 742 | 490 | 375 | 259 | 202 |
| 12 | 764 | 714 | 535 | 380 | 287 | 194 |
| 15 | 836 | 738 | 536 | 395 | 292 | 204 |
| 18 | 848 | 775 | 576 | 396 | 271 | 216 |
| 21 | 920 | 789 | 555 | 411 | 298 | 238 |

(Signed) HERSCHEL ROBERTS,
Deputy State Engineer and Surveyor.

The following tests as to the tensile strength of natural-cement mortar were made with the "Improved Shield" brand of Rosendale cement:

| Tensile strength in. | | Neat Cement. | 1 Cement, 2 Sand. |
|----------------------|----------|--------------|-------------------|
| ..... | 24 hours | 118 lbs. | ..... |
| ..... | 3 days | 161 " | ..... |
| ..... | 7 " | 204 " | 142 lbs. |
| ..... | 30 " | 318 " | 278 " |
| ..... | 60 " | 374 " | 352 " |
| ..... | 90 " | 398 " | 418 " |
| ..... | 180 " | 440 " | 500 " |
| ..... | 360 " | 501 " | 568 " |

The following tests on the crushing strength of concrete were made by Lathbury & Spackman, Philadelphia, Pa.

REPORT ON CRUSHING STRENGTH OF SIX-INCH CUBES.

| Composition. | Age. | Average Crushing Strength, Three Cubes to Each Test. |
|---|--------|--|
| 1 part Lehigh Portland cement. | 7 days | 36,270 lbs. |
| 2 parts sand. | 30 " | 85,810 " |
| 4 parts crushed stone. | 90 " | 98,087 " |
| 1 part Lehigh Portland cement | 7 days | 28,433 lbs. |
| 3 parts sand. | 30 " | 62,003 " |
| 6 parts crushed stone. | 90 " | 73,073 " |
| 1 part Lehigh Portland cement. | 7 days | 22,687 lbs. |
| 4 parts sand. | 30 " | 48,790 " |
| 8 parts crushed stone. | 90 " | 61,230 " |

The following report of U. S. Engineer Corps gives the result of tests made with Atlas Portland cement in concrete of different proportions.

OFFICIAL REPORT U. S. GOVERNMENT ENGINEERS ON ATLAS PORTLAND CEMENT.

REPORT OF TESTS OF CRUSHING STRENGTH OF ONE-FOOT CUBE OF CONCRETE.
Made by Capt. Wm. M. Black, Corps Engineers, U. S. A., Washington, D. C.,
Dec. 1, 1897.

| No. | Composition. | Age. | Crushing Strength. |
|-----|---|----------|--------------------|
| 7 | 1 part Atlas cement 2 parts sand 6 parts broken stone | 10 days | 137,500 lbs. |
| | | 2 months | 255,000 " |
| | | 6 " | 320,000 " |
| | | 12 " | 440,000 " |
| 11 | 1 part Atlas cement 2 parts sand 3 parts gravel 3 parts broken stone | 10 days | 95,000 lbs. |
| | | 2 months | 232,500 " |
| | | 6 " | 280,000 " |
| | | 12 " | 405,000 " |
| 8 | 1 part Atlas cement 2 parts sand 2 parts gravel 4 parts broken stone | 10 days | 32,500 lbs. |
| | | 2 months | 267,500 " |
| | | 6 " | 295,000 " |
| | | 12 " | 390,000 " |

The following are the requirements of the U. S. Navy for tensile tests of Portland cement.

TENSILE STRENGTH.—The neat briquettes, prepared as specified, shall stand a minimum tensile strain per square inch, without breaking, as follows:

| | |
|--|----------|
| For 12 hours in air and 12 hours in water..... | 200 lbs. |
| “ 1 day “ “ “ 6 days “ “ | 550 “ |
| “ 1 “ “ “ “ 27 “ “ “ | 650 “ |

The mortar briquettes, prepared as specified, shall stand a minimum tensile strain per square inch, without breaking, as follows:

| | |
|--|----------|
| After 12 hours in air and 12 hours in water..... | 150 lbs. |
| “ 1 day “ “ “ 6 days “ “ | 200 “ |
| “ 1 “ “ “ “ 27 “ “ “ | 250 “ |

CRUSHING STRENGTH OF NATURAL-CEMENT CONCRETE.—Report of crushing tests made by the U. S. Government at the Watertown Arsenal, Watertown, Mass., of concrete blocks made with Akron Star Brand Natural Cement, the blocks being cubes, 12 inches each way, thus making each block one cubic foot of concrete. The strength given is the average of three blocks of each kind.

| Cement. | Sand. | Gravel. | Broken Stone. | Thirty Days, Lbs. | Seven Months, Lbs. | One Year, Lbs. |
|---------|----------|---------|---------------|-------------------|--------------------|----------------|
| 1 part | 1½ parts | 0 parts | 4 parts | 215,835 | 321,833 | 432,333 |
| 1 “ | 3 “ | 0 “ | 7½ “ | 150,367 | 290,167 | 306,667 |
| 1 “ | 2 “ | 3 “ | 4 “ | 161,200 | 319,867 | 329,500 |
| 1 “ | 2 “ | 7 “ | 0 “ | 110,267 | 239,533 | 264,700 |
| 1 “ | 2½ “ | 8 “ | 0 “ | 109,467 | 225,733 | 232,733 |

PROTECTION OF STEEL BY CONCRETE.—By tests made, it has been found that steel or iron when properly covered with cement mortar or concrete is perfectly protected from rust, but the mortar must have contact with and cover all surfaces of the steel. The concrete should be made wet enough so that it can be tamped close around the steel. With cinder concrete it should be thoroughly mixed and wet enough so that the cinders will not absorb all the water before the cement is tamped in place.

The following conclusions were arrived at by Mr. C. L. Norton after making a number of tests as to the value of cement mortar and concrete to protect steel from rust:

“(1) Neat Portland cement, even in thin layers, is an effective preventive of rusting.

“(2) Concretes to be effective in preventing rust must be dense and without voids or cracks. They should be mixed quite wet when applied to the metal.

“(3) The corrosion found in cinder concrete is mainly due to the iron oxide or rust in the cinders and not to the sulphur.

“(4) Cinder concrete, if free from voids and well rammed when wet, is about as effective as stone concrete in protecting steel.

“(5) It is of the utmost importance that the steel be clean when bedded in concrete. Scraping, pickling, a sand-blast, and lime should be used, if necessary, to have the metal clean when built into a wall.”

Fred. von Emperger, C.E., describes rods embedded in concrete under water for four hundred years coming out free from rust. W. G. F. Triest dug a wrench out of a concrete bridge pillar, which was free from rust after being embedded for twenty-two years. E. L. Ransome partly embedded some hoop iron in concrete blocks and left them exposed to sea air for many years. When the exposed iron had disappeared in rust, the blocks were cut open and the iron was found to be free from rust. The safety of the Chicago buildings supported by steel grillages depends on the concrete protecting this steel from corrosion. The wire netting in Monier pipe, after thirteen years' service, has been found in the same condition as when embedded. Professor Bauschinger has found an adhesive action between steel and cement mortar greater than the tensile strength of the latter.

During the construction of the Rapid Transit subway in New York City, a sidewalk laid in 1883 by Matt Taylor was torn up, and embedded in the concrete were found a number of steel rods which were in perfect condition after having been in the concrete for a period of nearly seventeen years.

DEPOSITING CONCRETE.—Concrete should be deposited just as soon as mixed; it should be spread in layers about 8 inches thick and rammed solid, and each succeeding layer put on before the one below has set; in this way the concrete becomes one mass, and a solid block is the result.

The concrete should never be dumped from any height, but should be deposited with a shovel. If it is dumped any distance the stone aggregate will become separated from the mortar.

Where any concrete is to be put on top or against any that

is already set the surface of the concrete already in place should be coated over with a thick cement grout, as this will insure the two masses adhering together.

SPECIFICATIONS FOR CONCRETE, ETC.

As a guide for the superintendent the subjoined extracts from specifications, which are considered very good are given.

The following regarding concrete was taken from the specifications prepared by the Reclamation Service of the United States Geological Survey.

CONCRETE.—This includes all concrete in place, except pressure pipes.

The cement will be furnished by the Secretary of the Interior. The concrete to be used on all of the structures on this canal will be composed of Portland cement, sand, and gravel, or broken stone, in the proportion of one barrel of cement, in the packed condition in which it is sold, to seven full barrels of the same size, of the aggregates when mixed together. To facilitate the work experiments will be made by the contractor with the carriers, whether wheelbarrows, boxes, or cars, used by him, so that this proportion of cement to aggregates may be maintained as nearly as possible, and the engineer will supervise these experiments and fix said proportion for the kind of carrier used at each piece of work. He will also make experiments with the aggregates themselves so as to get the most compact mass that can be made from them, and for such experiments no extra allowance will be made to the contractor. If the cement comes in sacks, then 380 pounds net of cement will constitute a barrel, and any ordinary cement barrel open at one end containing not more than 3.7 cubic feet will be used for measuring the aggregates. If broken stone is used, it must be hard and compact, and satisfactory to the engineer. The entire product of the crusher will be taken, provided there is not more than ten (10) per cent of the volume composed of dust or screenings. All of the rock must be of such sizes as will pass through a screen with two (2) inch square mesh. If gravel is used it must be clean, hard, and heavy, having at least a specific gravity of 2, and screened into three different sizes. None of the gravel is to exceed 2 inches in diameter. The mixture of such sizes will be made in the proportion fixed by

the engineer. A promiscuous mixture of sand and gravel will not be accepted. The sand must be clean and sharp and free from any clayey matter.

The mixing of the concrete, if hand labor is used, will be done in the following manner: A tight floor of either planks or sheet iron will be used for the mixing in all cases. The sand must be dry, and will first be piled on the floor with the cement in the proper proportions; the mass will then be shovelled over as many times as are necessary to make a thorough mixture of sand and cement; sufficient water will then be added to make a stiff mortar and the mass shovelled over twice or more, as may be necessary. The stone or gravel, which should be well wet, will then be added, and the entire mass shovelled over twice or more before shovelling into the carriers. This mixing must be done to the satisfaction of the engineer. If the mixing is done by machine, the latter will be subject to approval by the engineer. If at any time the machine fails to perform the mixing in a manner satisfactory to the engineer, it must be made satisfactory or removed, and another machine substituted, or mixing by hand resorted to. . . .

In all concrete walls over 2 ft. thick hard boulders, or fragments of hard sound rock, not exceeding 1 ft., or less than 6 ins., in any dimension, may be placed by hand in the soft concrete, provided no such stone comes nearer than 2 ins. to the exterior surface of the wall, or to any other boulder or stone so placed. . . . All concrete shall be well tamped, if put in dry, with heavy tamping-bars, until moisture appears on the surface; and, if wet, with suitable bars and shovels, so that porosity and rough surface may be avoided. Concrete will be used "wet" wherever practicable, and "dry" only when the nature of the work renders its use unavoidable.

MORTAR.—The following, regarding proportions of mortar, is taken from Cooper's "General Specifications for Foundations and Substructures":

"24. Cement mortar will be made by thoroughly incorporating the cement and sand in the following proportions, viz., one barrel of 300 pounds of natural cement and 12 cubic feet of sand, or one barrel of 375 pounds of Portland cement and 16 cubic feet of sand, with sufficient water to obtain the proper consistency.

"28. For foundations below the surface of the ground where the concrete will not be exposed to the action of running water

or to weather, the concrete shall be made of the following proportions: For each barrel of natural cement, 12 cubic feet of sand and 24 cubic feet of broken stone or coarse gravel.

“29. For monolithic piers and abutments, for cylindrical and wooden box piers, and for foundations where there is a liability to the action of running water or where the bottom is soft or of unequal firmness, the concrete shall be made of the following proportions: One barrel of Portland cement, 10 cubic feet of sand and 20 cubic feet of broken stone or coarse gravel.”

MORTAR, GROUT, AND CONCRETE.—The following specifications were prepared for the concrete work of the retaining-walls of the Pennsylvania R. R. Terminal Station, New York City:

In proportioning materials for mortar, grout, and concrete, 1 volume of cement shall be taken to mean 380 lbs. net. One volume of sand or broken stone shall be taken to mean $3\frac{1}{2}$ cu. ft. packed or shaken down. Sand and broken stone shall be measured in barrels or rectangular boxes. Measurements in wheelbarrows will not be permitted.

In preparing mortar, the specified amounts of cement and sand shall first be mixed dry to a uniform color. The water shall be added in such a manner as not to wash out any of the cement and the mixing proceeded with until the mortar is thoroughly mixed and of uniform consistency. The proportions of cement and sand will generally be 1 to $2\frac{1}{2}$ by volume, but when the work is wet, the proportion of sand shall be reduced as required by the engineer.

Grout will generally be in the proportion of 1 part of cement to 1 part of sand by volume. The materials shall be thoroughly mixed dry, and water then added, while the mixing proceeds, until the grout is of the required consistency. The mixing shall be continued vigorously, preventing the separation of sand, until the entire amount mixed is used.

Concrete will be in the proportion of 1 volume of cement to 3 volumes of sand and 6 volumes of stone, except in special cases where the engineer may require different proportions. For copings and bridge seats to a depth of 9 ins. and in narrow confined places, the smaller sized stone shall be used, and the proportions of sand and stone may be reduced to 2 volumes of the former and 3 volumes of the latter to 1 volume of cement. Whenever practicable the concrete shall be machine-mixed;

the mixing-machine shall be a rotary mixer, and of a pattern that will mix the concrete in batches and permit the definite measurement of the materials for each batch. When the engineer considers it impracticable to mix by machine, it may be mixed by hand, in the same proportions as above specified. The mixing shall be done on a platform of boards or planks securely fastened together. The cement and sand shall first be mixed and made into mortar as described. The broken stone, previously wetted, shall then be added and the mortar and stone turned over with shovels until the mortar is uniformly distributed through the mass and every stone is coated with mortar.

Where the walls of concrete masonry exceed 6 ft. in thickness, masses of stone may be built in; such stone shall be clean, hard, compact, and free from cracks or other unsoundness. They shall be set in at least 6-in. beds of concrete and have full bearings therein. They shall be set on their largest beds and shall be at least 6 ins. apart at every point and at least 12 ins. from the face of the wall. No stone shall be more than 2 ft. in thickness. The large stones shall not in the aggregate exceed 25 per cent of the total volume of the masonry containing them.

The degree of moisture for mortar, grout, and concrete shall be at all times as required by the engineer or his inspector; in general mortar shall be plastic, grout shall be fluid enough to be pumped, and concrete shall be of such consistency that it will quake when being deposited, but not wet enough to cause the stone to separate from the mixture.

Concrete shall be deposited in the work in such a manner as not to cause separation of mortar and stone. It shall be laid quickly in layers not exceeding 9 ins. in thickness and thoroughly rammed with rammers of such form and material as the engineer may approve; special shaped rammers will be required for corners and other places where ordinary rammers would not be effective. Compact, dense concrete must be obtained with all the voids between the stones filled with mortar. If voids are discovered at any time, the defective concrete shall be removed and immediately replaced by concrete of such mixture and in such manner as the engineer may direct.

When the placing of the concrete is suspended, the engineer may require a joint to be formed in a manner satisfactory to

him, so that the fresh concrete, when added, may have a bond. Before depositing fresh concrete the entire surface on which it is to be laid shall be cleaned, washed, brushed, and slushed over with grout of cement without sand.

The surface of freshly laid concrete shall be protected from injury in such a manner and for such time as the engineer may require; concrete injured in any manner shall be removed.

Water used in mortar, grout, and concrete shall be clean fresh water.

No mortar, grout, or concrete which has commenced to set shall be used anywhere in the work. Retempering of mortar or grout which has commenced to set will not be permitted.

Forms for concrete shall be substantial and must preserve their accurate shape until the concrete has set. Where the concrete will show in the finished work, the face of the form shall be built of matched and dressed planking finished truly to the lines and surfaces shown on the plans. Adequate measures shall be taken to prevent the adhesion of mortar to the forms. Forms which have become warped or distorted shall be replaced immediately.

Faces which will show in the finished work shall be true to the form intended and shall be smooth and free from cavities due to shortage of mortar. Exposed faces shall have a facing of mortar, 2 ins. thick, deposited simultaneously with the corresponding layers of concrete and separated from the concrete by a metal diaphragm of approved form. After the mortar and concrete have been deposited the diaphragm shall be removed and the materials well worked together by spading and tamping, so as to insure their bonding. Plastering the face after removing the forms will not be permitted. The facing mortar shall contain 1 volume of cement to $2\frac{1}{2}$ volumes of sand. Copings and bridge seats shall be finished with a layer of mortar 1 in. thick laid on the fresh concrete, thoroughly worked into its surface and finished smooth to true lines and surface by trowelling. They shall be kept damp and protected from the sun and rain for a period of at least 10 days.

Forms shall not be removed until permission has been given by the engineer.

Immediately after the forms are removed the exposed faces of the walls shall be washed over with a neat cement grout applied with a whitewash-brush.

Rock surfaces shall be thoroughly washed and cleaned before

concrete is deposited against them, and no concrete shall be deposited in water.

If leaks appear on the surface of the concrete at any time after removing the form, the contractor shall, at his own cost and expense, remove the concrete through which the water passes and replace it with sound concrete, and shall conduct the water to the base of the wall through channels or pipes in the concrete or take such other measures as the engineer may require.

SIDEWALK CONSTRUCTION.—In sidewalk work the superintendent must see that the foundations are excavated to the required depth, and that the foundation is put in of the material specified (broken stone or cinders are usually used for this purpose). Whatever material is used it should be rammed solid, and it is well to have it wet as it is laid, as it will then pack more solid.

When the concrete base of the walk is put down the superintendent should see that it is not made too wet or the water will run down through the foundation, taking a large part of the cement with it. The base of concrete should be thoroughly rammed, and before it sets the top or finishing coat should be put on, so that the top coat will take firm hold of the base and they will set and dry as one layer. The base and top coat are usually put down in blocks or sections about 4 or 5 feet wide, according to the size blocks it is desired to divide the walk into. Each alternate section is put down and laid between two pieces of 2×4 studding as guides. In this way a man can work from both sides of the section. After the first series of alternate sections are laid and set hard enough, they can be covered with plank and the men can work off these to fill in the balance of the walk.

The blocks should be cut through with a trowel or a strip of paper laid in the joints so the blocks will not become cemented together, which is likely to cause the blocks to crack through the middle in case there is any settlement. Some contractors use a thin strip of steel in the joint, which is taken out after the cement sets, but a strip of paper can easily be cut at the top of the cement and there is no danger of breaking off corners as with the steel plate when it is pulled out of the joint.

In finishing the top coat, the superintendent should see that it is floated and trowelled smooth, and that all joints and outside edges of the blocks are run with the jointing-tool; he should

see that the top coat is mixed stiff enough so it will set up ready for trowelling as desired, and should not permit any dry cement to be sprinkled on to take up the surplus water. Dry cement used for this purpose will cause the finished top to have a mottled appearance, or cause small hair cracks; these cracks are also caused by too much trowelling, as this brings the cement to the top and makes the top too rich. The cement should be floated and not trowelled until it is stiff enough, so that with a little trowelling it can be brought to a smooth surface. The top coat should not be less than 1 inch thick, and should be mixed in proportions of 1 cement to 1 of sand or fine granite chips.

Sidewalks should never be laid in freezing weather, and if laid in hot weather must be well protected from the heat.

They should be kept covered for four or five days and wet several times a day during this period.

The base and top coat must be made of the same cement; Portland and natural cements will not adhere together and should never be used, one for the base and the other for the top coat.

The following specifications are used by the city of Seattle, Wash., for sidewalks, etc.

Concrete shall be mixed as follows: Upon a tight platform of evenly laid plank of sufficient size; a correct proportion of gravel shall be evenly spread, and in no case more than 8 ins. deep. All material for concrete shall be accurately measured in suitable sized boxes. No counting by shovels or other approximation will be allowed. To determine the proper proportions, a barrel of cement weighing not less than 400 lbs. gross shall be taken as measuring $3\frac{1}{2}$ cu. ft. In a separate box the correct proportion of sand and cement shall be mixed dry until the whole mass is one even color. The gravel shall then be wetted and the mixture of dry sand and cement shall be evenly spread over it. Commencing at the corners, the men shall, with shovels, turn the mass over away from the centre, and coming back, turn it to the centre. In addition to the thorough wetting of the stones, if, in the judgment of the city engineer, it will be necessary, sufficient water shall be added to the mass by a rosehead sprinkler to enable the material to become thoroughly incorporated, and the process of mixing shall be continued until the surface of each stone is well covered with mortar. The concrete shall be spread upon the foundation as soon as mixed in a layer of such depth that after

having been thoroughly compacted with iron-shod rammers, 7 ins. square and weighing not less than 40 lbs., it shall not be in any place less than $3\frac{1}{2}$ ins. thick, and the upper surface shall be parallel with and not less than $\frac{1}{2}$ in. below the proposed surface of the completed pavement. To insure this the concrete shall be struck with a gauge which shall be shod with a steel plate not less than $\frac{1}{8}$ in. in thickness. Special care shall be taken to thoroughly tamp the concrete in all cases. It shall be tamped until a thin layer of water appears on the surface.

At such points as may be directed by the city engineer, and which shall be approximately 120 ft. apart, all concrete sidewalks shall have a joint $\frac{1}{2}$ in. in width, extending entirely through the concrete base and wearing surface. As soon as the concrete is thoroughly set, this joint shall be carefully cleaned and immediately poured full, even with the surface, with hot grade "D" asphalt, or with pavers' pitch No. 6.

When the bottom course is completed, and before the concrete has begun to set, the finishing or wearing course shall be laid down. The correct proportions of sand and cement shall be thoroughly mixed dry until of one uniform color and sufficient water added to make a mortar of proper consistency. The mortar shall be colored by mixing lampblack therewith, at the rate of about 2 lbs. of lampblack to 1 bbl. of cement. This quantity may be varied to produce the shade desired. The lampblack shall be thoroughly mixed with the cement mortar in such manner as to produce a uniform and even shade satisfactory to the city engineer. Special care must be taken to thoroughly trowel down the mortar in order to secure a perfect bond with the concrete base. It shall then be carefully smoothed to a uniform surface, which must not be disturbed after the first setting takes place.

V-shaped grooves $\frac{1}{4}$ inch in depth shall then be made with a suitable tool, dividing the pavement into blocks 2 feet square. The thickness of the completed wearing surface must not be less than $\frac{1}{2}$ in. at any point. On steep grades the cement coating shall be roughened in such manner as the city engineer may direct.

When the sidewalk is completed it shall be covered with such material as may be directed and kept moist by sprinkling for at least one week. The sprinkling shall be done as often as may be necessary to keep the sidewalk constantly moist.

The contractor will be required to stamp his name in letters 1 in. high and $\frac{1}{4}$ in. deep twice in each block on each side of street.

All concrete shall be laid in short sections and immediately covered with the wearing surface. Retempering of concrete or mortar will not be permitted. All mortar or concrete that has begun to set before ramming is completed shall be removed from the work. Any concrete or mortar that fails to show proper bond, or that fails to set after, in the opinion of the city engineer, it has been allowed sufficient time, shall be taken up and replaced by the contractor at his own expense with new concrete or mortar of proper quality.

Granolithic Sidewalk.—The following extract is taken from specifications prepared and used by the supervising architect of the U. S. Treasury Department:

The sidewalk shall be of 4 ins. of concrete with 1-in. finishing coat laid on 8 ins. of broken stone or cinders, the stone or cinders to be well rolled or tamped before the concrete is laid. The concrete shall be composed of one volume of Portland cement, two volumes of sand, and three volumes of clean hard stone broken to pass through a 1-in.-mesh sieve. Lay off in rectangular slabs about 4 ft. square, the joints to extend at least half way through the concrete, and before the concrete commences to set spread the finish coat, composed of equal volumes of Portland cement and finely crushed granite, mixed with only enough water to dampen the mass, as dusting with dry cement in finishing will not be permitted.

Trowel to smooth even surface cut through on lines coinciding with the joints in the concrete and finish the joints with a V-shaped tool. Leave 1½-in. margin around each slab.

In all work under the supervising architect samples of materials to be used must be submitted and approved before the work is commenced.

Weight of Concrete:

| | | | |
|-----------------------------|-------|----------|----------------|
| Cinder concrete. | about | 105 lbs. | per cubic foot |
| Crushed-stone concrete. . . | “ | 140 | “ “ “ “ |
| Gravel concrete. | “ | 150 | “ “ “ “ |
| Slag concrete. | “ | 135 | “ “ “ “ |

Per cent of strength of concrete at different ages:

| | | |
|--------------|-------------|-------------------|
| 30 days old, | 60 per cent | of full strength. |
| 60 “ “ | 75 “ “ | “ “ “ |
| 90 “ “ | 85 “ “ | “ “ “ |
| 120 “ “ | 90 “ “ | “ “ “ |
| 180 “ “ | 95 “ “ | “ “ “ |
| 360 “ “ | 100 “ “ | “ “ “ |

THE COMPOSITION OF CONCRETE FOR VARIOUS USES.

| Nature of Work. | Proportions. | | | | |
|--|--------------|----------------|-----------------------|---------------|--|
| | Cement | Sand. | Broken Stone. | Lime. | |
| Sidewalks, base. | 1 | 2 | 5 | ..... | 3-in. foundation of brokenstone, gravel, or cinders from 6 to 12 ins. deep. |
| Sidewalks, surface. . . | 1 | 1 | ..... | ..... | 1-in. crushed granite or sand. |
| Concrete, general use. | 1 | 3 | 7 | ..... | Broken stone from $\frac{1}{4}$ to 2 ins. in diameter. |
| Portland cement, lime, mortar. | 1 | 7 | ..... | 1 | |
| Concrete bridge foundations and abutment walls. | 1 | 3 | 6 | ..... | Stone to pass ring $1\frac{1}{2}$ ins. in diameter. |
| Concrete haunches, arches, catch-basins | 1 | 2 | 5 | ..... | Stone to pass ring $1\frac{1}{2}$ ins. in diameter. |
| Plastering faces of concrete arch and catch-basins. | 1 | $1\frac{1}{2}$ | ..... | ..... |  |
| Stable floors, base. . . | 1 | $1\frac{1}{2}$ | 3 | ..... | 3 ins. thick. |
| Stable floors, surface. | 1 | 1 | ..... | ..... | 2 ins. thick, hard-trowelled. Very fine sand, or preferably crushed granite. |
| Repairing masonry. . . | 1 | 3 | ..... | ..... |  |
| Stucco. | 1 | 3 | ..... | $\frac{1}{4}$ | $\frac{1}{2}$ to $\frac{3}{4}$ in. thick. |
| Plastering brick wall, first coat containing hair. | 1 | ..... | ..... | $\frac{1}{4}$ | $\frac{1}{2}$ in. thick. |
| Plastering brick wall, second coat applied before the first has set. | 1 | 2 | ..... | ..... | $\frac{1}{4}$ in. thick. |
| Concrete tanks, cisterns, etc. | 1 | 2 | 5 | ..... | Stone to pass 1-in. ring. |
| Concrete pillars, posts, walls, etc. | 1 | 2 | 3 | ..... | Broken stone to $\frac{3}{4}$ -in. ring. |
| Ornamental work. . . . | 1 | 2 | 3 | ..... | Fine-crushed granite. |
| Cinder and cement concrete for fire-proof floors. | 1 | $2\frac{1}{2}$ | 6 parts steam cinders | ..... |  |
| Cement grout for pouring between concrete blocks. . . . | 1 | 1 | ..... | ..... | Water should be added in sufficient quantity to produce a fluid condition. |

CONCRETE WASH.—The facing of concrete work employed by the Wabash Ry. for bridge abutments of concrete and concrete-steel consists in applying a facing wash composed of 1 part of plaster of Paris to 3 parts of cement, made very thin

SPECIFICATIONS FOR CEMENT-SIDEWALK CONSTRUCTION IN VARIOUS CITIES.

| City. | Foundation. | | Base. | | Wearing Surface. | | Dry Coating | | Size of Blocks. | Guarantee, Years. |
|-----------------------|--------------------|---|--------------------|--------------|--------------------|--------------|--------------|--------------|-------------------|-------------------|
| | Thickness, Inches. | Material. | Thickness, Inches. | Proportions. | Thickness, Inches. | Proportions. | Proportions. | Proportions. | | |
| Boston..... | 12 | Broken stone, gravel, or cinders..... | 3 | 1:2:5 | 1 | 1:1 | ..... | ..... | Bet. 3½-6 ft. sq. | 10 |
| Rochester, N. Y..... | 6 | Sand, gravel, broken stone, or cinders..... | † | 1:5 | 1 | 2:3 | ..... | ..... | ..... | 3 |
| Philadelphia, Pa..... | 3 | Sand, gravel, broken-brick stone, or cinders..... | 3 | ..... | 2 | 1:2 | ..... | ..... | ..... | ..... |
| Washington, D. C..... | 0 | ..... | 4 | 1:2:5 | 1 | 2:3 | ..... | ..... | ..... | 5 |
| Chicago, Ill..... | 0 or 12* | Cinders..... | 4½ av. | 1:2:5 | ¾ | 1:1 | ..... | ..... | 5 ft. X 6 ft. | 10 |
| Milwaukee, Wis..... | 4 | Cinders or broken stone.. | 2½ | 1:3:5 | 1 | 1:1 | ..... | ..... | ..... | ..... |
| St. Louis, Mo..... | 8 | Cinders..... | 3½ | 1:3 | ¾ | 1:1 | ..... | ..... | ..... | 1 |
| Omaha, Neb..... | 4 | Gravel, slag, or stone... . | 3 | 1:2:4 | 1 | 1:2 | ..... | ..... | ..... | 5 |

* Twelve-inch cinders required where the soil is not clean sand.

† Specified for each contract.

and put on with whitewash-brushes. This has been found very satisfactory.

LIME CONCRETE.—In Paris a concrete is much used, composed as follows:

Sand and gravel 8 parts, burned and powdered earth 1 part, pulverized clinkers and cinders 1 part, and unslaked hydraulic lime $1\frac{1}{2}$ parts. These materials are thoroughly mixed while dry and then dampened. This mixture sets in a short while and becomes very hard and strong in a few days. It is claimed for this concrete that it is not liable to crack or scale.

Experiments for volume on cement, sand, gravel, broken stone, mortar, and concrete are shown in the following table, the volumes being measured loose:

| Cement. | Volume of Loose Cement. | Water Added by Measure. | Volume of Stiff Cement Paste. |
|---------------------------------|-------------------------|-------------------------|-------------------------------|
| Portland cement (Atlas)..... | 1.00 | 0.35 | 0.78 |
| Natural cement. Louisville..... | 1.00 | 0.43 | 0.78 |

Remarks.—6.56 barrels of cement = 1 cubic yard measured loose.

| Aggregates. | Volume Loose. | Solids. | Voids. |
|---|---------------|---------|--------|
| 1. Sand, moist, fine, will pass 18-mesh sieve. . . | 1.00 | 0.57 | 0.43 |
| 2. Sand, moist, coarse, will not pass 18-mesh sieve. | 1.00 | 0.65 | 0.35 |
| 3. Sand, moist, coarse and fine mixed (ordinary). | 1.00 | 0.62 | 0.38 |
| 4. Sand, dry, coarse and fine mixed. | 1.00 | 0.70 | 0.30 |
| 5. Stone screenings and stone dust. | 1.00 | 0.58 | 0.42 |
| 6. Gravel, $\frac{3}{4}$ in. and under, 6 per cent coarse sand. | 1.00 | 0.67 | 0.33 |
| 7. Broken stone, 1 in. and under. | 1.00 | 0.54 | 0.46 |
| 8. Broken stone, $2\frac{1}{2}$ ins. and under, dust only screened out. | 1.00 | 0.59 | 0.41 |
| 9. Broken stone, $2\frac{1}{2}$ ins. and under, most small stones screened out. | 1.00 | 0.55 | 0.45 |

MORTARS WITH NO. 3 SAND.

| | | | | | | | | |
|--|------|------|------|------|------|------|------|------|
| Parts of sand mixed with 1 part of cement. | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 5.0 |
| Volume of slush mortar. | 1.40 | 1.78 | 2.17 | 2.55 | 2.98 | 3.39 | 3.82 | 4.65 |
| Required for 1 cubic yard: | | | | | | | | |
| Cement, bbls. | 4.70 | 3.70 | 3.04 | 2.58 | 2.21 | 1.94 | 1.72 | 1.41 |
| Sand, cubic yards. | 0.71 | 0.84 | 0.92 | 0.98 | 1.01 | 1.03 | 1.05 | 1.08 |
| Volume of dry facing mortar (rammed). | 1.22 | 1.57 | 1.93 | 2.28 | 2.64 | 2.99 | 3.35 | 4.08 |
| Required for 1 cubic yard: | | | | | | | | |
| Cement, bbls. | 5.40 | 4.18 | 3.41 | 2.88 | 2.49 | 2.20 | 1.96 | 1.61 |
| Sand, cubic yards. | 0.82 | 0.95 | 1.04 | 1.10 | 1.14 | 1.17 | 1.20 | 1.23 |

MATERIALS REQUIRED TO MAKE DIFFERENT CLASSES OF CONCRETE FOR CONNECTICUT AVE. BRIDGE, WASHINGTON, D. C.

The following concrete preparations were determined by Mr. A. W. Dow, Inspector of Asphalts and Cements, and W. J. Douglas, Engineer of Bridges, D. C.

Class A.

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.

9.00 cu. ft. sand.

20.25 " " stone.

Yielded 21.4 cu. ft. concrete when rammed into place.

Class B.

1:2½:6 (broken stone).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.

11.25 cu. ft. sand.

27.00 " " stone.

Yielded 27.66 cu. ft. concrete when rammed into place.

Class B.

1:2½:3:3 (3 gravel and 3 stone).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.

11.25 cu. ft. sand.

13.50 " " gravel.

13.50 " " stone.

Yielded 27.66 cu. ft. concrete when rammed into place.

Class C.

1:3:10 (gravel).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.

13.5 cu. ft. sand.

45.0 " " gravel.

Yielded 45 cu. ft. of concrete when rammed into place.

NOTES ON CEMENT CONCRETE, ETC.—Good cement should be a uniform bluish-gray color throughout; yellow checks or places indicate an excess of clay or that the cement has not been sufficiently burned; and it is then probably a quick-setting cement of low specific gravity and deficient strength.

CONCRETES.

Material Required for One Cubic Yard Rammed Concrete.

| Mixtures. | | | Stone, 1 Inch and Under, Dust Screened Out. | | | Stone, 2½ Ins. and Under, Dust Screened Out. | | | Stone, 2½ Ins., with Most Small Stone Screened Out. | | | Gravel, ¾ Inch and Under. | | |
|-----------|-------|--------|---|----------------|-----------------|--|----------------|-----------------|---|----------------|-----------------|---------------------------|----------------|------------------|
| Cement. | Sand. | Stone. | Cement, Bbls. | Sand, Cu. Yds. | Stone, Cu. Yds. | Cement, Bbls. | Sand, Cu. Yds. | Stone, Cu. Yds. | Cement, Bbls. | Sand, Cu. Yds. | Stone, Cu. Yds. | Cement, Bbls. | Sand, Cu. Yds. | Gravel, Cu. Yds. |
| 1 | 1.0 | 2.0 | 2.57 | 0.39 | 0.78 | 2.63 | 0.40 | 0.80 | 2.72 | 0.41 | 0.83 | 2.30 | 0.35 | 0.74 |
| 1 | 1.0 | 2.5 | 2.29 | 0.35 | 0.70 | 2.34 | 0.36 | 0.89 | 2.41 | 0.37 | 0.92 | 2.10 | 0.32 | 0.80 |
| 1 | 1.0 | 3.0 | 2.06 | 0.31 | 0.94 | 2.10 | 0.32 | 0.96 | 2.16 | 0.33 | 0.98 | 1.89 | 0.29 | 0.86 |
| 1 | 1.0 | 3.5 | 1.84 | 0.28 | 0.98 | 1.88 | 0.29 | 1.00 | 1.88 | 0.29 | 1.05 | 1.71 | 0.26 | 0.91 |
| 1 | 1.5 | 2.5 | 2.05 | 0.47 | 0.78 | 2.09 | 0.48 | 0.80 | 2.16 | 0.49 | 0.82 | 1.83 | 0.42 | 0.73 |
| 1 | 1.5 | 3.0 | 1.85 | 0.42 | 0.84 | 1.90 | 0.43 | 0.87 | 1.96 | 0.45 | 0.89 | 1.71 | 0.39 | 0.78 |
| 1 | 1.5 | 3.5 | 1.72 | 0.39 | 0.91 | 1.74 | 0.40 | 0.93 | 1.79 | 0.41 | 0.96 | 1.57 | 0.36 | 0.83 |
| 1 | 1.5 | 4.0 | 1.57 | 0.36 | 0.96 | 1.61 | 0.37 | 0.98 | 1.64 | 0.38 | 1.00 | 1.46 | 0.33 | 0.88 |
| 1 | 1.5 | 4.5 | 1.43 | 0.33 | 0.98 | 1.46 | 0.33 | 1.00 | 1.51 | 0.35 | 0.16 | 1.34 | 0.31 | 0.91 |
| 1 | 2.0 | 3.0 | 1.70 | 0.52 | 0.77 | 1.73 | 0.53 | 0.79 | 1.78 | 0.54 | 0.81 | 1.54 | 0.47 | 0.73 |
| 1 | 2.0 | 3.5 | 1.57 | 0.48 | 0.83 | 1.61 | 0.49 | 0.85 | 1.66 | 0.50 | 0.88 | 1.44 | 0.44 | 0.77 |
| 1 | 2.0 | 4.0 | 1.46 | 0.44 | 0.89 | 1.48 | 0.45 | 0.90 | 1.53 | 0.47 | 0.93 | 1.34 | 0.41 | 0.81 |
| 1 | 2.0 | 4.5 | 1.36 | 0.42 | 0.93 | 1.38 | 0.42 | 0.95 | 1.43 | 0.43 | 0.98 | 1.26 | 0.38 | 0.86 |
| 1 | 2.0 | 5.0 | 1.27 | 0.39 | 0.97 | 1.29 | 0.39 | 0.98 | 1.33 | 0.39 | 1.03 | 1.17 | 0.36 | 0.89 |
| 1 | 2.5 | 3.5 | 1.45 | 0.55 | 0.77 | 1.48 | 0.56 | 0.79 | 1.51 | 0.58 | 0.81 | 1.32 | 0.50 | 0.70 |
| 1 | 2.5 | 4.0 | 1.35 | 0.52 | 0.82 | 1.38 | 0.53 | 0.84 | 1.42 | 0.54 | 0.87 | 1.24 | 0.47 | 0.75 |
| 1 | 2.5 | 4.5 | 1.27 | 0.48 | 0.87 | 1.29 | 0.49 | 0.88 | 1.33 | 0.51 | 0.91 | 1.16 | 0.44 | 0.80 |
| 1 | 2.5 | 5.0 | 1.19 | 0.46 | 0.91 | 1.21 | 0.46 | 0.92 | 1.26 | 0.48 | 0.96 | 1.10 | 0.42 | 0.83 |
| 1 | 2.5 | 5.5 | 1.13 | 0.43 | 0.94 | 1.15 | 0.44 | 0.96 | 1.18 | 0.44 | 0.99 | 1.03 | 0.39 | 0.86 |
| 1 | 2.5 | 6.0 | 1.07 | 0.41 | 0.97 | 1.07 | 0.41 | 0.98 | 1.10 | 0.41 | 1.03 | 0.98 | 0.37 | 0.89 |
| 1 | 3.0 | 4.0 | 1.26 | 0.58 | 0.77 | 1.28 | 0.58 | 0.78 | 1.32 | 0.60 | 0.80 | 1.15 | 0.52 | 0.72 |
| 1 | 3.0 | 4.5 | 1.18 | 0.54 | 0.81 | 1.20 | 0.55 | 0.82 | 1.24 | 0.57 | 0.85 | 1.09 | 0.50 | 0.75 |
| 1 | 3.0 | 5.0 | 1.11 | 0.51 | 0.85 | 1.14 | 0.52 | 0.87 | 1.17 | 0.54 | 0.89 | 1.03 | 0.47 | 0.78 |
| 1 | 3.0 | 5.5 | 1.06 | 0.48 | 0.89 | 1.07 | 0.49 | 0.90 | 1.11 | 0.51 | 0.93 | 0.97 | 0.44 | 0.81 |
| 1 | 3.0 | 6.0 | 1.01 | 0.46 | 0.92 | 1.02 | 0.47 | 0.93 | 1.06 | 0.48 | 0.97 | 0.92 | 0.42 | 0.84 |
| 1 | 3.0 | 6.5 | 0.96 | 0.44 | 0.95 | 0.98 | 0.44 | 0.96 | 1.00 | 0.45 | 1.01 | 0.88 | 0.40 | 0.87 |
| 1 | 3.0 | 7.0 | 0.91 | 0.42 | 0.97 | 0.92 | 0.42 | 0.98 | 0.94 | 0.42 | 1.05 | 0.84 | 0.38 | 0.89 |
| 1 | 3.5 | 5.0 | 1.05 | 0.56 | 0.80 | 1.07 | 0.57 | 0.82 | 1.11 | 0.59 | 0.85 | 0.96 | 0.50 | 0.76 |
| 1 | 3.5 | 5.5 | 1.00 | 0.53 | 0.84 | 1.02 | 0.54 | 0.85 | 1.06 | 0.56 | 0.89 | 0.92 | 0.48 | 0.78 |
| 1 | 3.5 | 6.0 | 0.95 | 0.50 | 0.87 | 0.97 | 0.51 | 0.89 | 1.00 | 0.53 | 0.92 | 0.88 | 0.46 | 0.80 |
| 1 | 3.5 | 6.5 | 0.92 | 0.49 | 0.91 | 0.93 | 0.49 | 0.92 | 0.96 | 0.51 | 0.95 | 0.83 | 0.44 | 0.82 |
| 1 | 3.5 | 7.0 | 0.87 | 0.47 | 0.93 | 0.89 | 0.47 | 0.95 | 0.91 | 0.49 | 0.98 | 0.80 | 0.43 | 0.85 |
| 1 | 3.5 | 7.5 | 0.84 | 0.45 | 0.96 | 0.86 | 0.45 | 0.98 | 0.86 | 0.47 | 1.01 | 0.76 | 0.41 | 0.87 |
| 1 | 3.5 | 8.0 | 0.80 | 0.42 | 0.97 | 0.82 | 0.43 | 1.01 | 0.81 | 0.45 | 1.04 | 0.73 | 0.39 | 0.89 |
| 1 | 4.0 | 6.0 | 0.90 | 0.55 | 0.82 | 0.92 | 0.56 | 0.84 | 0.95 | 0.58 | 0.87 | 0.83 | 0.51 | 0.77 |
| 1 | 4.0 | 6.5 | 0.87 | 0.53 | 0.85 | 0.88 | 0.53 | 0.87 | 0.91 | 0.55 | 0.90 | 0.80 | 0.49 | 0.79 |
| 1 | 4.0 | 7.0 | 0.83 | 0.51 | 0.89 | 0.84 | 0.51 | 0.90 | 0.87 | 0.53 | 0.93 | 0.77 | 0.47 | 0.81 |
| 1 | 4.0 | 7.5 | 0.80 | 0.49 | 0.91 | 0.81 | 0.50 | 0.93 | 0.84 | 0.51 | 0.96 | 0.73 | 0.44 | 0.83 |
| 1 | 4.0 | 8.0 | 0.77 | 0.47 | 0.93 | 0.78 | 0.48 | 0.95 | 0.81 | 0.49 | 0.98 | 0.71 | 0.43 | 0.86 |
| 1 | 4.0 | 8.5 | 0.74 | 0.45 | 0.95 | 0.76 | 0.46 | 0.98 | 0.78 | 0.47 | 1.01 | 0.68 | 0.42 | 0.88 |
| 1 | 4.0 | 9.0 | 0.71 | 0.43 | 0.97 | 0.73 | 0.44 | 1.01 | 0.75 | 0.45 | 1.04 | 0.65 | 0.40 | 0.89 |
| 1 | 5.0 | 9.0 | 0.66 | 0.50 | 0.90 | 0.67 | 0.52 | 0.93 | 0.70 | 0.53 | 0.96 | 0.61 | 0.46 | 0.83 |
| 1 | 5.0 | 10.0 | 0.62 | 0.47 | 0.95 | 0.63 | 0.48 | 0.96 | 0.65 | 0.50 | 1.00 | 0.57 | 0.43 | 0.87 |

Cement that will stand a high test for seven days may have an excess of lime, which will cause it to deteriorate. The twenty-eight-day test is, therefore, very useful.

The most dangerous feature in Portland cement is the presence of too much magnesia and an excess of free lime, the latter indicated by the cracks and distortions in the test cakes and the former in the deficiency of tensile strength of the briquettes. Over 3 per cent of magnesia is excessive and dangerous.

For general information the following building material will make 1 cubic yard of concrete: 2400 pounds crushed stone, 295 pounds cement, 880 pounds sand, 700 pounds rough building stone.

Cement work which is to be painted must be fully hardened and dry. The best results are obtained after the concrete is a year old. A good preparatory coating for oil paint is a solution of water-glass in 4 parts of water. After two applications the surface is washed with water and water-glass applied again. When thoroughly dry the paint can be used.

The quality of cement-work is always improved by keeping it wet, especially during the process of setting. Cement should in no case be disturbed after it has attained its initial set.

When metal moulds are used for forming concrete, or metal lining for wooden forms, ordinary pork fat has been successfully used to prevent adhesion.

The white efflorescence sometimes seen defacing concrete is not permanent or serious, and it is easily removed by scrubbing with broom and water. It is caused by the wetting and drying of the concrete, which leaches out the alkali in the masonry from sand, water, and cement.

Sieves used to ascertain the fineness of cement:

| | | |
|--------------|--------|---------------------------|
| No. 50..... | 2,500 | meshes to the square inch |
| No. 74..... | 5,476 | “ “ “ “ “ |
| No. 100..... | 10,000 | “ “ “ “ “ |
| No. 200..... | 40,000 | “ “ “ “ “ |

In moulding a concrete block the operation should always be continuous and great care exercised in compacting the cement next to all parts of mould which mould the exterior surfaces. Great care should be exercised in removing the moulds, which under ordinary circumstances can be done twenty-four hours after the concrete has been in place. The block, after removal

of the mould, should be shaded by canvas or heavy burlap and kept thoroughly wetted for a number of days.

Neat cement reaches a greater strength at short periods than sand mixtures. Long-time tests prove, however, that sand mixtures ultimately attain equal and often greater strength than neat cement.

The compressive strength of cement is from eight to twelve times the tensile strength.

White sand or marble dust used in making concrete gives the finished work a lighter color than is attained by using ordinary sand.

When salt is used in concrete, to prevent freezing, it should always be thoroughly dissolved in water before it is added to the cement—one pound of salt to every 18 gallons of water when the thermometer is at 32° F., and one additional ounce of salt for every further degree below 32.

CONCRETE CONSTRUCTION.—Concrete was the most important of all the building materials used by the Romans, and the developments of the past few years have brought about changes until it is now recognized as one of the most important materials used at the present time.

A test as to the durability of concrete is found in the Pantheon at Rome, which was built by Agrippa, 27 B.C., nearly 2000 years ago. The circular walls are about 20 feet in thickness, and the roof is a hemispherical cement concrete dome with a 30-foot opening in the top and spanning in the clear 142 feet 6 inches. This is the most remarkable instance in the world's history, showing the great strength and durability in cement-concrete construction.

Concrete construction is usually done by building wood forms or moulds and ramming them full of concrete, either solid or with hollow walls. The superintendent must see that these forms are built tight and strong enough to withstand the pressure of the concrete while being rammed. If the concrete is to be reinforced with steel of any kind he must see that it is put in at the proper place and in sufficient quantity.

Forms.—Pine is the best wood for building forms or moulds; some other woods (especially California redwood) will stain the finished surface of the concrete.

Mouldings, rustications, etc., are built in the form and the concrete is rammed into them.

It is advisable to wet the concrete several times a day for

several days after it has been put in place, to prevent it drying too fast. In building forms for foundations, walls, etc., care must be taken to provide chases and openings for all pipes, etc., and where any wood is to be fastened to the concrete to build in bolts with the nut end sticking out from the face of the wall a sufficient distance to bolt up the woodwork.

Concrete is one of the best and most reliable of building materials when [mixed and put in place in a proper manner; where there have been failures in concrete construction it has generally been due to one of the following causes: Bad centring and forms, bad material, poor mixing, insufficient ramming, or insufficient and poor reinforcement.

It will be the duty of the superintendent to see that all the requirements of the plans and specifications are carried out to their strict intentions and meaning.

Concrete building-blocks in imitation of stone, etc., are now being made, which require close inspection to tell that they are not the natural stone. These are made in any shape or form desired and given any desired finish. In use these blocks are set and pointed the same as stone ashlar.

CONCRETE-STEEL CONSTRUCTION.—The following regulations for reinforced concrete-steel construction were issued by the Bureau of Buildings of the Borough of Manhattan, Greater New York, September 9, 1903:

1. The term "concrete-steel" in these regulations shall be understood to mean an approved concrete mixture reinforced by steel of any shape, so combined that the steel will take up the tensional stresses and assist in the resistance to shear.

2. Concrete-steel construction will be approved only for buildings which are not required to be fireproof by the Building Code, unless satisfactory fire and water tests shall have been made under the supervision of this bureau. Such tests shall be made in accordance with the regulations fixed by this bureau and conducted as nearly as practicable in the same manner as prescribed for fire-proof floor fillings in Section 106 of the Building Code. Each company offering a system of concrete-steel construction for fire-proof buildings must submit such construction to a fire and water test.

3. Before permission to erect any concrete-steel structure is issued complete drawings and specifications must be filed with the superintendent of buildings, showing all details of the construction, the size and position of all reinforcing-rods, stirrups, etc., and giving the composition of the concrete.

4. The execution of work shall be confided to workmen who shall be under the control of a competent foreman or superintendent.

5. The concrete must be mixed in the proportions of one of cement, two of sand, and four of stone or gravel; or the proportions may be such that the resistance of the concrete to crushing shall not be less than 2000 pounds per square inch after hardening for 28 days. The tests to determine this value must be made under the direction of the superintendent of buildings. The concrete used in concrete-steel construction must be what is usually known as a "wet" mixture.

6. Only high-grade Portland cements shall be permitted in concrete-steel construction. Such cements, when tested neat, shall, after one day in air, develop a tensile strength of at least 300 pounds per square inch; and after one day in air and six days in water shall develop a tensile strength of at least 500 pounds per square inch; and after one day in air and 27 days in water shall develop a tensile strength of at least 600 pounds per square inch. Other tests, as to fineness, constancy of volume, etc., made in accordance with the standard method prescribed by the American Society of Civil Engineers' Committee, may from time to time be prescribed by the superintendent of buildings.

7. The sand to be used must be clean, sharp, grit sand free from loam or dirt, and shall not be finer than the standard sample of the Bureau of Buildings.

8. The stone used in the concrete shall be a clean, broken trap-rock or gravel of a size that will pass through a $\frac{3}{4}$ -inch ring. In case it is desired to use any other material or other kind of stone than that specified, samples of same must first be submitted to and approved by the superintendent of buildings.

9. The steel shall meet the requirements of Section 21 of the Building Code.

10. Concrete-steel shall be so designed that the stresses in the concrete and the steel shall not exceed the following limits:

| | Pounds per Square Inch. |
|--|----------------------------|
| Extreme fibre stress on concrete in compression..... | 500 |
| Shearing stress in concrete..... | 50 |
| Concrete in direct compression..... | 350 |
| Tensile stress in steel..... | 16,000 |
| Shearing stress in steel..... | 10,000 |

11. The adhesion of concrete to steel shall be assumed to be not greater than the shearing strength of the concrete.

12. The ratio of the moduli of elasticity of concrete and steel shall be taken as 1 to 12.

13. The following assumption shall guide in the determination of the bending moments due to the external forces: Beams and girders shall be considered as simply supported at the ends, no allowance being made for the continuous construction over supports. Floor plates, when constructed continuous and when provided with reinforcement at top of plate over the supports, may be treated as continuous beams, the bending moment for uniformly distributed loads being taken at not less than $\frac{WL}{10}$; the bending moment may be taken as $\frac{WL}{20}$ in the case of square floor plates which are reinforced in both directions and supported on all sides. The floor plate to the extent of not more than ten times the width of any beam or girder may be taken as part of that beam or girder in computing its moment of resistance.

14. The moment of resistance of any concrete-steel construction under transverse loads shall be determined by formulas based on the following assumptions:

a. The bond between the concrete and steel is sufficient to make the two materials act together as a homogeneous solid.

b. The strain in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

c. The modulus of elasticity of the concrete remains constant within the limits of the working stresses fixed in these regulations.

From these assumptions it follows that the stress in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

The tensile strength of the concrete shall not be considered.

15. When the shearing stresses developed in any part of a construction exceed the safe working-strength concrete, as fixed in these regulations, a sufficient amount of steel shall be introduced in such a position that the deficiency in the resistance to shear is overcome.

16. When the safe limit of adhesion between the concrete and steel is exceeded, some provision must be made for transmitting the strength of the steel to the concrete.

17. Concrete-steel may be used for columns in which the ratio of length to least side or diameter does not exceed 12.

The reinforcing-rods must be tied together at intervals of not more than the least side or diameter of the column.

18. The contractor must be prepared to make load tests on any portion of a concrete-steel construction, within a reasonable time after erection, as often as may be required by the superintendent of buildings. The tests must show that the construction will sustain a load of three times that for which it is designed without any sign of failure.

Approved September 9, 1903.

HENRY S. THOMPSON,

Superintendent of Buildings for the Borough of Manhattan.

CONCRETE-FLOOR CONSTRUCTION.—There are a number of different systems of concrete-floor construction and fireproofing, each being controlled by a different company, and it will be the duty of the superintendent to keep himself posted regarding all the different systems, so that when one is put under his supervision he can readily judge if it is being done right.

A system of floor construction may be perfectly reliable when properly constructed but with poor material or workmanship it may result in a weak floor.

Cinder concrete reinforced in different ways with steel is the usual construction, and the superintendent must see that all the materials are the best and the reinforcing and workmanship done in a proper manner.

The proportions for a good cinder concrete are one part cement, two parts sand, and five parts cinders.

Regarding fire-proof floors the New York Building Code says:

Sec. 106. *Fire-proof Floors*.—Fire-proof floors shall be constructed with wrought-iron or steel floor-beams so arranged as to spacing and length of beams that the load to be supported by them, together with the weights of the materials used in the construction of the said floors, shall not cause a greater deflection of the said beams than one-thirtieth of an inch per foot of span under the total load; and they shall be tied together at intervals of not more than eight times the depth of the beam. Between the wrought-iron or steel floor-beams shall be placed brick arches springing from the lower flange of the steel beams. Said brick arches shall be designed with a rise to safely carry the imposed load, but never less than one and one-quarter inches for each foot of span between the beams, and they shall have a thickness of not less than four inches for spans of five feet or less and eight inches for

spans over five feet, or such thickness as may be required by the Board of Buildings. Said brick arches shall be composed of good, hard brick or hollow brick of ordinary dimensions laid to a line on the centres, properly and solidly bonded, each longitudinal line of brick breaking joints with the adjoining lines in the same ring and with the ring under it when more than a four-inch arch is used. The brick shall be well wet and the joints filled in solid with cement mortar. The arches shall be well grouted and properly keyed. Or the space between the beams may be filled in with hollow-tile arches of hard-burnt clay or porous terra-cotta of uniform density and hardness of burn. The skew-backs shall be of such form and section as to properly receive the thrust of said arch; and the said arches shall be of a depth and sectional area to carry the load to be imposed thereon, without straining the material beyond its safe working load, but said depth shall not be less than one and three-quarter inches for each foot of span, not including any portion of the depth of the tile projecting below the under side of the beams, a variable distance being allowed of not over six inches in the span between the beams, if the soffits of the tile are straight; but if said arches are segmental, having a rise of not less than one and one-quarter inches for each foot of span, the depth of the tile shall be not less than six inches. The joints shall be solidly filled with cement mortar as required for common brick arches and the arch so constructed that the key block shall always fall in the central portion. The shells and webs of all end construction blocks shall abut, one against another. Or the space between the beams may be filled with arches of Portland-cement concrete, segmental in form, and which shall have a rise of not less than one and one-quarter inches for each foot of span between the beams. The concrete shall be not less than four inches in thickness at the crown of the arch and shall be mixed in the proportions required by Section 18 of this Code. These arches shall in all cases be reinforced and protected on the under side with corrugated or sheet steel, steel ribs, or metal in other forms weighing not less than one pound per square foot and having no openings larger than three inches square. Or between the said beams may be placed solid or hollow burnt-clay, stone, brick, or concrete slabs in flat or curved shapes, concrete or other fire-proof composition, and any of said materials may be used in combination with wire cloth, expanded metal wire

strands, or wrought-iron or steel bars; but in any such construction and as a precedent condition to the same being used, tests shall be made as herein provided by the manufacturer thereof under the direction and to the satisfaction of the Board of Buildings, and evidence of the same shall be kept on file in the Department of Buildings, showing the nature of the test and the result of the test. Such tests shall be made by constructing within inclosure walls a platform consisting of four rolled steel beams, ten inches deep, weighing each twenty-five pounds per lineal foot, and placed four feet between the centres, and connected by transverse tie-rods, and with a clear span of fourteen feet for the two interior beams and with the two outer beams supported on the side walls throughout their length, and with both a filling between the said beams and a fire-proof protection of the exposed parts of the beams of the system to be tested, constructed as in actual practice, with the quality of material ordinarily used in that system and the ceiling plastered below, as in a finished job; such filling between the two interior beams being loaded with a distributed load of one hundred and fifty pounds per square foot of its area and all carried by such filling; and subjecting the platform so constructed to the continuous heat of a wood fire below, averaging not less than seventeen hundred degrees Fahrenheit for not less than four hours, during which time the platform shall have remained in such condition that no flame will have passed through the platform or any part of the same, and that no part of the load shall have fallen through, and that the beams shall have been protected from the heat to the extent that after applying to the under side of the platform at the end of the heat test a stream of water directed against the bottom of the platform and discharged through a one and one-eighth inch nozzle under sixty pounds pressure for five minutes, and after flooding the top of the platform with water under low pressure, and then again applying the stream of water through the nozzle under the sixty pounds pressure to the bottom of the platform for five minutes, and after a total load of six hundred pounds per square foot uniformly distributed over the middle bay shall have been applied and removed, after the platform shall have cooled, the maximum deflection of the interior beams shall not exceed two and one-half inches. The Board of Buildings may from time to time prescribe additional or different tests than the foregoing for systems of filling between

iron or steel floor-beams, and the protection of the exposed parts of the beams. Any system failing to meet the requirements of the test of heat, water, and weight as herein prescribed shall be prohibited from use in any building hereafter erected. Duly authenticated records of the tests heretofore made of any system of fire-proof floor filling and protection of the exposed parts of the beams may be presented to the Board of Buildings, and if the same be satisfactory to said Board, it shall be accepted as conclusive. No filling of any kind which may be injured by frost shall be placed between said floor-beams during freezing weather, and if the same is so placed during any winter month, it shall be temporarily covered with suitable material for protection from being frozen. On top of any arch, lintel, or other device which does not extend to and form a horizontal line with the top of the said floor-beams, cinder concrete or other suitable fire-proof material shall be placed to solidly fill up the space to a level with the top of the said floor-beams, and shall be carried to the under side of the wood floor-boards in case such be used. Temporary centring when used in placing fire-proof systems between floor-beams shall not be removed within twenty-four hours or until such time as the mortar or material has set. All fire-proof floor systems shall be of sufficient strength to safely carry the load to be imposed thereon without straining the material in any case beyond its safe working load. The bottom flanges of all wrought-iron or rolled-steel floor and flat roof beams, and all exposed portions of such beams below the abutments of the floor-arches, shall be entirely encased with hard-burnt clay, porous terracotta, or other fire-proof material allowed to be used for the filling between the beams under the provisions of this section, such incasing material to be properly secured to the beams.

The exposed sides and bottom plates or flanges of wrought-iron or rolled-steel girders supporting iron or steel floor-beams, or supporting floor-arches or floors, shall be entirely incased in the same manner. Openings through fire-proof floors for pipes, conduits, and similar purposes shall be shown on the plans. After the floors are constructed no opening greater than eight inches square shall be cut through said floors unless properly boxed or framed around with iron. And such openings shall be filled in with fire-proof material after the pipes or conduits are in place.

Sec. 107. *Incasing Interior Columns.*—All cast-iron, wrought-iron, or rolled-steel columns, including the lugs and brackets on

same, used in the interior of any fire-proof building, or used to support any fire-proof floor, shall be protected with not less than two inches of fire-proof material, securely applied. The extreme outer edge of lugs, brackets, and similar supporting metal may project to within seven-eighths of an inch of the surface of the fireproofing.

Expanded-metal Floor Construction.—The following cuts show the method of concrete floor construction used by the various expanded-metal companies. This is a flat cinder concrete arch reinforced with expanded metal as shown.

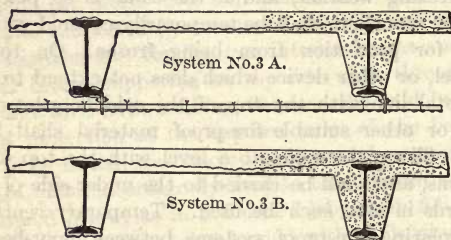


FIG. 125.

Systems 3 A and 3 B, Fig. 125, are alike except that 3 A has a flat ceiling supported on the under flange of the floor-beams. This system fireproofs the beam by a haunch fill of the cinder concrete.

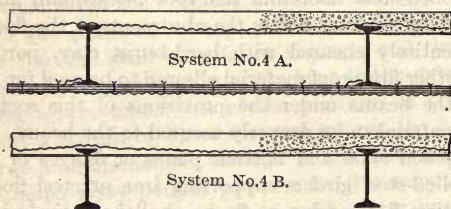
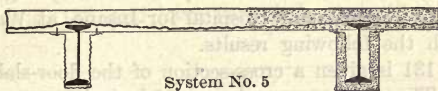


FIG. 126.

Systems 4 A and 4 B, Fig. 126, are alike except that 4 A has a flat ceiling suspended. By changing the thickness of the concrete and the quantity of metal spans, from four to ten feet can be built on this system.

System 5, Fig. 127, differs from 4 B in that the floor-beam is protected with a coat of plaster on a metal lath, which is furred to the beams, giving the panelled ceiling. The usual way of putting

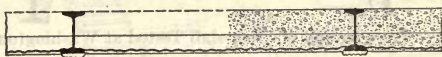
on this furring is to nail it up to the concrete as shown, but a better way is to put it in place before the floor is laid and turn it up over the top of the beam and wire it fast.



System No. 5

FIG. 127.

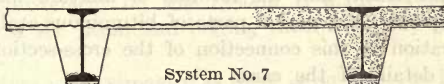
System 7, Fig. 129, is developed from System 8, where the beams are too deep for a fill above the concrete construction.



System No. 8

FIG. 128.

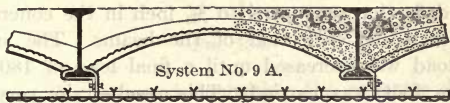
System 8, Fig. 128, is designed to be used where the floor-beams are light and can be used with economy with beams not over 7 ins. deep or more than 4 ft. 6 ins. on centres.



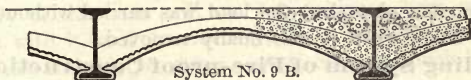
System No. 7

FIG. 129.

Systems 9 A and 9 B, Fig. 130, are designed for heavy loads, and is one of the strongest systems used.



System No. 9 A.



System No. 9 B.

FIG. 130.

In any of the above systems it will be the duty of the superintendent to see that the centring is put up solid enough to withstand the tamping of the concrete. See that the concrete

is mixed and put in place correctly, and as the strain on the expanded metal is a tensile one, see that it is stretched tight before the concrete is put on top.

A floor-arch of this construction, as shown by Fig. 131, was tested at the Government Hospital for Insane, at Washington, D. C., with the following results.

In Fig. 131 is given a cross-section of the floor-slab as built for test. The test was made on 15-inch beams which had



FIG. 131.—Cross-section of Floor-slab Tested at Washington, D. C.

bearings on foundations 20 feet apart, and a floor was built covering the whole distance from bearing to bearing. The test load was applied on an area $5' 6'' \times 5' 6''$, making a trifle over 30 square feet of area. Standard practice in this connection was followed, which means that the concrete plate was 3 inches thick, and the formula of mixture was 1 part cement, 2 parts sand, and 6 parts of bituminous-coal cinders. The illustration in this connection of the cross-section clearly shows the details of the case.

The arch was thirty-eight days old when it was first loaded with 600 pounds per square foot. Under that weight the arch showed a deflection of $\frac{1}{16}$ inch. There was also a slight deflection to the beams themselves. On the following day the load was increased to 1256 pounds per square foot, and at that time the deflection amounted to $\frac{3}{16}$ inch in the concrete plate, with an increased deflection of the beams. The succeeding day the load was increased until a final load of 1800 pounds per square foot was carried. This resulted in very marked beam deflection and twisting, and also some cracks appeared in the concrete plate, but the load was carried without falling for some days, when it was finally removed.

Roebling System of Fire-proof Construction.—In this system the concrete is reinforced with $\frac{1}{8}'' \times 2''$ flat steel bars set on edge, and by a quarter turn is hooked over the beam at each end. These bars act as fitch-plates when bedded in the concrete, and when put in place in a proper manner give great strength to the concrete.

The superintendent should see that the twist on the bar is made so it comes tight against the beam. The author has seen these bars put in where the twist was 4 or 5 inches away from the beam, and in this space the bar would be on its flat, as shown by Fig. 132, and have very little strength. He should

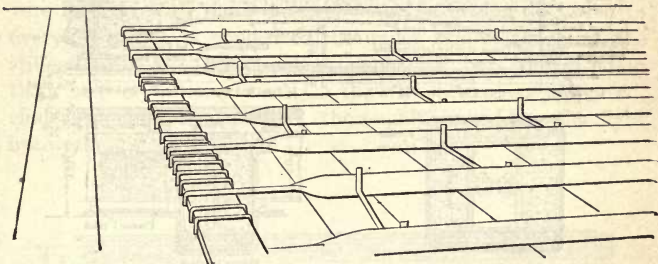


FIG. 132.

also see that the bars are hooked tight over the beam, as the strength depends materially on this.

An improvement on this system is made by running the bars across the beam and bolting them together, as shown by Fig. 133.

This gives more strength, as there is no twist, and the entire bar is on edge. This system is sometimes put in by hanging

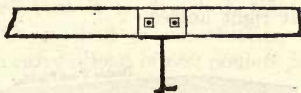


FIG. 133.

wire lath to the bars and depositing the concrete directly on the lath, but concrete deposited in this way must be made very dry or the water will run out, taking a large part of the cement with it, and if made dry, there is no way of ramming it to make it solid; by using a wood centre a much better and stronger floor can be made.

The following cuts show various types of this floor construction.

The "System A," or arch construction, with flat ceiling, is illustrated by Fig. 134. It consists of a wire-cloth arch, stiffened

in concrete and spans the interval between the iron beams in the form of a slab. The light iron framework consists of flat iron or steel bars set on edge and spaced 16 inches, centre to centre, with a quarter turn at both ends where the bars rest upon the iron beams. Spacers of half oval iron are placed at suitable intervals to separate and brace the bars. The Roebling Standard wire lathing, with the $\frac{1}{4}$ -inch solid-steel stiffening-rib woven in every $7\frac{1}{2}$ inches, is applied to the under side of the bars, the stiffening-ribs running crosswise under the bars and laced to them at every intersection. On the wire lathing so supported, cinder concrete is deposited, thoroughly imbedding the light ironwork.

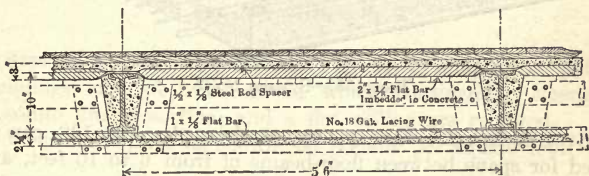


FIG. 136.—System B—Type 1.
(Dotted lines indicate temporary wood centring.)

The Renton System of Fire-proof Floors.—The Renton system of floor construction as shown by the following cuts is a flat concrete arch of cinder concrete, reinforced with ordinary barb wire. The strain on the wire being tensile, the superintendent should see that it is stretched tight and made fast at each end. This method of construction $4\frac{1}{2}$ inches thick has been tested to carry a load of 650 pounds per square foot.

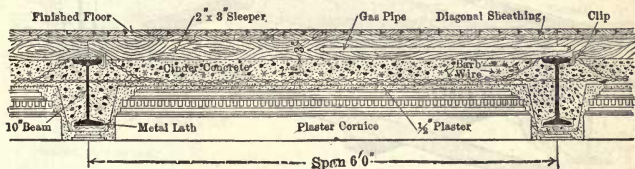


FIG. 137.—System No. 1.

SYSTEM No. 1.—This is perhaps the most popular system, as it gives a minimum thickness of floor and is adapted to

the conditions most commonly found in fire-proof buildings. It can be used for spans up to 8 feet, although a span of 6 feet is the most desirable.

Weight of concrete, about 34 pounds per square foot.

Weight of entire floor as shown, 52 pounds per square foot.

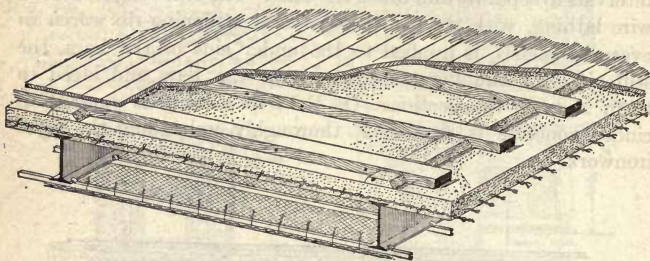


FIG. 138.—System No. 2.

SYSTEM No. 2.—This system, as shown by Fig. 138, can be used for spans between floor-beams of from 6 to 10 feet, and has ample strength for most mercantile buildings, factories, etc. It can be used either with or without the suspended flat ceiling shown.

Weight of entire floor, without ceiling, 40 pounds per square foot.

Weight of suspended ceiling, including plaster, 10 pounds per square foot.

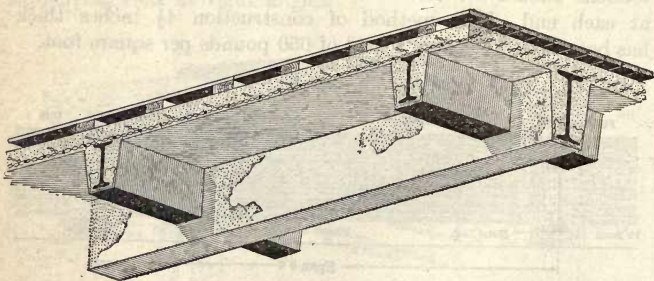


FIG. 139.—System No. 3.

SYSTEM No. 3.—This system, Fig. 139, is the same as No. 2, except that the floor-beams are thoroughly protected and the flat ceiling is omitted.

Weight per square foot for 4 inches of concrete, 10-inch steel beams, 6 feet on centres, 2×3 sleepers and a single wood floor, no plastering, 48 pounds.

Weight with cement top, 59 pounds per square foot. For ½-inch plastering add 5 pounds per square foot.

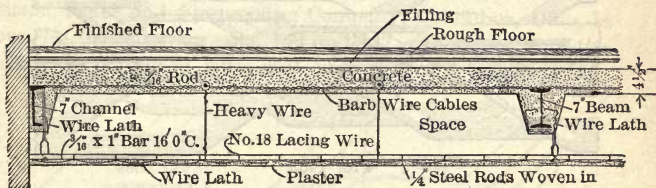


FIG. 140.—System No. 4.

SYSTEM No. 4.—This system, Fig. 40, is adapted to public buildings and all buildings in which considerable strength, absolute fire protection, and a flat ceiling are required.

Weight complete as shown, 60 pounds per square foot.

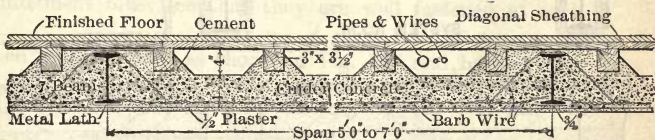


FIG. 141.—System No. 5.

SYSTEM No. 5.—This system, Fig. 141, is especially adapted to apartment houses, private residences, etc.

SYSTEM No. 6 (ARCH CONSTRUCTION).—This system, Fig. 142,

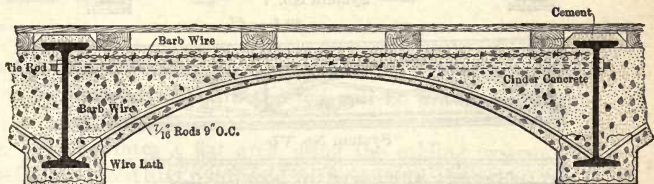


FIG. 142.—System No. 6 (Arch Construction).

is designed for warehouses, storage buildings, etc., and all buildings in which great strength and absolute fire protection are required. With a span of 6 feet this floor is guaranteed

to sustain a distributed load of 1000 pounds per square foot over its entire surface without falling.

“**Kuhne’s Sheet-metal Structural Element.**”—
The following cuts show a system of floor construction in which a

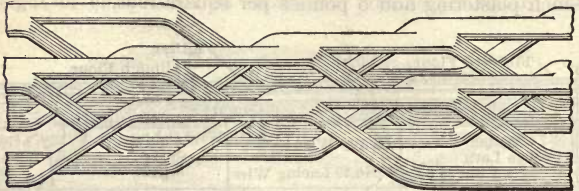
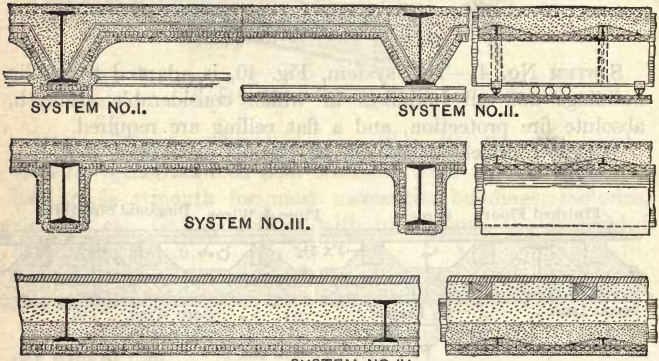
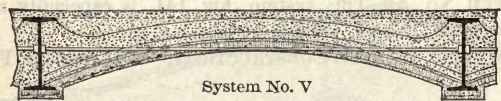


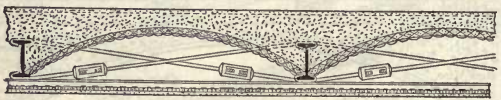
FIG. 143.



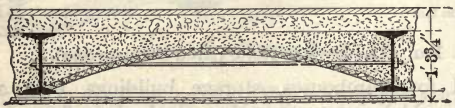
SYSTEM NO. I. SYSTEM NO. II. SYSTEM NO. III. SYSTEM NO. IV.
FIG. 144.



System No. V



System No. VI



System No. VII
FIG. 145.

patent metal lath which is cut and bent so as to form a series of trusses is used as a reinforcing material. This lath is manufactured by the Truss Metal Lath Company, New York.

Fig. 143 shows a view of the lath, and Figs. 144 and 145 show methods of floor construction.

International System.—This system, used by the International Fence and Fireproofing Company, Columbus, Ohio, is shown by the following cuts, 146 and 147. In this system the concrete is reinforced with wire rods and wire cables.

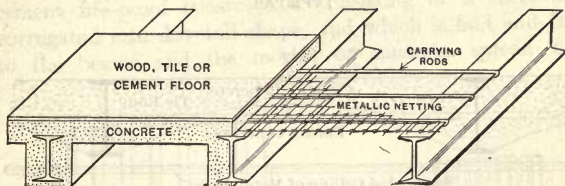


FIG. 146.

The strain on the wire and cables being a tensile one the superintendent must see that they are well fastened at each end.

When rods are used as shown in Fig. 147 and hooked over

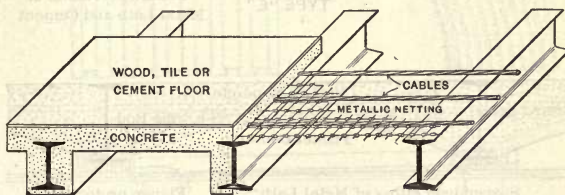


FIG. 147.

the beam, the rod should be bent while hot, so that when the hook is made over the beam the rod will be drawn tight and have no play.

Fig. 146 illustrates a flat arch, using the cabling system. I beams fully incased and reinforced with concrete, the cables running across the I beams and anchored thereto. The sheeting is distributed over the cables and both are imbedded well toward the bottom of the concrete stone. Anchors should be built in the wall to fasten the cables and sheeting when the walls are

built, and always have the brick laid in cement where anchors are placed.

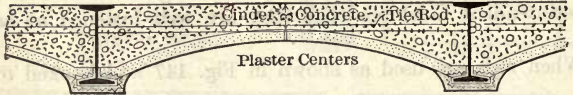
Fig. 147 represents flat arch with distributing rods, metallic sheeting, encased I beams, and section of concrete floor. Anchors should be built in the wall at a level with the top



TYPE "A"



TYPE "B"



TYPE "E"

Flange protection of
Metal Lath and Cement

TYPE "F"

Flange protection of
Metal Lath and Cement

TYPES OF VULCANITE FIRE-PROOF FLOOR ARCHES

FIG. 148.

the I beams, upon which the ends and outside sheets are fastened. Inside laps are attached by means of loops on the edge which are interwrapped with a twist.

The Vulcanite Fire-proof Floor.—The Vulcanite fire-proof floor system, constructed by The Vulcanite Paving Company, Philadelphia, is a cinder concrete arch put in on a plaster-of-Paris centre, as shown by Fig. 148. The plaster-of-Paris centre is cast in sections and put in place on the lower flange of the beam and the concrete spread over it. This is a very strong system of floor construction, as the strain on the concrete is a compressive one.

Ferrouinclave.—Ferrouinclave is the name of a steel and cement fire-proof construction consisting of a sheet of steel corrugated into dovetail shape, and which is laid and fastened to the beams and the mortar or concrete spread on top.

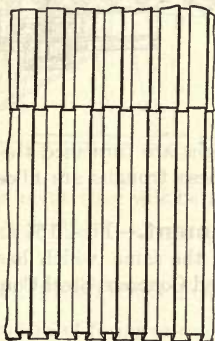


FIG. 149.

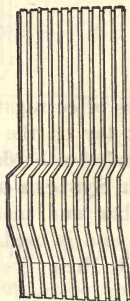


FIG. 150.—Sheet bent to shape.

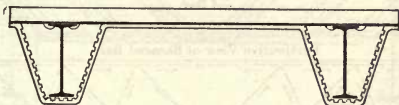


FIG. 151.

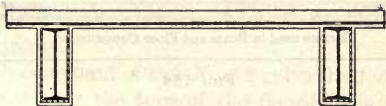


FIG. 152.

Figs. 149 and 150 show a sheet of the metal, and Figs. 151 and 152 show floor sections.

Buckeye Floor Construction.—Fig. 153 shows a method of floor construction patented and used by The Youngstown Iron and Steel Roofing Co., Youngstown, Ohio.

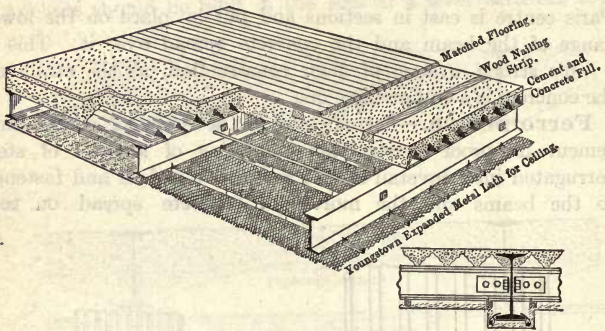


FIG. 153.

A series of corrugated metal troughs are furnished the exact length to lay on the beams, and these troughs are filled with the concrete to the desired depth.

Kahn System of Reinforcement.—Figs. 154 and 155 show a bar and method of using the same which has been patented and is used by The Trussed Concrete Steel Company, of Detroit, Mich.

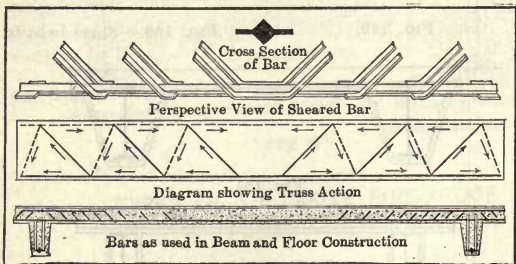


FIG. 154.

Metropolitan System.—This system, as shown by Figs. 156, 157, and 158, is a slab or arch made of plaster of Paris and wood chips, reinforced with wire cables in the form of

hog-chains and bedded in the concrete. The cables must be made secure at the ends and have just sag enough so that at

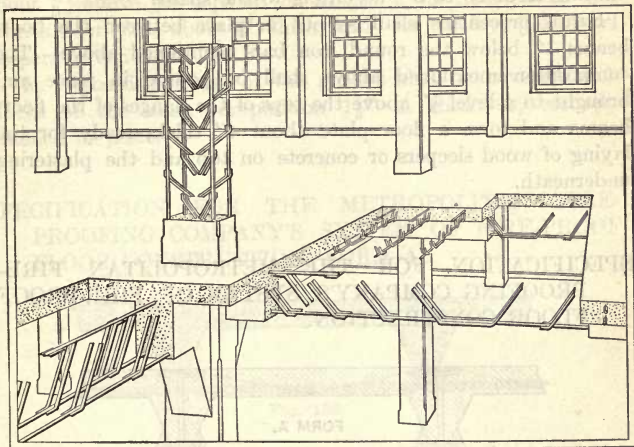


FIG. 155.

the low point they will be about one-half inch from the bottom of the concrete.

SPECIFICATIONS FOR ABOVE TYPE OF FLOOR.

By means of forms or centres placed about the bottom flanges of the floor beams and girders, a $1\frac{1}{2}$ " covering of composition, composed principally of plaster of Paris and wood chips, shall

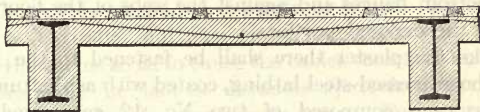


FIG. 156.

be cast in place, protecting the bottom flanges of the floor beams and girders.

Cables, each composed of two No. 12 galvanized wires, twisted, shall be carried over the tops of the floor-beams and shall be secured to walls by anchors and bars; or where they end on a beam, shall be secured to it by strong hooks. These cables shall be laid parallel and pass under round iron bars midway

between the beams, so as to cause the cables to deflect uniformly. The cables shall be laid at distances apart from each other, varying from 1" to 3", according to the spans.

Forms or centres shall be put in place between the floor-beams 1" below the round iron bars mentioned above. The composition mentioned above shall be poured in place and brought to a level $\frac{1}{2}$ " above the tops of the flanges of the floor-beams and form a floor plate about 4" thick, ready for the laying of wood sleepers or concrete on top and the plastering underneath.

SPECIFICATION FOR THE METROPOLITAN FIRE-PROOFING COMPANY'S SYSTEM OF FIRE-PROOF FLOOR CONSTRUCTION.

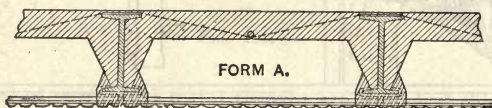


FIG. 157.

Metal clips shall be fastened to the bottom flanges of the floor-beams, which shall support $1'' \times \frac{3}{16}''$ flat iron bars spaced about 16" on centres running transversely with the floor-beams, the tops of such flats to be on a level about 1" below the bottom flanges.

Blocks $1\frac{1}{2}''$ thick of our composition, composed principally of plaster of Paris and wood chips, shall be fastened securely to the bottom flanges and against the webs of the floor-beams, covering the exposed portions.

To take the plaster there shall be fastened to the 1" flats herring-bone pressed-steel lathing, coated with asphaltum.

Cables, each composed of two No. 12 galvanized wires, twisted, shall be carried over the tops of the floor-beams and shall be secured to walls by anchors or bars, or where they end on a beam shall be secured to it by strong hooks. These cables shall be laid parallel and pass under round iron bars midway between the beams so as to cause the cables to deflect uniformly. The cables shall be laid at distances apart from each other varying from 1" to 3", according to spans. Forms or centres shall be put in place between the floor-beams 1" below the

round iron bars mentioned above. The composition mentioned above shall be poured in place and brought to a level about $\frac{1}{2}$ " above the tops of the flanges of the floor-beams and form a floor plate about 4" thick ready for the laying of wood sleepers or concrete.

The exposed portions of the girders shall be covered with blocks of the same composition $1\frac{1}{2}$ " in thickness, securely fastened in place.

SPECIFICATION FOR THE METROPOLITAN FIRE-PROOFING COMPANY'S SYSTEM OF FIRE-PROOF FLOOR CONSTRUCTION, FORM A2.



FIG. 158.

Metal clips shall be fastened to the bottom flanges of the floor-beams, which shall support $1'' \times \frac{3}{16}''$ flat iron bars spaced about 12" on centres, running transversely with the floor-beams, the tops of such flats to be on a level about 1' below the bottom flanges.

To take the plaster there shall be fastened to the 1" flats herring-bone pressed-steel lathing, coated with asphaltum.

Cables, each composed of two No. 12 galvanized wires, twisted, shall be carried over the tops of the floor-beams and shall be secured to walls by anchors or bars, or where they end on a beam shall be secured to it by strong hooks. These cables shall be laid parallel and pass under round iron bars midway between the beams so as to cause the cables to deflect uniformly. The cables shall be laid at distances apart from each other varying from 1" to 3", according to spans. Forms or centres shall be put in place between the floor-beams 1" below the round iron bars mentioned above. A composition composed principally of plaster of Paris and wood chips shall be poured in place and brought to a level about $\frac{1}{2}$ " above the tops of the flanges of the floor-beams covering the webs of the beams and forming a floor-plate about 4" thick, ready for the laying of wood sleepers or concrete.

The exposed portions of the girders shall be covered with

blocks of the same composition, $1\frac{1}{2}$ " in thickness, securely fastened in place.

The Ransome System.—The Ransome system of concrete and cold-twisted steel construction was invented by Mr. Ernest L. Ransome. The basis of this system is the combination of steel and concrete in such a manner as to give to the concrete all the tensional strength of steel, and thereby fully utilize the immense compressive strength inherent in the concrete. The patent for this system covers the use of cold-twisted rectangular steel bars, by means of which the spiral ribs formed upon the metal make a continuous lock between it and the concrete. By this means the ductility of the steel is controlled, defective steel detected, and a large percentage of strength added thereto.

The tensional strength of steel or iron (about 30 tons to the square inch) increases the strength of the concrete 100-fold. The Ransome bar strengthens the concrete so that in the heaviest floors for warehouse and sand factories bars of only $1\frac{1}{2}$ inches have been used. The extensive application of the Ransome system for fire-proof floors, spanning without steel beams, from 20 to 25 and 45 feet, represents one of its important successes.

To make a practical success of this principle a continuous bond between the iron and the concrete had to be invented, the ductility of the iron had to be controlled, and appliances for moulding had to be perfected, as well as means of controlling the shrinkage. Furthermore, it was desirable to give an artistic appearance to the structure. These, with other important and practical inventions, constituted the Ransome system.

This system of concrete-iron construction is universal in its application, covering the entire field now occupied by stone, brick, and terra-cotta, and is unrivalled for stairs, foundations, walls, floors, columns, partitions, harbor works, dry docks, piers, bridges, reservoirs, filter-beds, fortifications, retaining-walls, sidewalks, vault lights, etc.

The Ransome patents are owned by the Ransome Concrete Company, 26 Broadway, New York.

Hennebique System of Cement Concrete Construction.—The Hennebique system, Fig. 159, is not only a system of fire-proofing, but a mode of construction successfully applied to many uses, such as floors, bridges, reservoirs, docks, foundations, etc. Broadly speaking, the system, as

patented in 1898, is for concrete reinforced with ordinary round bars of iron or steel and stirrups of hoop iron.

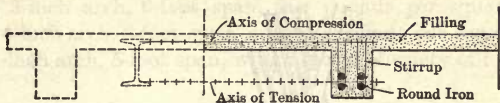


FIG. 159.—Section of Hennebique Floor.

The principle of the Hennebique system is to make the cement concrete subject only to compression stresses, resistance to which is its chief characteristic; and the iron subject to tensile stresses, which it is essentially adapted to meet. For floor construction plain, round iron bars, set in the lower part of a beam of rectangular or trapezoidal section, are the parts in tension; in that position the metal exerts its best quality, resistance in tension. A series of straps distributed along the beam connect the bar with the upper part of the concrete and make a series of fastenings which steady and support

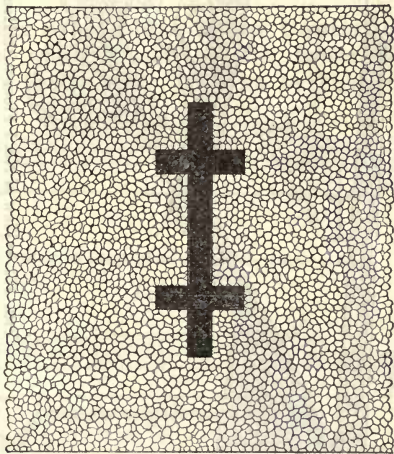


FIG. 160.—Two-inch Ribbed Bar Imbedded in $3\frac{1}{2}$ Inches of Concrete.

the bar. They carry to the upper part of the concrete the stresses which in them are tensile, but which are then distributed as compression stresses through the body of concrete.

The Hennebique system has been applied to many important uses in bridge engineering and general building operations.

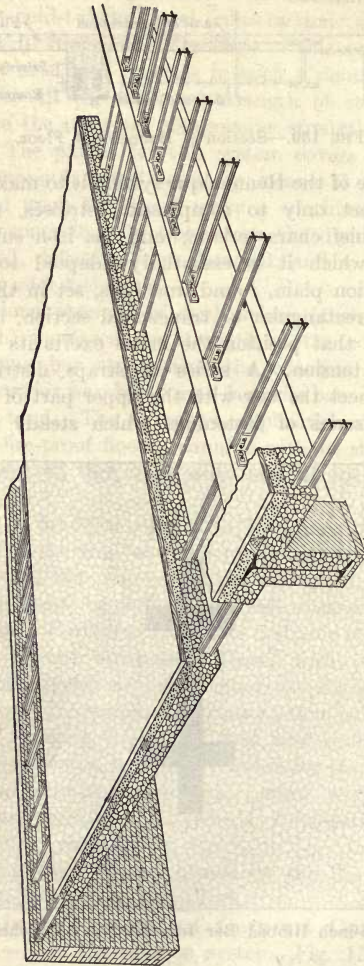


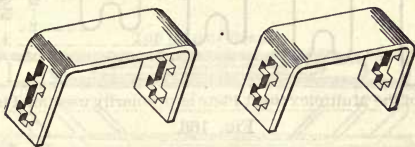
Fig. 161.—View of No. 1 Floor with Heavy Ribbed Bars Framed to Girders.

Columbian System of Floor Construction.—In the Columbian system, as shown by Figs 160, 161, and 162,

the concrete is reinforced with specially designed bars of steel hung on stirrups over the beams. This construction is guaranteed by the company to carry 200 pounds per square foot with a 3-inch arch, 6-foot span, 600 pounds per square foot with a 4-inch arch, 6-foot span, and 150 pounds per square foot on a 2½-inch arch, 5-foot span, with a factor of safety of four.



FIG. 162.—No. 3, Double Construction.



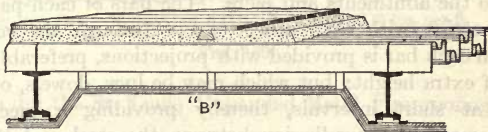
View of Stirrups for Bars, Floors Nos. 2 and 3.

Multiplex Steel-plate Floor Construction.—This construction, which is used by The Berger Manufacturing Company, of Canton, Ohio, is shown by Figs. 163–166. The



The Multiplex Steel Plate used in its simplest form

FIG. 163.

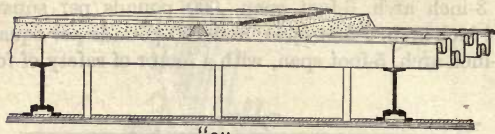


The Multiplex Steel Plate Floor with a Paneled Ceiling

FIG. 164.

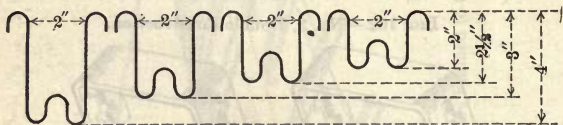
steel plate is corrugated and bent as shown, laid on top of the floor-beams and then filled with the cinder concrete

to a height of about 2 inches above the plate. The different methods of construction are shown in the cuts.



The Multiplex Steel Plate Floor with a Flat Ceiling,

FIG. 165.



Dimensions of the Multiplex Steel Plate as ordinarily used for Floor Arches,

FIG. 166.

The Thacher System of Concrete-steel Construction.—The concrete-steel arch, patented Jan. 10, 1899, and known as the Thacher system, may be described as follows: Steel bars (Fig. 167) in pairs, spaced at proper distances apart,



FIG. 167.—Bar used in the Thacher System.

and spliced at convenient intervals, are imbedded in the concrete near the outer and inner surfaces of the arch, and extend well into the abutments and piers. The bars of each pair have no connection with each other, except through the concrete, although each bar is provided with projections, preferably rivet-heads of extra height; but which may be lugs, dowels, or bolts, spaced at short intervals, thereby providing a mechanical reinforcement of the adhesion between the steel and the concrete, so that a complete crushing or shearing of the concrete must take place before a separation can be effected. The bars act as the flanges of a beam to assist the concrete in resisting the thrusts and bending moments to which the arch is sub-

jected. The shearing stresses are small, and are taken mostly by the concrete. The principal advantages claimed for this system are as follows: That it gives a larger moment of inertia, and consequently greater strength, for the same amount of steel; that a more reliable connection is secured between the steel and the concrete than in a system that depends on adhesion alone; and that the bars can be shipped straight in any convenient length and bent cold to any desired curve, resulting in less cost for manufacture and greater convenience in handling and shipping.

Cummings System of Reinforced Concrete Construction.—Fig. 168 shows a system of reinforced concrete

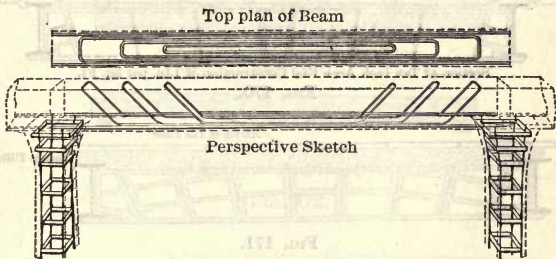


FIG. 168.

construction designed by Robert A. Cummings, Pittsburgh, Pa. The rod reinforcement as shown is bedded in the concrete beam.

Fig. 169 shows a corrugated steel bar used for concrete con-



$\frac{7}{8}$ in \square Bar. Net section, 0.55 \square in. Weight, 2.05 lbs. per ft.

FIG. 169.

struction by the St. Louis Expanded Metal Fireproofing Company.

These bars are made of various sizes and strengths.

Where there will be a tensile strain on concrete in floor construction, it should be made of fine crushed stone so as to make the highest quality of tension concrete. Cinders should be used in construction only where the greatest strain is in compression.

TOP FILLING.—Before any concrete filling is put in on top of any floors, the concrete floors or arches should be swept clean and then thoroughly wet, so the filling will take hold to the concrete arch already in place.

This filling is generally not made as strong with cement as the concrete in the arches, the usual proportions being about 1 cement, 3 sand, and 6 cinder or other aggregate.

Terra-cotta Arch Construction.—Figs. 170 and 171 show the ordinary terra-cotta arch, Fig. 171 is what is known as side construction, and Fig. 170 end construction.

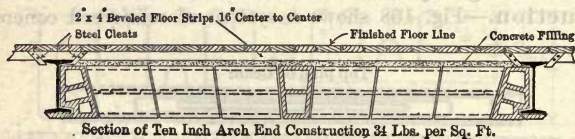


FIG. 170.

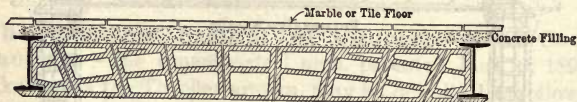


FIG. 171.

The main points to be observed in either of these arches are to see that the blocks are of the right size and that they are bedded in mortar the full width of the joint. The keys should be of a size so that they will shove into place and have a good bed of mortar.

The National Fire-proofing Co.'s Johnson System.—This system is a terra-cotta arch reinforced with wire, as shown by Fig. 172. The basis of this flooring is formed of large steel wires transversely interwoven with still larger wires placed 4 inches apart. These last run straight from bearing to bearing.

Over and through these wires is spread a bed of cement mortar and on this bed the tiles are set. On top of the tiles is spread 3 inches of cinder concrete. This makes a very strong floor.

"New York" Reinforced Terra-cotta Arch (Bevier Patent).—A system of reinforced terra-cotta arch construction now used by the The National Fireproofing Company is shown by Figs. 173-175.

In this construction a wire reinforcement in the form of a wire truss, the upper and lower chords being composed of

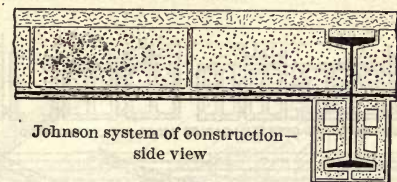


FIG. 172.

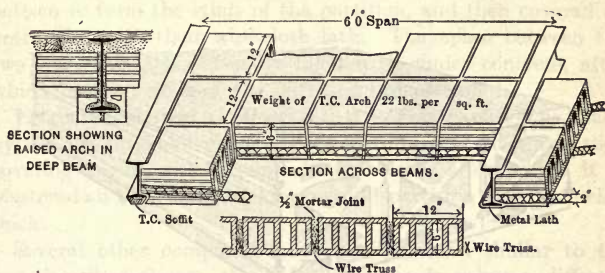
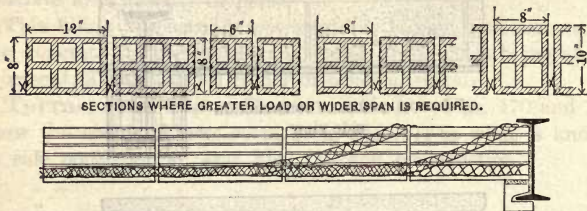


FIG. 173.—Above Arch Accepted by New York Building Department for Live Load of One Hundred and Fifty Pounds per Square Foot.

two No. 13 galvanized twisted wires and the diagonal members being single No. 14 wires, is bedded in the cross joints of the terra-cotta, thus adding strength to it.

The truss is placed on edge and runs from beam to beam in the vertical joint between adjoining blocks. the joint being about $\frac{1}{2}$ inch wide and the mortar well grouted around the wires.

“Herculean” Flat Arch.—The floor construction shown by Fig. 176 is known as the “Herculean” arch, and is used by Henry Maurer & Son of New York.



SECTIONS WHERE GREATER LOAD OR WIDER SPAN IS REQUIRED.

FIG. 174.—Half Section through Wide Span Arch, showing use of more than one piece of wire truss to give greater strength in centre and prevent shearing of blocks at ends of arch. Depth of blocks, number of trusses, and size of wires are proportioned to load and span.

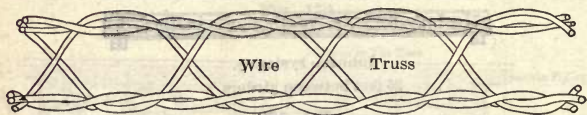


FIG. 175.—“New York” Reinforced Terra-cotta Arch (Bevier Patent).

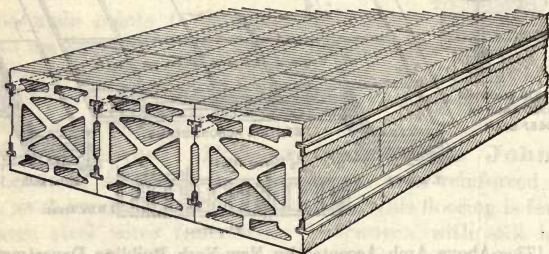


FIG. 176.—“Herculean” Flat Arch (Patented May 3, 1898, and February 6, 1900).

In this arch the terra-cotta is reinforced with steel tee irons as shown, and makes a very strong floor. In constructing this arch care should be taken to see that sufficient mortar is used so that when the tile blocks are shoved into position the mortar will fill all the spaces and the joint around the tee irons.

Fig. 177 shows a new style of terra-cotta arch of the end-construction system. As will be seen the number of webs in the blocks makes them very strong.

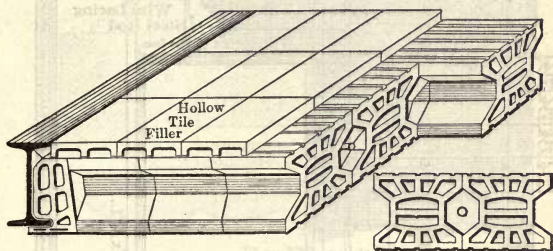


FIG. 177.

Fire-proof Partitions.—Each fireproofing company usually has its own system for putting up partitions, as well as floor construction, and the superintendent should keep himself familiar with all the different methods.

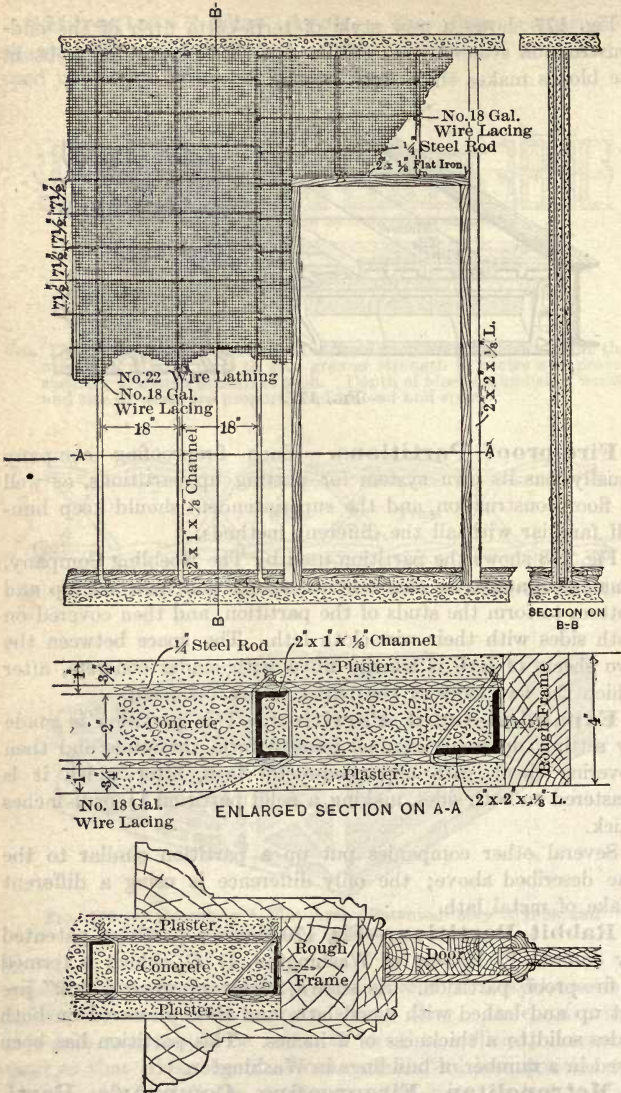
Fig. 178 shows the partition used by The Roebling Company. Small steel angles or channels are set up and fastened top and bottom to form the studs of the partition, and then covered on both sides with their wire-cloth lath. The space between the two sheets of lath is usually filled with cinder concrete, after which the two sides of the partition are plastered.

Expanded-metal Partition.—This partition is made by setting up small channel bars to form the studs and then covering them with expanded-metal lath, after which it is plastered on both sides, making a solid partition $1\frac{1}{2}$ or 2 inches thick.

Several other companies put up a partition similar to the one described above; the only difference is using a different make of metal lath.

Rabbit Partition.—Fig. 179 shows a partition patented by Samuel E. Rabbit of Washington, D. C., which is termed a fire-proof partition. As shown, strips of wood $\frac{7}{8}'' \times 2''$ are set up and lathed with wood lath, and then plastered on both sides solid to a thickness of 2 inches. This partition has been used in a number of buildings in Washington.

Metropolitan Fireproofing Company's Partition.—A partition now being used by The Metropolitan



TYPICAL SECTION OF WOOD TRIM

FIG. 178.—Roebbling Partition.

Fireproofing Company is shown by Fig. 180 and is described as follows:

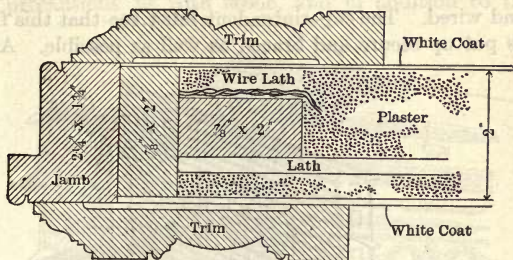


FIG. 179.

A newly patented fire-proof partition which is formed with 2-inch solid blocks of their fire-proof material, which has been fully demonstrated to be effectively fire-resisting, as well as fire-proof.

The partition is quickly put in place, can be finished and plastered at once, requires no upright studs to support it, holds nail well, and is when finished not over 3 inches thick.

Phoenix Wall Construction.—Fig. 181 shows a terra-cotta partition called the "Phoenix" which is put up by

Henry Maurer & Son, New York. The terra-cotta blocks have dovetail recesses on the sides to receive the plaster, and the partition is reinforced in each horizontal joint with a strip of band iron set in the terra-cotta as shown.

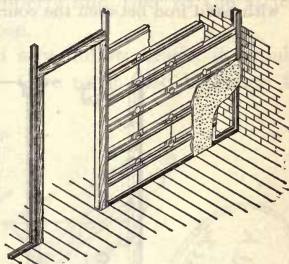


FIG. 180.

The Berger Fire-proof Partition.—This partition, as shown by Fig. 182, is made of expanded-metal lath fastened to a metal stud, which is made as shown, having prongs cut and bent out and which are used to fasten the lath to the stud. This partition is plastered on both sides solid.

Furring, Beams, etc.—Figs. 183 and 184 show one of the usual methods used to fur out beams, build false beams, etc. A piece of channel iron is bent the desired shape and fastened

to the beam or floor above. These ribs are usually spaced about 12 inches apart, then at each angle a $\frac{1}{4}$ -inch rod is run along and wired to the ribs, and over this frame the metal lath is bent and wired. The superintendent must see that this framework is put up secure and braced as well as possible. A good

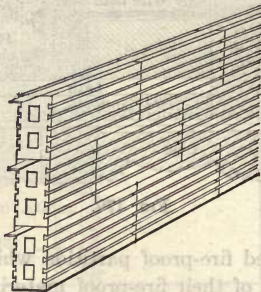


FIG. 181.—Method of Construction of the "Phoenix" Wall, 4 inches thick, with band iron between the courses. Size of blocks, $4 \times 8 \times 12$ inches.

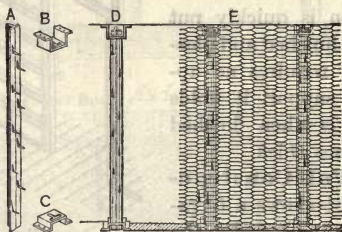


FIG. 182.—A shows Stud with Prongs; B and C, Top and Bottom Sockets; D, Stud in Position ready for Lath; E, Lath Attached to Stud by clinching down Prongs.

way to fasten the ribs is to run them up through the floor construction and turn them over into the concrete.

Architectural Terra-cotta.—Terra-cotta is used for the ornamentation and trimmings of buildings, taking the place of brick and stone to a great extent. It is made in various shades and colors, from white to deep red or brown, and is usually colored by means of chemicals, so that any color desired can be obtained.

The duty of the superintendent, where terra-cotta is used, will be to see that the blocks of terra-cotta, design, etc., con-

form to the details, that it is the desired color, and that each piece is in perfect condition. In setting, he should take the same precautions as with stone, and in addition to this see

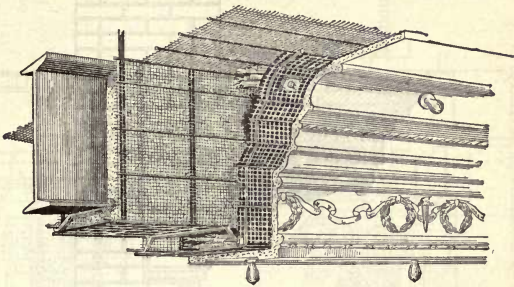


FIG. 183.

that every piece is anchored properly and tied to the structural iron provided for that purpose.

Where any weight will rest on any hollow block, it should be filled with brick and mortar. Care must also be taken to

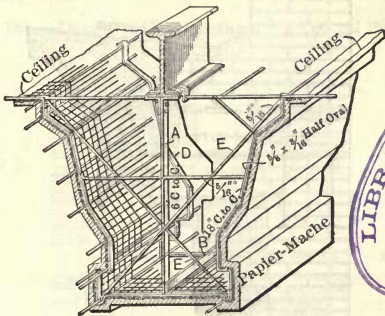
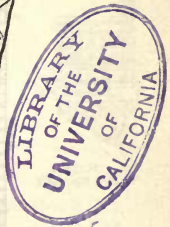


FIG. 184.



have all the joints filled with mortar so there will be no chance for the water to get into them.

Terra-cotta should always be set in strong cement mortar and each block thoroughly wet before being set.

Any blocks twisted or warped in burning, and which cannot be set straight or in line, should be rejected.

As soon as any terra-cotta is set it should be boxed in so as to prevent any damage being done to it by anything falling on it.

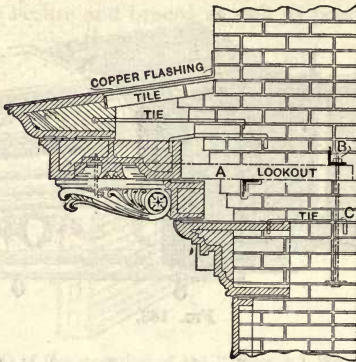


FIG. 185.—Section through a Main Cornice.

Lookouts *A* held down by continuous *L*, *B*, and rods *C*. *D* is a wall plate. Modillions are suspended from lookouts *A* by means of clips and hangers.

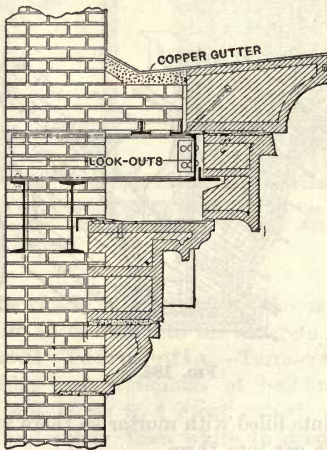


FIG. 186.—Section through a Main Cornice.

Figs. 185–188 show some typical methods of terra-cotta construction.

Fire-proof Construction and Fire Protection of Buildings.—It may not be amiss in introducing the follow-

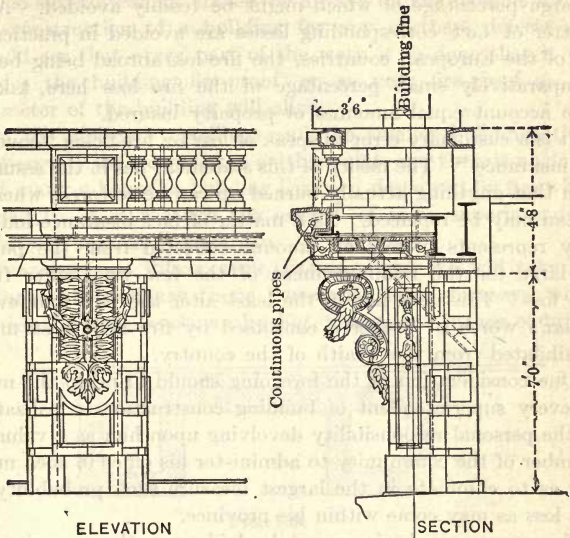


FIG. 187.—Details of Construction for a Central Pavilion.

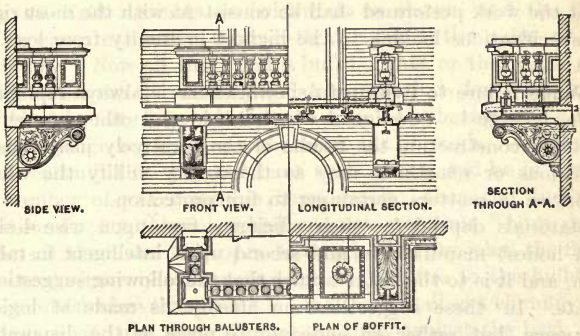


FIG. 188.—Suggestion for a Terra-cotta Balcony.

ing suggestions with regard to the installation of fire-proof construction to say a word regarding the general importance of the subject so far as building methods in the United States are concerned.

The annual fire loss, that is to say that portion of it paid by insurance companies in this country, is not far from \$150,000,000, a large percentage of which might be readily avoided. As a matter of fact corresponding losses are avoided in practically all of the European countries, the fire loss abroad being but a comparatively small percentage of the fire loss here, taking into account equal amounts of property insured.

It is a customary error to speak of loss by fire being "covered by insurance." The falsity of this statement lies in the assumption that anything actually burned up can be restored, whereas it can only be replaced. As a matter of fact insurance indemnity represents merely an amount collected from the public at large for the reimbursement of the few who suffer from fire loss. This does not in the least alter the fact that every dollar's worth of property consumed by fire is just so much annihilated from the wealth of the country.

Due consideration of the foregoing should bring to the mind of every superintendent of building construction a realization of the personal responsibility devolving upon him as a valuable member of the community to administer his office in such manner as to eliminate in the largest measure such probability of fire loss as may come within his province.

Too strong emphasis cannot be laid upon the necessity for the superintendent to administer his office in such manner that the work performed shall be consistent with the most rigid of specifications looking to the highest immunity from loss by fire.

While failure to live up to specifications is always reprehensible, it is to be questioned whether if in any other branch of building construction the results of comparatively insignificant omissions or remissions may so thoroughly nullify the whole effort as in matters pertaining to fire protection.

Materials depend for their efficiency first upon wise design and honest manufacture, and second upon intelligent installation, and it is to the latter branch that the following suggestions relate. In these suggestions no attempt is made at logical sequence, but rather an endeavor to place at the disposal of the superintendent certain data which may prove of immediate and practical value.

Fire Protection of Buildings.—In taking up this subject it is the aim of the author to point out and show some of the points in building construction of the present day that

are defects, inasmuch as they are liable to cause a fire or to assist it when once started.

The superintendent should be always on the lookout during the construction of a building for any of these defects and should see that every part of the work is so done that it will render the building fire-proof, or as near fire-proof as the character of the building will allow.

In the ordinary dwellings and the smaller buildings there is often very little care taken on this point, and there is no doubt that many a house or building has been destroyed by fire which gained its start through the neglect of some superintendent, architect, builder, or workman.

FRAME-HOUSE PROTECTION, FLUES, ETC.—We will take, for instance, the ordinary frame house with brick chimneys, which are usually built, as shown by Fig. 189, with 4 inches of brick-

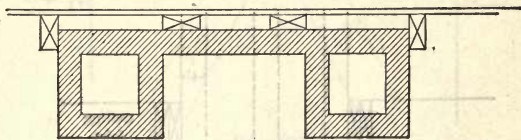


FIG. 189.

work around the flues and back of the fireplace. The studs are set tight against the brickwork as shown, and the floor trimmers are usually framed tight against the sides of the chimney. Now all this wood is but 4 inches or the width of a brick from the flue or fire, and how easy it is for a mason to overlook a "dry" joint or leave a little hole through this 4-inch wall, thus giving the fire a chance to get through. A chimney may be built this way and have such defects and be in use for a number of years and no harm result; then the flue may become lined with soot, which may at any time "burn out," when, if there should happen to be a hole or dry joint, the flame or sparks may be drawn through and set fire to the building. Then often when there is but a 4-inch back wall to a chimney and fireplace and the grate tile are set tight against the back wall the heat from the grate will be carried through and may be the means of setting fire to the studding behind the chimney.

All chimneys should either have 8 inches of brickwork around all outside walls of the flues, as shown by Fig. 190, or else have terra-cotta flue lining, and when flue lining is used the back

wall of the fireplace should be made 8 inches, or at least 6 inches, by setting a course of brick on edge and thus breaking joints with the back 4-inch wall. The flue lining should be carried up through the roof, or better still, to the top of the chimney.



FIG. 190.

Another weak point so far as fire protection is concerned in the ordinary house is where the flues are drawn together at the ceiling joist. Fig. 191 shows how this is usually done.

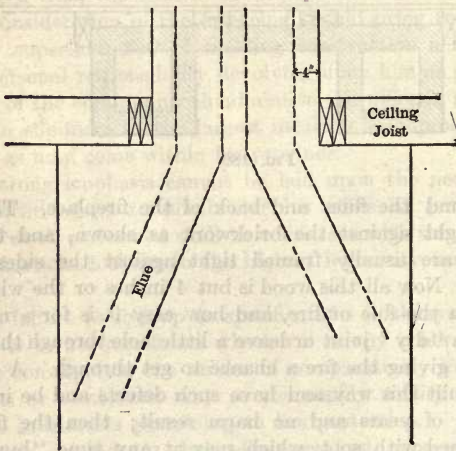


FIG. 191.

The main part of the chimney is cut off so that the ceiling joist will run across the top and frame around the flues, which are drawn together as shown.

This again leaves but 4 inches of brickwork between the flue and the wood joist, and as many a house has been destroyed by a fire starting in the attic, no doubt but some of the fires started at this point. The brickwork around the flues should

be carried up 8 inches until the chimney passes through the roof as shown by Fig. 192; then if desired it can be drawn in

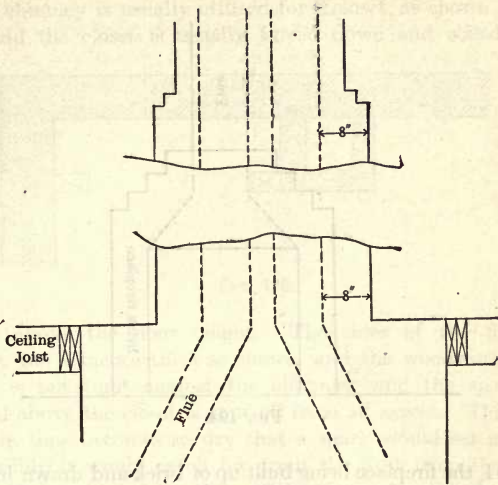


FIG. 192.

as shown, making a much better looking top than if there was no base to it.

HEARTH BOTTOMS.—Another point not to be overlooked is the common method of putting in wooden hearth bottoms, as shown by Fig. 120, page 87. This should not be allowed unless the wall is corbelled out as described by Fig. 121, page 87.

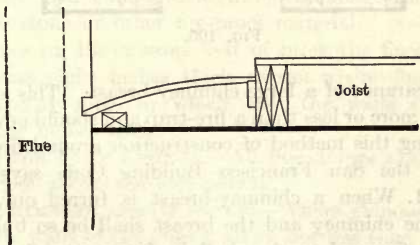


FIG. 193.

A brick arch or corrugated metal bent to a radius, as shown by Fig. 193, is much to be preferred.

STUDED FIREPLACES.—A cheap form of chimney which has been used throughout California and the South is shown by

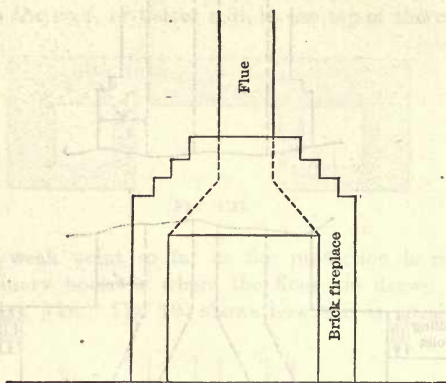


FIG. 194.

Fig. 194, the fireplace being built up of brick and drawn in at the top as shown; then a terra-cotta, or in some cases a sheet-iron pipe is run up for a flue. The fireplace and chimney is then studded around and plastered, as shown by Fig. 195, so as to give

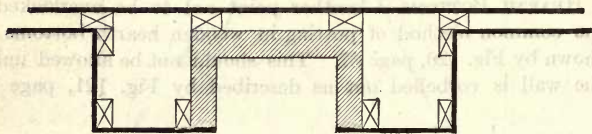


FIG. 195.

it the appearance of a large chimney-breast. This arrangement is nothing more or less than a fire-trap and should never be used.

Regarding this method of construction around fireplaces and chimneys, the San Francisco Building Code says:

“Sec. 21. When a chimney-breast is furred out, the space between the chimney and the breast shall be so built that the passage of fire and smoke shall be intercepted.”

This section of the Building Code states that the space shall be built so as to intercept the fire, but the only reliable way is to build a brick chimney and have no blank spaces.

CLOSETS AS FIRE-TRAPS.—In brick and frame houses the space along the side of the room formed by the projection or jamb of the chimney is usually utilized for a closet, as shown by Fig. 196, and the closet is usually furred down and ceiled a few

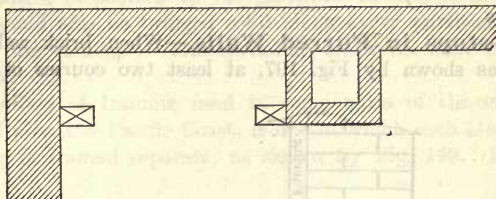


FIG. 196.

inches above the door height. The sides of the flues are usually but 4 inches thick as shown, and the woodwork of the closet is put tight against the chimney, and the space thus formed above the closet is shut off from all access. This woodwork in time becomes so dry that a spark would set it on fire or possibly it would catch fire from the heat from the flue.

This is considered by the author a very weak point in the ordinary house construction, so far as fire protection is concerned.

As mentioned before, the flues should either be lined with flue lining or the outside walls made 8 inches thick.

Chimneys and Flues in Frame Buildings.—

The following instructions regarding the construction of chimneys are given in the Building Code prepared by the National Board of Fire Underwriters:

MATERIAL.—All chimneys in frame buildings shall be built of brick or stone or other fire-proof material.

THICKNESS OF BRICKWORK.—If of brick the flues shall have walls at least eight inches thick, except where flues are lined with burnt-clay pipe, in which case the walls around flues may be four inches thick.

HEIGHT FOR FLUE LININGS.—All flue linings shall extend at least one foot above the roof-boards.

WHEN CHIMNEYS ARE OF STONE.—Where chimneys are built of stone the walls of the flues shall be not less than eight inches on all sides, and shall be lined with burnt-clay pipe.

HEIGHT FOR CHIMNEYS.—All chimneys shall be topped out at least four feet above the highest point of contact with the roof, and be properly capped.

PARTY-WALL CHIMNEYS.—Chimneys in party walls or serving two rooms on the same floor may be built in the walls or partitions.

INDEPENDENT CHIMNEYS.—Elsewhere, they shall be built inside of the frame, except in the case of ornamental or exposed chimneys

Fire-stops in Furred Walls.—When brick walls are furred, as shown by Fig. 197, at least two courses of brick

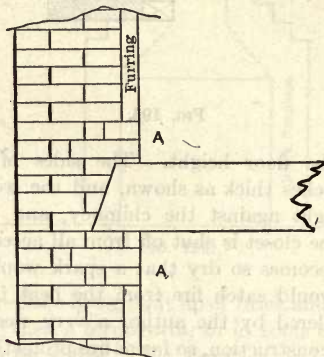


FIG. 197.

should be set out the full thickness of the furring, to form a fire-stop, both above and below the joist as shown at AA. If wood furring is used the plate can be set on this projection and the cap under, and wire lath should be used over the brick to prevent the plaster from cracking.

Wooden Nailing-plugs.—Another bad piece of work is the ordinary method carpenters have of driving wooden plugs in the joints of the brickwork of a chimney to nail the base to or to fasten the mantel. The author once saw a mantel take fire from this cause; the wooden plug caught fire and burned out, setting fire to the mantel. The base can always be fastened by nailing into the joints of the brickwork, or if the mortar will not hold the nail, metal wall plugs can be put in and the base nailed to the plugs. Mantels can be hung by driving hooks into the joints of the brickwork and the mantel hung to these hooks by eyes or staples screwed on the back of the mantel.

Bridging as Fire-stops in Partitions.—Where wooden partitions are used, whether inside or outside, and which

rest on the sill, they should have a row of solid bridging cut around at the floor level, as shown at *A*, Fig. 198, and if the studs run through two stories they should be bridged at the ceiling and floor levels, as shown at *B*, Fig. 198; this prevents any draught or suction up the partitions in case of fire. The joist should also be bridged solid along every partition, so in case of fire to keep it from spreading under the floor between the joist.

A method of framing used in some parts of the country, especially on the Pacific Coast, is one in which each story of a building is framed separate, as shown by Fig. 199. For fire

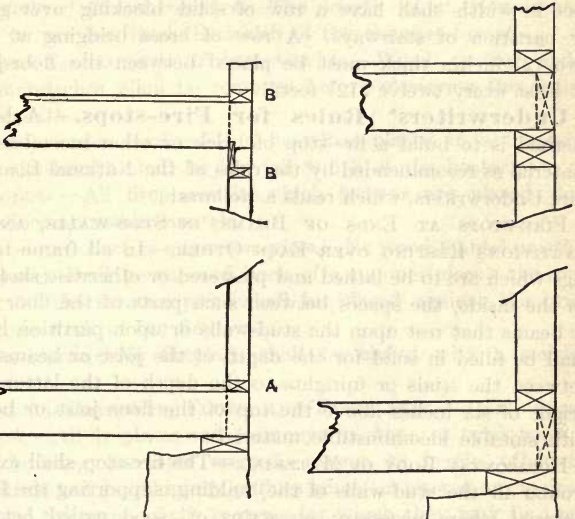


FIG. 198.

FIG. 199.

protection this is a very good method, as the plates and caps of the walls and partitions cut each story off separate from the others and there is no chance for fire to follow up the inside of the walls. Also see Brick-nogging, page 87.

Regarding this method of construction the San Francisco Building Code says:

"Sec. 19. When stories are framed separately, each tier of studding must have top and bottom plates, and the top plates must be doubled; when stories are not framed separately, proper bridging must be placed behind the ribbon at the

ceiling line and on top of the joist at the floor line. Bridging must be two inches thick and of the full width of the studding in every case.

“Sec. 20. BRIDGING.—All stud-walls, or partitions hereafter built, altered, or repaired, shall have one row of bridging for every seven feet in height over the first seven feet. Said bridging shall in all cases extend to the lathing or sheathing, so as to prevent the passage of fire and smoke, and shall be the same thickness as the studding. All outside walls and cross partitions shall be thoroughly and angle braced; all joists shall have solid end blocking. All buildings over twenty-five (25) feet in width shall have a row of solid blocking over girder or partition of stairways. A row of cross bridging at least two (2) inches thick must be placed between the floor-joists at least every twelve (12) feet.”

Underwriters' Rules for Fire-stops.—A better method is to build a fire-stop of brick or other incombustible material as recommended by the rules of the National Board of Fire Underwriters, which reads as follows:

FIRE-STOPS AT ENDS OF BEAMS, IN STUD-WALLS, AND IN PARTITIONS RESTING OVER EACH OTHER.—In all frame buildings which are to be lathed and plastered or otherwise sheathed on the inside, the spaces between such parts of the floor joist or beams that rest upon the stud-walls or upon partition heads shall be filled in solid for the depth of the joist or beams and between the studs or uprights to the depth of the latter to a height of six inches above the top of the floor joist or beams with suitable incombustible materials.

HORIZONTAL BODY OF MATERIAL.—The fire-stop shall extend around all the stud-walls of the building, supporting the filling material where necessary on strips of wood nailed between studs, and in all stud-partitions that rest directly over each other, and thus form a horizontal line of incombustible material to effectually cut off draft openings from story to story through floors, stud-walls, and partitions.

The Building Code of the National Board of Fire Underwriters gives the following rules regarding chimneys, flues, heating-pipes, etc., and which will be a good guide for the superintendent:

CHIMNEYS, FLUES, FIREPLACES, AND HEATING-PIPES.

Sec. 64. TRIMMER-ARCHES.—*To Support Hearths.*—All fireplaces and chimney-breasts where mantels are placed, whether intended for ordinary fireplace uses or not, shall have trimmer arches to support hearths.

Width of Trimmer-arches.—And the said arches shall be at least twenty inches in width, measured from the face of the chimney-breast, and they shall be constructed of brick, stone, or burnt clay.

Length of Trimmer-arches.—The length of a trimmer-arch shall be not less than the width of the chimney-breast.

Wood Centres under Trimmer-arches.—Wood centres under trimmer-arches shall be removed before plastering the ceiling underneath.

Hearth under Heater.—If a heater is placed in a fireplace, then the hearth shall be the full width of the heater.

Mantels.—All fireplaces in which heaters are placed shall have incombustible mantels.

Woodwork Back of a Summer-piece.—No wood mantel or other woodwork shall be exposed back of a summer-piece; the ironwork of the summer-piece shall be placed against the brick or stone work of the fireplace.

Fire-boards.—No fireplace shall be closed with a wooden fire-board.

Sec. 65. CHIMNEYS, FLUES, AND FIREPLACES.—*Joints Struck Smooth.*—All fireplaces and chimneys in stone or brick walls in any building hereafter erected, except as herein otherwise provided, and any chimney or flues hereafter altered or repaired, without reference to the purpose for which they may be used, shall have the joints struck smooth on the inside, except when lined on the inside with pipe.

Parging of Flues Prohibited.—No parging mortar shall be used on the inside of any fireplace, chimney, or flue.

Fireplace Backs, Thickness of.—The fire-backs of all fireplaces hereafter erected shall be not less than eight inches in thickness, of solid masonry.

Lining Behind Grate in Fireplace.—When a grate is set in a fireplace, a lining of fire-brick, at least two inches in thickness, shall be added to the fire-back, unless soapstone, tile, or cast iron is used, and filled solidly behind with fire-proof material.

Thickness for Smoke-flues of Boilers, Furnaces, etc.—The stone or brickwork of the smoke-flues of all boilers, furnaces, bakers' ovens, large cooking ranges, large laundry stoves, and all flues used for a similar purpose shall be at least eight inches in thickness, and shall be capped with terra-cotta, stone, or cast iron.

Inside of Flues for Boilers.—The inside four inches of all boiler-flues shall be fire-brick, laid in fire mortar, for a distance of twenty-five feet in any direction from the source of heat.

Smoke-flues of Steam-boilers.—All smoke-flues of smelting-furnaces or of steam-boilers, or other apparatus which heat the flues to a high temperature, shall be built with double walls of suitable thickness for the temperature with an air space between the walls, the inside four inches of the flues to be of fire-brick.

Height for Smoke-flues.—All smoke-flues shall extend at least three feet above a flat roof and at least two feet above a peak roof.

Tops of Chimneys on Three-story Dwellings and Stables.—On dwelling-houses and stables three stories or less in height not less than six of the top courses of a chimney may be laid in pure cement mortar and the brickwork carefully bonded and anchored together in lieu of coping.

CHIMNEYS, FLUES, AND FIREPLACES.—*Smoke-flues to be Lined with Cast-iron or Clay Pipe.*—In all buildings hereafter erected every smoke-flue, except the flues hereinbefore mentioned, shall be lined continuously on the inside with cast-iron or well-burnt clay, or terra-cotta pipe, made smooth on the inside, from the bottom of the flue, or from the throat of the fire-place, if the flue starts from the latter, and carried up continuously to the extreme height of the flue.

Ends of Lining Pipe to Fit Close.—The ends of all such lining pipes shall be made to fit close together, and the pipe shall be built in as the flue or flues are carried up.

Brickwork.—Each smoke-pipe shall be inclosed on all sides with not less than four inches of brickwork properly bonded together.

FLUES TO BE LEFT CLEAN AT COMPLETION OF BUILDING.—All flues in every building shall be properly cleaned and all rubbish removed, and the flues left smooth on the inside upon the completion of the building.

Sec. 66. CHIMNEY SUPPORTS.—*Forbidding Supports of Wood.*—No chimney shall be started or built upon any floor or beam of wood.

Corbelling.—In no case shall a chimney be corbelled out more than eight inches from the wall, and in all such cases the corbelling shall consist of at least five courses of brick.

Corbelling in Eight-inch Walls.—But no corbelling more than four inches shall be allowed in eight-inch brick walls.

Piers Supporting Chimneys.—Where chimneys are supported by piers, the piers shall start from the foundation on the same line with the chimney-breast, and shall be not less than twelve inches on the face, properly bonded into the walls.

Supports for Chimneys Cut Off Below.—When a chimney is to be cut off below, in whole or in part, it shall be wholly supported by stone, brick, iron, or steel.

Unsafe Chimneys.—All chimneys which shall be dangerous in any manner whatever shall be repaired and made safe or taken down.

Sec. 67. CHIMNEYS OF CUPOLAS.—*Foundry Cupolas.*—Iron cupola chimneys of foundries shall extend at least ten feet above the highest point of any roof within a radius of fifty feet of such cupola and be covered on top with a heavy wire netting.

Distance for Woodwork.—No woodwork shall be placed within two feet of the cupola.

Sec. 68. HOT-AIR FLUES, PIPES, AND VENT-DUCTS.—*Hot-air Flues to be Lined.*—All stone or brick hot-air flues and shafts shall be lined with tin, galvanized iron, or burnt-clay pipes.

Woodwork not to be Placed against Flues.—No wood casing, furring, or lath shall be placed against or cover any smoke-flue or metal pipe used to convey hot air or steam.

Forbidding Smoke-pipes through Floors.—No smoke-pipe shall pass through any wood floor.

Stovepipes, Distance from Ceilings and Partitions.—No stove-pipe shall be placed nearer than nine inches to any lath-and-plaster or board partition, ceiling, or any woodwork.

Metal Shields.—Smoke-pipes of laundry-stoves, large cooking-ranges, and of furnaces shall be not less than fifteen inches from any woodwork, unless they are properly guarded by metal shields; if so guarded, stovepipes shall be not less than six inches distant.

Distance.—Smoke-pipes of laundry-stoves, large cooking-ranges, and of furnaces shall be not less than nine inches distant from any woodwork.

Smoke-pipes through Partitions.—Where smoke-pipes pass through a lath-and-plaster partition they shall be guarded by

galvanized-iron ventilated thimbles at least twelve inches larger in diameter than the pipes, or by galvanized-iron thimbles built in at least eight inches of brickwork.

SMOKE-PIPES THROUGH ROOFS.—*Permit Necessary.*—No smoke-pipe shall pass through the roof of any building unless a special permit be first obtained from the Commissioner of Buildings for the same. If a permit is so granted, then the roof through which the smoke-pipe passes shall be protected in the following manner:

How Protected.—A galvanized-iron ventilated thimble of the following dimensions shall be placed; in case of a stovepipe, the diameter of the outside guard shall be not less than twelve inches, and the diameter of the inner one eight inches, and for all furnaces, or where similar large hot fires are used, the diameter of the outside guard shall be not less than eighteen inches, and the diameter of the inner one twelve inches.

Thimbles.—The smoke-pipe thimbles shall extend from the under side of the ceiling or roof beams to at least nine inches above the roof, and they shall have openings for ventilation at the lower end where the smoke-pipes enter, also at the top of the guards above the roof.

Smoke-pipe of Boiler through Roof.—Where a smoke-pipe of a boiler passes through a roof, the same shall be guarded by a ventilated thimble, same as before specified, thirty-six inches larger than the diameter of the smoke-pipe of the boiler.

HOT-AIR PIPES IN WALLS.—*Covering of Brick or Stone.*—Tin or other metal pipes in brick or stone walls used or intended to be used to convey heated air, shall be covered with brick or stone at least four inches in thickness.

HOT-AIR PIPES IN STUD PARTITIONS.—*Woodwork to be Guarded.*—Woodwork near hot-air pipes shall be guarded in the following manner: A hot-air pipe shall be placed inside another pipe, one inch larger in diameter, or a metal shield shall be placed not less than one-half inch from the hot-air pipe; the outside pipe or the metal shield shall remain one and a half inches away from the woodwork, and the latter must be tin-lined, or in lieu of the above protection, four inches of brickwork may be placed between the hot-air pipe and the woodwork. This shall not prevent the placing of metal lath and plaster directly on the face of hot-air pipes or the placing of woodwork on such metal lath or plaster, provided the distance is not less than seven-eighths of an inch,

Distance from Furnace.—No vertical hot-air pipe shall be placed in a stud partition, or in a wood inclosure, unless it be at least eight feet distant in a horizontal direction from the furnace.

HOT-AIR PIPES IN CLOSETS.—Hot-air pipes in closets shall be double, with a space of one inch between them.

HORIZONTAL HOT-AIR PIPES.—*Distance from Combustible Ceiling.*—Horizontal hot-air pipes shall be placed six inches below the floor-beams or ceiling; if the floor-beams or ceiling are plastered and protected by a metal shield, then the distance shall be not less than three inches.

DUCTS FOR VENTILATION.—*Construction.*—Vent flues or ducts for the removal of foul or vitiated air, in which the temperature of the air cannot exceed that of the rooms, may be constructed of iron or other incombustible material, and shall not be placed nearer than one inch to any woodwork, and no such pipe shall be used for any other purpose.

Material and Thickness of Same in Fire-proof Buildings.—In buildings of fire-proof construction ventilating shafts passing through floors shall be constructed of fire-proof material not less than four inches in thickness. Any opening in such ducts or shafts shall be protected by automatic closing doors or by metal louvres riveted into metal frames, and such ducts shall open to the outside of the building.

VENT-DUCTS IN PUBLIC SCHOOLS.—*How Constructed.*—In the support or construction of such ducts, if placed in a public school-room, no wood furring or other inflammable material shall be nearer than two inches to said flues or ducts, and shall be covered on all sides, other than those resting against brick, terra-cotta, or other incombustible material, with metal lath plastered with at least two heavy coats of mortar, and having at least one-half inch air space between the flues or ducts and the lath and plaster.

Sec. 69. STEAM AND HOT-WATER HEATING PIPES.—*Distance from Woodwork.*—Steam or hot-water heating pipes shall not be placed within two inches of any timber or woodwork, unless the timber or woodwork is protected by a metal shield; then the distance shall be not less than one inch.

Through Floors, how Protected.—All steam or hot-water heating pipes passing through floors and ceilings or lath and plastered partitions shall be protected by a metal tube one inch larger in diameter than the pipe, having a metal cap at the

floor, and where they are run in a horizontal direction between a floor and ceiling a metal shield shall be placed on the under side of the floor over them, and on the sides of wood beams running parallel with said pipes.

Wood-inclosing Boxes to be Lined with Metal.—All wood boxes or casings inclosing steam or hot-water heating pipes and all wood covers to recesses in walls in which steam or hot-water heating pipes are placed shall be lined with metal.

Incombustible Pipes.—All pipes or ducts used to convey air warmed by steam or hot water shall be of metal or other fire-proof material.

Pipe Coverings.—All steam and hot-water pipe coverings shall consist of fire-proof materials only.

PLUMBING PIPES PASSING THROUGH FLOORS.—Cold-water or other exposed plumbing pipes shall have the surrounding air space closed off at the ceiling and floor line of any floor through which any such pipe or pipes shall be carried.

Hot-air Pipes.—As the hot-air pipes, etc., are put in position the superintendent should pay close attention and see that the work is done properly, as mechanics often slight this part of the work, thinking it will soon be covered up.

Installation of Heating Plants, etc.—The Building Code of the city of Cleveland gives the following rules for installing heating-plants, steam and hot-air pipes, flues, etc., and will be a good guide for the superintendent.

HEATING.

The subjects under this title include all hearths, pipes, and heating apparatus and their inclosures within a building.

Sec. 1. FLUE CONNECTIONS.—All boilers, furnaces, fireplaces, ovens, and all other heating apparatus mentioned under this title shall be properly connected with a flue chimney or stack as direct and within the shortest distance possible.

This shall include all permanent or temporary heat generators which are used in the erection of a building, and no such heat generator shall hereafter be placed upon the floor or in close proximity to any building which allows the products of combustion to escape directly into the air within twenty (20) feet of any ceiling without being connected with some flue as herein prescribed.

Sec. 2. HEARTHES.—All hearths of fireplaces, irrespective of the fuel used, shall be supported by trimmer-arches of brick, stone, iron, or concrete, or be of single stone at least six (6)

inches thick, built into the chimney and supported by iron beams, one end of which shall be securely built into the masonry of the chimney or an adjoining wall, or which shall otherwise rest upon incombustible support.

The brick jambs of every fireplace or grate opening, independent of the lining, shall be at least one (1) brick wide each, and the back of such openings shall be at least one (1) brick thick. All hearths and trimmer-arches shall be at least twelve (12) inches longer on each side than the width of such openings, and at least twenty (20) inches wide in front of the chimney-breast. Brickwork over fireplaces and grate openings shall be supported by iron bars or brick arches.

The wooden covering in all buildings except those of the VI. and VII. classes under trimmer-arches to be removed before plastering the ceiling underneath.

Sec. 3. BOILERS.—*Brick-set.*—No brick-set boiler for the generation of hot water or steam for heating or power or any portable power boiler or engine over ten (10) horse-power shall be placed on any wood or combustible floor or beams.

Sec. 4. BOILERS.—*Portable.*—Wood or combustible floors and beams under and not less than three (3) feet in front and one (1) foot on the sides of all portable boilers shall be protected by a suitable brick foundation of not less than two (2) courses of brick well laid in mortar on sheet iron; the said sheet iron shall extend at least twenty-four (24) inches outside of the foundation at the sides and front. Bearing lines of bricks, laid on the flat, with air spaces between them, shall be placed on the foundation to support a cast-iron ash-pan of suitable thickness, on which the base of the boiler shall be placed, and shall have a flange, turned up in the front and on the sides, four (4) inches high; said pan shall be in width not less than the base of the boiler, and shall extend at least two (2) feet in front of it. If a boiler is supported on a cast-iron base with the bottom of the required thickness for an ash-pan, and is placed on bearing lines of brick in the same manner as specified for an ash-pan, then an ash-pan shall be placed in front of the said base and shall not be required to extend under it. All lath-and-plaster and wood ceilings and beams over and up to a distance of not less than four (4) feet in front of all boilers shall be shielded with metal. The distance from the top of the boiler to said shield shall be not less than twelve (12) inches. No combustible partition shall be within four (4) feet of the sides and back and

six (6) feet from the front of any boiler, unless said partition shall be covered with metal to the height of at least three (3) feet above the floor, and shall extend from the end or back of the boiler to at least five (5) feet in front of it; then the distance shall be not less than two (2) feet from the sides and five (5) feet from the front of the boiler.

Sec. 5. FURNACES.—*Brick-set.*—All brick-set hot-air furnaces shall have two (2) covers with an air space of at least two (2) inches between them; the inner cover of the hot-air chamber shall be either a brick arch or two (2) courses of brick laid on galvanized iron or tin, supported on iron bars; the outside cover, which is the top of the furnace, shall be made of brick or metal supported on iron bars and so constructed as to be perfectly tight, and shall be not less than four (4) inches below any combustible ceiling or floor beams.

A single concave iron cover may be used if rigidly supported on the margin and filled with sand to a depth of at least eight (8) inches in the centre and two (2) inches at the edges on all sides.

The walls of the furnace shall be built hollow in the following manner: One (1) inner and one (1) outer wall, each four (4) inches in thickness, properly bonded together with an air space of not less than two (2) inches between them. All brick-set furnaces shall be at least four (4) inches from all wood-work.

Sec. 6. FURNACES.—*Portable.*—All portable hot-air furnaces shall have a double-cased jacket of not less than No. 26 iron from the base to the top of casting, with an air space of at least one (1) inch between, and shall be placed at least two (2) feet from any wood or combustible partition or ceiling, unless the partitions and ceiling are properly protected by a metal shield when the distance shall not be less than one (1) foot. Wood floors under all portable furnaces shall be protected by two (2) courses of brickwork, well laid in mortar on sheet iron. Said brickwork shall extend at least two (2) feet beyond the furnace in front of the ash-pan.

Sec. 7. COLD-AIR BOXES.—The cold-air boxes of all hot-air furnaces shall be made of metal, brick, or other incombustible material for a distance of at least ten (10) feet from the furnace.

Sec. 8. RANGES.—Where a kitchen range is placed from twelve (12) to six (6) inches from a wood stud partition, the said partition shall be shielded with metal from the floor to the height of not less than three (3) feet higher than the range; if the range is less than six (6) inches from the partition, then the

studs shall be cut away and framed three (3) feet higher and one (1) foot wider than the range and filled into the face of the said stud partition with brick or fire-proof blocks with plaster thereon. All ranges on wood or combustible floors and beams that are not supported on legs and have ash-pans three (3) inches or more above their base shall be set on suitable brick foundations consisting of not less than two (2) courses of brick well laid in mortar on sheet iron, except small ranges that have ash-pans three (3) inches or more above their base, which shall be placed on at least one (1) course of brickwork on sheet iron or cement. No range shall be placed against a furred wall. All lath-and-plaster or wood ceilings over all large ranges, and ranges in hotels and restaurants, shall be guarded by metal hoods placed at least nine (9) inches below the ceiling. A ventilating pipe connected with a hood over a range shall be at least nine (9) inches from all lath and plaster or woodwork and shielded. If the pipe is less than nine (9) inches from lath and plaster and woodwork, then the pipe shall be covered with one-half ($\frac{1}{2}$) inch of asbestos plaster or other incombustible covering. No ventilating pipe connected with a hood over a range shall pass through any floor unless protected as prescribed in Sec. 13 for smoke-pipes.

Sec. 9. LAUNDRY-, COOKING-, AND HEATING-STOVES.—Laundry-stoves on wood or combustible floors shall have a course of brick, laid on metal, on the floor under and extended twenty-four (24) inches on all sides of them. All stoves for cooking and heating purposes shall be properly supported on iron legs resting on the floor, three (3) feet from all lath and plaster or woodwork; if the lath and plaster or woodwork is properly protected by a metal shield, then the distance shall be not less than eighteen (18) inches. A metal shield shall be placed under and twelve (12) inches in front of the ash-pan of all stoves that are placed on wood floors.

Sec. 10. GAS-STOVES AND RANGES.—All low gas-stoves shall be placed on iron stands, or the burners shall be at least six (6) inches above the base of the stoves, and metal guard plates placed four (4) inches below the burners, and all woodwork under them shall be covered with metal. Open gas-stoves shall be isolated in the same manner as provided for stoves in Sec. 9. Gas-ranges, if properly air insulated within themselves, shall be placed one (1) foot distant from all unprotected woodwork or plastered stud partitions.

The use of gas-burners or heaters, located in a floor system under an open register, or on the outside of the fire-pot of any hot-air furnace, in which the products of combustion are allowed to escape into a room, is hereby prohibited, and all such burners or heaters so located shall be removed within thirty (30) days after the passage of this Code.

For gas-fitting and fixtures see Title XXXIX.

Sec. 11. BAKE-OVENS.—Bake-ovens are to rest on solid foundations or metal beams and columns; the sides and ends shall be at least two (2) feet from any woodwork and the crown of arch at least four (4) feet from ceilings that have wood joists. The hearth in front of bake-oven shall extend at least three and one-half (3½) feet beyond the face of said oven, otherwise all woodwork shall be protected as prescribed for boilers in Sec. 4.

Sec. 12. CORE- AND ANNEALING-OVENS.—All core- and annealing-ovens, or any portable smelting-furnace, shall be set on incombustible hearths with an air-space of at least five (5) inches between hearths and the bottoms of such ovens or furnaces. The construction of hearths and protection of surrounding woodwork shall be the same as prescribed in Sec. 4 for portable boilers.

Sec. 13. SMOKE-PIPES.—Where smoke-pipes pass through a wood or plastered stud partition, or furred wall, or floor, they shall be surrounded either by a body of hard, incombustible material, measuring at least four (4) inches all around such smoke-pipe, or they shall be surrounded by a double safety thimble of sheet metal made of two (2) concentric rings of sheet metal at least one (1) inch apart, and the entire thimble so constructed that there will be a circulation of air between the two (2) rings forming the same. No smoke-pipe shall project through an external wall unless connected with a chimney or metal stack carried above the roof.

No stove- or smoke-pipe or any pipe conducting the products of combustion from any range, oven, or heater shall be concealed in any wood partition or be placed nearer than nine (9) inches to any unprotected lath-and-plaster or board partition, ceiling, or any woodwork.

Smoke-pipes of less diameter than twelve (12) inches shall be kept at least twelve (12) inches distant from any woodwork, unless the same is properly protected by a metal shield, in which case the distance shall not be less than three (3) inches.

Smoke-pipes of greater diameter than twelve (12) inches

and less area than six (6) square feet, must be kept at least twenty (20) inches from any woodwork, unless the same is properly protected by a shield, in which case the distance shall not be less than eight (8) inches.

Smoke-pipes of larger area than six (6) square feet shall be kept at least three (3) feet distant from any woodwork, unless the same is properly protected by a shield, in which case the distance shall not be less than sixteen (16) inches.

Sec. 14. SMOKE-PIPE SHIELDS.—The metal shields prescribed in the previous section shall be at least one and one-half ($1\frac{1}{2}$) the diameter of the pipe in width and shall have a ventilated air-space of at least one (1) inch between shield and woodwork. Incombustible covering, as prescribed in Sec. 19, may be substituted for metal shields, or the smoke-pipe may be covered as prescribed for steam-pipe in Sec. 17.

Sec. 15. HOT-AIR PIPES.—Hot-air pipes conveying hot air from hot-air furnaces built in between timbers or joists, or through the same, or through wood floors, or in wood partitions or other combustible materials, within ten (10) inches of the same, shall be made double.

The space between the two metal pipes on all sides shall be at least three-eighths ($\frac{3}{8}$) of an inch in the clear, and the two pipes shall be kept apart from each other by the insertion of a sufficient number of metallic separators between, one for every two (2) feet of length of the pipe. Such pipes are to be made with air-tight joints, without soldering them, and shall be securely fastened to the partitions at every two (2) foot interval and at least one-half ($\frac{1}{2}$) an inch from any unprotected woodwork.

No vertical hot-air pipe shall be placed in a stud partition, or in a wood inclosure, unless it be at least one-half ($\frac{1}{2}$) of a diameter of the least dimension of the furnace distant in a horizontal direction from the furnace. Hot-air pipes in closets shall be double, with an air-space as prescribed above, and shall be placed at least one (1) inch from any unprotected woodwork. Horizontal single hot-air pipes shall be placed six (6) inches below the floor-beams or ceiling; if the floor-beams or ceiling are plastered on metal lath or are protected by a metal shield one (1) inch therefrom, then the distance shall not be less than two (2) inches from such ceiling or shield.

When the air conveyed through pipes is heated in an ordinary hot-air furnace, or in any other apparatus by direct contact

of the air with the fire-box, the material used for these double ducts, pipes, and register-boxes shall be bright tin. Where the air is heated with hot-water or steam pipes, any other sheet metal, but of not less gauge than prescribed for tin, may be used for the pipes, and the use of double pipes is not obligatory.

Sec. 16. VENT-PIPES.—Vent flues or ducts for the removal of foul or vitiated air in which the temperature of the air cannot exceed that of the rooms may be constructed of iron or other incombustible material, and shall not be placed nearer than one (1) inch to any woodwork, and no such pipe shall be used for any other purpose.

In the support or construction of such ducts, if placed in a public school-room, no wood furring or other inflammable material shall be nearer than two (2) inches to said flues or ducts, and shall be covered on all sides other than those resting against brick, terra-cotta, or other incombustible material with metal lath, plastered with at least two (2) heavy coats of mortar and having at least one-half ($\frac{1}{2}$) inch air-space between the flues or ducts and the lath and plaster.

Sec. 17. STEAM AND HOT-WATER HEATING PIPES.—Steam and hot-water heating pipes shall not be placed within two (2) inches of any timber or woodwork, unless the timber or woodwork is protected by a metal shield; then the distance shall not be less than one-half ($\frac{1}{2}$) inch. All steam or hot-water heating pipes passing through floors and ceilings or lath and plastered partitions shall be protected by a metal tube one (1) inch larger in diameter than the pipe, having a metal cap at the floor and ceiling, and where they run in a horizontal direction between the floor and the ceiling they shall be supported on iron and a metal shield shall be placed on the under side of the floor over them, and on the sides of wood beams running parallel with said pipes; or said horizontal pipes shall be covered with incombustible pipe-covering at least three-quarters ($\frac{3}{4}$) of an inch thick. In no case shall lateral branches from rising lines to radiators or coils be allowed between any floor and ceiling line when such laterals cut into or through joists or beams in conflict with Sec. 5, Title XIII; and when such pipes are inaccessibly concealed, they shall be covered with incombustible material, as provided in Sections 18 and 19.

Sec. 18. WOOD CASINGS.—All wood boxes or casings inclosing steam or hot-water heating pipes, and all wood coverings to recesses in walls, in which steam or hot-water heating pipes

are placed, shall be lined with metal, or said pipes shall be covered with incombustible sectional pipe-covering at least three-quarters ($\frac{3}{4}$) of an inch thick.

Sec. 19. INCOMBUSTIBLE PIPE-COVERING.—No concealed pipe shall be covered with a covering whose non-conductivity depends upon cork, felt, or any other organic matter.

All coverings of heated surfaces, or surfaces requiring to be protected from heat, and all concealed or inaccessible steam or hot-water pipes, and all cold and ice water pipes, or other pipes, as prescribed in Sec. 12, Title XII, in buildings having iron frames, shall be made of standard fire-resisting covering, either of magnesium carbonate, calcium carbonate with binders of asbestos fibre, or asbestos fibre and sheet coverings.

Sec. 20. DUCTS FOR PIPES.—All ducts for hot-air, steam, or hot-water pipes shall be inclosed on all sides with fire-proof material, and the opening through each floor shall be properly fire-stopped.

Sec. 21. REGISTERS.—Registers located over a brick furnace shall be supported by a brick shaft built up from the cover of the hot-air chamber; said shaft shall be lined with a metal pipe, and all wood beams shall be trimmed away not less than four (4) inches from it. Where a register is placed on any woodwork in connection with a metal pipe or duct, the end of the said pipe or duct shall be flanged over on the woodwork under it. All registers for hot-air furnaces placed in any woodwork or combustible floors shall have stone or iron borders.

All register-boxes shall be made of tinsplate or galvanized iron with a flange on the top to fit the groove in the frame, the register to rest upon the same; there shall be an open space of two (2) inches on all sides of the register-box, extending from the under side of the border to and through the ceiling below. The said opening shall be fitted with a tight tin or galvanized-iron casing, the upper end of which shall be turned under the frame. When a register-box is placed in the floor over a portable furnace, the open space on all sides of the register-box shall be not less than three (3) inches. When only one register is connected with a furnace said register shall have no valve.

Register-boxes, heads, or collars in floors or walls shall be made double and set flush with floor or plaster line.

Sec. 22. NOTICE AS TO HEATING APPARATUS.—In cases where hot-water, steam, hot-air, or other heating appliances or furnaces

are hereafter placed in any building, or flues or fireplaces are changed or enlarged, due notice shall first be given to the Department of Buildings by the person or persons placing the said furnace or furnaces in said building, or by the contractor or superintendent of said work.

Sec. 23. BOILER-ROOMS.—No boiler for the generation of power shall be placed in any building of the VII. class if of greater capacity than ten (10) H.P. Boilers of more than ten (10) and less than seventy-five (75) horse-power shall not be located within eight (8) feet of any building of the VII. class; if of more than seventy-five (75) and less than two hundred and fifty (250) horse-power they shall be at least twenty (20) feet distant from any building of this class, and if of greater capacity than two hundred and fifty (250) horse-power, they shall not be less than thirty (30) feet distant.

Boiler- and fuel-rooms and smoke-houses which may hereafter be constructed shall be located not less than eight (8) feet distant from any other building and shall be built throughout of incombustible material. All the openings to such boiler- and fuel-rooms and smoke-houses, if same are located within thirty (30) feet of any other building, shall have shutters and doors of metal, or wood covered with metal on both sides and edges.

Boiler- and fuel-rooms, when constructed in buildings shall be separately inclosed in brick walls so arranged that all openings between them and other parts of the building will be securely closed with fire-doors at the end of each day's work.

Sec. 24. DRYING-ROOMS.—All walls, ceilings, and partitions inclosing drying-rooms, when not made of fire-proof material shall be wire-lathed and plastered, or covered with metal, tile, or other hard incombustible material.

Sec. 25. HEATING APPARATUS IN BASEMENTS.—All rooms in cellars or basements containing heating-boilers, furnaces, or stoves of any kind, if not constructed of fire-proof material shall have all ceilings lathed and plastered with two (2) coats of brown mortar.

When heating-boilers are used, that portion of the ceiling over the boiler and within a radius of four (4) feet therefrom shall be plastered on metal lath or be protected by incombustible shields.

Sec. 26. PROTECTION AGAINST MOLTEN METAL, HOT LIQUIDS, GASES, AND DUST.—In every factory or workshop, all machinery

and appliances connected therewith, also every vat, pan, or other structure with molten or hot liquids, shall be placed upon an incombustible foundation or hearth, and shall be constructed in such a manner and so guarded and further protected by such ventilating ducts or pipes as to protect those employed in their operation and use, or about them.

Sec. 27. ASH BOXES AND PITS.—All receptacles for ashes shall be of galvanized iron, brick, or other incombustible material. When the ash-pit is located in a basement or cellar it shall have brick walls at least one (1) brick in thickness, and if floor over same is of wood, such pit shall be covered over with either brick arching, stone, or concrete not less than four (4) inches thick with four (4) inches of air-space between the covering of pit and the ceiling, except for pits built directly under the trimmer-arches of hearths.

The ash-flues connected with the upper floors of any building shall be constructed and extend clear up to and above the roof, the same as chimneys.

A self-closing scuppered cast-iron ash-door shall be placed in each story at least two (2) feet above the floor. The metal collar attached to frame shall be at least one-half ($\frac{1}{2}$) inch distant from all woodwork and connection with flue made airtight. Such flues or pits may also be used for sweepings, but for no purpose which would be in violation of the ordinances of the city or the regulations of the Board of Health, and when such flues or pits are built in any building more than two (2) stories high and occupied for any other purpose than a dwelling such ash-pits must have the cleaning-out door accessible from the outside of the building only.

Classification of Fire-proof and Slow-burning Structures.—Highly fire-retardant as well as so-called fire-proof building construction, in structures of any considerable size, may be roughly divided into three classes.

First, mill construction, consisting of brick walls, very heavy solid wooden beams, posts, girders, and flooring, having no concealed spaces or ornamentation; vertical subdivisions such as elevator-shafts, stairways, etc., cut off by brick walls and the whole protected by automatic sprinklers. This type is found principally in the textile mills of New England and the Southern States.

Second, so-called fire-proof buildings having self-sustaining outside walls of brick or stone and interior supporting members

of steel or iron covered with some form of heat insulator, the horizontal sections of which are utilized as flooring.

Third, the so-called steel-cage type of building, consisting of a steel framework of sufficient strength to support the comparatively thin outside walls with which it is veneered, as well as such interior construction as may be essential to floors, partitions, etc.

The first of these types, the mill-constructed building, expressed the outcome of some fifty years of exceedingly expensive experience. This experience has shown that where such buildings are isolated and where specifications such as are furnished by the New England mutual insurance companies are followed the fire loss is reduced to a minimum. Complete description and typical plans, however, can be had gratis upon application to Edward Atkinson, 31 Milk Street, Boston, Mass.

The second type of building, namely the outside supporting walls with iron or steel interior framework, came into existence practically with the invention of the rolled I beam in about 1855.

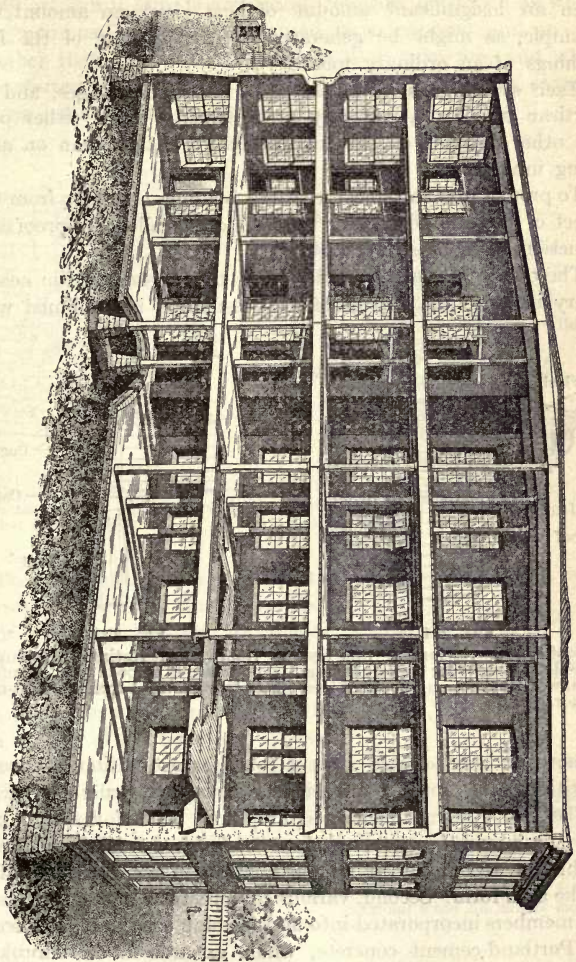
There is little to say from the fire-protection point of view to the superintendent regarding the construction of outside self-sustaining walls. Their limit of thickness and general details of construction are usually fixed within sufficiently safe limits by local building ordinances, which if followed out consistently should insure satisfactory results.

Coming to the matter of floors, partitions, and other highly fire-resistant interior subdivisions of the second type of building, it may be stated generally that they are very similar in form to corresponding portions of buildings of the third type, while the outside walls, partitions, etc., in the so-called cage-constructed building might, without much stretch of imagination, be considered merely as a vertical flooring inasmuch as each section is sustained upon the general steel framework. In view of the foregoing it is perhaps fair to treat outside walls of the cage type of building as well as interior floor and partition construction in both second and third class of buildings under one heading and make general suggestions for all at once.

As experiments have demonstrated clearly, the steel or iron structural members of a building, while composed of what is commonly regarded as thoroughly fire-proof material, are incapable of withstanding any considerable degree of heat without reducing their mechanical strength to such an extent as to

render them no longer self-supporting, let alone capable of supporting any outside load.

FIG. 200.



As is well known, steel has a comparatively low specific heat and is a good conductor of heat. These, together with the

fact that it loses its mechanical strength at a tremendously rapid rate when heated above 1200° to 1400° F., make exposed-steel construction exceedingly dangerous in the presence of even an insignificant amount of heat, such an amount, for example, as might be generated by the burning of the furnishings of an ordinary room.

Each system has its advantages, its disadvantages, and its partisan advocates, but any great superiority of either over the other depends on care of installation rather than on anything inherent.

To protect iron and steel structural building members from the effect of possible heat, many systems of so-called fire-proof construction have been put forward.

These may be roughly divided into two classes, and in nearly every instance the matter of heat-insulation is combined with

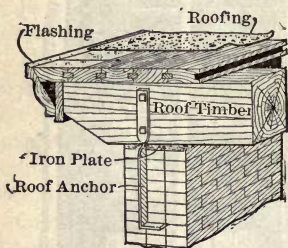


FIG. 201.

Roof-timber resting on cast-iron wall-plate, showing overhanging, open, wood cornice and wrought-iron anchor.

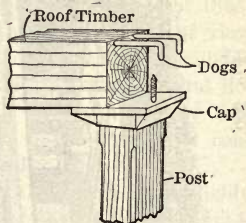


FIG. 202.

Roof-timber resting on column-cap, cast to fit slope of roof. Timbers held together by 1-inch wrought-iron dogs.

a more or less feasible system for the installation of floors, partitions, etc., and in some instances outside walls as well.

The two systems mentioned are, first, some form of baked clay, or moulded plaster or concrete finished in definite forms or blocks and intended for installation in some modification of the arch form. Second, various combinations of steel-supporting members incorporated into and forming a support for a body of Portland-cement concrete, which extends in an unbroken mass from one main structural element to another.

Slow-burning or Mill Construction.—This method of construction, shown by Fig. 200, has been brought into use

through the efforts of the Associated Factory Mutual Fire Insurance Companies of Boston.

While not being in any sense of the word a fire-proof construction, still it affords protection from fire, inasmuch as whatever combustible material is used is so exposed and so put together that it is difficult to cause it to take fire, and when once started it burns slowly and the fire is in plain sight, as there are no hollow walls or spaces to conceal it.

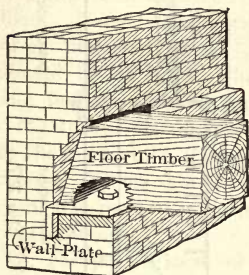


FIG. 203.

Floor-timber resting on cast-iron wall-plates, with lugs for anchoring timber to the wall.

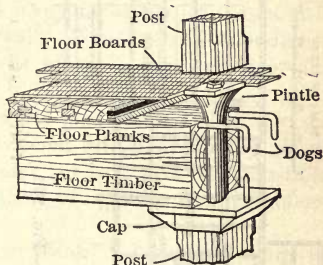


FIG. 204.

Cast-iron cap and pintle for columns and dogs for holding floor-timbers together.

The walls of this class of buildings are usually of brick, with or without piers or pilasters. The floor- and roof-timbers are made heavy enough so that they can be spaced about 8 feet apart, and are carried on wooden posts through the interior of the building. These posts are framed together with a cast-iron pintle, as shown by Figs. 204 and 205.

Where the floor-timbers or girders rest on the wall they are framed, as shown by Fig. 203, on a cast-iron plate or wall anchor-box.

The floor-timbers are covered with a 3-inch or 4-inch plank floor put together with hard-wood splines, and on top of this is usually laid a matched floor of some hard wood, and in some

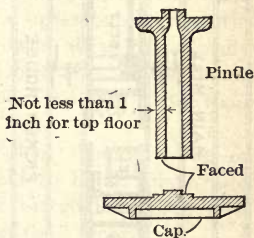
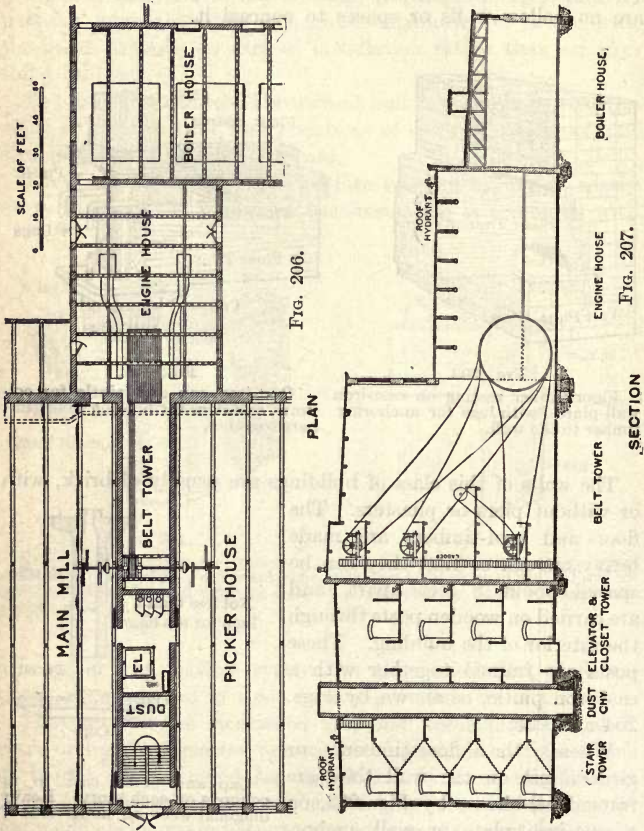


FIG. 205.

Cap and pintle cast to fit columns on each story. Heavy diagonal webs on under side of cap.

cases a double floor is laid on top of the plank floor, the first thickness of flooring being laid diagonally and the top floor laid so as to cross the plank floor.

In this system of construction the main object is to have no concealed spaces for fire to get into, or cause a draught, and



all timbers connecting with or resting on the walls should be so framed and fastened that if broken or burned off they will readily drop out without injury to the wall. In this construc-

tion each floor is isolated from the others so far as possible, the stairways, belt tower, vent shaft, etc., being cut off with brick walls extending to the roof, as shown by Figs. 206 and 207.

The special features of this method of construction as recommended by the associated factory mutual fire insurance companies are as follows:

1. WALLS.—Brick walls at least 1 foot thick in top story and increased in thickness at lower floors to support additional load. The pilastered wall has many favorable features and is often preferred to the plain wall. Window- and door-arches should be of brick, window-sills of sandstone, and door-sills and underpinning of granite.

2. ROOFS.—Roofs of 3-inch white pine plank, spiked directly to the heavy roof timbers and covered with 5-ply tar and gravel roofing. Roofs should pitch $\frac{1}{2}$ inch per foot. An incombustible cornice is recommended when there is exposure from neighboring buildings.

3. FLOORS.—Floors of spruce plank 4 inches or more in thickness according to the floor loads, spiked directly to the floor-timbers. In floors and roof, the bays should be 8 to $10\frac{1}{2}$ feet wide and all planks two bays in length, laid to break joints every 3 feet and grooved for hardwood splines. Usually a top floor of birch or maple is laid at right angles to the planking, but the best mills have a double top floor, the lower one of soft wood laid diagonally upon the plank and the upper one laid lengthwise. This latter method allows boards in alleys to be easily replaced when worn, and the diagonal boards brace the floors, prevent vibration, and distribute the floor load even better than the former method.

Between the planking and the top floor should be two or three layers of heavy tarred paper, laid to break joints, and each mopped with hot tar or similar material to produce a reasonably water-tight as well as dust-tight floor.

Rapid decay of basement or lower floors of mills makes it desirable, whenever wood is not absolutely necessary, to provide cement floors for these places. If wooden floors are required, crushed stone or cinders should be spread evenly over the surface and covered with a thick layer of hot tar concrete, into which an under floor of 2-inch seasoned plank should be pressed and the hardwood top floor-boards nailed across the plank. Cement concretes are apt to promote decay of wood in contact

with them. If extra support is required for heavy machinery, independent foundations of masonry should be provided.

4. **TIMBERS AND COLUMNS.**—All woodwork in standard construction, in order to be slow-burning, must be in large masses that present the least surface possible to a fire. No sticks less than 6 inches in width should be used, even for the lightest roofs, and for substantial roofs and floors much wider ones are needed. Timbers should be of sound Georgia pine, and for sizes up to 14×16 inches single sticks are preferred, but timbers 7 or 8 inches by 16 are often used in pairs, bolted together with a slight air-space between ($\frac{1}{8}$ to $\frac{1}{4}$ inch). They should not be painted, varnished, or filled for three years because of danger of dry rot, and an air-space should be left in the masonry around the ends for the same reason. Timbers should rest on cast-iron plates in the walls and on cast-iron caps on the columns.

Columns of Southern pine should be bored through the centre by a 1½-inch hole, with ½-inch vent-holes top and bottom, and ends should be carefully squared. They also should not be painted until thoroughly seasoned, to prevent dry rot. Columns should be set on pintles, which may be cast in one piece with a cap, or separately, as preferred. Columns of cast iron are preferred by some engineers, and when the building is equipped with automatic sprinklers have proved satisfactory.

5. **STAIRS, ELEVATORS, AND BELTS.**—One of the most important features of slow-burning construction is to make the floors continuous from wall to wall without holes for belts, stairways, or elevators, so that a fire may be confined to the floor where it starts. Elevators and stairs, as well as main belts, must be inclosed in brick towers, and all openings provided with self-closing fire-doors. These self-closing doors, as illustrated, should be hung on heavy, inclined, solid-steel rails and balanced by a weight held by a fusible link.

6. **WINDOWS.**—Windows to be placed as high and made as wide as possible to obtain the best light, and the use of ribbed glass is recommended in upper sashes. In the illustration windows with the ordinary rising sash are shown on the end wall in the upper story, and on the third story the English type, in which the lower sashes may be either fixed or rising, with a transom for ventilation. On the second floor is illustrated a window for wide panels, with a mullion in the centre.

ANCHORS ON JOISTS, ETC.—In mill or factory, and also in

house construction, the specifications will generally specify that the ends of the joists are to be bevelled on the ends 3 inches or 4 inches in the width of the joists. The idea for this is so in case the joists are broken or burned off they will readily drop out of the wall without doing any damage. Then often the same specifications will go on and call for wrought-iron anchors to be built in the wall and securely fastened to every third or fourth joist. These anchors are usually fastened to the sides of the joist and are often put up near the top edge of the joist, which should not be permitted, for if the anchors are fastened at or near the top of the joist and the joist should drop the anchor will either pull in a part of the wall or the lower corner of the end of the joist will force out a portion of the wall. Thus we find the intent of the specifications conflicting, one paragraph tending to release the joists and another fastening them more solid.

When anchors of this kind are used they should be put at the bottom of the joist, and if made of flat iron, as is usual, they should be given a quarter turn at the wall, so the flat of the iron will be in a position to bend easily if the joist should fall.

A more desirable anchor is a cast-iron box in which each joist is set and engaged with lugs, the box being built solid in the wall.

Regarding slow-burning and mill construction the Chicago Building Code says:

Sec. 68. SLOW-BURNING CONSTRUCTION DEFINED.—The term "slow-burning construction" shall apply to all buildings in which the structural members which carry the loads and strains which come upon the floors and roof thereof are made wholly or in part of combustible material, but throughout which the combustible as well as the incombustible materials shall be protected against injury from fire, by coverings of incombustible, non-heat-conducting material similar to those described under the head of "skeleton construction," except that a single covering of plastering on metal lath and metal furring shall be considered sufficient protection for the under side of joists, and that a deafening of mortar or its equivalent, applied at least one and one-half inches thick, shall be used to cover all floors and roof-surfaces above the joists of the same.

FIRE-PROOF COVERING OF POSTS AND ELEVATOR INCLOSURES
—Where oak posts of greater sectional area than one hundred

square inches are used, they need not have special fire-proof covering. All partitions and all elevator inclosures in buildings of this type shall be made entirely of incombustible material. The use of wood furring or of stud partitions shall not be allowed in buildings of this class.

Sec. 69. MILL CONSTRUCTION DEFINED.—The term "Mill Construction" shall apply to all buildings in which all the girders and joists supporting floors and roof have a sectional area of not less than seventy-two square inches, and above the joists of which there is laid a solid timber floor of thickness not less than three and three-fourths inches thick. Wooden posts used in buildings of this class shall not be of smaller sectional area than one hundred square inches. Partitions and elevator inclosures in buildings of this class shall be made entirely of incombustible material.

FIREPROOFING.—If iron pillars, girders, or beams are used in buildings of this class, they shall be protected as provided for fire-proof buildings; but the wooden posts, girders, and joists need not be protected by fire-proof covering. The use of wood furring, wood laths, or stud partitions shall not be permitted in buildings of this class.

The following regarding bond iron is taken from the San Francisco Building Code, and the author regards it as an excellent method of construction, as the flat iron gives a bearing for the joist and it also ties the wall together.

Sec. 130. BOND IRON.—Bond iron at least three by one-quarter ($3 \times \frac{1}{4}$) inches shall be placed under each tier of floor and ceiling joists of all brick and stone buildings other than Class "A" and run around the entire walls of the building, and must be lock-jointed and anchored at each angle

Fire Protection of Fire-proof Structures.—It is not the intention of the author, in taking up this subject of fire protection, to advocate any one or more of the many systems of fire-proof construction, or to recommend or condemn either tile or concrete construction, for it is his opinion that either tile or cinder-concrete fireproofing will stand any test of fire that it is liable to be subjected to, providing that the materials and workmanship used are of the best, and the work is done in the best possible manner.

We have only to notice the tests made by various authorities on the different systems of fireproofing to see that nearly all stand the most severe tests; and why? Because when an arch

is built for the purpose of making a test, it is always constructed of the best materials to be obtained, and in the best possible manner.

It is very amusing to read the reports and opinions of the different engineers and architects who visited the scene of some great conflagration, as at Baltimore. One engineer will visit the various buildings that have been damaged by the fire, and according to his report he could see nothing that withstood the fire element but burnt-tile construction; while another engineer will go over the same ground and find that all fireproofing failed except cinder-concrete construction. Then the trade journals will come out, some advocating tile fireproofing, and will publish long articles with photographs showing how tile had stood and concrete failed; while other journals will show that concrete construction had stood and tile had failed; and so to a person not interested in any one method of construction these reports and visits to the scene of the fire show that in places both tile and concrete withstood the hottest fire, and in other places they both failed.

Now, with these facts having but recently been brought before us, it will be the intention of the author to try and show where the work of fireproofing is usually slighted, and where it will be the duty of the superintendent to see that it is done as well as the best materials and workmanship can do it.

Floor Construction of Fire-proof Buildings.— This is one of the most vital points in the construction of a building, and one on which the preservation of the building depends to a great extent in case of fire. Each floor in a building acts as a barrier in case of fire between the different stories, and if the floor construction is weak or fails, then the fire has egress from floor to floor and the fire cannot be confined.

Nearly all the various systems of floor construction now used have been tested and have given excellent results in withstanding heat, except in cases where it has been shown that poor materials and bad workmanship have been used. The Baltimore fire proved that where good materials and workmanship had been used the various systems stood the heat remarkably well, but where bad materials and careless workmanship had been employed they failed.

As the work is so rushed in many instances, and so little care taken in superintending the work, it is little wonder that some buildings fail when put to a fire test.

In all the different methods of floor construction only the very best of materials and labor should be employed, and the work should be done under the direct supervision of a competent superintendent; no matter how good or competent workmen may be they will at times grow careless unless they know some one is watching them.

HOLLOW-TILE CONSTRUCTION.—Hollow tile is one of the oldest systems of fire-proof construction, and has given good results in past fires, where the arches were properly built; but where poor workmanship has been used it failed to stand as it should.

Mortar.—The mortar for setting tile should be made with the best Portland cement, and as Portland-cement mortar is too short or brittle to stick to the tile a little lime putty should be added.

The superintendent should see that just enough of the putty is used to make the mortar plastic enough so that it will stick to the tile as it is shoved into place. Hot lime mortar should never be used.

Setting Tile.—In setting the tile the sides of the beam should first be given a heavy coat of mortar, then the skew-back tile should be coated on the end which sets against the beam, and the tile shoved into place. The succeeding tile should then be coated with mortar on one end and side and shoved into place so as to obtain a solid joint of about $\frac{3}{8}$ inch, as this size joint is heavy enough for all tile-work. The tile used should be of such a size that the key will just fill the space with the above-sized joints; it should not be so tight that it will have to be forced or driven home. If the joints are a little large they should be wedged with a flat piece of tile or slate, but if the proper-sized tile is used this will not be necessary.

When setting tile arches the superintendent should have the workman complete the arch as he goes along. That is, finish each course of tile across the arch and insert the key before starting another course of tile. In side construction, when the tiles overlap and break joints the courses can be stepped back and the key put in place. This method gives the workman a better chance to get the joints slushed full of mortar and also prevents the wooden centre from sagging with the weight of the tile, which is the case when the tiles are all put in and the keys left out until the last.

In floor arches of end construction, if the workmen are not watched they are liable to get the courses of tile out of line, or one tile higher than another, so that the webs of the two adjoining tiles will not butt against each other, as shown by Fig. 208, the shaded section representing the end of one tile and the dotted lines that of the abutting tile.

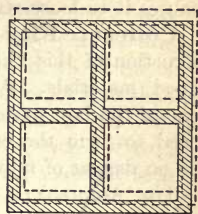


FIG. 208.

An arch built in this manner has very little strength. The webs of each succeeding tile should butt solid against the one already set and all joints should be filled solid with mortar.

After the Baltimore fire it was noticed in some of the buildings that the tile floors of side construction stood better than those of end construction, and no doubt the cause of this was that in the side construction it is easier for the mason to fill his joints than in the end construction, and the end construction mentioned had been slighted. This is one point that the superintendent should bear in mind when superintending any tile-work. After the arch is in place it is well to coat it over with about $\frac{1}{2}$ inch of mortar trowelled smooth, as this insures the filling of all holes and protects the tile.

The webs of tile, to resist fire effectively, should not be less than 1 inch in thickness, and all shoe-tiles for the protection of beams, etc., should be heavy enough so that the beam will be protected with at least 2 inches of tile and mortar, exclusive of the plastering. These shoes should be put on so that they are held in place and supported by the beam and its flange, and no wires should be used to hold them in place.

The lower lips on arch skew-backs are usually 2 inches or less in thickness and form the section of the block most easily chipped off in handling. Even 2 inches of insulation is quite thin enough on the lower flanges of beams and girders, and all chipped skew-backs should be rejected, as patching cannot be done successfully.

Wetting the Tile.—In warm weather all hollow tiles, whether dense or porous, should be well wet or water-soaked before laying. In freezing weather they must be kept dry.

It is good policy to suspend operations and not set any tiles when the weather is so cold as to prevent wetting the tiles.

Dry tiles draw the moisture from the cement mortar and causes it to loose strength.

Concrete Fire-proof Construction.—In fire-proof construction of this kind the main point to be observed is to get good materials. Portland-cement mortar has proven to be one of the best materials to withstand fire, and if the aggregate used to form the concrete is of like material, then there will be no danger of failure from a floor built of this material.

THE AGGREGATE.—Broken brick or tile makes the best aggregate, but on account of the cost is not much used. Broken stone is to be avoided, as stone will not stand the heat. Crushed slag or clinkers make a good aggregate and are entirely fire-proof. Cinders have been, and will be, the principal aggregate used for fire-proof concrete construction, because of its cheapness, and because cinders can be obtained in almost any locality.

In many cases the cinders that have been used to make the concrete have been fireproof in name only, and it is these cases that fail in case of fire. The ordinary cinders usually contain from 50 to 70 per cent of dirt, ash, and unburned coal, and this must all be taken out before it is a fire-proof material. The cinder aggregate should be composed of small or crushed clinkers, and if there is more than 10 per cent of dirt, ash, or unburned coal it should not be used. The superintendent should see that the cinders are so screened, and if necessary, washed, so as to obtain an aggregate of 90 per cent clinkers. A concrete made of this aggregate and Portland cement will withstand any fire it is liable to come in contact with.

PREPARING AND PLACING.—The concrete should be prepared and put in place as described on pages 167 and 174.

When beams, girders, columns, etc., are protected by concrete the concrete should not be less than $3\frac{1}{2}$ inches thick on the outer corners of the beam or column.

USE OF PLASTER OF PARIS.—Any floor construction in which plaster of Paris is used to any large extent should be avoided, or any wall plaster which has plaster of Paris as its base should not be used, as plaster of Paris will not stand excessive heat.

The Building Code of the city of Cleveland prohibits the use of plaster of Paris in the following:

Sec. 1. MATERIALS PROHIBITED.—No plaster of Paris, or sulphate of lime, and no coal, sawdust, coke, coke breeze, or unconsumed or partly consumed material, inclusive of cinders, containing any of the compounds of carbon and subject to com-

bustion, disintegration, or distillation at 1500° F., shall enter into any material used for the construction of the floors, partitions, covering for structural members, or in any part of fire-proof buildings of the I. and II. classes, except in the form of wall plastering or as a gauge for mortar. No quicklime shall be used in the composition of the material used in the construction of walls or floors except in combination with Portland cement when used for mortar in setting fire-proof material with a trowel.

Tile Partitions, Furring, etc.—All tile partitions should start directly on top of the floor arch or beam, and should never be built on top of any wood floor or floor strips. The tile should be well anchored to the adjoining walls and joints broken so as to get as rigid a wall as possible.

ARCHES OVER OPENINGS.—Over all openings the tile should be cut so as to form a flat arch, and no dependence should be placed on the frame to carry the tile.

NAILING-BLOCKS.—It has been the custom in the past to build in wood blocks as shown by Fig. 209, for nailing base or grounds to.

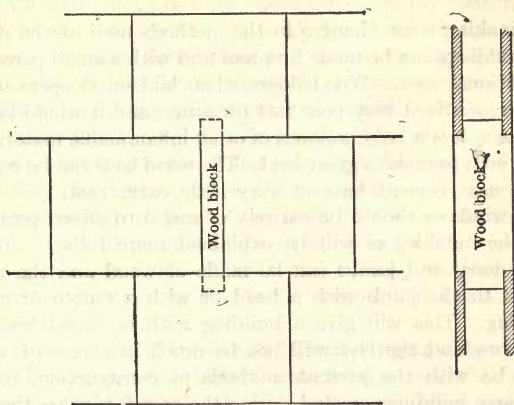


FIG. 209.

Blocks of this kind should not be used, but a wood block can be put inside the tile for nailing purposes as shown and described on page 303.

Casing of Columns, Furring, etc.—When iron or steel columns are furred or cased with tile, the tile should never

be less than 4 inches thick, and all space between the tile and iron should be filled solid with mortar and small pieces of tile, as this in itself is a good protection from fire. The tile should always be put up in such a manner that it will sustain itself, and never be dependent on wires or metal clips of any kind.

Wood in Fire-proof Structures.—During the past few years fire-proof materials have been gradually taking the place of wood in the construction of fire-proof buildings until at the present time all the wood used is in the floors, windows, doors, and trim; and it will be but a short while until all wood will be practically eliminated from any fire-proof structure. Window frames and sash are now made in metal, floors are made of various fire-proof compositions, doors are made of metal or of wood covered with metal, mouldings for trim and base can be made in metal or run in cement, so at the present time it is possible to erect a building that will have no combustible material whatever in its construction. But as construction of this kind means extra cost capitalists and builders will be averse to it unless forced to it by the building laws of the various cities.

By making some changes in the methods used at the present time buildings can be made fireproof and with a small percentage of additional cost. Wood floors when laid on sleepers bedded in concrete afford very poor fuel for a fire, and it would be hard to ignite unless a large amount of other inflammable material was in the room to make a great heat. The wood base can be replaced with a neat cement base at very little extra cost.

The windows should be entirely of metal to afford protection from the outside, as will be explained more fully.

The doors and jambs can be made of wood and the plaster finished to the jamb with a bead or with a stucco or cement moulding. This will give a building with no wood but floors and doors, and the cost will not be much in excess of what it would be with the present methods of construction.

In some buildings erected during the past few years the floors have been laid on strips which were simply laid on the floor-arch, and the space between not filled with concrete but left open.

This should never be permitted, as this space only makes a draught or sort of flue in case of fire. The space should be filled solid to the top of the floor strips with concrete.

Then heavy wood frames have been set in all openings of partitions, etc., and the tile built around them and across the top, the wood frames being depended upon to carry the tile over the opening. This should never be allowed. Wood blocks can be put inside the tile and the door-jambs can be nailed and fastened through the tile into these blocks, or the jamb can be bolted fast with toggle-bolts.

If it is desired to use a rough frame a 2-inch one is heavy enough and should be bolted fast to the tile, and the tile should be arched over the top so as to carry its own weight.

There are several processes by which wood can be rendered fireproof, and all wood used in a fire-proof building should be fire-proofed by an approved process.

Pipes, Wires, etc., in Fire-proof Buildings.—In all fire-proof buildings there should be provisions made for taking care of all pipes, conduits, wires, etc., without having them built in the partitions or in the casing of the columns, as is commonly done. A shaft should be built with brick walls extending from the cellar to the roof with outlets at each floor covered with fire-proof doors. The pipes can be carried up in such a shaft and branches taken off to supply each floor; a ladder should be provided the full length of the shaft with platforms at each floor, then the valves or stop-cocks controlling the various branches would be easily accessible. It was claimed by some parties after the Baltimore fire that the pipes encased in the column fireproofing of some of the buildings got so hot they buckled and forced off the fire-proof casing; but if they did it was because the fireproofing gave way or was not heavy enough to protect the pipes or they would not have got hot. Still all pipes should be run up in a shaft where they can be got at any time. When a pipe runs up in a partition or column the mason has to cut his tile around it and this weakens the fireproofing.

Stairways in Fire-proof Buildings.—The stairway or shaft in a fire-proof, or in fact in any brick or other than a frame structure, should be inclosed on all sides with brick walls, and all openings should be provided with fire-proof doors so that the stairway can be shut off from the rest of the building. These doors should be arranged so as to work automatically in case of fire. The stairs should be built of iron or other incombustible material, and if slate or marble treads or platforms are used the slate or marble should be supported under its entire surface

with metal or concrete. Marble and slate will not stand excessive heat, and the treads or platforms are liable to get hot and break in case of fire; this endangers the lives of firemen who may be using the stairs.

The spread of fire in a vertical direction is undoubtedly most effectively guarded against by making the floors continuous and unbroken; that is, eliminating all openings in the floors and placing the necessary means of communication, such as stairways, elevators, pipes, shafts, belts, etc., in shafts entirely separated from the rest of the building by brick walls. Elevator shafts, stairways, and corridors, in buildings where sightliness is an essential, can be thoroughly cut off from the remainder of the building by wire-glass partitions mounted in iron framework. This application is favored in office buildings, hotels, department stores, etc.

The Building Code recommended by the National Board of Fire Underwriters gives the following

RULES FOR FIRE-PROOF CONSTRUCTION.

Sec. 105. FIRE-PROOF BUILDINGS.—*Buildings Named.*—Every building hereafter erected or altered to be used as a theatre, lodging-house, school, jail, public station, hospital, asylum, institution for the use, care, or treatment of persons, the height of which exceeds three stories and not more than forty feet in height, and every building hereafter erected or altered to be used as a hotel or an apartment hotel which exceeds four stories and not more than fifty feet in height, excepting all buildings for which specifications and plans have been heretofore approved by the proper authorities, and every other building the height of which exceeds fifty-five feet or more than four stories in height, shall be built fireproof; that is to say—

Fire-proof Construction Stated.—They shall be constructed with walls of brick, stone, Portland-cement concrete, iron, or steel in which wood beams or lintels shall not be placed, and in which the floors and roofs shall be constructed with rolled wrought-iron or steel floor-beams, spaced not more than five feet on centres and otherwise so arranged as to spacing and length of beams that the load to be supported by them, together with the weights of the materials used in the construction of the said floors, shall not cause a greater deflection of the said beams than one-thirtieth of an inch per foot of span under the

total load; and they shall be tied together at intervals of not more than eight times the depth of the beams with suitable tie-rods.

Floor Filling between Beams.—Between the floor-beams shall be placed brick arches springing from the lower flanges of the steel beams, or the spaces between the beams may be filled with hollow-tile arches of hard-burnt clay or porous terra-cotta, or arches of Portland cement reinforced with metal, or such other fire-proof composition may be used, provided that in each and all cases the strength and method of construction shall be acceptable to the commissioner of buildings.

Stairs.—The stairs and staircase landings shall be entirely of brick, stone, Portland-cement concrete, iron, or steel.

Allowed Woodwork Mentioned.—No woodwork or other inflammable material shall be used in any of the partitions, furrings, or ceilings in any such fire-proof buildings, excepting, however, that when the height of the building does not exceed eight stories nor more than one hundred feet the doors and windows and their frames and trims, the casings, the interior finish when filled solidly at the back with fire-proof material, and the floor-boards and sleepers directly thereunder, may be of wood, but the space between the sleepers shall be solidly filled with fire-proof materials and extend up to the under side of the floor-boards.

When More than Eight Stories or More than 100 Feet High.—When the height of a fire-proof building exceeds eight stories, or more than one hundred feet, the floor surfaces shall be of stone, cement, rock asphalt, tiling, or similar incombustible material, or the sleepers and floor-boards may be of wood treated by some process approved by the commissioner of buildings to render the same fire-retarding.

Metal Window Frames and Sash.—All outside window frames and sash shall be of metal.

Inside Woodwork, how Treated.—The inside window frames and sash, doors, trim, and other interior finish may be of wood covered with metal, or of wood treated by some process approved by the commissioner of buildings, to render the same fire-retarding.

Hall and Permanent Partitions of Fire-proof Material.—All hall partitions or permanent partitions between rooms in fire-proof buildings shall be built of fire-proof material and shall not be started on wood sills nor on wood floor-boards, but

be built upon the fire-proof construction of the floor and extend to the fire-proof beam filling above.

Solid Space above Doors and Windows in Partitions.—The tops of all door and window openings in such partitions shall be at least twelve inches below the ceiling line.

Inclosing of Stair Halls.—In all fire-proof buildings other than stores, warehouses, and factories, if exceeding three stories and forty feet in height, the stair halls shall be inclosed on each story with fire-proof material, same as required for elevators, to so form an inclosure the floor area of which shall not be more than three times the united area of the floor openings for the elevators and stairs.

Sec. 106. FIRE-PROOF FLOOR FILLINGS BETWEEN BEAMS.—*Common Brick Arches.*—Between the wrought-iron or steel floor-beams shall be placed brick arches springing from the lower flange of the steel beams.

Rise per Foot of Span.—Said brick arches shall be designed with a rise to safely carry the imposed load, but never less than one and one-quarter inches for each foot of span between the beams, and they shall have a thickness of not less than four inches for spans of five feet or less and eight inches for spans over five feet, or such thickness as may be required by the commissioner of buildings.

How Laid.—Said brick arches shall be composed of good, hard brick or hollow brick of ordinary dimensions laid to a line on the centres, properly and solidly bonded, each longitudinal line of brick breaking joints with the adjoining lines in the same ring and with the ring under it when more than a four-inch arch is used. The brick shall be well wet and the joints filled in solid with cement mortar. The arches shall be well grouted and properly keyed.

Hollow-tile Arches of Burnt Clay or Terra-cotta.—Or the space between the beams may be filled in with hollow-tile arches of hard-burnt clay or porous terra-cotta of uniform density and hardness of burn.

Skew-backs.—The skew-backs shall be of such form and section as to properly receive the thrust of said arch; and the said arches shall be of a depth and sectional area to carry the load to be imposed thereon without straining the material beyond its safe working load, but said depth shall not be less than one and three-quarters inches for each foot of span, not including any portion of the depth of the tile projecting below

the under side of the beams, a variable distance being allowed of not over six inches in the span between the beams if the soffits of the tile are straight; but if said arches are segmental, having a rise of not less than one and one-quarter inches for each foot of span, the depth of the tile shall be not less than six inches.

Joints Filled with Cement Mortar.—The joints shall be solidly filled with cement mortar as required for common brick arches and the arch so constructed that the key parts shall always fall in the central portion.

End Construction.—The shells and web of all end-construction blocks shall abut, one against another.

Arches of Portland-cement Concrete Reinforced with Metal, Segmental in Form.—Or the space between the beams may be filled with arches of Portland-cement concrete, segmental in form, and which shall have a rise of not less than one and one-quarter inches for each foot of span between the beams.

Thickness at Crown of Arch.—The concrete shall be not less than four inches in thickness at the crown of the arch and shall be mixed in the proportions required by Section 18 of this Code.

Reinforced with Metal.—These arches shall in all cases be reinforced and protected on the under side with corrugated or sheet steel, steel ribs, or metal in other forms weighing not less than one pound per square foot and having no openings larger than three inches square.

Various Fillings between Floor-beams—Tests as a Precedent Condition of Use.—Or between the said beams may be placed solid- or hollow-burnt clay, stone, brick, or concrete slabs in flat or curved shapes, concrete or other fire-proof composition, and any of said materials may be used in combination with wire cloth, expanded metal, wire strands, or wrought-iron or steel bars; but in any such construction and as a precedent condition to the same being used, tests shall be made as herein provided by the manufacturer thereof under the direction and to the satisfaction of the Commissioner of Buildings, and evidence of the same shall be kept on file in the Department of Buildings, showing the nature of the test and the result of the test.

How Tests shall be Made.—Such tests shall be made by constructing within inclosure walls a platform consisting of four

rolled steel beams, ten inches deep, weighing each twenty-five pounds per lineal foot, and placed four feet between the centres, and connected by transverse tie-rods, and with a clear span of fourteen feet for the two interior beams and with the two outer beams supported on the side walls throughout their length, and with both a filling between the said beams, and a fire-proof protection of the exposed parts of the beams of the system to be tested, constructed as in actual practice, with the quality of material ordinarily used in that system and the ceiling plastered below, as in a finished job; such filling between the two interior beams being loaded with a distributed load of one hundred and fifty pounds per square foot of its area and all carried by such filling; and subjecting the platform so constructed to the continuous heat of a wood fire below, averaging not less than seventeen hundred degrees Fahrenheit for not less than four hours, during which time the platform shall have remained in such condition that no flame will have passed through the platform or any part of the same, and that no part of the load shall have fallen through, and that the beams shall have been protected from the heat to the extent that after applying to the under side of the platform at the end of the heat test a stream of water directed against the bottom of the platform and discharged through a one and one-eighth inch nozzle under sixty pounds pressure for five minutes, and after flooding the top of the platform with water under low pressure, and then again applying the stream of water through the nozzle under the sixty-pounds pressure to the bottom of the platform for five minutes, and after a total load of six hundred pounds per square foot uniformly distributed over the middle bay shall have been applied and removed, after the platform shall have cooled, the maximum deflection of the interior beams shall not exceed two and one-half inches.

Different Tests may be Prescribed.—The Commissioner of Buildings may from time to time prescribe additional or different tests than the foregoing for systems of filling between iron or steel floor-beams, and the protection of the exposed parts of the beams.

Systems Failing under Test, Use Prohibited.—Any system failing to meet the requirements of the test of heat, water, and weight as herein prescribed shall be prohibited from use in any building hereafter erected.

Authenticated Tests may be Accepted.—Duly authenticated

records of the test heretofore made of any system of fire-proof floor filling and protection of the exposed parts of the beams may be presented to the Commissioner of Buildings, and if the same be satisfactory to said Commissioner it shall be accepted as conclusive.

Protection against Injury by Freezing.—Temporarily Covered over when Necessary.—No filling of any kind which may be injured by frost shall be placed between said floor-beams during freezing weather, and if the same is so placed during any winter month, it shall be temporarily covered with suitable material for protection from being frozen.

Cinder-concrete Filling on Top, to be Filled up to Under Side of Wood Floor-boards.—On top of any arch, lintel, or other device which does not extend to and form a horizontal line with the top of the said floor-beams, cinder concrete, or other suitable fire-proof material shall be placed to solidly fill up the space to a level with the top of the said floor-beams, and shall be carried to the under side of the wood floor-boards in case such be used.

Temporary Centring, when to be Removed.—Temporary centring, when used in placing fire-proof systems between floor-beams, shall not be removed within twenty-four hours, or until such time as the mortar or material has set.

Strength for Fire-proof Floor Fillings—Material to be within Safe Bearing Load.—All fire-proof floor systems shall be of sufficient strength to safely carry the load to be imposed thereon without straining the material in any case beyond its safe working load.

Incasing Exposed Sides and Bottom Flanges of Beams and Girders.—Floor- and Roof-beams.—The bottom flanges of all wrought-iron or rolled-steel floor- and flat roof-beams, and all exposed portions of such beams below the abutments of the floor arches or filling between the floor-beams, shall be entirely incased with hard-burnt clay, porous terra-cotta, or other fire-proof material corresponding to the filling between the beams, such incasing material to be properly secured to the beams.

Girders.—The exposed sides and bottom plates or flanges of wrought-iron or rolled-steel girders supporting iron or steel floor-beams, or supporting floor arches or floors, shall be entirely incased in the same manner.

Pipe Openings through Fire-proof Floors to be Shown on Plans.—Openings through fire-proof floors for pipes, conduits,

and similar purposes shall be shown on the plans filed in the Department of Buildings.

Limited Size for Holes after Floors are in.—After the floors are constructed no opening greater than eight inches square shall be cut through said floors unless properly boxed or framed around with iron;

Openings to be Filled.—And such openings shall be filled in with fire-proof material after the pipes or conduits are in place.

Sec. 107. INCASING INTERIOR COLUMNS.—*Material and Thickness.*—All cast-iron, wrought-iron, or rolled-steel columns, including the lugs and brackets on same, used in the interior of any fire-proof building, or used to support any fire-proof floor, shall be entirely protected with not less than four inches of hard-burnt brickwork, terra-cotta, concrete, or other fire-proof material, securely applied, but no plaster of Paris nor lime mortar shall be used for this purpose.

Lugs and Brackets, Incasing of.—The extreme outer edge of lugs, brackets, and similar supporting metal may project to within seven-eighths of an inch of the surface of the fireproofing.

Prohibiting Pipes, Wires, Conduits, being Placed within Coverings of Columns, Girders, etc.—No pipes, wires, or conduits of any kind shall be incased in the fireproofing surrounding any column, girder, or beam of steel or iron, but shall be placed outside of such fireproofing.

Protection of Buildings from Fire from the Outside.—Until within recent years the aim of architects and engineers in designing fire-proof structures has been to design a building or structure which would be fire-proof against any fire originating within itself, giving very little thought to the protection of the structure from an outside fire.

One of the first instances of a large fire which demonstrated the fact that outside protection was necessary was when the Horne Building in Pittsburg, Pa., was burned in 1897. This building, filled with dry-goods, took fire from the heat of a fire on the opposite side of the street, the contents burned, and the building was gutted and damaged to a great extent. Then in more recent conflagrations the fact has become more evident that a building to be entirely fire-proof must be protected just as much, if not more, from an outside fire as from one within its own walls. The building itself may be constructed entirely of fire-proof materials, yet the contents of the building may be very inflammable, and if not protected from

fire from the outside would become ignited, and in burning do much damage to the building.

SELECTION OF MATERIALS.—The first consideration in the construction of a fire-proof building should be in the selection of the materials to be used, and if the building is to be erected to withstand fire from the outside, then only those materials should be used that are known to be able to withstand fire.

The fire-resisting qualities of brick, stone, etc., are about as follows, with brick ranking first: Brick, plain terra-cotta, concrete, sandstone containing iron, granite, limestone, marble.

The prevailing material of all outside walls should be brick; and stone or granite should not be used above the first or second stories. Granite or stone will not stand excessive heat, and in case of fire the heat above the first story is so intense that stone or granite will not stand. It is possible that in the first story of a building it would pass through a fire unharmed, providing the stone or granite had no sharp corners or projections to spall off.

In the brick it is advisable to have all exposed corners round or chamfered so as to prevent spalling.

No brick wall should be less than 18 inches thick, as a wall of less thickness is liable to crack when exposed to strong heat.

SILLS AND LINTELS.—The sills and lintels of the windows should be of terra-cotta or brick.

Terra-cotta is one of the best of fire-resisting materials, but should be made plain and have few projections and sharp corners. When any terra-cotta is built in the wall it should be backed up and filled solid with brick and mortar.

METAL WALL TIES AND SECRETE HEADERS.—Under no consideration should metal wall ties or secrete headers or bond be used in the walls of any structure that may have to withstand a fire, for the face course of brick, or veneering as it really is, will invariably crack and fall off in case of fire.

POINTING.—The pointing of the joints in the brick- or stonework should be made concave, for a convex joint will break off in case of fire.

CORNICES.—The cornices of a fire-proof building should be made of terra-cotta or sheet metal, and if sheet metal is used it should be fastened to iron brackets or supports, and in no case should wood be used for this purpose. When terra-cotta is used for cornices or any projections it should be firmly anchored to iron brackets provided for this purpose.

CEMENT MORTAR.—Cement mortar should be used throughout in all walls of a fire-proof building.

Protection of External Openings in Fire-proof Buildings.—The exterior door and window openings of a building are its weakest points in resisting an outside fire, and until recent years these points have received but little attention from architects and engineers when designing a building to be fire-proof.

Frames and sash are now made of metal, and with wire-glass and iron shutters a window or door opening can be so protected that it will withstand a most severe fire.

The metal frames should be made heavy enough and so anchored to the masonry that they will not warp or twist out of shape and let the sash drop out. The sash should be hung with a chain or ribbon that will not melt if it becomes hot, and the chain should be so fastened that there will be no danger of the weight becoming loose in case of fire and permitting the sash to drop.

Lead weights should not be used unless the box in the frame is so protected that the frame will not get hot enough to melt the weights, and thus let the sash drop down.

The glass also should be fastened in such a manner that there will be no danger of it dropping out.

The sash should be glazed with wire-glass not less than $\frac{1}{4}$ inch in thickness, as this offers a very effective resistance to fire; but the author is of the opinion that wire-glass in itself is not a sufficient protection to window openings. In addition to the wire-glass the openings should be provided with iron shutters. The old iron-clad shutter recommended by the National Board of Fire Underwriters has given a good account of itself in recent fires, but it cannot be expected to withstand extreme heat, for the wood will become charred and the metal covering warp out of shape, permitting an egress for flame.

Steel shutters should be used on all openings possible, the shutters being made of a single piece of plate not less than $\frac{1}{4}$ inch in thickness, and if any stiffening-bar or frame is used it should be fastened to the plate so as to allow for any unequal expansion between the frame and the plate. The shutters should be arranged so as to allow for expansion, and the fastenings made so that the shutters can readily be opened from the outside in case of fire within.

Where it is not possible to use a plate-shutter, a rolling one

can be used. These shutters are made of corrugated bars of sheet metal riveted and locked together, and when used for fire protection should be made of heavy sheet steel.

The main points to be considered when using metal shutters and doors of any kind are to see that they are fastened securely to the masonry and also that provisions have been made for expansion. The fastenings should be such that they will hold the door or shutter firmly in place and not allow it to warp open.

The following specifications have been accepted by The Chicago Underwriters' Association for metal frames and sash:

THE CHICAGO UNDERWRITERS' ASSOCIATION.

REQUIREMENTS FOR THE ACCEPTANCE OF WINDOWS OF APPROVED WIRE-GLASS IN METALLIC FRAMES AND SASH IN LIEU OF FIRE-SHUTTERS.

FRAMES.—All parts of frame and sash must be made of No. 24 galvanized iron or heavier, and of a quality soft enough to bend without breaking, or 18-oz. copper. Sides so made as to form an air-space at least 2 in. \times 4 in., made of three parts, two of which are locked entire length, making a half-inch seam of three thicknesses. The third to be locked to first two parts by inseparable cleats every 18 inches. The two parts already mentioned to provide in themselves weather qualities and inseparable cleats for holding glass, thereby insuring stability by reducing to a minimum the parts and connections.

TOP-RAIL.—To be made in one piece, so formed as to afford ample weather qualities.

THE SILL.—To be made of one piece, formed so as to afford ample weather qualities and condensation sheds with outlets.

THE MIDDLE RAIL.—To be made of two pieces, forming an air-chamber with inseparable cleats, lock-jointed, and of length sufficient to extend in and through sides of frame, where the same is lapped four ways onto sides and riveted. The top of this rail receiving sash is made with a wash.

Connections of various parts of frame must, in all cases, be made by lapping prior to riveting.

SASH.—The plain frame, having top, bottom, and two sides, of air-chamber construction and made so that depth of sash is 2 inches, and width of same back or front or rabbet is 2 inches,

The same shall be lock-jointed throughout, shall have inseparable cleats, and all necessary weather qualities. The corners of this frame shall be double-locked. Each corner of frame shall be double-locked on front, back, and at sharp corners, so as to completely dispense with the need of solder and rivets. The sash shall be so made as to correspond with frame at points of meeting, and the hanging of same must be on horizontal pivots above the centre, to allow quick closing, as hereinafter arranged for, automatically.

Reinforce frame where pivots enter by riveting a strip of $\frac{1}{8}$ -in. iron so bored as to allow a bearing for pivot.

The upright sash-rail must be made of one piece of galvanized iron or copper, with inseparable cleats and lock-jointed about an iron bar $\frac{1}{4}$ in. \times $1\frac{1}{2}$ in., in a manner to afford an air-chamber of 1 inch square, and rabbets for holding glass, and the same lapped and riveted to frame and sash.

MULLION WINDOWS.—Where an architect prepares clear opening for a mullion window, the metal frame must be reinforced at every point of division by structural iron, channels preferred. These divisions, that of necessity must be chambers of air-spaces, will afford ample room for channels. The channels must be built into window as made.

IN GENERAL.—Flat surfaces that retain water must be avoided. The lock shall be a double-spiral spring brass lock, and shall be bolted to middle rail and sash.

The window shall be made with stationary lower sash, and upper sash swung on bearings in upper half of sash, and shall be so equipped with fusible link, rings, and rod, that the same will close and lock automatically under fire.

The rabbets against which the glass is set shall be for glass of a small to medium dimension, $\frac{1}{2}$ in. wide, and for a glass of more than medium dimensions, $\frac{3}{4}$ in. wide.

The inseparable cleat must be at least $1\frac{1}{2}$ in. in length, and must repeat at least every 12 inches.

Windows of more than ordinary width shall be reinforced by structural iron in cross-rail.

Caution must be had against using glass of unreasonable dimensions. For a window 4 ft. \times 8 ft., arrange sashes for three lights each, or glass 15 \times 46. For a window 4 ft. \times 6 ft., arrange sash for two lights each, or glass 22 \times 34. For a window 5 ft. \times 8 ft., arrange sash for three lights each, or glass about 19 \times 46. My recommendations would be not to exceed in

width 18 inches, where height is 48 inches or more, and in no case to exceed 24 inches in width.

The following regarding shutters, etc., for protection against fire is taken from an address by John R. Freeman, Consulting Engineer, Providence, R. I., at the annual banquet of the National Board of Fire Underwriters, Delmonico's, New York, May 12, 1904, in response to the toast

“AN ENGINEER'S SUGGESTIONS TO FIRE UNDERWRITERS.”

CONCERNING FIRE-SHUTTERS.—A point which interested me exceedingly, in studying the Baltimore ruins, was to see whether thin wrought-iron or steel plate, such as is used for covering fire-shutters, had at any point been heated to a point where its power of resistance was seriously impaired. The ordinary underwriters' fire-shutter depends for its strength and its resistance upon its thin covering of very soft mild steel coated with tin. I examined thin sheet-steel lamp-shades, thin bands for pipe-coverings, tin boxes, filing-cases, and dozens of shutters themselves. In no place did I find any indication that metal of that quality had been so softened or had reached such a heat that it would be seriously impaired for the purpose of fire-shutters, and one of the great lessons that I brought away from the Baltimore fire was that our standard tin covering for the underwriters' shutter is all right, and that this covering material has sufficient power of resistance to withstand the fiercest heat of a great conflagration, but that we do need to find some better material than pine wood to fill it with. I also made careful examinations of copper in flashings, cornices, etc., to see if it had melted. In a few small spots in rare instances fusion had begun, but in general I found it had ample resistance to fusion, so that it can prudently be used for covering fire-shutters where something more ornamental or weatherproof than tinned plate is desired and expense is no bar.

The standard underwriter shutter of wood covered with tin did not give a very good account of itself in the Baltimore fire, and I think it can be said, without fear of serious contradiction, that the endurance of the ordinary underwriters' shutter of tin-clad wood is limited to not more than about half

an hour's endurance of a temperature of 1500 degrees, and that this limit is often passed in the heat of an ordinary conflagration, and that in many of the cases where single doors or shutters have shown up so well there has happened to be an incoming air-current that has helped to cool the shutter.

The limitations of the tin-clad wooden shutter were shown at one corner of the burned district in Baltimore. A large shirt factory whose windows were protected by wooden fire-shutters had a very close call. By heroic efforts with private pump and hose streams the employés saved the factory. I took particular interest in examining those shutters, and although this was not at the hottest part of the fire, I found, in parts of the shutter at the hottest exposure, that the pine wood was charred entirely through and all gone.

This matter of better shutters is one on which we should set some of our best talent at work in the experimental way. In your excellent laboratory in Chicago there is excellent apparatus for the needed tests. Although the present shutter and the present approved form of fire-door is all right nine-tenths of the time, and perhaps nineteen-twentieths of the time, it is not all that we need in a great conflagration.

I have said that buildings can be made fireproof against bad exposures. The possibility of making them so is found largely in the development of a superior thin form of fire-shutter, and in educating the architects and owners of buildings toward building a shape of window that is easily protected by the fire-shutter, and a neat window-jamb formed to receive this shutter when folded back *inside the window*.

Windows of suitable size for all ordinary office purpose can easily be so designed that they can be protected by fire-shutters, and that the shutters when open and folded back on the inside will not be obtrusive or unsightly. When a bad exposure fire comes the ruin of the sash and glazing can be paid for cheerfully if the contents of the building are saved.

I was very much interested in the efficiency of the plain steel-plate shutters on the inside of the windows in the Safe Deposit and Trust Company Building. These kept the fire out very successfully, notwithstanding that the large non-fire-proof building of the Baltimore *Sun*, which was entirely wrecked, and was one of the hottest parts of the entire conflagration, was only ten feet away. The damage was so imminent that the police ordered the men to leave the Safe Deposit

Building, and the heat melted the lead sash-weights within the cast-iron window-casings, destroyed the sash and glass, and chipped the brick walls, but the damage on the interior of the building was almost nothing. These steel-plate shutters were so set that they were free to expand, and they were free from ribs and of a form not likely to warp much, and they did in fact warp but little, and the casing and jamb were of such form that this warping of the shutter off its seat did not open a wide crack, and there was no combustible material near them on the inside to receive their radiant heat.

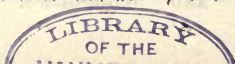
Capt. Sewell, if I understood his remarks aright, suggested a steel shutter stiffened by ribs.

Ribs are dangerous unless very carefully designed and attached, and as generally applied increase the liability to warp.

I happen to have been an eye-witness of the fire twenty or twenty-five years ago that gave to the tin-clad shutter its great start on the road to popularity. This fire was in the Pacific Mills, at Lawrence, Mass. In that case there was a tin-clad wooden fire-door, of what has since become standard construction, standing immediately beside a steel-plate shutter that was heavily ribbed on the edges. Apparently it was a fair comparative test for the two shutters. The ribbed-steel shutter warped away from its bearings two inches or three inches, as I now remember it, in a way that let the fire play freely around its edges, while the tin-clad wooden shutter remained in place without warping and was in good working order when the fire was over, the tin covering intact and the wood charred only about half an inch deep. These results were published far and wide, and this gave the first great impetus to tin-clad wooden shutters.

There have since been hundreds of demonstrations of the endurance of tin-clad shutters in fires, and I have taken advantage of many opportunities to examine carefully into the conditions under which they have been exposed. The result of these examinations has been to convince me that the endurance of the tin-clad shutter is limited; that its limit of endurance is often passed; that for severe cases we do need something better than the ordinary underwriters' tin-clad wooden shutter, and that we do need something very much better than the ribbed-steel shutter or the rolling jointed steel shutter.

At present the best we can do in any important case is to use two fire-shutters or fire-doors, one outside and another



inside; one will receive the brunt of the onslaught and perhaps in the course of half an hour or an hour warp or break down; the second, shielded behind the first, will stand up to its work until any ordinary fire is over.

It seems to me that the main reason why those steel shutters in Baltimore, at the building which I have just mentioned, performed so well was that they were free from ribs, and thus became heated more uniformly, with but very slight warping; that they happened to be so fastened to a frame that they were free to expand, and their seat happened to be of such a shape that, although the shutter did warp a little, this did not open much of a crack, and that there was no combustible material close to them on the inside.

The path of safety from exposure fires for office-buildings and the like lies in a window-casing formed so that we can attach to it a shutter of a form similar to the ordinary inside house-blind. Our ordinary business buildings have walls thick enough, so that by making the shutter in four folds, or leaves, two being hinged together, and these two in turn attached to the wall, making each fold in the shutter only about fifteen inches wide, the window will be wide enough for all practical purposes, and we can fold the shutter back within the window-jamb, very much as we do the inside blind.

To do that with the present ordinary tin-clad shutter would be almost impossible, because of the thickness of that form of shutter. It can be done with a steel-plate shutter without ribs and the radiation from the inside can be checked by some thin incombustible porous covering like asbestos board. If in our underwriters' laboratories, in our technical schools, and in our tours of survey we can direct attention to these views and urge the solution of the problem of how to make an efficient fire-shutter which shall only be three-quarters of an inch or an inch in thickness, I believe that before long the problem of protecting an office-building against exposure fires will be found solved.

It is entirely possible to design a window opening adapted to receive a safe shutter, so that it will be just as convenient for ordinary business purposes as the type now common. I think it probable that the best place for the shutters is *inside the glass*, sacrificing the glazed sash outside them in case of any great conflagration.

“WATER-CURTAINS” AND “WIRE-GLASS.”—We hear a good

deal nowadays about "water-curtains," and I would like to say just a word on that, because I think there is a great deal of misapprehension about their efficiency. I would like to say a word about wire-glass also, because although in general excellent I think there is a great misapprehension as to what wire-glass can do.

I began experimenting with wire-glass very soon after it first came out, and I have used it in numerous instances, and it is a most excellent material in its way, but it has its limitations; it has the same limitations that a water-curtain has, and that is, that it does not stop the passage of radiant heat.

You all have noticed how, when you are travelling in a railway train, perhaps at sixty miles an hour, and they happen to be burning a pile of ties along the track, that although your face is directed towards your newspaper, you will feel the flash of heat passing through the car window and striking against your face as you go past that pile of burning ties. That simply illustrates the great ease and rapidity with which radiant heat passes through glass.

Now, radiant heat passes through glass with wire netting in it almost as easily as it does through any other glass, and the record made by wire-glass in a certain building in Baltimore, which is pointed to with so much pride, is, I think, simply due to the fact that it was at a place where nothing combustible was immediately behind it. If you have a stock of dry goods, or wooden ware, or baled cotton or hemp just inside a wire-glass window without shutters, and there is a hot fire across the street, these can probably be set on fire with much promptness by the radiant heat passing through the glass, and the subject should be thoroughly studied on a large scale in our underwriters' laboratories. For safety, there must be something which will stop the radiant heat, and that can only be in the form of a shutter, and, by virtue of stopping the heat, the shutter will become hot.

The case with the water-curtain is very much the same as with the glass. Water is diathermous, as physicists call it—that is, radiant heat passes through water very easily.

We must, I believe, set down these stories that have been told about the efficiency of water-curtains as being mainly fairy tales.

This supposed efficiency of the water-curtain is another

topic which I hope that some one of our underwriters' laboratories and some of our schools of applied science will take up and investigate with precision of measurement.

I have heard stories of the wonderful efficiency of the water-curtain, but I must beg to disbelieve them, largely on theoretical grounds as yet. It is a matter which can be tested very easily.

The window-sprinkler came in for a good deal of praise in certain quarters in Baltimore. I took particular pains to investigate that, because I wanted to find just how far they merited it, and I have no doubt they did some good, but they are not entitled to anything like the glory that is claimed for them. They will tell you a great deal about the remarkable work done by the window-sprinklers in the Toronto fire. Now, I sent a bright young engineer up there especially to investigate that question and to go into it in detail, and to take photographs of the individual windows and to get right down to the bed-rock facts, and, from the mass of evidence that he brings back, I do not doubt that they did some good; but *the inside ordinary automatic sprinkler near each of these windows did very much more good.*

In short, if you want to provide against an exposure fire, I believe that the only way to do it is,

First, by a wall either of brick or cement concrete.

Second, by properly designed window openings and window casings, and

Third, by good shutters in those windows.

In the absence of shutters, automatic sprinklers, supplemented by heroic efforts with hose streams on the inside, may sometimes save the day; with great expense for water damage, but where exposures are bad, a good shutter on a proper window should be the first care of architect and owner.

Fire Resisting Devices.—Of the many fire-retardant and fire-resistant devices with which the modern building is equipped much lies in the province of the superintendent. Perhaps in even larger measure than in the realm of materials does proper installation secure success.

The more important of these devices have been the subject of extensive investigations by the engineering bodies of the National Board of Fire Underwriters, and rules governing their manufacture and installation have been issued. Copies of these rules may be had gratis on application to the Na-

tional Board of Fire Underwriters, 32 Nassau Street, New York City.

Among the subjects covered are the following:

Rules and requirements for the installation of automatic electric fire-alarm systems and the construction of thermostat alarm circuit closers; the construction and installation and use of acetylene-gas machines, and for the storage of calcium carbide; the installation of auxiliary fire-alarm systems; the installation of automatic-sprinkler equipments; the construction and installation of stationary chemical fire-extinguishers; the manufacture of wired glass and the construction of frames for wired and prism glass used as a fire retardant; the construction, installation, and use of gasolene vapor gas lighting machines, lamps, and systems; for the installation of electric wiring and apparatus.

Each of these subjects is so thoroughly and concisely covered by the several rules just mentioned that their careful perusal by the superintendent will provide both information and incentive looking to the exercise of the most judicious care in all fire protection matters within his province.

Among the most important of the National Board's rules are those which deal with sprinkler systems and with the manufacture and installation of wire-glass and frames to contain the same.

The automatic sprinkler is a device for applying water for the extinguishment of fire, such water to be applied automatically at the right spot and in the least volume necessary for such extinguishment. This is accomplished by valves or sprinkler-heads which will open by the effect of heat from the fire they are intended to extinguish.

To secure the most efficient sprinkler service, the following general conditions should prevail:

1. Sprinklers to be so located that every portion of the building can be covered by water. This necessitates an open type of construction, free from concealed spaces where water cannot penetrate.

2. Sprinkler piping to be of ample size and provided with water at all times. Should danger of freezing exist, what is called the "dry-pipe system" should be used.

3. The general supply of water should be of ample pressure and volume, and the service be automatic in its action at all times.

Location of sprinkler-heads, sizes of piping, and general instructions for installation are fully set forth in the National Board's rules, to which the superintendent should refer.

As fire-escapes are one of the main features of building protection, the following is taken from the Philadelphia Building Law:

Formula Governing the Erection of Fire-escapes.

—In accordance with the Act of Assembly approved June 3, 1885, and the Ordinance of Councils approved December 10, 1896, and supplemental thereto, the following formula will govern the matter of the design, construction, and erection of all fire-escapes hereafter required within the city of Philadelphia.

PLATFORMS.—The platforms shall consist of iron balconies not less than four (4) feet in width, the length of the platform to be dependent upon the size of the building and the number of its occupants. The inspector of the district will designate the length of such platform, which shall extend in front of, and not less than nine (9) inches beyond, at least two windows, except in the case of a doorway leading from the floor level of the building to the floor level of the platform, in which case such doorway opening will suffice. Each platform shall be provided with a landing at the head and foot of each stairway of not less than twenty-four (24) inches, the stairway opening of the top platform to be no longer than sufficient to provide clear headway. The floors of balconies must be of wrought iron or steel, one and one-half ($1\frac{1}{2}$) inches by five-sixteenths ($\frac{5}{16}$) inch slats, not more than one and one-fourth ($1\frac{1}{4}$) inches apart, and be securely riveted to frame and brackets. Outside angle frame to be not less than two and one-fourth ($2\frac{1}{4}$) inch angle iron. If flooring is made of wire, same to be not less than No. 6 wire gauge, three-fourths ($\frac{3}{4}$) inch mesh, securely fastened to frame and brackets. All stair openings to be sufficient to provide clear headway. In all cases platforms must be designed, constructed, and erected to safely sustain in all their parts a safe load, at a ratio of four to one, of not less than eighty (80) pounds per square foot of surface.

RAILINGS.—The outside top railing to extend around the entire length of the platform, and through the wall at each end, and to be properly secured by nuts and washers, or otherwise equally well braced and bolted. The top rail of the balcony must not be less than one (1) inch pipe iron, or material equally

as strong. The bottom rail must not be less than three-fourths ($\frac{3}{4}$) inch pipe iron, or material equally as strong, well leaded into the wall. The standards must be not less than one (1) inch pipe iron or material equally as strong, and must be securely connected with top and bottom rail and platform frame. Standards must also be securely braced by means of outside brackets at suitable intervals. Railings in all cases to extend around the stairway openings and be continuous down the stairway, the height of the railing to be not less than three (3) feet.

STAIRWAY.—Stairways must be designed, constructed, and erected to safely sustain in all their parts a safe load, at a ratio of four to one, of not less than one hundred (100) pounds per step, with the exception of the tread, which must safely sustain, at a ratio of four to one, a load of two hundred (200) pounds per tread. The treads to be not less than six (6) inches wide, and the rise not more than ten (10) inches. The stairs in all cases to be not less than twenty-four (24) inches wide, and the strings or horses to be not less than three (3) inch channels of iron or steel, or other shape equally as strong and to rest upon and be fastened to a bracket; said bracket to be fastened through the wall as otherwise provided for brackets. The strings or horses to be also securely fastened to the balcony at the top. The steps in all cases to be double riveted or bolted to the strings or horses.

BRACKETS.—Brackets must not be less than two and one-fourth ($2\frac{1}{4}$) inch angle iron, or material equally as strong, not more than three (3) feet apart, braced by means of not less than one (1) inch square, or one and one-fourth ($1\frac{1}{4}$) inch round iron, let into the wall at least four (4) inches, with shoulders on brace, and three (3) inch washer between shoulder and wall, and to extend down the wall four (4) feet from the top of the bracket, and out on the bracket angle three (3) feet from the wall. In all cases the bracket angle directly under the balcony must be secured to wall by means of bolts of suitable size passing through the wall, and four (4) inch washers. There must also be a bar of wrought iron or steel two (2) inches by three-eighths ($\frac{3}{8}$) inch, let into the wall four (4) inches edge-wise, between the brackets, and riveted to the balcony for the floor to rest upon. Whenever the bottom balcony is supported by means of suspension-rods (riveted or bolted) to the balcony above, the brackets (of the above balcony) shall be increased

in size to meet the increase strain occasioned thereby. The bottom balcony to have a drop-ladder of same construction as the stairway, to be hinged and hung with a counter weight. Whenever the drop-ladder is upheld by means of a counter balance-weight suspended to a chain, such weight shall hang within the platform railing if practicable.

In all cases the bolts, rivets, and other material used shall be proportioned so as to develop the full strength of the members connected by them.

All the parts of such fire-escapes must receive not less than two coats of paint—one coat in the shop and one after erection.

Formula for Construction of Tower Fire-escape.

—The said tower fire-escape shall be divided from the building by, and completely inclosed with, brick walls or such other fire-proof materials as shall be accepted by the Bureau of Building Inspection. The said walls to be built solidly from the foundation to and at least 36 inches above the roof.

The roof of said tower shall be built of hard, incombustible materials.

The stairs of said tower may be iron or wood; but in all cases there must be provided stone or iron thresholds, iron frames, or wood frames covered with metal, and iron doors, or wood doors covered with tin. The rise of said stairs shall not be more than eight (8) inches and the tread not less than nine (9) inches. The entrance to said tower shall be by means of an outside balcony or an incombustible vestibule, of which one side shall be entirely open and extend from the top of floor to under side of ceiling and the full width of the tower, the said open side to face a street or such open space as provides for exit of said tower.

There shall be a brick wall, or other wall of hard, incombustible material separating the tower from the vestibule. The opening into tower from said vestibule to be not over seven (7) feet in height. The floor, ceiling, and sides of said vestibule to be of hard, incombustible material.

The rails inclosing the side facing the open space or street, to be not over four (4) feet high and not less than three (3) feet, may be open or inclosed.

The entrance to the tower from the building shall be through the vestibule.

Towers that have not the fire-proof vestibule shall have outside balconies; floors of balconies to be solid, and built

of hard, incombustible material, and be of sufficient strength to carry the imposed weights.

The rails around said balconies shall be not over four (4) feet in height nor less than three (3) feet, and may be inclosed or open.

PART IV.

PAINTING AND PAVER-LAYING
 TRY; TIMBER, PLUMBING, TIN AND
 SHEET METAL WORK, PAINTING,
 GLAZING, AND PAPER-HANGING,
 IRONWORK, ELECTRIC-WIRING, ETC.
 HEATING.

Painting and Plastering. The duties of the superintendent during the course of the work will be first to see that the labor, when wooden laths are used, are sound, straight, and uniform, and free from any loose knots or oil. As the laths are put up, he should see that they are nailed solid and given the proper space between; they should be spaced about 1 inch apart for ordinary lime mortar and about 1 inch apart when any of the hard or patent mortars are used. The laths should have one nail to every second and two nails to each end. The perpendicular joints in the laths should be broken about every six feet. No laths should be used to fill out any corner or any other place. Where laths cross a partition over two inches wide a half or three fourths of an inch should be put under the laths so the plaster will have a chance to set.

Laths of various or other openings should have a low vertical joint as possible so as to prevent water. If possible the laths should extend across the opening.
 1000 laths 12 inches wide will cover about 575 sq. ft.
 1000 laths 11 inches wide will cover about 525 sq. ft.
 1000 laths require about 5 cords of lath nails, 6 cts. to a cord.

PART IV.

LATHING AND PLASTERING. CARPENTRY; TIMBER. PLUMBING. TIN AND SHEET METAL WORK. PAINTING, GLAZING, AND PAPER-HANGING. IRONWORK. ELECTRIC WIRING, ETC. HEATING.

Lathing and Plastering.—The duties of the superintendent during this branch of the work will be first to see that the laths, when wooden laths are used, are sound, straight-grained, and free from sap, loose knots, or oil.

As the laths are put on he should see that they are nailed solid and given the proper space between; they should be spaced about $\frac{3}{8}$ inch apart for ordinary lime mortar and about $\frac{1}{4}$ inch apart when any of the hard or patent plasters are used. The laths should have one nail to every bearing and have two nails to each end. The perpendicular joints in the laths should be broken about every six lath. No laths should be set vertical to fill out any corner or any other place. Where laths cross a bearing over two inches wide a lath or strip should be put under the laths so the plaster will have a chance to key.

Laths over door or other openings should have as few vertical joints as possible so as to prevent cracks; if possible the laths should extend across the opening.

1000 laths $1\frac{3}{8}$ inches wide will cover about 570 square feet.

1000 laths $1\frac{1}{2}$ inches wide will cover about 620 square feet.

1000 laths require about 5 pounds of lath nails, 6 nails to a lath.

METAL OR WIRE LATHING.—Where metal or wire lathing is used it must be stretched tight and securely fastened. If it is put on wooden joists or studs it should be fastened with staples, and if fastened to metal furring or beams should be fastened with galvanized or coated wire. All metal lathing should be coated to prevent rust; it is usually prepared in this way by the manufacturers. In all angles where wood or terra-cotta partitions join the main wall of the building there should be a strip of the metal lath bent in the angle and extending out on each side about six inches and securely fastened; this will prevent any cracks in the angles after the plastering is done.

CORNER BEADS.—Metal corner beads should be used on all external angles, and care must be taken in setting them to get them straight and fastened solid.

Plastering.—Lime for making mortar for plastering should be of the very best quality and free from all dirt. It should slake readily so there will be no unslaked particles of lime in the mortar to slake after it is put on the wall. If this happens the small pieces of lime swelling and slaking will cause small pieces of the plaster to fall off, leaving "pits" or holes. The lime should be slaked at least a week before being put on the wall.

SAND.—The sand should be sharp and angular, free from any dirt or oil or anything to stain the plaster. When sea sand is used it must be thoroughly washed with fresh water so as to remove all salt.

HAIR AND FIBRE.—These are used in the mortar to form a bond and bind the sheet of mortar together. Cattle hair is generally used, but of late years jute and several fibre products have been used satisfactorily to a great extent.

PLASTER OF PARIS.—Plaster of Paris is prepared by grinding and heating natural gypsum in a furnace so as to drive off its water of crystallization. Plaster of Paris owes its value to the property it possesses of absorbing water and passing into the water-soaked condition, in doing which it sets into a hard mass. This setting takes place quickly, but sufficient time elapses between mixing it with water and setting to permit it to be run into moulds or for coating surfaces, and to gauge the skim or finish coat and for running cornices, centre-pieces, and other ornamental work. Plaster of Paris should be kept in a dry place, as it readily absorbs moisture.

The superintendent should see that the mortar is made up at

least a week before it will be required for use. Ordinarily the hair is mixed with the mortar when it is made up, but on first-class work it should be added when the mortar is mixed for use.

When the hair is added to the mortar when the lime is first slaked there is danger of the hot lime burning the hair and causing it to rot.

Before the mortar is put on the superintendent should examine all grounds to see that they are straight and solid, also see that all gas and electric outlets are in their proper places, and that every possible provision has been made for securing the wood or other finish in place. All walls should be dusted off and wet before any mortar is put on. The superintendent should watch and see that the plasterers use sufficient force in spreading the first coat of mortar to force it through the lathing and key in all spaces. The space back of all wainscot or base should be plastered flush with the face of the grounds, so the wood will lay solid against the plaster.

Cornices or any ornamental work should be run and put in place before the finish or skim coat of plaster.

In putting on the skim coat the superintendent must see that it is given sufficient trowelling to bring it to a smooth glossy surface. By looking along the finished walls where the light strikes them he can tell if they have a good finish; there should be no trowel- or brush-marks show on the finished surface.

PATENT PLASTERS.—There are a number of hard or patent plasters on the market and sold under various names, as Adamant, King's Windsor, Rock Wall, Granite, Elastic Pulp, Ideal, Elyria Wood, Kallolite, Imperial Wall, etc.

The composition of the various plasters is pretty much the same, the hardness being based on the plaster of Paris or gypsum used in their manufacture. These plasters give good satisfaction and make a hard durable job of plastering. For quick work or for use in cold weather they are preferable to lime plaster, as they will set and harden much quicker.

When any of the hard finishes are used the plasterer will generally try to work lime putty in along with it to make it work smoother and easier. This may be permitted to the extent of about 15 per cent lime putty, but no more, and when this permission is granted the superintendent will have to watch to see that no more is used.

The covering capacity of the different patent plasters varies from 90 to 150 yards per ton of plaster.

OUTSIDE STUCCO-WORK.—This is the name usually given to exterior plastering, and is generally done with cement mortar. Care should be taken to keep any outside work from freezing, or from being dried too fast with the heat; it should be shaded to protect it from the sun, and wetting it two or three times a day for several days will improve it.

SCAGLIOLA.—This is a composition made to imitate marble. It is composed of plaster of Paris or Keene's cement mixed with glue or gelatine and the various colors are added to obtain the desired imitation. This work when properly done will take a good polish and makes a good imitation of marble.

CORNICES AND MOULDINGS.—Cornices, mouldings, etc., are usually run with a mould made of sheet iron and cut the reverse contour of the mouldings to be run.

Strips of wood are tacked around the walls and ceiling to form a guide to run the mould along. These moulds are usually made to set at right angles to the mouldings, thus leaving a space the width of the moulding or cornice at all angles which have to be worked out by hand. If the mould is made to set

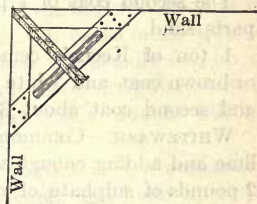


FIG. 210.

at an angle of 45° , or a true mitre with the moulding and the mould made to correspond with the profile of the mouldings on this angle, then the mould can be run in close to all angles. Fig. 210 shows how this mould is made and used.

PLASTERING DATA.—1 barrel of lime will make about $2\frac{3}{4}$ barrels of paste.

1 bushel of hair weighs about 15 pounds.

1 barrel of lime, 18 cubic feet of sand, and 22 pounds of hair will brown coat about 40 yards on wooden lath with $\frac{7}{8}$ -inch grounds, or about 32 yards on brick or terra-cotta walls with $\frac{5}{8}$ -inch grounds, or about 30 yards on wire or metal lath.

1 barrel of lime, 1 barrel of plaster of Paris, 1 barrel white sand will skim coat about 140 square yards.

First coat mortar=1 barrel lime, 18 cubic feet sand, $1\frac{1}{2}$ bushels hair.

Second coat mortar=1 barrel lime, $21\frac{1}{2}$ cubic feet sand, $\frac{3}{4}$ bushel hair.

LAFARGE CEMENT.—Lafarge cement is much used for outside stucco-work. It should be mixed as follows:

First coat, 1 part cement, 3 parts sand, 25 per cent lime paste, and sufficient hair.

Second coat, 1 part cement 2 parts sand, 10 per cent lime paste. 1 barrel of cement and 3 of sand will cover about 34 square yards $\frac{3}{8}$ inch thick.

1 barrel of cement and 2 of sand will cover about 25 square yards $\frac{3}{8}$ inch thick.

KEENE'S CEMENT.—This cement, or plaster, is made by recalcining plaster of Paris after soaking it in a solution of alum; it is used for wainscot, base, caps, etc., and also for hard finish.

The first coat is composed of 1 part cement, 1 part lime paste, and 3 parts sand.

The second coat of 1 part cement, 1 part lime paste, and 4 parts sand.

1 ton of Keene's cement will first coat about 475 yards, or brown coat and white hard finish about 300 yards, or first and second coat about 350 yards.

WHITEWASH.—Common whitewash is made by slaking fresh lime and adding enough water to make a thin paste; by using 2 pounds of sulphate of zinc and 1 pound of salt to each half bushel of lime the whitewash will be much harder and not crack. A half pint of linseed-oil to each gallon of whitewash will make it more durable for outside work. To color add to each bushel of lime 4 to 6 pounds of ochre for cream color; 6 to 8 pound-amber, 2 pounds Indian red, and 2 pounds of lampblack for fawn color; 6 to 8 pounds raw umber and 3 or 4 pounds lamps black for buff or stone color.

Carpentry.—In superintending this branch of work, the superintendent, in addition to examining the materials used, will be required to see that all work is fitted together and secured in a proper manner.

In fire-proof structures, among the first work of the carpenter will be the setting of the window-frames, laying floor strips, etc.

Before being set the window-frames should be examined to see that they conform to the detail drawings, that the pulleys and pockets are put in as desired, and that partitions are provided in the boxes to separate the weights. Care should be taken in setting the frames to get them plumb, and to show the proper reveal on the outside jamb; then they should be se-

curely fastened to the anchors or whatever means that have been provided for fastening them. As soon as the frames are set the sills should be covered to protect them from any damage.

FLOOR STRIPS.—The setting of the floor strips will require close attention to be got straight and level, and the superintendent should see that this is done or a bad floor will be the result. Where there is to be a diagonal underfloor laid there should be a floor strip around all sides of the room to catch the ends of the diagonal flooring. After the concrete filling is put in place all the floor strips should be examined with a straight-edge, and any not straight or level should be taken out and reset.

In putting down the floor strips, they should be run so that when the finished floor is laid it will run lengthwise of the room.

Wherever an underfloor is used it should be laid diagonally, as the top floor can then be laid across the floor strips, and also across the joints of the underfloor. If the underfloor is laid in the same direction as the top floor it will cause much trouble in laying the top floor, as the underfloor will usually cup up at the joints enough to make the top floor irregular, but if the top flooring crosses the underfloor this trouble will be avoided.

In terra-cotta and other fire-proof partitions it is customary to set a rough-wood frame in the opening, and build up to it. Care must be taken to have these frames set plumb and securely fastened top and bottom, and as the tile is built up against them, to fasten the tile to them with metal clips, or nails driven through the tile. As the partitions are built, provisions must be made for nailing or fastening the wood finish. (See page 303.)

JOISTS.—In framing wood joist for a building, they should be given a "camber" or crown of about $\frac{1}{2}$ inch in 20 feet, and the end should be cut on a bevel of about 4 inches, so that in case of fire the joist can drop out of the wall and do no damage. In levelling up joists no wood should be used, but the joist blocked where necessary with slate or flat pieces of iron. Wood joist in brick or stone walls should have the ends cut on a bevel, so that in case of fire, the joist can drop out without pulling down the wall.

In setting joists the superintendent should see that none are set less than 8 inches from the inside of any flue, and 4 inches from any chimney or hot-air pipe; he should watch as the

joist are framed together and see that all joints are tight and have good bearings.

BRIDGING.—All joists should be bridged as the specifications may call for. The bridging should be heavy enough so that two tenpenny nails can be used in each end without splitting the bridging. It should be cut and put in place by nailing the top end only, leaving the bottom end to be nailed after the floor is laid; in this way the flooring draws the joists to a straight line and the bridging braces and holds them there. The nails should be started in the lower end before the bridging is put in place; then all that remains to be done is to drive them home after the floor is laid.

GROUNDS.—This is one of the most particular parts of the carpenter-work, and one that is most often slighted. If the grounds are not put up solid and straight, then the plastering will be crooked and the wood finish will not fit the walls tight. The superintendent should pay special attention and see that all the grounds are put up in the best possible manner; he should take a straight-edge and try them, and if he finds any not straight, have them made so at once.

PARTITIONS.—All stud-partitions should be bridged at half-height; the studs should be brought to a line by tacking a straight piece of 2×4 or 2×6 along them as shown at *B*, Fig. 211. One of the best methods of bridging is shown in Fig. 211, called "herring-bone" bridging; material of the same dimensions as the studs is used, and being set on an angle, as shown, gives a good chance for nailing the ends of the bridging and making the partition solid.

Fig. 212 shows another good method of bridging, by running the bridging horizontally, but setting it diagonally across the stud, as shown at *A*, each alternate piece of bridging being set at opposite angles. Bridging set in this manner gives the plastering a chance to key, and there will be no "dead" plaster.



FIG. 211.

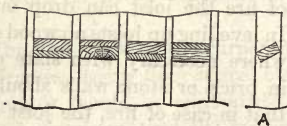


FIG. 212.

DOOR OPENINGS.—All door openings in partitions which carry any weight should be trussed as shown in Fig. 213, and

for bracing it is well to continue the brace to the floor, as shown. In stud partitions a block should be placed at the sides of the door openings to catch and nail the end of the base to, as shown at *A*, Fig. 213.

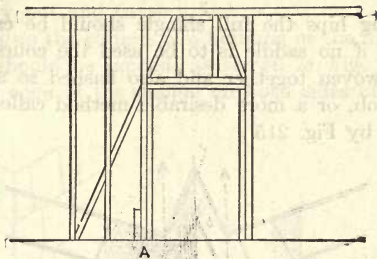


FIG. 213.

ANGLES.—Care must be taken to make all angles solid, and in no case should one be permitted to set the partition-studs so that laths can be run from one room to another. Fig. 214

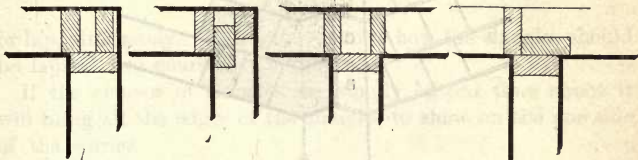


FIG. 214.

shows several methods of setting studs at angles. All studs for partitions should be sized to a width, and all caps and plates sized to a width and thickness; this saves much time and trouble and makes straight work.

SHINGLING.—In laying shingles the essential points are that the shingles be not too wide, that each shingle receives two nails, that they are not laid too much to the weather, that the joints are well broken, that the shingles have a good lap and are fitted close along any ridges, hips, etc. Shingles should not be over 7 inches wide to make a good roof, and any over this width should be split in two. Each shingle should receive two nails, regardless of its width. Shingles should not be laid more than 5 inches to the weather, and $4\frac{1}{2}$ inches makes a better roof. In laying shingles the joints should be broken and the shingles lapped enough, so that there is

no danger of the water following under the shingle to the joint in the course below; care should be taken to break joints with the last two courses laid so that, in case a shingle should split under a joint, the split will not come over a joint in the course below.

In shingling hips the full shingle should be carried out to the hip, and if no saddle is to be used the courses should be lapped and woven together and also flashed so as to make a water-tight job, or a more desirable method called the Boston hip is shown by Fig. 215.

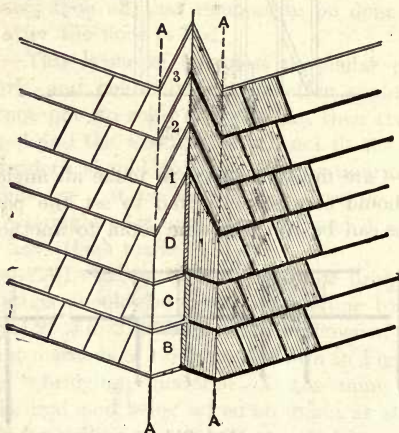


FIG. 215.

Gauged shingles or shingles of a uniform width should be selected to shingle the hip and two lines drawn on the sheathing parallel to the hip, as at *AA*, *AA*. The roof-shingles should be carried up to these lines in steps as shown by 1, 2, 3, after which the hip should be shingled, as shown by *B*, *C*, *D*, working the shingles so they lap alternately as shown. This makes a very neat and water-tight hip.

When valleys are to be shingled close and flashed, the superintendent must see that flashings of a large enough size are used and that no nails are driven where they will be liable to cause a leak.

In open valleys, in order to keep both sides of the shingles straight, a good scheme is to lay a studding of the desired width in the valley and fit the shingles up to it on both sides.

The superintendent should see that the shinglers do not drive nails through the roof in building their scaffold. This is often done and the nail-holes plugged up as they take down the scaffold; but it should never be permitted, for the plugs will rot or dry out and cause a leak.

In shingling up the corners of a building or the hips of a roof, the shingles should be lapped, as shown in Fig. 216, as this will show the edge of the shingle on both sides of the corner,

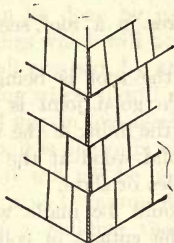


FIG. 216.

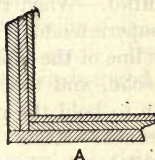


FIG. 217.

or hip, alternately. A, Fig. 217, shows how the shingles should be lapped two courses at a time.

If the courses of shingles are simply lapped time about it will bring all the edges of the shingles to show on the one side of the corner.

Flashing should be used up the sides of all frames and across the top, or any place where the water is liable to penetrate. Shingles should always be laid with galvanized nails.

Four pounds of 4d common or three pounds of 3d common wire nails will put on 1000 shingles.

The following table shows the number of shingles required to a square and the surface 1000 shingles will cover:

| Exposure to the Weather in Inches. | Number of Square Feet of Roof Covered by One Thousand Shingles. | | Number of Shingles Required for One Hundred Square Feet of Roof. | |
|------------------------------------|---|------------------|--|------------------|
| | Four Inches Wide. | Six Inches Wide. | Four Inches Wide. | Six Inches Wide. |
| 4 | 111 | 167 | 900 | 600 |
| 5 | 139 | 208 | 720 | 480 |
| 6 | 167 | 250 | 600 | 400 |
| 7 | 194 | 291 | 514 | 343 |
| 8 | 222 | 333 | 450 | 300 |

The average width of shingles is 4 inches; thus 1000 shingles is the equivalent of 1000 shingles 4 inches wide. This is usually four bunches, as each bunch contains 250 shingles, although on the Pacific Coast the redwood shingles are put up 200 to a bunch and four bunches are sold for 1000 shingles, while in reality they contain but 800. This same rule is used by the shinglers in that section of the country: they charge so much a thousand for laying the shingles, but call four bunches 1000.

To approximate the number of squares in a roof, see page 555.

SHEATHING.—When the sheathing of the roof is being put on the superintendent should see that a good joint is made along the line of the hips and valleys, so the lining of the valley will lay solid, and that there will be solid wood at the angle of the hip to hold the nails of the shingles or slate.

FLAG-POLES.—Masts or flag-poles should be made with a small swell to them, as described for the entasis of columns, page 574.

PITCH OF STAIRS.—In putting up horses for stairs and getting them out the tread should be made to pitch about $\frac{1}{8}$ inch in its width, as this makes a much easier stair than if the treads were perfectly level.

SASH AND DOORS.—Great care must be taken in fitting sash and doors, and also in hanging them; they should have just enough play to work without binding. One of the main troubles with sash is found in the thickness of the sash and meeting-rail, the sash often being made too thick for the runs in the frame. When the meeting-rails are too thick they will strike as the bottom sash is closed and pull the top sash down from the top; then when the bottom sash is raised there will be too much play between the sash and the parting bead, as shown at *B*, Fig. 218, and the sash will rattle. *A*, Fig. 218, shows how the meeting-rails should come together. Care also must be taken in hanging the sash to get the proper weights so the sash will

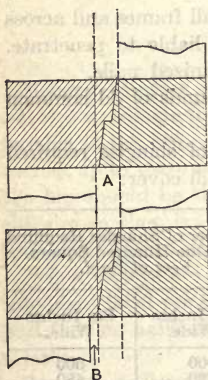


FIG. 218.

be evenly balanced.

PANEL-MOULDINGS.—The superintendent should examine all doors and panel-work and see how the mouldings are nailed or fastened. The moulding should be nailed to the rail or stile as shown at *A*, Fig. 219, and not to the panel. If the moulding is fastened to the panel and the panel shrinks, as it generally does, it will make an open joint as shown at *B*.

In nailing up finish or any interior work, the nails should be concealed as much as possible; this can be done by nailing in members of the mouldings which will be covered, or if the moulding is all exposed, by nailing in the quirks of the moulding where it will not be noticed after being puttied up; in quartered oak, chestnut, ash, etc.,

if the nail is driven in one of the pores of the wood and puttied neatly it will not be noticeable.



FIG. 219.

SECURING INTERIOR WOOD TRIM.—During the entire construction of a building the superintendent must see that proper provisions are made as the work progresses for nailing or fastening the wood finish or trim. Until recent days it has been customary to build wood blocks in the wall and nail the trim to these blocks. Wood blocks in some cases do not give entire satisfaction, as they are liable to shrink and come loose, and this will usually happen unless they are built in properly.

Of late some architects go so far as to specify that no wood blocks or plugs shall be used to secure the inside trim. Still there are some places where, if built in properly, a wood block will give better satisfaction than anything else for nailing and securing the trim. For base moulding, chair-rail, picture mould, etc., a wood block, if cut dove-

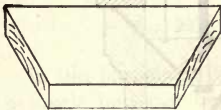


FIG. 220.

tail shape as shown by Fig. 220 and built solid in the wall will give good satisfaction and can never come loose, or take a wood block and drive nails in both sides, leaving the nails project out about $\frac{1}{4}$ inch and build this in the wall so the projecting nails are bedded in the mortar joint, it will always remain solid and secure.

If it is not desired to use wood blocks exposed, a terra-cotta block filled with wood and built in the wall will answer quite as well provided nails long enough are used so as to reach into the wood.

All door openings in terra-cotta walls usually have a rough stud frame, as shown at *A*, Fig. 221, and the tile should be built up to this frame and each course nailed or anchored to the stud.

Wherever there is to be any nailing in the terra-cotta the author has derived the best satisfaction by inserting a wood



FIG. 221.

block in the tile as shown at *B*, Fig. 221, and then nailing through the tile into the block. Terra-cotta is supposed to hold a nail, but will not give satisfaction for nailing trim to; the jar of the hammer in setting the nail will nearly always jar the nail loose.

Fig. 222 shows a good method of fastening window-frames and securing the trim; the bolts as shown are built in as the

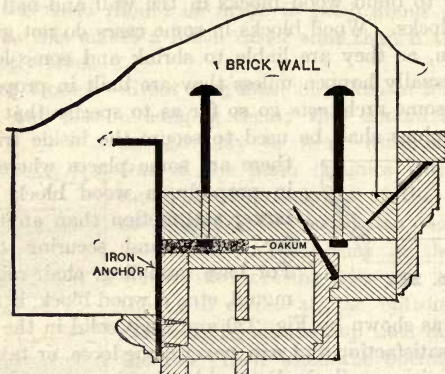


FIG. 222.

walls are built, and a 2-inch nailing-piece is bolted fast as shown, keeping one edge out to form a plaster ground. The frame can be set and anchored as shown, and the trim nailed to the nailing-piece before the back strip is put on.

The space around the frame should always be well calked with oakum or mineral wool.

Door-frames and trim in brick openings can be secured in a similar manner.

Metal nailing-plugs are used to some extent for securing finish or trim, but nothing gives as good satisfaction as wood securely anchored. In some cases expansion-bolts can be used with good satisfaction where there is nothing to nail to.

Figs. 223 and 224 show a method the author has used for fastening up wainscoting to brick walls, the bolts, as shown, being built in as the walls were built; the blocking or core piece, as shown, is bolted fast to the wall as the wainscot is put up and bolted fast. The cap and base can then be nailed securely to the wainscot and blocking.

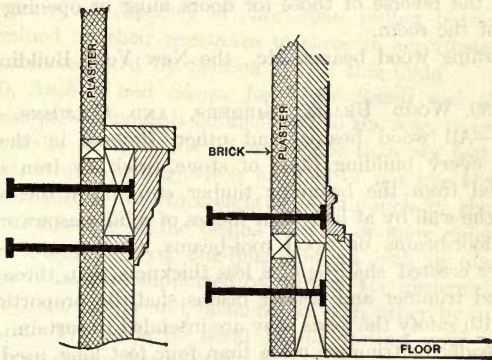


FIG. 223.

FIG. 224.

In tile partitions, in place of a bolt being built in the wall a toggle bolt can be used.

HARDWARE.—All hardware should be fitted in place before any painting or varnishing is done, and when this is done the superintendent should have it left in place long enough for him to examine it and see that all pieces work easily. After examining them all he should have all hardware taken off and put on final at the completion of the painting.

HANDS OF DOORS.—The hand of a door is determined from the outside of a building, room, or closet. Door No. 1 in Fig. 225 is a right-hand door because it opens to the right as you enter the room, and No. 2 is a left-hand door, as it opens to the left as you enter.

If the doors open to the outside, as shown in Fig. 226, door

No. 1 will be a right-hand reverse bevel, because it opens to the right, and No. 2 will be a left-hand reverse bevel, as it opens to the left, but the bevel for locks for these doors will

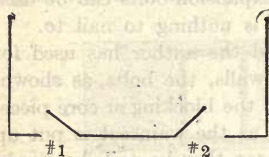


FIG. 225.

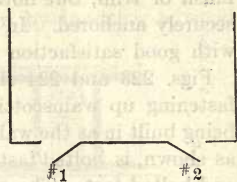


FIG. 226.

be just the reverse of those for doors hung or opening on the inside of the room.

Regarding wood beams, etc., the New York Building Code says:

Sec. 59. WOOD BEAMS, GIRDERS, AND COLUMNS.—*Wood Beams.*—All wood beams and other timbers in the party wall of every building built of stone, brick, or iron shall be separated from the beam or timber entering in the opposite side of the wall by at least four inches of solid masonwork. No wood floor-beams or wood roof-beams used in any building hereafter erected shall be of a less thickness than three inches. All wood trimmer and header beams shall be proportioned to carry with safety the loads they are intended to sustain. Every wood header or trimmer more than four feet long used in any building shall be hung in stirrup-irons of suitable thickness for the size of the timbers. Every wood beam, except header and tail beams, shall rest at one end four inches in the wall, or upon a girder as authorized by this Code. The ends of all wood floor- and roof-beams, where they rest on brick walls, shall be cut to a bevel of three inches on their depth. In no case shall either end of a floor- or roof-beam be supported on stud partitions, except in frame buildings. All wood floor- and wood roof-beams shall be properly bridged with cross-bridging, and the distance between bridging or between bridging and walls shall not exceed eight feet. All wood beams shall be trimmed away from all flues and chimneys, whether the same be a smoke, air, or any other flue or chimney. The trimmer beam shall be not less than eight inches from the inside face of a flue and four inches from the outside of a chimney-breast, and the header beam not less than two inches from the

outside face of the brick or stone work of the same, except that for the smoke-flues of boilers and furnaces where the brickwork is required to be eight inches in thickness, the trimmer beam shall be not less than twelve inches from the inside of the flue. The header beam, carrying the tail beams of a floor, and supporting the trimmer arch in front of a fireplace, shall be not less than twenty inches from the chimney-breast. The safe carrying capacity of wood beams for uniformly distributed loads shall be determined by multiplying the area in square inches by its depth in inches and dividing this product by the span of the beam in feet. This result is to be multiplied by seventy for hemlock, ninety for spruce and white pine, one hundred and twenty for oak, and by one hundred and forty for yellow pine. The safe carrying capacity of short-span timber beams shall be determined by their resistance to shear in accordance with the unit stresses fixed by Section 139 of this Code.

Sec. 60. *anchors and Straps for Wood Beams and Girders.*—Each tier of beams shall be anchored to the side, front, rear, or party walls at intervals of not more than six feet apart with good, strong, wrought-iron anchors of not less than one and a half inches by three-eighths of an inch in size, well fastened to the side of the beams by two or more nails made of wrought iron at least one-fourth of an inch in diameter. Where the beams are supported by girders, the girders shall be anchored to the walls and fastened to each other by suitable iron straps. The ends of wood beams resting upon girders shall be butted together end to end and strapped by wrought-iron straps of the same size and distance apart, and in the same beam as the wall anchors, and shall be fastened in the same manner as said wall anchors.

Or they may lap each other at least twelve inches and be well spiked or bolted together where lapped.

Each tier of beams front and rear, opposite each pier, shall have hardwood anchor strips dovetailed into the beams diagonally, which strips shall cover at least four beams and be one inch thick and four inches wide, but no such anchor strips shall be let in within four feet of the centre line of the beams; or wood strips may be nailed on the top of the beams and kept in place until the floors are being laid. Every pier and wall, front or rear, shall be well anchored to the beams of each story with the same size anchors as are required for side walls, which anchors shall hook over the fourth beam.

Sec. 61. *Wood Columns and Plates.*—All timber columns shall be squared at the ends perpendicular to their axes.

To prevent the unit stresses from exceeding those fixed in this Code, timber or iron cap and base plates shall be provided.

Additional iron cheek plates shall be placed between the cap and base plates and bolted to the girders when required to transmit the loads with safety.

Sec. 62. **TIMBER FOR TRUSSES.**—When compression members of trusses are of timber they shall be strained in the direction of the fibre only. When timber is strained in tension, it shall be strained in the direction of the fibre only. The working stress in timber struts of pin-connected trusses shall not exceed seventy-five per cent of the working stresses established in section 139, this Code.

Sec. 63. **BOLTS AND WASHERS FOR TIMBER-WORK.**—All bolts used in connection with timber and wood-beam work shall be provided with washers of such proportions as will reduce the compression on the wood at the face of the washer to that allowed in Section 139, this Code, supposing the bolt to be strained to its limit.

Nails.—*Functions and Requirements.*—Nails are used to fasten pieces of wood superposed or adjacent to each other. They are driven perpendicularly to the materials when they are superposed and obliquely when adjacent. In the former case they draw directly in line of the axis of the nail, and in the latter, obliquely to its axis; in this case the rigidity or transverse strength of the nail plays an important part.

In all cases the adhesive resistance of a nail is nearly in ratio to the area of surface of the nail subjected to compression of the wood fibre, into which it is imbedded. It is therefore requisite that the greater portion of the nail be imbedded in the piece to which another is fastened; but in no instance is it necessary that it should penetrate through it.

Adhesive Resistance.—This property in a nail is secondary to none, and must always be supplemented with the proper area of head to increase the crushing strength of wood fibre, in order that a nail may fulfil its primary function of holding pieces together by compression.

It has been found in practice that the cut nail is harder to drive in than the wire nail, on account of the blunt point and tapering sides. While it has more adhesive resistance than a smooth wire nail of the same length, this is due directly to the

fact that two of its sides are tapering, or wedging, and that it has nearly twice the area of compression; but the slightest withdrawal of the nail releases the wedge, which immediately reduces the area of compression and lowers its adhesive resistance about 40 per cent.

This is not so with the wire nail, because the area of compression only varies as the distance the nail is imbedded, and its adhesive resistance is nearly in ratio to this area.

From what has been stated it is readily seen that the greatest area of compression and adhesive resistance in a cut nail is towards the head of the nail, whereas it should be at the point, while in the wire nail it varies only as the units of its length; therefore the excess of metal used and the very form of the cut nail is primarily wrong, as proved by modern practice, and is contrary to the very sense of its purpose, while the wire nail fulfils the requirements of a perfect nail.

Herein follow tables showing comparative tests of smooth steel wire nails, steel cut nails, and coated steel wire nails, with reference to their area of compression and adhesive resistance to pull.

TESTS SHOWING ADHESIVE RESISTANCE FOR EACH ONE-HALF INCH UNIT OF LENGTH OF NAIL IMBEDDED INTO WHITE PINE.

| Kind of Nail. | Com- mercial Gauge. | Diam- eter in Inches. | Adhesive Resistance in Pounds for Each $\frac{1}{2}$ -inch Unit. | | | |
|------------------------------------|---------------------------|-----------------------------|---|------------------|----------------|----------------|
| | | | 2 Ins., Lbs. | 1½ Ins., Lbs. | 1 In., Lbs. | ½ In., Lbs. |
| 8d common smooth wire..... | 10½ | .135 | 210 | 170 | 140 | 90 |
| 10d common smooth wire..... | 9 | .148 | 200 | 150 | 110 | 80 |
| 20d common smooth wire..... | 6 | .192 | 220 | 130 | 110 | 80 |
| 8d common coated wire nail.... | 11 | .120 | 370 | 280 | 220 | 120 |
| 10d common coated wire nail.... | 10 | .135 | 400 | 330 | 250 | 150 |
| | Dimensions. | | | | | |
| 8d common cut steel... | | 10½ × 9 | 260 | 90 | 40 | 0 |
| 10d common cut steel... | | 10½ × 5½ | 320 | 140 | 60 | 0 |
| 20d common cut steel... | | 7 × 4 | 230 | 90 | 40 | 0 |

Remarks.—The resistance here given was recorded on the machine gauge, the nail being driven into the wood 2 inches deep, then each reading of the gauge was taken successively as the nail was withdrawn to the measurements given.

A CUT NAIL LOSES FORTY PER CENT OF ITS ADHESIVE RESISTANCE THE MOMENT IT HAS BEEN SLIGHTLY WITHDRAWN.

| Kind of Nail. | Commercial Gauge. | Distance Imbedded, Inches. | Resistance to Initial Pull, Lbs. | Resistance Second Pull, Lbs. | Resistance Loss after First Pull. | Per Cent Loss. |
|-------------------------|-------------------|----------------------------|----------------------------------|------------------------------|-----------------------------------|----------------|
| 8d cut common | 10½ | 1½ | 260 | 160 | 100 | 40 |
| 12d " " | 9 | 2 | 390 | 220 | 170 | 43 |

Remarks.—The first pull extracted the nail about $\frac{3}{8}$ inch.

ORDNANCE DEPARTMENT, U. S. A.

Reports of mechanical tests made with the United States Testing Machine at Watertown Arsenal, Watertown, Mass., June 30, 1902, and August 5 and 16, 1902, for J. C. Pearson Company.

(Nails driven perpendicular to the grain of the wood. All nails driven in the same stick.)

| Test Number. | Description of Nail. | | | Length Driven, Inches. | Adhesive Resistance, Total Lbs. | Average, Lbs. |
|--------------|-----------------------------|-------------------|-----------------------|------------------------|---------------------------------|---------------|
| | Size and Name. | Diameter, Inches. | Total Length, Inches. | | | |
| 11.989 | 10d common smooth | .145 | 2.99 | 2.50 | 136 | 167 |
| | 10d " " " " | .145 | 2.99 | | | |
| | 10d " " " " | .145 | 2.99 | | | |
| 12.058 | 10d coated | .117 | 3.00 | 2.50 | 414 | 418 |
| | 10d " " " " | .117 | 3.00 | | | |
| | 10d " " " " | .117 | 3.00 | | | |
| 11.991 | 9d common smooth | .132 | 2.83 | 2.25 | 226 | 182 |
| | 9d " " " " | .132 | 2.83 | | | |
| | 9d " " " " | .132 | 2.83 | | | |
| 11.992 | 9d coated | .114 | 2.68 | 2.25 | 345 | 327 |
| | 9d " " " " | .114 | 2.68 | | | |
| | 9d " " " " | .114 | 2.68 | | | |
| 11.993 | 8d common smooth | .132 | 2.52 | 2.00 | 146 | 189 |
| | 8d " " " " | .132 | 2.52 | | | |
| | 8d " " " " | .132 | 2.52 | | | |
| 12.044 | 8d coated | .112 | 2.39 | 2.00 | 322 | 316 |
| | 8d " " " " | .112 | 2.39 | | | |
| | 8d " " " " | .112 | 2.39 | | | |
| 11.998 | 6d common smooth | .097 | 2.05 | 1.625 | 100 | 106 |
| | 6d " " " " | .097 | 2.05 | | | |
| | 6d " " " " | .097 | 2.05 | | | |
| 12.059 | 6d coated | .092 | 1.94 | 1.625 | 214 | 226 |
| | 6d " " " " | .092 | 1.94 | | | |
| | 6d " " " " | .092 | 1.94 | | | |

The coated nails used in making the above tests were those manufactured by J. C. Pearson Company, Boston.

The various kinds of nails derive their names from their shape, material from which they are made, or from the use for which they are intended.

The term penny, as applied to nails, is derived from pound. It originally meant so many pounds to the thousand. Three-penny nails would mean three pounds to the thousand nails; eight-penny, eight pounds to the thousand nails, etc. Now the term penny is used only to refer to the length of the nail.

- 3 lbs. 8d nails will lay one square flooring,
- 2 " 8d " " " " " sheathing.
- 2 " 8d " " " " " siding.

For quantity of nails required see Lathing, Shingling, and Slating.

SPIKES, NAILS, AND TACKS.

| Standard Steel Wire Nails. | | | | | | Steel Wire Spikes. | | | Common Iron Nails. | | |
|----------------------------|-----------------|-------------------|----------------|-------------------|----------------|--------------------|-------------------|----------------|--------------------|-----------------|----------------|
| Sizes. | Length, Inches. | Common. | | Finishing. | | Length, Inches. | Diameter, Inches. | Number per Lb. | Sizes. | Length, Inches. | Number per Lb. |
| | | Diameter, Inches. | Number per Lb. | Diameter, Inches. | Number per Lb. | | | | | | |
| 2d | 1 | .0524 | 1060 | .0453 | 1558 | 3 | .1620 | 41 | 2d | 1 | 800 |
| 3d | 1½ | .0588 | 640 | .0508 | 913 | 3½ | .1819 | 30 | 3d | 1½ | 400 |
| 4d | 1¾ | .0720 | 380 | .0508 | 761 | 4 | .2043 | 23 | 4d | 1¾ | 300 |
| 5d | 1¾ | .0764 | 275 | .0571 | 500 | 4½ | .2294 | 17 | 5d | 1¾ | 200 |
| 6d | 2 | .0808 | 210 | .0641 | 350 | 5 | .2576 | 13 | 6d | 2 | 150 |
| 7d | 2½ | .0858 | 160 | .0641 | 315 | 5½ | .2893 | 11 | 7d | 2½ | 120 |
| 8d | 2¾ | .0935 | 115 | .0720 | 214 | 6 | .2893 | 10 | 8d | 2¾ | 85 |
| 9d | 2¾ | .0963 | 93 | .0720 | 195 | 6½ | .2249 | 7½ | 9d | 2¾ | 75 |
| 10d | 3 | .1082 | 77 | .0808 | 137 | 7 | .2249 | 7 | 10d | 3 | 60 |
| 12d | 3½ | .1144 | 60 | .0808 | 127 | 8 | .3648 | 5 | 12d | 3½ | 50 |
| 16d | 3½ | .1285 | 48 | .0907 | 90 | 9 | .3648 | 4½ | 16d | 3½ | 40 |
| 20d | 4 | .1620 | 31 | .1019 | 62 | ..... | ..... | ..... | 20d | 4 | 20 |
| 30d | 4½ | .1819 | 22 | ..... | ..... | ..... | ..... | ..... | 30d | 4½ | 16 |
| 40d | 5 | .2043 | 17 | ..... | ..... | ..... | ..... | ..... | 40d | 5 | 14 |
| 50d | 5½ | .2294 | 13 | ..... | ..... | ..... | ..... | ..... | 50d | 5½ | 11 |
| 60d | 6 | .2576 | 11 | ..... | ..... | ..... | ..... | ..... | 60d | 6 | 8 |

TACKS.

| Title, Ounce. | Length, Inches. | Number per Pound. | Title, Ounce. | Length, Inches. | Number per Pound. | Title, Ounce. | Length, Inches. | Number per Pound. |
|---------------|-----------------|-------------------|---------------|-----------------|-------------------|---------------|-----------------|-------------------|
| 1 | ⅛ | 16,000 | 4 | 7/16 | 4000 | 14 | 1¾ | 1143 |
| 1½ | 3/16 | 10,666 | 6 | 9/16 | 2666 | 16 | 7/8 | 1000 |
| 2 | ¼ | 8,000 | 8 | 5/8 | 2000 | 18 | 15/16 | 888 |
| 2½ | 5/16 | 6,400 | 10 | 11/16 | 1600 | 20 | 1 | 800 |
| 3 | 3/8 | 5,333 | 12 | ¾ | 1333 | 22 | 1¼ | 727 |
| | | | | | | 24 | 1½ | 666 |

WROUGHT SPIKES.

Number to a keg of 150 pounds.

| L'gth, Ins. | ¼ In., Num- ber. | ⅝ In., Num- ber. | ⅜ In., Num- ber. | L'gth, Ins. | ¼ In., Num- ber. | ⅝ In., Num- ber. | ⅜ In., Num- ber. | 7/16 In., Num- ber. | ½ In., Num- ber. |
|----------------|------------------------|------------------------|------------------------|----------------|------------------------|------------------------|------------------------|---------------------------|------------------------|
| 3 | 2250 | .... | .... | 7 | 1161 | 662 | 482 | 445 | 306 |
| 3½ | 1890 | 1208 | .... | 8 | .... | 635 | 455 | 384 | 256 |
| 4 | 1650 | 1135 | .... | 9 | .... | 573 | 424 | 300 | 240 |
| 4½ | 1464 | 1064 | .... | 10 | .... | .... | 391 | 270 | 222 |
| 5 | 1380 | 930 | 742 | 11 | .... | .... | .... | 249 | 203 |
| 6 | 1292 | 868 | 570 | 12 | .... | .... | .... | 236 | 180 |

WEIGHT OF COPPER NAILS.

CUT COPPER SLATING NAILS.

1½ inch, about 190 to the pound.

1½ inch, about 135 to the pound.

CUT YELLOW METAL SLATING NAILS.

1½ inch, about 154 to the pound.

1½ inch, about 140 to the pound.

COPPER WIRE SLATING NAILS.

7/8 inch No. 12 gauge about 303 per pound.

1 " " 12 " " 270 " "

1¼ " " 11 " " 196 " "

1½ " " 10 " " 134 " "

1¼ " " 12 " " 231 " "

1½ " " 12 " " 210 " "

NUMBER OF BOAT SPIKES TO 200-POUND KEG.

| Length, Inches. | Diameter. | | | | | | |
|--------------------|-------------------|-------------------|-------------------|----------------------|-------------------|---------------------|-------------------|
| | ¼ Inch Square. | ⅝ Inch Square. | ⅜ Inch Square. | 7/16 Inch Square. | ½ Inch Square. | 5/8 Inch Square. | ¾ Inch Square. |
| 3 | 3300 | .... | .... | .... | .... | .... | .... |
| 3½ | 2880 | .... | .... | .... | .... | .... | .... |
| 4 | 2343 | 1671 | .... | .... | .... | .... | .... |
| 4½ | 2200 | 1364 | 1039 | .... | .... | .... | .... |
| 5 | 2030 | 1308 | 935 | .... | .... | .... | .... |
| 5½ | 1828 | 1175 | 880 | .... | .... | .... | .... |
| 6 | 1624 | 1115 | 710 | 562 | 433 | .... | .... |
| 7 | 1420 | 988 | 665 | 516 | 400 | .... | .... |
| 8 | 1220 | 849 | 602 | 453 | 337 | .... | .... |
| 9 | .... | .... | 519 | 409 | 305 | .... | .... |
| 10 | .... | .... | 468 | 369 | 297 | 182 | .... |
| 12 | .... | .... | 410 | 302 | 241 | 155 | .... |
| 14 | .... | .... | .... | .... | 216 | 130 | 95 |
| 16 | .... | .... | .... | .... | 182 | 122 | 80 |

NUMBER AND DIAMETER OF WOOD SCREWS.

| Number. | Diameter. | Number. | Diameter. | Number. | Diameter. | Number. | Diameter. |
|---------|-----------|---------|-----------|---------|-----------|---------|-----------|
| 0 | .056 | 8 | .162 | 16 | .268 | 24 | .374 |
| 1 | .069 | 9 | .175 | 17 | .281 | 25 | .387 |
| 2 | .082 | 10 | .188 | 18 | .293 | 26 | .401 |
| 3 | .096 | 11 | .201 | 19 | .308 | 27 | .414 |
| 4 | .109 | 12 | .215 | 20 | .321 | 28 | .427 |
| 5 | .122 | 13 | .228 | 21 | .334 | 29 | .440 |
| 6 | .135 | 14 | .241 | 22 | .347 | 30 | .453 |
| 7 | .149 | 15 | .255 | 23 | .361 | | |

Timber.—DESCRIPTION OF THE VARIOUS WOODS USED IN CONSTRUCTION.—*White Pine*, or Northern pine, is found in the northern part of the United States and in Canada. It is a light, soft, straight-grained wood of a light yellowish color; it is mostly used in buildings for trim and mouldings, where the work is to be painted or stained. It is one of the most reliable of woods for staying in place after it is put up, as it does not twist and warp like some of the other woods.

Georgia Pine, which is also known as pitch or hard pine, and is usually specified as “long-leaf pine,” is found along the southern coast of the United States, from Virginia to Texas; it is the best variety of the yellow pine, and is much used for flooring, and also for heavy framing. It is a very strong wood and contains much resin. It should not be used under ground or in damp places, as it decays very fast in such places. The other species of yellow pine are often sold as Georgia “long-leaf,” but they are much softer and not so strong. The superintendent should make himself familiar with the different species so as to be able to distinguish them.

Spruce is the name given to all the varieties of the spruce-fir tree, of which there are four: white, black, Norway, and single spruce. Spruce is a very tough light wood, with a reddish color, and is much used for framing lumber; it is also much used for piles, as it preserves well in the water or in damp places.

Oregon Pine.—This is the best framing lumber found in the United States. It is much harder and stronger than the white pine and does not contain as much resin as the yellow pine. It can be got in any size and length and is much used for masts and spars.

Hemlock is similar to spruce in appearance, but is a much inferior wood. It is very brittle, splits very easily, and is often

found shaky. The grain is very coarse and the concentric circular layers of the wood separate easily. It is only used as a cheap framing lumber, and for sheathing, as it holds a nail better than the soft pine.

White Cedar is a soft white, fine-grained wood, and is very durable when exposed to dampness, hence it makes good shingles, for which purpose it is much used.

Red Cedar is a similar wood to the white cedar, but is of a reddish-brown color. It possesses a strong odor which repels insects, and on this account is much used for making chests, lining wardrobes, etc. It is also a good wood for use in damp places, as it stands the moisture very well.

Cypress is a wood somewhat similar to cedar, and is much used for shingles, and for use where dampness is to be considered. It is found in the southern and southwestern parts of the United States.

Red Wood, which is the common name given to the Sequoia or "big trees" of California, is a valuable lumber for building purposes where great strength is not necessary. It has great lasting qualities when exposed to dampness and makes the best of shingles. For sills or posts in the ground it is one of the best woods to be found. It makes good weather-boarding or mouldings and takes the paint well. It is of a dull-reddish color and makes a very nice finish when finished natural.

White Oak is the hardest of the several varieties of oak, and is found in the eastern half of the United States. The wood is very heavy, hard, and strong, and is used where strength is desired.

Red Oak is of a more open grain than the white oak and is softer and not so strong. It is more easily worked and is much used for inside finish. Red oak when quarter-sawed makes one of the most pleasing finishes to the eye.

Ash.—This wood grows in the northern part of the United States. It is very heavy and hard, is usually white in color, and is used for finish and for furniture.

Hickory is the heaviest, toughest, hardest, and strongest of all woods found in America. It is very close-grained and is very flexible. It is not used much for building purposes, unless for wedges, pins, and such like.

Locust is a hard, close-grained wood of a yellowish color; its use is principally for posts in the ground or such places, as it is a very lasting wood in damp places.

Black Walnut is a heavy, hard wood of a dark-brown color and has a very nice even grain. On account of its value it is not used much for building purposes, but its use is confined mostly to furniture and cabinet work.

White Walnut (butternut) is a specie of the walnut; the wood is lighter in color and heavier in grain. Its uses are about the same as black walnut.

Cherry—This wood, which is obtained from the wild-cherry tree, is used for interior finish and for furniture. It is hard, close-grained, and very durable; it takes a high polish and stands well, as it is not liable to twist or warp.

Birch is much similar to cherry in structure and in appearance, but it does not stand as well, being more liable to twist and warp.

Maple is a hard, heavy, strong, close-grained wood of a light color. It is one of the best woods in use for flooring, and is much used for this purpose. The "bird's-eye" maple, which is covered with small spots which resemble small knots, is used for finish and for furniture.

Chestnut, which is a soft, coarse-grained wood of a somewhat similar color to oak, is found in the eastern part of the United States. It is not a strong wood, being very brittle, but its lasting qualities are very good. It is used for inside finish and resembles oak. It is also used for outside structures exposed to the weather, on account of its durability.

Poplar (whitewood) is a wood of a yellowish color, soft and brittle, with a close grain. It is used mostly for mouldings or inside finish, frequently to imitate hard woods, as it has a close grain and takes stain well. The sap-wood is nearly white in color.

Mahogany.—This wood comes from the West Indies and Central America, and is very valuable. It is used principally in the manufacture of furniture; also for finishing in the more expensive houses or buildings.

When timber of any kind is to be used in any structure or construction of any kind, it will be the duty of the superintendent to see that it is free from all defects, of which the most common are rot, dry-rot, wind-shakes, splits, bad knots, sap, etc.

In lumber which contains sap, and which has been piled for some time, just after being sawed, and piled without sticking, the sap will usually turn a dark-blue or drab color. This

is "black or blue sap" and is the first stages of "dry-rot," and any lumber in this condition should be rejected.

Lumber which has been cut from trees growing in soft soil or swamps is often found to contain "wind-shakes," caused by the usually rapid growth of the trees and the swaying or bending of the trees by the wind. These shakes are cracks separating the concentric circular rings of the wood.

Heart-shakes, or splits, are the cracks found in the heart of the log, usually caused by the shrinkage of the log, or the heart of the tree or log separating from the outside layers of the wood.

A sound stick of timber when struck a sharp blow with a hammer on the end should give forth a clear ringing sound, and which can be heard by a person placing his ear at the opposite end of the stick. If the sound is dull and faint it is an indication of decay or some defect in the stick.

Timber for posts carrying great weight should be from the heart of the tree, as this is usually the strongest, and the compression strength will be the same on all outside parts of the stick.

Timber for flag-poles or masts should also be from the heart of the tree. If one side of the stick is heart-wood and the opposite side of the stick is wood from out next the bark the unequal shrinkage of the two sides of the stick in length will cause the stick to bow and become crooked.

Timber before being used should be well seasoned either by natural or artificial means. Timber if piled when sawed and strips placed between each layer of timber so as to permit the air to get to all sides of the timber will season for ordinary use in from seven months to two years, according to the kind of wood and the size of the sticks.

When timber is used in any place where shrinkage in the timber may weaken the structure, the superintendent should make sure that the timber has been well seasoned and is perfectly dry.

When lumber of any kind is brought to the work the superintendent should see that it is piled up and covered in a proper manner to protect it from the sun and weather, as good lumber can be very easily spoiled by carelessness in piling or covering.

The shrinkage of timber is shown by the following table:

| | |
|------------------------------|---------------------|
| Cedar..... | 12 to 11.40 inches. |
| Elm..... | 12 to 11.70 “ |
| Oak..... | 12 to 11.75 “ |
| Pine (white)..... | 12 to 11.80 “ |
| Pine (yellow)..... | 12 to 11.90 “ |
| Pine (yellow long-leaf)..... | 12 to 11.95 “ |
| Redwood (California)..... | 12 to 11.95 “ |
| Spruce..... | 12 to 11.85 “ |

The working strength of timber as given by the New York Building Code is shown by the following table:

WORKING STRENGTH PER SQUARE INCH IN POUNDS.

| Name of Wood. | Direct Compression. | | Tension. | Shearing. | | Safe Extreme Fibre Stress (Bending). |
|----------------------|---------------------|---------------|----------|-------------|---------------|--------------------------------------|
| | With Grain. | Across Grain. | | With Fibre. | Across Fibre. | |
| Oak. | 900 | 800 | 1000 | 100 | 600 | 1000 |
| Yellow pine. | 1000 | 600 | 1200 | 70 | 500 | 1200 |
| White pine. | 800 | 400 | 800 | 40 | 250 | 800 |
| Spruce. | 800 | 400 | 800 | 50 | 320 | 800 |
| Locust. | 1200 | 1000 | .... | 100 | 720 | 1200 |
| Hemlock. | 500 | 500 | .... | 40 | 275 | 600 |
| Chestnut. | 500 | 1000 | .... | ... | 150 | 800 |

LASTING QUALITIES OF WOOD IN THE EARTH.—Experiments have been made by driving sticks of different woods into the ground, by which it is ascertained that in five years all of those made of oak, elm, fir, ash, soft mahogany, and all varieties of pine were almost totally rotten; larch and teak were decayed on the outside; acacia was only slightly decayed on the outside; hard mahogany and cedar of Lebanon were in good condition; Virginia cedar was as good as when put in. California redwood is also one of the best woods for use in damp places, as it is very slow to decay.

Any wood to be exposed to much dampness should if possible be coated or impregnated with some preservative. The most effectual method of preserving wood from decay is to force the preservative, such as creosote or other mixture, into the pores of the wood. Plants for doing this are found in nearly all the large cities.

For timbers, etc., to be used underground, a coat of coal-tar applied hot is a good method of preserving the wood from rot.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR RECTANGULAR
SPRUCE OR WHITE-PINE BEAMS ONE INCH THICK.

The following table has been calculated for extreme fibre stresses of 750 pounds per square inch corresponding to the following values for moduli of rupture recommended by Prof. Lanza, viz.:

| | |
|----------------------------|-----------|
| Spruce and white pine..... | 3000 lbs. |
| Oak..... | 4000 " |
| Yellow pine..... | 5000 " |

For oak increase values in table by $\frac{1}{3}$. For yellow pine increase values in table by $\frac{1}{3}$.

The safe load for any other values per square inch is found by increasing or decreasing the loads given in the table in the same proportion as the increased or decreased fibre stress.

| Span in Feet. | Depth of Beam. | | | | | | | | | | |
|---------------------|----------------|-----------|-----------|-----------|------------|------------|------------|------------|------------|------------|------------|
| | 6 Ins. | 7 Ins. | 8 Ins. | 9 Ins. | 10 Ins. | 11 Ins. | 12 Ins. | 13 Ins. | 14 Ins. | 15 Ins. | 16 Ins. |
| 5 | 600 | 820 | 1070 | 1350 | 1670 | 2020 | 2400 | 2820 | 3270 | 3750 | 4270 |
| 6 | 500 | 680 | 890 | 1120 | 1390 | 1680 | 2000 | 2350 | 2730 | 3120 | 3560 |
| 7 | 430 | 580 | 760 | 960 | 1190 | 1440 | 1710 | 2010 | 2330 | 2680 | 3050 |
| 8 | 380 | 510 | 670 | 840 | 1040 | 1260 | 1500 | 1760 | 2040 | 2340 | 2670 |
| 9 | 330 | 460 | 590 | 750 | 930 | 1120 | 1330 | 1560 | 1810 | 2080 | 2370 |
| 10 | 300 | 410 | 530 | 670 | 830 | 1010 | 1200 | 1410 | 1630 | 1880 | 2130 |
| 11 | 270 | 370 | 490 | 610 | 760 | 920 | 1090 | 1280 | 1490 | 1710 | 1940 |
| 12 | 250 | 340 | 440 | 560 | 690 | 840 | 1000 | 1180 | 1360 | 1560 | 1780 |
| 13 | 230 | 310 | 410 | 520 | 640 | 780 | 930 | 1080 | 1260 | 1440 | 1640 |
| 14 | 210 | 290 | 380 | 480 | 590 | 720 | 860 | 1010 | 1170 | 1340 | 1530 |
| 15 | 200 | 270 | 360 | 450 | 560 | 670 | 800 | 940 | 1090 | 1250 | 1420 |
| 16 | 190 | 260 | 330 | 420 | 520 | 630 | 750 | 880 | 1020 | 1180 | 1330 |
| 17 | 180 | 240 | 310 | 400 | 490 | 590 | 710 | 830 | 960 | 1100 | 1260 |
| 18 | 170 | 230 | 290 | 370 | 460 | 560 | 670 | 780 | 910 | 1040 | 1190 |
| 19 | 160 | 210 | 280 | 360 | 440 | 530 | 630 | 740 | 860 | 990 | 1130 |
| 20 | 150 | 200 | 270 | 340 | 420 | 510 | 600 | 710 | 820 | 940 | 1070 |
| 21 | 140 | 190 | 260 | 320 | 390 | 480 | 570 | 670 | 780 | 890 | 1020 |
| 22 | 140 | 190 | 240 | 310 | 380 | 460 | 540 | 640 | 740 | 850 | 970 |
| 23 | 130 | 180 | 230 | 290 | 360 | 440 | 520 | 610 | 710 | 810 | 920 |
| 24 | 130 | 170 | 220 | 280 | 350 | 420 | 500 | 590 | 680 | 780 | 890 |
| 25 | 120 | 160 | 210 | 270 | 330 | 410 | 480 | 560 | 660 | 750 | 860 |
| 26 | 110 | 160 | 210 | 260 | 320 | 390 | 460 | 540 | 630 | 720 | 820 |
| 27 | 110 | 150 | 200 | 250 | 310 | 370 | 440 | 520 | 610 | 690 | 790 |
| 28 | 110 | 140 | 190 | 240 | 300 | 360 | 430 | 500 | 580 | 670 | 760 |
| 29 | 110 | 140 | 180 | 230 | 290 | 350 | 410 | 490 | 560 | 640 | 740 |

To obtain the safe load for any thickness multiply values for 1 inch by thickness of beam.

To obtain the required thickness for any load divide by safe load for 1 inch.

SAFE LOADS FOR RECTANGULAR WOODEN PILLARS
(SEASONED).

l = length of pillar in inches;
 d = width of smallest side in inches.

| | | |
|---|---|---|
| Yellow Pine (Southern). $\frac{1125}{1 + \frac{l^2}{1100d^2}}$ | White Oak. $\frac{925}{1 + \frac{l^2}{1100d^2}}$ | White Pine and Spruce. $\frac{800}{1 + \frac{l^2}{1100d^2}}$ |
|---|---|---|

These formulæ give safe loads of one-fourth the ultimate strength for short pillars, decreasing to one-fifth the ultimate for long pillars.

| Ratio of Length to Least Side $\frac{l}{d}$ | Safe Loads in Pounds per Square Inch of Section. | | |
|---|--|------------|---------------------------|
| | Yellow Pine (Southern). | White Oak. | White Pine and Spruce. |
| 12 | 995 | 818 | 707 |
| 14 | 955 | 785 | 679 |
| 16 | 913 | 750 | 649 |
| 18 | 869 | 715 | 618 |
| 20 | 825 | 678 | 587 |
| 22 | 781 | 642 | 556 |
| 24 | 738 | 607 | 525 |
| 26 | 697 | 575 | 495 |
| 28 | 657 | 541 | 467 |
| 30 | 619 | 509 | 440 |
| 32 | 583 | 479 | 414 |
| 34 | 549 | 451 | 390 |
| 36 | 516 | 425 | 367 |
| 38 | 487 | 400 | 346 |
| 40 | 458 | 377 | 326 |

The Cleveland Building Code gives the following proportions for wood and other columns:

Sec. 14. LENGTH OF COLUMNS, POSTS, AND PIERS.—No free-standing or built-in column, pier, or post shall exceed the following proportions of the least side or diameter to the height without being anchored, stayed, or tied by beams or girders in at least two (2) directions at right angles to each other:

| | |
|---------------------------|------|
| Brick piers..... | 1: 8 |
| Block stone piers | 1:10 |
| Wooden posts, short | 1:16 |

| | |
|-------------------------------|------|
| Wooden posts, long..... | 1:24 |
| Cast-iron columns, short..... | 1:20 |
| Cast-iron columns, long..... | 1:30 |
| Wrought-iron columns..... | 1:40 |
| Steel columns..... | 1:44 |

SAFE LOADS IN TONS OF 2000 POUNDS FOR SQUARE WOODEN PILLARS.

| Unsup- ported Length of Col- umn in Feet. | Size of Pillar in Inches. | | | | | | |
|--|---------------------------|-------|-------|-------|-------|-------|-------|
| | 6×6 | 8×8 | 9×9 | 10×10 | 12×12 | 14×14 | 16×16 |
| WHITE PINE OR SPRUCE. | | | | | | | |
| 6 | 12.80 | ..... | ..... | ..... | ..... | ..... | ..... |
| 8 | 11.70 | 22.7 | 29.6 | ..... | ..... | ..... | ..... |
| 10 | 10.60 | 21.3 | 28.0 | 35.5 | ..... | ..... | ..... |
| 12 | 9.54 | 19.8 | 26.3 | 33.7 | 51.1 | ..... | ..... |
| 14 | 8.46 | 18.4 | 24.7 | 31.9 | 49.0 | 69.6 | ..... |
| 16 | 7.38 | 17.0 | 23.1 | 30.1 | 46.8 | 67.0 | 91.0 |
| 18 | ..... | 15.5 | 21.5 | 28.3 | 44.7 | 64.5 | 88.0 |
| 20 | ..... | 14.1 | 19.8 | 26.5 | 42.5 | 62.0 | 85.2 |
| 22 | ..... | ..... | 18.2 | 24.7 | 40.3 | 59.5 | 82.3 |
| 24 | ..... | ..... | ..... | 22.9 | 38.2 | 57.0 | 79.4 |
| WHITE OAK. | | | | | | | |
| 6 | 14.80 | ..... | ..... | ..... | ..... | ..... | ..... |
| 8 | 13.50 | 26.2 | 34.0 | ..... | ..... | ..... | ..... |
| 10 | 12.20 | 24.6 | 32.4 | 41.0 | ..... | ..... | ..... |
| 12 | 11.00 | 22.7 | 30.4 | 39.1 | 59.1 | ..... | ..... |
| 14 | 9.73 | 21.1 | 28.4 | 36.7 | 56.9 | 80.4 | ..... |
| 16 | 8.64 | 19.5 | 26.5 | 34.6 | 54.0 | 77.8 | 105.0 |
| 18 | ..... | 17.8 | 24.7 | 32.4 | 51.1 | 74.5 | 102.0 |
| 20 | ..... | 16.3 | 22.7 | 30.5 | 49.1 | 71.3 | 98.5 |
| 22 | ..... | ..... | 21.1 | 28.2 | 46.1 | 68.3 | 94.7 |
| 24 | ..... | ..... | ..... | 26.4 | 43.9 | 65.5 | 90.9 |
| YELLOW PINE (SOUTHERN). | | | | | | | |
| 6 | 18.0 | ..... | ..... | ..... | ..... | ..... | ..... |
| 8 | 16.4 | 32.0 | 41.6 | ..... | ..... | ..... | ..... |
| 10 | 14.9 | 29.9 | 39.4 | 50.0 | ..... | ..... | ..... |
| 12 | 13.3 | 27.8 | 36.9 | 47.6 | 72.0 | ..... | ..... |
| 14 | 11.9 | 25.8 | 34.7 | 44.7 | 69.1 | 98.0 | 132.0 |
| 16 | 10.4 | 23.7 | 32.3 | 42.3 | 65.5 | 94.6 | 128.0 |
| 18 | ..... | 21.8 | 30.0 | 39.5 | 62.6 | 90.7 | 124.0 |
| 20 | ..... | 19.8 | 27.8 | 37.0 | 59.8 | 86.9 | 120.0 |
| 22 | ..... | ..... | 25.7 | 34.6 | 56.2 | 83.6 | 115.0 |
| 24 | ..... | ..... | ..... | 32.2 | 53.3 | 80.0 | 111.0 |

As a guide to the superintendent for inspection of lumber of various kinds the rules for inspection of the different lumber associations are given as follows:

SOUTHERN LUMBER MANUFACTURERS' ASSOCIATION.

RULES FOR THE GRADING AND CLASSIFICATION OF
YELLOW PINE.

General Instructions.—1. YELLOW-PINE LUMBER shall be graded and classified according to the following rules and specifications as to quality, and dressed stock shall conform to the subjoined table of standard sizes, *except where otherwise expressly stipulated between buyer and seller.*

2. Recognized defects in yellow pine are knots, knot-holes, splits (either from seasoning ring hearts or rough handling), shake, wane, red heart, rot, rotten streaks, worm-holes, pitch streaks, pitch pockets, solid pitch, torn grain, loosened grain, seasoning or kiln checks, and black or blue sap-stains.

3. KNOTS.—Knots shall be classified as pin, standard, and large, as to size; and round and spike, as to form; and as sound, loose, encased, pith and rotten, as to quality.

4. A pin knot is sound and not over $\frac{1}{2}$ inch in diameter.

5. A standard knot is sound and not over $1\frac{1}{2}$ inches in diameter.

6. A large knot is sound and any size over $1\frac{1}{2}$ inches in diameter.

7. A round knot is oval or circular in form, and the mean or average diameter of the same shall be considered in applying and construing the rules.

8. A spike knot is one sawn in a lengthwise direction.

9. A sound knot is one solid across its face, is as hard as the wood it is in, may be either red or black, and is so fixed by growth or position that it will retain its place in the piece.

10. A loose knot is one not held firmly in place by growth or position.

11. A pith knot is a small, sound knot with a pith-hole not more than $\frac{1}{4}$ inch in diameter in the centre.

LUMBER MEASURE.

| Inches Wide. | Length in Feet. | | | | | | |
|-----------------|-----------------|-----|-----|-----|-----|-----|-----|
| | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 1 × 8 | 8 | 9 | 11 | 12 | 13 | 15 | 16 |
| 1 × 10 | 10 | 12 | 13 | 15 | 17 | 18 | 20 |
| 1 × 12 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 2 × 3 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 2 × 4 | 8 | 9 | 11 | 12 | 13 | 15 | 16 |
| 2 × 6 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 2 × 8 | 16 | 19 | 21 | 24 | 27 | 29 | 32 |
| 2 × 10 | 20 | 23 | 27 | 30 | 33 | 37 | 40 |
| 2 × 12 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 2 × 14 | 28 | 33 | 37 | 42 | 47 | 51 | 56 |
| 2 × 16 | 32 | 37 | 43 | 48 | 53 | 59 | 64 |
| 3 × 4 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
| 3 × 6 | 18 | 21 | 24 | 27 | 30 | 33 | 36 |
| 3 × 8 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 3 × 10 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 3 × 12 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 3 × 14 | 42 | 49 | 56 | 63 | 70 | 77 | 84 |
| 3 × 16 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 4 × 4 | 16 | 19 | 21 | 24 | 27 | 29 | 32 |
| 4 × 6 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
| 4 × 8 | 32 | 37 | 43 | 48 | 53 | 59 | 64 |
| 4 × 10 | 40 | 47 | 53 | 60 | 67 | 73 | 80 |
| 4 × 12 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 6 × 6 | 36 | 42 | 48 | 54 | 60 | 66 | 72 |
| 6 × 8 | 48 | 56 | 64 | 72 | 80 | 88 | 96 |
| 6 × 10 | 60 | 70 | 80 | 90 | 100 | 110 | 120 |
| 6 × 12 | 72 | 84 | 96 | 108 | 120 | 132 | 144 |
| 6 × 14 | 84 | 98 | 112 | 126 | 140 | 154 | 168 |
| 6 × 16 | 96 | 112 | 128 | 144 | 160 | 176 | 192 |
| 8 × 8 | 64 | 75 | 85 | 96 | 107 | 117 | 128 |
| 8 × 10 | 80 | 93 | 107 | 120 | 133 | 147 | 160 |
| 8 × 12 | 96 | 112 | 128 | 144 | 160 | 176 | 192 |
| 8 × 14 | 112 | 131 | 149 | 168 | 187 | 205 | 224 |
| 8 × 16 | 128 | 149 | 171 | 192 | 213 | 235 | 256 |
| 10 × 10 | 100 | 117 | 133 | 150 | 167 | 183 | 200 |
| 10 × 12 | 120 | 140 | 160 | 180 | 200 | 220 | 240 |
| 12 × 12 | 144 | 168 | 192 | 216 | 240 | 264 | 288 |

12. An incased knot is one surrounded wholly or in part by bark or pitch.

13. A rotten knot is one not as hard as the wood it is in.

14. PITCH.—Pitch pockets are openings between the grain of the wood containing more or less pitch or bark, and shall be classified as large and small pitch pockets.

15. A standard pitch pocket is one not over $\frac{3}{8}$ of an inch in open width or 3 inches in length.

A small pitch pocket is one less than $\frac{1}{8}$ of an inch in open width.

16. A pitch pocket showing open on both sides of the piece

LUMBER MEASURE.

| Inches Wide. | Length in Feet. | | | | | | | |
|-----------------|-----------------|-----|-----|-----|-----|-----|-----|-----|
| | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| 2×3 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 2×4 | 17 | 19 | 20 | 21 | 23 | 24 | 25 | 27 |
| 2×6 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| 2×8 | 35 | 37 | 40 | 43 | 45 | 48 | 51 | 53 |
| 2×10 | 43 | 47 | 50 | 53 | 57 | 60 | 63 | 67 |
| 2×12 | 52 | 56 | 60 | 64 | 68 | 72 | 76 | 80 |
| 2×14 | 61 | 65 | 70 | 75 | 79 | 84 | 89 | 93 |
| 2×16 | 69 | 75 | 80 | 85 | 91 | 96 | 101 | 107 |
| 3×4 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| 3×6 | 39 | 42 | 45 | 48 | 51 | 54 | 57 | 60 |
| 3×8 | 52 | 56 | 60 | 64 | 68 | 72 | 76 | 80 |
| 3×10 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
| 3×12 | 78 | 84 | 90 | 96 | 102 | 108 | 114 | 120 |
| 3×14 | 91 | 98 | 105 | 112 | 119 | 126 | 133 | 140 |
| 3×16 | 104 | 112 | 120 | 128 | 136 | 144 | 152 | 160 |
| 4×4 | 35 | 37 | 40 | 43 | 45 | 48 | 51 | 53 |
| 4×6 | 52 | 56 | 60 | 64 | 68 | 72 | 76 | 80 |
| 4×8 | 69 | 75 | 80 | 85 | 91 | 96 | 101 | 107 |
| 4×10 | 87 | 93 | 100 | 107 | 113 | 120 | 127 | 133 |
| 4×12 | 104 | 112 | 120 | 128 | 136 | 144 | 152 | 160 |
| 6×6 | 78 | 84 | 90 | 96 | 102 | 108 | 114 | 120 |
| 6×8 | 104 | 112 | 120 | 128 | 136 | 144 | 152 | 160 |
| 6×10 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 |
| 6×12 | 156 | 168 | 180 | 192 | 204 | 216 | 228 | 240 |
| 6×14 | 182 | 196 | 210 | 224 | 238 | 252 | 266 | 280 |
| 6×16 | 208 | 224 | 240 | 256 | 272 | 288 | 304 | 320 |
| 8×8 | 139 | 149 | 160 | 171 | 181 | 192 | 203 | 213 |
| 8×10 | 173 | 187 | 200 | 213 | 227 | 240 | 253 | 267 |
| 8×12 | 208 | 224 | 240 | 256 | 272 | 288 | 304 | 320 |
| 8×14 | 243 | 261 | 280 | 299 | 317 | 336 | 355 | 373 |
| 8×16 | 277 | 299 | 320 | 341 | 363 | 384 | 405 | 427 |
| 10×10 | 217 | 233 | 250 | 267 | 283 | 300 | 317 | 333 |
| 10×12 | 260 | 280 | 300 | 320 | 340 | 360 | 380 | 400 |
| 12×12 | 312 | 336 | 360 | 384 | 408 | 432 | 456 | 480 |

$\frac{1}{8}$ of an inch or more in width shall be considered the same as a knot-hole.

17. A pitch streak is a well-defined accumulation of pitch at one point in the piece, and when not sufficient to develop a well-defined streak, it shall not be considered a defect.

18. A small pitch streak shall be equivalent to not over one-twelfth the width and one-sixth the length of the piece it is in.

A standard pitch streak shall be equivalent to not over one-sixth the width and one-third of the length of the piece it is in.

19. SAP.—Bright sap shall not be considered a defect in any of the grades provided for and described in these rules.

The restriction or exclusion of bright sap constitutes a special class of material which can only be secured by *special contract*.

20. Blued sap shall not be considered a defect in any of the grades of common lumber.

21. MISCELLANEOUS.—Firm red heart shall not be considered a defect in any of the grades of common lumber.

22. Defects in rough stock caused by improper manufacture and drying will reduce grade, unless they can be removed in dressing such stock to standard sizes.

23. All stock shall be inspected on the face side to determine the grade. For stock surfaced one side the dressed surface shall be considered the face side. And for stock rough or dressed two sides, the best side shall be considered the face, but the reverse side of all such stock should not be more than one grade lower.

24. Imperfect manufacture in dressed stock, such as torn grain, loosened grain, broken knots, mismatched, insufficient tongue or groove on flooring, ceiling, drop-siding, etc., shall be considered defects, and will reduce grade according as they are slight or serious in their effects on the use of the stock.

25. Pieces of either flooring, ceiling, or drop-siding having less than $\frac{3}{16}$ inch of tongue shall not be admitted in any grade above No. 2 Common, pieces with $\frac{3}{16}$ inch or more of tongue to be admitted in any grade.

26. In all grades of flooring, ceiling, drop-siding, etc., wane on the reverse side, not exceeding one-third the width and one-sixth the length of any piece, provided the wane does not extend into the tongue, nor over one-half the thickness below the groove, is admissible.

27. Chipped grain consists in a part of the surface being chipped or broken out in small particles below the line of the cut, and as usually found should not be classed as torn grain and shall not be considered a defect.

28. Torn grain consists in a part of the wood being torn out in dressing. It occurs around knots and curly places.

29. Loosened grain consists in a point of one grain being torn loose from the next grain. It occurs on the heart side of the piece, and is a serious defect, especially in flooring.

30. The grade of all regular stock shall be determined by the number, character, and position of the defects visible in any piece. The enumerated defects admissible in any grade are

intended to be descriptive of the *coarsest* pieces *such grades may contain*. The average quality of the grade should be about midway between such pieces and the coarsest pieces allowed in the next higher grade.

31. Lumber and timber sawed for specific purposes must be inspected with a view to its adaptability for the use intended. Material not conforming to standard sizes, for agricultural-implement companies, wagon companies, car-manufacturing companies, railway companies, etc., shall be governed by special contract.

32. The standard lengths are multiples of two feet, ten to twenty-four feet, inclusive, for boards, stripes, dimension, joists, and timbers. Longer or shorter lengths than those herein specified are special. Odd and fractional lengths shall be counted as of the next higher even length.

33. On stock-width shipments of No. 1 Common and better lumber, either rough or dressed one or two sides, no piece shall be admissible that is more than $\frac{1}{4}$ inch scant on 8-inch and under; $\frac{3}{8}$ inch scant on 10-inch, or $\frac{1}{2}$ inch scant on 12-inch or wider. All 4-inch and wider No. 2 Common stock may go $\frac{1}{2}$ inch scant in width.

34. Yellow pine of a better grade than No. 1 Common, up to 4 inches in width, shall be classified as to grain as edge grain and flat grain.

Edge grain has been variously designated as rift sawn, vertical grain, quarter sawn, all being commercially synonymous terms. Edge-grain stock is especially desirable for flooring and admits no piece in which the angle of the grain exceeds 45 degrees from verticle at any point, thus excluding all pieces that will sliver or shell from wear. Such as will not meet these requirements shall be known as flat grain.

35. *All dressed stock shall be measured and sold strip count, viz., full size of rough material necessarily used in its manufacture.*

All sizes 1 inch or less in thickness shall be counted as 1 inch thick.

36. Equivalent means equal, and in construing and applying these rules, the defects allowed, whether specified or not, are understood to be equivalent in damaging effect to those mentioned applying to stock under consideration.

37. The foregoing general observations shall apply to and govern the application of the following rules:

DRESSED YELLOW-PINE FINISHING.—Grades: First and Second Clear, Third Clear.

38. *First and Second Clear.* Inch, $1\frac{1}{4}$, $1\frac{1}{2}$, and 2-inch, dressed one or two sides up to and including 8 inches wide, must show one face practically clear of all defects. 10 inches wide will admit any one of the following defects: One split not more than 6 inches long, one small pitch pocket, one pin knot, pitch streak, or blue sap stain not to exceed the equivalent of 6 square inches. One-third of any shipment of 12- and 14-inch in addition to one straight split not to exceed in length the width of the piece will admit any one of the following defects or its equivalent: Three pin knots, one standard knot, two small pitch pockets, or one large pitch pocket, one small pitch streak, small kiln or seasoning checks, one blue sap stain $1\frac{1}{2}$ inches wide running across the face of the piece.

Each two inches above 14 inches in width, in addition to one straight split, not to exceed in length the width of the piece, will admit any two of the defects allowed in 12-inch or their equivalent. Pieces otherwise admissible which have loosened or torn grain on the face side shall be put in a lower grade.

39. *Special.*—In case both sides are desired clear special contract must be made. Defective dressing on the reverse side of finishing is admissible.

40. *Third Clear.*—Inch, $1\frac{1}{4}$, $1\frac{1}{2}$, and 2-inch, dressed two sides up to and including 10 inches in width, in addition to one straight split not to exceed in length the width of the piece, may have any two of the following defects or their equivalent: Slight torn grain, three pin knots, one standard knot, three small pitch pockets, one standard pitch pocket, one standard pitch streak, three blue sap stains 2 inches wide across the face or blue sap not over 8 inches deep on one end, wane not to exceed 1 inch in width and $\frac{1}{8}$ the length of the piece, or small kiln or seasoning checks. Twelve or 14 inches will admit three of the above defects or their equivalent.

FLOORING.—Grades: A, B, and C Flat, A, B, and C Edge Grain, No. 1 and 2 Fence.

Special Section.—Defects named in Flooring and Ceiling are based upon a piece manufactured from $1 \times 4-12$, and pieces larger or smaller than this will take a greater or less number of defects, proportioned to their size on this basis.

41. *A Flat Flooring* must be practically free from defects on the face side and well manufactured.

42. *B Flat Flooring* may have any two of the following defects or their equivalent: Blue sap stain not to exceed 15 per cent of the face, three pin knots, one standard knot, three small pitch pockets, one standard pitch pocket, one standard pitch streak, slight torn grain, or small kiln or seasoning checks.

Pieces otherwise good enough for A, but containing not over six small pinworm-holes that have no blue sap about them, shall be admitted in B.

43. *Edge-grain Flooring* shall take the same inspection as flat grain, except as to the angle of the grain.

43½. *Heart-face Edge Grain* shall be free from sap on face side.

43¾. *Flat-grain C Flooring* shall consist of stock that falls below a B grade of flooring in working B and better strips, and will admit of any two of the following or their equivalent of combined defects: 60 per cent of blue sap, pitch streak, or firm red heart; chipped or torn grain not over $\frac{1}{16}$ inch deep in three places in one piece, or other machine defects that will lay without waste; shake or seasoning checks that do not go through, two standard pitch pockets, or six small pitch pockets, twenty pinworm-holes, two standard or six pin knots, or two pith knots; pieces otherwise as good as "A" can have one defect (as a knot-hole) that can be cut out by wasting $1\frac{1}{2}$ inches of the length of the piece.

44. *No. 1 Fence Flooring* may contain the following defects or their equivalent: Sound knots not over one-half the width of the piece at any one point throughout its length; spike knots whose length is not over one-half the width of the piece, and if on the edge not to exceed one-half the thickness; three pith knots, pitch, pitch pockets, blue sap, firm red heart, seasoning checks or slight shake, twenty pinworm-holes, chipped, loosened, or torn grain not over $\frac{1}{8}$ inch deep in three places in a piece, or other machine defects that will lay without waste; and if otherwise as good as "B" one defect (like a knot-hole) that can be cut out by wasting 3 inches of the length of the piece.

45. *No. 2 Fence Flooring* admit all pieces that will not grade as good as No. 1 Fence Flooring, that can be used for cheap floors or sheathing without a waste of more than one-fourth

the length of any one piece, and admits all the defects named in No. 2 Common Fencing.

46. *Centre Matched Flooring* shall be required to come up to grade on face side only.

CEILING.—Grades: A, B, No. 1 and No. 2 Common.

47. *A Ceiling* must be practically free from defects on the face side and well manufactured.

48. *B Ceiling* will admit of any two of the following defects or their equivalent: Slight torn grain, three pin knots, one standard knot, three small pitch pockets, one standard pitch pocket, one small pitch streak, seasoning or kiln checks that do not go through, blue sap stain or firm red heart not to exceed 15 per cent of the face.

Pieces otherwise good enough for A, but containing not over six small pinworm-holes that have no blue sap about them, shall be admitted in B.

49. *No. 1 Common Ceiling* will admit sound knots not over one-half the width of piece in the rough, blue sap, pitch streaks, pitch pockets, firm red heart, slight shake, torn grain, kiln or seasoning checks, or defects in manufacture.

Pieces otherwise good enough for A, but containing one loose or unsound knot or knot-hole, 1½ inches in diameter or less, shall be graded No. 1 Common.

Pieces otherwise good enough for A, but containing not over ten small pinworm-holes that have no blue stain about them, shall be graded No. 1 Common.

Pieces otherwise good enough for A, but containing one pith knot, shall be admitted in the grade of No. 1 Common.

50. *No. 2 Common Ceiling* admits of all pieces not as good as No. 1 Common that can be used without waste of more than one-fourth the length of any one piece.

WAGON-BOTTOMS.—Grades: A and B.

51. *Wagon-bottoms* unless otherwise ordered (see section 31) shall be graded the same as A and B Flat Flooring.

DROP-SIDING.—Grades: A, B, and No. 1 Common.

52. *A Drop-siding* must be practically free from defects on the face side and well manufactured.

53. *B Drop-siding* will admit any two of the following defects or their equivalent: Slight-torn grain, three pin knots, one standard knot, blue sap stain or firm red heart not to exceed 15 per cent of the face, and slight kiln and seasoning checks.

Pieces otherwise good enough for A, but containing not over

six small pinworm-holes that have no blue sap about them, shall be admitted in B.

54. *No. 1 Common Drop-siding* will admit one standard pitch streak or one large pitch pocket, or their equivalent; and in addition, sound knots not over one-half the width of piece in the rough, blue sap stain, firm red heart, slight shake, torn grain, defects in manufacture, and kiln or seasoning checks that do not go through the piece.

Pieces otherwise good enough for A, but containing one loose or unsound knot or knot-hole $1\frac{1}{2}$ inches in diameter or less, shall be graded No. 1 Common.

Pieces otherwise good enough for A, but containing not over *ten small pinworm-holes* that have no blue stain about them, shall be graded No. 1 Common.

Pieces otherwise good enough for A, but containing one pith knot, shall be admitted in the grade of No. 1 Common.

BEVEL-SIDING.—Grades: A, B, and No. 1 Common.

55. *Bevel-siding* shall be graded according to the rules for drop-siding, and will admit in addition slight imperfections on the thin edge, which will be covered by the lap when laid $4\frac{1}{2}$ inches to the weather.

PARTITION.—Grades: A, B, and No. 1 Common.

56. *Partition* shall be graded according to ceiling rules, and must meet the requirements of the specified grades on the face side only, but the reverse side shall not be more than one grade lower.

MOULDED CASING AND BASE. WINDOW- AND DOOR-JAMBS.—Grades: A and B.

57. *A Moulded Casing and Base* must be practically free from defects on the face side and well manufactured.

58. *B Casing or Base* consists of rejections made after dressing stock inspected in the rough as "A." The defects admitted in B Ceiling shall be allowed.

Window- and Door-jambs shall be graded the same as moulded casing and base.

See section No. 35 for width.

COMMON BOARDS, SHIPLAP, AND BARN SIDING, 8, 10, AND 12 INCHES WIDE.—Grades: No. 1, No. 2, and No. 3 Common.

59. *No. 1 Common Boards*, dressed one or two sides, and *No. 1 Common Shiplap and Barn Siding* shall be well manufactured; will admit any number of sound knots, not over one-

fourth of the width of the piece if located at the edge, nor over one-third of the width of the piece if located away from the edge; or their equivalent spike knots—provided, however, that the spike knots when located on the edge do not occupy more than one-half the thickness of said edge—two pith knots, one straight split not to exceed in length the width of the piece, pitch, pitch pockets, blue sap, seasoning checks that do not go through, firm red heart, wane $\frac{1}{2}$ inch deep on edge, and one-third the length of the piece or its equivalent, and a limited number of small pinworm-holes well scattered. These boards should be firm and strong and suitable for use in all ordinary construction.

GROOVED ROOFING.—*Grooved Roofing* shall be graded by rules governing No. 1 Boards, omitting the pith knots, worm-holes, and splits in end.

60. *No. 2 Common Boards*, dressed one or two sides, and *No. 2 Common Shiplap*, *No. 2 Common Grooved Roofing* may contain any number of knots, none of which are over $4\frac{1}{2}$ inches in diameter, or their equivalent spike knots, worm-holes, one straight split one-fourth the length of the piece, but must be free from through-rotten streaks, through-heart shakes over one-half of the length of the piece, and wane over 2 inches wide exceeding one-half the length of the piece.

A knot-hole $1\frac{1}{2}$ inches in diameter, or its equivalent in small knot-holes or rotten streaks, will be allowed, provided the piece is otherwise as good as No. 1 Common.

FENCING, 3, 4, AND 6 INCHES WIDE.—Grades: No. 1, 2, and 3 Common.

61. *No. 1 Fencing* may contain the following defects or their equivalent: Sound knots, not over one-half width of piece at any point throughout its length; spike knots whose length is not over one-half the width of the piece, and if on the edge not to exceed one-half the thickness, three pith knots or their equivalent, wane one-half inch deep on edge and one-half of the length of the piece, pitch, pitch pockets, blue sap, seasoning checks, firm red heart, and a limited number of small pinworm-holes well scattered.

62. *No. 2 Fencing*, in addition to the defects allowed in No. 1 Common, will admit the following defects or their equivalent. Knots that do not badly weaken the piece at any point, small, unsound or loose knots, one straight split one-fourth the length of the piece, worm-holes, rotten streaks that do not

go through; shake and wane, but must be good enough to be used in full length as fencing.

A knot-hole $1\frac{1}{2}$ inches in diameter or its equivalent in small hollow knots will be allowed, provided the piece is otherwise as good as No. 1 Common.

63. *No. 3 Fencing* and *No. 3 Boards* are defective lumber, and will admit of coarse knots, knot-holes, very wormy pieces, some red rot and other defects that will not prevent its use as a whole for cheap sheathing or cutting one-half its length as No. 2 Common.

64. Miscut 1-inch boards and fencing which do not fall below $\frac{3}{4}$ inch in thickness shall be admitted in No. 2 Common, provided the grade of such thin stock is otherwise as good as No. 1 Common.

DIMENSION. S. 1 S. 1 E.—Grades: No. 1, No. 2, and No. 3 Common.

65. Inspection of dimension is a question of strength and uniformity of size, and whatever reduces its strength in cross-section must be considered a defect to that extent.

66. *No. 1 Common Dimension* may contain sound knots, none of which in 2×4 s should be larger than 2 inches in diameter on one or both sides of the piece, and on wider stock which does not occupy more than one-third of the cross-section at any point throughout its length if located at the edge of the piece, or more than one-half of the cross-section if located away from the edge; two pith knots, or smaller or more defective knots which do not weaken the piece more than the knot aforesaid; will admit of seasoning checks, firm red heart, heart-shakes that do not go through, wane, pitch, blue sap stains, pitch pockets, splits in ends not exceeding in length the width of the piece, a limited number of small pinworm-holes well scattered, and such other defects as do not prevent its use as substantial structural material.

67. *No. 2 Common Dimension* may have knots which do not occupy more than one-half of the cross-section at any one point if located at the edge of the piece, nor more than two-thirds of the cross-section if located away from the edge; smaller, loose, hollow, or rotten knots that do not weaken the piece more than the knots aforesaid; will admit rotten streaks, shake, wane, worm-holes, and other defects which do not prevent its use without waste.

68. *No. 3 Dimension* will include all pieces falling below

No. 2 grade which are sound enough to use for cheap building material.

69. Miscut 2-inch stock which does not fall below $1\frac{1}{2}$ inches in thickness shall be admitted in No. 2 Common, provided such pieces are in all other respects as good as No. 1 Common.

70. ROUGH YELLOW PINE FINISHING.—Finish must be evenly manufactured, and shall embrace all sizes from 1 to 2 inches in thickness by 4 inches and over in width.

71. No inch, $1\frac{1}{4}$ and $1\frac{1}{2}$ finishing lumber, unless otherwise ordered, shall measure when dry more than $\frac{1}{16}$ inch scant in thickness and on 2-inch it may be $\frac{1}{8}$ inch scant.

72. Wane and seasoning checks that will dress out in working to standard thickness and widths are admissible.

73. Subject to the foregoing provisions, rough-finishing shall be graded according to the specifications applying to dressed finishing lumber.

All rough finishing lumber, if thicker than specified thickness for dry or green stock, may be dressed to such standard thickness, and when so dressed shall be considered as rough stock.

When like grade on both faces is required, *special contract* must be made.

74. COMMON BOARDS, FENCING, AND DIMENSION.—Rough common boards and fencing must be well manufactured, and should not be less than $\frac{7}{8}$ inch thick when dry.

75. Rough 2-inch common shall be well manufactured and not less than $1\frac{1}{8}$ inches thick when green, or $1\frac{3}{4}$ inches thick when dry. The several widths must not be less than $\frac{1}{8}$ inch over the standard dressing width for such stock.

Rough common dimension of a greater thickness than 2 inches and less than 4 inches shall be subject to special contract as to thickness and width.

76. *Rough Dimension*, if thicker than specified thickness for dry or green stock, may be dressed to such standard thickness, and when so dressed shall be considered as rough stock.

77. The defects admissible in rough boards, fencing, and dimension shall be the same as those applying to dressed stock of like kind and grade, and such further defects as would disappear in dressing to standard sizes of such material shall be allowed.

78. No. 1 COMMON TIMBERS.—*Rough Timbers*, 4×4 and larger, shall not be more than $\frac{1}{4}$ inch scant when green, and

be well manufactured, with not less than three square edges, and must be free from knots that will materially weaken the piece.

Timbers 10×10 in size may have a 2-inch wane on one corner, measured on faces, or its equivalent on two or more corners, one-third the length of the piece. Larger sizes may have proportionately greater defects.

Shakes extending not over one-eighth of the length of the piece are admissible, and seasoning checks shall not be considered a defect.

79. Dressed timbers shall conform in grading to the specifications applying to rough timbers of same size.

80. Rough timbers, if thicker than specified thickness for dry or green stock, may be dressed to such standard thickness and when so dressed shall be considered as rough stock.

STANDARD SIZES OF DRESSED LUMBER.—*Finishing*.—1-inch S. 1 S. or 2 S. to $\frac{13}{16}$, $1\frac{1}{4}$ inch S. 1 S. or 2 S. to $1\frac{3}{4}$, $1\frac{1}{2}$ inch S. 1 S. or 2 S. to $1\frac{1}{2}$, 2 inch S. 1 S. or 2 S. to $1\frac{3}{4}$ inches.

Moulded Casing and Base.— $\frac{13}{16}$ to patterns as per Southern Lumber Manufacturers' Association Moulding Book, 1901 edition. 1×4 S. 4 S. shall be $3\frac{1}{2}$ inches wide, finished, and 1×6 S. 4 S. shall be $5\frac{1}{2}$ inches wide, finished.

Flooring.—The standard of 1×3, 1×4, and 1×6 inches shall be $\frac{13}{16} \times 2\frac{1}{4}$, $3\frac{1}{4}$, and $5\frac{1}{4}$ inches, $1\frac{1}{4}$ -inch flooring shall be $1\frac{3}{4}$ inches thick.

Drop Siding.—D. and M. $\frac{3}{4} \times 3\frac{1}{4}$ and $5\frac{1}{4}$ inches; shiplap, $\frac{3}{4} \times 5$ inch face, $5\frac{1}{2}$ over all.

Partition.— $\frac{3}{4} \times 3\frac{1}{4}$ and $5\frac{1}{4}$ inches.

Ceiling.— $\frac{3}{8}$ -inch ceiling, $\frac{5}{16}$ inch; $\frac{1}{2}$ -inch ceiling, $\frac{7}{16}$ inch; $\frac{5}{8}$ -inch ceiling, $\frac{9}{16}$ inch; $\frac{3}{4}$ -inch ceiling $\frac{11}{16}$ inch. Same width as flooring. The bead on all ceiling and partition shall be depressed $\frac{1}{2}$ of an inch below surface line of piece.

Bevel Siding.—To be made from stock S. 4 S. to $\frac{13}{16} \times 5\frac{1}{2}$ and resawed on a bevel.

*Window- and Door-jamb*s.—(See section 35.)

Dressed, rabbeted, and ploughed as ordered, worked $\frac{3}{8}$ inch scant of width.

Boards and Fencing.—1-inch S. 1 S. or 2 S. to $\frac{13}{16}$ inch.

Shiplap.—8-, 10-, and 12-inch. $\frac{13}{16} \times 7\frac{1}{8}$, $9\frac{1}{8}$, and $11\frac{1}{8}$ inches.

D. and M.—8-, 10-, and 12-inch. $\frac{13}{16} \times 7\frac{1}{8}$, $9\frac{1}{8}$, and $11\frac{1}{8}$ inches.

Grooved Roofing.—10- and 12-inch S. 1 S. and 2 E. to $\frac{13}{16} \times 9\frac{1}{2}$ and $11\frac{1}{2}$.

Wagon-bottoms, unless otherwise ordered (see section 31), shall be made in sets 38 and 42 inches face and from stock 4 inches or over in width.

Dimension.— 2×4 D. 1 S. and 1 E. to $1\frac{5}{8} \times 3\frac{5}{8}$ inches; 2×6 D. 1 S. and 1 E. to $1\frac{5}{8} \times 5\frac{5}{8}$ inches; 2×8 D. 1 S. and 1 E. to $1\frac{5}{8} \times 7\frac{1}{2}$ inches; 2×10 D. 1 S. and 1 E. to $1\frac{5}{8} \times 9\frac{1}{2}$ inches; 2×12 D. 1 S. and 1 E. to $1\frac{5}{8} \times 11\frac{1}{2}$ inches; 4×4 and 4×6 D. 1 S. and 1 E. to $\frac{3}{8}$ inch off side and edge; S. 4 S. $\frac{1}{4}$ inch off each side.

SOUTHERN CYPRESS LUMBER ASSOCIATION.

In effect February 22, 1897.

Strips.—4" to 6" strips shall be graded A, B, C, D, and read the same as flooring grades.

Siding.—"Clear and A" Siding may have 1" of bright sap on thin edge, and may contain one small sound knot.

"B" may have $\frac{1}{3}$ of face bright sap if otherwise clear, or in lieu of $\frac{1}{3}$ sap may contain two small sound knots.

"C" may be all bright sap or may have one to five knots, the whole not aggregating over 3", or knots or other defects that can be removed in two cuts with waste not exceeding 12" in length, or three pinworm-holes, and may have check or split at one end, not exceeding 12" in length.

"D" may have stained sap and pinworm-holes, or may have other defects that will not cause a waste to exceed $\frac{1}{3}$ the piece.

DRESSED FINISHING.—Seven inches (7") and up random width to be two grades, as described in *1st and 2d Clear and Select*.

FLOORING, CEILING, AND PARTITION.—Clear must be free of sap and defects.

"A" may have 1" bright sap on one edge, may contain one small sound knot, or may have bright sap $\frac{1}{4}$ its width on one end for not exceeding two feet from end.

"B" may have $\frac{1}{3}$ of its face bright sap if otherwise clear, or in lieu of bright sap contain two small sound knots, or may have a split not to exceed 9" at one end.

"C" may have all bright sap, or may have one to five knots, the whole not aggregating over 3", or knots or other defects that can be removed in two cuts with waste not to exceed 12" in length, or may have three pinworm-holes, or may have check or split at one end not to exceed 12" in length.

"D" may have stained sap and pinworm-holes, or may have unsound knots or other defects that will not cause a waste to exceed $\frac{1}{3}$ of the piece.

DRESSED FINISHING.—Strips 1, $1\frac{1}{4}$, and $1\frac{1}{2} \times 4$ to 6 inches wide to be graded as *1st and 2d Clear and Select*. The above 1st and 2d Clear strips, which are 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ thick, shall have one heart face, and will admit one inch sap, on one edge. *Select* may be all bright sap, or in lieu of sap may contain two standard knots. 2×4 and 2×6 to be graded Clear and Select as described in above 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ strips.

SQUARES.—Squares to be graded Clear and Select 4×4 to 10×10 . A clear square to admit $\frac{1}{4}$ its size of sap on one corner. Select may have half bright sap.

SHINGLES.—*Best.*—A dimension shingle, 4, 5, and 6 inches, each width separately bunched, sixteen inches long, five butts to measure two inches, all heart free of shakes, knots, and other defects.

Primes.—Dimension, each width separately bunched, sixteen inches long, five butts to measure two inches, admitting tight knots and sap, free of shakes and other defects, but with no knots within eight inches of the butt.

Extra "A."—Same as Primes, except random width and may admit of shingles fourteen inches long.

Clippers.—Any shingles which are sound for five inches from the butts—worm-holes excepted—and two and one-half inches or up in width.

WEIGHTS.

| | Pounds per M. |
|---|---------------|
| Lumber, rough, 2 inches and under | 3000 |
| Lumber, rough, $2\frac{1}{2}$ and 3 inches | 3500 |
| $\frac{7}{8}$ -inch flooring and ceiling. | 2300 |
| $\frac{5}{8}$ -inch ceiling. | 1600 |
| $\frac{1}{2}$ -inch ceiling. | 1300 |
| $\frac{3}{8}$ -inch ceiling. | 1000 |
| $\frac{1}{2}$ -inch bevel siding. | 1000 |
| Shingles, all grades. | 300 |
| $\frac{3}{8}$ -inch plaster lath. | 500 |
| $\frac{5}{8}$ -inch fence lath. | 900 |
| $1\frac{1}{4} \times 1\frac{1}{4} \times 4$ D. & H. pickets | 1600 |
| $\frac{7}{8} \times 2\frac{1}{2} \times 4$ D. & H. pickets | 1800 |
| 2-inch O. G. battens. | 500 |
| $2\frac{1}{2}$ -inch O. G. battens. | 600 |
| 3-inch O. G. battens. | 700 |

GAUGES FOR MATCHED LUMBER.—*Flooring*.— 1×4 and 1×6 shall be $\frac{3}{2}$ " by $3\frac{1}{4}$ " and $\frac{3}{2} \times 5\frac{1}{4}$ ".

$1\frac{1}{4}$ " flooring shall be $1\frac{3}{2}$ ".

Ceiling.— $\frac{3}{8}$ " shall be $\frac{5}{16}$ "; $\frac{1}{2}$ " shall be $\frac{7}{16}$ "; $\frac{5}{8}$ " shall be $\frac{9}{16}$ "; $\frac{3}{4}$ " shall be $\frac{11}{16}$ ", and the width shall be the same as flooring.

TANK STOCK shall be 5" and over in width, $1\frac{1}{4}$ " to 4" thick, and 8' and over long. Pieces up to 7" shall be free of sap. Pieces wider than 7" may have 1" of sound sap on one edge, not to exceed half the length and half the thickness of the piece. In all widths, sound knots that do not impair its usefulness for tank purposes may be admitted.

1ST AND 2D CLEAR shall be 8" and over in width. Pieces 8" to 10" may have 1" of bright sap on each edge, or its equivalent on one edge, otherwise they must be clear. Pieces 10" and under 12" wide may have $1\frac{1}{2}$ " of bright sap on each edge, or 3" on one edge, and one standard knot $1\frac{1}{4}$ " in diameter.

Pieces 12" wide may have one standard knot and 2" of bright sap on each edge, or the equivalent on one edge; or in lieu of sap may have two standard knots or their equivalents. Pieces wider than 12" may admit of defects in proportion as width increases. Pieces 14" and wider may have one straight split not over 10" to 12" long, when comparatively free from other defects. Slight season checks allowed in above grade.

SELECTS shall have one face side and be 7" and over in width. Pieces 10" and under in width shall admit two standard knots of $1\frac{1}{4}$ " in diameter, and an additional standard knot for every two inches in width, over 10". Bright sap not considered a defect. Unsound knots that do not go through the piece to be allowed. Pieces free from other defects, 10" and over wide, to admit pinworm-holes on one edge one-tenth the width of the piece. Season checks no defect. Slight wane on 10" pieces and over, allowed on one side, not over 3 feet in length. When no other defects appear, slight amount stained sap may be allowed. Pieces 10" and over in width may have a straight split not to exceed 12" in one end, when comparatively free from other defects.

SHOP.—Shop to be 6" and over in width, 8' and over in length, and to include all lumber that will not go into above grades, but that will cut for shop use 60 per cent clear of waste.

MERCHANTABLE OR COMMON may be any width, admitting sap, knots, shake, or peck, when the strength is not impaired.

RULES FOR GRADING EASTERN OREGON WHITE PINE.

Common lumber will be divided into four grades as follows: No. 1 Common, No. 2 Common, No. 3 Common or Sheathing, and No. 4 Common or Culls.

NO. 1 COMMON BOARDS AND STRIPS shall include all sound, tight-knotted stock whether red or black knots, but must be free from large coarse knots that will weaken the piece or loose knots that will fall out in the seasoning or handling. A small amount of blue sap stain is admissible in a piece where the knot defects are not very pronounced.

EX. 1. NO. 1 COMMON 1×12 —16 S. 1 S.—Has five red knots from $1\frac{1}{2}$ to 2 in. in diameter, three limb knots or V $1\frac{1}{2} \times 3$ in., but running in not more than one-half thickness of the board; also twelve small black and red knots all sound and well scattered, these smaller knots varying in size from $\frac{1}{2}$ in. to 1 in. in diameter.

EX. 2. NO. 1 COMMON 1×12 —20 S. 1 S.—Has seven red knots from $1\frac{1}{2}$ in. to 2 in. in diameter and five red branch knots extending across not more than one-third the width of the board nor running in not more than one-half the thickness of the board; also several small sound knots from $\frac{1}{2}$ in. to $1\frac{1}{4}$ in. in diameter. This is a heart board.

EX. 3. NO. 1 COMMON 1×10 —16 GROOVED ROOFING.—This piece contains three sound smooth knots from $1\frac{1}{2}$ to 2 in. in diameter and eight small red knots from $\frac{1}{2}$ to 1 in. in diameter and a small amount of blue stain.

EX. 4. NO. 1 COMMON 1×8 —16 SHIPLAP OR RUSTIC.—This piece contains three sound red knots from $1\frac{1}{4}$ in. to $1\frac{1}{2}$ in. in diameter and eight or ten small sound knots and pin knots and will admit of a small amount of blue stain. The piece must work smooth and sound.

EX. 5. NO. 1 COMMON 1×6 —16 FENCING S. 1 S.—This piece contains five sound knots from 1 in. to $1\frac{1}{2}$ in. in diameter well scattered and some small sound tight knot that will in no way weaken the piece. It will also admit of some blue stain.

EX. 6. NO. 1 COMMON 1×4 —16 FENCING S. 1 S.—Has three sound knots from 1 in. to $1\frac{1}{2}$ in. well scattered through the piece and a few smaller sound knots, but none that will impair the

strength of the board. It will also admit of a small streak of blue stain.

No. 2 COMMON BOARDS AND STRIPS shall also be sound in appearance, but will admit of larger and coarser knots not necessarily sound and more sap stain than No. 1 Common. It will also admit of larger and coarser V or limb knots, but not so large or so coarse as to weaken the piece or materially impair its strength. It shall be free from knot-holes, rot, or splits, but should a knot on the edge of the board slough off in the milling it will not disqualify it for this grade. It must have a good bearing on both sides. A single split not to exceed 2 feet in length in one end of a piece shall not disqualify it for this grade.

Ex. 1. No. 2 COMMON 1×12 —16 S. 1 S.—Has five knots $2\frac{1}{2}$ to 3 in. in diameter and three limb or V knots and a number of smaller knots and will admit of considerable discoloration. All the knots must be firmly set and the limb knots must not extend more than one-half the width of the piece.

Ex. 2. No. 2 COMMON 1×12 —20 S. 1 S.—Has six knots from $2\frac{1}{2}$ to 3 in. in diameter and five limb or V knots that do not extend across over half the face of the board and a number of smaller knots from $\frac{1}{2}$ to $1\frac{1}{2}$ in. in diameter. All knots firmly set and well distributed. One-third of the face of the piece is slightly stained.

Ex. 3. No. 2 COMMON 1×10 —16 S. 1 S.—Has three round knots 3 in. in diameter and several smaller knots from $1\frac{1}{2}$ to 2 in. in diameter and a number of knots from $\frac{1}{2}$ to $1\frac{1}{4}$ in. in diameter, but all well scattered and firmly set.

Ex. 4. No. 2 COMMON 1×8 —16 S. 1 S.—Has several red and black knots from 2 in. to $2\frac{1}{2}$ in. in diameter and a number of smaller knots scattered throughout the piece and all firm; will also admit of medium-sized live-limb knots.

Ex. 5. 1×6 —16 No. 2 COMMON S. 1 S.—Will admit of large red or black knots scattered throughout the centre of the piece where they do not materially impair its strength.

Ex. 6. 1×4 —16 No. 2 COMMON S. 1 S.—Graded practically the same as 1×6 No. 2 Common, admitting of the large knots not to exceed 2 in. scattered throughout the piece, but no large knots in the edge of the board.

No. 3 COMMON OR SHEATHING.—Will not only admit of all defects of the better grades, but will also admit of large loose knots and knot-holes and any amount of blue stain or pitch and a split extending not more than one-third length of board; but

no rot will be admitted in this grade except the unsound knots or red stain if the wood is quite firm. The boards of this grade must be of good thickness and full size, i.e., no pieces of split or broken boards will be allowed to go in this grade.

No. 4 COMMON OR CULLS.—The defects characterizing this grade are red- and black-rot pieces showing numerous large worm-holes or a large number of knot-holes or pieces that are extremely coarse-knotted or badly split.

Eastern Oregon White Pine Selects or Uppers will be divided into three grades of finish and shall be known as A or No. 1, B or No. 2, and C or No. 3.

A OR No. 1 FINISH shall be perfectly bright on the face side and free of knots or stain or pitch seams. The reverse side of the board may show one knot 1 in. in diameter or two knots less than 1 in. and small pitch seams, and may admit of a slight discoloration. Wider pieces will admit of relatively more defects on the reverse side.

B OR No. 2 FINISH will admit of more defects, larger and coarser knots, longer pitch seams and also some stain if not too pronounced. A 12-in. piece may show one knot 1½ in. to 2 in. in diameter or two or three smaller knots; also a few small pitch seams. Light-blue sap stain may extend over not to exceed one-third of the face of the board where the knot defects are not so pronounced. In wider boards the defects may increase proportionately.

C OR No. 3 FINISH.—This is the lowest recognized grade of finish lumber and will admit of quite serious defects as long as the piece has the appearance of finish in the knotty type. A 12-in. piece may contain a large number of small knots and one or two very coarse knots or occasionally a knot-hole if board is otherwise fairly clear, or in the absence of knots the whole face of the piece may be blue, but where the piece is very blue no other defects are admissible. In this grade of finish the appearance of the face side only will be taken into consideration except that the reverse side must have a good bearing.

FLOORING, DROP SIDING, RUSTIC, AND CEILING, SELECT.—In grading this lumber the same rules will be used that govern the other selects except that the grade is determined from the face side only. In all except ceiling, and that only when it is specified as partition, then the grade shall be determined from the poorer side, but it should always be borne in mind that the reverse side should have a good bearing surface and nothing will be

allowed in A or B that would materially weaken the piece and only in a C when the defect may be removed by wasting six inches.

COMMON FLOORING.—All flooring in the common grades shall be graded the same as wider pieces in the same grade, with the proper allowance for width.

BEVEL SIDING.—Care shall be taken in selecting this stock, which shall be free from knots in the edge, as in working the knots are liable to drop out, and a knot broken out in the thick edge gives the piece a rough appearance.

This siding shall be graded into four grades: No. 1 or A, No. 2 or B, No. 3 or C, No. 4 or D.

In A, or No. 1, the only defects admissible are a sound knot not to exceed $\frac{1}{4}$ in. in diameter or a very slight pitch pocket in a piece 12 feet or longer.

B, or No. 2, will admit of the defects in A or No. 1, together with other defects such as a small amount of stain, larger pitch pockets, or a little pitch or two or three small sound knots not exceeding $\frac{1}{2}$ in. in diameter.

In C, or No. 3, the defects admissible are the same as B or No. 2, only more pronounced. It will admit of more discoloration and also of one or two loose knots or small knot-holes provided there would not be more than six inches of waste in the piece by cutting out these defects, and when the waste is allowed the balance of the piece must show a B face.

D, or No. 4, will admit of all the defects of the better grades and any amount of blue stain, or where the piece is badly discolored it shall be practically free of other defects. This grade is practically a cutting grade when not colored.

FACTORY PLANK.—Grades described under this head are valued for cutting-up qualities only and should not be confounded, either in quality or value, with grades outlined in another part of this book for yard purposes.

Factory plank of all kinds shall be graded for the percentages of door cuttings that can be obtained.

Two grades of door cuttings only shall be recognized, and are to be known as No. 1 and No. 2 cuttings.

The only defect admissible in No. 1 cuttings is white sap.

The grade of No. 1 door cuttings must be free from all other defects.

The grade of No. 2 door cuttings will admit of one defect only in any one piece. This may be a small knot of sound character, not to exceed five-eighths of an inch in diameter, or the defect may be slightly stained sap which does not extend over more than one-half of the face of the piece on one side.

No. 1 Shop Common.—The sizes and grades of cuttings admissible in the grade of No. 1 Shop Common are as follows:

No. 1 Stiles in width $5\frac{1}{2}$ or 6 in. and in length from 6 ft. 8 in. to 7 ft. 6 in.

No. 1 Rails 9 or 10 in. wide and from 2 ft. 4 in. to 3 ft. in length.

No. 1 Muntins $5\frac{1}{2}$ in. wide and from 3 ft. 6 in. to 4 ft. in length.

Any number of pieces of either the stiles or rails mentioned above are admissible in the grade of No. 1 Shop Common; but only two muntins of the sizes mentioned above shall be considered, and one No. 2 door stile may also be considered, in securing the required percentage of cuttings in any given plank.

Each plank of No. 1 Shop Common shall contain not less than 50 per cent nor more than 70 per cent of door cuttings of the sizes and grades above mentioned.

No. 2 Shop Common.—The sizes admissible in No. 2 Shop Common are as follows:

Stiles in width $5\frac{1}{2}$ in. or 6 in. and from 6 ft. 8 in. to 7 ft. 6 in. in length.

Rails 9 or 10 in. in width and from 2 ft. 4 in. to 3 ft. in length.

Top rails $5\frac{1}{2}$ in. wide and from 2 ft. 4 in. to 3 ft. in length. Top rails must, however, be of No. 1 door-cutting quality.

Muntins $5\frac{1}{2}$ in. wide and from 3 ft. 6 in. to 4 ft. in length.

Any number of cuttings of any one of the above sizes are admissible in the grade of No. 2 Shop Common.

Each piece of No. 2 Shop Common shall contain either one of the following: At least 25 per cent of No. 1 door cuttings, or not less than 40 per cent of all No. 2 door cuttings, or not less than $33\frac{1}{3}$ per cent of No. 1 and No. 2 door cuttings combined.

No. 3 Shop Common, $1\frac{1}{4}$ in., $1\frac{1}{2}$ in., and 2 in., will admit all below the grades described as No. 2 Shop Common, except such plank without cuttings as:

Show excessive rot.

Excessively pitch pieces.

Pieces stained on the greater part of both sides.

The type where there are no cuttings between knots and those knots are too unsound to be admitted in a cheap door.

A few small worm- or grub-holes, when not combined with blue sap or other serious defects, are admissible on one side of the piece only.

DOUGLAS FIR OR OREGON PINE.

GRADING RULES.

NOTES TO SURVEYORS.

BUREAU OF GRADES AND INSPECTION.—Surveyors at ports within the jurisdiction of the established Bureau of Grades and Inspection will receive their appointment from and be subject to the instructions of the properly designated officers of said Bureau, particularly as to an interpretation of the following rules:

At ports outside of said jurisdiction the surveyor shall be satisfactory to and subject to the mutual instructions of both buyer and seller as to any special conditions, but otherwise shall conform to the rules hereinafter noted and exercise his best judgment as to a correct interpretation thereof.

SALE MEASURE.—All intermediate (odd or fractional) lengths shall be measured as of the contents of the next longer length, unless otherwise especially instructed by the proper parties.

All lumber sawn less than 1" in thickness shall be measured as of 1" (i.e., at surface measure).

All rough lumber 1" and over in thickness shall be measured at board-measure contents.

All worked lumber shall be measured at board-measure contents *before* working.

Sizes 4" and under in thickness will be worked $\frac{1}{8}$ " less for each side surfaced. Sizes over 4" in thickness will be worked $\frac{1}{4}$ " less for each side surfaced.

T. & G. S. 1 S. shall be worked $\frac{1}{8}$ " less in thickness and $\frac{3}{8}$ " narrower on face.

All sizes are subject to natural shrinkage, whether "green," partially or wholly seasoned, and in such cases the surveyor will make allowance for variations from above.

Recognized defects are knots, knot-holes, splits (either from seasoning, ring heart, or rough handling), shakes, wane, red

heart, rot, rotten streaks, worm-holes, pitch seams, pitch pockets, solid pitch, chipped grain, torn grain, loosened grain, seasoning checks, and black sap.

KNOTS shall be classified as pin, small, standard, and large as to size; round and spike as to form; and sound, loose, incased, pith, and rotten as to quality.

A pin knot is sound and not over $\frac{1}{2}$ " in diameter.

A small knot is sound and not over 1" in diameter.

A standard knot is sound and not over $1\frac{1}{2}$ " in diameter.

A large knot is sound and any size over $1\frac{1}{2}$ " in diameter.

A round knot may be oval or circular in form, and the mean or average diameter shall be considered in applying these rules.

A spike knot is one sawn in a lengthwise direction.

A sound knot is one solid across its face, as hard as the wood it is in, and so fixed by growth or position that it will retain its place in the piece.

A loose knot is one not held firmly in place by growth or position.

An incased knot is one surrounded wholly or in part by bark or pitch.

A pith knot is a small sound knot with a pith hole not more than $\frac{1}{4}$ " in the centre.

A rotten knot is one not as hard as the wood it is in.

PITCH.—Seams are openings between the grain of wood containing more or less pitch and shall be classified as large and small.

A large pitch seam is one $\frac{1}{8}$ " and over in open width and not over 8" in length.

A small pitch seam is one less than $\frac{1}{8}$ " in open width and not exceeding 4" in length.

A pitch pocket is a well-defined accumulation of pitch at one point of the piece.

A pitch seam or pocket showing open on both sides of the piece $\frac{1}{8}$ " or more in width shall be considered the equivalent of a knot-hole.

GRAIN.—Chipped grain consists of a part of the surface being chipped or broken out in small particles below the surface, but shall not be classed as torn grain.

Torn grain consists of a part of the wood being torn out in dressing, usually around knots or curly places.

Loosened grain consists of the point of one grain being torn loose from the next grain, noticeable on the heart side of a piece.

SAP.—Colored, blue or black.

Bright sap shall not be considered a defect unless the surveyor shall receive from the supervising inspector, or both buyer and seller, contrary instructions.

SUNDRIES.—Firm red heart shall not be considered a defect in any of the grades of commons.

Occasional variations in sawing, or occasional scant thickness, shall not be considered a defect when not rendering the piece unfitted for its probable use.

Imperfect manufacture in dressed stock, such as chipped grain, torn grain, loosened grain, broken knots, mismatching, or insufficient tongue or groove, will reduce the grade, according to whether such defects are slight or serious, in their effect upon the use of the piece.

Equivalent, in the application of these rules, means that the defects allowed, whether specified or not, are understood to be equivalent in damaging effect to those specially mentioned.

The grades of all regular stock shall be determined by the number, character, and position of defects visible in any piece. The enumerated defects permissible in any grade are intended to be descriptive of the coarsest piece such grade may contain hereunder; the average quality of the grade should be about midway between such piece and the coarsest piece allowed in the next higher grade.

DOUGLAS FIR.

Grades shall be known and designated as follows:

ROUGH AND WORKED COMMONS.—“Merchantable,” “Seconds,” “Refuse.”

ROUGH UPPERS.—“Clear,” “Select.”

Car Stock—“No. 1,” “No. 2.”

Ship Stuff—“No. 1,” “No. 2.”

WORKED UPPERS.—D. & M. Flooring—“No. 1,” “No. 2,” “No. 3.”

Stepping—“No. 1,” “No. 2,” “No. 3.”

Rustic—“No. 1,” “No. 2,” “No. 3.”

Ceiling—“No. 1,” “No. 2,” “No. 3.”

ROUGH COMMONS.—*Merchantable*.—This grade shall consist of lengths 10' and over (except shorter lengths be ordered) of sound, strong lumber, free from loose or rotten knots, knot-holes, splits, shakes, wane, rot, pitch seams (open on both sides of the piece), or other defects that materially impair the

strength of the piece; well manufactured and suitable for good substantial construction purposes, or the purpose for which it is intended. Will allow:

Occasional variations in sawing, or occasional scant thicknesses.

Sound large knots.

Large pitch seams.

Bright or colored sap on corners one-third the width and one-half the thickness.

Firm red heart.

Recognized defects in all cases to be considered in connection with size of piece and its quality otherwise.

Bill Stuff shall consist of sizes ordered for specific construction and not intended for "Yard Stock," and must be inspected with the view of its adaptability to the uses intended, and unless manifestly unfit therefor shall be surveyed under this grade, except the order be for a higher grade.

Seconds.—This grade shall consist of lengths 10' and over (except shorter lengths be ordered) having any of the recognized defects which exclude it from grading as Merchantable. Will allow:

Recognized defects which render it unfit for good substantial construction purposes but suitable for an inferior class of work.

Refuse.—This grade shall consist only of commons absolutely unfit for any other use than firewood.

ROUGH UPPERS.—*Selects*.—Shall be sound, strong lumber, and in flooring, ceiling, and finish stock of good grain, well manufactured. Will allow:

In sizes under 6"×6":

Pin knots, bright sap on corners one-quarter the width and one-half the thickness, and small pitch seams. Not more than two such defects in for each 10 linear feet.

In sizes 6"×6" and over:

Small and standard knots varying in diameter according to size of piece.

Bright sap on corners not to exceed 3" on both faces and edges.

Large pitch seams.

Recognized defects to be considered in all cases in connection with size of piece and its general quality.

Clears.—Flooring, ceiling, and finish stock shall be sound, close grain, well sawn, and on one side and two edges free from defects impairing its use for probable purposes intended.

Edge grain in widths 12" and wider shall be so graded if showing grain on edge within an angle of 45 degrees for at least three-fourths of width and otherwise free from defects on one face and two edges.

Slash grain (nearly parallel to surface) shall be otherwise free from recognized defects on one face and two edges.

Other lumber in this grade shall be uniformly sawn and generally free from recognized defects. Will allow—

In dimensions containing 24" or less to the linear foot:

Bright sap when not exceeding one-quarter the width, thickness, or length.

Small pitch seams when not extending through the piece. In dimensions 3" to 6" thick and over 8" to 12" wide:

Pin knots when on one side and lower half of edges.

Bright sap not exceeding one-fourth the face or edges, or one-third the length.

Small pitch seams when not extending through the piece. In dimensions larger than above:

Small knots, according to size of piece, when on one face and lower half of edges, leaving one face and upper half of edges clear.

Bright sap on corners not exceeding 3" on face and edges, or one-half the length.

Large pitch seams when not extending through the piece.

Ship Stuff.—All lumber for this purpose shall be strong, of live wood, and close grain.

No. 1 Plank.—Includes outboard planking, garboards, wales, clamps, rails, and lumber for similar purposes; if worked, to be fairly smooth. Will allow:

Small tight, hard knots when not on corners or calking seam.

Bright sap on face side edges not exceeding one-quarter the width or thickness.

Small pitch seams not extending through the piece.

Said defects to be considered in connection with size of piece and its quality otherwise.

No. 1 Decking.—Shall be uniformly sawn, close grain, free from recognized defects on one face and both edges, and if

worked to be of uniform size and fairly smooth. Flat sizes shall show edge grain on broad face, and both square and flat sizes be free from recognized defects on edge grain face. Will allow:

Pin knots on under side and lower part of calking edges.

Bright sap on face side edges not exceeding one-eighth the width and one-fourth the thickness.

No. 2 Plank and Decking.—This grade shall include all of above material not suited for grading as No. 1 hereunder, but in quality shall be equal to the grade of Select.

Car Stock.—Lumber in this grade shall be strong, of fine grain, and uniformly sawn. Sizes 2" thick and less and 12" and less wide shall be practically clear, free from all recognized defects that would impair it for its intended use. Will allow in dimensions over 2" thick and 12" wide:

Small knots, according to size of piece.

Bright sap in limited amount, according to size of piece.

Small pitch seams.

Said defects to be considered in connection with size of piece and its quality otherwise.

No. 2.—This grade shall include material impaired by recognized defects from grading as No. 1, but generally conforming to the grade of "Selects."

Car Siding and Roofing.—To be graded under rules for D. & M. ceiling.

WORKED UPPERS.—*D. & M. Flooring. No. 1.*—This grade shall consist of lengths 10' and up (except shorter lengths be ordered), edge grain on face for three-quarters of width; of sound, close grain lumber, and free from recognized defects on face and edges; well worked and conform generally to grade of Clears. Will allow:

One pin knot in each piece.

Bright sap when not extending over one-quarter face and length.

Only one such defect allowed in any one piece.

No. 2.—This grade shall consist of edge or slash grain of lengths 10' and up (except shorter lengths when ordered), well worked and conform generally to the grade of Selects. Will allow:

Small knots if not appearing on edges.

Bright sap when not extending over one-half the face and length.

Small pitch seams.

Chipped grain.

Said defects to be considered in connection with length of piece and its quality otherwise. Not more than two such defects to each 12 linear feet.

No. 3.—This grade shall consist of lengths 6' and up regardless of grain and conform generally to grade of Merchantable.

Stepping.—This material shall consist of lengths 10' and over (except shorter lengths be ordered), and defects allowed shall be considered with regard to length of piece.

No. 1.—This grade shall conform generally to grade of Clears, be worked smooth on one side, shall show edge grain on face to extent of not less than three-fourths of width, and free from defects on face and one edge.

No. 2.—This grade shall show edge grain on face to extent of not less than one-half the width and conform generally to grade of "Selects." Will allow:

Pin knots on one face or one edge.

Bright sap when not extending over one-quarter the width.

Small pitch seams.

Chipped grain and other recognized defects impairing it from grading as No. 1.

No. 3.—This grade shall be regardless of grain and conform generally to grade of Merchantable.

Rustic Siding and Ceiling. No. 1.—Shall consist of lengths 10' and up (except shorter lengths be ordered), sound lumber, regardless of grain, free from recognized defects on face and edges, well worked, and conform generally to grade of "Clears." Will allow:

One pin knot.

Or bright sap not extending over one-quarter width or length of piece.

Only one such defect allowed in any one piece.

No. 2.—This grade shall conform generally to grade of "Selects." Will allow:

Small knots if not appearing on edges.

Bright sap when not extending over one-half the face and length.

Small pitch seams if not extending through the piece.

Chipped grain.

Said defects to be considered in connection with size and length of piece.

No. 3.—Shall conform generally to grade of Merchantable.

CALIFORNIA REDWOOD.

CLEAR REDWOOD.—No. 1. Shall be good and sound, clear of knots, splits, sap and shakes, and well manufactured to standard thickness. Will allow:

Small birdseye.

Slash-grained sawing.

No. 2. Shall be inferior in quality to No. 1. Will allow:

Small sound knots and pin knots, sap on end and edge not exceeding 4 per cent of area.

Slight roughness in milling.

Tank, Panel, and Casing Stock.—Shall be good and sound clear of knots, splits, sap, and shakes, and well manufactured.

Sap Clear.—This grade shall conform generally to No. 1 and No. 2 Clear, except that it shall contain sap in excess of 4 per cent of the area. Will allow:

Discoloration of sap.

Flooring, Ceiling, and Rustic Stock.—No. 1. Shall be the grade of No. 1 clear. Will allow:

Slash-grained sawing that will probably not rough up in working.

No. 2. Shall conform to the grade of No. 2 clear.

Standard Grade, Rustic Stock.—Will allow:

3 or 4 sound standard (1¼" diameter) knots.

1 or 2 sound knots not to exceed 2" in diameter.

Sap with small knots.

Poor machining, which would make it unfit for No. 1 and No. 2 clear.

Half-inch Lumber.—Shall be graded under the same rules as inch lumber of the same quality.

GRADES, COMMON.—No. 1. This grade shall consist of sound, strong lumber, free from rot, large shake and large, loose knots. It shall be well manufactured and suitable for good, substantial construction purposes. Will allow:

Occasional variations in widths and thickness.

Knots, weather check, and small shake that do not materially impair its strength.

Sap not to exceed 4 per cent of the area of outside surfaces.

No. 2. This grade shall consist of lumber having any of the recognized defects which exclude it from the No. 1 grade. Will allow:

Sap, loose and rotten knots and shakes; also splits not extending over one-fourth the length of the piece.

Recognized defects which render it unfit for good, substantial construction purposes but suitable for an inferior class of work.

No. 3. This grade shall consist of anything that is not good enough to go into No. 2 grade, but which can be used for any purpose as lumber.

DIFFERENT KINDS OF WOOD AND WHERE FOUND.

| NAME. | WHERE FOUND. | NAME. | WHERE FOUND. |
|-------------------------|------------------------------|--------------------------|-------------------------------------|
| Acacia. | Warm climates. | East India | |
| Alder. | Europe, etc. | blackwood. | East Indies. |
| Almond. | South of Europe. | Ebony. | Ceylon, Africa, India. |
| Amboine. | Africa. | Elder. | Jamaica. |
| Apple. | Europe, America. | Elm. | Europe. |
| Apple (crab). | East. United States. | “ red. | East. United States. |
| Arbor-vitæ. | Temperate climates. | “ white. | “ “ “ |
| Ash. | Britain, etc. | Fir, red silver. | Sierra Nevada Mts. |
| “ black. | East. United States. | “ Scotch. | Europe. |
| “ blue. | “ “ “ | “ silver. | California. |
| “ white. | “ “ “ | Fustic. | North and South America. |
| Bamboo. | China and India. | Greenheart. | Guiana, Trinidad. |
| Barwood. | Africa. | Gum, black and | |
| Basswood. | East. United States. | red. | East. United States. |
| Beech. | “ “ “ | Hawthorn. | Europe, etc. |
| Birch. | Europe, America. | Hazel. | “ “ “ |
| Bite. | India. | H e m l o c k | |
| Black Botany | | (spruce). | North America. |
| Bay wood. | Australia. | Hickory. | America. |
| Blue-gum. | “ | Holly. | Europe, Southeastern United States. |
| Bog-oak. | England, Ireland. | Hoonsay. | India. |
| Boxwood. | Southern and western Europe. | Ironwood. | East. United States. |
| Brazil wood. | Brazil. | “ red. | Jamaica. |
| Buckeye. | Tennessee and North. | Jackwood. | Asia, Ceylon. |
| Bullet-tree. | Jamaica. | Juniper. | (See Cedar.) |
| Buttonwood. | (See Sycamore.) | Kiaboca. | East Indies. |
| Calamander. | Ceylon. | Kingwood. | Brazil. |
| Camphor. | Warm climates. | Laburnum. | Europe. |
| Camwood. | Africa. | Lancewood. | South America. |
| Canary-wood. | Brazil. | “ black. | Jamaica. |
| Caugica-wood. | “ | Larch. | Europe. |
| Catalpa. | East. United States. | “ Western. | Oregon. |
| Cedar, bastard. | Southern California. | Laurel, moun- | |
| “ red. | East. United States. | tain. | Penn. and South. |
| “ yellow. | Utah to Pacific Coast. | Leopard-wood. | Central America. |

DIFFERENT KINDS OF WOOD AND WHERE FOUND—(Continued).

| NAME. | WHERE FOUND. |
|----------------------|---|
| Cedar, Spanish. | West Indies and South America. |
| “ Western. | Utah to Oregon. |
| “ white. | United States. |
| “ West India. | West Indies. |
| Cherry. | Europe, America. |
| Cherry, wild, black. | East. United States. |
| Cherry-tree. | Australia. |
| Chestnut. | America, Europe. |
| Cocoa-wood. | West Indies. |
| Coquilla-nut. | Brazil. |
| Cork-oak. | Southwest Europe. |
| Cottonwood. | West. United States. |
| Cowdi-pine. | Temperate climates. |
| Cypress. | So. United States. |
| “ | New Zealand. |
| Deodar. | India. |
| Dogwood. | Tasmania, Jamaica, and East. United States. |
| Mustaiba. | Brazil. |
| Myrtle. | Southern Europe, Tasmania. |
| Nellec. | India. |
| Nettle-tree. | South of Europe. |
| Norfolk Island pine. | Norfolk Island. |
| Norway spruce. | Norway. |
| Novaladdi. | India. |
| Oak | Europe, etc. |
| “ African. | Africa. |
| “ black. | East. United States. |
| “ white. | “ “ “ |
| “ red. | “ “ “ |
| “ chestnut. | “ “ “ |
| Olive | Europe, Syria, California. |
| Osage orange. | Arkansas and South. |
| Osiers. | Europe. |
| Oyster Bay wood. | Tasmania. |
| Paddle-wood. | Guiana. |
| Palm. | Tropical climates. |
| Partridge-wood. | West Indies, South America. |
| Pine. | Europe and Asia. |
| “ yellow. | North America. |
| “ red. | “ “ |
| “ white. | “ “ |
| “ spruce. | “ “ |
| Plane. | North America, Asia, Britain. |
| Plum. | Britain, etc. |
| Poon. | West Indies. |
| Poplar. | Europe, Asia. |
| “ | East. United States. |
| Porcupine-wo'd. | Tropical climates. |
| Prima Vera. | Mexico. |
| Purpleheart. | Brazil. |
| Quassia. | Tropical climates. |
| Rattans. | “ |
| Red sanders. | India. |
| Redwood. | California. |

| NAME. | WHERE FOUND. |
|---------------------------------|--|
| Lignum-vitæ. | West Indies and Florida. |
| Lime. | Europe. |
| Linn. | East. United States. |
| Locust. | West Indies. |
| “ | East of Missippissi River. |
| Mahogany. | Central America and Cuba. |
| “ moun- tain. | Rocky Mountains. |
| “ white. | (See Prima Vera.) |
| Mangrove. | Tropics. |
| Maple, black. | East. United States. |
| “ red. | “ “ “ |
| “ sugar. | “ “ “ |
| Mountain-ash. | Australia, Britain, etc. |
| Mulberry. | Europe and China. |
| “ red. | East. United States. |
| Muskwood. | Tasmania, New South Wales. |
| Rhododendron. | Himalaya. |
| Rosewood. | Tasmania. |
| Sandalwood. | India. |
| Sapan-wood. | “ |
| Sassafras. | America, Tasmania. |
| Satinwood. | East Indies. |
| Saul. | “ |
| Scotch fir. | Scotland. |
| Service-tree. | East. United States. |
| She-oak. | Tasmania. |
| Silverwood. | Cape of Good Hope. |
| Snakewood. | West Indies. |
| Spindle-tree. | Britain, etc. |
| Spruce, black. | Sierra Nevada Mts. |
| “ Engle- man's. | Rocky Mountains. |
| Stringy-bark. | Australia. |
| Sycamore. | Temperate climates. |
| “ | East. United States. |
| “ | (fig) Egypt. |
| Tamarack (Amer- ican larch). | Northern and Northeastern United States. |
| Teak, African. | Africa. |
| “ Indian. | India. |
| Thorn. | East. United States. |
| Toonwood. | India. |
| Toqua. | Himalaya. |
| Tulip-wood. | Australia. |
| Vegetable ivory. | Central America. |
| Walnut, black. | East. United States. |
| White (utter- nut. | “ “ “ |
| “ English. | Europe. |
| “ French. | Persia, Asia Minor. |
| Whitewood. | New South Wales. |
| Willow. | Europe, America. |
| Yacca-wood. | Jamaica. |
| Yew-wood. | Britain, California, Oregon. |
| Zebra. | Brazil. |

352 STRENGTH, WEIGHT, ETC., OF VARIOUS WOODS.

STRENGTH, WEIGHT, ETC., OF VARIOUS WOODS.

| Name. | Strength per Sq. In. in Lbs. | | Moduli of Elasticity. | Relative Hardn ^{ss} Shell-bark Hickory being 1000. | Weight per Cubic Foot. | Specific Gravity. |
|--------------------------|------------------------------|---------------------------------|-----------------------|---|------------------------|-------------------|
| | Tensile. | Crushing in Direction of Grain. | | | | |
| Acacia-wood. | | | | | 46.5 | .750 |
| Alder-wood. | | 6,150 | | | 50 | .800 |
| Apple-wood. | | | | 700 | 49 | .793 |
| Ash (white). | 17,000 | 8,600 | | 775 | 40.77 | .610 |
| Ash (brown). | 11,000 | | | | 38.96 | .623 |
| Boxwood. | 18,000 | 10,000 | | | 62 | .990 |
| Birch. | 15,000 | 8,000 | | 630 | 35.44 | .567 |
| Beech. | 11,500 | 9,000 | | 660 | 40.42 | .650 |
| Butternut. | 9,000 | 6,000 | | 440 | 23.50 | .376 |
| Cherry. | | | | 550 | 44.70 | .715 |
| Chestnut. | 10,500 | 5,000 | 1,000,000 | 520 | 41.25 | .660 |
| Cork. | | | | | 15 | .240 |
| Cedar (white). | 11,400 | 6,500 | 700,000 | 540 | 37.25 | .596 |
| Cedar (red). | 9,000 | 6,000 | | | 35 | .560 |
| Cypress. | 5,000 | 6,000 | 900,000 | | 27.60 | .441 |
| Dogwood. | | | | 750 | 47.25 | .750 |
| Ebony. | | | | | 86.16 | 1.331 |
| Elm. | 13,000 | 8,000 | | 580 | 42 | .671 |
| Fir. | 10,000 | 7,000 | 1,200,000 | | 32 | .512 |
| Gum. | 17,000 | 7,000 | | | 52.69 | .843 |
| Hazel. | | | | 720 | 53.75 | .860 |
| Holly. | | | | | 47.50 | .760 |
| Hickory (pignut) | 15,000 | 9,000 | | 950 | 49.50 | .792 |
| Hickory (shell-bark). | 18,000 | 10,000 | | 1000 | 43.12 | .690 |
| Hemlock. | 8,740 | 5,400 | 900,000 | | 23.00 | .368 |
| Hackmatack. | | | | | 37.00 | .592 |
| Juniper. | | | | | 35.37 | .566 |
| Lancewood. | | | | | 45 | .720 |
| Larch. | 9,500 | | | | 34.55 | .552 |
| Lignum-vitæ. | 12,000 | 9,000 | | | 83.31 | 1.333 |
| Logwood. | | | | | 57.06 | .913 |
| Locust. | 20,000 | 11,720 | | | 45.50 | .728 |
| Mahogany. | 12,000 | 6,000 | | | 55.75 | .829 |
| Maple (hard). | 10,000 | 9,000 | | 550 | 46.87 | .750 |
| Maple (white). | 10,000 | 7,000 | | | 36 | .576 |
| Oak (white). | 16,000 | 6,000 | 1,100,000 | 850 | 53.75 | .860 |
| Oak (red or black). | 10,000 | 8,000 | | 700 | 40.75 | .652 |
| Pear. | 9,800 | | | | 47 | .752 |
| Plum. | | | | | 49.06 | .785 |
| Poplar. | 7,000 | 5,000 | | 510 | 23.99 | .383 |
| Pine (white). | 7,000 | 5,000 | 1,000,000 | 300 | 30 | .480 |
| Pine (Norway). | 8,300 | 7,000 | 1,200,000 | | 33.25 | .532 |
| Pine (yellow). | 16,000 | 5,500 | 1,200,000 | 540 | 38.40 | .612 |
| Pine (yellow long-leaf). | 20,000 | 9,000 | 1,700,000 | | 43.62 | .698 |
| Pine (Oregon). | 13,800 | 7,000 | 1,400,000 | | 34 | .544 |
| Rosewood. | | | | | 45.50 | .728 |
| Redwood (Cal.). | 8,000 | 2,500 | 7,000,000 | | 26.23 | .419 |
| Satinwood. | | | | | 55.31 | .885 |
| Spruce (white). | 14,000 | 6,500 | 1,200,000 | | 31.25 | .500 |
| Tamarack. | | | | | 23.93 | .383 |
| Walnut. | 10,000 | 8,000 | | 650 | 41.93 | .671 |
| Willow. | 12,000 | | | | 33.40 | .535 |

Plumbing.—In this part of the work the superintendent must see that the materials are all as specified; he should see that the pipe used is of the right size and weight, and that all fixtures are in perfect condition. He should provide himself with a catalogue of the various fixtures to be used so he will know if the proper fixtures are provided.

In running the sewers and soil-pipes he must see that a proper fall is given, which should not be less than that given in the following table:

| | | | | | | | | | |
|---------------------------------|----|----|----|----|----|----|----|----|-----|
| Diameter of pipe, inches. . . . | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Length to 1 foot of fall, feet. | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |

A small pipe should have a greater fall than a large one on account of the friction being greater compared with the amount of water used.

All turns and connections should be made with Y branches and $\frac{1}{8}$ bends. If the joints are made with lead the superintendent should see that they are made with one pouring of the lead and calked tight.

When earthenware pipe is used for sewers they must be examined for cracks, and to see if the bowl is in perfect condition care must be taken in making the cement joints so as to leave the inside of the pipes smooth and level; as the pipes are laid the inside should be wiped out so as to wipe out any surplus cement on the inside. Fig. 227, A, shows how pipes of

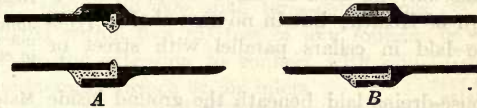


FIG. 227.

this kind are often laid, while Fig. 227, B, shows how they should be laid.

After all sewers, soil- and vent-pipes are in place they should be tested by plugging the bottom or main outlet and filling all the pipes to the roof level; this test should remain on for at least six hours, after which all pipes and joints should be thoroughly examined for leaks.

Soil- and vent-pipes should be securely fastened to the walls and the vertical runs of pipe should set on a firm footing. Lead pipe should be examined before using as to weight and thick-

ness, and as to quality and condition of the pipe. By rough handling of the coil of pipe in many cases the pipe is flattened so as to render it unfit for use.

In laying water-pipes, or in fact pipes of any kind, they should be laid so that they will drain themselves, and in no case should any pipe be placed so as to cause a seal or trap in the pipe.

Stopcocks should be placed on all water lines where they can be got at conveniently, controlling each fixture or set of fixtures.

After all fixtures are in place the pipe and fixtures should be tested with smoke, which is applied at the main outlet by burning rags or waste saturated with oil, and forcing the smoke up the pipes; after the pipes are filled with smoke the whole system should be gone over and any joint or connection where there is an odor of smoke should be examined, as any smell of smoke is an indication of a leak. This test is mainly for the connections of the fixtures, as the pipes have already been tested by the water test.

The water system should be tested by hydraulic pressure.

The following rules regarding plumbing are taken from the Philadelphia Building Code:

Rule 10. The main drain of every house or building shall be separately and independently connected with the street sewer, where one is provided; and where there is no sewer in the street, and it is necessary to construct a private sewer to connect with one on an adjacent street, such plans may be used as may be approved by the Board of Health; but in no case shall a joint drain be laid in cellars parallel with street or alley.

Main drain to be connected with street sewer.

When private sewer is necessary, plans must be approved by Board of Health.

Joint drain not to be laid in cellars.

All house-drains laid beneath the ground inside of buildings or beneath the cellar floor shall be of plain, extra-heavy cast-iron pipe, with well leaded and calked joints, or of wrought iron, with screw joints made with a paste of red lead and treated to prevent corrosion.

Material to be used in underground house-drains.

All other drains or soil-pipes connected with the main drain, or where the main drain pipe is above the cellar floor, shall be of plain cast-iron pipe, or of wrought-iron pipe with screw joints made with a paste of red lead and treated to prevent corrosion.

Material to be used in other drain- or soil-pipes.

Outside of the buildings, where the soil is of sufficient solidity for a proper foundation cylindrical terra-cotta pipes of the best quality, free from flaws, splits, or cracks, perfectly burned, and well glazed over the entire inner and outer surfaces may be used, laid on a smooth bottom, with a special groove cut in the bottom of trench for each hub (in order to give the pipe a solid bearing on its entire length) and the soil well rammed on each side of the pipe. The spigot and hub ends shall be concentric.

The space between the hub and pipe shall be thoroughly filled with the best cement mortar, made of equal parts of the best American natural cement and bar sand thoroughly mixed dry, and water enough afterward added to give it proper consistency. The cement must be mixed in small quantities at a time and used as soon as made. The joints must be carefully wiped and pointed, and all mortar that may be left inside thoroughly cleaned out and the pipe left clean and smooth throughout, for which purpose a swab shall be used.

No tempered-up cement shall be used. A straight-edge shall be used, and the different sections shall be laid in perfect line on the bottom and sides; but in no case shall terra-cotta pipes be permitted within five (5) feet of any foundation-wall, or for extension to connect with rain-water conductors, surface or air inlets.

Note.—After the test has been approved by the inspector, iron drain- or soil-pipes may be tar-coated. But in no case shall any coating be applied to cast-iron soil- or drain-pipes until test has been applied and approved by the inspector.

Rule 11. The house-drain shall be not less than four (4) inches, nor more than ten (10) inches in diameter, and the fall shall not be less than one-half ($\frac{1}{2}$) an inch to the foot, unless by special permission of the Board of Health; it shall be laid in a trench cut at a uniform grade, or it may be constructed along the foundation-

Terra-cotta drain-pipes may be used outside of buildings under certain conditions.

Space between hub and pipe to be filled with cement mortar.

Joints to be properly finished.

Quality of cement.

Terra-cotta pipes not to be within 5 feet of foundation-wall, nor used for extensions.

Coating of pipes not to be done until after approval by inspector.

Construction of house-drains.

walls above the cellar floor, resting on nine (9) inch brick piers laid in cement mortar (said piers to be not more than seven (7) feet apart) and securely fastened to said walls; no tests shall be made by the inspector until said pipes are secured as above described.

Rule 12. The arrangement of soil- and waste-pipes shall be as direct as possible. All changes in direction on horizontal pipes shall be made with Y branches, one-sixteenth ($\frac{1}{16}$) or one-eighth ($\frac{1}{8}$) bends.

Arrangement of house-drains.

Rule 13. The house-drain shall be provided with a horizontal trap, placed immediately inside the cellar wall nearest to the sewer, or at the curb. The trap shall have a hand-hole, for convenience in cleaning, the cover of which shall be properly fitted and the joints made air-tight.

Location of main trap of house-drain.

Note.—If the trap and the main drain is placed inside of the cellar wall, there shall be no clear-out between the water seal of the trap and the sewer.

Main trap to have a hand-hole.

Rule 14. There shall be an inlet for fresh air entering the drain just inside the water seal of the main trap, and also at the rear of the system, when the vertical line of soil-pipe is located in the central part of the building and the main fresh-air inlet is deemed insufficient to ventilate the entire system. Said inlets shall be at least four (4) inches in diameter, leading to the outer air and opening at any convenient place, with an accessible clean-out. Where air inlets are located off the footway, on grass plots, lawns, etc., they shall extend not less than six (6) nor more than fifteen (15) inches above the surface of the ground and be protected by a cowl securely fastened with bolts.

Location of fresh-air inlets in drains.

Rule 15. Where the drain passes through a new foundation-wall a relieving arch shall be built over it with a two (2) inch clearance on either side.

Relieving arch required when drain-pipe passes through a new foundation-wall.

Rule 16. Every vertical soil-pipe shall extend at least two (2) feet above the highest part of the

building or contiguous property, and shall be of undiminished size, with the outlet uncovered except with a wire guard. Such soil-pipe shall not open near a window nor an air-shaft ventilating living-rooms.

Rule 17. Every branch or horizontal line of soil-pipe to which a group of two (2) or more water-closets is to be connected, and every branch line of horizontal soil-pipe eight (8) feet or more in length, to which a water-closet is to be connected, shall be ventilated, either by extending said soil-pipe, undiminished in size, to at least two (2) feet above the highest part of the building or contiguous property, or by extending said soil-pipe and connecting it with the main soil-pipe above the highest fixture, or by a ventilating pipe connected to the crown of each water-closet trap, not less than two (2) inches in diameter, which shall be increased one-half ($\frac{1}{2}$) an inch in diameter for every fifteen (15) feet in length, and connected to a special air-pipe, which shall not be less than four (4) inches in diameter, or by connecting said ventilating pipe with the main soil-pipe above the highest fixture.

Rule 18. Where a separate line of waste-pipes is used, not connected with sewer-pipes, it shall also be carried two (2) feet above the highest part of the building or contiguous property, unless otherwise permitted by the Board of Health. But in no case shall a waste-pipe connect with a rain-water conductor.

Rule 19. There shall be no traps, caps, or cowls on soil- and waste-pipes which will interfere with the system of ventilation.

Rule 20. All soil-, waste-, anti-siphon pipes and traps inside of new buildings, and of the new work in old buildings, and also of the entire system when alterations are made in old buildings, and the owner or agent of said building or buildings shall have contracted to have the entire drainage system tested, shall have openings stopped and a test of not less than three (3) pounds atmospheric pressure to the square inch applied.

Construction of vertical soil- or waste-pipes.

Branch or horizontal soil-pipes to which water-closets are connected to be ventilated; manner of such ventilation.

Construction of waste-pipes not connected with sewer-pipes.

Waste-pipe not to connect with rain-water conductor.

No obstruction to ventilation to be placed on soil or waste-pipes.

Test of not less than 3 pounds pressure per square inch to be applied to drain-pipes and traps.

Rule 21. The drain-, soil-, and waste-pipes, and the traps, shall, if practicable, be exposed to view for ready inspection at all times, and for convenience in repairing. When placed within walls or partitions and not exposed to view, or not covered with woodwork fastened with screws so as to be readily removed, or when not easily accessible, extra-heavy pipes shall be used at the discretion of the Board of Health.

Drain-pipes and traps to be easily accessible when practicable.

When drain-pipes and traps are not easily accessible, heavy pipe to be used.

Rule 22. No drainage work shall be covered or concealed in any way until after it has been examined and approved by a house-drainage inspector, and notice must be sent to the Board of Health, in writing, when the work is sufficiently advanced for such inspection; and immediately on the completion of the work application must be made for final inspection. The failure on the part of a master plumber to make said application for final inspection, or the violation of any of the rules of the Board of Health in the construction of any drainage work, and failure to correct the fault after notification, will be deemed sufficient cause to place his name on the delinquent list until he has complied with said rules and regulations. Any attempt on the part of a master plumber to construct or alter a system of drainage during the time his name appears on said delinquent list will subject him to criminal prosecution.

Drainage work not to be covered or concealed until inspected.

Notice to Board of Health.

Final inspection.

Name of master plumber to be placed on delinquent list for violation of rules of Board of Health.

Criminal prosecution in case a delinquent shall do any drainage work.

Rule 23. All drain and anti-siphon pipes of cast iron shall be sound, free from holes, and of a uniform thickness, and shall conform to the following relative weights:

Quality and weight of drain- and soil-pipes.

| Standard. | | | | Extra Heavy. | | | |
|-----------|-------|----|-----------|--------------|-------|-----|-----------|
| In. | Lbs. | | | In. | Lbs. | | |
| 2 | pipe, | 4 | per foot. | 2 | pipe, | 5½ | per foot. |
| 3 | " | 6 | " | 3 | " | 9½ | " |
| 4 | " | 9 | " | 4 | " | 13 | " |
| 5 | " | 12 | " | 5 | " | 17 | " |
| 6 | " | 15 | " | 6 | " | 20 | " |
| 7 | " | 20 | " | 7 | " | 27 | " |
| 8 | " | 25 | " | 8 | " | 33½ | " |
| 10 | " | 35 | " | 10 | " | 45 | " |
| 12 | " | 45 | " | 12 | " | 54 | " |

Rule 24. All drain and anti-siphon cast-iron pipes shall have the weight per foot and the name of the manufacturer cast on the exterior surface, directly back of the hub of each section, in characters not less than one-half ($\frac{1}{2}$) inch in length.

Name of manufacturer and weight per foot to be cast on drain- and soil-pipes.

Rule 25. Lead waste-pipes may be used for horizontal lines that are two (2) inches or less in diameter, and shall have not less than the following prescribed weights:

When lead waste-pipes may be used.

| | | | |
|-----------------|------------|--------|-------|
| 1 | inch pipe, | 2 lbs. | 0 oz. |
| 1 $\frac{1}{4}$ | " " | 2 " | 8 " |
| 1 $\frac{1}{2}$ | " " | 3 " | 8 " |
| 2 | " " | 4 " | 0 " |

Weight of lead pipes.

Rule 26. Lead bends or traps for water-closets shall not be less than one-eighth ($\frac{1}{8}$) of an inch in thickness.

Thickness of lead bends or traps for water-closets.

Rule 27. Waste-pipes from wash-basins, sinks, and bath-tubs shall not be less than one and one-quarter ($1\frac{1}{4}$) inches in diameter, and wash-tray waste-pipes not less than one and one-half ($1\frac{1}{2}$) inches in diameter.

Diameter of water-pipes from wash-basins, sinks, bath-tubs, and wash-trays.

Rule 28. All joints in cast-iron drain-, soil-, and waste-pipes shall be so calked with oakum and lead, or with cement made of iron filings and salammoniac, as to make them gas-tight.

Joints in cast-iron drain-pipes to be calked.

Rule 29. All connections of lead with iron pipe shall be made with a brass ferrule not less than one-eighth ($\frac{1}{8}$) of an inch in thickness, put in the hub of the iron pipe and calked in with lead, except in cases of iron water-closet traps or old work, when drilling and tapping is permitted. The lead pipe shall be attached to the ferrule by a wiped solder joint.

Connections of lead with iron pipe to be made with a brass ferrule; how connection to be made.

Rule 30. All connections of lead pipe shall be by wiped solder joints.

Connections of lead pipe to be by solder joints.

Rule 31. Every water-closet, sink, basin, wash-tray, bath, and every tub or set of tubs, shall be separately and effectually trapped.

Water-closets, sinks, etc., to be separately trapped.

Rule 32. The trap must be placed as near the fixture as practicable. All waste-pipes shall be provided with strong metallic strainers. All

Location of traps.
Strainers.

drains from hydrants shall be trapped and in a manner accessible for cleaning out.

Drains from hydrants.

Rule 33. Traps of fixtures shall be protected from siphonage. All anti-siphon pipes shall be carried up and through the roof or connected with the main soil-pipes above the highest fixture.

Traps to be protected from siphonage.

Rule 34. Every anti-siphon pipe shall be of lead, of galvanized gas-pipe, or of plain cast-iron pipe. Where these pipes go through the roof they shall extend two (2) feet above the highest part of the building or contiguous property; they may be combined by branching together those which serve several traps. These pipes where not vertical must always be a continuous slope, to avoid collecting water by condensation.

Construction of anti-siphon pipes.

Material to be used in anti-siphon pipes.

Construction of same.

Rule 35. All drip- or overflow-pipes from safes under wash-basins, baths, urinals, water-closets, or other fixtures shall be by a special pipe run to an open sink outside the house or some conspicuous point; and in no case shall any such pipe be connected with a soil-, drain-, or waste-pipe.

Construction of drip- or overflow-pipes.

Rule 36. No waste-pipe from a refrigerator or other receptacle in which provisions are stored shall be connected with any drain-, soil-, or other waste-pipe. Such waste-pipes shall be so arranged as to admit of frequent flushing, and shall be as short as possible.

Waste-pipe from refrigerator, etc., not to be connected with any drain-pipe.

Rule 37. The overflow-pipes from tanks and the waste-pipes from refrigerators shall discharge into an open fixture properly trapped.

Discharge of overflow from tanks and refrigerator waste-pipes.

Rule 38. All water-closets within buildings shall be supplied with water from special tanks or cistern which shall hold not less than eight (8) gallons of water when up to the level of the overflow-pipe for each closet supplied, excepting automatic or siphon tanks, which shall hold not less than five (5) gallons of water for each closet supplied; the water in said tanks shall not be used for any other purpose. The flushing-pipe of all tanks shall not be less than one and one-quarter (1 $\frac{1}{4}$) inches in diameter.

Water-closets to be supplied with water from flushing-tanks.

Capacity of such tanks.

Size of flushing-pipe.

Rule 39. No closet, except those placed in the yard, shall be supplied directly from the supply pipes.

Water-closets not to be supplied directly from main.

Rule 40. A group of closets may be supplied from one tank, but water-closets on different floors shall not be flushed from one tank.

Supplying different closets from same tank.

Rule 41. Water-closets, when placed in the yard, shall be so arranged as to be conveniently and adequately flushed, and their water-supply pipes and traps shall be protected from freezing by placing them in a hopper-pit, at least three and one-half ($3\frac{1}{2}$) feet below the surface of the ground, the walls of which shall be of brick or stone laid in cement mortar. The water-pipe from the hopper stopcock shall be conveyed to the drain through a three-eighths ($\frac{3}{8}$) inch pipe, properly connected.

Yard water-closets to be adequately flushed.

Protection of supply pipes to same from freezing.

Rule 42. The inclosure of the yard water-closet shall be ventilated by slatted openings, and there shall be a trap-door in the floor of sufficient size for access to the hopper-pit.

Inclosure of yard water-closets to be ventilated and have trap-door in floor.

Rule 43. Water-closets must not be located in the sleeping-apartments of any building, nor in any room or apartment which has not direct communication with the external air either by a window or an air-shaft having an area to the open air of at least four (4) square feet.

Water-closets not to be located in sleeping-apartments nor in apartment without communication with external air.

Rule 44. The containers of all water-closets shall be supplied with fresh air and properly ventilated, as approved by the Board of Health.

Containers of water-closets to be ventilated.

Rule 45. All water-closets within a building using lead connections shall have a cast-brass flange not less than three-sixteenths ($\frac{3}{16}$) of an inch in thickness (fitted with a pure-rubber gasket of sufficient thickness to insure a tight joint) bolted to the closet.

Lead connections to water-closets within a building.

Rule 46. Where latrines are used for schools they shall be of iron, properly supplied with water, and located in the yard at least twenty (20) feet from the building when practicable.

Construction of latrines for schools.

Rule 47. Rain-water conductors shall be connected with the house-drain or sewer and be

Rain-water conductors to be connected

provided with a trap the seal of which shall be not less than five (5) inches. Said trap shall have a hand-hole for convenience in cleaning, the cover of which shall be made air-tight.

Rain conductors shall not be connected outside of the main trap, nor used as soil-, waste-, or vent-pipes; nor shall any soil-, waste-, or air-pipe be used as a rain conductor, and if placed within a building shall be of cast iron with leaded joints.

Rule 48. No steam exhaust or waste from steam-pipes shall be connected with any house-drain or soil-pipe.

Rule 49. No privy vault or cesspool for sewage shall hereafter be constructed in any part of the city where a sewer is at all accessible.

Rule 50. No connection from any cesspool or privy-well shall be made with any sewer, nor shall any water-closet or house-drainage empty into a cesspool or privy-well.

Rule 51. In rural districts waste-pipes from buildings may be connected with cesspools constructed for that special purpose, properly flagged or arched over, and not water-tight, by special permission of the Board of Health.

Rule 52. Privy-vaults must be constructed as follows: Each building situate on an unsewered street must have a privy-vault not less than four (4) feet in diameter and ten (10) feet deep in the clear, lined with hard brick nine (9) inches in thickness, laid in cement mortar, and proved to be water-tight.

Rule 53. Privy-vaults shall not be located within two (2) feet of party lines, or within twenty (20) feet of a building when practicable; and before any privy-vault shall be constructed, application shall be made and a permit for same issued by the Board of Health.

Rule 54. No opening will be permitted in the drain-pipe of any building for the purpose of draining a cellar, unless by special permission by the Board of Health.

with house-drain or sewer and provided with trap; trap to have hand-hole.

Rain conductors not to be connected outside of main traps, nor used as soil- or waste-pipes.

Steam-exhaust pipes not to be connected with drain-pipes.

Privy-vault or cesspool not to be constructed where a sewer is accessible.

Connection of cesspool or privy-well not to be made with sewer.

Water-closet or house drainage not to empty into cesspool or privy-well.

Waste-pipes may be connected with cesspools in rural districts.

Construction of privy-vaults.

Privy-vaults not to be located within 2 feet of party lines or 20 feet of a building.

Permit for construction of privy-vault required.

No opening to be in drain-pipe for draining cellar unless by permission.

Rule 55. Cellar-drains shall be constructed as follows: By a system of French drains, or field tile, to a catch-basin, flagged over; the outlet pipe shall be properly trapped and connected with the house-drain, and shall also be provided with a back-pressure valve or stopcock the required size.

Construction of cellar drains.

FLOW OF WATER IN HOUSE-SERVICE PIPES.

(Thomson Meter Co.)

| Condition of Discharge. | Pressure in Main, Lbs. per Sq. In. | Discharge in Cubic Feet per Minute from the Pipe. | | | | | | | | |
|---|------------------------------------|---|---------------|-------|-----------------|-------|--------|--------|--------|--------|
| | | Nominal Diameters of Iron or Lead Service-pipe in Inches. | | | | | | | | |
| | | $\frac{1}{2}$ | $\frac{3}{4}$ | 1 | 1 $\frac{1}{2}$ | 2 | 3 | 4 | 6 | |
| Through 35 feet of service-pipe, no back pressure. | 30 | 1.10 | 1.92 | 3.01 | 6.13 | 16.58 | 33.34 | 88.16 | 173.85 | 444.63 |
| | 40 | 1.27 | 2.22 | 3.48 | 7.08 | 19.14 | 38.50 | 101.80 | 200.75 | 513.42 |
| | 50 | 1.42 | 2.48 | 3.89 | 7.92 | 21.40 | 43.04 | 113.82 | 224.44 | 574.02 |
| | 60 | 1.56 | 2.71 | 4.26 | 8.67 | 23.44 | 47.15 | 124.68 | 245.87 | 628.81 |
| | 75 | 1.74 | 3.03 | 4.77 | 9.70 | 26.21 | 52.71 | 139.39 | 274.89 | 703.03 |
| | 100 | 2.01 | 3.50 | 5.50 | 11.20 | 30.27 | 60.87 | 160.96 | 317.41 | 811.79 |
| 130 | 2.29 | 3.99 | 6.28 | 12.77 | 34.51 | 69.40 | 183.52 | 361.91 | 925.58 | |
| Through 100 feet of service-pipe, no back pressure. | 30 | 0.66 | 1.16 | 1.84 | 3.78 | 10.40 | 21.30 | 58.19 | 118.13 | 317.23 |
| | 40 | 0.77 | 1.34 | 2.12 | 4.36 | 12.01 | 24.59 | 67.19 | 136.41 | 366.30 |
| | 50 | 0.86 | 1.50 | 2.37 | 4.88 | 13.43 | 27.50 | 75.13 | 152.51 | 409.54 |
| | 60 | 0.94 | 1.65 | 2.60 | 5.34 | 14.71 | 30.12 | 82.30 | 167.06 | 448.63 |
| | 75 | 1.05 | 1.84 | 2.91 | 5.97 | 16.45 | 33.68 | 92.01 | 186.78 | 501.58 |
| | 100 | 1.22 | 2.13 | 3.36 | 6.90 | 18.99 | 38.89 | 106.24 | 215.68 | 579.18 |
| 130 | 1.39 | 2.42 | 3.83 | 7.86 | 21.66 | 44.34 | 121.14 | 245.91 | 660.36 | |
| Through 100 feet of service-pipe and 15 feet vertical rise. | 30 | 0.55 | 0.96 | 1.52 | 3.11 | 8.57 | 17.55 | 47.90 | 97.17 | 260.56 |
| | 40 | 0.66 | 1.15 | 1.81 | 3.72 | 10.24 | 20.95 | 57.20 | 116.01 | 311.09 |
| | 50 | 0.75 | 1.31 | 2.06 | 4.24 | 11.67 | 23.87 | 65.18 | 132.20 | 354.49 |
| | 60 | 0.83 | 1.45 | 2.29 | 4.70 | 12.94 | 26.48 | 72.28 | 146.61 | 393.13 |
| | 75 | 0.94 | 1.64 | 2.59 | 5.32 | 14.64 | 29.96 | 81.79 | 165.90 | 444.85 |
| | 100 | 1.10 | 1.92 | 3.02 | 6.21 | 17.10 | 35.00 | 95.55 | 193.82 | 519.72 |
| 130 | 1.26 | 2.20 | 3.48 | 7.14 | 19.66 | 40.23 | 109.82 | 222.75 | 597.31 | |
| Through 100 feet of service-pipe and 30 feet vertical rise. | 30 | 0.44 | 0.77 | 1.22 | 2.50 | 6.80 | 14.11 | 38.63 | 78.54 | 211.54 |
| | 40 | 0.55 | 0.97 | 1.53 | 3.15 | 8.68 | 17.79 | 48.68 | 98.98 | 266.59 |
| | 50 | 0.65 | 1.14 | 1.79 | 3.69 | 10.16 | 20.82 | 56.98 | 115.87 | 312.08 |
| | 60 | 0.73 | 1.28 | 2.02 | 4.15 | 11.45 | 23.47 | 64.22 | 130.59 | 351.73 |
| | 75 | 0.84 | 1.47 | 2.32 | 4.77 | 13.15 | 26.95 | 73.76 | 149.99 | 403.98 |
| | 100 | 1.00 | 1.74 | 2.75 | 5.65 | 15.58 | 31.93 | 87.38 | 177.67 | 478.55 |
| 130 | 1.15 | 2.02 | 3.19 | 6.55 | 18.07 | 37.02 | 101.33 | 206.04 | 554.96 | |

SAFE PRESSURES AND EQUIVALENT HEADS OF WATER FOR CAST-IRON PIPE OF DIFFERENT SIZES AND THICKNESSES.

(Calculated by F. H. Lewis from Fanning's Formula.)

| Thickness. | Size of Pipe. | | | | | | | | | | | | | | | | | |
|------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|
| | 4 Inches. | | 6 Inches. | | 8 Inches. | | 10 Inches. | | 12 Inches. | | 14 Inches. | | 16 Inches. | | 18 Inches. | | 20 Inches. | |
| | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. |
| 1 1/2 | 112 | 258 | 49 | 112 | 42 | 18 | 101 | 44 | 24 | 55 | 42 | 97 | 56 | 129 | 41 | 95 | 51 | 118 |
| 1 1/4 | 224 | 516 | 124 | 280 | 171 | 74 | 205 | 89 | 62 | 143 | 74 | 170 | 84 | 194 | 66 | 152 | 74 | 170 |
| 1 1/8 | 336 | 774 | 199 | 458 | 300 | 130 | 304 | 132 | 99 | 228 | 106 | 244 | 112 | 258 | 91 | 210 | 96 | 221 |
| 1 1/2 | 448 | 1032 | 274 | 631 | 429 | 186 | 408 | 177 | 137 | 316 | 138 | 316 | 140 | 323 | 116 | 267 | 119 | 274 |
| 1 1/4 | 560 | 1390 | 349 | 844 | 566 | 231 | 516 | 224 | 174 | 401 | 170 | 392 | 168 | 387 | 141 | 325 | 141 | 325 |
| 1 1/8 | 672 | 1848 | 424 | 1117 | 703 | 276 | 680 | 271 | 212 | 488 | 202 | 465 | 196 | 452 | 166 | 382 | 166 | 382 |
| 1 1/2 | 784 | 2536 | 500 | 1480 | 840 | 321 | 904 | 318 | 249 | 574 | 234 | 538 | 224 | 516 | 191 | 440 | 191 | 440 |
| 1 1/4 | 896 | 3424 | 575 | 2000 | 1008 | 366 | 1208 | 365 | 286 | 760 | 266 | 612 | 266 | 612 | 216 | 497 | 216 | 497 |
| 1 1/8 | 1008 | 4512 | 650 | 2664 | 1246 | 411 | 1552 | 410 | 323 | 1046 | 298 | 800 | 298 | 800 | 241 | 547 | 241 | 547 |
| 1 1/2 | 1120 | 6000 | 725 | 3568 | 1514 | 456 | 2048 | 455 | 360 | 1432 | 330 | 1074 | 330 | 1074 | 276 | 607 | 276 | 607 |
| 1 1/4 | 1232 | 8064 | 800 | 4832 | 1802 | 501 | 2752 | 500 | 397 | 1918 | 362 | 1466 | 362 | 1466 | 301 | 687 | 301 | 687 |
| 1 1/8 | 1344 | 10752 | 875 | 6496 | 2190 | 546 | 3716 | 545 | 434 | 2604 | 394 | 1950 | 394 | 1950 | 326 | 747 | 326 | 747 |
| 1 1/2 | 1456 | 14400 | 950 | 8672 | 2678 | 591 | 4960 | 590 | 471 | 3490 | 436 | 2636 | 436 | 2636 | 351 | 807 | 351 | 807 |
| 1 1/4 | 1568 | 19104 | 1025 | 11616 | 3286 | 636 | 6674 | 635 | 508 | 4776 | 471 | 3490 | 471 | 3490 | 376 | 867 | 376 | 867 |
| 1 1/8 | 1680 | 25440 | 1100 | 15680 | 3994 | 681 | 9088 | 680 | 545 | 6462 | 513 | 3874 | 513 | 3874 | 401 | 927 | 401 | 927 |
| 1 1/2 | 1792 | 33360 | 1175 | 21056 | 4802 | 726 | 12412 | 725 | 582 | 8848 | 546 | 4118 | 546 | 4118 | 426 | 987 | 426 | 987 |
| 1 1/4 | 1904 | 44800 | 1250 | 28416 | 5710 | 771 | 16846 | 770 | 619 | 12034 | 591 | 4362 | 591 | 4362 | 451 | 1047 | 451 | 1047 |
| 1 1/8 | 2016 | 60480 | 1325 | 38080 | 6718 | 816 | 22880 | 815 | 656 | 16470 | 636 | 4606 | 636 | 4606 | 476 | 1107 | 476 | 1107 |
| 1 1/2 | 2128 | 80640 | 1400 | 50432 | 7826 | 861 | 30814 | 860 | 693 | 22306 | 681 | 4850 | 681 | 4850 | 501 | 1167 | 501 | 1167 |
| 1 1/4 | 2240 | 107520 | 1475 | 67888 | 9034 | 906 | 41748 | 905 | 730 | 30242 | 726 | 5094 | 726 | 5094 | 526 | 1227 | 526 | 1227 |
| 1 1/8 | 2352 | 144000 | 1550 | 91936 | 10342 | 951 | 56182 | 950 | 767 | 40678 | 771 | 5338 | 771 | 5338 | 551 | 1287 | 551 | 1287 |
| 1 1/2 | 2464 | 191040 | 1625 | 124480 | 11850 | 996 | 75216 | 995 | 804 | 54114 | 816 | 5582 | 816 | 5582 | 576 | 1347 | 576 | 1347 |
| 1 1/4 | 2576 | 254400 | 1700 | 168000 | 13558 | 1041 | 100850 | 1040 | 841 | 71550 | 846 | 5826 | 846 | 5826 | 601 | 1407 | 601 | 1407 |
| 1 1/8 | 2688 | 333600 | 1775 | 227520 | 15466 | 1086 | 135184 | 1085 | 878 | 95986 | 871 | 6070 | 871 | 6070 | 626 | 1467 | 626 | 1467 |
| 1 1/2 | 2800 | 448000 | 1850 | 308160 | 17674 | 1131 | 181618 | 1130 | 915 | 128422 | 906 | 6314 | 906 | 6314 | 651 | 1527 | 651 | 1527 |
| 1 1/4 | 2912 | 604800 | 1925 | 416640 | 20182 | 1176 | 243052 | 1175 | 952 | 170858 | 931 | 6558 | 931 | 6558 | 676 | 1587 | 676 | 1587 |
| 1 1/8 | 3024 | 806400 | 2000 | 559200 | 22990 | 1221 | 324486 | 2000 | 989 | 228294 | 976 | 6802 | 976 | 6802 | 701 | 1647 | 701 | 1647 |
| 1 1/2 | 3136 | 1075200 | 2075 | 753760 | 26198 | 1266 | 435920 | 2075 | 1026 | 302730 | 1001 | 7046 | 1001 | 7046 | 726 | 1707 | 726 | 1707 |
| 1 1/4 | 3248 | 1440000 | 2150 | 1028320 | 29806 | 1311 | 580354 | 2150 | 1063 | 398166 | 1046 | 7290 | 1046 | 7290 | 751 | 1767 | 751 | 1767 |
| 1 1/8 | 3360 | 1910400 | 2225 | 1393760 | 34814 | 1356 | 775788 | 2225 | 1100 | 522602 | 1091 | 7534 | 1091 | 7534 | 776 | 1827 | 776 | 1827 |
| 1 1/2 | 3472 | 2544000 | 2300 | 1888000 | 41422 | 1401 | 1041222 | 2300 | 1137 | 697038 | 1136 | 7778 | 1136 | 7778 | 801 | 1887 | 801 | 1887 |
| 1 1/4 | 3584 | 3336000 | 2375 | 2542400 | 49830 | 1446 | 1395656 | 2375 | 1174 | 921474 | 1181 | 8022 | 1181 | 8022 | 826 | 1947 | 826 | 1947 |
| 1 1/8 | 3696 | 4480000 | 2450 | 3406800 | 59438 | 1491 | 1870090 | 2450 | 1211 | 1215910 | 1226 | 8266 | 1226 | 8266 | 851 | 2007 | 851 | 2007 |
| 1 1/2 | 3808 | 6048000 | 2525 | 4541200 | 70646 | 1536 | 2504524 | 2525 | 1248 | 1600346 | 1271 | 8510 | 1271 | 8510 | 876 | 2067 | 876 | 2067 |
| 1 1/4 | 3920 | 8064000 | 2600 | 6085600 | 83854 | 1581 | 3338958 | 2600 | 1285 | 2084782 | 1316 | 8754 | 1316 | 8754 | 901 | 2127 | 901 | 2127 |
| 1 1/8 | 4032 | 10752000 | 2675 | 8230000 | 99462 | 1626 | 4453392 | 2675 | 1322 | 2769218 | 1361 | 8998 | 1361 | 8998 | 926 | 2187 | 926 | 2187 |
| 1 1/2 | 4144 | 14400000 | 2750 | 11074400 | 117870 | 1671 | 5947826 | 2750 | 1359 | 3653654 | 1406 | 9242 | 1406 | 9242 | 951 | 2247 | 951 | 2247 |
| 1 1/4 | 4256 | 19104000 | 2825 | 14818800 | 139478 | 1716 | 7902260 | 2825 | 1396 | 4838090 | 1451 | 9486 | 1451 | 9486 | 976 | 2307 | 976 | 2307 |
| 1 1/8 | 4368 | 25440000 | 2900 | 19863200 | 164686 | 1761 | 10546694 | 2900 | 1433 | 6422526 | 1496 | 9730 | 1496 | 9730 | 1001 | 2367 | 1001 | 2367 |
| 1 1/2 | 4480 | 33360000 | 2975 | 26707600 | 193694 | 1806 | 14091128 | 2975 | 1470 | 8516982 | 1541 | 9974 | 1541 | 9974 | 1026 | 2427 | 1026 | 2427 |
| 1 1/4 | 4592 | 44800000 | 3050 | 35852000 | 227702 | 1851 | 18635562 | 3050 | 1507 | 11161418 | 1586 | 10218 | 1586 | 10218 | 1051 | 2487 | 1051 | 2487 |
| 1 1/8 | 4704 | 60480000 | 3125 | 48796400 | 267710 | 1896 | 24879996 | 3125 | 1544 | 14505854 | 1631 | 10462 | 1631 | 10462 | 1076 | 2547 | 1076 | 2547 |
| 1 1/2 | 4816 | 80640000 | 3200 | 66240800 | 324718 | 1941 | 33424430 | 3200 | 1581 | 19350290 | 1676 | 10706 | 1676 | 10706 | 1101 | 2607 | 1101 | 2607 |
| 1 1/4 | 4928 | 107520000 | 3275 | 89685200 | 389726 | 1986 | 45068864 | 3275 | 1618 | 25694726 | 1721 | 10950 | 1721 | 10950 | 1126 | 2667 | 1126 | 2667 |
| 1 1/8 | 5040 | 144000000 | 3350 | 121129600 | 464734 | 2031 | 59613298 | 3350 | 1655 | 34139162 | 1766 | 11194 | 1766 | 11194 | 1151 | 2727 | 1151 | 2727 |
| 1 1/2 | 5152 | 191040000 | 3425 | 163574000 | 554742 | 2076 | 79157732 | 3425 | 1692 | 45083608 | 1811 | 11438 | 1811 | 11438 | 1176 | 2787 | 1176 | 2787 |
| 1 1/4 | 5264 | 254400000 | 3500 | 219018400 | 659750 | 2121 | 105602166 | 3500 | 1729 | 59028044 | 1856 | 11682 | 1856 | 11682 | 1201 | 2847 | 1201 | 2847 |
| 1 1/8 | 5376 | 333600000 | 3575 | 293462800 | 784758 | 2166 | 139046594 | 3575 | 1766 | 77472480 | 1901 | 11926 | 1901 | 11926 | 1226 | 2907 | 1226 | 2907 |
| 1 1/2 | 5488 | 448000000 | 3650 | 396907200 | 934766 | 2211 | 183491022 | 3650 | 1803 | 102916916 | 1946 | 12170 | 1946 | 12170 | 1251 | 2967 | 1251 | 2967 |
| 1 1/4 | 5600 | 604800000 | 3725 | 531351600 | 1114774 | 2256 | 243935450 | 3725 | 1840 | 134361352 | 1991 | 12414 | 1991 | 12414 | 1276 | 3027 | 1276 | 3027 |
| 1 1/8 | 5712 | 806400000 | 3800 | 711796000 | 1329782 | 2301 | 324379878 | 3800 | 1877 | 175805788 | 2036 | 12658 | 2036 | 12658 | 1301 | 3087 | 1301 | 3087 |
| 1 1/2 | 5824 | 1075200000 | 3875 | 956240400 | 1584790 | 2346 | 434824306 | 3875 | 1914 | 233250224 | 2081 | 12902 | 2081 | 12902 | 1326 | 3147 | 1326 | 3147 |
| 1 1/4 | 5936 | 1440000000 | 3950 | 1280684800 | 1884798 | 2391 | 579268734 | 3950 | 1951 | 305694660 | 2126 | 13146 | 2126 | 13146 | 1351 | 3207 | 1351 | 3207 |
| 1 1/8 | 6048 | 1910400000 | 4025 | 1705129200 | 2234806 | 2436 | 774713162 | 4025 | 1988 | 398139096 | 2171 | 13390 | 2171 | 13390 | 1376 | 3267 | 1376 | 3267 |
| 1 1/2 | 6160 | 2544000000 | 4100 | 2269573600 | 2644814 | 2481 | 1049157590 | 4100 | 2025 | 522583532 | 2216 | 13634 | 2216 | 13634 | 1401 | 3327 | 1401 | 3327 |
| 1 1/4 | 6272 | 3336000000 | 4175 | 3014018000 | 3124822 | 2526 | 1393601918 | 4175 | 2062 | 697027968 | 2261 | 13878 | 2261 | 13878 | 1426 | 3387 | 1426 | 3387 |
| 1 1/8 | 6384 | 4480000000 | 4250 | 4018462400 | 3694830 | 2571 | 1858046246 | 4250 | 2100 | 921472404 | 2306 | 14122 | 2306 | 14122 | 1451 | 3447 | 1451 | 3447 |
| 1 1/2 | 6496 | 6048000000 | 4325 | 5362906800 | 4374838 | 2616 | 2482490574 | 4325 | 2137 | 1215916840 | 2351 | 14366 | 2351 | 14366 | 1476 | 3507 | 1476 | 3507 |

SAFE PRESSURES AND EQUIVALENT HEADS OF WATER FOR CAST-IRON PIPE OF DIFFERENT SIZES AND THICKNESSES—(Continued).

| Thickness. | Size of Pipe. | | | | | | | | | | | | | | | | | |
|------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|---------------------|---------------|
| | 22 Inches. | | 24 Inches. | | 27 Inches. | | 30 Inches. | | 33 Inches. | | 36 Inches. | | 42 Inches. | | 48 Inches. | | 60 Inches. | |
| | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. | Pressure in Pounds. | Head in Feet. |
| 1 1/4 | 40 | 92 | 30 | 69 | 19 | 64 | 24 | 55 | 42 | 97 | 32 | 74 | 38 | 88 | 24 | 55 | 34 | 78 |
| 1 1/8 | 60 | 138 | 49 | 113 | 36 | 83 | 39 | 90 | 55 | 127 | 44 | 101 | 59 | 136 | 43 | 99 | 49 | 113 |
| 1 1/2 | 80 | 184 | 68 | 157 | 52 | 120 | 54 | 124 | 74 | 172 | 64 | 143 | 81 | 187 | 62 | 143 | 64 | 147 |
| 1 3/8 | 101 | 233 | 86 | 198 | 69 | 159 | 69 | 159 | 97 | 221 | 82 | 189 | 103 | 237 | 81 | 187 | 79 | 182 |
| 1 1/4 | 121 | 279 | 105 | 242 | 85 | 196 | 84 | 194 | 127 | 286 | 107 | 247 | 124 | 286 | 118 | 272 | 94 | 217 |
| 1 1/2 | 142 | 327 | 124 | 286 | 102 | 235 | 114 | 263 | 159 | 348 | 132 | 304 | 145 | 334 | 136 | 313 | 109 | 251 |
| 1 3/8 | 182 | 419 | 161 | 371 | 135 | 311 | 144 | 332 | 221 | 410 | 178 | 410 | 188 | 433 | 174 | 401 | 139 | 320 |
| 1 1/2 | 224 | 516 | 199 | 458 | 169 | 389 | 174 | 401 | 286 | 537 | 205 | 472 | 210 | 484 | 193 | 445 | 154 | 355 |
| 1 3/4 | 224 | 516 | 237 | 546 | 202 | 465 | 204 | 470 | 333 | 537 | 233 | 537 | 210 | 484 | 212 | 488 | 184 | 424 |
| 1 1/2 | 224 | 516 | 237 | 546 | 236 | 544 | 234 | 538 | 333 | 537 | 233 | 537 | 210 | 484 | 212 | 488 | 184 | 424 |
| 1 3/4 | 224 | 516 | 237 | 546 | 236 | 544 | 234 | 538 | 333 | 537 | 233 | 537 | 210 | 484 | 212 | 488 | 184 | 424 |
| 2 1/4 | 224 | 516 | 237 | 546 | 236 | 544 | 234 | 538 | 333 | 537 | 233 | 537 | 210 | 484 | 212 | 488 | 184 | 424 |
| 2 1/2 | 224 | 516 | 237 | 546 | 236 | 544 | 234 | 538 | 333 | 537 | 233 | 537 | 210 | 484 | 212 | 488 | 184 | 424 |
| 2 3/4 | 224 | 516 | 237 | 546 | 236 | 544 | 234 | 538 | 333 | 537 | 233 | 537 | 210 | 484 | 212 | 488 | 184 | 424 |
| 3 1/4 | 224 | 516 | 237 | 546 | 236 | 544 | 234 | 538 | 333 | 537 | 233 | 537 | 210 | 484 | 212 | 488 | 184 | 424 |

FORMULA FOR THICKNESS OF CAST-IRON WATER-PIPE.

- $t = .00008hd + .01d + .36$ Shedd;
- $t = .00006hd + .0133d + .296$ Warren Foundry;
- $t = .000058hd + .0152 + .312$ Francis;
- $t = .000048hd + .013d + .32$ Dupuit;
- $t = .00004hd + .1\sqrt{d} + .15$ Box;
- $t = .000135hd + .4 - .0011d$ Whitman;
- $t = .00006(h + 230d) + .333 - .0033d$ Fanning;
- $t = .00015hd + .25 - .0052d$ Meggs;

in which t = thickness in inches, h = head in feet, d = diameter.

SIZE AND WEIGHT OF LEAD PIPE.

| Calibre. | Ultimate Strength. | Working Strength. | Weight per Foot. Lbs. Oz. |
|-------------------------------------|--------------------|-------------------|------------------------------|
| $\frac{1}{8}$ inch tubing. .... | .... | .... | 3 $\frac{1}{2}$ |
| " extra-light tubing. .... | .... | .... | 4 |
| " light tubing. .... | .... | .... | 6 |
| " medium tubing. .... | .... | .... | 8 |
| " strong tubing. .... | .... | .... | 10 |
| " extra strong. .... | .... | .... | 1 2 |
| " aqueduct. | 1187 | 296 | 0 8 |
| " light. | 1342 | 335 | 0 12 |
| " medium. | 1381 | 347 | 1 0 |
| " strong. | 1627 | 406 | 1 8 |
| " extra strong. | 1968 | 492 | 2 0 |
| " aqueduct. | 782 | 195 | 0 10 |
| " extra light. | 980 | 245 | 0 12 |
| " light. | 1285 | 321 | 1 0 |
| " medium. | 1393 | 343 | 1 4 |
| " strong. | 1655 | 413 | 1 12 |
| " extra strong. | 1787 | 446 | 2 8 |
| " aqueduct. | 708 | 177 | 0 12 |
| " extra light. | 795 | 198 | 1 4 |
| " light. | 987 | 246 | 1 12 |
| " medium. | 1152 | 288 | 2 0 |
| " strong. | 1380 | 345 | 2 8 |
| " extra strong. | 1548 | 387 | 3 0 |
| " aqueduct. | 505 | 126 | 1 0 |
| " extra light. | 782 | 195 | 1 8 |
| " light. | 865 | 216 | 2 0 |
| " medium. | 1072 | 268 | 2 4 |
| " strong. | 1225 | 306 | 3 0 |
| " extra strong. | 1462 | 365 | 3 8 |
| " aqueduct. | 518 | 129 | 1 8 |
| " extra light. | 562 | 140 | 2 0 |
| " light. | 745 | 186 | 2 8 |
| " medium. | 857 | 214 | 3 4 |
| " strong. | 910 | 227 | 4 0 |
| " extra strong. | 1230 | 307 | 4 12 |
| $1\frac{1}{8}$ " aqueduct. | 350 | 87 | 2 0 |
| $1\frac{1}{8}$ " extra light. | 420 | 105 | 2 8 |
| $1\frac{1}{8}$ " light. | 546 | 136 | 3 0 |
| $1\frac{1}{8}$ " medium. | 685 | 171 | 3 12 |
| $1\frac{1}{8}$ " strong. | 823 | 205 | 4 12 |
| $1\frac{1}{8}$ " extra strong. | 962 | 240 | 6 0 |
| $1\frac{1}{8}$ " aqueduct. | 315 | 78 | 3 0 |

SIZE AND WEIGHT OF LEAD PIPE—(Continued).

| Calibre. | Ultimate Strength. | Working Strength. | Weight per Foot. | |
|--------------------------|--------------------|-------------------|------------------|-----|
| | | | Lbs. | Oz. |
| 1½ inch extra light..... | 430 | 107 | 3 | 8 |
| 1½ " light..... | 506 | 126 | 4 | 0 |
| 1½ " medium..... | 628 | 157 | 5 | 0 |
| 1½ " strong..... | 700 | 175 | 6 | 0 |
| 1½ " extra strong..... | 742 | 185 | 7 | 8 |
| 1¼ " extra light..... | ..... | ..... | 3 | 12 |
| 1¼ " light..... | ..... | ..... | 4 | 8 |
| 1¼ " medium..... | 318 | 79 | 5 | 8 |
| 1¼ " strong..... | ..... | 93 | 6 | 8 |
| 1¼ " extra strong..... | ..... | 116 | 8 | 0 |
| 2 " waste..... | 200 | 50 | 3 | 0 |
| 2 " extra light..... | 260 | 65 | 4 | 0 |
| 2 " light..... | 360 | 90 | 5 | 0 |
| 2 " medium..... | 405 | 101 | 7 | 0 |
| 2 " strong..... | 511 | 127 | 8 | 0 |
| 2 " extra strong..... | 611 | 152 | 9 | 0 |
| 2 " ⅜ thick..... | ..... | ..... | 8 | 0 |
| 2 " ¼ thick..... | ..... | ..... | 11 | 0 |
| 2 " ⅓ thick..... | ..... | ..... | 14 | 0 |
| 2 " ⅔ thick..... | ..... | ..... | 17 | 0 |
| 3 " waste..... | ..... | ..... | 5 | 0 |
| 3 " ⅓ thick..... | ..... | ..... | 9 | 0 |
| 3 " ½ thick..... | ..... | ..... | 12 | 0 |
| 3 " ⅔ thick..... | ..... | ..... | 16 | 0 |
| 3 " ¾ thick..... | ..... | ..... | 20 | 0 |
| 3 ½ " ⅓ thick..... | ..... | ..... | 15 | 0 |
| 3 ½ " ½ thick..... | ..... | ..... | 18 | 0 |
| 3 ½ " ⅔ thick..... | ..... | ..... | 21 | 0 |
| 4 " waste..... | ..... | ..... | 5 | 0 |
| 4 " ⅓ thick..... | ..... | ..... | 7 | 0 |
| 4 " ½ thick..... | ..... | ..... | 16 | 0 |
| 4 " ⅔ thick..... | ..... | ..... | 21 | 0 |
| 4 " ¾ thick..... | ..... | ..... | 25 | 0 |
| 4 " waste..... | ..... | ..... | 30 | 0 |
| 4 ½ " waste..... | ..... | ..... | 6 | 0 |
| 5 " "..... | ..... | ..... | 8 | 0 |

PURE BLOCK-TIN PIPE.

| Calibre. | Wei'ht per Foot. Oz. | Calibre. | Weight per Foot. Lbs. Oz. |
|-------------------------|----------------------|----------------------------|---------------------------|
| 1 inch strong..... | 2½ | 1 inch double extra strong | 15 |
| " extra strong..... | 5 | " extra strong..... | 9 |
| " double extra strong.. | 6 | " double extra strong.. | 14 |
| " double extra strong.. | 6½ | " extra strong..... | 11 |
| " extra strong..... | 6 | " double extra strong | 1 0 |
| " double extra strong.. | 8 | 1 " extra strong..... | 14 |
| " strong..... | 6½ | 1 " double extra strong | 1 4 |
| " extra strong..... | 10 | | |

WEIGHTS AND SIZES OF SHEET LEAD.

| | | | | | | | |
|------------------------|----|----|----|----|----|----|----|
| Pounds per square foot | 2½ | 3 | 3½ | 4 | 4½ | 5 | 6 |
| Wire-gauge number. . . | 19 | 18 | 17 | 16 | 15 | 14 | 13 |
| Pounds per square foot | 7 | 8 | 9 | 10 | 11 | 12 | |
| Wire-gauge number. . . | 12 | 11 | 10 | 9 | 8 | 7 | |

(A square foot of sheet lead 1/16 of an inch thick weighs 4 pounds.)

APPROXIMATE WEIGHTS OF CAST-IRON SOIL-PIPE AND FITTINGS.

STANDARD.

| Size, inches. | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 |
|-------------------------------|----|----|----|-----|-----|------|------|-----|
| Pipe. pounds per foot | 3½ | 4½ | 6½ | 8½ | 10 | 17 | 23 | 33 |
| Crosses pounds each | 5 | 10 | 12 | 16 | 24 | 45 | 45 | 45 |
| Double Y branch " " | 8 | 11 | 18 | 26 | 37 | 45 | 45 | 45 |
| Double hubs. " " | 3 | 4 | 6 | 8 | 10 | 16 | 26 | 26 |
| Eighth bends. " " | 3 | 4½ | 6 | 8 | 11 | 24 | 32½ | 32½ |
| Half Y branches " " | 4½ | 6½ | 10 | 14 | 16 | 34 | 41 | 41 |
| Quarter bends. " " | 4 | 5½ | 8 | 10 | 14½ | 34 | 41 | 41 |
| Reducers. " " | 4 | 5 | 6 | 8 | 9 | 9 | 9 | 9 |
| Sixth bends. " " | 3 | 4½ | 6 | 8 | 11 | 24 | 32½ | 32½ |
| Sleeves. " " | 2½ | 4 | 5 | 6 | 7 | 7 | 7 | 7 |
| T branches. " " | 4 | 8 | 10 | 15 | 20 | 38 | 55 | 55 |
| Traps. " " | 5½ | 10 | 19 | 26 | 35 | 42 | 70 | 70 |
| Y branches. " " | 5 | 9 | 13 | 18 | 25 | 42 | 70 | 70 |
| Size, inches. | | | | 2×8 | 3×8 | 4×12 | 5×12 | 6×8 |
| Offsets, pounds each. | | | | 5 | 8 | 15 | 20 | 22 |

EXTRA HEAVY.

| Size, inches. | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 |
|--------------------------------|----|----|----|-----|-----|------|------|-----|
| Pipe. pounds per foot. | 5½ | 9½ | 13 | 17 | 20 | 34 | 45 | 54 |
| Crosses pounds each | 10 | 20 | 24 | 32 | 48 | 85 | 85 | 85 |
| Double Y branch. " " | 12 | 20 | 32 | 42 | 60 | 85 | 85 | 85 |
| Double hubs. " " | 4½ | 7 | 8 | 11 | 14 | 28 | 47 | 47 |
| Eighth bends. " " | 4½ | 6½ | 9½ | 12 | 16 | 35½ | 59½ | 59½ |
| Half Y branches " " | 9 | 13 | 18 | 24 | 30 | 44 | 74 | 74 |
| Quarter bends. " " | 6 | 8 | 12 | 15 | 20 | 44 | 74 | 74 |
| Reducers. " " | 4 | 6 | 8 | 11 | 16 | 16 | 16 | 16 |
| Sixth bends " " | 4½ | 6½ | 9½ | 12 | 16 | 35½ | 59½ | 59½ |
| Sleeves " " | 4 | 6 | 7 | 9 | 10 | 10 | 10 | 10 |
| T branches. " " | 7 | 13 | 20 | 25 | 34 | 50 | 104 | 104 |
| Traps. " " | 9 | 18 | 28 | 45 | 68 | 85 | 151 | 151 |
| Y branches. " " | 10 | 15 | 25 | 32 | 45 | 85 | 151 | 151 |
| Size, inches. | | | | 2×8 | 3×8 | 4×12 | 5×12 | 6×8 |
| Offsets, pounds each. | | | | 9 | 15 | 23 | 30 | 38 |

CAPACITY AND SIZE OF GALVANIZED BOILERS.

| Capacity. | Size. | Weight of Boiler. | Total Weight Filled with Water. |
|-----------------|---------------------|-------------------|---------------------------------|
| 18 gallons..... | 3 feet by 12 inches | 47 | 196 |
| 21 "..... | 3½ " " 12 " | 49 | 224 |
| 24 "..... | 4 " " 12 " | 57 | 257 |
| 24 "..... | 3 " " 14 " | 52 | 255 |
| 27 "..... | 4½ " " 12 " | 66 | 291 |
| 28 "..... | 3½ " " 14 " | 66 | 299 |
| 30 "..... | 5 " " 12 " | 72 | 322 |
| 32 "..... | 4 " " 14 " | 72 | 339 |
| 35 "..... | 5 " " 13 " | 76 | 367 |
| 36 "..... | 6 " " 12 " | 85 | 384 |
| 36 "..... | 4½ " " 14 " | 78 | 377 |
| 40 "..... | 5 " " 14 " | 85 | 418 |
| 42 "..... | 4 " " 16 " | 95 | 444 |
| 47 "..... | 4½ " " 16 " | 102 | 493 |
| 48 "..... | 6 " " 14 " | 102 | 503 |
| 52 "..... | 5 " " 16 " | 119 | 551 |
| 53 "..... | 4 " " 18 " | 119 | 562 |
| 63 "..... | 6 " " 16 " | 146 | 670 |
| 66 "..... | 5 " " 18 " | 150 | 699 |
| 79 "..... | 6 " " 18 " | 171 | 829 |
| 82 "..... | 5 " " 20 " | 192 | 875 |
| 98 "..... | 6 " " 20 " | 210 | 1026 |
| 100 "..... | 5 " " 22 " | 220 | 1053 |
| 120 "..... | 6 " " 22 " | 265 | 1264 |
| 120 "..... | 5 " " 24 " | 260 | 1259 |
| 144 "..... | 6 " " 24 " | 332 | 1531 |
| 168 "..... | 7 " " 24 " | 348 | 1747 |
| 192 "..... | 8 " " 24 " | 391 | 1990 |

TABLE OF WEIGHTS PER LINEAL FOOT OF SEAMLESS BRASS AND COPPER TUBING.

IRON PIPE SIZES.

Made to correspond with iron tubes and to fit iron tube fittings.

| Same as Iron Size. | Exact Outside Diameter. | Exact Inside Diameter. | About Inside Diameter. | Weight per Foot. | |
|--------------------|-------------------------|------------------------|------------------------|------------------|---------|
| | Decimals. | Decimals. | Fractions. | Brass. | Copper. |
| Inches. | Inches. | Inches. | Inches. | Lbs. | Lbs. |
| ½ | .405 | .281 | ½ | .25 | .26 |
| ¾ | .540 | .375 | ¾ | .43 | .45 |
| 1 | .675 | .484 | 1 | .62 | .65 |
| 1¼ | .840 | .625 | 1¼ | .90 | .95 |
| 1½ | 1.04 | .822 | 1½ | 1.25 | 1.31 |
| 1¾ | 1.315 | 1.062 | 1¾ | 1.70 | 1.79 |
| 2 | 1.66 | 1.368 | 2 | 2.50 | 2.63 |
| 2½ | 1.90 | 1.600 | 2½ | 3.00 | 3.15 |
| 3 | 2.375 | 2.062 | 3 | 4.00 | 4.20 |
| 3½ | 2.875 | 2.500 | 3½ | 5.75 | 6.04 |
| 4 | 3.50 | 3.062 | 4 | 8.30 | 8.72 |
| 4½ | 4.00 | 3.5000 | 4½ | 10.90 | 11.45 |
| 5 | 4.50 | 4.000 | 5 | 12.70 | 13.33 |
| 5½ | 5.00 | 4.5000 | 5½ | 13.90 | 14.60 |
| 6 | 5.563 | 5.062 | 6 | 15.75 | 16.54 |
| 6½ | 6.625 | 6.125 | 6½ | 18.31 | 19.23 |

SEAMLESS BRASS AND COPPER TUBING—(Continued).

EXTRA-HEAVY IRON PIPE SIZES.

| Same as Extra-heavy Iron Pipe. | Exact Outside Diameter. | Exact Inside Diameter. | Approximate Weight in Pounds per Foot. | |
|--------------------------------------|-------------------------------|------------------------------|---|---------|
| | | | Brass. | Copper. |
| Inches. | Inches. | Inches. | Lbs. | Lbs. |
| $\frac{1}{2}$ | .405 | .205 | .370 | .389 |
| $\frac{3}{4}$ | .504 | .294 | .625 | .651 |
| $\frac{1}{2}$ | .675 | .421 | .830 | .872 |
| $\frac{3}{4}$ | .840 | .542 | 1.200 | 1.260 |
| $\frac{1}{2}$ | 1.050 | .736 | 1.660 | 1.743 |
| 1 | 1.315 | .951 | 2.360 | 2.478 |
| $1\frac{1}{2}$ | 1.660 | 1.272 | 3.300 | 3.465 |
| $1\frac{1}{2}$ | 1.900 | 1.494 | 4.250 | 4.462 |
| 2 | 2.375 | 1.933 | 5.460 | 5.733 |
| $2\frac{1}{2}$ | 2.875 | 2.315 | 8.300 | 8.715 |
| 3 | 3.500 | 2.892 | 11.200 | 11.760 |
| $3\frac{1}{2}$ | 4.00 | 3.358 | 13.700 | 14.385 |
| 4 | 4.50 | 3.818 | 16.500 | 17.325 |
| 5 | 5.563 | 4.813 | 22.800 | 23.940 |
| 6 | 6.625 | 5.750 | 32.000 | 33.600 |

SIZE, WEIGHTS, ETC., OF VITRIFIED SALT-GLAZED
SEWER-PIPE.

| Calibre of Pipe. | Thickness of Pipe. | Weight per Foot. | Feet to 15-ton Car Load. |
|---------------------|-----------------------|---------------------|-----------------------------|
| 3 inches | $\frac{1}{2}$ inch | 6 pounds | 5000 |
| 4 " | " | $7\frac{1}{2}$ " | 4000 |
| 5 " | " | $11\frac{1}{2}$ " | 2610 |
| 6 " | " | 16 " | 1880 |
| 8 " | " | 22 " | 1366 |
| 10 " | " | 31 " | 970 |
| 12 " | " | 41 " | 734 |
| 14 " | " | 50 " | 600 |
| 16 " | $1\frac{1}{4}$ inches | 66 " | 456 |
| 18 " | $1\frac{1}{2}$ " | 80 " | 376 |
| 20 " | $1\frac{3}{4}$ " | 90 " | 334 |
| 22 " | 2 " | 100 " | 300 |
| 24 " | $2\frac{1}{4}$ " | 120 " | 250 |
| 30 " | $2\frac{1}{2}$ " | 190 " | 158 |

DOUBLE-STRENGTH PIPE.

| Calibre of Pipe. | Thickness of Pipe. | Weight per Foot. | Feet to 15-ton Car Load. |
|---------------------|-----------------------|---------------------|-----------------------------|
| 15 inches | $1\frac{1}{4}$ inches | 65 pounds | 462 |
| 18 " | $1\frac{1}{2}$ " | 100 " | 300 |
| 21 " | $1\frac{3}{4}$ " | 132 " | 228 |
| 24 " | 2 " | 175 " | 172 |
| 30 " | $2\frac{1}{2}$ " | 260 " | 116 |

TERRA COTTA FLUE-LININGS.

| Inside Measure. | Outside Measure. | Form. | Weight per Foot. | Feet to Car Load of 15 Tons. |
|---------------------------------------|-------------------------------------|--------|------------------|------------------------------|
| 5 inches | 7 inches | Round | 14 pounds | 2144 |
| 6 " | 8 " | " | 19 " | 1580 |
| 8 " | 10 " | " | 22 " | 1364 |
| 10 " | 12 $\frac{1}{2}$ " | " | 30 " | 1000 |
| 3 $\frac{1}{2}$ × 7 $\frac{1}{2}$ " | 4 $\frac{1}{2}$ × 8 $\frac{1}{2}$ " | Square | 10 " | 3000 |
| 7 × 7 " | 8 $\frac{1}{2}$ × 8 $\frac{1}{2}$ " | " | 20 " | 1500 |
| 7 × 11 $\frac{1}{2}$ " | 8 $\frac{1}{2}$ × 13 " | " | 30 " | 1000 |
| 7 × 15 $\frac{1}{2}$ " | 8 $\frac{1}{2}$ × 17 " | " | 33 " | 910 |
| 11 $\frac{1}{2}$ × 11 $\frac{1}{2}$ " | 13 × 13 " | " | 37 " | 810 |
| 11 $\frac{1}{2}$ × 15 $\frac{1}{2}$ " | 13 × 17 " | " | 40 " | 750 |
| 15 $\frac{1}{2}$ × 15 $\frac{1}{2}$ " | 17 × 17 " | " | 50 " | 600 |

Gas-piping, etc.—The gas-pipes in a building should be wrought iron or soft steel of standard make. The fittings should be galvanized, as the zinc coating makes the fittings more solid and durable. Each piece of pipe before being put in place should be looked or blown through to see if it is clear of any stoppage. No gas-fitters' cement should be permitted to be used in any joints except the caps on the outlets. In running a line of pipe it should run in as direct a line and with as few turns as possible. All pipes should be run with a uniform fall to the riser or starting-point, so that any water which may gather will run back to the main. In taking off branches or outlets from any run of pipe they should always be taken out at the side and all drop lights should be taken from a tee fitting in a short branch and the branch extended about a foot beyond the tee and capped; this insures the drop to hang plumb.

Bracket lights should always be brought from the floor below, as gas should never be made to run down a pipe where it is possible to do otherwise, where convenient separate risers should be run to each floor and controlled by stopcocks in the cellar where they can be got at. When pipes cross wooden beams or joists, the pipes should be run across the top of the beams and the beams notched as little as possible, and not more than two feet from a bearing.

When the pipes are all in place the superintendent should go over them and see that all outlets are provided for, and that all pipe are laid in the best possible manner. He should then have them tested to 8 or 10 pounds pressure, which should be left on for about twenty-five minutes. After the test is

made, a good scheme is to leave the pressure on and loosen the cap on each outlet separately and notice if the pressure goes down as each one is loosened; this will show if the pipes are all clear, or if any of them contains any obstruction. The test on the pipes should be repeated just before the plastering is commenced, and again when it is finished.

The following table shows the size of pipes and number of burners which they will supply:

| Greatest Number of Feet to be Run. | Size of Pipe. | Greatest Number of Burners to be Supplied. | Greatest Number of Feet to be Run. | Size of Pipe. | Greatest Number of Burners to be Supplied. |
|------------------------------------|------------------------|--|------------------------------------|------------------------|--|
| 20 feet | $\frac{3}{4}$ inch | 2 | 150 feet | 1 $\frac{1}{2}$ inches | 70 |
| 30 " | " | 4 | 200 " | 2 " | 140 |
| 50 " | " | 15 | 300 " | 2 $\frac{1}{2}$ " | 225 |
| 70 " | 1 " | 25 | 400 " | 3 " | 300 |
| 100 " | 1 $\frac{1}{2}$ inches | 40 | 500 " | 4 " | 500 |

Computing the Pressure.—Pressures which have been measured in inches of water or mercury may be translated in pounds per square inch or foot by multiplying the reading by the following figures:

One inch of water at 62° equals 5.2 pounds per square foot.

One inch of water at 62° equals 0.0361 pound per square inch.

One inch of mercury at 62° equals 0.4897 pound per square inch.

Pressures per square inch or square foot may be converted into inches or feet of water, or inches of mercury, by multiplying the pressure by the following figures:

One pound per square foot equals 0.1923 inch of water.

One pound per square inch equals 27.7 inches of water at 62°.

One pound per square inch equals 2.042 inches of mercury at 62°.

Increase of Pressure.—The increase of pressure in each 10 feet of rise in pipes with gas of various densities is as follows:

| | | | | | | | | |
|---|---|-------|-------|------|------|------|------|------|
| Rise in pressure (ins. of water). | 0 | .0147 | .0293 | .044 | .058 | .073 | .088 | .102 |
| Density of gas. | 1 | .9 | .8 | .7 | .6 | .5 | .4 | .3 |

Example.—The pressure in the basement at the meter is 1.2 of water; what will be the pressure at the sixth story, 70 feet above, the density of the gas being .4?

Solution.—The table shows that the increase will be 0.088 inch for each 10 feet of rise, therefore 0.088×7 equals 0.616 inch increase. Then the pressure at the sixth story equals $1.2 + 0.616 = 1.816$.

CAPACITY OF GAS-PIPES UNDER A PRESSURE OF 10.4 LBS. PER SQUARE FOOT.

| Diameter of Pipe in Inches. | Maximum Length in Feet. | Capacity per Hour. | |
|--------------------------------|----------------------------|--------------------------|------------------------------|
| | | Coal Gas, Cubic Feet. | Gasoline Gas, Cubic Feet. |
| $\frac{1}{4}$ | 6 | 10 | ... |
| $\frac{1}{2}$ | 20 | 15 | 10 |
| $\frac{3}{4}$ | 30 | 30 | 20 |
| 1 | 50 | 100 | 75 |
| $1\frac{1}{4}$ | 70 | 175 | 125 |
| $1\frac{1}{2}$ | 100 | 300 | 200 |
| $1\frac{3}{4}$ | 150 | 500 | 350 |
| 2 | 200 | 1000 | 700 |
| $2\frac{1}{2}$ | 300 | 1500 | 1100 |
| 3 | 450 | 2250 | 1500 |
| 4 | 600 | 3750 | 2500 |

Flow of Gas in Pipes.—If d =diameter of pipe in inches; Q =quantity of gas delivered in cubic feet per hour; l =length of pipe in yards; h =pressure in inches of water-column; s =specific gravity of the gas, air being one; then

$$Q = 1000 \sqrt{\frac{d^5 h}{sl}}; \text{ (Molesworth);}$$

$$Q = 1350 d^2 \sqrt{\frac{dh}{sl}} \text{ (King's Treatise on Coal-gas);}$$

$$Q = 1290 \sqrt{\frac{d^5 h}{d(s+l)}} \text{ (J. P. Gill, } Am. Gas-light Jour., 1894).$$

Mr. Gill's formula is said to be based on experimental data, and to make allowance for obstructions by tar, etc., that tend to check the flow of gas through the pipe.

An experiment made by Mr. Klegg, in London, on a 4-inch pipe 6 miles long gave a discharge that corresponds very closely with that computed by the use of Molesworth's formula.

MAXIMUM SUPPLY OF GAS THROUGH PIPES IN CUBIC FEET
PER HOUR, SPECIFIC GRAVITY BEING 0.45.

Formula, $Q = 1000\sqrt{d^5h + sl}$. (Molesworth.)

LENGTH OF PIPE = 10 YARDS.

| Diameter of Pipe in Inches. | [Pressure by the Water-gauge in Inches. | | | | | | | | | |
|-----------------------------|---|-----|------|------|------|------|------|------|------|------|
| | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
| 1/8 | 13 | 18 | 22 | 26 | 29 | 31 | 34 | 36 | 38 | 41 |
| 1/4 | 26 | 37 | 46 | 53 | 59 | 64 | 70 | 74 | 79 | 83 |
| 3/8 | 73 | 103 | 126 | 145 | 162 | 187 | 192 | 205 | 218 | 230 |
| 1/2 | 149 | 211 | 258 | 298 | 333 | 365 | 394 | 422 | 447 | 471 |
| 5/8 | 260 | 368 | 451 | 521 | 582 | 638 | 689 | 737 | 781 | 823 |
| 1 | 411 | 581 | 711 | 821 | 918 | 1006 | 1082 | 1162 | 1232 | 1299 |
| 2 | 843 | 112 | 1460 | 1686 | 1886 | 2066 | 2231 | 2385 | 2530 | 2667 |

LENGTH OF PIPE = 100 YARDS.

| Diameter of Pipe in Inches. | Pressure by the Water-gauge in Inches. | | | | | | | | | | |
|-----------------------------|--|------|------|------|------|------|------|------|------|------|------|
| | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.75 | 1.0 | 1.25 | 1.5 | 2.0 | 2.5 |
| 1/8 | 8 | 12 | 14 | 17 | 19 | 23 | 26 | 29 | 32 | 36 | 42 |
| 1/4 | 23 | 32 | 42 | 46 | 51 | 63 | 73 | 81 | 89 | 103 | 115 |
| 3/8 | 47 | 67 | 82 | 94 | 105 | 129 | 149 | 167 | 183 | 211 | 236 |
| 1/2 | 82 | 116 | 143 | 165 | 184 | 225 | 260 | 291 | 319 | 368 | 412 |
| 5/8 | 130 | 184 | 225 | 260 | 290 | 356 | 411 | 459 | 503 | 581 | 649 |
| 1 | 267 | 377 | 462 | 533 | 596 | 730 | 843 | 943 | 1033 | 1193 | 1333 |
| 1 1/4 | 466 | 659 | 807 | 932 | 1042 | 1276 | 1473 | 1647 | 1804 | 2083 | 2329 |
| 1 1/2 | 735 | 1039 | 1270 | 1470 | 1643 | 2012 | 2323 | 2598 | 2846 | 3286 | 3674 |
| 2 | 1080 | 1528 | 1871 | 2161 | 2416 | 2958 | 3416 | 3820 | 4184 | 4831 | 5402 |
| 3 | 1508 | 2133 | 2613 | 3017 | 3373 | 4131 | 4770 | 5333 | 5842 | 6746 | 7542 |

LENGTH OF PIPE = 1000 YARDS.

| Diameter of Pipe in Inches. | Pressure by the Water-gauge in Inches. | | | | | | |
|-----------------------------|--|------|------|------|------|------|------|
| | 0.5 | 0.75 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 1 | 33 | 41 | 47 | 58 | 67 | 75 | 82 |
| 1 1/4 | 92 | 113 | 130 | 159 | 184 | 205 | 226 |
| 1 1/2 | 189 | 231 | 267 | 327 | 377 | 422 | 462 |
| 2 | 329 | 403 | 466 | 571 | 659 | 737 | 807 |
| 3 | 520 | 636 | 735 | 900 | 1039 | 1162 | 1273 |
| 4 | 1067 | 1306 | 1508 | 1847 | 2133 | 2385 | 2613 |
| 5 | 1863 | 2282 | 2635 | 3227 | 3727 | 4167 | 4564 |
| 6 | 2939 | 3600 | 4157 | 5091 | 5879 | 6573 | 7200 |

MAXIMUM SUPPLY OF GAS THROUGH PIPES, ETC.—(Continued).

LENGTH OF PIPE=5000 YARDS.

| Diameter of Pipe in Inches. | Pressure by the Water-gauge in Inches. | | | | |
|-----------------------------|--|-------|-------|-------|-------|
| | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |
| 2 | 119 | 146 | 169 | 189 | 207 |
| 3 | 329 | 402 | 465 | 520 | 569 |
| 4 | 675 | 826 | 955 | 1067 | 1168 |
| 5 | 1179 | 1443 | 1667 | 1863 | 2041 |
| 6 | 1859 | 2277 | 2629 | 2939 | 3220 |
| 7 | 2733 | 3347 | 3865 | 4321 | 4734 |
| 8 | 3816 | 4674 | 5397 | 6034 | 6610 |
| 9 | 5123 | 6274 | 7245 | 8100 | 8873 |
| 10 | 6667 | 8165 | 9428 | 10541 | 11547 |
| 12 | 10516 | 12880 | 14872 | 16628 | 18215 |

Where there is apt to be trouble from frost no pipe less than $\frac{3}{4}$ inch should be used, and in extremely cold climates the smallest size should not be less than 1 inch.

To provide for the resistance due to bends, one rule is to allow a pressure of 0.204 inch of water-column for each right-angled elbow.

AQUEOUS VAPOR CONTAINED IN 1000 CUBIC FEET OF GAS AT INDICATED TEMPERATURE.

| Temp. Degrees. | Volume Aqueous Vapor. | Temp. Degrees. | Volume Aqueous Vapor. | Temp. Degrees. | Volume Aqueous Vapor. |
|----------------|-----------------------|----------------|-----------------------|----------------|-----------------------|
| 40 | 9.33 | 54 | 15.33 | 68 | 24.06 |
| 41 | 9.73 | 55 | 15.86 | 69 | 24.83 |
| 42 | 10.13 | 56 | 16.40 | 70 | 25.66 |
| 43 | 10.53 | 57 | 16.93 | 71 | 26.53 |
| 44 | 10.93 | 58 | 17.53 | 72 | 27.40 |
| 45 | 11.33 | 59 | 18.10 | 73 | 28.30 |
| 46 | 11.73 | 60 | 18.66 | 74 | 29.23 |
| 47 | 12.13 | 61 | 19.23 | 75 | 30.20 |
| 48 | 12.53 | 62 | 19.80 | 76 | 31.20 |
| 49 | 12.93 | 63 | 20.50 | 77 | 32.20 |
| 50 | 13.33 | 64 | 21.20 | 78 | 33.23 |
| 51 | 13.80 | 65 | 21.90 | 79 | 34.23 |
| 52 | 14.26 | 66 | 22.60 | 80 | 35.33 |
| 53 | 14.80 | 67 | 23.30 | 81 | 36.43 |



NATIONAL TUBE COMPANY.
BLACK OR GALVANIZED STANDARD WEIGHT PIPE.

| Nominal. | Diameter | | Thick-ness. | Circumference. | | Transverse Areas. | | | Nominal Weight per Foot. Pounds. | Threads per Inch |
|----------|-----------|-----------|-------------|----------------|-----------|-------------------|-----------|--------|----------------------------------|------------------|
| | External. | Internal. | | External. | Internal. | External. | Internal. | Metal. | | |
| 1 | .405 | .269 | .068 | 1.272 | .845 | .1288 | .0568 | .0720 | .241 | 27 |
| 1 | .540 | .364 | .088 | 1.696 | 1.144 | .2290 | .1041 | .1249 | .42 | 18 |
| 1 | .675 | .493 | .091 | 2.121 | 1.549 | .3578 | .1909 | .1669 | .559 | 18 |
| 1 | .840 | .622 | .109 | 2.639 | 1.954 | .5542 | .3039 | .2503 | .837 | 14 |
| 1 | 1.050 | .824 | .113 | 3.299 | 2.589 | .8659 | .5333 | .3326 | 1.115 | 14 |
| 1 | 1.315 | 1.047 | .134 | 4.131 | 3.289 | 1.3581 | .8609 | .4972 | 1.668 | 11½ |
| 1 | 1.660 | 1.380 | .140 | 5.215 | 4.335 | 2.1642 | 1.4957 | .6685 | 2.244 | 11 |
| 1 | 1.900 | 1.610 | .145 | 5.969 | 5.058 | 2.8353 | 2.0358 | .7995 | 2.678 | 11 |
| 2 | 2.375 | 2.067 | .154 | 7.461 | 6.494 | 4.4301 | 3.3556 | 1.074 | 3.609 | 8 |
| 2 | 2.875 | 2.467 | .204 | 9.032 | 7.750 | 6.4918 | 4.7800 | 1.712 | 5.739 | 8 |
| 3 | 3.500 | 3.066 | .217 | 10.996 | 9.632 | 9.6211 | 7.3827 | 2.680 | 7.536 | 8 |
| 3 | 3.500 | 3.066 | .226 | 12.566 | 11.146 | 12.566 | 9.886 | 2.680 | 9.001 | 8 |
| 4 | 4.000 | 3.548 | .237 | 14.137 | 12.648 | 15.904 | 12.730 | 3.174 | 10.665 | 8 |
| 4 | 4.000 | 3.548 | .246 | 15.708 | 14.162 | 19.635 | 15.960 | 3.675 | 12.34 | 8 |
| 4 | 4.500 | 4.026 | .259 | 17.477 | 15.849 | 24.306 | 19.985 | 4.321 | 14.502 | 8 |
| 5 | 5.563 | 5.045 | .280 | 20.813 | 19.054 | 34.472 | 28.886 | 5.586 | 18.762 | 8 |
| 6 | 6.625 | 6.065 | .301 | 23.955 | 22.063 | 45.664 | 38.743 | 6.921 | 23.271 | 8 |
| 7 | 7.625 | 7.023 | .322 | 27.096 | 25.073 | 58.426 | 50.021 | 8.405 | 28.177 | 8 |
| 8 | 8.625 | 7.981 | .344 | 30.238 | 28.076 | 72.760 | 62.722 | 10.04 | 33.701 | 8 |
| 9 | 9.625 | 8.937 | .366 | 33.772 | 31.472 | 90.763 | 78.822 | 11.94 | 40.065 | 8 |
| 10 | 10.750 | 10.018 | .375 | 36.913 | 34.558 | 108.43 | 95.034 | 13.40 | 45.95 | 8 |
| 11 | 11.750 | 11.000 | .375 | 40.055 | 37.699 | 127.68 | 113.09 | 14.59 | 48.985 | 8 |
| 12 | 12.750 | 12.000 | .375 | | | | | | | |

Allow variation in weight per foot of 5 per cent above and 5 per cent below. Cannot cut closer to length than 1½ inch. Shipped threads and couplings unless otherwise ordered.

NATIONAL TUBE COMPANY.
STANDARD EXTRA STRONG PIPE.

| Nominal. | Diameter. | | Thick-ness. | Circumference. | | Transverse Areas. | | | Nominal Weight per Foot, Pounds. | Threads per Inch. |
|----------|-----------|-----------|-------------|----------------|-----------|-------------------|-----------|--------|----------------------------------|-------------------|
| | External. | Internal. | | External. | Internal. | External. | Internal. | Metal. | | |
| 1 1/4 | .405 | .205 | .100 | 1.272 | .644 | 1.29 | .033 | .096 | .29 | 27 |
| 1 1/2 | .540 | .294 | .123 | 1.696 | .924 | .229 | .068 | .161 | .54 | 18 |
| 2 | .675 | .421 | .127 | 2.121 | 1.323 | .358 | .139 | .219 | .74 | 14 |
| 2 1/2 | .840 | .542 | .149 | 2.639 | 1.703 | .554 | .231 | .323 | 1.09 | 14 |
| 3 | 1.050 | .736 | .157 | 3.299 | 2.312 | .866 | .425 | .441 | 1.39 | 11 1/2 |
| 3 1/2 | 1.315 | .951 | .182 | 4.131 | 2.988 | 1.358 | .710 | .648 | 2.17 | 11 1/2 |
| 4 | 1.660 | 1.272 | .194 | 5.215 | 3.996 | 2.164 | 1.271 | .893 | 3.00 | 8 |
| 4 1/2 | 1.900 | 1.494 | .203 | 5.969 | 4.694 | 2.835 | 1.753 | 1.082 | 3.63 | 8 |
| 5 | 2.375 | 1.933 | .221 | 7.461 | 6.073 | 4.430 | 2.935 | 1.495 | 5.02 | 8 |
| 5 1/2 | 2.875 | 2.315 | .280 | 9.032 | 7.273 | 6.492 | 4.209 | 2.283 | 7.67 | 8 |
| 6 | 3.500 | 2.892 | .304 | 10.996 | 9.086 | 9.621 | 6.569 | 3.052 | 10.25 | 8 |
| 6 1/2 | 4.000 | 3.358 | .321 | 12.566 | 10.549 | 12.566 | 8.856 | 3.710 | 12.47 | 8 |
| 7 | 4.500 | 3.818 | .341 | 14.137 | 11.995 | 15.904 | 11.449 | 4.455 | 14.97 | 8 |
| 7 1/2 | 5.000 | 4.280 | .360 | 15.708 | 13.446 | 19.635 | 14.387 | 5.248 | 18.22 | 8 |
| 8 | 5.563 | 4.813 | .375 | 17.477 | 15.120 | 24.306 | 18.193 | 6.113 | 20.54 | 8 |
| 8 1/2 | 6.625 | 5.751 | .437 | 20.813 | 18.067 | 34.472 | 25.976 | 8.496 | 28.58 | 8 |
| 9 | 7.625 | 6.625 | .500 | 23.955 | 20.813 | 45.664 | 34.472 | 11.192 | 37.67 | 8 |
| 9 1/2 | 8.625 | 7.625 | .500 | 27.096 | 23.955 | 58.426 | 45.664 | 12.762 | 43.00 | 8 |
| 10 | 9.625 | 8.625 | .500 | 30.238 | 27.096 | 72.760 | 58.426 | 14.334 | 48.25 | 8 |
| 10 1/2 | 10.750 | 9.750 | .500 | 33.772 | 30.631 | 90.763 | 74.662 | 16.101 | 54.25 | 8 |
| 12 | 12.750 | 11.750 | .500 | 40.055 | 36.914 | 127.68 | 108.43 | 19.25 | 65.00 | 8 |

Allow variation in weight per foot of 5 per cent above and 5 per cent below standard. Cannot cut to length closer than 1/4 inch. Shipped plain ends unless otherwise ordered. Where extra-strong pipe is ordered with threads and couplings, our regular line-pipe couplings will be furnished unless otherwise specified.

NATIONAL TUBE COMPANY.
STANDARD DOUBLE EXTRA STRONG PIPE.

| Nominal. | Diameter. | | Thick-ness. | Circumference. | | Transverse Areas. | | | Nominal Weight per Foot. Pounds. | Threads per Inch. |
|---------------|-----------|-----------|-------------|----------------|-----------|-------------------|-----------|--------|----------------------------------|-------------------|
| | External. | Internal. | | External. | Internal. | External. | Internal. | Metal. | | |
| $\frac{1}{2}$ | .840 | .244 | .298 | 2.639 | .767 | .554 | .047 | .507 | 1.7 | 14 |
| $\frac{3}{4}$ | 1.050 | .422 | .314 | 3.299 | 1.326 | .866 | .140 | .726 | 2.44 | 14 |
| 1 | 1.315 | .587 | .364 | 4.131 | 1.844 | 1.358 | .271 | 1.087 | 3.65 | 11½ |
| 1½ | 1.660 | .885 | .388 | 5.215 | 2.780 | 2.164 | .615 | 1.549 | 5.2 | 11 |
| 2 | 1.900 | 1.088 | .406 | 5.969 | 3.418 | 2.835 | .930 | 1.905 | 6.4 | 8 |
| 2½ | 2.375 | 1.491 | .442 | 7.461 | 4.684 | 4.430 | 1.744 | 2.686 | 9.02 | 8 |
| 3 | 2.875 | 1.755 | .560 | 9.032 | 5.514 | 6.492 | 2.419 | 4.073 | 13.68 | 8 |
| 3½ | 3.500 | 2.284 | .608 | 10.996 | 7.176 | 9.621 | 4.097 | 5.524 | 18.56 | 8 |
| 4 | 4.000 | 2.716 | .642 | 12.566 | 8.533 | 12.566 | 5.794 | 6.772 | 22.75 | 8 |
| 4½ | 4.500 | 3.136 | .682 | 14.137 | 9.852 | 15.904 | 7.724 | 8.180 | 27.48 | 8 |
| 5 | 5.000 | 3.564 | .718 | 15.708 | 11.197 | 19.635 | 9.976 | 9.659 | 32.53 | 8 |
| 5½ | 5.563 | 4.063 | .750 | 17.477 | 12.764 | 24.306 | 12.965 | 11.341 | 38.12 | 8 |
| 6 | 6.625 | 4.875 | .875 | 20.813 | 15.315 | 34.472 | 18.665 | 15.807 | 53.11 | 8 |
| 7 | 7.625 | 5.875 | .875 | 23.955 | 18.457 | 45.664 | 27.109 | 18.555 | 62.38 | 8 |
| 8 | 8.625 | 6.875 | .875 | 27.096 | 21.598 | 58.426 | 37.122 | 21.304 | 71.62 | 8 |

Allow variation of 5 per cent above and 5 per cent below standard in weight per foot. Cannot cut to length closer than $\frac{1}{8}$ inch. Shipped plain ends unless otherwise ordered.

How Steel and Wrought-iron Pipes are Made.¹—

LAP-WELDING.—The plate for the larger sizes of pipe is first laid upon a travelling-table and the edges scarfed or bevelled. It is then heated in a bending furnace and rolled up into pipe form with the scarfed edges overlapping. The plates for the smaller sizes are formed up by being drawn through the die shown in the accompanying illustration. This consists of a stout cast-iron bending die the front half of which next the furnace door is flared out to receive the plate. Inside the die is a mandrel of the shape shown in the smaller engraving, whose rear portion is of about the size of the finished pipe. As the plate is pushed out of the furnace it is drawn by a pair of tongs through the die the flaring sides of which curve the plate until its edges meet and lap as they pass through the tubular end of the die. The plates, now bent up into form and known as skelp, are heated in a gas-fired welding furnace, and when they have reached a welding heat the skelp is pushed through the door at the back of the furnace into the welding-rolls, which are located just outside the door. The rolls, which are concave, are curved to the desired radius, and between them, held in position by a long bar, is a "ball," or mandrel, of the same diameter as the inside of the pipe. As the skelp passes through the rolls, its lapping edges are squeezed together between the rolls and the mandrel and a perfect weld is made. Each piece of pipe is carefully examined and all doubtful welds are rejected. The rough pipe then goes through the sizing rolls, in which it is brought to the exact diameter. Then it passes to the cross-straightening rolls the axes of which are inclined at an angle, as shown in the accompanying illustration. By this time it is perfectly true and straight, and to prevent it from warping as it cools, it is rolled and conveyed on a cooling-table to a straightening-machine, where it receives its final straightening in dies controlled by hydraulic pressure. The ends are then cut off, and after being threaded and the coupling put on, the pipe is tested in a hydraulic testing-machine, the smaller sizes at from 600 to 1500 pounds, the larger at from 500 to 750 pounds to the square inch. For oil-well tubing the tests run as high as 2500 pounds to the square inch.

BUTT-WELDING.—The smaller sizes of pipes are butt-welded. The plates, which are not scarfed as in the larger pipe, are

¹ *Scientific American.*

heated in the furnace, and when raised to a welding heat are drawn through a bell-shaped die the diameter of which is a little less than that of the skelp. The pressure thus induced is sufficient to squeeze the edges together and form the plate into a perfectly welded pipe.

WEIGHTS OF CAST-IRON PIPE IN POUNDS.

Standard Water-pipe.

| Lbs. Lead per Joint. | Ounces Jute per Joint. | Size Pipe. | Thick-ness. | Weight per Foot with Bell. | Weight per Length with Bell. | Weight of Bell. |
|----------------------|------------------------|------------|-------------------|----------------------------|------------------------------|-----------------|
| 3 | 2.8 | 3" | $\frac{15}{16}$ " | 17 | 204 | 12 |
| 5.5 | 3.5 | 4" | $\frac{15}{16}$ " | 22 | 264 | 12 |
| 8 | 5.0 | 6" | $\frac{3}{4}$ " | 34 | 408 | 24 |
| 11 | 7.0 | 8" | $\frac{17}{32}$ " | 47 | 564 | 36 |
| 14 | 8.5 | 10" | $\frac{3}{8}$ " | 64 | 768 | 48 |
| 18 | 11.0 | 12" | $\frac{15}{16}$ " | 82 | 984 | 60 |
| 21 | 13.0 | 14" | $\frac{11}{16}$ " | 105 | 1260 | 72 |
| 24 | 15.0 | 16" | $\frac{3}{4}$ " | 133 | 1596 | 108 |
| 27 | 16.0 | 18" | $\frac{13}{16}$ " | 160 | 1920 | 120 |
| 31 | 20.0 | 20" | $\frac{15}{16}$ " | 190 | 2280 | 144 |
| 36 | 24.0 | 24" | 1" | 260 | 3120 | 180 |
| 50 | 33.0 | 30" | $1\frac{1}{8}$ " | 360 | 4320 | 204 |
| 76 | 48.0 | 36" | $1\frac{1}{4}$ " | 488 | 5856 | 360 |
| 95 | 58.0 | 42" | $1\frac{3}{8}$ " | 625 | 7500 | 468 |
| 112 | 70.0 | 48" | $1\frac{5}{16}$ " | 830 | 9960 | 648 |
| 170 | 100.0 | 60" | $1\frac{7}{8}$ " | 1220 | 14640 | 960 |

Standard Gas-pipe.

| Lbs. Lead per Joint. | Ounces Jute per Joint. | Size Pipe. | Thick-ness. | Weight per Foot with Bell. | Weight per Length with Bell. | Weight of Bell. |
|----------------------|------------------------|------------|-------------------|----------------------------|------------------------------|-----------------|
| 3 | 2.8 | 3" | $\frac{25}{64}$ " | 14 | 168 | 12 |
| 5.5 | 3.5 | 4" | $\frac{15}{64}$ " | 19 | 228 | 12 |
| 8 | 5.0 | 6" | $\frac{3}{32}$ " | 30.5 | 366 | 18 |
| 11 | 7.0 | 8" | $\frac{15}{64}$ " | 41 | 492 | 24 |
| 14 | 8.5 | 10" | $\frac{3}{32}$ " | 56 | 672 | 48 |
| 18 | 11.0 | 12" | $\frac{15}{64}$ " | 74 | 888 | 60 |
| 21 | 13.0 | 14" | $\frac{3}{16}$ " | 92 | 1104 | 72 |
| 24 | 15.0 | 16" | $\frac{11}{64}$ " | 112 | 1344 | 96 |
| 27 | 16.0 | 18" | $\frac{3}{16}$ " | 133 | 1596 | 108 |
| 31 | 20.0 | 20" | $\frac{11}{16}$ " | 159 | 1908 | 120 |
| 36 | 24.0 | 24" | $\frac{13}{64}$ " | 205 | 2460 | 132 |
| 50 | 33.0 | 30" | $\frac{3}{8}$ " | 275 | 3300 | 168 |
| 76 | 48.0 | 36" | $\frac{11}{16}$ " | 368 | 4416 | 304 |

The above tables show the weights which have been adopted by the United States Cast Iron Pipe and Foundry Company as standard weights for water- and gas-pipe respectively for ordinary service.

LIST OF STANDARD SPECIALS.

(Approximate weight.)

| Size in In. | Wt. in Lbs. | Size in In. | Wt. in Lbs. | Size in In. | Wt. in Lbs. |
|-------------|-------------|-------------|-------------|----------------------|-------------|
| Crosses. | | Tees. | | Tees. | |
| 2 | 40 | 2 | 28 | 24×12 | 1425 |
| 3 | 110 | 3 | 85 | 24×8 | 1375 |
| 3×2 | 90 | 3×2 | 76 | 24×6 | 1450 |
| 4 | 140 | 4 | 110 | 30 | 3025 |
| 4×3 | 114 | 4×3 | 120 | 30×24 | 2640 |
| 4×2 | 90 | 4×2 | 87 | 30×20 | 2380 |
| 6 | 200 | 6 | 170 | 30×12 | 2035 |
| 6×4 | 160 | 6×4 | 145 | 30×10 | 2050 |
| 6×3 | 160 | 6×3 | 145 | 30×6 | 1825 |
| 8 | 330 | 6×2 | 75 | 36 | 5140 |
| 8×6 | 280 | 8 | 290 | 36×30 | 4200 |
| 8×4 | 265 | 8×6 | 280 | 36×12 | 4050 |
| 8×3 | 225 | 8×4 | 220 | | |
| 10 | 595 | 8×3 | 220 | 45° Branch Pipes. | |
| 10×8 | 415 | 10 | 390 | 3 | 90 |
| 10×6 | 430 | 10×8 | 345 | 4 | 125 |
| 10×4 | 390 | 10×6 | 370 | 6 | 205 |
| 10×3 | 370 | 10×4 | 350 | 6×6×4 | 145 |
| 12 | 740 | 10×3 | 330 | 8 | 330 |
| 12×10 | 650 | 12 | 600 | 8×6 | 330 |
| 12×8 | 620 | 12×10 | 555 | 24 | 2765 |
| 12×6 | 540 | 12×8 | 530 | 24×24×20 | 2145 |
| 12×4 | 525 | 12×6 | 525 | 30 | 4170 |
| 12×3 | 495 | 12×4 | 550 | 36 | 10300 |
| 14×10 | 750 | 14×12 | 650 | Sleeves. | |
| 14×8 | 625 | 14×10 | 650 | 2 | 10 |
| 14×6 | 570 | 14×8 | 575 | 3 | 30 |
| 16 | 1100 | 14×6 | 545 | 4 | 45 |
| 16×14 | 1070 | 14×4 | 525 | 6 | 100 |
| 16×12 | 1000 | 14×3 | 490 | 8 | 120 |
| 16×10 | 1010 | 16 | 790 | 10 | 140 |
| 16×8 | 825 | 16×14 | 850 | 12 | 190 |
| 16×6 | 700 | 16×12 | 850 | 14 | 208 |
| 16×4 | 690 | 16×10 | 825 | 16 | 350 |
| 18 | 1560 | 16×8 | 755 | 18 | 340 |
| 20 | 1790 | 16×6 | 680 | 20 | 400 |
| 20×12 | 1370 | 16×4 | 655 | 24 | 710 |
| 20×10 | 1225 | 18 | 1235 | 30 | 965 |
| 20×8 | 1335 | 20 | 1475 | 36 | 1200 |
| 20×6 | 1000 | 20×16 | 1115 | | |
| 20×4 | 1000 | 20×12 | 1025 | | |
| 24 | 2400 | 20×10 | 1090 | | |
| 24×20 | 2020 | 20×8 | 1070 | | |
| 24×6 | 1340 | 20×6 | 875 | | |
| 30×20 | 2635 | 20×4 | 845 | | |
| 30×12 | 2250 | 24×10 | 1465 | | |
| 30×8 | 1995 | 24 | 2000 | | |
| | | 24×20 | 1730 | | |

hooked together the hook joints are beaten down with a wooden mallet and then soldered.

When it is desired to make some allowance for contraction and expansion the sheets should be fastened with tin clips nailed to the roof as shown by Fig. 228; in this way there are no nails through the sheets of tin, but they are held in place by the clips. Fig. 229 shows a section of the joint.

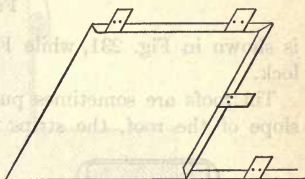


FIG. 228.

Standing seam roofs are also fastened with clips nailed to the sheathing and turned down in the standing seam. Fig. 230, 1, 2, 3, shows a standing seam roof in the different stages of construction.

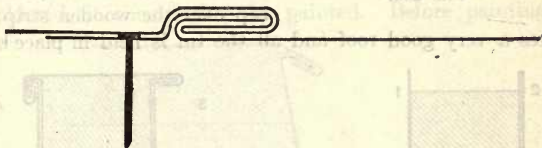


FIG. 229.

Fig. 230, at 5, shows the joint turned down in a flat lock joint.

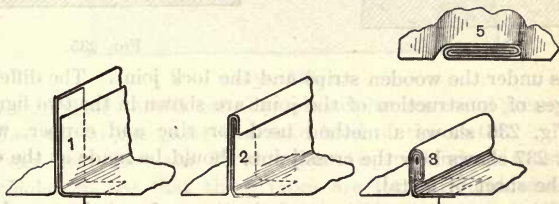


FIG. 230.

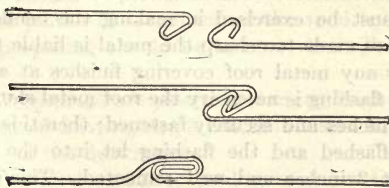


FIG. 231.

In standing seam roofs or any roof where the tin is laid in long lengths the cross-joints should be double-locked; this



FIG. 232.

is shown in Fig. 231, while Fig. 232 shows the ordinary single lock.

Tin roofs are sometimes put on in lengths running with the slope of the roof, the strips of tin being turned up and laid between strips of wood, as shown by Fig. 233. This method is used to make an allowance for expansion and contraction.

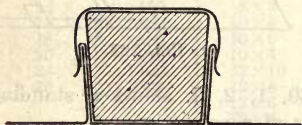


FIG. 233.

Figs. 234 and 235 show another method of putting a cap over the wooden strip; this makes a very good roof and all the tin is held in place by the

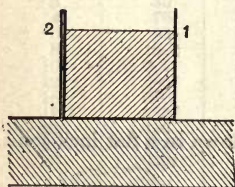


FIG. 234.

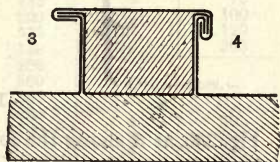


FIG. 235.

clips under the wooden strips and the lock joint. The different stages of construction of the joint are shown in the two figures.

Fig. 236 shows a method used for zinc and copper, while Fig. 237 shows how the cross-joints should be made at the ends of the sheet of metal.

A rise or step should be made in the roof and the two sheets of metal turned and locked as shown in Fig. 237. In working zinc care must be exercised in making the bends and angles, for if they are made too sharp the metal is liable to crack.

Wherever any metal roof covering finishes at a wall or any place where flashing is necessary the roof metal should be turned up 8 or 10 inches and securely fastened; then this metal should be counter-flashed and the flashing let into the joint of the wall at least 2 inches and well cemented. This is one part of the work that the superintendent should pay particular attention to, so as to get everything water-tight.

In all metal roofing the main points are to get the roof watertight and to make provision for expansion and contraction.

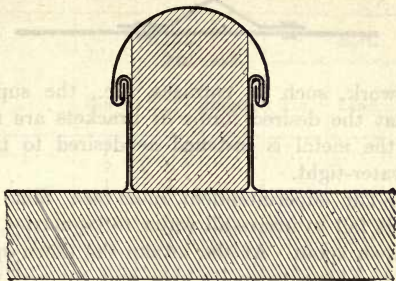


FIG. 236.

PAINING.—As soon as the roofing is in place and the joints all soldered, it should then be painted. Before painting the

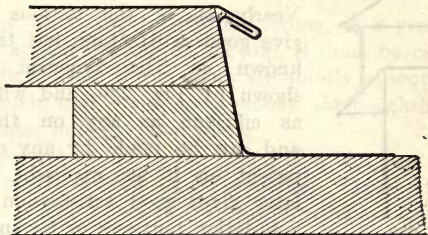


FIG. 237.

superintendent should see that all surplus resin and grease are cleaned off so the paint can take hold of the metal.

VENT AND HOT-AIR PIPES.—The superintendent must be particular to see that these pipes are located right and the openings put at the proper height. When the opening is at the bottom it should be just above the wood base, so the flange of the register plate will set on top of the wood base. In vent-pipes the top opening should be as near the ceiling or cornice as possible.

The hot-air openings are placed at various heights according to the system of heating employed, and these heights should be indicated on the drawings.

All pipes should run as direct and have as few turns as possible.

Any pipe having a width of 18 inches or over should be stiff-

ened by having ribs riveted across them about 2 feet apart. Fig. 238 shows a section of the rib.



FIG. 238.

In metal-work, such as cornices, etc., the superintendent must see that the desired forms or brackets are fastened securely and the metal is fastened as desired to the brackets and made water-tight.

GUTTERS.—The superintendent must see that all gutters have sufficient fall to insure all water to be carried to the conductor, or down spout. At the intake the down spout should be enlarged to about twice its area and covered with a wire screen to prevent leaves or dirt from entering the pipe.

VENTILATORS.—There are a number of various kinds and styles of ventilators on the market, the majority of which are sold under patent. Nearly all of the various ventilators give good satisfaction, but there is one, known as The Emerson Ventilator, shown by Fig. 239, and which is just as efficient as any on the market, and can be made by any one, as the patent on it has expired. This ventilator gives good satisfaction either for ventilation purposes or for smoke, as its shape insures an upward draft no matter

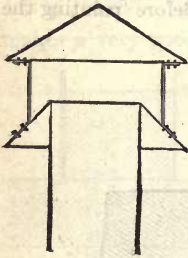


FIG. 239.

which way the wind is blowing.

TIN-PLATE.—Tin-plate is sheet iron, or steel coated with tin. Terne-plate is a plate of sheet iron coated with tin and lead and is inferior in quality to the tin-plate. The best plates are those known to be made by the "charcoal" or "old" process.

Plates coated with tin are known as "bright tin," while those coated with a mixture of tin and lead are known as "terne" or "dull" plates.

Plates are made in two thicknesses, IC and IX. The IC is No. 30 gauge and weighs .5 pounds to the square foot; the IX is No. 28 gauge and weighs .625 pounds per foot.

Imperfect sheets are called "wasters," and the letter W on a box after the IC or IX indicates that the box contains imperfect sheets.

COMPOSITION AND FUSING-POINTS OF SOLDER.

| Kind. | Hard. | | | Soft. | | | Fus- ing- point. |
|------------------------|-------|--------------|---------------|-------|-------|---------------|------------------------|
| | Zinc. | Cop- per. | Silver. | Tin. | Lead. | Bis- muth. | |
| Spelter, hardest..... | 1 | ..... | ..... | ..... | ..... | ..... | 700° |
| “ hard..... | 2 | 3 | ..... | ..... | ..... | ..... | 550° |
| “ soft..... | 1 | 1 | ..... | ..... | ..... | ..... | ..... |
| “ fine..... | 2 | 2 | $\frac{1}{4}$ | ..... | ..... | ..... | ..... |
| Silver, hard..... | ..... | 1 | $\frac{1}{4}$ | ..... | ..... | ..... | ..... |
| “ medium..... | ..... | 1 | 3 | ..... | ..... | ..... | ..... |
| “ soft..... | ..... | 1 | 2 | ..... | ..... | ..... | ..... |
| Plumbers', coarse..... | ..... | ..... | ..... | 1 | 3 | ..... | 480° |
| “ ordinary..... | ..... | ..... | ..... | 1 | 2 | ..... | 441° |
| “ fine..... | ..... | ..... | ..... | 2 | 3 | ..... | 400° |
| Tinners'..... | ..... | ..... | ..... | 1 | 1 | ..... | 370° |
| For tin pipe..... | ..... | ..... | ..... | 3 | 2 | ..... | 330° |
| “ “ “..... | ..... | ..... | ..... | 4 | 4 | 1 | ..... |

Solder may be tested by melting, when, if a great many bright spots appear floating on the top, it must be considered too soft or fine, while if the spots are totally absent, it contains too much lead. Tin spots about three-eighths of an inch in diameter indicate good solder.

Fluxes are used to aid in the fusion of solder and to clean the surface of the metals to be soldered. Those commonly used and the metals to which they are applied are as follows:

| Flux. | Metals to be Joined. |
|---|---|
| Rosin..... | Lead, tin, or tinned metals. |
| Tallow..... | Copper, iron, and lead. |
| Sal ammoniac..... | Dirty zinc, copper, and brass. |
| Muriatic or hydro- chloric acid..... | Clean zinc, copper, tin, or tinned metals. |
| Chloride of zinc..... | Lead, zinc, tin tubes, and tinned metals. |
| Borax..... | Iron, steel, copper, brass, gold, and platinum. |

SOLDERS TO USE FOR DIFFERENT METALS.

| Material to be Soldered. | Solder to Use. |
|------------------------------------|------------------------|
| Tin..... | Soft, coarse or fine. |
| Lead..... | Soft, coarse. |
| Brass, copper, iron, and zinc..... | “ “ |
| Pewter..... | Pewterers' or fusible. |
| Brass..... | Spelter, soft. |
| Copper and iron..... | “ “ or hard. |

TO SOLDER ALUMINUM.—The solder consists of aluminum 5 parts, antimony 5 parts, and zinc 90 parts. To make it harder, use a little more antimony and a little less zinc. The following is the process of making the solder and the method of using it:

The aluminum is first melted in a pot; the zinc is then added, and when this is melted, the antimony is added. The metal is then thoroughly puddled with sal ammoniac. When the surface of the metal is quite clear and white, it should be poured into sticks ready for use, the cinders being first removed.

To make joints in aluminum with this solder, the two or more surfaces to be joined should be cleaned, either by scraping or by using acid; and the surfaces should be well coated with the solder, special care being taken that the solder penetrates into the surface of the metal without burning it. The parts to be joined should then be placed together and kept in close contact. Heat should now be applied till the solder melts, any surplus that squeezes out being wiped off.

Table showing quantity of 14"×20" tin required to cover a given number of square feet with flat-seam tin roofing. A sheet of 14"×20" with $\frac{1}{2}$ " edges measures, when edged or folded, 13"×19", or 247 square inches. In the following all fractional parts of a sheet are counted a full sheet.

| Number of Sq. Ft. | Sheets Required. | Number of Sq. Ft. | Sheets Required. | Number of Sq. Ft. | Sheets Required. | Number of Sq. Ft. | Sheets Required. |
|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|
| 100 | 59 | 330 | 193 | 560 | 327 | 780 | 455 |
| 110 | 65 | 340 | 199 | 570 | 333 | 790 | 461 |
| 120 | 70 | 350 | 205 | 580 | 339 | 800 | 467 |
| 130 | 76 | 360 | 210 | 590 | 344 | 810 | 473 |
| 140 | 82 | 370 | 216 | 600 | 350 | 820 | 479 |
| 150 | 88 | 380 | 222 | 610 | 356 | 830 | 484 |
| 160 | 94 | 390 | 228 | 620 | 362 | 840 | 490 |
| 170 | 100 | 400 | 234 | 630 | 368 | 850 | 496 |
| 180 | 105 | 410 | 240 | 640 | 374 | 860 | 502 |
| 190 | 111 | 420 | 245 | 650 | 379 | 870 | 508 |
| 200 | 117 | 430 | 251 | 660 | 385 | 880 | 514 |
| 210 | 123 | 440 | 257 | 670 | 391 | 890 | 519 |
| 220 | 129 | 450 | 263 | 680 | 397 | 900 | 525 |
| 230 | 135 | 460 | 269 | 690 | 403 | 910 | 531 |
| 240 | 140 | 470 | 275 | 700 | 409 | 920 | 537 |
| 250 | 146 | 480 | 280 | 710 | 414 | 930 | 543 |
| 260 | 152 | 490 | 286 | 720 | 420 | 940 | 549 |
| 270 | 158 | 500 | 292 | 730 | 426 | 950 | 554 |
| 280 | 164 | 510 | 298 | 740 | 432 | 960 | 560 |
| 290 | 170 | 520 | 304 | 750 | 438 | 970 | 566 |
| 300 | 175 | 530 | 309 | 760 | 444 | 980 | 572 |
| 310 | 181 | 540 | 315 | 770 | 449 | 990 | 578 |
| 320 | 187 | 550 | 321 | | | | |

1000 square feet, 583 sheets. A box of 112 sheets 14"×20" will cover approximately 192 square feet.

U. S. STANDARD GAUGE. (FOR SHEET AND PLATE IRON AND STEEL.)

(Copy.)

(Public—Number 137.)

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 of Gauge. | Thickness. | | Weight. | | Number of 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. | |
| 0000000 | 1/2 | .5 | 320 | 20 | 0000000 |
| 000000 | 15/32 | .46875 | 300 | 18.75 | 000000 |
| 00000 | 7/16 | .4375 | 280 | 17.5 | 00000 |
| 0000 | 13/32 | .40625 | 260 | 16.25 | 0000 |
| 000 | 3/8 | .375 | 240 | 15 | 000 |
| 00 | 11/32 | .34375 | 220 | 13.75 | 00 |
| 0 | 5/16 | .3125 | 200 | 12.5 | 0 |
| 1 | 9/32 | .28125 | 180 | 11.25 | 1 |
| 2 | 17/64 | .265625 | 170 | 10.625 | 2 |
| 3 | 1/4 | .25 | 160 | 10 | 3 |
| 4 | 15/64 | .234375 | 150 | 9.375 | 4 |
| 5 | 7/32 | .21875 | 140 | 8.75 | 5 |
| 6 | 13/64 | .203125 | 130 | 8.125 | 6 |
| 7 | 3/16 | .1875 | 120 | 7.5 | 7 |
| 8 | 11/64 | .171875 | 110 | 6.875 | 8 |
| 9 | 5/32 | .15625 | 100 | 6.25 | 9 |
| 10 | 9/64 | .140625 | 90 | 5.625 | 10 |
| 11 | 1/8 | .125 | 80 | 5 | 11 |
| 12 | 7/64 | .109375 | 70 | 4.375 | 12 |
| 13 | 3/32 | .09375 | 60 | 3.75 | 13 |
| 14 | 5/64 | .078125 | 50 | 3.125 | 14 |
| 15 | 9/128 | .0703125 | 45 | 2.8125 | 15 |
| 16 | 1/16 | .0625 | 40 | 2.5 | 16 |
| 17 | 9/160 | .05625 | 36 | 2.25 | 17 |
| 18 | 1/20 | .05 | 32 | 2 | 18 |
| 19 | 7/160 | .04375 | 28 | 1.75 | 19 |
| 20 | 3/80 | .0375 | 24 | 1.5 | 20 |
| 21 | 11/320 | .034375 | 22 | 1.375 | 21 |
| 22 | 1/32 | .03125 | 20 | 1.25 | 22 |
| 23 | 9/320 | .028125 | 18 | 1.125 | 23 |
| 24 | 1/40 | .025 | 16 | 1 | 24 |
| 25 | 7/320 | .021875 | 14 | .875 | 25 |
| 26 | 3/160 | .01875 | 12 | .75 | 26 |
| 27 | 11/640 | .0171875 | 11 | .6875 | 27 |
| 28 | 1/64 | .015625 | 10 | .625 | 28 |
| 29 | 9/640 | .0140625 | 9 | .5625 | 29 |
| 30 | 1/80 | .0125 | 8 | .5 | 30 |
| 31 | 7/640 | .0109375 | 7 | .4375 | 31 |
| 32 | 13/1280 | .01015625 | 6½ | .40625 | 32 |
| 33 | 3/320 | .009375 | 6 | .375 | 33 |
| 34 | 11/1280 | .00859375 | 5½ | .34375 | 34 |
| 35 | 5/640 | .0078125 | 5 | .3125 | 35 |
| 36 | 9/1280 | .00703125 | 4½ | .28125 | 36 |
| 37 | 17/2560 | .006640625 | 4¼ | .265625 | 37 |
| 38 | 1/160 | .00625 | 4 | .25 | 38 |

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 articles 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.

TABLE OF WEIGHTS OF IRON AND STEEL SHEETING
PER SQUARE FOOT. (Kent.)

| Thickness by Stubs' or Birmingham Gauge. | | | | Thickness by American (Brown & Sharpe's) Gauge. | | | |
|--|-----------------------|-------|--------|---|-----------------------|-------|--------|
| No. of Gauge. | Thick-ness in Inches. | Iron. | Steel. | No. of Gauge. | Thick-ness in Inches. | Iron. | Steel. |
| 0000 | .454 | 18.16 | 18.52 | 0000 | .46 | 18.40 | 18.77 |
| 000 | .425 | 17.00 | 17.34 | 000 | .4096 | 16.38 | 16.71 |
| 00 | .38 | 15.20 | 15.30 | 00 | .3648 | 14.59 | 14.88 |
| 0 | .34 | 13.60 | 13.87 | 0 | .3249 | 13.00 | 13.26 |
| 1 | .3 | 12.00 | 12.24 | 1 | .2893 | 11.57 | 11.80 |
| 2 | .284 | 11.36 | 11.59 | 2 | .2576 | 10.30 | 10.51 |
| 3 | .259 | 10.36 | 10.57 | 3 | .2294 | 9.18 | 9.36 |
| 4 | .238 | 9.52 | 9.71 | 4 | .2043 | 8.17 | 8.34 |
| 5 | .22 | 8.80 | 8.98 | 5 | .1819 | 7.28 | 7.42 |
| 6 | .203 | 8.12 | 8.28 | 6 | .1620 | 6.48 | 6.61 |
| 7 | .18 | 7.20 | 7.34 | 7 | .1443 | 5.77 | 5.89 |
| 8 | .165 | 6.60 | 6.73 | 8 | .1285 | 5.14 | 5.24 |
| 9 | .148 | 5.92 | 6.04 | 9 | .1144 | 4.58 | 4.67 |
| 10 | .134 | 5.36 | 5.47 | 10 | .1019 | 4.08 | 4.16 |
| 11 | .12 | 4.80 | 4.90 | 11 | .0907 | 3.63 | 3.70 |
| 12 | .109 | 4.36 | 4.45 | 12 | .0808 | 3.23 | 3.30 |
| 13 | .095 | 3.80 | 3.88 | 13 | .0720 | 2.88 | 2.94 |
| 14 | .083 | 3.32 | 3.39 | 14 | .0641 | 2.56 | 2.62 |
| 15 | .072 | 2.88 | 2.94 | 15 | .0571 | 2.28 | 2.33 |
| 16 | .065 | 2.60 | 2.65 | 16 | .0508 | 2.03 | 2.07 |
| 17 | .058 | 2.32 | 2.37 | 17 | .0453 | 1.81 | 1.85 |
| 18 | .049 | 1.96 | 2.00 | 18 | .0403 | 1.61 | 1.64 |
| 19 | .042 | 1.68 | 1.71 | 19 | .0359 | 1.44 | 1.46 |
| 20 | .035 | 1.40 | 1.43 | 20 | .0320 | 1.28 | 1.31 |
| 21 | .032 | 1.28 | 1.31 | 21 | .0285 | 1.14 | 1.16 |
| 22 | .028 | 1.12 | 1.14 | 22 | .0253 | 1.01 | 1.03 |
| 23 | .025 | 1.00 | 1.02 | 23 | .0226 | .904 | .922 |
| 24 | .022 | .88 | .898 | 24 | .0201 | .804 | .820 |
| 25 | .02 | .80 | .816 | 25 | .0179 | .716 | .730 |
| 26 | .018 | .72 | .734 | 26 | .0159 | .636 | .649 |
| 27 | .016 | .64 | .653 | 27 | .0142 | .568 | .579 |
| 28 | .014 | .56 | .571 | 28 | .0126 | .504 | .514 |
| 29 | .013 | .52 | .530 | 29 | .0113 | .452 | .461 |
| 30 | .012 | .48 | .490 | 30 | .0100 | .400 | .408 |
| 31 | .01 | .40 | .408 | 31 | .0089 | .356 | .363 |
| 32 | .009 | .36 | .367 | 32 | .0080 | .320 | .326 |
| 33 | .008 | .32 | .326 | 33 | .0071 | .284 | .290 |
| 34 | .007 | .28 | .286 | 34 | .0063 | .252 | .257 |
| 35 | .005 | .20 | .204 | 35 | .0056 | .224 | .228 |

| | | |
|----------------------------|-------|--------|
| | Iron. | Steel. |
| Specific gravity..... | 7.7 | 7.854 |
| Weight per cubic foot..... | 480 | 489.6 |
| “ “ “ inch..... | .2778 | .2833 |

As there are many gauges in use differing from each other, and even the thicknesses of a certain specified gauge, as the Birmingham, are not assumed the same by all manufacturers, orders for sheets and wires should always state the weight per square foot or the thickness in thousandths of an inch.

STANDING SEAM TIN ROOFING.—Table showing quantity of 20"×28" tin required to cover a given number of square feet with standing seam roofing. The standing seams and the locks on a steep roof require 2¼" off the width and ¼" off the length of the sheet; fractional parts are counted as a full sheet. A sheet will cover 475 square inches.

| Number of Sq. Ft. | Sheets Re-quired. | Number of Sq. Ft. | Sheets Re-quired. | Number of Sq. Ft. | Sheets Re-quired. | Number of Sq. Ft. | Sheets Re-quired. |
|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| 100 | 31 | 330 | 100 | 560 | 173 | 780 | 237 |
| 110 | 34 | 340 | 103 | 570 | 176 | 790 | 240 |
| 120 | 37 | 350 | 106 | 580 | 182 | 800 | 243 |
| 130 | 40 | 360 | 109 | 590 | 185 | 810 | 246 |
| 140 | 43 | 370 | 112 | 600 | 184 | 820 | 249 |
| 150 | 46 | 380 | 115 | 610 | 135 | 830 | 252 |
| 160 | 49 | 390 | 118 | 620 | 188 | 840 | 255 |
| 170 | 52 | 400 | 122 | 630 | 191 | 850 | 258 |
| 180 | 55 | 410 | 125 | 640 | 194 | 860 | 261 |
| 190 | 58 | 420 | 128 | 650 | 197 | 870 | 264 |
| 200 | 61 | 430 | 131 | 660 | 200 | 880 | 267 |
| 210 | 64 | 440 | 134 | 670 | 203 | 890 | 270 |
| 220 | 67 | 450 | 137 | 680 | 206 | 900 | 273 |
| 230 | 70 | 460 | 140 | 690 | 207 | 910 | 276 |
| 240 | 73 | 470 | 143 | 700 | 212 | 920 | 279 |
| 250 | 76 | 480 | 147 | 710 | 215 | 930 | 282 |
| 260 | 79 | 490 | 149 | 720 | 218 | 940 | 285 |
| 270 | 82 | 500 | 152 | 730 | 221 | 950 | 288 |
| 280 | 85 | 510 | 158 | 740 | 224 | 960 | 291 |
| 290 | 88 | 520 | 161 | 750 | 228 | 970 | 294 |
| 300 | 91 | 530 | 164 | 760 | 231 | 980 | 297 |
| 310 | 94 | 540 | 167 | 770 | 234 | 990 | 300 |
| 320 | 97 | 550 | 170 | | | | |

1000 square feet 303 sheets. A full box 112 sheets 20"×28" will cover approximately 370 square feet.

The common sizes of tin plates are 10×14" and multiples of that measure. The sizes most generally used are 14×20" and 20×28".

WEIGHT OF SHEETS PER SQUARE FOOT.

| Black. United States Standard Weights. | | | | Galvanized. National Association of Galvanized Sheet-iron Manufacturers' Weights. | | | |
|---|---------|---------|---------|---|---------|---------|---------|
| Number. | Pounds. | Number. | Pounds. | Number. | Ounces. | Number. | Ounces. |
| 10 | 5.625 | 21 | 1.375 | 10 | 92½ | 21 | 24½ |
| 11 | 5 | 22 | 1.25 | 11 | 82½ | 22 | 22½ |
| 12 | 4.375 | 23 | 1.125 | 12 | 72½ | 23 | 20½ |
| 13 | 3.75 | 24 | 1 | 13 | 62½ | 24 | 18½ |
| 14 | 3.125 | 25 | .875 | 14 | 52½ | 25 | 16½ |
| 15 | 2.8125 | 26 | .75 | 15 | 47½ | 26 | 14½ |
| 16 | 2.5 | 27 | .6875 | 16 | 42½ | 27 | 13½ |
| 17 | 2.25 | 28 | .625 | 17 | 38½ | 28 | 12½ |
| 18 | 2 | 29 | .5625 | 18 | 34½ | 29 | 11½ |
| 19 | 1.75 | 30 | .5 | 19 | 30½ | 30 | 10½ |
| 20 | 1.50 | | | 20 | 26½ | | |

WEIGHT OF BLACK PLATES BEFORE BEING COATED.

| | IC 14×20 | IC 20×28 | IX 14×20 | IX 20×28 |
|--|-------------------|--------------------|--------------------|--------------------|
| Black plates before coating weigh per 112 sheets.... | Lbs. 95 to 100 | Lbs. 190 to 200 | Lbs. 125 to 130 | Lbs. 250 to 260 |

NET WEIGHT PER BOX TIN PLATES.

Basis 14×20, 112.

| Trade term.... | 80-lb | 85-lb | 90-lb | 95-lb | 100-lb | IC | IXL | IX | IXX | IXXX | IXXXX | |
|-----------------------------|-----------------|-------|-------|-------|--------|-----|-----|-----|-----|------|-------|-----|
| Weight per box, lbs. | 80 | 85 | 90 | 95 | 100 | 107 | 128 | 135 | 155 | 175 | 195 | |
| Nearest wire-gauge No. | 33 | 32 | 31 | 31 | 30 | 30 | 28 | 28 | 27 | 26 | 25 | |
| Size of Sheets. | Sheets per Box. | | | | | | | | | | | |
| 10 × 14 | 225 | 80 | 85 | 90 | 95 | 100 | 107 | 128 | 135 | 155 | 175 | 195 |
| 14 × 20 | 112 | 80 | 85 | 90 | 95 | 100 | 107 | 128 | 135 | 155 | 175 | 195 |
| 20 × 28 | 112 | 160 | 170 | 180 | 190 | 200 | 214 | 256 | 270 | 310 | 350 | 390 |
| 10 × 20 | 225 | 114 | 121 | 129 | 136 | 143 | 153 | 183 | 193 | 221 | 250 | 279 |
| 11 × 22 | 225 | 138 | 147 | 156 | 164 | 172 | 184 | 222 | 234 | 268 | 302 | 337 |
| 11½ × 23 | 225 | 151 | 161 | 170 | 179 | 189 | 202 | 242 | 255 | 293 | 331 | 368 |
| 12 × 12 | 225 | 82 | 87 | 93 | 98 | 103 | 110 | 132 | 139 | 159 | 180 | 201 |
| 12 × 24 | 112 | 82 | 87 | 93 | 98 | 103 | 110 | 132 | 139 | 159 | 180 | 201 |
| 13 × 13 | 225 | 97 | 103 | 109 | 115 | 121 | 129 | 154 | 163 | 187 | 211 | 235 |
| 13 × 26 | 112 | 97 | 103 | 109 | 115 | 121 | 129 | 154 | 163 | 187 | 211 | 235 |
| 14 × 14 | 225 | 112 | 119 | 126 | 133 | 140 | 150 | 179 | 189 | 217 | 245 | 273 |
| 14 × 28 | 112 | 112 | 119 | 126 | 133 | 140 | 150 | 179 | 189 | 217 | 245 | 273 |
| 15 × 15 | 225 | 129 | 137 | 145 | 153 | 161 | 172 | 206 | 217 | 249 | 281 | 313 |
| 16 × 16 | 225 | 146 | 155 | 165 | 174 | 183 | 196 | 234 | 247 | 283 | 320 | 357 |
| 17 × 17 | 225 | 165 | 175 | 186 | 196 | 206 | 221 | 264 | 279 | 320 | 361 | 403 |
| 18 × 18 | 112 | 93 | 98 | 104 | 110 | 116 | 124 | 148 | 156 | 179 | 202 | 226 |
| 19 × 19 | 112 | 103 | 110 | 116 | 122 | 129 | 138 | 165 | 174 | 200 | 226 | 251 |
| 20 × 20 | 112 | 114 | 121 | 129 | 136 | 143 | 153 | 183 | 193 | 221 | 250 | 279 |
| 21 × 21 | 112 | 126 | 134 | 142 | 150 | 158 | 169 | 202 | 213 | 244 | 276 | 307 |
| 22 × 22 | 112 | 138 | 147 | 156 | 164 | 172 | 184 | 221 | 234 | 268 | 302 | 337 |
| 23 × 23 | 112 | 151 | 161 | 170 | 179 | 189 | 202 | 242 | 255 | 293 | 331 | 368 |
| 24 × 24 | 112 | 164 | 175 | 185 | 195 | 204 | 220 | 263 | 278 | 319 | 360 | 401 |
| 26 × 26 | 112 | 193 | 205 | 217 | 229 | 241 | 258 | 309 | 326 | 374 | 422 | 471 |
| 16 × 20 | 112 | 91 | 97 | 103 | 109 | 114 | 122 | 146 | 154 | 177 | 200 | 223 |
| 14 × 31 | 112 | 124 | 132 | 140 | 147 | 155 | 166 | 198 | 209 | 240 | 271 | 302 |
| 11½ × 22½ | 112 | 73 | 78 | 82 | 87 | 91 | 98 | ... | ... | ... | ... | ... |
| 13½ × 17½ | 112 | 67 | 71 | 76 | 80 | 84 | 90 | ... | ... | ... | ... | ... |
| 13½ × 19½ | 112 | 73 | 77 | 82 | 87 | 91 | 97 | ... | ... | ... | ... | ... |
| 13½ × 19½ | 112 | 75 | 80 | 85 | 89 | 94 | 100 | ... | ... | ... | ... | ... |
| 13½ × 19½ | 112 | 76 | 81 | 86 | 90 | 95 | 102 | ... | ... | ... | ... | ... |
| 14 × 18½ | 124 | 83 | 88 | 93 | 98 | 103 | 110 | ... | ... | ... | ... | ... |
| 14 × 19½ | 120 | 83 | 88 | 93 | 98 | 103 | 110 | ... | ... | ... | ... | ... |
| 14 × 21 | 112 | 84 | 89 | 95 | 100 | 105 | 112 | ... | ... | ... | ... | ... |
| 14 × 22 | 112 | 88 | 94 | 99 | 105 | 110 | 118 | ... | ... | ... | ... | ... |
| 14 × 22½ | 112 | 89 | 95 | 100 | 106 | 111 | 119 | ... | ... | ... | ... | ... |
| 15½ × 23 | 112 | 102 | 108 | 115 | 121 | 127 | 136 | ... | ... | ... | ... | ... |

TABLE OF WEIGHTS PER LINEAL FOOT OF BRASS AND COPPER RODS.

| Inches. | Brass. | | Copper. | |
|------------------------|---------|---------|---------|---------|
| | Round. | Square. | Round. | Square. |
| | Pounds. | Pounds. | Pounds. | Pounds. |
| $\frac{1}{16}$ | .011 | .014 | .01155 | .0147 |
| $\frac{1}{8}$ | .045 | .055 | .047 | .060 |
| $\frac{3}{16}$ | .100 | .125 | .106 | .13497 |
| $\frac{1}{4}$ | .175 | .225 | .189 | .241 |
| $\frac{5}{16}$ | .275 | .350 | .296 | .377 |
| $\frac{3}{8}$ | .395 | .510 | .426 | .542 |
| $\frac{7}{16}$ | .540 | .690 | .579 | .737 |
| $\frac{1}{2}$ | .710 | .905 | .757 | .964 |
| $\frac{9}{16}$ | .90 | 1.15 | .958 | 1.22 |
| $\frac{5}{8}$ | 1.10 | 1.40 | 1.182 | 1.51 |
| $\frac{11}{16}$ | 1.35 | 1.72 | 1.431 | 1.82 |
| $\frac{3}{4}$ | 1.66 | 2.05 | 1.703 | 2.17 |
| $\frac{13}{16}$ | 1.85 | 2.40 | 1.998 | 2.54 |
| $\frac{7}{8}$ | 2.15 | 2.75 | 2.318 | 2.95 |
| $\frac{15}{16}$ | 2.48 | 3.15 | 2.660 | 3.39 |
| 1..... | 2.85 | 3.65 | 3.03 | 3.86 |
| $1\frac{1}{16}$ | 3.20 | 4.08 | 3.42 | 4.35 |
| $1\frac{1}{8}$ | 3.57 | 4.55 | 3.831 | 4.88 |
| $1\frac{3}{16}$ | 3.97 | 5.08 | 4.269 | 5.44 |
| $1\frac{1}{4}$ | 4.41 | 5.65 | 4.723 | 6.01 |
| $1\frac{5}{16}$ | 4.86 | 6.22 | 5.21 | 6.63 |
| $1\frac{3}{8}$ | 5.35 | 6.81 | 5.723 | 7.24 |
| $1\frac{7}{16}$ | 5.85 | 7.45 | 6.255 | 7.97 |
| $1\frac{1}{2}$ | 6.37 | 8.13 | 6.811 | 8.67 |
| $1\frac{9}{16}$ | 6.92 | 8.83 | 7.39 | 9.41 |
| $1\frac{5}{8}$ | 7.48 | 9.55 | 7.993 | 10.18 |
| $1\frac{11}{16}$ | 8.05 | 10.27 | 8.45 | 10.73 |
| $1\frac{3}{4}$ | 8.65 | 11.00 | 9.27 | 11.80 |
| $1\frac{13}{16}$ | 9.29 | 11.82 | 9.76 | 12.43 |
| $1\frac{7}{8}$ | 9.95 | 12.68 | 10.642 | 13.55 |
| $1\frac{5}{4}$ | 10.58 | 13.50 | 11.11 | 14.15 |
| 2..... | 11.25 | 14.35 | 12.108 | 15.42 |
| $2\frac{1}{8}$ | 12.78 | 16.27 | 13.668 | 17.42 |
| $2\frac{1}{4}$ | 14.32 | 18.24 | 15.325 | 19.51 |
| $2\frac{3}{8}$ | 15.96 | 20.32 | 17.075 | 21.74 |
| $2\frac{1}{2}$ | 17.68 | 22.53 | 18.916 | 24.09 |
| $2\frac{5}{8}$ | 19.50 | 24.83 | 20.856 | 26.56 |
| $2\frac{3}{4}$ | 21.40 | 27.25 | 22.891 | 29.05 |
| $2\frac{7}{8}$ | 23.39 | 29.78 | 25.019 | 31.86 |
| 3..... | 25.47 | 32.43 | 27.243 | 34.69 |
| $3\frac{1}{4}$ | 30.45 | 38.77 | 31.972 | 40.71 |
| $3\frac{1}{2}$ | 35.31 | 44.96 | 37.081 | 47.22 |
| 4..... | 46.124 | 58.73 | 48.433 | 61.67 |

To find the weight of octagon rod, take the weight of round rod of a given size and multiply by 1.084.

To find the weight of hexagon rod, take the weight of round rod of a given size and multiply by 1.12.

These tables are theoretically correct, but variations must be expected in practice.

Painting.—**MATERIALS.**—The most common materials used for mixing paints are linseed-oil, turpentine and benzine, and zinc white. Generally speaking, and with many exceptions of course, two or more of these substances in combination, with varying proportions of the several colors, constitute the house-painting materials on the market.

Linseed-oil.—Linseed-oil is pressed from the seeds of the flax plant, and after purification becomes the raw oil of commerce. After being heated in connection with certain oxidizing agents (driers) such as red lead, litharge, manganese oxide, manganese borate, etc., either by means of direct fire or in a steam-jacketed kettle, it is known as boiled oil.

The peculiar quality of linseed-oil to absorb oxygen from the air, and in oxidizing to form a tough, elastic substance, known as linoxyn (a property which it possesses in common with a few other so-called drying oils—poppy-oil, nut-oil, etc.), gives it special value in paint- and varnish-making. Any admixture with mineral oils or non-drying vegetable oils greatly impairs or wholly destroys this value, so that for painting purposes it is most essential to know that the oil employed is absolutely pure.

Good raw linseed-oil is pale in color and transparent, has very little odor and is sweet to the taste. If it is dark in color and dries very slowly it indicates an inferior oil. Linseed-oil should have an age of six months before being used, and more age improves it. Raw oil spread on a glass should dry in from two to three days, according to the state of the weather.

Boiled Oil.—Boiled linseed-oil, commonly called boiled oil, is prepared by heating the raw oil with certain driers. By this process the drying qualities of the oil are greatly improved; the drying qualities of raw oil are also improved by simply boiling it, but when such substances are added as mentioned below, this improvement is greatly enhanced. Dark drying oil may be made of these ingredients: To 1 gallon of raw oil add 1 pound of red lead, 1 pound of umber, and 1 pound of litharge.

The oil is heated to about 200° F. When it looks brown and the scum is burned off, the substances mentioned are added; the whole is then brought up to about 400° F., and for two or three hours kept at that temperature. The oil is then drawn

off and the albuminous matter allowed to deposit, after which it is ready for use. The umber is added simply to give the oil a dark color.

Pale drying oil may be made by mixing 7 pounds of litharge or acetate of lead to each gallon of oil and raising to a moderate temperature.

For common work, drying oil can be made by adding $1\frac{1}{2}$ pounds of red lead to a gallon of oil and allowing the mixture to settle after having been boiled.

Boiled oil is much thicker and darker in color than the raw oil. When spread on a glass in a thin film it should dry in from twelve to twenty-four hours, depending on the condition of the weather.

Raw oil is used for interior work and for grinding colors; the boiled oil is used for outside work and is not suited for grinding. For outside work the boiled oil gives the paint a much more glossy finish than the raw oil, for when the raw oil is used, a liquid or other drier must be added, and this takes away the lustre from the oil.

The bung-hole process, so-called, is the simple injection of manganese drier into a barrel of raw linseed at proper temperature.

Raw oil in which a certain percentage of liquid japan drier has been mixed is often sold as boiled oil.

Fish-oil, cottonseed-oil, and vegetable oils are often substituted for boiled oils.

Linseed-oil to which turpentine has been added (in small quantity) dries more rapidly than without the turpentine because it spreads over more surface, being thinner, and so comes in contact with a larger body of air, which dries it in the diluted state faster.

Turpentine is not a drier, simply a thinner.

Linseed-oil is often adulterated by adding fish, hemp, cottonseed, resin, and mineral oils. These adulterations are hard to detect except by chemical analysis; they change the odor somewhat and the specific gravity.

The superintendent should always keep himself in possession of a sample of both the raw and boiled oils which he knows to be pure, and with which he can compare any oils which may be used under his supervision.

Good linseed-oil should be of a light straw color, weigh $7\frac{1}{2}$ pounds to the gallon, boil at 130° C. (260° F.), solidify at 27° C.

(17° F.), and have a specific gravity at 15° C. (60° F.) of 20° Baumé (0.932).

To test for the presence of fish-oil, shake equal parts of oil and strong nitric acid in a small glass vial and let it stand fifteen to thirty minutes. In pure linseed-oil the upper stratum will be olive-green, which gradually changes to a brown, and the lower stratum will be almost colorless; if fish-oil is present, the upper stratum will be of a deep red brown and the lower stratum will be deep red or cherry-red. If only a small amount of fish-oil is present, the color of the lower stratum may gradually disappear until it becomes almost colorless.

To test for petroleum, shake the oil with concentrated solution of potash or soda containing a little grain alcohol and then add a little warm water and shake again. Let it stand for about thirty minutes, and if any petroleum is present it will separate and float on top.

To test for cottonseed-oil, put samples of the oil in tubes and place them in a freezing mixture such as ice or snow and salt. If the mixture solidifies at 0° or 10° to 13° F., then cottonseed-oil is probably present, as pure linseed-oil solidifies at 17° F.

HYDROMETER TESTS.—First test the specific gravity of an oil known to be pure, and then test the doubtful oil at the same temperature.

Twenty-five per cent of cottonseed-oil will make a difference of 1° Baumé less than pure linseed-oil at the same temperature.

Ten per cent of petroleum will make a difference of $\frac{3}{4}$ ° less and 20 per cent will make a difference of 1½° less at the same temperature.

The quality of linseed-oil may be determined by looking through a vial filled with it and turned towards the light. If poor in quality, the oil tends towards opacity, appears turbid or milky, while its taste is strong and rancid.

Turpentine.—Spirits of turpentine is a volatile oil, obtained by distilling with water, in an ordinary copper still, turpentine previously melted and strained. The distilled product is colorless, limpid, very fluid, and has a peculiar smell. The residuum left after distillation is called resin.

The ordinary use of spirits of turpentine is to thin oil paints, to flatten white and other colors, or to remove superfluous color in graining. It prevents paint, however, from bearing

out, and when used alone will not fix the paint on the surface to which it is applied.

Good turpentine is colorless and has a pleasant pungent odor; if adulterated or of an inferior quality it will have a disagreeable odor.

When evaporated, good turpentine should have a very slight residue, and when spread on a glass in a thin film should dry in twelve to twenty-four hours.

Turpentine is often adulterated with mineral oils. The pure turpentine loses bulk by evaporation and gains weight upon exposure to the air. Adulterated with mineral oils, the spirit evaporates, leaving the oil without any assistance in hardening.

Turpentine containing such oils will usually leave a greasy stain on white paper, a drop of it on a watch-crystal will reflect prismatic colors in the direct rays of the sun, and the hydrometer will stand in such a mixture above 32°.

But little if any turpentine should be used on good work. The result of the use of turpentine is that the proportion of oil is reduced. This enables the painter to conceal the painted surface with fewer coats than would otherwise suffice. Turpentine also hastens the drying of the paint by reducing the quantity of the oil, and the turpentine itself possessing some oxidizing or drying properties.

Good turpentine should be crystal-clear and water-white, weigh 7 pounds to the gallon, boil at 160° to 165° C. (320° to 340° F.), and have a specific gravity at 15° C. (59° F.) of 31° Baumé hydrometer (0.870).

The presence of benzine or naphtha in turpentine can usually be detected by the odor; with the hydrometer test 5 per cent of this adulterant will make a difference of 1½° Baumé.

The presence of petroleum can usually be detected by the delicate "bluish bloom" or smoky bluish-yellow cloud it imparts to the turpentine.

To detect small quantities of petroleum, fill two white glass vials, one with the doubtful article and one with turpentine known to be pure; hold both over a piece of black paper and look directly down into the liquid; 3 to 5 per cent of petroleum will impart a decided bloom or cloud to the "turps." With the hydrometer test 5 per cent of petroleum will make a difference of ½° Baumé.

| | | | | | | |
|---|---|---|---|---|------|---|
| Pure turpentine at 15° C. (59° F.) is 31° Baumé hydrometer. | | | | | | |
| 5% benzine | “ | “ | “ | “ | 32½° | “ |
| 15% “ | “ | “ | “ | “ | 34° | “ |
| 25% “ | “ | “ | “ | “ | 38° | “ |
| 5% petroleum | “ | “ | “ | “ | 31½° | “ |
| 10% “ | “ | “ | “ | “ | 32° | “ |
| 25% “ | “ | “ | “ | “ | 34° | “ |
| 33½% “ | “ | “ | “ | “ | 35½° | “ |

White Lead.—The discovery of white lead is lost in the mists of antiquity. It has been a familiar painting material for many centuries, and the earliest recorded method of production differed only in detail from that generally practised at the present day. In most European and American factories the method used is that known as the “Old Dutch” process of corrosion. The chief exceptions are the single plant in France producing the celebrated *Ceruse de Clichy*; the few German factories producing “Kremnitz white” by dry precipitation; the one plant in England producing the celebrated Pattison white lead by wet precipitation; and the two equally famous plants of the Carter White Lead Company in this country, practising corrosion by a controllable chemical process acting on the lead in a finely comminuted form, the last named being merely a technical modification of the older process, shortening the time required for completion.

The old Dutch process of corrosion is in outline as follows: The pig or metallic lead is melted and cast into perforated disks, called buckles, about 6 inches in diameter, which are put into pots containing each about one pint of dilute vinegar. These are placed in rooms holding several layers, or tiers, 600 to 1000 pots each. The pots are covered with boards and layers of tanbark, placed between each tier. The rooms, technically called beds, are kept closed from three to four months. During this period the heat and the carbonic-acid gas generated by fermentation of the tan, together with the acid vapors, combine to corrode the lead into a white flaky substance.

This, after it is crushed, screened, ground in water and dried, forms the white lead of commerce, and is either sold in the dry state to mixed paint and color manufacturers or ground in linseed-oil and sold for general painting purposes.

White lead thus produced is a compound of lead hydroxide

and lead carbonate, generally retaining a residue of acetic acid and more or less water. It is exceedingly variable in composition, nearly every sample analyzed showing different proportions of the constituent components. Thus in four analyses reported by Prof. Hurst the proportion of carbonate ranged from 63.35 per cent to 72.15 per cent; that of the hydroxide from 25.19 to 36.14; and that of the moisture from 0.42 to nothing. Prof. Church gives the ideal proportion as 70 per cent of the carbonate to 30 per cent of the hydrate, but this exact proportion is very rarely attained in practice. Five different American brands of pure old Dutch process white lead analyzed a few years since by Mr. Convers proved to be constituted as follows:

| | I. | II. | III. | IV. | V. |
|------------------------|-------|-------|-------|-------|-------|
| Lead carbonate | 85.32 | 79.37 | 78.58 | 77.98 | 69.96 |
| Lead hydrate | 14.83 | 19.80 | 20.11 | 20.60 | 30.19 |
| Lead oxide . . . . . | ..... | ..... | 1.48 | 1.48 | ..... |
| Water | .03 | .21 | ..... | ..... | .07 |

The samples analyzed were dry leads and not the product in oil as sold to the consumer. The latter, especially when mixed without drying, as in the pulp process, will generally show a higher percentage of moisture, while acetic acid and uncorroded particles of lead, left by imperfect grinding and washing, are not rare; Church reports as high as 11 per cent of lead acetate in flake white.

This, the ordinary white lead of commerce, is a heavy, opaque material, ranging in color from yellowish white (cream color) to grayish white; indeed, it seldom happens that two separate corruptions yield precisely the same shade of tone. This variation is, of course, unimportant, except in attempting to match shades by the addition of definite proportions of color.

Precipitated white lead is made by suspending rolls of thin sheet lead or small bars over malt vinegar or pyroligneous acid in closed vessels, the evaporation of the acid being kept up by heat applied to the vessels while immersed in a steam bath. The white lead produced by precipitation is generally considered inferior to that prepared by corrosion, wanting, as it is, in density or body, and when mixed with its vehicle, absorbing too much oil.

Sublimed Lead is obtained as a by-product in the smelting

of lead ores. The products of this smelting are pig lead, slags poor enough in lead to be thrown away, and the "fume," which is white and in a fine state of subdivision, suitable for a white pigment, and is sold as such either dry or ground in oil. It is known to the trade as Joplin lead, being manufactured first at Joplin, Mo., or as Picher lead, from the name of the company manufacturing it.

Adulterations.—White lead may be either pure or mixed with various substances, such as sulphate of baryta, sulphate of lead, sulphate of lime, whiting, chalk, zinc white, etc.; these substances do not combine so well with oil as does white lead, nor do they so well protect the surfaces to which they are applied.

Sulphate of baryta, the most common adulterant, is a dense, heavy, white substance, very much like white lead in appearance. It absorbs very little oil, and can usually be detected by the gritty feeling produced when the paint is rubbed between the fingers.

Pure white lead is insoluble in water, effervesces with dilute hydrochloric acid, dissolving when heated, and is easily soluble in dilute nitric acid. When heated on a piece of glass the white lead becomes yellow.

To test dry lead, digest a small quantity with nitric acid, in which it dissolves readily on boiling. When ground with oil, the oil should be burned off and the residue treated with nitric acid; or the white lead ground with oil may be boiled for some time with strong nitric acid, which destroys the oil and dissolves the lead on the addition of water. If sulphate of baryta be present, it being insoluble in the acid, it remains behind and can be collected on a filter, washed with hot distilled water, and weighed.

The presence of other adulterants may be detected by the change in the specific gravity of the lead when dry, or by various methods of analysis.

Zinc White.—Zinc white is hydrated zinc carbonate or oxide. It is perfectly durable in oil and water, but wanting in body. For inside work, zinc is preferable to white lead, and for outside work, about 25 per cent of zinc in the lead color makes a better paint than the pure lead. For use in its pure state, zinc white should be finely ground in refined linseed-oil with the proper proportions of manganese drier, and if for interior use, should have a small proportion of good white varnish.

In painting in pure zinc, the first coat may be tinted with black, over which the second coat will make a perfect covering.

A soft brush with long hairs should be used, brushing lightly, and the paint should be applied a little thicker than a lead paint.

The purity of zinc may be determined by washing out the oil with benzine and dissolving the pigment in sulphuric acid. Any residue shows the presence of other pigments. On a painted surface the presence of lead can be determined by scratching a spot through the paint and applying a drop of sodium sulphide of 100° Baumé. If lead be present it will cause a decided discoloration. *

Red Lead (Red Oxide of Lead).—This is one of the oldest pigments, formerly known as minium or saturnine red. It is a deutoxide of lead prepared by subjecting massicot to the heat of a furnace, with an expanded surface and free accession of air.

Red lead is often adulterated with red oxide of iron, brick-dust, or mineral paints. To test, heat the red lead and treat with dilute nitric acid; the red lead will be dissolved and the adulterants remain. Boiling hydrochloric acid extracts the sesquioxide of iron from the residue.

Oxide of Iron is produced from the brown hematic ores; the ore is roasted and separated from impurities and then ground.

Antimony Vermilion (Sulphide of Antimony) is produced from antimony ore. It is sometimes used as a substitute for red lead.

Vermilion is a sulphuret of mercury, which previous to its being levigated is called cinnabar. Vermilion is adulterated with red lead, brightened with eosine, and with logwood mixed with molasses. Powder vermilion may be tested by placing a small quantity on a piece of paper laid on a hard surface; cover this with a card or other piece of paper, which rub with the thumb-nail or smooth handle of a penknife. If the vermilion be pure, it will on the removal of the paper present a smooth surface of the uniform original color, but if adulterated with red lead, etc., it will appear orange or yellow.

Indian Red is ground hematite ore or peroxide of iron, but can be made artificially by calcining sulphate of iron. It is sometimes called Persian red.

Scarlet Red.—A name given to a very bright scarlet shade of iron-oxide pigments.

Venetian Red.—A red pigment made by heating ochres. Light-red color works well in oil or water. This red is not only useful as a solid color of extreme permanence, but the tints are clean and sharp even when reduced to a delicate rose tint. Many common Venetian reds are made in a crude manner with a cheap, coarse base.

Oxide.—Oxide reds are noted for their permanency and durability. They owe their color to ferric oxide by the precipitation of iron solutions.

Lakes.—A class of pigments of ancient origin, made extensively of cochineal, combined with tin and alumina. Florentine lake, Dutch pink, and rose pink contain an excess of metallic base in their composition.

YELLOWS.—*Chrome Yellow* is obtained from the subchromate of lead. Frequently adulterated with gypsum, it is prepared by mixing diluted solutions of acetate or nitrate of lead and bichromate of potash.

Naples Yellow.—This old and well-known pigment is a compound of the oxides of lead and antimony. This pigment is generally replaced by chrome yellows.

King's Yellow, the least durable of the yellow pigments, is obtained from arsenic. It is sometimes called Chinese yellow and should never be used for good painting.

OCHRES.—A most important group of natural pigments found in many places. The depth of color is variable; in some it is strong, in others weak.

Yellow Ochre is a natural clay, colored by oxide of iron. It varies in color from yellow to brown.

Raw Sienna appears to be an iron ore, considered as a crude natural yellow lake.

Dutch Pink.—Strange to say a yellow lake should be called Dutch pink, still such is the case.

This pigment is a yellow lake prepared from Persian berries by precipitating with alum and whiting.

BLACK PIGMENTS.—*Lampblack* is simply the soot obtained by burning resinous woods, tallow, coal-tar, oil, bituminous coal, etc. It is a purely carbonaceous substance of fine texture and very durable.

Ivory-black is obtained by calcining or charring to blackness in a closed vessel waste ivory and then grinding. This makes a superior black, but is more expensive than the others.

Bone-black is prepared from bones by a similar process to ivory-black, using bones as the raw material. It has a reddish tint, and unless well burned tends toward a brown color.

Frankfort or Vegetable Black is a pigment prepared from the sediment of wine, vine twigs, and tendrils from which the tartar has been washed, by burning in the same manner as ivory-black. It is used mostly by printers.

Blue Black is a well-burned and levigated charcoal of a cool neutral color, very much like the Frankfort black.

BLUE PIGMENTS.—*Prussian Blue* is made by mixing prussiate of potash with a salt of iron. The prussiate of potash is obtained by calcining and digesting old leather, blood, hoofs, or other animal matter with carbonate of potash and iron filings.

Indigo Blue is a pigment manufactured in the East and West Indies from several plants, but principally from the anil, or indigofera. It is very inferior to Prussian blue.

Cobalt Blue is an oxide of cobalt made by roasting cobalt ore.

Blue Lead is obtained by subliming lead similar to the process used for making sublimed white lead.

Ultramarine Blue.—Ultramarine is one of the most important blue pigments at the disposal of the painter. The ultramarine of commerce is largely made artificially by furnacing a mixture of silica, china clay, sulphur, soda, sodium sulphate, and rosin, these ingredients being mixed together in various portions according to the character of the ultramarine desired. Several qualities of ultramarine are made, varying in depth of tone, tint, fineness, and other qualities.

Ultramarine is a blue pigment of exceedingly bright character, varying from a pale greenish blue to a violet-blue. It is extensively used in water painting, distemper, fresco-work, printing of all kinds, and laundry purposes. When exposed to all ordinary atmospheric conditions it is quite permanent, which is a most important feature of ultramarine. It is easily affected when treated with acids, as the color is destroyed, although it is unaffected by boiling with alkaline solutions of any kind. Some varieties of ultramarine are reddened in tone by being mixed with a solution of alum or alumina sulphate.

The use of even the most carefully selected ultramarine with white lead is not to be recommended, as it is a sulphur compound and liable to blacken the lead.

Prussian blue is without this defect, having no sulphur in it.

Bremen Blue.—Bremen blue is a basic carbonate of copper, soluble in acids; on adding ammonia a deep-blue solution is obtained, a reaction which is highly characteristic of copper.

GREEN.—*Chrome Green.*—An oxide of the metal chromium, and usually made by fusing together bichromate of potash and boracic acid. It is the most permanent green known, very bright, not acted on by acids, heat, or alkalies.

Greens known by various trade names are produced by treating the acetate or carbonate of copper with sal ammoniac. Greens are also made from the arsenites of copper, and from cobalt and ferrous oxide of zinc.

BROWN.—Umber is the name of a brown pigment obtained through the agency of oxide of iron from naturally colored clays, some coming from Turkey, and some from Umbria, in Italy, from which it derives its name. When in its natural state it is called raw umber, but after being calcined at a low temperature it is called burnt umber.

Raw Sienna is a clay stained with oxides of iron and manganese. It was originally found in Sienna, Italy. Siennas differ from ochres in being rather more transparent, making them very serviceable in staining properties.

Burnt Sienna is of a bright orange-red color, permanent in color and mixes well with oil and water.

Vandyke Brown.—A natural earth of warm brown color resembling the umbers, works well in oil or water, and is permanent.

COMPOUND COLORS.—In mixing different colored paints to produce any desired tint, it is best to have the principal ingredient thick and add to it the other colors thinner. In the following list of the combinations of colors required to produce a required tint, the first-named color is the principal ingredient and the others follow in the order of their importance:

- Buff—white, yellow ochre, red.
- Chestnut—red, black, yellow.
- Chocolate—raw umber, red, black.
- Claret—red, umber, black.
- Copper—red, yellow, black.
- Dove—white, vermilion, blue, yellow.
- Drab—white, yellow ochre, red, black.
- Fawn—white, yellow, red.
- Flesh—white, yellow ochre, vermilion.
- Freestone—red, black, yellow ochre, white.

French gray—white, Prussian blue, lake.

Gray—white lead, black.

Gold—white, stone ochre, red.

Green bronze—chrome, green, black, yellow.

Green pea—white, chrome green.

Lemon—white, chrome yellow.

Limestone—white, yellow ochre, black, red.

Olive—yellow, blue, black, white.

Orange—yellow, red.

Peach—white, vermilion.

Pearl—white, black, blue.

Pink—white, vermilion, lake.

Purple—violet, with more red and white.

Rose—white, madder lake.

Sandstone—white, yellow ochre, black, red.

Snuff—yellow, Vandyke brown.

Violet—red, blue, white.

The following table gives the proportions of colors for some of the most common colors:

| Colors. | Ingredients by Weight. | | | | | | |
|---------------|------------------------|-------------|-----------|------------|------------|--------------|-----------------------------|
| | White Lead. | Lamp-black. | Red Lead. | Red Ochre. | Verdigris. | Burnt Umber. | Spanish Brown or Raw Umber. |
| White..... | 100 | ... | ... | ... | ... | ... | .... |
| Black..... | ... | 100 | ... | ... | ... | ... | .... |
| Green..... | 25 | ... | ... | ... | 75 | ... | .... |
| Stone..... | 99 | ... | ... | ... | ... | 1 | .... |
| Lead..... | 98 | 2 | ... | ... | ... | ... | .... |
| Red..... | ... | ... | 50 | 50 | ... | ... | .... |
| Chocolate.... | ... | 4 | ... | ... | ... | ... | 96 |

PREPARING FOR AND APPLYING PAINTS.—In preparing work for painting too much care cannot be exercised, as succeeding coats and the final result depend very much on the proper condition of the work when the priming coat is applied.

First, all the rough places in the wood should be rubbed down with a block covered with sandpaper and all mouldings cleaned out with the same. Then every knot, however small, every indication of sap-wood or discoloration of any kind, and every appearance of pitch or gum, should be carefully covered with a coat of shellac. If the work is to be finished in a light color, or if it is inside work, white shellac should be used.

When the work is to be finished in two coats, the putty used for stopping the nail-holes and other indentations should be made of white lead, worked up with whiting to the proper consistency, and the filling should be done after the first coat has become well dried. When more than two coats are to be put on, the filling or putty should be used between the first and second coat, and ordinary linseed-oil putty should be used.

As a rule white should never be used as a priming coat; no matter how many coats are to be put on the result will be more satisfactory if the first coat be darkened a little with lampblack.

The way to produce solid, uniform work is by making every succeeding coat a little lighter in color than the one preceding it.

It is well to use for priming the same color as the work is to be finished; if it is to be finished green, use green for priming, or if to be finished blue, let blue be the groundwork. All work should be primed, especially with regard to the finishing color.

The paint should be put on by strokes parallel to the grain of the wood; and long smooth pieces, such as window- and door-casings, should be finished by drawing the brush the full length, so that there will be no breaks or brush-marks. The brush must always be at right angles to the surface being painted, and only the ends of the hairs touching it; in this way the paint is spread evenly and forced into the pores of the wood. No paint should be put on top of a preceding coat unless it is perfectly dry and hard.

When paint is applied to walls and ceilings the plaster must be perfectly dry and free from all moisture.

Paint for exterior work should be mixed with boiled linseed-oil.

Painting Tinwork.—Before painting tin, all surplus resin, grease, or oil must be carefully removed. If necessary the surface should be washed with benzine. Red lead is usually used for painting tin. It should be composed of 15 pounds red lead to 1 gallon of linseed-oil. Tinwork should be painted as soon as possible after being put in place, and if any rust shows it should be carefully removed.

Painting Ironwork.—Before painting wrought iron or steel care must be taken to have all scales, grease, rust, etc., removed. The scales can be taken off by brushing with a stiff wire brush,

and the rust can be removed by scraping with steel scrapers, or by a sand-blast, or by pickling in diluted acid, which is washed off with water. All indications of rust should be removed before any paint is put on, for a small spot of rust may grow under the paint and in time cause a flake of the paint to scale off. Deep rust can be burned off with a gasoline torch; the heat converts the rust into peroxide of iron, which can be dusted off. When red lead is used for painting iron or steel it should be composed of 25 pounds of lead to 1 gallon of oil. It will require the close attention of the superintendent to have it put on this thick, for it is hard to spread, but when it is mixed thin it will run and the lead will settle to the lower part of the iron, leaving just a coat of oil.

When any interior painting is being done, all windows should be covered to keep the paint off the glass; a little precaution at this time will save lots of work in the future.

Cleaning Old Paint.—This may be effected by washing it with a solution of pearlash in water. If the surface is greasy, it should be treated with fresh quicklime mixed in water, washed off and reapplied until the grease is entirely removed.

Removing Old Paint.—Dissolve 2 ounces of soft soap and 4 ounces of potash in boiling water; add $\frac{1}{2}$ pound of quicklime; apply hot and leave from twelve to twenty-four hours. This will enable the old paint to be washed off with hot water.

VARNISHES.—Varnish is a solution of certain gums or resins in alcohol, turpentine, linseed-oil, or the like, and is applied to produce a hard shining transparent coat on the surface.

To estimate the quality of a varnish, the following points are to be considered: (1) Quickness in drying; (2) hardness of film or coating; (3) toughness of film; (4) amount of gloss; (5) permanence of gloss; (6) durability on exposure to weather.

Varnish Gums.—Under the names of copal and damar various gums in the form of resins which are found in various parts of the world are employed in the manufacture of varnishes. The typical copal comes from the west coast of Africa, and is found as a fossil in the river-beds and soft ground of the district. The gathering is done during the wet season, when the ground is sufficiently soft to permit of its being dug into by negroes, who use such primitive tools that they are ineffective in dry season. The botanical origin of copal is unknown. Some authorities assign it to a tree, now extinct, along the coast. Copal from this section comes in rough angular pieces

covered with a crust of disintegrated resin; when scraped off the resin is found lustrous, quite transparent, and almost colorless. It melts at 400° F. When powdered about 33½ per cent after long digestion will dissolve in ether, while the rest simply swells up. When melted it gives off a small proportion of an oily liquid which contains a terpene; the residue on cooling will set into a hard, brittle mass soluble in ether, turpentine, or chloroform, etc. It is on this property of becoming soluble after being fused that the manufacture of varnishes from copals is based, and from which the best class of carriage and cabinet-makers' varnishes are made.

The Singapore damar is generally considered the true damar, from the Amboyna pine tree, exuded out of certain excrescences which grow a little above the root of the tree. In Java and Sumatra the resin is allowed to flow out naturally; in some localities natives make incisions to promote the flow. The Singapore damar comes in form of rounded pieces with powdery crust, transparent and quite brittle. It is soluble in turpentine, ether, chloroform, etc. Damar produces a varnish which is pale, lustrous, and dries with a very hard coat. Varnishes requiring a clear, light, brilliant, lustrous finish are made from the best damar.

A great variety of varnish gums are also employed in the manufacture of varnish, although the above described are considered the best of their class.

Much care must be exercised in applying varnish to get it spread on evenly; a fine hair-brush must be used and the varnish well spread out, but not worked enough to make it froth or foam; it must be worked out thin enough so that it will not run, and no succeeding coat of varnish should be put on until the preceding coat is hard and dry. Each coat of varnish should be well sandpapered before another one is put on.

Good varnish should dry and be free from stickiness in from one to two days.

The more oil a varnish contains the less liable it is to crack.

One pint of varnish will single coat about 14 square yards.

FINISHING OF CALIFORNIA REDWOOD.—California redwood is being more generally used for inside finish every year, and on account of its peculiarities in regard to finishing and varnishing, the following directions are given, which if followed will produce the best results.

Formula for Finishing Redwood: Shellac Finish.—First give one coat of orange-gum shellac (which is a good quality of gum shellac and alcohol), applied very thin. If more color is required, give another coat of orange shellac, waiting at least twenty-four hours after giving the first coat. Take No. 1 sandpaper and work the raised grain, caused by shellacking down to a surface; then give one coat of white shellac. Let this coat be heavy and stand twenty-four hours to harden; if you finish quicker than this the whole is liable to crack. Then rub with curled hair or haircloth until the gloss is taken off. Then apply another coat of white shellac a little thinner. Let stand two days and rub with curled hair or haircloth same as first coat; then apply a third coat of white shellac same as second, and let stand two days; rub down to a surface with No. 00 pulverized pumice-stone, felt, and water, being careful not to rub through the varnish on the corners; clean off thoroughly dry with chamois skin; then take pulverized rottenstone and water and a piece of dry felt and rub the work thoroughly with the same; clean off with water and dry with chamois skin, or instead of cleaning off the rottenstone with water and drying with chamois skin, take the palm of the hand and rub the rottenstone until it is dry, which will bring it to a fine gloss (but to finish in this latter way the finisher's hand must be perfectly soft and free from dust or grit), and take a soft cloth and wipe the hands off often, because if the least bit of grit accumulates it mars the work; then take raw linseed-oil, a little fine cotton batting, and rub work over thoroughly, and take a piece of dry soft cotton cloth and wipe it off.

To do better work, rub with pumice-stone between every other coat of shellac, and the more times rubbed and shellacked, the finer the work turned out, or, in other words, by finishing the wood smooth to commence with, and putting on five to seven coats of shellac and rubbing between every other coat, the finest piano finish can be obtained.

To finish a DEAD finish, use no rottenstone, but instead rub in pulverized pumice-stone and water, clean off thoroughly, and oil off with raw linseed-oil.

To give redwood a bright, rich color, take the following: One-fourth pound dry Venetian red and put in two quarts of turpentine, stir up and let settle; then use the turpentine, which will be colored a very little. Apply this for first coat.

Other formulas for finishing are used to a great extent. For instance, many use last coats of rubbing varnish, because it is softer to work and polishes easier, but where they are used none but the best grades are desirable; also all good grades of rubbing varnish take from five to thirty days to dry each coat. The quick-drying grades have more or less resin in them and scratch white.

Shellac, being very hard, is, of course, more expensive to rub down, but the firmness is a protection to the wood, and it is known to be the most durable finish for any kind of wood.

Never buy prepared shellac, but buy the gum shellac and alcohol and cut it, as most prepared shellac is cut with cheaper ingredients than alcohol, and oftentimes spoils what otherwise would have been a nice finish.

Use it quickly, so as not to show laps, as it dries fast.

Varnish Finish.—Use only good grades of varnish, which will cost at least \$2.50 per gallon, and for fine work even better grades should be used. A gallon of varnish covers so much surface it hardly pays to use anything cheaper than \$3 varnish in good work. First coat should be applied very thin—about one-half turpentine and one-half varnish. Other coats can be used full strength. This will insure good color and will improve with age. Any amount of rubbing can be done that is desired, but three-coat work, with sandpaper after first coat and rubbing after last coat, makes *good* work for house finish.

Wax Finish.—Use beeswax cut with turpentine until as thin as linseed-oil; apply with brush. Second coat use as thick as lobbered milk. Apply with soft cloth and rub till dry; the more rubbed the better it will look. This will not show much finish at first, but in a few months the wood will gradually grow richer in color, and one of the most pleasing and restful effects to the eye is obtained. It produces what is called a dead finish. This does not scratch white, and if bruised at any time can be easily repaired with a little of the last coat, and should it grow dusky or too dull looking with age can be brightened up like new by rubbing with soft cloth wrung out of warm water.

Front Doors and Exterior Work.—For front doors and exterior work use only the *best coach varnish*, which is made from gums that will stand 550 degrees of heat before melting. This is the only thing that will stand the hot rays of the sun. Use no shellac with this.

Formula for Removing Dark Stains from Redwood: Use Crystallized Oxalic Acid.—Put in a bottle, pour water over it, and let dissolve. There is no danger of getting the solution too strong, as the water will take up only a certain portion of the acid. By wetting a cloth with this solution all stains can be rubbed off.

Caution.—Bottles should be marked "Poison." In using be careful that there are no sores on the hands.

Fillers.—Fillers should never be used in redwood, as most of them contain linseed-oil, which will spoil the work.

Caution.—Never use anything next to the wood that contain linseed-oil, as the acid in the wood seems to turn the oil into a sort of soapy condition that destroys all the fine lustre of the grain.

SHELLAC.—Lac is a resinous secretion found surrounding the twigs and branches of several trees in India and neighboring districts. The secretion is formed from the sap of trees, which sap is of a gummy and resinous nature, by the female of the lac insect, *coccus lacca*. The insect punctures the bark of the tree and commences to secrete the lac, in which it soon becomes completely enveloped; it then lays its eggs inside the deposit of lac and then dies. The young insects when they are born bore their way through the lac and swarm over the branches of the tree.

Shellac is the principal commercial variety of lac and is prepared and sold in large quantities. It is prepared from the seed lac by drying the latter product. The dried lac is then placed in large bags made of cotton cloth of medium texture.

The bag of lac is held by two men in front of a large fire. The heat of the fire soon melts the lac, which flows out of the bag, the men assisting the flow by twisting the bag so as to squeeze out the contents; the molten lac drops into a trough placed in front of the fire.

A cylinder of wood covered with brass is mounted on axles so as to be in a slightly inclined position; an operator dips a ladle into the trough of lac and pours it over the surface of the cylinder with a platen leaf. It rapidly sets, when it is stripped off the cylinder by means of a knife and is ready for the market. The best quality of shellac is known as orange shellac, which is a pale brownish orange color, but quite transparent.

White shellac is obtained through the method of bleaching orange shellac with oxalic acid, etc.

PUMICE.—Pumice, as is well known, is of volcanic origin, being a trachytic lava which has been rendered light by the escape of gases when in the molten state. The best stone is almost exclusively obtained from Monte Chirica, on the little island of Lipari, off the coast of Italy. The stone is brought to the surface of two great craters of extinct volcanoes in blocks or baskets by the natives, of whom about 1000 are employed in the industry. The supply is said to be practically inexhaustible.

Pumice is not merely used for scouring and cleaning purposes, but also for polishing and rubbing down between coats on finishing work for coaches, carriages, and interior woodwork. It is also used for wood filler.

ROSIN.—When the resinous exudations from various species of pine-trees are distilled with the aid of steam the products are a volatile spiritous substance, turpentine, leaving a liquid residue which, when cold, forms a hard, solid mass, known as rosin. Rosin is translucent and amber-colored, brittle, and melts at 212° Fahr.; at a higher temperature it decomposes into water, spirit, and oil.

Rosin is soluble in water, alcohol, turpentine, ether, benzine, and petroleum spirit. It is largely used in the preparation of cheap varnishes; such varnishes, however, do not possess the durability characteristic of copal or kauri varnishes.

Filling Hardwoods.—Oak, chestnut, ash, and all woods with large pores must have a coat of filler before being varnished, and unless the filler is well rubbed into all the pores and all the cavities are filled level with the surface of the wood, a satisfactory job of varnishing cannot be obtained. The superintendent should pay close attention to the work as it is being filled, so as to get a perfect surface to apply the varnish to.

The essential parts of a hardwood filler are a transparent, non-absorbent, mineral base and a proper proportion of linseed-oil and japan to make a good binder.

Transparent, for the reason that when cleaned off the lights or growths of wood must show up clear. China clay, whiting, paris white are not good, as they are all opaque; a filler made with such a base leaves a clouded, muddy appearance that is

particularly objectionable to the present style of antique oak, the market requiring the greatest possible contrast between the growth and the pore.

Non-absorbent, because the sole purpose of a filler is to bear the varnish up over the pore equally as bold as it is over the growth, thus producing an even surface on which to rub or polish. Such absorbents as powdered pumice-stone, etc., absolutely fail to produce the required result.

Mineral as a mineral is unshrinkable. Corn-starch and all other vegetable matter shrink with time; the varnish drops with it, leaving a depression at each pore.

Pinholes.—Failure to rub the filler well into the pore produces pinholes, or, more properly speaking, blow-holes. These are more often found in second-growth straight-grained oak, that possessing a deeper pore than most other wood; they are caused by the filler being wiped off instead of rubbed in, and thereby forced to the very bottom of the pore, thus driving out all the air. Failure to get rid of the air in the pore means that as the filler dries it gradually sags down, compressing the air to such a degree that it blows its way out, making a pinhole that is there to stay. Any number of coats that may be applied simply continue to blow out, as the hole is too small for the material to flow in and fill it up—each coat forming a cap that drops down until the confined air becomes stronger and blows out.

The filler is the foundation of the finish. "As the foundation is, so is the structure," is the old saying. Does it not apply with equal force to a filler finishing? Is it not quite as true that well-filled work requires less varnish to body it up to the requisite volume for a polished surface? Is it not also equally as certain that it requires more scouring to obtain that surface? Now, as a natural sequence to this, would it not be cheaper to pay a little more per piece, have the filling inspected, rejecting it if not up to the standard, get the foundation right, and save both higher-priced material and time?

Thinning.—Quite 90 per cent of the complaints of filler are directly traceable to the thinning. This is in a great measure due to the filler salesman, who represents that $7\frac{1}{2}$ to 8 pounds of filler to the gallon of liquid is all that is necessary to produce good results. An exhaustive investigation of the five most prominent fillers on the market show the best results and least wastage with the following proportions: For ash and mahogany,

7½; walnut, 8; quartered oak, 12; straight-grained oak, 14; and chestnut, 15 pounds of paste filler to the gallon of liquid.

Another phase of this trouble, and the most serious abuse to which filler is subjected, has grown out of the habit of breaking up the day's supply of filler in the morning. Neglect to stir the filler whilst in use permits the heavier particles to go to the bottom, resulting in using out too large a portion of the binder. When it grows thick turpentine or benzine is added, but no additional binder is supplied, hence the last of the day's work is not so well filled as that of the morning hours, and the varnish coat must supply the deficiency of binder.

STAINS.—Stains are liquid preparations of different tints, applied to the surface of the cheaper woods, in order to give them the appearance of the more rare and expensive woods, such as rosewood, mahogany, walnut, etc.

Suitable stains to imitate different woods may be prepared as follows:

Cherry.—Rain-water, 3 quarts; annetto, 4 ounces; boil in a copper kettle till the annetto is dissolved; then put in a piece of potash the size of a walnut; keep on the fire half an hour and it is then ready for use.

Mahogany.—(1) Put 2 ounces of dragon's blood, bruised, into a quart of oil of turpentine; let stand in a warm place until dissolved, when it is ready for use.

(2) Dragon's blood, ½ ounce; alkanet, ¼ ounce; aloes, 1 drachm; spirits of wine, 16 ounces.

Birch.—To finish to represent mahogany, coat with a weak solution of bichromate of potash, then stain with rose-pink Vandyke brown, and burnt Sienna; then shellac, with a little Bismarck brown dissolved in the shellac. This makes a better stain and more lasting than a water stain.

Red.—Brazil-wood, 11 parts; alum, 4 parts; water, 85 parts; boil together.

Blue.—Logwood, 7 parts; blue vitriol, 1 part; water, 22 parts; boil.

Black.—Logwood, 9 parts; sulphate of iron, 1 part; water, 25 parts; boil.

Green.—Verdigris, 1 part; vinegar, 3 parts; dissolve.

Yellow.—French berries, 7 parts; alum, 1 part; water, 10 parts; boil.

Purple.—Logwood, 11 parts; alum, 3 parts; water, 29 parts boil.

Black Walnut.—Burnt umber, 2 parts; rose-pink, 1 part; glue, 1 part; water sufficient to mix; heat and dissolve completely.

Ebony.—Drop-black, 2 parts; rose-pink, 1 part; turpentine sufficient to mix.

Satinwood.—Alcohol, 2 parts; powdered gamboge, 3 ounces; ground turmeric, 6 ounces; steep and strain through muslin.

Rosewood.—Alcohol, 1 gallon; camwood, 2 ounces; set in a warm place twenty-four hours, then add aqua fortis, 1 ounce; extract logwood, 3 ounces; when dissolved is ready for use.

DATA ON PAINTING.—One pound of paint will cover from $3\frac{1}{2}$ to 4 square yards of wood for the first coat, and from $4\frac{1}{2}$ to 6 square yards for each additional coat; on brickwork, it will cover about 3 and 4 square yards respectively. Colored paints will cover about one-fourth more surface than white paint.

Prepared shingle stains will cover about 200 square feet of surface if put on with a brush, or will be sufficient for dipping about 500 smooth shingles or 400 rough ones.

One gallon of liquid filler, hard oil finish, or varnish generally, will cover from 350 to 400 square feet of surface for first coat, and from 400 to 500 square feet of surface for subsequent coats.

One gallon of ready-mixed paint will cover 250 to 300 square feet of wood surface one coat, or 175 to 225 square feet two coats, or 125 to 150 square feet three coats.

White lead and oil will cover about 15 per cent less than the above.

BITUMINOUS, ASPHALT, ETC., PAINTS.—Bituminous or asphalt paints are prepared by dissolving bitumen in paraffine, petroleum, naphtha, or benzine.

P. B. paint is composed of asphaltum, linseed-oil, turpentine, and kauri-gum.

Coal-tar paint is composed of pure coal-tar, or coal-tar mixed with lime or other inert pigment, and mixed with fish or mineral oils. It is also made by mixing coal-tar and benzine; this makes a fair roof paint. Coal-tar paint is often substituted for asphaltum paint.

Graphite paint is prepared by mixing graphite with boiled linseed-oil to which a small percentage of litharge, red lead, manganese, or other metallic salt has been added at the time of boiling.

Prince's metallic paint is made from a blue magnetic iron ore, containing about 50 per cent of iron peroxide, 25 per cent

limestone, and 25 per cent sulphur. It is mined in Carbon County, Pa. The prepared pigment is said to contain 72 per cent of iron peroxide and 28 per cent of hydraulic cement. It is mixed in oil, and comes in one color, brown. It is one of the best paints for roofs and rough outside work.

There are a number of other metallic paints made from materials similar to Prince's and which possess about the same qualities.

VARIOUS METHODS OF COLORING OAK.—*Flemish Oak.*—Dissolve $\frac{1}{2}$ pound of bichromate of potash in one gallon of water. Coat the wood, and when dry, sandpaper down smooth; then coat with best drop-black, ground japan, thinned with turpentine. Let stand five minutes and wipe off clean; then coat with pure grain shellac and sandpaper with No. 0 sandpaper; then coat with beeswax, 1 pound to a gallon of turpentine, $\frac{1}{4}$ pound of drop-black mixed in the wax; then wipe off clean with cheese-cloth.

Weathered Oak.—Give the woodwork one coat of strong ammonia. When dry, sandpaper down smooth and stain it with a mixture composed of lampblack, ochre, and 2 pounds of silica to a gallon of stain. Wipe off with cheese-cloth, then give one coat of wax and wipe off clean. If a brownish shade is desired, put in 1 ounce of bichromate of potash and ammonia, or if a greenish shade, put in some green and stain.

Verde Finish.—One ounce of nigrocene dissolved in $\frac{1}{2}$ gallon of water. Give woodwork one coat; when dry sandpaper, care being taken not to rub off the edges; then fill with a bright green filler, with some white lead in the filler. When thoroughly dry, give one coat of pure grain shellac and then wax, or it should be finished with three coats of varnish and rubbed. This finish leaves the pores of a bright-green color, while the rest of the wood is almost black.

Black Oak.—One ounce of nigrocene to $\frac{1}{2}$ gallon of water. Give the woodwork one coat; then fill up with a black filler; then one coat of shellac and three coats of varnish rubbed with pumice-stone and water; then oil and wipe clean.

Birch.—To finish to represent mahogany, coat with a weak solution of bichromate of potash, then shellac, with a little Bismarck brown.

HARMONY AND CONTRAST IN COLORS.—White contrasts with black and harmonizes with gray.

- White contrasts with brown and harmonizes with buff.
- White contrasts with blue and harmonizes with sky-blue.
- White contrasts with purple and harmonizes with rose.
- White contrasts with green and harmonizes with pea-green.
- Cold greens contrast with crimson and harmonize with olive.
- Cold greens contrast with purple and harmonize with citrine.
- Cold greens contrast with white and harmonize with blues.
- Cold greens contrast with pink and harmonize with brown.
- Cold greens contrast with gold and harmonize with black.
- Cold greens contrast with orange and harmonize with gray.
- Warm greens contrast with crimson and harmonize with yellow.
- Warm greens contrast with maroons and harmonize with orange.
- Warm greens contrast with purple and harmonize with citrine.
- Warm greens contrast with red and harmonize with sky-blue.
- Warm greens contrast with pink and harmonize with gray.
- Warm greens contrast with white and harmonize with white.
- Warm greens contrast with black and harmonize with brown.
- Warm greens contrast with lavender and harmonize with buff.
- Greens contrast with colors containing red and harmonize with colors containing yellow or blue.
- Orange contrasts with purple and harmonizes with yellow.
- Orange contrasts with blue and harmonizes with red.
- Orange contrasts with black and harmonizes with red.
- Orange contrasts with black and harmonizes with warm green.
- Orange contrasts with olive and harmonizes with warm brown.
- Orange contrasts with crimson and harmonizes with white.
- Orange contrasts with gray and harmonizes with buff.
- Orange requires blue, black, purple, or dark colors for contrasts and warm colors for harmony.
- Citrine contrasts with purple and harmonizes with yellows.
- Citrine contrasts with blue and harmonizes with orange.
- Citrine contrasts with black and harmonizes with white.
- Citrine contrasts with brown and harmonizes with green.
- Citrine contrasts with crimson and harmonizes with buff.
- Russet contrasts with green and harmonizes with red.
- Russet contrasts with black and harmonizes with yellow.
- Russet contrasts with olive and harmonizes with orange.
- Russet contrasts with gray and harmonizes with brown.
- Olive contrasts with orange and harmonizes with green.

Olive contrasts with red and harmonizes with blue.

Olive contrasts with white and harmonizes with black.

Olive contrasts with maroon and harmonizes with brown.

Gold contrasts with any dark color, but looks richer with purple, green, blue, black, and brown than with the other colors. It harmonizes with all light colors, but least with yellow. The best harmony is with white.

GLASS.—All glass is composed of three chemical elements, viz., silica, soda, and some metallic oxide. There are three varieties of glass used in architectural work, namely, crown glass, sheet glass, and plate glass.

Crown glass is made by dipping the end of the blow-pipe in the melting-pot and collecting a ball of the molten glass on the end of the tube and blowing the glass into a globe. This globe is again heated while it is rotated rapidly and spreads out into a large flat, called a "table," under the influence of the centrifugal force of rotation. This flat piece of glass is then cut up into panes.

Sheet glass is made similarly to crown glass except that the glass as it is blown is rolled on a moulding block, causing the glass to take the form of a long cylinder. The ends of this cylinder are cut off and the cylinder split lengthwise; the split cylinder is then put in the flattening-kiln, where it is heated and flattened out into a flat sheet of glass. When cooled it is cut into panes.

Plate glass is pressed or rolled on a table by a large iron roller, the glass is squeezed out before the advancing roller and pressed into a sheet of the desired size. The thickness of the sheet is gauged by strips of metal on each side of the table. The sheets after being rolled are put into the annealing-oven for several days and then polished by grinding to an even surface and polishing and smoothing with fine emery and felt rubbers.

The defects in glass are very apparent and consist of waves, air-bubbles, twists, sand-specks, and patches of color.

Sheet glass is of various qualities, weighing from 12 to 42 ounces per square foot. Every $\frac{1}{16}$ inch in thickness adds about 13 ounces to the weight per square foot. Glass is usually sold by the box, containing 50 square feet of glass regardless of the size of the panes; it is sold in three thicknesses and grades, viz., AA, A, and B, of which AA is the best and thickest. On the Pacific Coast it is usually graded by weight as 15-ounce,

21-ounce, and 26-ounce glass, and which corresponds to the AA, A, and B grades of the Eastern market.

The thickness of the ordinary window glass is known as single strength and double strength. Thus AA double strength would mean the best quality and thickness.

The finished plates of polished plate glass varies in thickness from $\frac{1}{4}$ to $\frac{3}{8}$ inch.

GLAZING.—All glass should be bedded in a layer of putty spread in the rebate of the sash and the glass pressed down

ROLLS OF PAPER REQUIRED TO COVER THE WALLS
OF A ROOM.

| Size of Room. | Height of Ceiling. | Number of Doors. | Number of Windows. | Rolls of Paper. | Yards of Border. |
|---------------|--------------------|------------------|--------------------|-----------------|------------------|
| 7×9..... | 8 | 1 | 1 | 6 | 11 |
| 7×9..... | 9 | 1 | 1 | 7 | 11 |
| 7×9..... | 10 | 1 | 1 | 8 | 11 |
| 7×9..... | 12 | 1 | 1 | 10 | 11 |
| 8×10..... | 8 | 1 | 1 | 7 | 12 |
| 8×10..... | 9 | 1 | 1 | 8 | 12 |
| 8×10..... | 10 | 1 | 1 | 9 | 12 |
| 8×10..... | 12 | 1 | 1 | 11 | 12 |
| 9×11..... | 8 | 1 | 1 | 8 | 14 |
| 9×11..... | 9 | 1 | 1 | 10 | 14 |
| 9×11..... | 10 | 1 | 1 | 11 | 14 |
| 9×11..... | 12 | 1 | 1 | 13 | 14 |
| 10×12..... | 8 | 1 | 1 | 9 | 14 |
| 10×12..... | 9 | 1 | 1 | 10 | 15 |
| 10×12..... | 10 | 1 | 1 | 11 | 15 |
| 10×12..... | 12 | 1 | 1 | 13 | 15 |
| 11×12..... | 8 | 2 | 2 | 8 | 16 |
| 11×12..... | 9 | 2 | 2 | 9 | 16 |
| 11×12..... | 10 | 2 | 2 | 10 | 16 |
| 11×12..... | 12 | 2 | 2 | 13 | 16 |
| 12×13..... | 8 | 2 | 2 | 8 | 17 |
| 12×13..... | 9 | 2 | 2 | 10 | 17 |
| 12×13..... | 10 | 2 | 2 | 11 | 17 |
| 12×13..... | 12 | 2 | 2 | 14 | 17 |
| 12×15..... | 8 | 2 | 2 | 10 | 18 |
| 12×15..... | 9 | 2 | 2 | 11 | 18 |
| 12×15..... | 10 | 2 | 2 | 12 | 18 |
| 12×15..... | 12 | 2 | 2 | 15 | 18 |
| 13×15..... | 8 | 2 | 2 | 10 | 19 |
| 13×15..... | 9 | 2 | 2 | 11 | 19 |
| 13×15..... | 10 | 2 | 2 | 13 | 19 |
| 13×15..... | 12 | 2 | 2 | 16 | 19 |
| 14×16..... | 9 | 2 | 2 | 12 | 20 |
| 14×16..... | 10 | 2 | 2 | 14 | 20 |
| 14×16..... | 12 | 2 | 2 | 17 | 20 |
| 14×18..... | 9 | 2 | 2 | 13 | 22 |
| 14×18..... | 10 | 2 | 2 | 15 | 22 |
| 14×18..... | 12 | 2 | 2 | 19 | 22 |
| 15×16..... | 10 | 2 | 2 | 15 | 21 |
| 15×17..... | 12 | 2 | 2 | 19 | 22 |

Deduct one-half roll of paper for each ordinary door or window extra-size, 4×7 feet.

A double roll of wall-paper contains about 72 square feet.

into this bed so as to lay solid; it should then be secured with a sufficient number of points or "sprigs" and then "front glazed." In glazing the sash care must be taken not to put the putty on heavy enough to project over the wood rebate and thus show from the inside of the sash. All sash should have a coat of paint or oil before being glazed, so the putty will take hold of the wood.

PAPER-HANGING.—To prepare the walls, make a size of glue and water, then give the walls a coat of a very weak solution of the same. To make a paste, take 2 pounds of fine flour, put in a pail, add cold water, and stir it up together in a thick paste. Take a piece of alum about the size of a small chestnut, pound it fine and throw it into the paste; mix well. Then take about 6 quarts of boiling water and mix with the paste while hot until the whole is brought to a proper consistency. This makes an excellent paste, and is fit for use when cold.

The table on page 421 shows how many single rolls of wall-paper are required to cover the walls of a room of the dimensions indicated by the figures in the left-hand column, also the number of yards of border required.

Cast Iron.—Cast iron is the remelted pig iron run in moulds of the desired shape. A cast-iron casting should show a smooth clean surface and have all angles run true and sharp. There should be no "blow" or "sand" holes.

Cast iron when broken should show a close-grained texture, and the fracture should have a light-bluish color. The iron should be soft enough so it can be dented by a blow of a hammer on a corner without breaking off pieces.

The superintendent should examine all cast iron closely, as very often "blow" or "sand" holes are stopped up with putty.

A casting when struck with a hammer should give a clear ring; if it gives a dull sound it indicates a crack or holes stopped up.

Cast-iron columns should be examined as to the thickness of the metal, for if the core in casting has been placed a little out of centre then the column will have thick iron on one side and thin iron on the other.

Cast-iron pipes should be tapped with a hammer to sound for cracks, "blow" or "sand" holes, and also examined to see if they are of the required thickness, and that the bead and hub are well formed.

SPECIFICATIONS FOR STRUCTURAL CAST IRON.

STRUCTURAL CAST IRON.—Except when chilled iron is specified, all castings shall be tough gray iron, free from injurious cold-shuts or blow-holes, true to pattern, and of a workmanlike finish. Sample pieces 1 inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining on a clear span of 4 feet 8 inches a central load of 500 pounds when tested in the rough bar.

DATA REGARDING CAST IRON.—Specific gravity, 7.10 to 7.50.
Weight per cubic foot, 450 pounds.

Ultimate strength: Tensile, 13,000 to 29,000 pounds per square inch; compressive, 85,000 to 125,000 pounds per square inch; shearing, 25,000 pounds per square inch; torsion, 8600 pounds per square inch; transverse, 500 to 4000 pounds per square inch.

Working strength: Tensile, 3000 pounds per square inch; compressive, 80,000 pounds per square inch; transverse, 600 pounds per square inch; shearing, 6000 pounds per square inch; torsion, 5000 pounds per square inch.

Shrinkage, $\frac{1}{8}$ inch per foot.

Melting-point, 2000° F.

MALLEABLE CAST IRON.—Malleable cast iron is cast iron which has been deprived of some of its carbon by heating to a red heat, together with some chemical compound having a strong affinity for carbon, and then allowing it to cool slowly. Such castings are not as brittle as the ordinary cast iron.

STRENGTH OF MALLEABLE CAST IRON.

Tensile. 25,000 to 50,000 pounds per square inch.
Elongation. 1 to 2 per cent in 4 inches.
Elastic limit. 15,000 to 21,000.

The same care should be taken in examining malleable cast-iron castings as with the ordinary cast iron.

The use of cast or malleable iron for structural purposes should be confined to those parts or members which only will have to withstand a compressive strain.

The following tables, on pages 424 and 425, gives the strength and safe load for cast-iron columns.

ULTIMATE STRENGTH OF HOLLOW ROUND AND HOLLOW RECTANGULAR CAST-IRON COLUMNS.

Ultimate strength in pounds per square inch:

| ROUND COLUMNS. | | | RECTANGULAR COLUMNS. | | |
|------------------------------|--------------------------------|------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Square Bearing. 80000 | Pin and Square. 80000 | Pin Bearing. 80000 | Square Bearing. 80000 | Pin and Square. 80000 | Pin Bearing. 80000 |
| $1 + \frac{(12l)^2}{800d^2}$ | $1 + \frac{3(12l)^2}{1600d^2}$ | $1 + \frac{(12l)^2}{400d^2}$ | $1 + \frac{3(12l)^2}{3200d^2}$ | $1 + \frac{9(12l)^2}{6400d^2}$ | $1 + \frac{3(12l)^2}{1600d^2}$ |

l = length of column in feet;

d = external diameter or least side of rectangle in inches.

| $\frac{l}{d}$ | Round Columns. Ultimate Strength in Pounds per Square Inch. | | | Rectangular Columns. Ultimate Strength in Pounds per Square Inch. | | |
|---------------|---|-----------------|--------------|---|-----------------|--------------|
| | Square Bearing. | Pin and Square. | Pin Bearing. | Square Bearing. | Pin and Square. | Pin Bearing. |
| 1.0 | 67800 | 62990 | 58820 | 70480 | 66520 | 62990 |
| 1.1 | 65690 | 60300 | 55730 | 68790 | 64260 | 60300 |
| 1.2 | 63530 | 57600 | 52690 | 67000 | 61940 | 57600 |
| 1.3 | 61340 | 54930 | 49740 | 65140 | 59600 | 54960 |
| 1.4 | 59140 | 52310 | 46900 | 63260 | 57270 | 52320 |
| 1.5 | 56940 | 49770 | 44290 | 61350 | 54960 | 49760 |
| 1.6 | 54760 | 47300 | 41630 | 59450 | 52680 | 47300 |
| 1.7 | 52620 | 44940 | 39210 | 57550 | 50460 | 44960 |
| 1.8 | 50530 | 42670 | 36930 | 55670 | 48300 | 42670 |
| 1.9 | 48490 | 40510 | 34790 | 53800 | 46230 | 40510 |
| 2.0 | 46510 | 38460 | 32790 | 51940 | 44200 | 38460 |
| 2.1 | 44600 | 36520 | 30920 | 50160 | 42260 | 36520 |
| 2.2 | 42750 | 34680 | 29180 | 48400 | 40400 | 34680 |
| 2.3 | 40980 | 32940 | 27540 | 46670 | 38630 | 32950 |
| 2.4 | 39280 | 31310 | 26030 | 44990 | 36930 | 31310 |
| 2.5 | 37650 | 29770 | 24620 | 43390 | 35310 | 29760 |
| 2.6 | 36090 | 28320 | 23300 | 41820 | 33770 | 28320 |
| 2.7 | 34600 | 26950 | 22070 | 40320 | 32310 | 26950 |
| 2.8 | 33180 | 25670 | 20930 | 38870 | 30920 | 25670 |
| 2.9 | 31820 | 24460 | 19860 | 37470 | 29600 | 24460 |
| 3.0 | 30530 | 23320 | 18870 | 36120 | 28340 | 23320 |
| 3.1 | 29310 | 22250 | 17940 | 34830 | 27150 | 22250 |
| 3.2 | 28140 | 21250 | 17070 | 33580 | 26030 | 21250 |
| 3.3 | 27030 | 20300 | 16260 | 32390 | 24960 | 20300 |
| 3.4 | 25970 | 19410 | 15500 | 31240 | 23940 | 19410 |

SAFE LOADS IN TONS OF 2000 LBS. FOR HOLLOW ROUND CAST-IRON COLUMNS.

| Outside Diameter, Inches. | Thickness of Metal. | Length of Columns in Feet. | | | | | | | | | Sectional Area, Inches. | Weight, Lbs. of Col. per Ft. of L'gth. |
|---------------------------|---------------------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------------------------|--|
| | | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | | |
| | | Tons | Tons | Tons | Tons | Tons | Tons | Tons | Tons | Tons | | |
| 6 | $\frac{1}{4}$ | 26.2 | 23.0 | 20.1 | 17.5 | 15.2 | 13.2 | 11.5 | ..... | ..... | 8.6 | 26.95 |
| 6 | $\frac{3}{8}$ | 37.5 | 33.0 | 28.8 | 25.0 | 21.7 | 18.9 | 16.5 | ..... | ..... | 12.4 | 38.59 |
| 6 | $\frac{1}{2}$ | 42.7 | 37.6 | 32.8 | 28.5 | 24.7 | 21.5 | 18.8 | ..... | ..... | 14.1 | 43.96 |
| 6 | 1 | 47.6 | 41.9 | 36.5 | 31.8 | 27.6 | 24.0 | 21.0 | ..... | ..... | 15.7 | 49.01 |
| 6 | 1 $\frac{1}{8}$ | 52.2 | 46.0 | 40.1 | 34.8 | 30.2 | 26.3 | 23.0 | ..... | ..... | 17.2 | 53.76 |
| 7 | $\frac{3}{4}$ | 47.7 | 43.1 | 38.5 | 34.3 | 30.4 | 26.9 | 23.9 | 21.2 | 18.9 | 14.7 | 45.96 |
| 7 | 1 | 61.1 | 55.2 | 49.3 | 43.8 | 38.9 | 34.4 | 30.6 | 27.1 | 24.2 | 18.9 | 58.90 |
| 7 | 1 $\frac{1}{8}$ | 67.2 | 60.8 | 54.3 | 48.3 | 42.8 | 37.9 | 33.7 | 29.9 | 26.7 | 20.8 | 64.77 |
| 8 | $\frac{3}{4}$ | 57.9 | 53.3 | 48.6 | 44.1 | 39.7 | 35.8 | 32.2 | 28.9 | 26.1 | 17.1 | 53.29 |
| 8 | 1 | 74.6 | 68.7 | 62.5 | 56.7 | 51.1 | 46.0 | 41.4 | 37.3 | 33.6 | 22.0 | 68.64 |
| 8 | 1 $\frac{1}{4}$ | 89.9 | 82.8 | 75.5 | 68.4 | 61.7 | 55.5 | 49.9 | 44.9 | 40.5 | 26.5 | 82.71 |
| 9 | $\frac{3}{4}$ | 68.1 | 63.6 | 58.9 | 54.2 | 49.6 | 45.2 | 41.2 | 37.5 | 34.1 | 19.4 | 60.65 |
| 9 | 1 | 88.0 | 82.3 | 76.2 | 70.0 | 64.1 | 58.4 | 53.2 | 48.4 | 44.1 | 25.1 | 78.40 |
| 9 | 1 $\frac{1}{8}$ | 106.6 | 99.6 | 92.2 | 84.8 | 77.6 | 70.8 | 64.4 | 58.7 | 53.4 | 30.4 | 94.94 |
| 9 | 1 $\frac{1}{2}$ | 123.8 | 115.7 | 107.1 | 98.5 | 90.1 | 82.2 | 74.8 | 68.1 | 62.0 | 35.3 | 110.26 |
| 9 | 1 $\frac{3}{4}$ | 139.6 | 130.5 | 120.8 | 111.1 | 101.6 | 92.7 | 84.4 | 76.8 | 69.9 | 39.9 | 124.36 |
| 10 | 1 | 101.4 | 95.9 | 89.8 | 83.6 | 77.4 | 71.5 | 65.8 | 60.5 | 55.5 | 28.3 | 88.23 |
| 10 | 1 $\frac{1}{4}$ | 123.3 | 116.5 | 109.1 | 101.6 | 94.1 | 86.8 | 79.9 | 73.4 | 67.5 | 34.4 | 107.23 |
| 10 | 1 $\frac{1}{2}$ | 143.7 | 135.8 | 127.3 | 118.5 | 109.7 | 101.2 | 93.2 | 85.6 | 78.7 | 40.1 | 124.99 |
| 10 | 1 $\frac{3}{4}$ | 162.7 | 153.8 | 144.1 | 134.1 | 124.2 | 114.6 | 105.5 | 97.0 | 89.1 | 45.4 | 141.65 |
| 11 | 1 | 114.8 | 109.4 | 103.5 | 97.3 | 91.0 | 84.8 | 80.2 | 73.1 | 67.7 | 31.4 | 98.03 |
| 11 | 1 $\frac{1}{4}$ | 139.9 | 133.3 | 126.1 | 118.6 | 110.9 | 103.3 | 97.8 | 89.4 | 82.5 | 38.3 | 119.46 |
| 11 | 1 $\frac{1}{2}$ | 163.5 | 155.9 | 147.5 | 138.6 | 128.7 | 120.8 | 114.3 | 104.1 | 96.4 | 44.8 | 139.68 |
| 11 | 1 $\frac{3}{4}$ | 185.7 | 177.1 | 167.5 | 157.5 | 147.3 | 137.2 | 129.8 | 118.3 | 109.5 | 50.9 | 158.68 |
| 11 | 2 | 206.6 | 196.9 | 186.3 | 175.1 | 163.8 | 152.6 | 144.4 | 131.5 | 121.8 | 56.6 | 176.44 |
| 12 | 1 | 128.0 | 122.9 | 117.2 | 111.0 | 104.7 | 98.4 | 92.2 | 86.1 | 80.4 | 34.6 | 107.51 |
| 12 | 1 $\frac{1}{4}$ | 156.4 | 150.1 | 143.1 | 135.7 | 127.9 | 120.2 | 112.6 | 105.2 | 98.2 | 42.2 | 131.41 |
| 12 | 1 $\frac{1}{2}$ | 183.3 | 175.9 | 167.7 | 159.0 | 149.9 | 140.9 | 132.0 | 123.3 | 115.1 | 49.5 | 154.10 |
| 12 | 1 $\frac{3}{4}$ | 208.7 | 200.4 | 191.0 | 181.1 | 170.7 | 160.4 | 150.3 | 140.5 | 131.1 | 56.4 | 175.53 |
| 12 | 2 | 232.7 | 223.4 | 213.0 | 201.9 | 190.4 | 178.9 | 167.6 | 156.6 | 146.1 | 62.8 | 195.75 |
| 13 | 1 | 141.2 | 136.3 | 130.7 | 124.7 | 118.5 | 112.1 | 105.8 | 99.5 | 93.5 | 37.7 | 117.53 |
| 13 | 1 $\frac{1}{4}$ | 172.8 | 166.8 | 160.0 | 152.7 | 145.0 | 137.2 | 129.4 | 121.8 | 114.4 | 46.1 | 143.86 |
| 13 | 1 $\frac{1}{2}$ | 203.0 | 195.9 | 187.9 | 179.3 | 170.3 | 161.1 | 152.0 | 143.1 | 134.3 | 54.2 | 168.98 |
| 13 | 1 $\frac{3}{4}$ | 231.6 | 223.6 | 214.5 | 204.7 | 194.4 | 183.9 | 173.5 | 163.3 | 153.3 | 61.9 | 192.88 |
| 13 | 2 | 258.9 | 249.9 | 239.7 | 228.7 | 217.3 | 205.5 | 193.9 | 182.5 | 171.3 | 69.1 | 215.56 |
| 14 | 1 | 154.3 | 149.6 | 144.3 | 138.5 | 132.3 | 125.9 | 119.5 | 113.1 | 106.8 | 40.8 | 127.60 |
| 14 | 1 $\frac{1}{4}$ | 189.2 | 183.4 | 176.9 | 169.7 | 162.2 | 154.4 | 146.5 | 138.6 | 131.0 | 50.1 | 156.31 |
| 14 | 1 $\frac{1}{2}$ | 222.6 | 215.8 | 208.1 | 199.7 | 190.8 | 181.7 | 172.3 | 163.1 | 154.1 | 58.9 | 183.67 |
| 14 | 1 $\frac{3}{4}$ | 254.4 | 246.7 | 237.9 | 228.3 | 218.1 | 207.6 | 197.0 | 186.5 | 176.2 | 67.4 | 210.00 |
| 14 | 2 | 284.8 | 276.2 | 266.4 | 255.6 | 244.2 | 232.4 | 220.6 | 208.8 | 197.2 | 75.4 | 235.12 |
| 15 | 1 | 167.4 | 162.9 | 157.8 | 152.1 | 146.0 | 139.7 | 133.3 | 126.8 | 120.4 | 44.0 | 137.28 |
| 15 | 1 $\frac{1}{4}$ | 205.5 | 200.0 | 193.7 | 186.7 | 179.3 | 171.5 | 163.6 | 155.7 | 147.9 | 54.0 | 168.48 |
| 15 | 1 $\frac{1}{2}$ | 242.1 | 235.7 | 228.2 | 220.0 | 211.2 | 202.1 | 192.8 | 183.5 | 174.2 | 63.6 | 198.74 |
| 15 | 1 $\frac{3}{4}$ | 277.2 | 269.8 | 261.3 | 251.9 | 241.9 | 231.4 | 220.7 | 210.1 | 199.5 | 72.9 | 227.45 |
| 15 | 2 | 310.8 | 302.5 | 293.0 | 282.5 | 271.2 | 259.5 | 247.5 | 235.5 | 223.6 | 81.7 | 254.90 |

If all cast-iron or other hollow columns are filled with concrete after being set it adds to their strength and affords protection from rust and fire.

Wrought Iron.—Wrought iron, when perfect, is simply pure iron; wrought iron has the advantage over other iron in that it can be welded when heated to nearly a white heat.

Good iron should be soft and tough, and when broken should show small crystals of a uniform size and color, and fine silky fibres, or if broken gradually should show long silky fibres of a gray-bluish color.

Good iron should bend cold 180° degrees around a circle whose diameter is twice the thickness of the piece, for bar iron, and three times the thickness for plates.

DATA ON WROUGHT IRON.

Specific gravity 7.79.

Weight per cubic foot 480 to 485 pounds per cubic foot.

Melting-point 2734° to 3000° Fahr.

Ultimate tensile strength 30,000 to 70,000 pounds.

Ultimate compressive strength 40,000 to 125,000 pounds.

Ultimate shearing strength 40,000 pounds.

Working strength, tensile, 10,000 to 15,000 pounds per square inch.

Working strength, compressive, 36,000 pounds per square inch.

Working strength, shearing, 6000 to 9000 pounds per square inch.

Structural Iron and Steel.—Steel is a compound of iron with from .01 to 1.5 per cent of carbon. It also contains minute quantities of silicon, sulphur, phosphorus, etc. The process of making steel may be classed under two heads: by adding carbon to wrought iron, and by abstracting carbon from cast iron. The former is used for making tool steel and the latter for making large masses of steel for ordinary uses.

Good soft steel should bend cold through 180° , and close down flat upon itself without cracking.

A simple test for iron or steel is to take a small sample, file it smooth on all sides, and place it in dilute nitric or sulphuric acid for about twelve hours, then wash and dry it. The action of the acid will show the structure of the material, from which its quality can be judged.

The best steel will show a frosty appearance; ordinary steel, honeycombed; the best iron will show fine fibres, while if the composition or structure of the iron is uneven, the acid will reveal it.

All structural steel or iron work should be inspected at the shops, just before being riveted together, and again after the work is finished and ready for painting.

When inspecting the work at the shop notice should be taken to see that all members, beams, etc., are perfectly straight, and that all are of the dimensions called for by the drawings. The superintendent, or inspector, should examine each piece as to dimensions, locations of rivets, bolt-holes, etc., and see that they are all located correctly. He should see that the holes for riveting are of the correct size and that when the work is put together the holes come directly opposite each other. As each piece is inspected it should be stamped or marked so that when it is received at the work there will be an indication of shop inspection.

As the material is delivered at the work, the superintendent should examine it for the shop inspector's mark, and if there is any which does not bear this mark, when there has been a shop inspection made, it should be examined closely for defects.

The superintendent should see that the work has been properly painted, and if not, have a coat of paint put on as soon as possible. He should also see that all columns or other members have been faced off as required by the specifications.

In erecting the work all columns, etc., should be started level, so they will be carried level throughout the structure.

As the work is put together, he should see that all holes for bolts or rivets come opposite, and should not allow the drift-pin to be used except for drawing the work together. If the bolt or rivet will not enter he should have the hole reamed out and a larger bolt or rivet used.

Where bolts are used in any of the flanges of the members bevelled washers should be used on the bevelled flange.

As soon as the work is put together he should see that it receives a coat of paint at once, and have any rust which may appear scraped off.

The following, by C. J. Tilden, Assoc. M. Am. Soc. C. E., Assistant Engineer New York Rapid Transit Commission, 242 St. Nicholas Ave., New York City, is very instructive in regard to riveting, etc.

RIVETS IN STRUCTURAL STEEL WORK.*—A theoretically perfect rivet should fill the hole completely, be of homogeneous material throughout, and have two well-formed heads. The

* Condensed from an article in the *Harvard Engineering Journal*.

strength of a riveted joint depends, theoretically, on but two considerations: first, the shearing strength of the rivet material, usually soft steel; and, second, the number of rivets used. When comparatively thin plates are joined by rivets of large diameter, it may happen that the resistance of the metal to crushing is less than the shearing strength of one rivet; in which case the crushing or "bearing" value of the metal determines the value to be given to each rivet in calculating the strength of the joint. The question then arises with what degree of safety may the designing engineer accept these theoretical assumptions, and how are they borne out by the conditions which occur in shop practice?

In the first place, the material of a rivet is not homogeneous. In a large majority of cases it is probable that test-pieces taken from different parts of a rivet after driving, assuming that such small pieces could be properly tested, would show widely different characteristics, and these totally different from similar tests of the same rivet before driving. A very good idea of the great difference in quality of rivet material after driving may be gained by watching for a few hours a shop-gang engaged in cutting out rivets which have been condemned by the inspector. Sometimes the metal is hard, tough, and fibrous; then again nearly as soft, to all appearances, as lead or pewter; and occasionally the rivet-head will fly off at the first blow of the hammer, apparently almost as hard and brittle as glass.

A second noteworthy discrepancy in the design of riveted joints is the failure to take account of the action of the rivet-heads in bringing the two or more surfaces into very close contact, so that a large amount of friction is developed. It is quite possible that this friction may amount to more than the shearing strength of the rivet. In any event it is a very important factor in the strength of a riveted joint.

In the diagram, Fig. 240, are shown some of the more frequent imperfections in rivet-work, resulting from carelessness of the workmen. At *a*, for comparison, is sketched a perfectly driven rivet. The original form is shown dotted, the "shank" being $\frac{1}{16}$ or $\frac{3}{32}$ of an inch less in diameter than the hole which it is to fill, and enough longer than the "grip" or length between heads, to allow the formation of the new head, and the squeezing out of the rivet material sufficiently to fill the hole completely. Both heads should be concentric with the shank, and the rivet

should be perfectly tight, giving a clear, sharp ring when struck with a light hammer.

At *b* is shown a loose rivet which has been "calked," with a cold-chisel, to make it appear tight under the inspector's hammer—a favorite trick of careless riveting-gangs, and often very difficult to detect; if suspected, a close examination should be made of the head of the rivet for signs of the calking-tool, especially if the rivet has been generously bespattered with fresh paint or tobacco-juice. Both these commodities, always plentiful in the shop, are favorite means of concealment for "scamped" work of this character. A result very similar to calking, but much harder to discover, is sometimes secured by using the riveting-machine, or "bull" as it is familiarly known to the shop men, on the cold rivet. The movable cup of the "bull" is brought sharply against the rivet-head, securing somewhat the effect of a blow, and this is repeated four or five times on each loose rivet. In general, this machine-calking is not very effective, but the writer has known instances where it has been successful. It is well-nigh impossible to tell from the appearance of the rivet-head afterwards if this trick has been attempted. A very slight polish on the head of the rivet is about all the evidence that ever appears, and this is readily hidden by a dab of grease or dirt, or the ever-ready tobacco-juice. It is a form of "scamping" that is seldom resorted to, however, as it is more

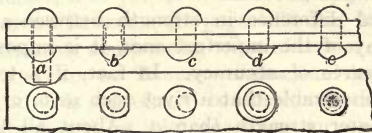


FIG. 240.



FIG. 241.

work than calking with the cold-chisel, and far less likely to accomplish its purpose.

The sketch, *b*, also shows the probable result of heating the rivet unevenly. Where the heating is done in an ordinary portable forge, fired with coke, the forge-tender gets into the habit of heating only that part of the rivet which is to be upset to form the head, leaving the remainder comparatively cool. Referring to Fig. 241, for example, from the lower end of the rivet to, perhaps, the point *x*, the metal is at white heat; above that it cools rapidly until the head is practically "cold," often

not even a dull-red color. This uneven heating not only prevents the rivet from upsetting throughout its length, and so filling the hole, but is apt to injure the quality of the metal above the point x , owing to its being worked under the hammer at too low a temperature.

Careless manipulation of the riveting-machine may result in the condition shown at c , where the head is not concentric with the shank. The fault can be detected only by comparison with the other rivets in the joint, showing uneven spacing and irregular lines.

The condition shown at d results from too much metal in the shank of the rivet before driving, giving a "soldier-cap" head. The reverse of this is shown at e .

It must not be supposed that these defects are the only ones which occur in rivet-work; they are only a few of the more frequent errors of this kind that may be observed in any shop. Combinations of two or more of the forms shown occur not infrequently, and an almost endless variety of changes may be rung on each one. Of the four types, b and e should be condemned unquestionably whenever found, being not only bad workmanship, but unreliable; c and d probably develop the full strength of the rivet, and may be allowed to pass if strength is the only consideration; but if the work is to be exposed they should be cut out and replaced, as they are sure to look ragged in finished work.

As to the actual difference in strength between a perfect rivet, as a , and any of the imperfect ones, it is impossible to judge with any degree of accuracy. In fact, if a test were made it is quite conceivable that a rivet such as b , or even e , might develop greater strength than a . About all that can be said is that this is not likely to happen, but rather the reverse, as a properly driven rivet is more likely to develop its full strength than one which is imperfect in any way. But this is not reducing the question to any scientific basis, and, indeed, it cannot be so reduced. Rigid specifications are required for riveted work, and the work in the shop is subjected to the most careful inspection, not because a carelessly driven rivet is less strong, by any definitely calculable percentage, than one which is properly driven, but for the simple reason that careful and accurate work is more reliable.

The nearest approach to a theoretically perfect rivet is probably the turned bolt which is occasionally used for field con-

nections. In such cases it is the practice of some engineers to require the holes to be drilled instead of punched, or "sub-punched and reamed"—that is, punched to a diameter about $\frac{1}{4}$ inch less than that of the bolt to be used and reamed to proper size. The bolt is turned to a driving fit, and the threaded part is of slightly reduced diameter, the shoulder, *s*, protecting the thread while the bolt is driven home. To keep the nut in place after it is screwed up tight, the projecting threaded end of the bolt is upset against the nut. In spite of the reliability of this connection, however, its high cost precludes its general use.

Fig. 241 shows a form of rivet which has certain advantages and disadvantages over the ordinary shape. In this form the shank is slightly increased in diameter (exaggerated in the drawing) for a distance of $\frac{1}{2}$ to $\frac{3}{4}$ inch from the head. Directly under the head, at the base of the cone-like enlargement, the shank has the same diameter as the hole into which the rivet is to go—that is, from $\frac{1}{16}$ to $\frac{3}{32}$ inch larger than the main part of the shank. This is an advantage in the shop, where the rivet is sure to be uniformly heated throughout its length, as it insures the complete filling of the hole up to the rivet-head. In the field, however, where the rivets are likely to be unevenly heated, such a design would be of doubtful advantage. A rivet of this shape might easily appear sound and tight under the inspector's hammer, and yet have been very imperfectly driven.

TABLES ON RIVETS.—On pages 432 and 433 are given tables on the shearing and bearing value of rivets.

EXPLANATION OF TABLES.—In transmitting stresses by means of rivets, it is customary to disregard the friction between the parts joined as too uncertain an element to be relied upon to any extent. The rivets must then be proportioned for the entire stress which is to be transmitted from one plate or group of plates to the other, and they must be of sufficient size and number to present ample resistance to shearing and afford sufficient bearing area so as not to cause a crushing of the metal at the rivet-holes. This latter condition, while generally observed for pins, is very often entirely overlooked in riveted work. Its observance, in most cases of riveted girders with single webs, determines the size and number of rivets to be used and frequently makes it necessary to adopt a greater thickness of web than would otherwise be required. Thus, if the web is $\frac{5}{16}$ inch thick, the rivets connecting the same with

SHEARING AND BEARING VALUE OF RIVETS.

(All Dimensions in Inches.)

| Diameter of Rivet. | | Area in Square Inches. | Single Shear at 6000 Lbs. | Bearing Value for | | | |
|--------------------|----------|------------------------|---------------------------|-------------------|----------------|---------------|---------------|
| Inches. | | | | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{8}$ |
| Fraction. | Decimal. | | | | | | |
| $\frac{3}{8}$ | .375 | .1104 | 660 | 1130 | 1410 | 1690 | .... |
| $\frac{1}{2}$ | .500 | .1963 | 1180 | 1500 | 1880 | 2250 | 2630 |
| $\frac{5}{8}$ | .625 | .3063 | 1840 | 1880 | 2340 | 2810 | 3280 |
| $\frac{3}{4}$ | .750 | .4418 | 2650 | 2250 | 2810 | 3380 | 3940 |
| $\frac{7}{8}$ | .875 | .6013 | 3610 | 2630 | 3280 | 3940 | 4590 |
| 1 | 1.000 | .7854 | 4710 | 3000 | 3750 | 4500 | 5250 |

| Diameter of Rivet. | | Area in Square Inches. | Single Shear at 7500 Lbs. | Bearing Value for | | | |
|--------------------|----------|------------------------|---------------------------|-------------------|----------------|---------------|---------------|
| Inches. | | | | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{8}$ |
| Fraction. | Decimal. | | | | | | |
| $\frac{3}{8}$ | .375 | .1104 | 830 | 1410 | 1760 | 2110 | .... |
| $\frac{1}{2}$ | .500 | .1963 | 1470 | 1880 | 2340 | 2810 | 3280 |
| $\frac{5}{8}$ | .625 | .3068 | 2300 | 2340 | 2930 | 3520 | 4100 |
| $\frac{3}{4}$ | .750 | .4418 | 3310 | 2810 | 3520 | 4220 | 4920 |
| $\frac{7}{8}$ | .875 | .6013 | 4510 | 3280 | 4100 | 4920 | 5740 |
| 1 | 1.000 | .7854 | 5890 | 3750 | 4690 | 5620 | 6560 |

| Diameter of Rivet. | | Area in Square Inches. | Single Shear at 10000 Lbs. | Bearing Value for | | | |
|--------------------|----------|------------------------|----------------------------|-------------------|----------------|---------------|---------------|
| Inches. | | | | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{8}$ |
| Fraction. | Decimal. | | | | | | |
| $\frac{3}{8}$ | .375 | .1104 | 1100 | 1880 | 2340 | 2810 | .... |
| $\frac{1}{2}$ | .500 | .1963 | 1960 | 2500 | 3130 | 3750 | 4380 |
| $\frac{5}{8}$ | .625 | .3068 | 3070 | 3130 | 3910 | 4690 | 5470 |
| $\frac{3}{4}$ | .750 | .4418 | 4420 | 3750 | 4690 | 5630 | 6560 |
| $\frac{7}{8}$ | .875 | .6013 | 6010 | 4380 | 5470 | 6570 | 7660 |
| 1 | 1.000 | .7854 | 7850 | 5000 | 6250 | 7500 | 8750 |

| Diameter of Rivet. | | Area in Square Inches. | Single Shear at 12000 Lbs. | Bearing Value for | | | |
|--------------------|----------|------------------------|----------------------------|-------------------|----------------|---------------|---------------|
| Inches. | | | | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{8}$ |
| Fraction. | Decimal. | | | | | | |
| $\frac{3}{8}$ | .375 | .1104 | 1320 | 2350 | 2930 | 3520 | .... |
| $\frac{1}{2}$ | .500 | .1963 | 2360 | 3130 | 3910 | 4690 | 5470 |
| $\frac{5}{8}$ | .625 | .3063 | 3680 | 3910 | 4880 | 5860 | 6840 |
| $\frac{3}{4}$ | .750 | .4418 | 5300 | 4690 | 5860 | 7030 | 8210 |
| $\frac{7}{8}$ | .875 | .6013 | 7220 | 5470 | 6840 | 8210 | 9580 |
| 1 | 1.000 | .7854 | 9430 | 6250 | 7820 | 9380 | 10940 |

In above tables all bearing values above or to right of upper zigzag lines are greater than double shear. Values between upper and lower zigzag lines are less than double and greater than single shear.

SHEARING AND BEARING VALUE OF RIVETS.

(All Dimensions in Inches.)

Different Thicknesses of Plate in Inches at 12,000 Lbs. per Square Inch.

| $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | 1 |
|---------------|----------------|---------------|-----------------|---------------|-----------------|---------------|-----------------|-------|
| | | | | | | | | |
| 3000 | .... | .... | .... | .... | .... | .... | .... | .... |
| 3750 | 4220 | 4690 | .... | .... | .... | .... | .... | .... |
| 4500 | 5060 | 5630 | 6190 | 6750 | .... | .... | .... | .... |
| 5250 | 5910 | 6560 | 7220 | 7880 | 8530 | 9190 | 9840 | .... |
| 6000 | 6750 | 7500 | 8250 | 9000 | 9750 | 10500 | 11250 | 12000 |

Different Thicknesses of Plate in Inches at 15,000 Lbs. per Square Inch.

| $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | 1 |
|---------------|----------------|---------------|-----------------|---------------|-----------------|---------------|-----------------|-------|
| | | | | | | | | |
| 3750 | .... | .... | .... | .... | .... | .... | .... | .... |
| 4690 | 5280 | 5860 | .... | .... | .... | .... | .... | .... |
| 5630 | 6330 | 7030 | 7720 | 8440 | .... | .... | .... | .... |
| 6560 | 7380 | 8200 | 9030 | 9850 | 10670 | 11480 | 12300 | .... |
| 7500 | 8440 | 9380 | 10310 | 11250 | 12190 | 13130 | 14060 | 15000 |

Different Thicknesses of Plate in Inches at 20,000 Lbs. per Square Inch.

| $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | 1 |
|---------------|----------------|---------------|-----------------|---------------|-----------------|---------------|-----------------|-------|
| | | | | | | | | |
| 5000 | .... | .... | .... | .... | .... | .... | .... | .... |
| 6250 | 7030 | 7810 | .... | .... | .... | .... | .... | .... |
| 7500 | 8440 | 9380 | 10310 | 11250 | .... | .... | .... | .... |
| 8750 | 9840 | 10940 | 12030 | 13130 | 14220 | 15310 | 16410 | .... |
| 10000 | 11250 | 12500 | 13750 | 15000 | 16250 | 17500 | 18750 | 20000 |

Different Thicknesses of Plate in Inches at 25,000 Lbs. per Square Inch.

| $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | 1 |
|---------------|----------------|---------------|-----------------|---------------|-----------------|---------------|-----------------|-------|
| | | | | | | | | |
| 6250 | .... | .... | .... | .... | .... | .... | .... | .... |
| 7810 | 8790 | 9770 | .... | .... | .... | .... | .... | .... |
| 9380 | 10550 | 11720 | 12890 | 14060 | .... | .... | .... | .... |
| 10940 | 12310 | 13670 | 15040 | 16410 | 17770 | 19140 | 20510 | .... |
| 12500 | 14060 | 15630 | 17190 | 18750 | 20320 | 21880 | 23440 | 25000 |

Values below and to left of lower zigzag lines are less than single shear.

the flange angles have a bearing value of only 3520 pounds for a $\frac{3}{4}$ -inch rivet, while their shearing value is $= 2 \times 3310 = 6620$ pounds per rivet, the rivets being in double shear. Consequently, while the usual thickness of web of floor-beams for railway bridges is $\frac{3}{8}$ inch, it sometimes becomes necessary for shallow floor-beams to increase this thickness to $\frac{1}{2}$ inch and even $\frac{5}{8}$ inch, in order that the pressure of the rivets upon the semi-intrados of the rivet-holes be not excessive between the points of support of floor-beam and of application of the load



FIG. 242.

(in which space the transmission of strain from web to flanges takes place).

Fig. 242 shows the signs used by draughtsmen to designate the shape and style of rivets desired in the work.

The following requirements for iron and steel construction is taken from the New York Building Code.

Sec. 21. STRUCTURAL MATERIAL.—*Wrought Iron*.—All wrought iron shall be uniform in character, fibrous, tough, and ductile. It shall have an ultimate tensile resistance of not less than 48,000 lbs. per square inch, an elastic limit of not less than 24,000 lbs. per square inch, and an elongation of 20 per cent in eight inches, when tested in small specimens.

Steel.—All structural steel shall have an ultimate tensile strength of from 54,000 pounds to 64,000 pounds per square inch. Its elastic limit shall be not less than 32,000 pounds per square inch and a minimum elongation of not less than 20 per cent in eight inches. Rivet steel shall have an ultimate strength of from 50,000 to 58,000 pounds per square inch.

Cast Steel.—Shall be made of open-hearth steel, containing one-quarter to one-half per cent of carbon, not over eight one-hundredths of one per cent of phosphorus, and shall be practically free from blow-holes.

Cast Iron.—Shall be of good foundry mixture, producing a clean, tough, gray iron. Sample bars, five feet long, one inch square, cast in sand moulds, placed on supports four feet six inches apart, shall bear a central load of 450 pounds before breaking. Castings shall be free of serious blow-holes, cinder-spots, and cold-shuts. Ultimate tensile strength shall be not less than 16,000 pounds per square inch when tested in small specimens.

SPECIFICATIONS FOR IRON AND STEEL CONSTRUCTION.

Sec. 110. *Skeleton Construction.*—Where columns are used to support iron or steel girders carrying inclosure walls, the said columns shall be of cast iron, wrought iron, or rolled steel, and on their exposed outer and inner surfaces be constructed to resist fire by having a casing of brickwork not less than eight inches in thickness on the outer surfaces, nor less than four inches in thickness on the inner surfaces, and all bonded into the brickwork of the inclosure walls. The exposed sides of the iron or steel girders shall be similarly covered in with brickwork not less than four inches in thickness on the outer surfaces and tied and bonded, but the extreme outer edge of the flanges of beams, or plates or angles connected to the beams, may project to within two inches of the outside surface of the brick casing. The inside surfaces of girders may be similarly covered with brickwork, or if projecting inside of the wall, they shall be protected by terra-cotta, concrete, or other fire-proof material. Girders for the support of the inclosure walls shall be placed at the floor line of each story.

Sec. 111. *Steel and Wrought-iron Columns.*—No part of a steel or wrought-iron column shall be less than one-quarter of an inch thick. No wrought-iron or rolled-steel column shall have an unsupported length of more than forty times its least lateral dimension or diameter, except as modified by Section 138 of this Code, and also except in such cases as the commissioners of buildings may specially allow a greater unsupported length.

The ends of all columns shall be faced to a plane surface at right angles to the axis of the columns and the connection between them shall be made with splice-plates. The joint may be effected by rivets of sufficient size and number to transmit the entire stress, and then the splice-plates shall be equal in sectional area to the area of columns spliced. When the section of the columns to be spliced is such that splice-plates cannot be used, a connection formed of plates and angles may be used, designed to properly distribute the stress. No material, whether in the body of the column or used as lattice-bar or stay-plate, shall be used in any wrought-iron or steel column of less thickness than one-thirty-second of its unsupported width measured between centres of rivets transversely, or one-sixteenth the distance between centres of rivets in the direction of the stress. Stay-plates are to have not less than four rivets, and are to be spaced so that the ratio of length by the least radius of gyration of the parts connected does not exceed forty; the distance between nearest rivets of two stay-plates shall in this case be considered as length. Steel and wrought-iron columns shall be made in one, two, or three-story lengths, and the materials shall be rolled in one length wherever practicable to avoid intermediate splices. Where any part of the section of a column projects beyond that of the column below, the difference shall be made up by filling plates secured to column by the proper number of rivets. Shoes of iron or steel, as described for cast-iron columns, or built shoes of plates and shapes may be used, complying with same requirements.

Sec. 112. *Cast-iron Columns.*—Cast-iron columns shall not have less diameter than five inches or less thickness than three-quarters of an inch; nor shall they have an unsupported length of more than twenty times their least lateral dimensions or diameter, except as modified by Section 138 of this Code, and except the same may form part of an elevator inclosure or staircase, and also except in such cases as the commissioner of buildings having jurisdiction may specially allow a greater unsupported length. All cast-iron columns shall be of good workmanship and material. The top and bottom flanges, seats, and lugs shall be of ample strength, reinforced by fillets and brackets; they shall be not less than one inch in thickness when finished. All columns must be faced at the ends to a true surface perpendicular to the axis of the column. Column joints shall be secured by not less than four bolts each, not less

than three-quarters of an inch in diameter. The holes for these bolts shall be drilled in a template. The core of a column below a joint shall be not larger than the core of the column above and the metal shall be tapered down for a distance of not less than six inches, or a joint plate may be inserted of sufficient strength to distribute the load. The thickness of metal shall be not less than one-twelfth the diameter or the greatest lateral dimension of cross-section, but never less than three-quarters of an inch. Wherever the core of a cast-iron column has shifted more than one-fourth the thickness of the shell, the strength shall be computed assuming the thickness of metal all around equal to the thinnest part, and the column shall be condemned if this computation shows the strength to be less than required by this Code. Wherever blow-holes or imperfections are found in a cast-iron column which reduces the area of the cross-section at that point more than ten per cent, such column shall be condemned. Cast-iron posts or columns not cast with one open side or back, before being set up in place, shall have a three-eighths of an inch hole drilled in the shaft of each post or column, by the manufacturer or contractor furnishing the same, to exhibit the thickness of the castings; and any other similar sized hole or holes which the commissioners of buildings may require shall be drilled in the said posts or columns by the said manufacturer or contractor at his own expense.

Iron or steel shoes or plates shall be used under the bottom tier of columns to properly distribute the load on the foundation. Shoes shall be planed on top.

Sec. 113. *Double Columns.*—In all buildings hereafter erected or altered, where any iron or steel column or columns are used to support a wall or part thereof, whether the same be an exterior or an interior wall, and columns located below the level of the sidewalk which are used to support exterior walls or arches over vaults, the said column or columns shall be either constructed double, that is, an outer and an inner column, the inner column alone to be of sufficient strength to sustain safely the weight to be imposed thereon, and the outer columns shall be one inch shorter than the inner columns, or such other iron or steel column of sufficient strength and protected with not less than two inches of fire-proof material securely applied, except that double or protected columns shall not be required for walls fronting on streets or courts.

Sec. 114. *Party-wall Posts*.—If iron or steel posts are to be used as party posts in front of a party wall, and intended for two buildings, then the said posts shall be not less in width than the thickness of the party wall, nor less in depth than the thickness of the wall to be supported above. Iron or steel posts in front of side, division, or party walls shall be filled up solid with masonry and made perfectly tight between the posts and walls. Intermediate posts may be used, which shall be sufficiently strong, and the lintels thereon shall have sufficient bearings to carry the weight above with safety.

Sec. 115. *Plates between Joints of Open-back Columns*.—Iron or steel posts or columns with one or more open sides and backs shall have solid iron plates on top of each, excepting where pierced for the passage of pipes.

Sec. 116. *Steel and Iron Girders*.—Rivets in flanges shall be spaced so that the least value of a rivet for either shear or bearing is equal or greater than the increment of strain due to the distance between adjoining rivets. All other rules given under riveting shall be followed. The length of rivets between heads shall be limited to four times the diameter. The compression flange of plate girders shall be secured against buckling if its length exceeds thirty times its width. If splices are used, they shall fully make good the members spliced in either tension or compression. Stiffeners shall be provided over supports and under concentrated loads; they shall be of sufficient strength as a column to carry the loads, and shall be connected with a sufficient number of rivets to transmit the stresses into the web plate. Stiffeners shall fit so as to support the flanges of the girders. If the unsupported depth of the web plate exceeds sixty times its thickness, stiffeners shall be used at intervals not exceeding one hundred and twenty times the thickness of the web.

Sec. 117. *Rolled-steel and Wrought-iron Beams Used as Girders*.—When rolled-steel or wrought-iron beams are used in pairs to form a girder, they shall be connected together by bolts and iron separators at intervals of not more than five feet. All beams twelve inches and over in depth shall have at least two bolts to each separator.

Sec. 118. *Cast-iron Lintels*.—Cast-iron lintels shall not be used for spans exceeding sixteen feet. Cast-iron lintels or beams shall be not less than three-quarters of an inch in thickness in any of their parts.

Sec. 119. *Plates under Ends of Lintels and Girders.*—When the lintels or girders are supported at the ends by brick walls or piers they shall rest upon cut-granite or bluestone blocks at least ten inches thick, or upon cast-iron plates of equal strength by the full size of the bearings. In case the opening is less than twelve feet, the stone blocks may be five inches in thickness, or cast-iron plates of equal strength by the full size of the bearings, may be used, provided that in all cases the safe loads do not exceed those fixed by Section 139 of this Code.

Sec. 120. *Rolled-steel and Wrought-iron Floor- and Roof-beams.*—All rolled-steel and wrought-iron floor- and roof-beams used in buildings shall be of full weight, straight and free from injurious defects. Holes for tie-rods shall be placed as near the thrust of the arch as practicable. The distance between tie-rods in floors shall not exceed eight feet, and shall not exceed eight times the depth of floor-beams twelve inches and under. Channels or other shapes, where used as skew-backs, shall have a sufficient resisting moment to take up the thrust of the arch. Bearing plates of stone or metal shall be used to reduce the pressure on the wall to the working stress. Beams resting on girders shall be securely riveted or bolted to the same; where joined on a girder, tie-straps of one-half inch net sectional area shall be used, with rivets or bolts to correspond. Anchors shall be provided at the ends of all such beams bearing on walls.

Sec. 121. *Templates under Ends of Steel or Iron Floor-beams.*—Under the ends of all iron or steel beams where they rest on the walls, a stone or cast-iron template shall be built into the walls. Templates under ends of steel or iron beams shall be of such dimensions as to bring no greater pressure upon the brickwork than that allowed by Section 139 of this Code. When rolled-iron or steel floor-beams, not exceeding six inches in depth, are placed not more than thirty inches on centres, no templates shall be required.

Sec. 122. *Framing and Connecting Structural Work.*—All iron or steel trimmer-beams, headers, and tail-beams, shall be suitably framed and connected together, and the iron or steel girders, columns, beams, trusses, and all other ironwork of all floors and roofs shall be strapped, bolted, anchored, and connected together, and to the walls.

All beams framed into and supported by other beams or girders shall be connected thereto by angles or knees of a

proper size and thickness, and have sufficient bolts or rivets in both legs of each connecting angle to transmit the entire weight or load coming on the beam to the supporting beam or girder. In no case shall the shearing value of the bolts or rivets or the bearing value of the connecting angles, provided for in Section 139 of this Code, be exceeded.

Sec. 123. *Riveting of Structural-steel and Wrought-iron Work.*—The distance from centre of a rivet-hole to the edge of the material shall be not less than

| | | | | | |
|--|----------------|----------------|-----------------------------|---|---|
| | $\frac{5}{8}$ | of an inch for | $\frac{1}{2}$ -inch rivets. | | |
| | $\frac{7}{8}$ | “ “ “ “ | $\frac{5}{8}$ | “ | “ |
| | $1\frac{1}{8}$ | “ “ “ “ | $\frac{3}{4}$ | “ | “ |
| | $1\frac{3}{8}$ | “ “ “ “ | $\frac{7}{8}$ | “ | “ |
| | $1\frac{1}{2}$ | “ “ “ “ | 1 | “ | “ |

Wherever possible, however, the distance shall be equal to two diameters. All rivets, wherever practicable, shall be machine-driven. The rivets in connections shall be proportioned and placed to suit the stresses. The pitch of rivets shall never be less than three diameters of the rivet, nor more than six inches. In the direction of the stress it shall not exceed sixteen times the least thickness of the outside member. At right angles to the stress it shall not exceed thirty-two times the least thickness of the outside member. All holes shall be punched accurately, so that upon assembling a cold rivet will enter the hole without straining the material by drifting. Occasional slight errors shall be corrected by reaming. The rivets shall fill the holes completely; the heads shall be hemispherical and concentric with the axis of the rivet. Gussets shall be provided wherever required, of sufficient thickness and size to accommodate the number of rivets necessary to make a connection.

Sec. 124. *Bolting of Structural-steel and Wrought-iron Work*—Where riveting is not made mandatory connections may be effected by bolts. These bolts shall be of wrought iron or mild steel, and they shall have U. S. Standard threads. The threads shall be full and clean, the nut shall be truly concentric with the bolt, and the thread shall be of sufficient length to allow the nut to be screwed up tightly. When bolts go through bevel-flanges, bevel-washers to match shall be used so that head and nut of bolt are parallel. When bolts are used for suspenders, the

working stresses shall be reduced for wrought iron to ten thousand pounds and for steel to fourteen thousand pounds per square inch of net area, and the load shall be transmitted into the head or nut by strong washers distributing the pressure evenly over the entire surface of the same. Turned bolts in reamed holes shall be deemed a substitute for field-rivets.

Sec. 125. *Steel and Wrought-iron Trusses.*—Trusses shall be of such design that the stresses in each member can be calculated. All trusses shall be held rigidly in position by efficient systems of lateral and sway bracing, struts being spaced so that the maximum limit of length to least radius of gyration, established in Section 111 of this Code, is not exceeded. Any member of a truss subjected to transverse stress, in addition to direct tension or compression, shall have the stresses causing such strain added to the direct stresses coming on the member, and the total stresses thus formed shall in no case exceed the working stresses stated in Section 139 of this Code.

Sec. 126. *Riveted-steel and Wrought-iron Trusses.*—For tension members, the actual net area only, after deducting rivet-holes, one-eighth inch larger than the rivets, shall be considered as resisting the stress. If tension members are made of angle-irons riveted through one flange only, only that flange shall be considered in proportioning areas. Rivets to be proportioned as prescribed in Section 123 of this Code. If the axes of two adjoining web members do not intersect within the line of the chords, sufficient area shall be added to the chord to take up the bending strains. No bolts shall be used in the connections of riveted trusses, excepting when riveting is impracticable, and then the holes shall be drilled or reamed.

Sec. 127. *Steel and Iron Pin-connected Trusses.*—The bending stresses on pins shall be limited to twenty thousand pounds for steel and fifteen thousand pounds for iron. All compression members in pin-connected trusses shall be proportioned, using seventy-five per cent of the permissible working stress for columns. The heads of all eye-bars shall be made by upsetting or forging. No weld will be allowed in the body of the bar. Steel eye-bars shall be annealed. Bars shall be straight before boring. All pinholes shall be bored true, and at right angles to the axis of the members, and must fit the pin within one-thirty-second of an inch. The distances of pinholes from centre to centre for corresponding members shall be alike, so that, when piled upon one another, pins will pass through both ends with-

out forcing. Eyes and screw-ends shall be so proportioned that upon test to destruction, fracture will take place in the body of the member. All pins shall be accurately turned. Pin-plates shall be provided wherever necessary to reduce the stresses on pins to the working stresses prescribed in Section 139 of this Code. These pin-plates shall be connected to the members by rivets of sufficient size and number to transmit the stresses without exceeding working stresses. All rivets in members of pin-connected trusses shall be machine-driven. All rivets in pin-plates which are necessary to transmit stress shall be also machine-driven. The main connections of members shall be made by pins. Other connections may be made by bolts. If there is a combination of riveted and pin-connected members in one truss, these members shall comply with the requirements for pin-connected trusses; but the riveting shall comply with the requirements of Section 126 of this Code.

Sec. 128. *Iron and Other Metal Fronts to be Filled In.*—All cast-iron or metal fronts shall be backed up or filled in with masonry of the thicknesses provided for in Sections 31 and 32.

Sec. 129.—*Painting of Structural Metal-work.*—All structural metal-work shall be cleaned of all scale, dirt, and rust, and be thoroughly coated with one coat of paint. Cast-iron columns shall not be painted until after inspection by the Department of Buildings. Where surfaces in riveted work come in contact, they shall be painted before assembling. After erection all work shall be painted at least one additional coat. All iron or steel used under water shall be inclosed with concrete.

SPECIFICATIONS FOR CONSTRUCTIONAL IRON.

1. CHARACTER AND FINISH.—All wrought iron must be tough, ductile, fibrous, and of uniform quality. Finished bars must be thoroughly welded during the rolling, and be straight, smooth, and free from injurious seams, blisters, buckles, cracks, or imperfect edges.

2. MANUFACTURE.—No specific process or provision of manufacture will be demanded, provided the material fulfils the requirements of these specifications.

3. STANDARD TEST-PIECE.—The tensile strength, limit of elasticity and ductility, shall be determined from a standard test-piece of as near $\frac{1}{2}$ -square-inch sectional area as possible. The elongation shall be measured on an original length of 8 inches.

4. **ELASTIC LIMIT.**—Iron of all grades shall have an elastic limit of not less than 26,000 pounds per square inch.

5. **HIGH TEST OR TENSION IRON.**—When tested in specimens of uniform sectional area of at least $\frac{1}{2}$ square inch, taken from members which have been rolled to a section of not more than $4\frac{1}{2}$ square inches, the iron shall show a minimum ultimate strength of 50,000 pounds per square inch, and a minimum elongation of 18 per cent in 8 inches.

6. Specimens taken from bars of a larger cross-section than $4\frac{1}{2}$ square inches will be allowed a reduction of 500 pounds for each additional square inch of section, down to a minimum of 48,000 pounds, and have an elongation of 15 per cent in 8 inches.

7. **BENDING TEST.**—All iron for tension members must bend cold through 90 degrees to a curve whose diameter is not over twice the thickness of the piece, without cracking. At least one sample in three must bend through 180 degrees to this curve, without cracking. When nicked on one side and bent by a blow from a sledge, the fracture must be mostly fibrous.

8. **ANGLE AND OTHER-SHAPED IRON.**—The same-sized specimens taken from angle and other-shaped iron shall have a minimum ultimate strength of 48,000 pounds per square inch, and a minimum elongation of 15 per cent in 8 inches.

9. Specimens from angle and other-shaped iron must bend cold through 90 degrees to a curve whose diameter is not over twice the thickness of the piece, without cracking.

10. **PLATES.**—The same-sized specimens, taken from plates 8 inches to 24 inches in width, shall show a minimum ultimate strength of 48,000 pounds per square inch, and a minimum elongation of 15 per cent in 8 inches; plates from 24 inches to 36 inches wide shall show a minimum ultimate strength of 46,000 pounds per square inch, and elongate 10 per cent in 8 inches; plates over 36 inches wide shall have a minimum elongation of 8 per cent in 8 inches.

11. Samples of plate iron shall stand bending cold through 90 degrees to a curve whose diameter is not over three times its thickness, without cracking. When nicked and bent cold, the fracture must be mostly fibrous.

12. **RIVET IRON.**—Rivet iron shall have the same physical requirements as high-test iron, and, in addition, shall bend cold 180 degrees to a curve whose diameter is equal to the

thickness of the rod tested, without sign of fracture on the convex side.

13. **PIN IRON.**—Specimens taken from pin iron under 4 inches diameter shall have a minimum ultimate strength of 50,000 pounds per square inch, and elongate 15 per cent in 8 inches. Rounds over 4 inches diameter, having a minimum elongation of 10 per cent in 8 inches will be satisfactory.

14. **FULL-SIZE TEST.**—Full-size pieces of flat, round, or square iron, not over $4\frac{1}{2}$ inches in sectional area, shall have an ultimate strength of 50,000 pounds per square inch, and stretch $12\frac{1}{2}$ per cent in the body of the bar. Bars of a larger sectional area than $4\frac{1}{2}$ square inches will be allowed a reduction of 1000 pounds per square inch, down to a minimum of 46,000 pounds per square inch, and stretch 10 per cent in the body of the bar.

15. **VARIATION IN WEIGHT.**—The variation in cross-section or weight of rolled material of more than $2\frac{1}{2}$ per cent from that specified may be cause for rejection.

SPECIFICATIONS FOR CONSTRUCTIONAL STEEL.

1. **PROCESS OF MANUFACTURE.**—Steel may be made by either the open-hearth or Bessemer process.

2. **TEST-PIECES.**—The tensile strength, limit of elasticity and ductility shall be determined from a standard test-piece cut from the finished material and planed or turned parallel; the piece to have as near $\frac{1}{2}$ square inch sectional area as possible, and elongation to be measured on an original length of 8 inches; two test-pieces to be taken from each heat or blow of finished material, one for tension and one for bending.

3. Every finished piece of steel shall be stamped on one side near the middle with the blow number identifying the melt; and steel for pins shall have the melt number stamped on the ends. Rivet and lacing steel, and small pieces for pin-plates and stiffeners, may be shipped in bundles securely wired together, with the melt number on a metal tag attached.

4. **FINISH.**—Finished bars must be free from injurious seams, flaws, or cracks, and have a workmanlike finish.

5. **GRADE OF STEEL.**—Steel shall be of three grades: **SOFT, MEDIUM, HIGH.**

6. **SOFT STEEL.**—Specimens from finished material for test, cut to size specified above, shall have an ultimate strength of from

54,000 to 62,000 pounds per square inch; elastic limit one-half the ultimate strength; minimum elongation of 26 per cent in 8 inches; minimum reduction of area at fracture, 50 per cent. This grade of steel to bend cold 180 degrees flat on itself, without sign of fracture on the outside of the bent portion.

7. MEDIUM STEEL.—Specimens from finished material for test, cut to size specified above, shall have an ultimate strength of 60,000 to 68,000 pounds per square inch; elastic limit one-half the ultimate strength; minimum elongation 20 per cent in 8 inches; minimum reduction of area at fracture, 40 per cent. This grade of steel to bend cold 180 degrees to a diameter equal to the thickness of the piece tested, without crack or flaw on the outside of the bent portion.

8. HIGH STEEL.—Specimens from finished material for test, cut to size specified above, shall have an ultimate strength of 66,000 pounds to 74,000 pounds per square inch; elastic limit one-half the ultimate strength; minimum elongation 18 per cent in 8 inches; minimum reduction of area at fracture, 35 per cent. This grade of steel to bend cold 180 degrees to a diameter equal to three times the thickness of the test-piece, without crack or flaw on the outside of the bent portion.

9. PIN STEEL.—Pins made of either of the above-mentioned grades of steel shall, on specimen test-pieces cut from finished material, fill the physical requirements of the grade of steel from which it is rolled, for ultimate strength, elastic limit, and bending, but the elongation shall be decreased 5 per cent, and reduction of area at fracture 10 per cent from that specified.

10. VARIATION IN WEIGHT.—The variation in cross-section or weight of more than $2\frac{1}{2}$ per cent from that specified will be sufficient cause for rejection.

11. FULL-SIZE TESTS OF STEEL BARS.—Full-size tests of steel used for eye-bars shall not be required to show more than 10 per cent elongation in the body of the bar, and tensile strength not more than 4000 pounds below the minimum tensile strength required in specimen tests of the grade of steel from which it is rolled.

SPECIFICATIONS FOR WORKMANSHIP.

1. INSPECTION.—Inspection of work shall be made as it progresses, and at as early a period as the nature of the work permits.

2. All workmanship must be first-class. All abutting surfaces of compression members, except flanges of plate girders where the joints are fully spliced, must be planed or turned to even bearings so that they shall be in such contact throughout as may be obtained by such means. All finished surfaces must be protected by white lead and tallow.

3. The rivet-holes for splice plates of abutting members shall be so accurately spaced that when the members are brought into position the holes shall be truly opposite before the rivets are driven.

4. Rollers must be finished perfectly round and roller-beds planed.

5. RIVETS.—The pitch of rivets in all classes of work shall never exceed 6 in., nor 16 times the thinnest outside plate, nor be less than 3 diameters of the rivet. The rivets used shall generally be $\frac{5}{8}$, $\frac{3}{4}$, and $\frac{7}{8}$ in. diameter. The distance between the edge of any piece and the centre of a rivet-hole must never be less than $1\frac{1}{4}$ in., except for bars less than $2\frac{1}{2}$ in. wide. When practicable it shall be at least 2 diameters of the rivet. Rivets must completely fill the holes, have full heads concentric with the rivet, of a height not less than .6 the diameter of the rivet, and in full contact with the surface, or be countersunk when so required, and machine-driven wherever practicable.

6. PUNCHING.—The diameter of the punch shall not exceed by more than $\frac{1}{16}$ in. the diameter of the rivets to be used, and all holes must be clean cuts, without torn or ragged edges. Rivet-holes must be accurately spaced; the use of drift-pins will be allowed only for bringing together the several parts forming a member, and they must not be driven with such force as to disturb the metal about the holes.

7. Built members must, when finished, be true and free from twists, kinks, buckles, or open joints between the component pieces.

8. EYE-BARS AND PINHOLES.—All pinholes must be accurately bored at right angles to the axis of the members, unless

otherwise shown in the drawings, and in pieces not adjustable for length no variation of more than $\frac{1}{32}$ of an inch will be allowed in the length between centres of pinholes; the diameter of the pinholes shall not exceed that of the pins by more than $\frac{1}{32}$ in., nor by more than $\frac{1}{50}$ in. for pins under $3\frac{1}{2}$ in. diameter. Eye-bars must be straight before boring; the holes must be in the centre of the heads, and on the centre line of the bars. Whenever eye-bars are to be packed more than $\frac{1}{8}$ of an inch to the foot of their length out of parallel with the axis of the structure, they must be bent with a gentle curve until the head stands at right angles to the pin in their intended positions before being bored. All eye-bars belonging to the same panel, when placed in a pile, must allow the pin at each end to pass through at the same time without forcing. No welds will be allowed in the body of the bar of eye-bars, laterals, or counters, except to form the loops of laterals, counters, and sway-rods; eyes of laterals, stirrups, sway-rods, and counters must be bored.

PILOT-NUTS.—Pins and lateral bolts must be finished perfectly round and straight, and the party contracting to erect the work must provide pilot-nuts where necessary to preserve the threads while the pins are being driven. Thimbles or washers must be used whenever required to fill the vacant spaces on pins or bolts.

9. **ANNEALING.**—In all cases where a steel piece in which the full strength is required has been partially heated the whole piece must be subsequently annealed. All bends in steel must be made cold, or if the degree of curvature is so great as to require heating, the whole piece must be subsequently annealed.

10. **PAINING.**—All surfaces inaccessible after assembling must be well painted or oiled before the parts are assembled.

11. The decision of the engineer shall control as to the interpretation of drawings and specifications during the execution of work thereunder, but this shall not deprive the contractor of his right to redress, after the completion of the work, for an improper decision.

NOTES ON STEEL AND IRON.—1. The average weight of wrought iron is 480 lbs. per cubic foot. A bar 1 inch square and 3 feet long weighs, therefore, exactly 10 lbs. Hence:

To find the sectional area, given the weight per foot, multiply by 0.3.

To find the weight per foot, given the sectional area, multiply by $\frac{10}{3}$.

2. The weight of steel is 2 per cent greater than that of wrought iron.

To find sectional area, given weight per foot, divide by 3.4.

To find weight per foot, given sectional area, multiply by 3.4.

3. The centre load at which a bar of wrought iron 1 in. square and 12 ins. centre to centre of points of support will give way is very nearly *one ton* (of 2240 lbs.).

4. Within the elastic limit the extension and compression of wrought iron is very nearly one ten-thousandth of its length for a stress of *one ton* (of 2240 lbs.) per square inch.

For cast iron this ratio is one five-thousandth for tension, but becomes variable for compression.

5. The contraction or expansion of wrought iron under changes of temperature is about one ten-thousandth of its length for a variation of 15° Fahr.

The stress thus induced, if the ends are held rigidly fixed, will be about *one ton* (of 2240 lbs.) per square inch of cross-section.

6. The coefficient of expansion of wrought iron for 100° Fahr. is 0.000686. Therefore for a variation in temperature of 125°, a bar of wrought iron 100 feet long will expand or contract 1.029 inches.

Conversely, a change in length of 1 inch per hundred feet would be produced by a variation in temperature of 121.5° Fahr.

7. The melting-point of iron and steel is about as follows:

| | |
|------------------------|-------------|
| Wrought iron | 3000° Fahr. |
| Cast iron | 2000° “ |
| Steel | 2400° “ |

8. The welding heat of wrought iron is 2733° Fahr.

MISCELLANEOUS NOTES.—1. Thrust of arch per lineal foot

$$T = \frac{1.5wl^2}{r},$$

in which w = load per square foot, r = rise in arch in inches, and l = span in feet.

2. Approximately the radius of gyration for a box section is four-tenths the least side.

The working strength of iron and steel as given by the Chicago Building Code is as follows:

STRESSES—CAST-IRON FIBRE—STRAINS—LENGTH.

Sec. 92. The stresses in materials hereafter used in construction, produced by the calculated strains due to their own weight and applied loads, shall in no case exceed the following:

Cast iron: { Extreme fibre strains tension..... 2,500 lbs.
 { For columns..... 10,000 "

Reduced by Gordon's formula. Reduced for eccentric load.

No cast-iron column shall have a length to exceed twenty times its diameter or least side.

STRESSES IN POUNDS PER SQUARE INCH.

| | Wrought Iron. | Steel. |
|--|---------------|--------|
| Extreme fibre stresses, I beams and shapes.... | 12,000 | 16,000 |
| Extreme fibre stresses, built beams..... | 10,000 | 15,000 |
| Tension..... | 12,000 | 15,000 |
| Shearing..... | 7,500 | 10,000 |
| Direct-bearing pins and rivets..... | 15,000 | 20,000 |
| Bending on pins..... | 18,000 | 22,500 |
| * For columns and compression members..... | 12,000 | 15,000 |

* Reduced for ratio of length of column to its least radius of gyration by approved modern formulæ. Reduced for eccentric load.

WEIGHTS OF FLAT ROLLED STEEL.

PER LINEAL FOOT.

One Cubic Foot Weighing 489.6 Lbs.

| Thick- ness in Inches. | 1" | 1 $\frac{1}{4}$ " | 1 $\frac{1}{2}$ " | 1 $\frac{3}{4}$ " | 2" | 2 $\frac{1}{4}$ " | 2 $\frac{1}{2}$ " | 2 $\frac{3}{4}$ " | 3" |
|------------------------------|------|-------------------|-------------------|-------------------|-------|-------------------|-------------------|-------------------|-------|
| $\frac{3}{16}$ | .638 | .797 | .957 | 1.11 | 1.28 | 1.44 | 1.59 | 1.75 | 7.65 |
| $\frac{1}{4}$ | .850 | 1.06 | 1.28 | 1.49 | 1.70 | 1.91 | 2.12 | 2.34 | 10.20 |
| $\frac{5}{16}$ | 1.06 | 1.33 | 1.59 | 1.86 | 2.12 | 2.39 | 2.65 | 2.92 | 12.75 |
| $\frac{3}{8}$ | 1.28 | 1.59 | 1.92 | 2.23 | 2.55 | 2.87 | 3.19 | 3.51 | 15.30 |
| $\frac{7}{16}$ | 1.49 | 1.86 | 2.23 | 2.60 | 2.98 | 3.35 | 3.72 | 4.09 | 17.85 |
| $\frac{1}{2}$ | 1.70 | 2.12 | 2.55 | 2.98 | 3.40 | 3.83 | 4.25 | 4.67 | 20.40 |
| $\frac{9}{16}$ | 1.92 | 2.39 | 2.87 | 3.35 | 3.83 | 4.30 | 4.78 | 5.26 | 22.95 |
| $\frac{5}{8}$ | 2.12 | 2.65 | 3.19 | 3.72 | 4.25 | 4.78 | 5.31 | 5.84 | 25.50 |
| $\frac{11}{16}$ | 2.34 | 2.92 | 3.51 | 4.09 | 4.67 | 5.26 | 5.84 | 6.43 | 28.05 |
| $\frac{3}{4}$ | 2.55 | 3.19 | 3.83 | 4.47 | 5.10 | 5.75 | 6.38 | 7.02 | 30.60 |
| $\frac{13}{16}$ | 2.76 | 3.45 | 4.14 | 4.84 | 5.53 | 6.21 | 6.90 | 7.60 | 33.15 |
| $\frac{7}{8}$ | 2.98 | 3.72 | 4.47 | 5.20 | 5.95 | 6.69 | 7.44 | 8.18 | 35.70 |
| $\frac{15}{16}$ | 3.19 | 3.99 | 4.78 | 5.58 | 6.38 | 7.18 | 7.97 | 8.77 | 38.25 |
| 1 | 3.40 | 4.25 | 5.10 | 5.95 | 6.80 | 7.65 | 8.50 | 9.35 | 40.80 |
| $1\frac{1}{16}$ | 3.61 | 4.52 | 5.42 | 6.32 | 7.22 | 8.13 | 9.03 | 9.93 | 43.35 |
| $1\frac{1}{8}$ | 3.83 | 4.78 | 5.74 | 6.70 | 7.65 | 8.61 | 9.57 | 10.52 | 45.90 |
| $1\frac{3}{16}$ | 4.04 | 5.05 | 6.06 | 7.07 | 8.08 | 9.09 | 10.10 | 11.11 | 48.45 |
| $1\frac{1}{4}$ | 4.25 | 5.31 | 6.38 | 7.44 | 8.50 | 9.57 | 10.63 | 11.69 | 51.00 |
| $1\frac{5}{16}$ | 4.46 | 5.58 | 6.69 | 7.81 | 8.93 | 10.04 | 11.16 | 12.27 | 53.55 |
| $1\frac{3}{8}$ | 4.67 | 5.84 | 7.02 | 8.18 | 9.35 | 10.52 | 11.69 | 12.85 | 56.10 |
| $1\frac{7}{16}$ | 4.89 | 6.11 | 7.34 | 8.56 | 9.78 | 11.00 | 12.22 | 13.44 | 58.65 |
| $1\frac{1}{2}$ | 5.10 | 6.38 | 7.65 | 8.93 | 10.20 | 11.48 | 12.75 | 14.03 | 61.20 |
| $1\frac{9}{16}$ | 5.32 | 6.64 | 7.97 | 9.30 | 10.63 | 11.95 | 13.28 | 14.61 | 63.75 |
| $1\frac{5}{8}$ | 5.52 | 6.90 | 8.29 | 9.67 | 11.05 | 12.43 | 13.81 | 15.19 | 66.30 |
| $1\frac{11}{16}$ | 5.74 | 7.17 | 8.61 | 10.04 | 11.47 | 12.91 | 14.34 | 15.78 | 68.85 |
| $1\frac{3}{4}$ | 5.95 | 7.44 | 8.93 | 10.42 | 11.90 | 13.40 | 14.88 | 16.37 | 71.40 |
| $1\frac{13}{16}$ | 6.16 | 7.70 | 9.24 | 10.79 | 12.33 | 13.86 | 15.40 | 16.95 | 73.95 |
| $1\frac{7}{8}$ | 6.38 | 7.97 | 9.57 | 11.15 | 12.75 | 14.34 | 15.94 | 17.53 | 76.50 |
| $1\frac{15}{16}$ | 6.59 | 8.24 | 9.88 | 11.53 | 13.18 | 14.83 | 16.47 | 18.12 | 79.05 |
| 2 | 6.80 | 8.50 | 10.20 | 11.90 | 13.60 | 15.30 | 17.00 | 18.70 | 81.60 |

WEIGHTS OF FLAT ROLLED STEEL—(Continued).
PER LINEAL FOOT.

| Thick- ness in Inches. | 3" | 3½" | 3½" | 3¾" | 4" | 4¼" | 4½" | 4¾" | 12" |
|------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| $\frac{3}{16}$ | 1.91 | 2.07 | 2.23 | 2.39 | 2.55 | 2.71 | 2.87 | 3.03 | 7.65 |
| $\frac{1}{4}$ | 2.55 | 2.76 | 2.98 | 3.19 | 3.40 | 3.61 | 3.83 | 4.04 | 10.20 |
| $\frac{5}{16}$ | 3.19 | 3.45 | 3.72 | 3.99 | 4.25 | 4.52 | 4.78 | 5.05 | 12.75 |
| $\frac{3}{8}$ | 3.83 | 4.15 | 4.47 | 4.78 | 5.10 | 5.42 | 5.74 | 6.06 | 15.30 |
| $\frac{7}{16}$ | 4.46 | 4.83 | 5.20 | 5.58 | 5.95 | 6.32 | 6.70 | 7.07 | 17.85 |
| $\frac{1}{2}$ | 5.10 | 5.53 | 5.95 | 6.38 | 6.80 | 7.22 | 7.65 | 8.08 | 20.40 |
| $\frac{9}{16}$ | 5.74 | 6.22 | 6.70 | 7.17 | 7.65 | 8.13 | 8.61 | 9.09 | 22.95 |
| $\frac{5}{8}$ | 6.38 | 6.91 | 7.44 | 7.97 | 8.50 | 9.03 | 9.57 | 10.10 | 25.50 |
| $\frac{11}{16}$ | 7.02 | 7.60 | 8.18 | 8.76 | 9.35 | 9.93 | 10.52 | 11.11 | 28.05 |
| $\frac{3}{4}$ | 7.65 | 8.29 | 8.93 | 9.57 | 10.20 | 10.84 | 11.48 | 12.12 | 30.60 |
| $\frac{13}{16}$ | 8.29 | 8.98 | 9.67 | 10.36 | 11.05 | 11.74 | 12.43 | 13.12 | 33.15 |
| $\frac{7}{8}$ | 8.93 | 9.67 | 10.41 | 11.16 | 11.90 | 12.65 | 13.39 | 14.13 | 35.70 |
| $\frac{15}{16}$ | 9.57 | 10.36 | 11.16 | 11.95 | 12.75 | 13.55 | 14.34 | 15.14 | 38.25 |
| 1 | 10.20 | 11.05 | 11.90 | 12.75 | 13.60 | 14.45 | 15.30 | 16.15 | 40.80 |
| $1\frac{1}{16}$ | 10.84 | 11.74 | 12.65 | 13.55 | 14.45 | 15.35 | 16.26 | 17.16 | 43.35 |
| $1\frac{1}{8}$ | 11.48 | 12.43 | 13.39 | 14.34 | 15.30 | 16.26 | 17.22 | 18.17 | 45.90 |
| $1\frac{3}{16}$ | 12.12 | 13.12 | 14.13 | 15.14 | 16.15 | 17.16 | 18.17 | 19.18 | 48.45 |
| $1\frac{1}{4}$ | 12.75 | 13.81 | 14.87 | 15.94 | 17.00 | 18.06 | 19.13 | 20.19 | 51.00 |
| $1\frac{5}{16}$ | 13.39 | 14.50 | 15.62 | 16.74 | 17.85 | 18.96 | 20.08 | 21.20 | 53.55 |
| $1\frac{3}{8}$ | 14.03 | 15.20 | 16.36 | 17.53 | 18.70 | 19.87 | 21.04 | 22.21 | 56.10 |
| $1\frac{7}{16}$ | 14.66 | 15.88 | 17.10 | 18.33 | 19.55 | 20.77 | 21.99 | 23.22 | 58.65 |
| $1\frac{1}{2}$ | 15.30 | 16.58 | 17.85 | 19.13 | 20.40 | 21.68 | 22.95 | 24.23 | 61.20 |
| $1\frac{9}{16}$ | 15.94 | 17.27 | 18.60 | 19.92 | 21.25 | 22.58 | 23.91 | 25.24 | 63.75 |
| $1\frac{5}{8}$ | 16.58 | 17.96 | 19.34 | 20.72 | 22.10 | 23.48 | 24.87 | 26.25 | 66.30 |
| $1\frac{11}{16}$ | 17.22 | 18.65 | 20.08 | 21.51 | 22.95 | 24.38 | 25.82 | 27.26 | 68.85 |
| $1\frac{3}{4}$ | 17.85 | 19.34 | 20.83 | 22.32 | 23.80 | 25.29 | 26.78 | 28.27 | 71.40 |
| $1\frac{13}{16}$ | 18.49 | 20.03 | 21.57 | 23.11 | 24.65 | 26.19 | 27.73 | 29.27 | 73.95 |
| $1\frac{7}{8}$ | 19.13 | 20.72 | 22.31 | 23.91 | 25.50 | 27.10 | 28.69 | 30.28 | 76.50 |
| $1\frac{15}{16}$ | 19.77 | 21.41 | 23.06 | 24.70 | 26.35 | 28.00 | 29.64 | 31.29 | 79.05 |
| 2 | 20.40 | 22.10 | 23.80 | 25.50 | 27.20 | 28.90 | 30.60 | 32.30 | 81.60 |

WEIGHTS OF FLAT ROLLED STEEL—(Continued).

PER LINEAL FOOT.

| Thick- ness in Inches. | 5" | 5 $\frac{1}{4}$ " | 5 $\frac{1}{2}$ " | 5 $\frac{3}{4}$ " | 6" | 6 $\frac{1}{4}$ " | 6 $\frac{1}{2}$ " | 6 $\frac{3}{4}$ " | 12" |
|------------------------------|-------|-------------------|-------------------|-------------------|-------|-------------------|-------------------|-------------------|-------|
| $\frac{3}{16}$ | 3.19 | 3.35 | 3.51 | 3.67 | 3.83 | 3.99 | 4.14 | 4.30 | 7.65 |
| $\frac{1}{4}$ | 4.25 | 4.46 | 4.67 | 4.89 | 5.10 | 5.31 | 5.53 | 5.74 | 10.20 |
| $\frac{5}{16}$ | 5.31 | 5.58 | 5.84 | 6.11 | 6.38 | 6.64 | 6.90 | 7.17 | 12.75 |
| $\frac{3}{8}$ | 6.38 | 6.69 | 7.02 | 7.34 | 7.65 | 7.97 | 8.29 | 8.61 | 15.30 |
| $\frac{7}{16}$ | 7.44 | 7.81 | 8.18 | 8.56 | 8.93 | 9.29 | 9.67 | 10.04 | 17.85 |
| $\frac{1}{2}$ | 8.50 | 8.93 | 9.35 | 9.77 | 10.20 | 10.63 | 11.05 | 11.48 | 20.40 |
| $\frac{9}{16}$ | 9.57 | 10.04 | 10.52 | 11.00 | 11.48 | 11.95 | 12.43 | 12.91 | 22.95 |
| $\frac{5}{8}$ | 10.63 | 11.16 | 11.69 | 12.22 | 12.75 | 13.28 | 13.81 | 14.34 | 25.50 |
| $\frac{11}{16}$ | 11.69 | 12.27 | 12.85 | 13.44 | 14.03 | 14.61 | 15.20 | 15.78 | 28.05 |
| $\frac{3}{4}$ | 12.75 | 13.39 | 14.03 | 14.67 | 15.30 | 15.94 | 16.58 | 17.22 | 30.60 |
| $\frac{13}{16}$ | 13.81 | 14.50 | 15.19 | 15.88 | 16.58 | 17.27 | 17.95 | 18.65 | 33.15 |
| $\frac{7}{8}$ | 14.87 | 15.62 | 16.36 | 17.10 | 17.85 | 18.60 | 19.34 | 20.08 | 35.70 |
| $\frac{15}{16}$ | 15.94 | 16.74 | 17.53 | 18.33 | 19.13 | 19.92 | 20.72 | 21.51 | 38.25 |
| 1 | 17.00 | 17.85 | 18.70 | 19.55 | 20.40 | 21.25 | 22.10 | 22.95 | 40.80 |
| $1\frac{1}{16}$ | 18.06 | 18.96 | 19.87 | 20.77 | 21.68 | 22.58 | 23.48 | 24.39 | 43.35 |
| $1\frac{1}{8}$ | 19.13 | 20.08 | 21.04 | 21.99 | 22.95 | 23.91 | 24.87 | 25.82 | 45.90 |
| $1\frac{1}{4}$ | 20.19 | 21.20 | 22.21 | 23.22 | 24.23 | 25.23 | 26.24 | 27.25 | 48.45 |
| $1\frac{3}{4}$ | 21.25 | 22.32 | 23.38 | 24.44 | 25.50 | 26.56 | 27.62 | 28.69 | 51.00 |
| $1\frac{5}{16}$ | 22.32 | 23.43 | 24.54 | 25.66 | 26.78 | 27.90 | 29.01 | 30.12 | 53.55 |
| $1\frac{3}{8}$ | 23.38 | 24.54 | 25.71 | 26.88 | 28.05 | 29.22 | 30.39 | 31.56 | 56.10 |
| $1\frac{7}{16}$ | 24.44 | 25.66 | 26.88 | 28.10 | 29.33 | 30.55 | 31.77 | 32.99 | 58.65 |
| $1\frac{1}{2}$ | 25.50 | 26.78 | 28.05 | 29.33 | 30.60 | 31.88 | 33.15 | 34.43 | 61.20 |
| $1\frac{9}{16}$ | 26.57 | 27.89 | 29.22 | 30.55 | 31.88 | 33.20 | 34.53 | 35.86 | 63.75 |
| $1\frac{5}{8}$ | 27.63 | 29.01 | 30.39 | 31.77 | 33.15 | 34.53 | 35.91 | 37.29 | 66.30 |
| $1\frac{11}{16}$ | 28.69 | 30.12 | 31.55 | 32.99 | 34.43 | 35.86 | 37.30 | 38.73 | 68.85 |
| $1\frac{3}{4}$ | 29.75 | 31.24 | 32.73 | 34.22 | 35.70 | 37.19 | 38.68 | 40.17 | 71.40 |
| $1\frac{13}{16}$ | 30.81 | 32.35 | 33.89 | 35.43 | 36.98 | 38.52 | 40.05 | 41.60 | 73.95 |
| $1\frac{7}{8}$ | 31.87 | 33.47 | 35.06 | 36.65 | 38.25 | 39.85 | 41.44 | 43.03 | 76.50 |
| $1\frac{15}{16}$ | 32.94 | 34.59 | 36.23 | 37.88 | 39.53 | 41.17 | 42.82 | 44.46 | 79.05 |
| 2 | 34.00 | 35.70 | 37.40 | 39.10 | 40.80 | 42.50 | 44.20 | 45.90 | 81.60 |

WEIGHTS OF FLAT ROLLED STEEL—(Continued).

PER LINEAL FOOT.

| Thick- ness in Inches. | 7" | 7¼" | 7½" | 7¾" | 8" | 8¼" | 8½" | 8¾" | 12" |
|------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| $\frac{3}{16}$ | 4.46 | 4.62 | 4.78 | 4.94 | 5.10 | 5.26 | 5.42 | 5.58 | 7.65 |
| $\frac{1}{4}$ | 5.95 | 6.16 | 6.36 | 6.58 | 6.80 | 7.01 | 7.22 | 7.43 | 10.20 |
| $\frac{5}{16}$ | 7.44 | 7.70 | 7.97 | 8.23 | 8.50 | 8.76 | 9.03 | 9.29 | 12.75 |
| $\frac{3}{8}$ | 8.93 | 9.25 | 9.57 | 9.88 | 10.20 | 10.52 | 10.84 | 11.16 | 15.30 |
| $\frac{7}{16}$ | 10.41 | 10.78 | 11.16 | 11.53 | 11.90 | 12.27 | 12.64 | 13.02 | 17.85 |
| $\frac{1}{2}$ | 11.90 | 12.32 | 12.75 | 13.18 | 13.60 | 14.03 | 14.44 | 14.87 | 20.40 |
| $\frac{9}{16}$ | 13.39 | 13.86 | 14.34 | 14.82 | 15.30 | 15.78 | 16.26 | 16.74 | 22.95 |
| $\frac{5}{8}$ | 14.87 | 15.40 | 15.94 | 16.47 | 17.00 | 17.53 | 18.06 | 18.59 | 25.50 |
| $\frac{11}{16}$ | 16.36 | 16.94 | 17.53 | 18.12 | 18.70 | 19.28 | 19.86 | 20.45 | 28.05 |
| $\frac{3}{4}$ | 17.85 | 18.49 | 19.13 | 19.77 | 20.40 | 21.04 | 21.68 | 22.32 | 30.60 |
| $\frac{13}{16}$ | 19.34 | 20.03 | 20.72 | 21.41 | 22.10 | 22.79 | 23.48 | 24.17 | 33.15 |
| $\frac{7}{8}$ | 20.83 | 21.57 | 22.32 | 23.05 | 23.80 | 24.55 | 25.30 | 26.04 | 35.70 |
| $\frac{15}{16}$ | 22.32 | 23.11 | 23.91 | 24.70 | 25.50 | 26.30 | 27.10 | 27.89 | 38.25 |
| 1 | 23.80 | 24.65 | 25.50 | 26.35 | 27.20 | 28.05 | 28.90 | 29.75 | 40.80 |
| $1\frac{1}{16}$ | 25.29 | 26.19 | 27.10 | 28.00 | 28.90 | 29.80 | 30.70 | 31.61 | 43.35 |
| $1\frac{1}{8}$ | 26.78 | 27.73 | 28.68 | 29.64 | 30.60 | 31.56 | 32.52 | 33.47 | 45.90 |
| $1\frac{3}{16}$ | 28.26 | 29.27 | 30.28 | 31.29 | 32.30 | 33.31 | 34.32 | 35.33 | 48.45 |
| $1\frac{1}{4}$ | 29.75 | 30.81 | 31.88 | 32.94 | 34.00 | 35.06 | 36.12 | 37.20 | 51.00 |
| $1\frac{5}{16}$ | 31.23 | 32.35 | 33.48 | 34.59 | 35.70 | 36.81 | 37.93 | 39.05 | 53.55 |
| $1\frac{3}{8}$ | 32.72 | 33.89 | 35.06 | 36.23 | 37.40 | 38.57 | 39.74 | 40.91 | 56.10 |
| $1\frac{7}{16}$ | 34.21 | 35.44 | 36.66 | 37.88 | 39.10 | 40.32 | 41.54 | 42.77 | 58.65 |
| $1\frac{1}{2}$ | 35.70 | 36.98 | 38.26 | 39.53 | 40.80 | 42.08 | 43.35 | 44.63 | 61.20 |
| $1\frac{9}{16}$ | 37.19 | 38.51 | 39.84 | 41.17 | 42.50 | 43.83 | 45.16 | 46.49 | 63.75 |
| $1\frac{5}{8}$ | 38.67 | 40.05 | 41.44 | 42.82 | 44.20 | 45.58 | 46.96 | 48.34 | 66.30 |
| $1\frac{11}{16}$ | 40.16 | 41.59 | 43.03 | 44.47 | 45.90 | 47.33 | 48.76 | 50.20 | 68.85 |
| $1\frac{3}{4}$ | 41.65 | 43.14 | 44.63 | 46.12 | 47.60 | 49.09 | 50.58 | 52.07 | 71.40 |
| $1\frac{13}{16}$ | 43.14 | 44.68 | 46.22 | 47.76 | 49.30 | 50.84 | 52.38 | 53.92 | 73.95 |
| $1\frac{7}{8}$ | 44.63 | 46.22 | 47.82 | 49.40 | 51.00 | 52.60 | 54.20 | 55.79 | 76.50 |
| $1\frac{15}{16}$ | 46.12 | 47.76 | 49.41 | 51.05 | 52.70 | 54.35 | 56.00 | 57.64 | 79.05 |
| 2 | 47.60 | 49.30 | 51.00 | 52.70 | 54.40 | 56.10 | 57.80 | 59.50 | 81.60 |

WEIGHTS OF FLAT ROLLED STEEL—(Continued).

PER LINEAL FOOT.

| Thick- ness in Inches. | 9" | 9½" | 9¾" | 9¾" | 10" | 10¼" | 10½" | 10¾" | 12" |
|------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| $\frac{3}{16}$ | 5.74 | 5.90 | 6.06 | 6.22 | 6.38 | 6.54 | 6.70 | 6.86 | 7.65 |
| $\frac{1}{4}$ | 7.65 | 7.86 | 8.08 | 8.29 | 8.50 | 8.71 | 8.92 | 9.14 | 10.20 |
| $\frac{5}{16}$ | 9.56 | 9.83 | 10.10 | 10.36 | 10.62 | 10.89 | 11.16 | 11.42 | 12.75 |
| $\frac{3}{8}$ | 11.48 | 11.80 | 12.12 | 12.44 | 12.75 | 13.07 | 13.39 | 13.71 | 15.30 |
| $\frac{7}{16}$ | 13.40 | 13.76 | 14.14 | 14.51 | 14.88 | 15.25 | 15.62 | 15.99 | 17.85 |
| $\frac{1}{2}$ | 15.30 | 15.73 | 16.16 | 16.58 | 17.00 | 17.42 | 17.85 | 18.28 | 20.40 |
| $\frac{9}{16}$ | 17.22 | 17.69 | 18.18 | 18.65 | 19.14 | 19.61 | 20.08 | 20.56 | 22.95 |
| $\frac{5}{8}$ | 19.13 | 19.65 | 20.19 | 20.72 | 21.25 | 21.78 | 22.32 | 22.85 | 25.50 |
| $\frac{11}{16}$ | 21.04 | 21.62 | 22.21 | 22.79 | 23.38 | 23.96 | 24.54 | 25.13 | 28.05 |
| $\frac{3}{4}$ | 22.96 | 23.59 | 24.23 | 24.86 | 25.50 | 26.14 | 26.78 | 27.42 | 30.60 |
| $\frac{13}{16}$ | 24.86 | 25.55 | 26.24 | 26.94 | 27.62 | 28.32 | 29.00 | 29.69 | 33.15 |
| $\frac{7}{8}$ | 26.78 | 27.52 | 28.26 | 29.01 | 29.75 | 30.50 | 31.24 | 31.98 | 35.70 |
| $\frac{15}{16}$ | 28.69 | 29.49 | 30.28 | 31.08 | 31.88 | 32.67 | 33.48 | 34.28 | 38.25 |
| 1 | 30.60 | 31.45 | 32.30 | 33.15 | 34.00 | 34.85 | 35.70 | 36.55 | 40.80 |
| $1\frac{1}{16}$ | 32.52 | 33.41 | 34.32 | 35.22 | 36.12 | 37.03 | 37.92 | 38.83 | 43.35 |
| $1\frac{1}{8}$ | 34.43 | 35.38 | 36.34 | 37.29 | 38.25 | 39.21 | 40.17 | 41.12 | 45.90 |
| $1\frac{3}{16}$ | 36.34 | 37.35 | 38.36 | 39.37 | 40.38 | 41.39 | 42.40 | 43.40 | 48.45 |
| $1\frac{1}{4}$ | 38.26 | 39.31 | 40.37 | 41.44 | 42.50 | 43.56 | 44.63 | 45.69 | 51.00 |
| $1\frac{5}{16}$ | 40.16 | 41.28 | 42.40 | 43.52 | 44.64 | 45.75 | 46.86 | 47.97 | 53.55 |
| $1\frac{3}{8}$ | 42.08 | 43.25 | 44.41 | 45.58 | 46.75 | 47.92 | 49.08 | 50.25 | 56.10 |
| $1\frac{7}{16}$ | 44.00 | 45.22 | 46.44 | 47.66 | 48.88 | 50.10 | 51.32 | 52.54 | 58.65 |
| $1\frac{1}{2}$ | 45.90 | 47.18 | 48.45 | 49.73 | 51.00 | 52.28 | 53.55 | 54.83 | 61.20 |
| $1\frac{9}{16}$ | 47.82 | 49.14 | 50.48 | 51.80 | 53.14 | 54.46 | 55.78 | 57.11 | 63.75 |
| $1\frac{5}{8}$ | 49.73 | 51.10 | 52.49 | 53.87 | 55.25 | 56.63 | 58.02 | 59.40 | 66.30 |
| $1\frac{11}{16}$ | 51.64 | 53.07 | 54.51 | 55.94 | 57.38 | 58.81 | 60.24 | 61.68 | 68.85 |
| $1\frac{3}{4}$ | 53.56 | 55.04 | 56.53 | 58.01 | 59.50 | 60.99 | 62.48 | 63.97 | 71.40 |
| $1\frac{13}{16}$ | 55.46 | 57.00 | 58.54 | 60.09 | 61.62 | 63.17 | 64.70 | 66.24 | 73.95 |
| $1\frac{7}{8}$ | 57.38 | 58.97 | 60.56 | 62.16 | 63.75 | 65.35 | 66.94 | 68.53 | 76.50 |
| $1\frac{15}{16}$ | 59.29 | 60.94 | 62.58 | 64.23 | 65.88 | 67.52 | 69.18 | 70.83 | 79.05 |
| 2 | 61.20 | 62.90 | 64.60 | 66.30 | 68.00 | 69.70 | 71.40 | 73.10 | 81.60 |

WEIGHTS OF FLAT ROLLED STEEL—(Continued).
PER LINEAL FOOT.

| Thick- ness in Inches. | 11" | 11¼" | 11½" | 11¾" | 12" | 12¼" | 12½" | 12¾" |
|------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 3/16 | 7.02 | 7.17 | 7.32 | 7.49 | 7.65 | 7.82 | 7.98 | 8.13 |
| ¼ | 9.34 | 9.57 | 9.78 | 10.00 | 10.20 | 10.42 | 10.63 | 10.84 |
| 5/16 | 11.68 | 11.95 | 12.22 | 12.49 | 12.75 | 13.01 | 13.28 | 13.55 |
| 3/8 | 14.03 | 14.35 | 14.68 | 14.99 | 15.30 | 15.62 | 15.94 | 16.26 |
| 7/16 | 16.36 | 16.74 | 17.12 | 17.49 | 17.85 | 18.23 | 18.60 | 18.97 |
| ½ | 18.70 | 19.13 | 19.55 | 19.97 | 20.40 | 20.82 | 21.25 | 21.67 |
| 9/16 | 21.02 | 21.51 | 22.00 | 22.48 | 22.95 | 23.43 | 23.90 | 24.39 |
| 5/8 | 23.38 | 23.91 | 24.44 | 24.97 | 25.50 | 26.03 | 26.56 | 27.09 |
| 11/16 | 25.70 | 26.30 | 26.88 | 27.47 | 28.05 | 28.64 | 29.22 | 29.80 |
| ¾ | 28.05 | 28.68 | 29.33 | 29.97 | 30.60 | 31.25 | 31.88 | 32.52 |
| 13/16 | 30.40 | 31.08 | 31.76 | 32.46 | 33.15 | 33.83 | 34.53 | 35.22 |
| 7/8 | 32.72 | 33.47 | 34.21 | 34.95 | 35.70 | 36.44 | 37.19 | 37.93 |
| 15/16 | 35.06 | 35.86 | 36.66 | 37.46 | 38.25 | 39.05 | 39.84 | 40.64 |
| 1 | 37.40 | 38.25 | 39.10 | 39.95 | 40.80 | 41.65 | 42.50 | 43.35 |
| 1 1/16 | 39.74 | 40.64 | 41.54 | 42.54 | 43.35 | 44.25 | 45.16 | 46.06 |
| 1 1/8 | 42.08 | 43.04 | 44.00 | 44.94 | 45.90 | 46.86 | 47.82 | 48.77 |
| 1 3/16 | 44.42 | 45.42 | 46.44 | 47.45 | 48.45 | 49.46 | 50.46 | 51.48 |
| 1 ¼ | 46.76 | 47.82 | 48.88 | 49.94 | 51.00 | 52.06 | 53.12 | 54.19 |
| 1 5/16 | 49.08 | 50.20 | 51.32 | 52.44 | 53.55 | 54.67 | 55.78 | 56.90 |
| 1 3/8 | 51.42 | 52.59 | 53.76 | 54.93 | 56.10 | 57.27 | 58.44 | 59.60 |
| 1 7/16 | 53.76 | 54.99 | 56.21 | 57.43 | 58.65 | 59.87 | 60.10 | 62.32 |
| 1 ½ | 56.10 | 57.37 | 58.65 | 59.93 | 61.20 | 62.48 | 63.75 | 65.03 |
| 1 9/16 | 58.42 | 59.76 | 61.10 | 62.43 | 63.75 | 65.08 | 66.40 | 67.74 |
| 1 5/8 | 60.78 | 62.16 | 63.54 | 64.92 | 66.30 | 67.68 | 69.06 | 70.44 |
| 1 11/16 | 63.10 | 64.55 | 65.98 | 67.42 | 68.85 | 70.29 | 71.72 | 73.15 |
| 1 ¾ | 65.45 | 66.93 | 68.43 | 69.92 | 71.40 | 72.90 | 74.38 | 75.87 |
| 1 13/16 | 67.80 | 69.33 | 70.86 | 72.41 | 73.95 | 75.48 | 77.03 | 78.57 |
| 1 7/8 | 70.12 | 71.72 | 73.31 | 74.90 | 76.50 | 78.09 | 79.69 | 81.28 |
| 1 15/16 | 72.46 | 74.11 | 75.76 | 77.41 | 79.05 | 80.70 | 82.34 | 83.99 |
| 2 | 74.80 | 76.50 | 78.20 | 79.90 | 81.60 | 83.30 | 85.00 | 86.70 |

The weights for 12-inch width are repeated on each page to facilitate making the additions necessary to obtain the weights of plates wider than 12 inches. Thus, to find the weight of 15½ × ½ in. add the weights to be found in the same line for 3½ × ½ and 12 × ½ = 10.41 + 35.70 = 46.11 lbs.

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS.

One cubic foot of steel weighing 489.6 lbs.

| Thickness or Diameter in Inches. | Weight of \square Bar One Foot Long. | Weight of \circ Bar One Foot Long. | Area of \square Bar in Square Inches. | Area of \circ Bar in Square Inches. | Circumference of \circ Bar in Inches. |
|----------------------------------|--|--------------------------------------|---|---------------------------------------|---|
| 0 | | | | | |
| $\frac{1}{16}$ | .013 | .010 | .0039 | .0031 | .1963 |
| $\frac{1}{8}$ | .053 | .042 | .0156 | .0123 | .3927 |
| $\frac{3}{16}$ | .119 | .094 | .0352 | .0276 | .5890 |
| $\frac{1}{4}$ | .212 | .167 | .0625 | .0491 | .7854 |
| $\frac{5}{16}$ | .333 | .261 | .0977 | .0767 | .9817 |
| $\frac{3}{8}$ | .478 | .375 | .1406 | .1104 | 1.1781 |
| $\frac{7}{16}$ | .651 | .511 | .1914 | .1503 | 1.3744 |
| $\frac{1}{2}$ | .850 | .667 | .2500 | .1963 | 1.5708 |
| $\frac{9}{16}$ | 1.076 | .845 | .3164 | .2485 | 1.7671 |
| $\frac{5}{8}$ | 1.328 | 1.043 | .3906 | .3068 | 1.9635 |
| $\frac{11}{16}$ | 1.608 | 1.262 | .4727 | .3712 | 2.1598 |
| $\frac{3}{4}$ | 1.913 | 1.502 | .5625 | .4418 | 2.3562 |
| $\frac{13}{16}$ | 2.245 | 1.763 | .6602 | .5185 | 2.5525 |
| $\frac{7}{8}$ | 2.603 | 2.044 | .7656 | .6013 | 2.7489 |
| $\frac{15}{16}$ | 2.989 | 2.347 | .8789 | .6903 | 2.9452 |
| 1 | 3.400 | 2.670 | 1.0000 | .7854 | 3.1416 |
| $\frac{1}{16}$ | 3.838 | 3.014 | 1.1289 | .8866 | 3.3379 |
| $\frac{1}{8}$ | 4.303 | 3.379 | 1.2656 | .9940 | 3.5343 |
| $\frac{3}{16}$ | 4.795 | 3.766 | 1.4102 | 1.1075 | 3.7306 |
| $\frac{1}{4}$ | 5.312 | 4.173 | 1.5625 | 1.2272 | 3.9270 |
| $\frac{5}{16}$ | 5.857 | 4.600 | 1.7227 | 1.3530 | 4.1233 |
| $\frac{3}{8}$ | 6.428 | 5.049 | 1.8906 | 1.4849 | 4.3197 |
| $\frac{7}{16}$ | 7.026 | 5.518 | 2.0664 | 1.6230 | 4.5160 |
| $\frac{1}{2}$ | 7.650 | 6.008 | 2.2500 | 1.7671 | 4.7124 |
| $\frac{9}{16}$ | 8.301 | 6.520 | 2.4414 | 1.9175 | 4.9087 |
| $\frac{5}{8}$ | 8.978 | 7.051 | 2.6406 | 2.0739 | 5.1051 |
| $\frac{11}{16}$ | 9.682 | 7.604 | 2.8477 | 2.2365 | 5.3014 |
| $\frac{3}{4}$ | 10.41 | 8.178 | 3.0625 | 2.4053 | 5.4978 |
| $\frac{13}{16}$ | 11.17 | 8.773 | 3.2852 | 2.5802 | 5.6941 |
| $\frac{7}{8}$ | 11.95 | 9.388 | 3.5156 | 2.7612 | 5.8905 |
| $\frac{15}{16}$ | 12.76 | 10.02 | 3.7539 | 2.9483 | 6.0868 |

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS—(Continued).

| Thickness or Diameter in Inches. | Weight of □ Bar One Foot Long. | Weight of ○ Bar One Foot Long. | Area of □ Bar in Square Inches. | Area of ○ Bar in Square Inches. | Circumference of ○ Bar in Inches. |
|----------------------------------|--------------------------------|--------------------------------|---------------------------------|---------------------------------|-----------------------------------|
| 2 | 13.60 | 10.68 | 4.0000 | 3.1416 | 6.2832 |
| $\frac{1}{16}$ | 14.46 | 11.36 | 4.2539 | 3.3410 | 6.4795 |
| $\frac{1}{8}$ | 15.35 | 12.06 | 4.5156 | 3.5466 | 6.6759 |
| $\frac{3}{16}$ | 16.27 | 12.78 | 4.7852 | 3.7583 | 6.8722 |
| $\frac{1}{4}$ | 17.22 | 13.52 | 5.0625 | 3.9761 | 7.0686 |
| $\frac{5}{16}$ | 18.19 | 14.28 | 5.3477 | 4.2000 | 7.2649 |
| $\frac{3}{8}$ | 19.18 | 15.07 | 5.6406 | 4.4301 | 7.4613 |
| $\frac{7}{16}$ | 20.20 | 15.86 | 5.9414 | 4.6664 | 7.6576 |
| $\frac{1}{2}$ | 21.25 | 16.69 | 6.2500 | 4.9087 | 7.8540 |
| $\frac{9}{16}$ | 22.33 | 17.53 | 6.5664 | 5.1572 | 8.0503 |
| $\frac{5}{8}$ | 23.43 | 18.40 | 6.8906 | 5.4119 | 8.2467 |
| $\frac{11}{16}$ | 24.56 | 19.29 | 7.2227 | 5.6727 | 8.4430 |
| $\frac{3}{4}$ | 25.71 | 20.20 | 7.5625 | 5.9396 | 8.6394 |
| $\frac{13}{16}$ | 26.90 | 21.12 | 7.9102 | 6.2126 | 8.8357 |
| $\frac{7}{8}$ | 28.10 | 22.07 | 8.2656 | 6.4918 | 9.0321 |
| $\frac{15}{16}$ | 29.34 | 23.04 | 8.6289 | 6.7771 | 9.2284 |
| 3 | 30.60 | 24.03 | 9.0000 | 7.0686 | 9.4248 |
| $\frac{1}{16}$ | 31.89 | 25.04 | 9.3789 | 7.3662 | 9.6211 |
| $\frac{1}{8}$ | 33.20 | 26.08 | 9.7656 | 7.6699 | 9.8175 |
| $\frac{3}{16}$ | 34.55 | 27.13 | 10.160 | 7.9798 | 10.014 |
| $\frac{1}{4}$ | 35.92 | 28.20 | 10.563 | 8.2958 | 10.210 |
| $\frac{5}{16}$ | 37.31 | 29.30 | 10.973 | 8.6179 | 10.407 |
| $\frac{3}{8}$ | 38.73 | 30.42 | 11.391 | 8.9462 | 10.603 |
| $\frac{7}{16}$ | 40.18 | 31.56 | 11.816 | 9.2806 | 10.799 |
| $\frac{1}{2}$ | 41.65 | 32.71 | 12.250 | 9.6211 | 10.996 |
| $\frac{9}{16}$ | 43.14 | 33.90 | 12.691 | 9.9678 | 11.192 |
| $\frac{5}{8}$ | 44.68 | 35.09 | 13.141 | 10.321 | 11.388 |
| $\frac{11}{16}$ | 46.24 | 36.31 | 13.598 | 10.680 | 11.585 |
| $\frac{3}{4}$ | 47.82 | 37.56 | 14.063 | 11.045 | 11.781 |
| $\frac{13}{16}$ | 49.42 | 38.81 | 14.535 | 11.416 | 11.977 |
| $\frac{7}{8}$ | 51.05 | 40.10 | 15.016 | 11.793 | 12.174 |
| $\frac{15}{16}$ | 52.71 | 41.40 | 15.504 | 12.177 | 12.370 |

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS—(Continued).

| Thickness or Diameter in Inches. | Weight of □ Bar One Foot Long. | Weight of ○ Bar One Foot Long. | Area of □ Bar in Square Inches. | Area of ○ Bar in Square Inches. | Circumference of ○ Bar in Inches. |
|----------------------------------|--------------------------------|--------------------------------|---------------------------------|---------------------------------|-----------------------------------|
| 4 | 54.40 | 42.73 | 16.000 | 12.566 | 12.566 |
| $\frac{1}{16}$ | 56.11 | 44.07 | 16.504 | 12.962 | 12.763 |
| $\frac{1}{8}$ | 57.85 | 45.44 | 17.016 | 13.364 | 12.959 |
| $\frac{3}{16}$ | 59.62 | 46.83 | 17.535 | 13.772 | 13.155 |
| $\frac{1}{4}$ | 61.41 | 48.24 | 18.063 | 14.186 | 13.352 |
| $\frac{5}{16}$ | 63.23 | 49.66 | 18.598 | 14.607 | 13.548 |
| $\frac{3}{8}$ | 65.08 | 51.11 | 19.141 | 15.033 | 13.744 |
| $\frac{7}{16}$ | 66.95 | 52.58 | 19.691 | 15.466 | 13.941 |
| $\frac{1}{2}$ | 68.85 | 54.07 | 20.250 | 15.904 | 14.137 |
| $\frac{9}{16}$ | 70.78 | 55.59 | 20.816 | 16.349 | 14.334 |
| $\frac{5}{8}$ | 72.73 | 57.12 | 21.391 | 16.800 | 14.530 |
| $\frac{11}{16}$ | 74.70 | 58.67 | 21.973 | 17.257 | 14.726 |
| $\frac{3}{4}$ | 76.71 | 60.25 | 22.563 | 17.721 | 14.923 |
| $\frac{13}{16}$ | 78.74 | 61.84 | 23.160 | 18.190 | 15.119 |
| $\frac{7}{8}$ | 80.81 | 63.46 | 23.766 | 18.665 | 15.315 |
| $\frac{15}{16}$ | 82.89 | 65.10 | 24.379 | 19.147 | 15.512 |
| 5 | 85.00 | 66.76 | 25.000 | 19.635 | 15.708 |
| $\frac{1}{16}$ | 87.14 | 68.44 | 25.629 | 20.129 | 15.904 |
| $\frac{1}{8}$ | 89.30 | 70.14 | 26.266 | 20.629 | 16.101 |
| $\frac{3}{16}$ | 91.49 | 71.86 | 26.910 | 21.135 | 16.297 |
| $\frac{1}{4}$ | 93.72 | 73.60 | 27.563 | 21.648 | 16.493 |
| $\frac{5}{16}$ | 95.96 | 75.37 | 28.223 | 22.166 | 16.690 |
| $\frac{3}{8}$ | 98.23 | 77.15 | 28.891 | 22.691 | 16.886 |
| $\frac{7}{16}$ | 100.5 | 78.95 | 29.566 | 23.221 | 17.082 |
| $\frac{1}{2}$ | 102.8 | 80.77 | 30.250 | 23.758 | 17.279 |
| $\frac{9}{16}$ | 105.2 | 82.62 | 30.941 | 24.301 | 17.475 |
| $\frac{5}{8}$ | 107.6 | 84.49 | 31.641 | 24.850 | 17.671 |
| $\frac{11}{16}$ | 110.0 | 86.38 | 32.348 | 25.406 | 17.868 |
| $\frac{3}{4}$ | 112.4 | 88.29 | 33.063 | 25.967 | 18.064 |
| $\frac{13}{16}$ | 114.9 | 90.22 | 33.785 | 26.535 | 18.261 |
| $\frac{7}{8}$ | 117.4 | 92.17 | 34.516 | 27.109 | 18.457 |
| $\frac{15}{16}$ | 119.9 | 94.14 | 35.254 | 27.688 | 18.653 |

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS—(Continued).

| Thickness or Diameter in Inches. | Weight of □ Bar One Foot Long | Weight of ○ Bar One Foot Long. | Area of □ Bar in Square Inches. | Area of ○ Bar in Square Inches. | Circumference of ○ Bar in Inches. |
|----------------------------------|-------------------------------|--------------------------------|---------------------------------|---------------------------------|-----------------------------------|
| 6 | 122.4 | 96.14 | 36.000 | 28.274 | 18.850 |
| $\frac{1}{16}$ | 125.0 | 98.14 | 36.754 | 28.866 | 19.046 |
| $\frac{1}{8}$ | 127.6 | 100.2 | 37.516 | 29.465 | 19.242 |
| $\frac{3}{16}$ | 130.2 | 102.2 | 38.285 | 30.069 | 19.439 |
| $\frac{1}{4}$ | 132.8 | 104.3 | 39.063 | 30.680 | 19.635 |
| $\frac{5}{16}$ | 135.5 | 106.4 | 39.848 | 31.296 | 19.831 |
| $\frac{3}{8}$ | 138.2 | 108.5 | 40.641 | 31.919 | 20.028 |
| $\frac{7}{16}$ | 140.9 | 110.7 | 41.441 | 32.548 | 20.224 |
| $\frac{1}{2}$ | 143.6 | 112.8 | 42.250 | 33.183 | 20.420 |
| $\frac{9}{16}$ | 146.5 | 114.9 | 43.066 | 33.824 | 20.617 |
| $\frac{5}{8}$ | 149.2 | 117.2 | 43.891 | 34.472 | 20.813 |
| $\frac{11}{16}$ | 152.1 | 119.4 | 44.723 | 35.125 | 21.009 |
| $\frac{3}{4}$ | 154.9 | 121.7 | 45.563 | 35.785 | 21.206 |
| $\frac{13}{16}$ | 157.8 | 123.9 | 46.410 | 36.450 | 21.402 |
| $\frac{7}{8}$ | 160.8 | 126.2 | 47.266 | 37.122 | 21.598 |
| $\frac{15}{16}$ | 163.6 | 128.5 | 48.129 | 37.800 | 21.795 |
| 7 | 166.6 | 130.9 | 49.000 | 38.485 | 21.991 |
| $\frac{1}{16}$ | 169.6 | 133.2 | 49.879 | 39.175 | 22.187 |
| $\frac{1}{8}$ | 172.6 | 135.6 | 50.766 | 39.871 | 22.384 |
| $\frac{3}{16}$ | 175.6 | 137.9 | 51.660 | 40.574 | 22.580 |
| $\frac{1}{4}$ | 178.7 | 140.4 | 52.563 | 41.282 | 22.777 |
| $\frac{5}{16}$ | 181.8 | 142.8 | 53.473 | 41.997 | 22.973 |
| $\frac{3}{8}$ | 184.9 | 145.3 | 54.391 | 42.718 | 23.169 |
| $\frac{7}{16}$ | 188.1 | 147.7 | 55.316 | 43.445 | 23.366 |
| $\frac{1}{2}$ | 191.3 | 150.2 | 56.250 | 44.179 | 23.562 |
| $\frac{9}{16}$ | 194.4 | 152.7 | 57.191 | 44.918 | 23.758 |
| $\frac{5}{8}$ | 197.7 | 155.2 | 58.141 | 45.664 | 23.955 |
| $\frac{11}{16}$ | 200.9 | 157.8 | 59.098 | 46.415 | 24.151 |
| $\frac{3}{4}$ | 204.2 | 160.3 | 60.063 | 47.173 | 24.347 |
| $\frac{13}{16}$ | 207.6 | 163.0 | 61.035 | 47.937 | 24.544 |
| $\frac{7}{8}$ | 210.8 | 165.6 | 62.016 | 48.707 | 24.740 |
| $\frac{15}{16}$ | 214.2 | 168.2 | 63.004 | 49.483 | 24.936 |

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS—(Continued).

| Thickness or Diameter in Inches. | Weight of □ Bar One Foot Long. | Weight of ○ Bar One Foot Long. | Area of □ Bar in Square Inches. | Area of ○ Bar in Square Inches. | Circumference of ○ Bar in Inches. |
|----------------------------------|--------------------------------|--------------------------------|---------------------------------|---------------------------------|-----------------------------------|
| 8 | 217.6 | 171.0 | 64.000 | 50.265 | 25.133 |
| $\frac{1}{16}$ | 221.0 | 173.6 | 65.004 | 51.054 | 25.329 |
| $\frac{1}{8}$ | 224.5 | 176.3 | 66.016 | 51.849 | 25.525 |
| $\frac{3}{16}$ | 228.0 | 179.0 | 67.035 | 52.649 | 25.722 |
| $\frac{1}{4}$ | 231.4 | 181.8 | 68.063 | 53.456 | 25.918 |
| $\frac{5}{16}$ | 234.9 | 184.5 | 69.098 | 54.269 | 26.114 |
| $\frac{3}{8}$ | 238.5 | 187.3 | 70.141 | 55.088 | 26.311 |
| $\frac{7}{16}$ | 242.0 | 190.1 | 71.191 | 55.914 | 26.507 |
| $\frac{1}{2}$ | 245.6 | 193.0 | 72.250 | 56.745 | 26.704 |
| $\frac{9}{16}$ | 249.3 | 195.7 | 73.316 | 57.583 | 26.900 |
| $\frac{5}{8}$ | 252.9 | 198.7 | 74.391 | 58.426 | 27.096 |
| $\frac{11}{16}$ | 256.6 | 201.6 | 75.473 | 59.276 | 27.293 |
| $\frac{3}{4}$ | 260.3 | 204.4 | 76.563 | 60.132 | 27.489 |
| $\frac{13}{16}$ | 264.1 | 207.4 | 77.660 | 60.994 | 27.685 |
| $\frac{7}{8}$ | 267.9 | 210.3 | 78.766 | 61.862 | 27.882 |
| $\frac{15}{16}$ | 271.6 | 213.3 | 79.879 | 62.737 | 28.078 |
| 9 | 275.4 | 216.3 | 81.000 | 63.617 | 28.274 |
| $\frac{1}{16}$ | 279.3 | 219.3 | 82.129 | 64.505 | 28.471 |
| $\frac{1}{8}$ | 283.2 | 222.4 | 83.266 | 65.397 | 28.667 |
| $\frac{3}{16}$ | 287.0 | 225.4 | 84.410 | 66.296 | 28.863 |
| $\frac{1}{4}$ | 290.9 | 228.5 | 85.563 | 67.201 | 29.060 |
| $\frac{5}{16}$ | 294.9 | 231.5 | 86.723 | 68.112 | 29.256 |
| $\frac{3}{8}$ | 298.9 | 234.7 | 87.891 | 69.029 | 29.452 |
| $\frac{7}{16}$ | 302.8 | 237.9 | 89.066 | 69.953 | 29.649 |
| $\frac{1}{2}$ | 306.8 | 241.0 | 90.250 | 70.882 | 29.845 |
| $\frac{9}{16}$ | 310.9 | 244.2 | 91.441 | 71.818 | 30.041 |
| $\frac{5}{8}$ | 315.0 | 247.4 | 92.641 | 72.760 | 30.238 |
| $\frac{11}{16}$ | 319.1 | 250.6 | 93.848 | 73.708 | 30.434 |
| $\frac{3}{4}$ | 323.2 | 253.9 | 95.063 | 74.662 | 30.631 |
| $\frac{13}{16}$ | 327.4 | 257.1 | 96.285 | 75.622 | 30.827 |
| $\frac{7}{8}$ | 331.6 | 260.4 | 97.516 | 76.589 | 31.023 |
| $\frac{15}{16}$ | 335.8 | 263.7 | 98.754 | 77.561 | 31.022 |

WEIGHT OF SHEETS OF WROUGHT IRON, STEEL, COPPER,
AND BRASS (from HASWELL).

Weights per square foot. Thickness by Birmingham Gauge.

| Number of Gauge. | Thickness in Inches. | Iron. | Steel. | Copper. | Brass. |
|----------------------|----------------------|--------|--------|---------|--------|
| 0000 | .454 | 18.22 | 18.46 | 20.57 | 19.43 |
| 000 | .425 | 17.05 | 17.28 | 19.25 | 18.19 |
| 00 | .38 | 15.25 | 15.45 | 17.21 | 16.26 |
| 0 | .34 | 13.64 | 13.82 | 15.40 | 14.55 |
| 1 | .3 | 12.04 | 12.20 | 13.59 | 12.84 |
| 2 | .284 | 11.40 | 11.55 | 12.87 | 12.16 |
| 3 | .259 | 10.39 | 10.53 | 11.73 | 11.09 |
| 4 | .238 | 9.55 | 9.68 | 10.78 | 10.19 |
| 5 | .22 | 8.83 | 8.95 | 9.97 | 9.42 |
| 6 | .203 | 8.15 | 8.25 | 9.20 | 8.69 |
| 7 | .18 | 7.22 | 7.32 | 8.15 | 7.70 |
| 8 | .165 | 6.62 | 6.71 | 7.47 | 7.06 |
| 9 | .148 | 5.94 | 6.02 | 6.70 | 6.33 |
| 10 | .134 | 5.38 | 5.45 | 6.07 | 5.74 |
| 11 | .12 | 4.82 | 4.88 | 5.44 | 5.14 |
| 12 | .109 | 4.37 | 4.43 | 4.94 | 4.67 |
| 13 | .095 | 3.81 | 3.86 | 4.30 | 4.07 |
| 14 | .083 | 3.33 | 3.37 | 3.76 | 3.55 |
| 15 | .072 | 2.89 | 2.93 | 3.26 | 3.08 |
| 16 | .065 | 2.61 | 2.64 | 2.94 | 2.78 |
| 17 | .058 | 2.33 | 2.36 | 2.63 | 2.48 |
| 18 | .049 | 1.97 | 1.99 | 2.22 | 2.10 |
| 19 | .042 | 1.69 | 1.71 | 1.90 | 1.80 |
| 20 | .035 | 1.40 | 1.42 | 1.59 | 1.50 |
| 21 | .032 | 1.28 | 1.30 | 1.45 | 1.37 |
| 22 | .028 | 1.12 | 1.14 | 1.27 | 1.20 |
| 23 | .025 | 1.00 | 1.02 | 1.13 | 1.07 |
| 24 | .022 | .883 | .895 | 1.00 | .942 |
| 25 | .02 | .803 | .813 | .906 | .856 |
| 26 | .018 | .722 | .732 | .815 | .770 |
| 27 | .016 | .642 | .651 | .725 | .685 |
| 28 | .014 | .562 | .569 | .634 | .599 |
| 29 | .013 | .522 | .529 | .589 | .556 |
| 30 | .012 | .482 | .488 | .544 | .514 |
| 31 | .01 | .401 | .407 | .453 | .428 |
| 32 | .009 | .361 | .366 | .408 | .385 |
| 33 | .008 | .321 | .325 | .362 | .342 |
| 34 | .007 | .281 | .285 | .317 | .300 |
| 35 | .005 | .201 | .203 | .227 | .214 |
| Specific gravity.... | | 7.704 | 7.806 | 8.698 | 8.218 |
| Weight cubic foot.. | | 481.75 | 487.75 | 543.6 | 513.6 |
| Weight cubic inch.. | | .2787 | .2823 | .3146 | .2972 |

WEIGHT OF SHEETS OF WROUGHT IRON, STEEL, COPPER
AND BRASS (from HASWELL).

Weights per sq. ft. Thickness by American (Browne & Sharpe's) Gauge.

| Number of Gauge. | Thickness in Inches. | Iron. | Steel. | Copper. | Brass. |
|------------------|----------------------|-------|--------|---------|--------|
| 0000 | .46 | 18.46 | 18.70 | 20.84 | 19.69 |
| 000 | .4096 | 16.44 | 16.66 | 18.56 | 17.53 |
| 00 | .3648 | 14.64 | 14.83 | 16.53 | 15.61 |
| 0 | .3249 | 13.04 | 13.21 | 14.72 | 13.90 |
| 1 | .2893 | 11.61 | 11.76 | 13.11 | 12.38 |
| 2 | .2576 | 10.34 | 10.48 | 11.67 | 11.03 |
| 3 | .2294 | 9.21 | 9.33 | 10.39 | 9.82 |
| 4 | .2043 | 8.20 | 8.31 | 9.26 | 8.74 |
| 5 | .1819 | 7.30 | 7.40 | 8.24 | 7.79 |
| 6 | .1620 | 6.50 | 6.59 | 7.34 | 6.93 |
| 7 | .1443 | 5.79 | 5.87 | 6.54 | 6.18 |
| 8 | .1285 | 5.16 | 5.22 | 5.82 | 5.50 |
| 9 | .1144 | 4.59 | 4.65 | 5.18 | 4.90 |
| 10 | .1019 | 4.09 | 4.14 | 4.62 | 4.36 |
| 11 | .0907 | 3.64 | 3.69 | 4.11 | 3.88 |
| 12 | .0808 | 3.24 | 3.29 | 3.66 | 3.46 |
| 13 | .0720 | 2.89 | 2.93 | 3.26 | 3.08 |
| 14 | .0641 | 2.57 | 2.61 | 2.90 | 2.74 |
| 15 | .0571 | 2.29 | 2.32 | 2.59 | 2.44 |
| 16 | .0508 | 2.04 | 2.07 | 2.30 | 2.18 |
| 17 | .0453 | 1.82 | 1.84 | 2.05 | 1.94 |
| 18 | .0403 | 1.62 | 1.64 | 1.83 | 1.73 |
| 19 | .0359 | 1.44 | 1.46 | 1.63 | 1.54 |
| 20 | .0320 | 1.28 | 1.30 | 1.45 | 1.37 |
| 21 | .0285 | 1.14 | 1.16 | 1.29 | 1.22 |
| 22 | .0253 | 1.02 | 1.03 | 1.15 | 1.08 |
| 23 | .0226 | .906 | .918 | 1.02 | .966 |
| 24 | .0201 | .807 | .817 | .911 | .860 |
| 25 | .0179 | .718 | .728 | .811 | .766 |
| 26 | .0159 | .640 | .648 | .722 | .682 |
| 27 | .0142 | .570 | .577 | .643 | .608 |
| 28 | .0126 | .507 | .514 | .573 | .541 |
| 29 | .0113 | .452 | .458 | .510 | .482 |
| 30 | .0100 | .402 | .408 | .454 | .429 |
| 31 | .0089 | .358 | .363 | .404 | .382 |
| 32 | .0080 | .319 | .323 | .360 | .340 |
| 33 | .0071 | .284 | .288 | .321 | .303 |
| 34 | .0063 | .253 | .256 | .286 | .270 |
| 35 | .0056 | .225 | .228 | .254 | .240 |

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

| Distance between Supports in Feet. | 24" I. | | 20" I. | | 18" I. | | 15" I. | | | Add for Every Lb. Increase in Weight. | |
|------------------------------------|---------|---------------------------------------|---------|---------|---------------------------------------|---------|---------------------------------------|---------|---------|---------------------------------------|---------|
| | 80 Lbs. | Add for Every Lb. Increase in Weight. | 80 Lbs. | 65 Lbs. | Add for Every Lb. Increase in Weight. | 55 Lbs. | Add for Every Lb. Increase in Weight. | 80 Lbs. | 60 Lbs. | | 42 Lbs. |
| 12 | 77.33 | .53 | 65.18 | 51.98 | .44 | 39.29 | .39 | 47.14 | 36.09 | 26.18 | .33 |
| 13 | 71.38 | .48 | 60.16 | 47.98 | .40 | 36.27 | .36 | 43.51 | 33.31 | 24.17 | .30 |
| 14 | 66.28 | .45 | 55.87 | 44.56 | .37 | 33.68 | .34 | 40.40 | 30.93 | 22.44 | .28 |
| 15 | 61.86 | .42 | 52.14 | 41.59 | .35 | 31.43 | .31 | 37.71 | 28.87 | 20.94 | .26 |
| 16 | 58.00 | .39 | 48.88 | 38.99 | .33 | 29.47 | .29 | 35.35 | 27.07 | 19.63 | .24 |
| 17 | 54.58 | .37 | 46.01 | 36.69 | .31 | 27.74 | .28 | 33.27 | 25.47 | 18.48 | .23 |
| 18 | 51.56 | .35 | 43.45 | 34.66 | .29 | 26.19 | .26 | 31.42 | 24.06 | 17.45 | .22 |
| 19 | 48.84 | .33 | 41.17 | 32.83 | .28 | 24.82 | .25 | 29.77 | 22.79 | 16.53 | .21 |
| 20 | 46.40 | .32 | 39.11 | 31.19 | .26 | 23.58 | .24 | 28.28 | 21.65 | 15.71 | .20 |
| 21 | 44.19 | .30 | 37.24 | 29.70 | .25 | 22.45 | .22 | 26.94 | 20.62 | 14.96 | .19 |
| 22 | 42.18 | .29 | 35.55 | 28.35 | .24 | 21.43 | .21 | 25.71 | 19.68 | 14.28 | .18 |
| 23 | 40.35 | .27 | 34.01 | 27.12 | .23 | 20.50 | .20 | 24.59 | 18.83 | 13.66 | .17 |
| 24 | 38.67 | .26 | 32.59 | 25.99 | .22 | 19.65 | .20 | 23.57 | 18.04 | 13.19 | .16 |
| 25 | 37.12 | .25 | 31.29 | 24.95 | .21 | 18.86 | .19 | 22.63 | 17.32 | 12.57 | .16 |
| 26 | 35.69 | .24 | 30.08 | 23.99 | .20 | 18.14 | .18 | 21.76 | 16.66 | 12.08 | .15 |
| 27 | 34.37 | .23 | 28.97 | 23.10 | .19 | 17.46 | .17 | 20.95 | 16.04 | 11.64 | .14 |
| 28 | 33.14 | .23 | 27.93 | 22.28 | .19 | 16.84 | .17 | 20.20 | 15.47 | 11.22 | .14 |
| 29 | 32.00 | .22 | 26.97 | 21.51 | .18 | 16.26 | .16 | 19.51 | 14.93 | 10.83 | .13 |
| 30 | 30.93 | .21 | 26.07 | 20.79 | .17 | 15.72 | .16 | 18.86 | 14.43 | 10.47 | .13 |
| 31 | 29.94 | .20 | 25.23 | 20.12 | .17 | 15.21 | .15 | 18.25 | 13.97 | 10.13 | .13 |
| 32 | 29.00 | .20 | 24.44 | 19.49 | .16 | 14.73 | .15 | 17.68 | 13.53 | 9.82 | .12 |
| 33 | 28.12 | .19 | 23.70 | 18.90 | .16 | 14.29 | .14 | 17.14 | 13.12 | 9.52 | .12 |
| 34 | 27.29 | .19 | 23.00 | 18.35 | .15 | 13.87 | .14 | 16.64 | 12.74 | 9.24 | .11 |
| 35 | 26.51 | .18 | 22.35 | 17.82 | .15 | 13.47 | .13 | 16.16 | 12.37 | 8.98 | .11 |
| 36 | 25.78 | .18 | 21.73 | 17.33 | .15 | 13.10 | .13 | 15.71 | 12.03 | 8.73 | .11 |

Safe loads given include weight of beam. Maximum fibre stress, 16,000 lbs. per square inch.



SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

| Distance between Supports in Feet. | 12" I. | | Add for Every Lb. Increase in Weight. | 10" I. | Add for Every Lb. Increase in Weight. | 9" I. | Add for Every Lb. Increase in Weight. | Distance between Supports in Feet. | 8" I. | Add for Every Lb. Increase in Weight. |
|------------------------------------|---------|-----------|---------------------------------------|---------|---------------------------------------|---------|---------------------------------------|------------------------------------|---------|---------------------------------------|
| | 40 Lbs. | 31.5 Lbs. | | 25 Lbs. | | 21 Lbs. | | | 18 Lbs. | |
| 12 | 19.92 | 15.99 | .26 | 10.85 | .22 | 8.39 | .20 | 5 | 15.17 | .42 |
| 13 | 18.39 | 14.76 | .24 | 10.02 | .20 | 7.74 | .18 | 6 | 12.64 | .35 |
| 14 | 17.08 | 13.70 | .23 | 9.30 | .19 | 7.19 | .17 | 7 | 10.84 | .30 |
| 15 | 15.94 | 12.79 | .21 | 8.68 | .17 | 6.71 | .16 | 8 | 9.48 | .26 |
| 16 | 14.94 | 11.99 | .20 | 8.14 | .16 | 6.29 | .15 | 9 | 8.43 | .23 |
| 17 | 14.06 | 11.29 | .19 | 7.66 | .15 | 5.92 | .14 | 10 | 7.59 | .21 |
| 18 | 13.28 | 10.66 | .18 | 7.24 | .14 | 5.59 | .13 | 11 | 6.90 | .19 |
| 19 | 12.58 | 10.10 | .17 | 6.86 | .14 | 5.30 | .12 | 12 | 6.32 | .18 |
| 20 | 11.95 | 9.59 | .16 | 6.51 | .13 | 5.03 | .12 | 13 | 5.83 | .16 |
| 21 | 11.38 | 9.14 | .15 | 6.20 | .12 | 4.79 | .11 | 14 | 5.42 | .15 |
| 22 | 10.87 | 8.72 | .14 | 5.92 | .12 | 4.58 | .11 | 15 | 5.06 | .14 |
| 23 | 10.39 | 8.34 | .14 | 5.66 | .11 | 4.38 | .10 | 16 | 4.74 | .13 |
| 24 | 9.96 | 7.99 | .13 | 5.43 | .11 | 4.19 | .10 | 17 | 4.46 | .12 |
| 25 | 9.56 | 7.67 | .13 | 5.21 | .10 | 4.03 | .09 | 18 | 4.21 | .12 |
| 26 | 9.19 | 7.38 | .12 | 5.01 | .10 | 3.87 | .09 | 19 | 3.99 | .11 |
| 27 | 8.85 | 7.11 | .12 | 4.82 | .10 | 3.73 | .09 | 20 | 3.79 | .11 |
| 28 | 8.54 | 6.85 | .11 | 4.65 | .09 | 3.59 | .08 | 21 | 3.61 | .10 |
| 29 | 8.24 | 6.62 | .11 | 4.49 | .09 | 3.47 | .08 | ..... | ..... | ..... |
| 30 | 7.97 | 6.40 | .11 | 4.34 | .09 | 3.36 | .08 | ..... | ..... | ..... |

Safe loads given include weight of beam. Maximum fibre stress, 16,000 lbs. per square inch.



SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

| Distance between Supports in Feet. | 7" I. | | 6" I. | | 5" I. | | 4" I. | | 3" I. | |
|------------------------------------|---------|---------------------------------------|------------|---------------------------------------|-----------|---------------------------------------|----------|---------------------------------------|----------|---------------------------------------|
| | 15 lbs. | Add for Every Lb. Increase in Weight. | 12.25 lbs. | Add for Every Lb. Increase in Weight. | 9.75 lbs. | Add for Every Lb. Increase in Weight. | 7.5 lbs. | Add for Every Lb. Increase in Weight. | 5.5 lbs. | Add for Every Lb. Increase in Weight. |
| 5 | 11.04 | .36 | 7.75 | .31 | 5.16 | .26 | 3.18 | .21 | 1.76 | .16 |
| 6 | 9.20 | .30 | 6.46 | .26 | 4.30 | .22 | 2.65 | .18 | 1.47 | .13 |
| 7 | 7.89 | .26 | 5.54 | .22 | 3.69 | .19 | 2.27 | .15 | 1.26 | .11 |
| 8 | 6.90 | .23 | 4.84 | .19 | 3.23 | .16 | 1.99 | .13 | 1.10 | .10 |
| 9 | 6.13 | .20 | 4.31 | .17 | 2.87 | .14 | 1.77 | .12 | 0.98 | .09 |
| 10 | 5.52 | .18 | 3.88 | .16 | 2.58 | .13 | 1.59 | .11 | 0.88 | .08 |
| 11 | 5.02 | .16 | 3.52 | .14 | 2.35 | .12 | 1.45 | .10 | 0.80 | .07 |
| 12 | 4.60 | .15 | 3.23 | .13 | 2.15 | .11 | 1.33 | .09 | 0.73 | .07 |
| 13 | 4.25 | .14 | 2.98 | .12 | 1.98 | .10 | 1.22 | .08 | 0.68 | .06 |
| 14 | 3.94 | .13 | 2.77 | .11 | 1.84 | .09 | 1.14 | .08 | 0.63 | .06 |
| 15 | 3.68 | .12 | 2.58 | .10 | 1.72 | .09 | 1.06 | .07 | 0.59 | .05 |
| 16 | 3.45 | .11 | 2.42 | .10 | 1.61 | .08 | 0.99 | .07 | 0.55 | .05 |
| 17 | 3.25 | .11 | 2.28 | .09 | 1.52 | .08 | 0.94 | .06 | 0.52 | .05 |
| 18 | 3.07 | .10 | 2.15 | .09 | 1.43 | .07 | 0.88 | .06 | 0.49 | .04 |
| 19 | 2.91 | .09 | 2.04 | .08 | 1.36 | .07 | 0.84 | .06 | 0.46 | .04 |
| 20 | 2.76 | .09 | 1.94 | .08 | 1.29 | .07 | 0.80 | .05 | 0.44 | .04 |
| 21 | 2.63 | .09 | 1.85 | .07 | 1.23 | .06 | 0.76 | .05 | 0.42 | .04 |

Safe loads given include weight of beam. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL CHANNELS.

In Tons of 2000 Lbs.

| Distance between Supports in Feet. | 15" □ | Add for Every Lb. Increase in Weight. | 12" □ | Add for Every Lb. Increase in Weight. | 10" □ | Add for Every Lb. Increase in Weight. | 9" □ | Add for Every Lb. Increase in Weight. |
|------------------------------------|---------|---------------------------------------|-----------|---------------------------------------|---------|---------------------------------------|------------|---------------------------------------|
| | 33 lbs. | | 20.5 lbs. | | 15 lbs. | | 13.25 lbs. | |
| 10 | 22.23 | .39 | 11.39 | .32 | 7.14 | .26 | 5.61 | .24 |
| 11 | 20.20 | .35 | 10.35 | .29 | 6.49 | .24 | 5.10 | .21 |
| 12 | 18.52 | .33 | 9.49 | .26 | 5.95 | .22 | 4.68 | .20 |
| 13 | 17.10 | .30 | 8.76 | .24 | 5.49 | .20 | 4.32 | .18 |
| 14 | 15.87 | .28 | 8.14 | .23 | 5.10 | .19 | 4.01 | .17 |
| 15 | 14.82 | .26 | 7.59 | .21 | 4.76 | .17 | 3.74 | .16 |
| 16 | 13.89 | .24 | 7.12 | .20 | 4.46 | .16 | 3.51 | .15 |
| 17 | 13.07 | .23 | 6.70 | .18 | 4.20 | .15 | 3.30 | .14 |
| 18 | 12.35 | .22 | 6.33 | .18 | 3.96 | .14 | 3.12 | .13 |
| 19 | 11.70 | .21 | 5.99 | .17 | 3.76 | .14 | 2.95 | .12 |
| 20 | 11.11 | .20 | 5.70 | .16 | 3.57 | .13 | 2.81 | .12 |
| 21 | 10.58 | .19 | 5.42 | .15 | 3.40 | .12 | 2.67 | .11 |
| 22 | 10.10 | .18 | 5.18 | .14 | 3.24 | .12 | 2.55 | .11 |
| 23 | 9.66 | .17 | 4.95 | .14 | 3.10 | .11 | 2.44 | .10 |
| 24 | 9.26 | .16 | 4.75 | .13 | 2.97 | .11 | 2.34 | .10 |
| 25 | 8.89 | .16 | 4.56 | .13 | 2.85 | .10 | 2.24 | .09 |
| 26 | 8.55 | .15 | 4.38 | .12 | 2.74 | .10 | 2.16 | .09 |
| 27 | 8.23 | .14 | 4.22 | .12 | 2.64 | .10 | 2.08 | .09 |
| 28 | 7.94 | .14 | 4.07 | .11 | 2.55 | .09 | 2.00 | .08 |
| 29 | 7.66 | .13 | 3.93 | .11 | 2.46 | .09 | 1.93 | .08 |
| 30 | 7.41 | .13 | 3.80 | .11 | 2.38 | .09 | 1.87 | .08 |

Safe loads given include weight of channel. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL CHANNELS.

In Tons of 2000 Lbs.

| Distance between Supports in Feet. | 8" □ | | 7" □ | | 6" □ | | 5" □ | | 4" □ | | 3" □ | |
|------------------------------------|------------|---------------------------------------|-----------|---------------------------------------|--------|---------------------------------------|----------|---------------------------------------|-----------|---------------------------------------|--------|---------------------------------------|
| | 11.25 Lbs. | Add for Every Lb. Increase in Weight. | 9.75 Lbs. | Add for Every Lb. Increase in Weight. | 8 Lbs. | Add for Every Lb. Increase in Weight. | 6.5 Lbs. | Add for Every Lb. Increase in Weight. | 5.25 Lbs. | Add for Every Lb. Increase in Weight. | 4 Lbs. | Add for Every Lb. Increase in Weight. |
| 5 | 8.61 | .42 | 6.68 | .36 | 4.62 | .31 | 3.16 | .26 | 2.02 | .21 | 1.16 | .16 |
| 6 | 7.18 | .35 | 5.57 | .30 | 3.85 | .26 | 2.63 | .22 | 1.68 | .18 | .97 | .13 |
| 7 | 6.15 | .30 | 4.77 | .26 | 3.30 | .22 | 2.26 | .19 | 1.44 | .15 | .83 | .11 |
| 8 | 5.38 | .26 | 4.18 | .23 | 2.89 | .19 | 1.98 | .16 | 1.26 | .13 | .73 | .10 |
| 9 | 4.78 | .23 | 3.71 | .20 | 2.57 | .17 | 1.76 | .14 | 1.12 | .12 | .64 | .09 |
| 10 | 4.31 | .21 | 3.34 | .18 | 2.31 | .16 | 1.58 | .13 | 1.01 | .11 | .58 | .08 |
| 11 | 3.91 | .19 | 3.04 | .16 | 2.10 | .14 | 1.44 | .12 | .92 | .10 | .53 | .07 |
| 12 | 3.59 | .18 | 2.78 | .15 | 1.93 | .13 | 1.32 | .11 | .84 | .09 | .48 | .07 |
| 13 | 3.31 | .16 | 2.57 | .14 | 1.78 | .12 | 1.22 | .10 | .78 | .08 | .45 | .06 |
| 14 | 3.08 | .15 | 2.39 | .13 | 1.65 | .11 | 1.13 | .09 | .72 | .08 | .41 | .06 |
| 15 | 2.87 | .14 | 2.23 | .12 | 1.54 | .10 | 1.05 | .09 | .67 | .07 | .39 | .05 |
| 16 | 2.69 | .13 | 2.09 | .11 | 1.44 | .10 | .99 | .08 | .63 | .07 | .36 | .05 |
| 17 | 2.53 | .12 | 1.96 | .11 | 1.36 | .09 | .93 | .08 | .59 | .06 | .34 | .05 |
| 18 | 2.39 | .11 | 1.86 | .10 | 1.28 | .09 | .88 | .07 | .56 | .06 | .32 | .04 |
| 19 | 2.27 | .11 | 1.76 | .09 | 1.22 | .08 | .83 | .07 | .53 | .06 | .31 | .04 |
| 20 | 2.15 | .11 | 1.67 | .09 | 1.16 | .08 | .79 | .07 | .51 | .05 | .29 | .04 |
| 21 | 2.05 | .10 | 1.59 | .09 | 1.10 | .07 | .75 | .06 | .48 | .05 | .28 | .04 |
| 22 | 1.96 | .10 | 1.52 | .08 | 1.05 | .07 | .72 | .06 | .46 | .05 | .26 | .04 |
| 23 | 1.87 | .09 | 1.45 | .08 | 1.00 | .07 | .69 | .06 | .44 | .05 | .25 | .03 |
| 24 | 1.79 | .09 | 1.39 | .08 | .96 | .06 | .66 | .05 | .42 | .04 | .24 | .03 |
| 25 | 1.72 | .08 | 1.34 | .07 | .92 | .06 | .63 | .05 | .40 | .04 | .23 | .03 |

Safe loads given include weight of channel. Maximum fibre stress, 16,000 lbs. per square inch.

PROPERTIES OF


| 1 Section Index. | 2 Depth of Beam, Inches. | 3 Weight per Foot, Pounds. | 4 Area of Section, Square Inches. | 5 Thickness of Web, Inches. | 6 Width of Flange, Inches. | 7 Mom. of Inertia, Neutral Axis Per- pendicular to Web at Centre. | 8 Mom. of Inertia, Neutral Axis Coin- cident with Centre Line of Web. | 9 Radius of Gyration, Neutral Axis Per- pendicular to Web at Centre. |
|---------------------|--------------------------------|----------------------------------|---|-----------------------------------|----------------------------------|---|---|--|
| | | | | | | <i>I</i> | <i>I'</i> | <i>r</i> |
| B 1 | 24 | 100.00 | 29.41 | 0.754 | 7.254 | 2380.3 | 48.56 | 9.00 |
| | | 95.00 | 27.94 | 0.692 | 7.192 | 2309.6 | 47.10 | 9.09 |
| | | 90.00 | 26.47 | 0.631 | 7.131 | 2239.1 | 45.70 | 9.20 |
| | | 85.00 | 25.00 | 0.570 | 7.070 | 2168.6 | 44.35 | 9.31 |
| | | 80.00 | 23.32 | 0.500 | 7.000 | 2087.9 | 42.86 | 9.46 |
| B 2 | 20 | 100.00 | 29.41 | 0.884 | 7.284 | 1655.8 | 52.65 | 7.50 |
| | | 95.00 | 27.94 | 0.810 | 7.210 | 1606.8 | 50.78 | 7.58 |
| | | 90.00 | 26.47 | 0.737 | 7.137 | 1557.8 | 48.98 | 7.67 |
| | | 85.00 | 25.00 | 0.663 | 7.063 | 1508.7 | 47.25 | 7.77 |
| | | 80.00 | 23.73 | 0.600 | 7.000 | 1466.5 | 45.81 | 7.86 |
| B 3 | 20 | 75.00 | 22.06 | 0.649 | 6.399 | 1268.9 | 30.25 | 7.58 |
| | | 70.00 | 20.59 | 0.575 | 6.325 | 1219.9 | 29.04 | 7.70 |
| | | 65.00 | 19.08 | 0.500 | 6.250 | 1169.6 | 27.86 | 7.83 |
| B80 | 18 | 70.00 | 20.59 | 0.719 | 6.259 | 921.3 | 24.62 | 6.69 |
| | | 65.00 | 19.12 | 0.637 | 6.177 | 881.5 | 23.47 | 6.79 |
| | | 60.00 | 17.65 | 0.555 | 6.095 | 841.8 | 22.38 | 6.91 |
| | | 55.00 | 15.93 | 0.460 | 6.000 | 795.6 | 21.19 | 7.07 |
| B 4 | 15 | 100.00 | 29.41 | 1.184 | 6.774 | 900.5 | 50.98 | 5.53 |
| | | 95.00 | 27.94 | 1.085 | 6.675 | 872.9 | 48.37 | 5.59 |
| | | 90.00 | 26.47 | 0.987 | 6.577 | 845.4 | 45.91 | 5.65 |
| | | 85.00 | 25.00 | 0.889 | 6.479 | 817.8 | 43.57 | 5.72 |
| | | 80.00 | 23.81 | 0.810 | 6.400 | 795.5 | 41.76 | 5.78 |
| B 5 | 15 | 75.00 | 22.06 | 0.882 | 6.292 | 691.2 | 30.68 | 5.60 |
| | | 70.00 | 20.59 | 0.784 | 6.194 | 663.6 | 29.00 | 5.68 |
| | | 65.00 | 19.12 | 0.686 | 6.096 | 636.0 | 27.42 | 5.77 |
| | | 60.00 | 17.67 | 0.590 | 6.000 | 609.0 | 25.96 | 5.87 |
| B 7 | 15 | 55.00 | 16.18 | 0.656 | 5.746 | 511.0 | 17.06 | 5.62 |
| | | 50.00 | 14.71 | 0.558 | 5.648 | 483.4 | 16.04 | 5.73 |
| | | 45.00 | 13.24 | 0.460 | 5.550 | 455.8 | 15.00 | 5.87 |
| | | 42.00 | 12.48 | 0.410 | 5.500 | 441.7 | 14.62 | 5.95 |
| B 8 | 12 | 55.00 | 16.18 | 0.822 | 5.612 | 321.0 | 17.46 | 4.45 |
| | | 50.00 | 14.71 | 0.699 | 5.489 | 303.3 | 16.12 | 4.54 |
| | | 45.00 | 13.24 | 0.576 | 5.366 | 285.7 | 14.89 | 4.65 |
| | | 40.00 | 11.84 | 0.460 | 5.250 | 268.9 | 13.81 | 4.77 |
| B 9 | 12 | 35.00 | 10.29 | 0.436 | 5.086 | 228.3 | 10.07 | 4.71 |
| | | 31.50 | 9.26 | 0.350 | 5.000 | 215.8 | 9.50 | 4.83 |
| B10 | 10 | 40.00 | 11.76 | 0.749 | 5.099 | 158.7 | 9.50 | 3.67 |
| | | 35.00 | 10.29 | 0.602 | 4.952 | 146.4 | 8.52 | 3.77 |
| | | 30.00 | 8.82 | 0.455 | 4.805 | 134.2 | 7.65 | 3.90 |
| | | 25.00 | 7.37 | 0.310 | 4.660 | 122.1 | 6.89 | 4.07 |

L = safe load in pounds uniformly distributed; l = span in feet.

M' = moment of forces in foot-pounds; C and C' = coefficients given on opposite page.

Weights in heavy print are standard, others are special.

I BEAMS.

| 10 Radius of Gyration, Neutral Axis Coin- cident with Centre Line of Web. | 11 Section Modulus, Neutral Axis Per- pendicular to Web at Centre. | 12 Coefficient of Stren ^h for Fibre Stress of 16,000 Lbs. per Sq. In. Used for Build- ings. | 13 Coefficient of Stren ^h for Fibre Stress of 12,500 Lbs. per Sq. In. Used for Bridges. | 14 Distance Centre to Centre Re- quired to make Radii of Gyration Equal.  | 15 Section Index. |
|---|--|---|---|---|----------------------|
| 1.28 | 198.4 | 2115800 | 1653000 | 17.82 | |
| 1.30 | 192.5 | 2052900 | 1603900 | 17.99 | |
| 1.31 | 186.6 | 1990300 | 1554900 | 18.21 | B 1 |
| 1.33 | 180.7 | 1927600 | 1505900 | 18.43 | |
| 1.36 | 174.0 | 1855900 | 1449900 | 18.72 | |
| 1.34 | 165.6 | 1766100 | 1379800 | 14.76 | |
| 1.35 | 160.7 | 1713900 | 1339000 | 14.92 | |
| 1.36 | 155.8 | 1661600 | 1298100 | 15.10 | B 2 |
| 1.37 | 150.9 | 1609300 | 1257200 | 15.30 | |
| 1.39 | 146.7 | 1564300 | 1222100 | 15.47 | |
| 1.17 | 126.9 | 1353500 | 1057400 | 14.98 | |
| 1.19 | 122.0 | 1301200 | 1016600 | 15.21 | B 3 |
| 1.21 | 117.0 | 1247600 | 974700 | 15.47 | |
| 1.09 | 102.4 | 1091900 | 853000 | 13.20 | |
| 1.11 | 97.9 | 1044800 | 816200 | 13.40 | |
| 1.13 | 93.5 | 997700 | 779500 | 13.63 | B80 |
| 1.15 | 88.4 | 943000 | 736700 | 13.95 | |
| 1.31 | 120.1 | 1280700 | 1000600 | 10.75 | |
| 1.32 | 116.4 | 1241500 | 969900 | 10.86 | |
| 1.32 | 112.7 | 1202300 | 939300 | 10.99 | B 4 |
| 1.32 | 109.0 | 1163000 | 908600 | 11.13 | |
| 1.32 | 106.1 | 1131300 | 883900 | 11.25 | |
| 1.18 | 92.2 | 983000 | 768000 | 10.95 | |
| 1.19 | 88.5 | 943800 | 737400 | 11.11 | |
| 1.20 | 84.8 | 904600 | 706700 | 11.29 | B 5 |
| 1.21 | 81.2 | 866100 | 676600 | 11.49 | |
| 1.02 | 68.1 | 726800 | 567800 | 11.05 | |
| 1.04 | 64.5 | 687500 | 537100 | 11.27 | |
| 1.07 | 60.8 | 648200 | 506400 | 11.54 | B 7 |
| 1.08 | 58.9 | 628300 | 490800 | 11.70 | |
| 1.04 | 53.5 | 570600 | 445800 | 8.65 | |
| 1.05 | 50.6 | 539200 | 421300 | 8.83 | |
| 1.06 | 47.6 | 507900 | 396800 | 9.06 | B 8 |
| 1.08 | 44.8 | 478100 | 373500 | 9.29 | |
| 0.99 | 38.0 | 405800 | 317000 | 9.21 | |
| 1.01 | 36.0 | 383700 | 299700 | 9.45 | B 9 |
| 0.90 | 31.7 | 338500 | 264500 | 7.12 | |
| 0.91 | 29.3 | 312400 | 244100 | 7.32 | |
| 0.93 | 26.8 | 286300 | 223600 | 7.57 | B11 |
| 0.97 | 24.4 | 260500 | 203500 | 7.91 | |


$$L = \frac{C \text{ or } C'}{l}; \quad M' = \frac{C \text{ or } C'}{8}; \quad C \text{ or } C' = Ll = 8M' = \frac{8fS}{12}.$$

PROPERTIES OF

| 1 Section Index. | 2 Depth of Beam, Inches. | 3 Weight per Foot, Pounds. | 4 Area of Section, Square Inches. | 5 Thickness of Web, Inches. | 6 Width of Flange, Inches. | Mom. of Inertia, Neutral Axis Per- pendicular to Web at Centre. I | Mom. of Inertia, Neutral Axis Coin- cident with Centre Line of Web. I' | Radius of Gyration, Neutral Axis Per- pendicular to Web at Centre. r |
|---------------------|--------------------------------|----------------------------------|---|-----------------------------------|----------------------------------|---|--|--|
| B13 | 9 | 35.00 | 10.29 | 0.732 | 4.772 | 111.8 | 7.31 | 3.29 |
| | | 30.00 | 8.82 | 0.569 | 4.609 | 101.9 | 6.42 | 3.40 |
| | | 25.00 | 7.35 | 0.406 | 4.446 | 91.9 | 5.65 | 3.54 |
| | | 21.00 | 6.31 | 0.290 | 4.330 | 84.9 | 5.16 | 3.67 |
| B15 | 8 | 25.50 | 7.50 | 0.541 | 4.271 | 68.4 | 4.75 | 3.02 |
| | | 23.00 | 6.76 | 0.449 | 4.179 | 64.5 | 4.39 | 3.09 |
| | | 20.50 | 6.03 | 0.357 | 4.087 | 60.6 | 4.07 | 3.17 |
| | | 18.00 | 5.33 | 0.270 | 4.000 | 56.9 | 3.78 | 3.27 |
| B17 | 7 | 20.00 | 5.88 | 0.458 | 3.868 | 42.2 | 3.24 | 2.68 |
| | | 17.50 | 5.15 | 0.353 | 3.763 | 39.2 | 2.94 | 2.76 |
| | | 15.00 | 4.42 | 0.250 | 3.660 | 36.2 | 2.67 | 2.86 |
| B19 | 6 | 17.25 | 5.07 | 0.475 | 3.575 | 26.2 | 2.36 | 2.27 |
| | | 14.75 | 4.34 | 0.352 | 3.452 | 24.0 | 2.09 | 2.35 |
| | | 12.25 | 3.61 | 0.230 | 3.330 | 21.8 | 1.85 | 2.46 |
| B21 | 5 | 14.75 | 4.34 | 0.504 | 3.294 | 15.2 | 1.70 | 1.87 |
| | | 12.25 | 3.60 | 0.357 | 3.147 | 13.6 | 1.45 | 1.94 |
| | | 9.75 | 2.87 | 0.210 | 3.000 | 12.1 | 1.23 | 2.05 |
| B23 | 4 | 10.50 | 3.09 | 0.410 | 2.880 | 7.1 | 1.01 | 1.52 |
| | | 9.50 | 2.79 | 0.337 | 2.807 | 6.7 | 0.93 | 1.55 |
| | | 8.50 | 2.50 | 0.263 | 2.733 | 6.4 | 0.85 | 1.59 |
| | | 7.50 | 2.21 | 0.190 | 2.660 | 6.0 | 0.77 | 1.64 |
| B77 | 3 | 7.50 | 2.21 | 0.361 | 2.521 | 2.9 | 0.60 | 1.15 |
| | | 6.50 | 1.91 | 0.263 | 2.423 | 2.7 | 0.53 | 1.19 |
| | | 5.50 | 1.63 | 0.170 | 2.330 | 2.5 | 0.46 | 1.23 |

Weights in heavy print are standard, others are special.

I BEAMS—(Continued).

| Radius of Gyration, Neutral Axis Coin- cident with Centre Line of Web. | Section Modulus, Neutral Axis Per- pendicular to Web at Centre. | Coefficient of Stren'h for Fibre Stress of 16,000 Lbs. per Sq. In. Used for Buildings. | Coefficient of Stren'h for Fibre Stress of 12,500 Lbs. per Sq. In. Used for Bridges. | Distance Centre to Centre Re- quired to make Radii of Gyration Equal. | Section Index. |
|---|--|--|--|--|----------------|
| r | S | C | C' |  | |
| 0.84 | 24.8 | 265000 | 207000 | 6.36 | |
| 0.85 | 22.6 | 241500 | 188700 | 7.58 | |
| 0.88 | 20.4 | 217900 | 170300 | 6.86 | B13 |
| 0.90 | 18.9 | 201300 | 157300 | 7.12 | |
| 0.80 | 17.1 | 182500 | 142600 | 5.82 | |
| 0.81 | 16.1 | 172000 | 134400 | 5.96 | |
| 0.82 | 15.1 | 161600 | 126200 | 6.12 | B15 |
| 0.84 | 14.2 | 151700 | 118500 | 6.32 | |
| 0.74 | 12.1 | 128600 | 100400 | 5.15 | |
| 0.76 | 11.2 | 119400 | 93300 | 5.31 | B17 |
| 0.78 | 10.4 | 110400 | 86300 | 5.50 | |
| 0.68 | 8.7 | 93100 | 72800 | 4.33 | |
| 0.69 | 8.0 | 85300 | 66600 | 4.49 | B19 |
| 0.72 | 7.3 | 77500 | 60500 | 4.70 | |
| 0.63 | 6.1 | 64600 | 50500 | .... |  |
| 0.63 | 5.4 | 58100 | 45400 | .... | B21 |
| 0.65 | 4.8 | 51600 | 40300 | .... |  |
| 0.57 | 3.6 | 38100 | 29800 | .... |  |
| 0.58 | 3.4 | 36000 | 28100 | .... |  |
| 0.58 | 3.2 | 33900 | 26500 | .... | B23 |
| 0.59 | 3.0 | 31800 | 24900 | .... |  |
| 0.52 | 1.9 | 20700 | 16200 | .... |  |
| 0.52 | 1.8 | 19100 | 15000 | .... | B77 |
| 0.53 | 1.7 | 17600 | 13800 | .... |  |

PROPERTIES OF

| 1 Section Index. | 2 Depth of Channel, Inches. | 3 Weight per Foot, Pounds. | 4 Area of Section, Square Inches. | 5 Thickness of Web, Inches. | 6 Width of Flange, Inches. | 7 Mom. of Inertia, Neutral Axis Per- pendicular to Web at Centre. | 8 Mom. of Inertia, Neutral Axis Par- allel with Centre Line of Web. | 9 Radius of Gyration, Neutral Axis Per- pendicular to Web at Centre. |
|---------------------|-----------------------------------|----------------------------------|---|-----------------------------------|----------------------------------|---|---|--|
| | | | | | | <i>I</i> | <i>I'</i> | <i>r</i> |
| C 1 | 15 | 55.00 | 16.18 | 0.818 | 3.818 | 430.2 | 12.19 | 5.16 |
| | | 50.00 | 14.71 | 0.720 | 3.720 | 402.7 | 11.22 | 5.23 |
| | | 45.00 | 13.24 | 0.622 | 3.622 | 375.1 | 10.29 | 5.32 |
| | | 40.00 | 11.76 | 0.524 | 3.524 | 347.5 | 9.39 | 5.43 |
| | | 35.00 | 10.29 | 0.426 | 3.426 | 320.0 | 8.48 | 5.58 |
| | | 33.00 | 9.90 | 0.400 | 3.400 | 312.6 | 8.23 | 5.62 |
| C 2 | 12 | 40.00 | 11.76 | 0.758 | 3.418 | 197.0 | 6.63 | 4.09 |
| | | 35.00 | 10.29 | 0.636 | 3.296 | 179.3 | 5.90 | 4.17 |
| | | 30.00 | 8.82 | 0.513 | 3.173 | 161.7 | 5.21 | 4.28 |
| | | 25.00 | 7.35 | 0.390 | 3.050 | 144.0 | 4.53 | 4.43 |
| | | 20.50 | 6.03 | 0.280 | 2.940 | 128.1 | 3.91 | 4.61 |
| C 3 | 10 | 35.00 | 10.29 | 0.823 | 3.183 | 115.5 | 4.66 | 3.35 |
| | | 30.00 | 8.82 | 0.676 | 3.036 | 103.2 | 3.90 | 3.42 |
| | | 25.00 | 7.35 | 0.529 | 2.889 | 91.0 | 3.40 | 3.52 |
| | | 20.00 | 5.88 | 0.382 | 2.742 | 78.7 | 2.85 | 3.66 |
| | | 15.00 | 4.46 | 0.240 | 2.600 | 66.9 | 2.30 | 3.87 |
| C 4 | 9 | 25.00 | 7.35 | 0.615 | 2.815 | 70.7 | 2.98 | 3.10 |
| | | 20.00 | 5.88 | 0.452 | 2.652 | 60.8 | 2.45 | 3.21 |
| | | 15.00 | 4.41 | 0.288 | 2.488 | 50.9 | 1.95 | 3.40 |
| | | 13.25 | 3.89 | 0.230 | 2.430 | 47.3 | 1.77 | 3.49 |
| C 5 | 8 | 21.25 | 6.25 | 0.582 | 2.622 | 47.8 | 2.25 | 2.77 |
| | | 18.75 | 5.51 | 0.490 | 2.530 | 43.8 | 2.01 | 2.82 |
| | | 16.25 | 4.78 | 0.399 | 2.439 | 39.9 | 1.78 | 2.89 |
| | | 13.75 | 4.04 | 0.307 | 2.347 | 36.0 | 1.55 | 2.98 |
| | | 11.25 | 3.35 | 0.220 | 2.260 | 32.3 | 1.33 | 3.11 |
| C 6 | 7 | 19.75 | 5.81 | 0.633 | 2.513 | 33.2 | 1.85 | 2.39 |
| | | 17.25 | 5.07 | 0.528 | 2.408 | 30.2 | 1.62 | 2.44 |
| | | 14.75 | 4.34 | 0.423 | 2.303 | 27.2 | 1.40 | 2.50 |
| | | 12.25 | 3.60 | 0.318 | 2.198 | 24.2 | 1.19 | 2.59 |
| | | 9.75 | 2.85 | 0.210 | 2.090 | 21.1 | 0.98 | 2.72 |
| C 7 | 6 | 15.50 | 4.56 | 0.563 | 2.283 | 19.5 | 1.28 | 2.07 |
| | | 13.00 | 3.82 | 0.440 | 2.160 | 17.3 | 1.07 | 2.13 |
| | | 10.50 | 3.09 | 0.318 | 2.038 | 15.1 | 0.88 | 2.21 |
| | | 8.00 | 2.38 | 0.200 | 1.920 | 13.0 | 0.70 | 2.34 |
| C 8 | 5 | 11.50 | 3.38 | 0.477 | 2.037 | 10.4 | 0.82 | 1.75 |
| | | 9.00 | 2.65 | 0.330 | 1.890 | 8.9 | 0.64 | 1.83 |
| | | 6.50 | 1.95 | 0.190 | 1.750 | 7.4 | 0.48 | 1.95 |
| C 9 | 4 | 7.25 | 2.13 | 0.325 | 1.725 | 4.6 | 0.44 | 1.46 |
| | | 6.25 | 1.84 | 0.252 | 1.652 | 4.2 | 0.38 | 1.51 |
| | | 5.25 | 1.55 | 0.180 | 1.580 | 3.8 | 0.32 | 1.56 |
| C72 | 3 | 6.00 | 1.76 | 0.362 | 1.602 | 2.1 | 0.31 | 1.08 |
| | | 5.00 | 1.47 | 0.264 | 1.504 | 1.8 | 0.25 | 1.12 |
| | | 4.00 | 1.19 | 0.170 | 1.410 | 1.6 | 0.20 | 1.17 |

L = safe load in pounds uniformly distributed; *l* = span in feet.

M' = moment of forces in foot-pounds; *C* and *C'* = coefficients given on opposite page.

Weights in heavy print are standard, others are special.

CHANNELS.

| Radius of Gyration, Neutral Axis Par- allel with Centre Line of Web. | Section Modulus, Neutral Axis Per- pendicular to Web at Centre. | Coefficient of Stren ^h for Fibre Stress of 16,000 Lbs. per Sq. In. Used for Buildings. | Coefficient of Stren ^h for Fibre Stress of 12,500 Lbs. per Sq. In. Used for Bridges. | Distance Required to make Radii of Gyration Equal. | Distance of Centre of Gravity from Outside of Web. | Section Index. |
|---|--|---|---|---|--|----------------|
| r | S | C | C' | $\frac{d}{r}$ | s | |
| .868 | 57.4 | 611900 | 478000 | 8.53 | 0.823 | |
| .873 | 53.7 | 572700 | 447400 | 8.71 | 0.803 | |
| .882 | 50.0 | 533500 | 416800 | 8.92 | 0.788 | |
| .893 | 46.3 | 494200 | 386100 | 9.15 | 0.783 | C 1 |
| .908 | 42.7 | 455000 | 355500 | 9.43 | 0.789 | |
| .912 | 41.7 | 444500 | 347300 | 9.50 | 0.794 | |
| .751 | 32.8 | 350200 | 273600 | 6.60 | 0.722 | |
| .757 | 29.9 | 318800 | 249100 | 6.81 | 0.694 | |
| .768 | 26.9 | 287400 | 224500 | 7.07 | 0.677 | C 2 |
| .785 | 24.0 | 256100 | 200000 | 7.36 | 0.678 | |
| .805 | 21.4 | 227800 | 178000 | 7.67 | 0.704 | |
| .672 | 23.1 | 246400 | 192500 | 5.17 | 0.695 | |
| .672 | 20.6 | 220300 | 172100 | 5.40 | 0.651 | |
| .680 | 18.2 | 194100 | 151700 | 5.67 | 0.620 | C 3 |
| .696 | 15.7 | 168000 | 131200 | 5.97 | 0.609 | |
| .718 | 13.4 | 142700 | 111500 | 6.33 | 0.639 | |
| .637 | 15.7 | 167600 | 130900 | 4.84 | 0.615 | |
| .646 | 13.5 | 144100 | 112600 | 5.12 | 0.585 | |
| .665 | 11.3 | 120500 | 94200 | 5.49 | 0.590 | C 4 |
| .674 | 10.5 | 112200 | 87600 | 5.63 | 0.607 | |
| .600 | 11.9 | 127400 | 99500 | 4.23 | 0.587 | |
| .603 | 11.0 | 116900 | 91300 | 4.38 | 0.567 | |
| .610 | 10.0 | 106400 | 83200 | 4.54 | 0.556 | C 5 |
| .619 | 9.0 | 96000 | 75000 | 4.72 | 0.557 | |
| .630 | 8.1 | 86100 | 67300 | 4.94 | 0.576 | |
| .565 | 9.5 | 101100 | 79000 | 3.48 | 0.583 | |
| .564 | 8.6 | 92000 | 71800 | 3.64 | 0.555 | |
| .568 | 7.8 | 82800 | 64700 | 3.80 | 0.535 | C 6 |
| .575 | 6.9 | 73700 | 57500 | 3.99 | 0.528 | |
| .586 | 6.0 | 66800 | 52200 | 4.22 | 0.546 | |
| .529 | 6.5 | 69500 | 54300 | 2.91 | 0.546 | |
| .529 | 5.8 | 61600 | 48100 | 3.09 | 0.517 | |
| .534 | 5.0 | 53800 | 42000 | 3.28 | 0.503 | C 7 |
| .542 | 4.3 | 46200 | 36100 | 3.52 | 0.517 | |
| .493 | 4.2 | 44400 | 34700 | 2.34 | 0.508 | |
| .493 | 3.5 | 37900 | 29600 | 2.56 | 0.481 | C 8 |
| .498 | 3.0 | 31600 | 24700 | 2.79 | 0.489 | |
| .455 | 2.3 | 24400 | 19000 | 1.85 | 0.463 | |
| .454 | 2.1 | 22300 | 17400 | 1.96 | 0.458 | C 9 |
| .453 | 1.9 | 20200 | 15800 | 2.06 | 0.464 | |
| .421 | 1.4 | 14700 | 11500 | 1.07 | 0.459 | |
| .415 | 1.2 | 13100 | 10300 | 1.19 | 0.443 | C72 |
| .409 | 1.1 | 11600 | 9100 | 1.31 | 0.443 | |

$$L = \frac{C \text{ or } C'}{l}; \quad M' = \frac{C \text{ or } C'}{8}; \quad C \text{ or } C' = Ll = 8M' = \frac{8lS}{12}.$$

The sectional index numbers in the previous tables refer to sections in the Carnegie Steel Co.'s Handbook.

EXPLANATION OF TABLES ON THE PROPERTIES OF STANDARD AND SPECIAL I BEAMS AND CHANNELS.

The tables on I beams and channels are calculated for all weights to which each pattern is rolled.

Columns 12 and 13 in the tables for I beams and channels give coefficients by the help of which the safe, uniformly distributed load may be readily and quickly determined. To do this, it is only necessary to divide the coefficient given by the span or distance between supports in feet.

If a section is to be selected (as will usually be the case) intended to carry a certain load for a length of span already determined on, it will only be necessary to ascertain the coefficient which this load and span will require and refer to the table for a section having a coefficient of this value. The coefficient is obtained by multiplying the load in pounds uniformly distributed by the span length in feet.

In case the load is not uniformly distributed, but is concentrated at the middle of the span, multiply the load by 2 and then consider it as uniformly distributed. The deflection will be $\frac{8}{16}$ of the deflection for the latter load.

For other cases of loading, obtain the bending moment in foot-pounds (the most common cases are given on page 478); this multiplied by 8 will give the coefficient required.

If the loads are quiescent, the coefficients for fibre stress of 16,000 pounds per square inch for steel may be used; but if moving loads are to be provided for, the coefficient for 12,500 pounds should be taken. Inasmuch as the effects of impact may be very considerable (the stresses produced in an unyielding, inelastic material by a load suddenly applied being double those produced by the same load in a quiescent state), it will sometimes be advisable to use still smaller fibre stresses than those given in the tables. In such cases the coefficients can readily be determined by proportion. Thus, for a fibre stress of 8000 pounds per square inch, the coefficient will equal the coefficient for 16,000 pounds fibre stress divided by 2.

The section moduli are used to determine the fibre stress per square inch in a beam or other shape, subjected to bending or transverse stresses, by simply dividing the same into the bending moment expressed in inch-pounds.

Column 14 in the table of the "Properties of Beams" gives the distance c. t. c. of beams making the radii of gyration equal for both axes.

The length of a beam used as a strut should not exceed 125 times its least radius of gyration.

Column 14 in the table of the "Properties of Standard Channels" gives the distance which the channels should be placed back to back to make the radii of gyration equal for both axes. Column 15 in the same table can be used to obtain the radius of gyration for struts consisting of two channels when the distance back to back varies from that given in the table.

These tables have all been prepared with great care. No approximations have entered into any of the calculations, so that the figures given may be relied upon as accurate.

Examples.—I. What section of I beam will be required to carry 40,000 lbs. uniformly distributed, including its own weight, over a span of 16 ft. between supports, allowing a fibre stress of 16,000 lbs. per square inch?

Answer.—The coefficient (C) required = $40,000 \times 16 = 640,000$.

In table of Properties of I Beams, page 469, look in column 12 for the nearest number corresponding to 640,000, which is 648,200. Therefore the beam to be used is 15 in. 45 lbs.

The tables on pages 463 to 465 for I beams give the loads which a beam will carry safely (distributed uniformly over its length) for the distances between supports indicated. These loads include the weight of the beam, which must be deducted in order to arrive at the *net load* which the beam will carry. On pages 466 to 467 will also be found the safe loads for channels

For beams of heavier sections than those calculated in the tables, a separate column of corrections is given for each size, stating the proper increase of safe load for every additional pound in the weight per foot of beam. The values given are based on a maximum fibre stress of 16,000 pounds per square inch.

GENERAL FORMULÆ ON THE FLEXURE OF BEAMS OF ANY CROSS-SECTION.

Let A = area of section in square inches,

l = length of span in inches,

W = load uniformly distributed in pounds,

M = bending moment in inch-pounds,

h = height of cross-section, out to out, in inches,

n = distance of centre of gravity of section, from top or from bottom, in inches,

f = stress per square inch in extreme fibres of beam, either top or bottom, in pounds, according as n relates to distance from top or from bottom of section,

D = maximum deflection in inches,

I = moment of inertia of section neutral axis through centre of gravity,

I'' = moment of inertia of section neutral axis parallel to above, but not through centre of gravity,

d = distance between these neutral axes,

S = section modulus,

r = radius of gyration in inches,

E = modulus of elasticity for steel 29,000,000;

$$\text{then: } S = \frac{I}{n}, \quad r = \sqrt{\frac{I}{A}},$$

$$M = \frac{fI}{n} = fS,$$

$$f = \frac{Mn}{I} = \frac{M}{S},$$

$$W = \frac{8fI}{ln} = \frac{8f}{l}S,$$

$$f = \frac{Wln}{8I} = \frac{Wl}{8S},$$

$$I'' = I + Ad^2,$$

$$D = \frac{5Wl^3}{384EI} \text{ for beam supported at both ends and uniformly loaded,}$$

$$D = \frac{Pl^3}{48EI} \text{ for beam supported at both ends and loaded with a single load } P \text{ at middle,}$$

$$D = \frac{Wl^3}{8EI} \text{ for beam fixed at one end and unsupported at the other and uniformly loaded,}$$

$D = \frac{Pl^3}{3EI}$ for beam fixed at one end and unsupported at other and loaded with a single load P at the latter end.

SPECIAL CASES OF LOADING.—I. Beam loaded by a single load P at a point distant b feet from the left hand and a feet from the right-hand support.

l = length of beam between supports = $a + b$.

Pressure or reaction at left-hand support = $P\frac{a}{l}$ and at right-

hand support = $P\frac{b}{l}$.

Maximum bending moment neglecting dead weight of beam occurs at point of application of the load and = $\frac{Pab}{l}$.

P = load given in tables pages 463 to 467 $\times \frac{l^2}{8ab}$.

When $a = b = \frac{1}{2}l$:

Reaction = $\frac{P}{2}$; maximum bending moment = $\frac{Pl}{4}$ and P = load given in tables $\times \frac{1}{2}$.

II. Beam fixed at one end and unsupported at the other, l representing the length of beam from end to support.

If loaded by a uniformly distributed load W :

Maximum bending moment occurs at support and = $\frac{Wl}{2}$.

W = load given in tables pages 463 to 467 $\times \frac{1}{4}$.

If loaded with a single load P at its extremity:

Maximum bending moment occurs at support and = Pl .

P = load given in tables $\times \frac{1}{3}$.

When beams have no lateral support the safe load is given in the following table:

BEAMS WITHOUT LATERAL SUPPORT.

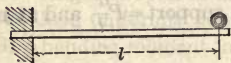
| Length of Beam. | Proportion of Tabular Load Forming Greatest Safe Load. |
|-----------------------|--|
| 20 times flange width | Whole tabular load |
| 30 " " " | 9/10 " " |
| 40 " " " | 8/10 " " |
| 50 " " " | 7/10 " " |
| 60 " " " | 6/10 " " |
| 70 " " " | 5/10 " " |

BENDING MOMENTS AND DEFLECTIONS OF BEAMS UNDER VARIOUS SYSTEMS OF LOADING.

W = total load.
 l = length of beam.

I = moment of inertia.
 E = modulus of elasticity.

- (1) Beam fixed at one end and loaded at the other.

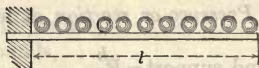


Safe load = $\frac{1}{2}$ that given in tables.
 Maximum bending moment at point of support = Wl .

Maximum shear at point of support = W .

$$\text{Deflection} = \frac{Wl^3}{3EI}$$

- (2) Beam fixed at one end and uniformly loaded.



Safe load = $\frac{1}{2}$ that given in tables.
 Maximum bending moment at point of support = $\frac{Wl}{2}$.

Maximum shear at point of support = W .

$$\text{Deflection} = \frac{Wl^3}{8EI}$$

- (3) Beam supported at both ends, single load in the middle.

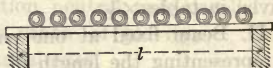


Safe load = $\frac{1}{2}$ that given in tables.
 Maximum bending moment at middle of beam = $\frac{Wl}{4}$.

Maximum shear at points of support = $\frac{1}{2}W$.

$$\text{Deflection} = \frac{Wl^3}{48EI}$$

- (4) Beam supported at both ends and uniformly loaded.

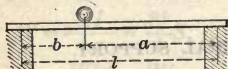


Safe load = that given in tables.
 Maximum bending moment at middle of beam = $\frac{Wl}{8}$.

Maximum shear at points of support = $\frac{1}{2}W$.

$$\text{Deflection} = \frac{Wl^3}{76.8EI}$$

- (5) Beam supported at both ends, single unsymmetrical load.

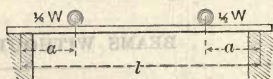


Safe load = that given in tables $\times \frac{l^2}{8ab}$.
 Maximum bending moment under load = $\frac{Wab}{l}$.

Maximum shears: at support near $a = \frac{Wb}{l}$; at other support = $\frac{Wa}{l}$.

$$\text{Max. deflec.} = \frac{Wab(2l-a)}{9EI} \sqrt{\frac{1}{3}a(2l-a)}$$

- (6) Beam supported at both ends two symmetrical loads.



Safe load = that given in tables $\times \frac{l}{4a}$.
 Maximum bending moment between loads = $\frac{1}{2}Wa$.

Maximum shear between load and nearer support = $\frac{1}{2}W$.

$$\text{Max. deflection} = \frac{Wa}{48EI} (3l^2 - 4a^2)$$

TROUGH-PLATE FLOORING.—The trough and corrugated plate sections shown below are used for floors of bridges and fire-proof buildings, as shown in Fig. 243.

The following tables give weights per lineal foot of each rolled section and per square foot of floor surface for thicknesses varying by $\frac{1}{16}$ inch; also the section modulus for 1 foot in width and the safe loads per square foot for spans of different lengths, using fibre stresses of 12,000 and 10,000 pounds.

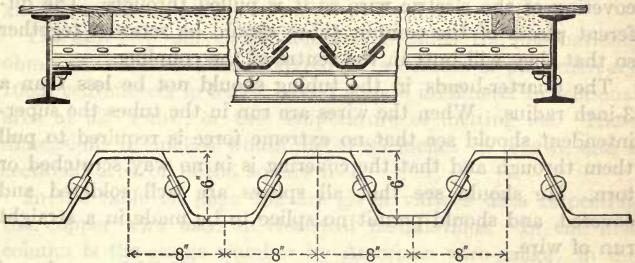


FIG. 243.

PROPERTIES OF TROUGH SECTION.

| | | | | | |
|---|---------------|----------------|---------------|-----------------|----------------|
| Section index..... | M 10 | M 11 | M 12 | M 13 | M 14 |
| Thickness of base..... | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $1\frac{1}{16}$ | $1\frac{1}{4}$ |
| Weight per lineal foot..... | 16.3 | 18.0 | 19.7 | 21.4 | 23.2 |
| Weight per square foot..... | 25.00 | 28.15 | 31.31 | 34.48 | 37.74 |
| Section modulus for 1 ft. in width..... | 11.56 | 13.06 | 14.57 | 16.12 | 17.67 |

SAFE LOADS IN POUNDS PER SQUARE FOOT OF FLOOR FOR SPANS OF DIFFERENT LENGTHS.

| Span in Feet. | M 10 | | M 11 | | M 12 | | M 13 | | M 14 | |
|---------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| | 12,000 Lbs. | 10,000 Lbs. | 12,000 Lbs. | 10,000 Lbs. | 12,000 Lbs. | 10,000 Lbs. | 12,000 Lbs. | 10,000 Lbs. | 12,000 Lbs. | 10,000 Lbs. |
| 5 | 3699 | 3083 | 4179 | 3483 | 4662 | 3885 | 5158 | 4298 | 5654 | 4712 |
| 6 | 2569 | 2141 | 2902 | 2418 | 3238 | 2698 | 3582 | 2985 | 3927 | 3272 |
| 7 | 1887 | 1573 | 2132 | 1777 | 2379 | 1983 | 2632 | 2193 | 2885 | 2404 |
| 8 | 1445 | 1204 | 1633 | 1361 | 1821 | 1517 | 2015 | 1679 | 2209 | 1841 |
| 9 | 1142 | 952 | 1290 | 1075 | 1439 | 1199 | 1592 | 1327 | 1745 | 1454 |
| 10 | 925 | 771 | 1045 | 871 | 1166 | 972 | 1290 | 1075 | 1414 | 1178 |
| 11 | 764 | 637 | 864 | 720 | 963 | 803 | 1066 | 888 | 1168 | 973 |
| 12 | 642 | 535 | 726 | 605 | 809 | 674 | 896 | 747 | 982 | 818 |
| 13 | 547 | 456 | 618 | 515 | 690 | 575 | 763 | 636 | 836 | 697 |
| 14 | 472 | 393 | 533 | 444 | 595 | 496 | 658 | 548 | 721 | 601 |
| 15 | 411 | 343 | 464 | 387 | 518 | 432 | 573 | 478 | 628 | 523 |
| 16 | 361 | 301 | 408 | 340 | 455 | 379 | 504 | 420 | 552 | 460 |

Safe loads given include weight of section.

Electric Wiring, etc.—During the progress of this part of the work, the superintendent must pay close attention, as the conduits are put in place, to see that they are laid properly, and all outlets left at the proper location; he should see that no more bends are put in a line of conduits than are absolutely necessary, and as the conduits are being put together he should see that the inside end of each piece is reamed out so there will be no burr to catch the steel fishing-wire or to tear the covering of the electric wire as it is pulled through. The different pieces of the conduit tubes should be screwed together so that they will butt in the centre of the coupling.

The quarter-bends in the tubing should not be less than a 3-inch radius. When the wires are run in the tubes the superintendent should see that no extreme force is required to pull them through and that the covering is in no way scratched or torn. He should see that all splices are well soldered and covered, and should permit no splice to be made in a straight run of wire.

The superintendent should provide himself with samples of the wires to be used so as to determine if the proper-sized conduits are being put in. The conduits should be large enough so that the wires can be easily drawn through them.

Electrical Terms, etc.—A broken circuit is one in which its conducting elements are disconnected in such a manner as to prevent the current from flowing.

A closed or completed circuit is one whose conducting elements are so connected as to allow the current to flow.

A circuit is said to be grounded when the earth or ground forms a part of the conducting path, and conducts the current into the earth.

AMPERE.—A current of water is the rate of flow, or the intensity or strength at which the water flows. We say, for instance, the water flows through a pipe at the rate of 1 gallon per second. Similarly the unit of the electric current is one coulomb per second. This is the ampere or unit rate of flow, or unit of current strength, or simply the unit of current of electricity.

In the case of the waterflow, we have no single word to express the strength of the current, but have to speak of the quantity and time.

OHM.—A pipe of small diameter offers a greater resistance to the flow of water than a pipe of larger dimension. So a wire

of small diameter offers more resistance to an electric current than a wire of larger diameter. If we double the cross-section of a wire we halve its resistance. If we double the length of a wire, we double its resistance. If we double the cross-section and double the length of a wire, the resistance remains the same. This law may be expressed thus: For a wire of a given substance the resistance is directly proportional to the length, and inversely proportional to the cross-section. The unit of electrical resistance is called an ohm.

The unit now universally adopted is called the international ohm and is the resistance offered by a column of pure mercury 106.3 centimeters in length and 1 square millimeter in sectional area at 32° Fahr., or the temperature of melting ice. These dimensions in inches would be 41.85 inches in length, and a sectional area of .00155 square inch.

In the table on page 482 are given various data respecting the copper wire used in electrical installations. In the first column is the gauge number by American wire-gauge; in the second column is the diameter as measured in mils (one mil one one-thousandth of an inch); the third column shows the area of cross-section in circular mils. It is usual to adopt this method for round wire instead of the old way of expressing the area in fractions of a square inch, in which case the diameter is squared and the product multiplied by .7854. If the second operation be omitted, and the diameter, as measured in thousandths of an inch, be only squared (or multiplied by itself), the result is expressed in circular thousandths or circular mils.

Example.—What is the area in circular mils of a wire $2\frac{1}{2}$ inches in diameter?

Answer.— $2\frac{1}{2}$ inches = 2500 mils. $2500^2 = 2500 \times 2500 = 6,250,000$ circular mils.

The resistance of copper wire being low, a unit of length of 1000 feet is usually taken in tables of resistance, and this unit is considered in the eighth column.

The resistance of any length of conductor may be found by the following formula:

$$R = \frac{LR_1}{1000}$$

Where R = required resistance;

L = length of conductor;

R_1 = resistance per 1000 feet of conductor.

TABLE OF DIMENSIONS AND RESISTANCES OF PURE COPPER WIRE.*

| American Gauge, B. & S. No. | Diameter, Mills. | Area. | | Weight and Length, Specific Gravity, 8.9. | | | Resistance at 75° Fahr. | | | |
|--------------------------------|---------------------|---|---|--|------------------------|--------------------|--------------------------|-------------------|------------------|--------------------|
| | | Circular Mils (d ²) 1 Mil = .001 Inch. | Square Inches, (d ² × .7854) | Pounds per 1000 Feet. | Pounds per Mile. | Feet per Pound. | R Ohms per 1000 Feet. | Ohms per Mile. | Feet per Ohm. | Ohms per Pound. |
| 0000 | 460.000 | 211600.00 | 166190 | 639.33 | 3375.7 | 1.56 | .04906 | .25903 | 20383 | .00076736 |
| 000 | 409.640 | 167805.00 | 131790 | 507.01 | 2677.0 | 1.97 | .06186 | .32664 | 16165 | .00012039 |
| 0 | 364.800 | 133079.40 | 104520 | 402.09 | 2123.0 | 2.49 | .07801 | .41187 | 12820 | .00019423 |
| 0 | 324.950 | 105592.50 | 82932 | 319.04 | 1684.5 | 3.13 | .09831 | .51909 | 10409 | .00030772 |
| 1 | 289.300 | 83694.20 | 65733 | 252.88 | 1335.2 | 3.95 | .12404 | .65490 | 8062.3 | .00048994 |
| 2 | 257.630 | 66373.00 | 52130 | 200.54 | 1058.8 | 4.99 | .15640 | .82582 | 6393.7 | .00078045 |
| 3 | 229.420 | 52634.00 | 41339 | 159.03 | 839.68 | 6.29 | .19723 | 1.0414 | 5070.2 | .0012406 |
| 4 | 204.310 | 41742.00 | 32784 | 126.12 | 665.91 | 7.93 | .24869 | 1.3131 | 4021.0 | .0019721 |
| 5 | 181.940 | 33102.00 | 25998 | 100.01 | 528.05 | 10.00 | .31361 | 1.6558 | 3188.7 | .0031361 |
| 6 | 162.020 | 26250.50 | 20617 | 79.32 | 418.81 | 12.61 | .39546 | 2.0881 | 2528.7 | .0049868 |
| 7 | 144.280 | 20816.00 | 16349 | 62.90 | 332.11 | 15.90 | .49871 | 2.6331 | 2005.2 | .0079294 |
| 8 | 128.490 | 16509.00 | 12966 | 49.88 | 263.37 | 20.05 | .62881 | 3.3201 | 1590.3 | .012608 |
| 9 | 114.430 | 13594.00 | 10284 | 39.56 | 208.88 | 25.28 | .79281 | 4.1860 | 1261.3 | .020042 |
| 10 | 101.890 | 10381.00 | 8153.2 | 31.37 | 165.63 | 31.38 | 1.02607 | 5.2800 | 1000.0 | .031380 |
| 11 | 90.742 | 8234.00 | 6467.0 | 24.88 | 137.37 | 40.20 | 1.2607 | 6.6568 | 793.18 | .050682 |

Rule.—To find the resistance of any length of wire, divide that length in feet by 1000, and multiply by the figure giving the resistance of that wire per thousand feet, as found in the table on page 482.

VOLT.—The unit of electric pressure, or electromotive force, or difference of potential, is called the volt. We speak of an electromotive force of so many volts as we might speak of a head of water of so many feet, or of a steam pressure of so many pounds per square inch. Water may fall from a higher to a lower level, a certain vertical distance, say of 10 feet; so of electricity it is said to fall through a difference of potential of say 10 volts.

With a known resistance in ohms and a known strength of current in amperes, the electromotive force in volts is determined by Ohm's law, for, by transposing,

$$C = \frac{E}{R} \text{ may be written } E = CR.$$

WATT.—This unit of power is called the volt-ampere, or the watt. One watt equals $\frac{1}{746}$ of a horse-power, or 1 horse-power equals 746 watts. Hence it is expressed in electrical work thus:

$$\text{Horse-power} = \frac{\text{watts}}{746} \text{ or, } \text{watts} = \text{H.P.} \times 746.$$

As 1 watt is the product of 1 ampere and 1 volt, it can be seen that work can be done at the same rate with great current strength and low electromotive force, or with small current strength and high electromotive force; for instance, 100 amperes \times 10 volts = 1000 watts, and 10 amperes \times 100 volts = 1000 watts.

EQUIVALENTS OF ELECTRICAL UNITS.

1 Horse-power = 33,000 foot-pounds per minute.

1 Kilowatt = 44,235 foot-pounds per minute.

1 Horse-power = 746 watts.

1 Kilowatt = 1.34 H.P.

1 B.T.U. (British Thermal Unit) = 772 foot-pounds.



- 1 Watt = 44.236 foot-pounds per minute.
- 1 Watt = 2654.16 foot-pounds per hour.
- 1 H.P. = 42.746 B.T.U. per minute.
- 1 H.P. = 2564.76 B.T.U. per hour.
- 1 K.W. = 0.955 B.T.U. per second.
- 1 K.W. = 57.3 B.T.U. per minute.
- 1 K.W. = 3438 B.T.U. per hour.
- 1 B.T.U. = 17.452 watt minutes.
- 1 B.T.U. = 0.2909 watt hours.

Latent heat of evaporation of water = 966 B.T.U.

Latent heat of melting of water = 142 B.T.U.

To evaporate 1 pound water from and at 212° = 16.859 K.W. minutes.

To evaporate 1 pound water from and at 212° = 0.281 K.W. hours.

Weight per cubic foot of water = 62.42 pounds.

Weight per gallon of water = 8.33 pounds.

| Watts per Candle-power. | 50 Volts. | | | 52 Volts. | | | 100 Volts. | |
|-------------------------|-----------|------|------|-----------|-------|-------|------------|-------|
| | 3.1 | 3.5 | 4.0 | 3.1 | 3.5 | 4.0 | 3.1 | 3.5 |
| 8 C.P. | .496 | .56 | .64 | .477 | .538 | .615 | .248 | .280 |
| 10 C.P. | .620 | .70 | .80 | .596 | .673 | .769 | .310 | .350 |
| 16 C.P. | .992 | 1.12 | 1.28 | .954 | 1.077 | 1.231 | .496 | .560 |
| 20 C.P. | 1.240 | 1.40 | 1.60 | 1.192 | 1.346 | 1.538 | .620 | .700 |
| 24 C.P. | 1.488 | 1.68 | 1.92 | 1.431 | 1.615 | 1.846 | .744 | .840 |
| 32 C.P. | 1.984 | 2.24 | 2.56 | 1.908 | 2.154 | 2.461 | .992 | 1.120 |

| Watts per Candle-power. | Series Ry. Lamps. | | | | | | | |
|-------------------------|-------------------|-------|------------|-------|--------|--------|--------|--------|
| | 104 Volts. | | 110 Volts. | | 220 V. | 500 V. | 550 V. | 600 V. |
| | 3.1 | 3.5 | 3.1 | 3.5 | 4.0 | 4.0 | 4.0 | 4.0 |
| 8 C.P. | .238 | .269 | .225 | .255 | .145 | .064 | .058 | .053 |
| 10 C.P. | .298 | .337 | .282 | .318 | .182 | .080 | .073 | .067 |
| 16 C.P. | .477 | .538 | .451 | .520 | .291 | .128 | .116 | .107 |
| 20 C.P. | .596 | .673 | .564 | .636 | .363 | .160 | .145 | .133 |
| 24 C.P. | .715 | .808 | .676 | .764 | .436 | .192 | .175 | .160 |
| 32 C.P. | .954 | 1.077 | .902 | 1.018 | .582 | .256 | .233 | .213 |

AMPERES PER LAMP.—The above table is arranged to show the amperes per lamp for lamps of different candle-powers and efficiencies at various voltages. The upper row of figures shows the voltage, the second shows the watts per candle-power,

or efficiency, and the figures below show the corresponding amperes per lamp for different candle-powers.

This table is made in accordance with the best information obtainable from manufacturers on the efficiency of standard lamps in use. Lamps of other efficiencies are on the market, but those shown are standard for good practice at the present time.

INCANDESCENT WIRING TABLE.

The table on page 487 is arranged to enable wiremen to select the right sizes of wire for service connections and inside work. The figures at the top indicate distance in feet to centre of distribution, in reality half the length of the circuit; the four columns at the left showing the number of 16-candle-power lamps at various voltages; the other figures showing the sizes of wire, Brown & Sharpe gauge, to be used for distributing the number of lamps stated at the distances indicated and with the loss of 1 volt.

For example: To distribute 30 lamps of 110 volts at a distance of 80 feet with a loss of 1 volt. In column of 110-volt lamps find the number 30, then follow the same line of figures to the right until the column headed 80 is reached, and it appears that No. 6 wire must be used.

The same table may be used for other losses than 1 volt by dividing the given number of lamps by the number of volts to be lost, then with this product proceed as before in the table.

For example: To distribute 30 lamps of 110 volts at a distance of 80 feet with a loss of 2 volts, divide 30 by 2, which gives 15, then find 15 in the column headed 110 volts and follow the same line of figures to the right until column headed 80 is reached, and it is found that No. 8 wire must be used.

No wire smaller than No. 14 is shown in the table, as the National Board of Fire Underwriters prohibits the use of a smaller size. Odd sizes smaller than No. 5 are not commercial and are therefore omitted.

In calculating the sizes of wire as shown in the incandescent wiring table a formula (A) has been used in which there is a constant 10.7, the number of circular mils in a copper wire which would have a resistance of 1 ohm for 1 foot of length. 1 ampere through 1 ohm resistance loses 1 volt. To determine the size of wire necessary for carrying a given current a given distance in feet, multiply the number of feet by 2 to obtain the

TABLE FOR FORMULAS, A, B, AND C.

| Feet to End of Circuit. | Feet \times 2×10.70 | Feet to End of Circuit. | Feet \times 2×10.70 | Feet to End of Circuit. | Feet \times 2×10.70 |
|-------------------------------|-----------------------------------|-------------------------------|-----------------------------------|-------------------------------|-----------------------------------|
| 5 | 107 | 300 | 6,420 | 690 | 14,766 |
| 10 | 214 | 305 | 6,527 | 700 | 14,980 |
| 15 | 321 | 310 | 6,634 | 710 | 15,194 |
| 20 | 428 | 315 | 6,741 | 720 | 15,408 |
| 25 | 535 | 320 | 6,848 | 730 | 15,622 |
| 30 | 642 | 325 | 6,955 | 740 | 15,836 |
| 35 | 749 | 330 | 7,062 | 750 | 16,050 |
| 40 | 856 | 335 | 7,169 | 760 | 16,264 |
| 45 | 963 | 340 | 7,276 | 770 | 16,478 |
| 50 | 1070 | 345 | 7,383 | 780 | 16,692 |
| 55 | 1177 | 350 | 7,490 | 790 | 16,906 |
| 60 | 1284 | 355 | 7,597 | 800 | 17,120 |
| 65 | 1391 | 360 | 7,704 | 810 | 17,334 |
| 70 | 1498 | 365 | 7,811 | 820 | 17,548 |
| 75 | 1605 | 370 | 7,918 | 830 | 17,762 |
| 80 | 1712 | 375 | 8,025 | 840 | 17,976 |
| 85 | 1819 | 380 | 8,132 | 850 | 18,190 |
| 90 | 1926 | 385 | 8,239 | 860 | 18,404 |
| 95 | 2033 | 390 | 8,346 | 870 | 18,618 |
| 100 | 2140 | 395 | 8,453 | 880 | 18,832 |
| 105 | 2247 | 400 | 8,560 | 890 | 19,046 |
| 110 | 2354 | 405 | 8,667 | 900 | 19,260 |
| 115 | 2461 | 410 | 8,774 | 910 | 19,474 |
| 120 | 2568 | 415 | 8,881 | 920 | 19,688 |
| 125 | 2675 | 420 | 8,988 | 930 | 19,902 |
| 130 | 2782 | 425 | 9,095 | 940 | 20,116 |
| 135 | 2889 | 430 | 9,202 | 950 | 20,330 |
| 140 | 2996 | 435 | 9,309 | 960 | 20,544 |
| 145 | 3103 | 440 | 9,416 | 970 | 20,758 |
| 150 | 3210 | 445 | 9,523 | 980 | 20,972 |
| 155 | 3317 | 450 | 9,630 | 990 | 21,186 |
| 160 | 3424 | 455 | 9,737 | 1000 | 21,400 |
| 165 | 3531 | 460 | 9,844 | 1010 | 21,614 |
| 170 | 3638 | 465 | 9,951 | 1020 | 21,828 |
| 175 | 3745 | 470 | 10,058 | 1030 | 22,042 |
| 180 | 3852 | 475 | 10,165 | 1040 | 22,256 |
| 185 | 3959 | 480 | 10,272 | 1050 | 22,470 |
| 190 | 4066 | 485 | 10,379 | 1060 | 22,684 |
| 195 | 4173 | 490 | 10,486 | 1070 | 22,898 |
| 200 | 4280 | 495 | 10,593 | 1080 | 23,112 |
| 205 | 4387 | 500 | 10,700 | 1090 | 23,326 |
| 210 | 4494 | 510 | 10,914 | 1100 | 23,540 |
| 215 | 4601 | 520 | 11,128 | 1110 | 23,754 |
| 220 | 4708 | 530 | 11,342 | 1120 | 23,968 |
| 225 | 4815 | 540 | 11,556 | 1130 | 24,182 |
| 230 | 4922 | 550 | 11,770 | 1140 | 24,396 |
| 235 | 5029 | 560 | 11,984 | 1150 | 24,610 |
| 240 | 5136 | 570 | 12,198 | 1160 | 24,824 |
| 245 | 5243 | 580 | 12,412 | 1170 | 25,038 |
| 250 | 5350 | 590 | 12,626 | 1180 | 25,252 |
| 255 | 5457 | 600 | 12,840 | 1190 | 25,466 |
| 260 | 5564 | 610 | 13,054 | 1200 | 25,680 |
| 265 | 5671 | 620 | 13,268 | 1210 | 25,894 |
| 270 | 5778 | 630 | 13,482 | 1220 | 26,108 |
| 275 | 5885 | 640 | 13,696 | 1230 | 26,322 |
| 280 | 5992 | 650 | 13,910 | 1240 | 26,536 |
| 285 | 6099 | 660 | 14,124 | 1250 | 26,750 |
| 290 | 6206 | 670 | 14,338 | 1260 | 26,964 |
| 295 | 6313 | 680 | 14,552 | 1270 | 27,178 |

TABLE FOR FORMULAS, A, B, AND C.

| Feet to End of Circuit. | Feet × 2 × 10.70 | Feet to End of Circuit. | Feet × 2 × 10.70 | Feet to End of Circuit. | Feet × 2 × 10.70 |
|-------------------------------|---------------------|-------------------------------|---------------------|-------------------------------|---------------------|
| 1280 | 27 392 | 1870 | 40,018 | 4200 | 89,880 |
| 1290 | 27 606 | 1880 | 40,232 | 4250 | 90,959 |
| 1300 | 27 820 | 1890 | 40,446 | 4300 | 92,020 |
| 1310 | 28,034 | 1900 | 40,660 | 4350 | 93,090 |
| 1320 | 28,248 | 1910 | 40,874 | 4400 | 94,160 |
| 1330 | 28,462 | 1920 | 41,088 | 4450 | 95,230 |
| 1340 | 28,676 | 1930 | 41,302 | 4500 | 96,300 |
| 1350 | 28,890 | 1940 | 41,516 | 4550 | 97,370 |
| 1360 | 29,104 | 1950 | 41,730 | 4600 | 98,440 |
| 1370 | 29,318 | 1960 | 41,944 | 4650 | 99,510 |
| 1380 | 29,532 | 1970 | 42,158 | 4700 | 100,580 |
| 1390 | 29,746 | 1980 | 42,372 | 4750 | 101,650 |
| 1400 | 29,960 | 1990 | 42,586 | 4800 | 102,720 |
| 1410 | 30,174 | 2000 | 42,800 | 4850 | 103,790 |
| 1420 | 30,388 | 2050 | 43,870 | 4900 | 104,860 |
| 1430 | 30,602 | 2100 | 44,940 | 4950 | 105,930 |
| 1440 | 30,816 | 2150 | 46,010 | 5000 | 107,000 |
| 1450 | 31,030 | 2200 | 47,080 | 5050 | 108,070 |
| 1460 | 31,244 | 2250 | 48,150 | 5100 | 109,140 |
| 1470 | 31,458 | 2300 | 49,220 | 5150 | 110,210 |
| 1480 | 31,672 | 2350 | 50,290 | 5200 | 111,280 |
| 1490 | 31,886 | 2400 | 51,360 | 5250 | 112,350 |
| 1500 | 32,100 | 2450 | 52,430 | 5300 | 113,420 |
| 1510 | 32,314 | 2500 | 53,500 | 5350 | 114,490 |
| 1520 | 32,528 | 2550 | 54,570 | 5400 | 115,560 |
| 1530 | 32,742 | 2600 | 55,640 | 5450 | 116,630 |
| 1540 | 32,956 | 2650 | 56,710 | 5500 | 117,700 |
| 1550 | 33,170 | 2700 | 57,780 | 5550 | 118,770 |
| 1560 | 33,384 | 2750 | 58,850 | 5600 | 119,840 |
| 1570 | 33,598 | 2800 | 59,920 | 5650 | 120,910 |
| 1580 | 33,812 | 2850 | 60,990 | 5700 | 121,980 |
| 1590 | 34,026 | 2900 | 62,060 | 5750 | 123,050 |
| 1600 | 34,240 | 2950 | 63,130 | 5800 | 124,120 |
| 1610 | 34,454 | 3000 | 64,200 | 5850 | 125,190 |
| 1620 | 34,668 | 3050 | 65,270 | 5900 | 126,260 |
| 1630 | 34,882 | 3100 | 66,340 | 5950 | 127,330 |
| 1640 | 35,096 | 3150 | 67,410 | 6000 | 128,400 |
| 1650 | 35,310 | 3200 | 68,480 | | |
| 1660 | 35,524 | 3250 | 69,550 | Miles. | |
| 1670 | 35,738 | 3300 | 70,620 | ½ | 564,96 |
| 1680 | 35,952 | 3350 | 71,690 | 1 | 112,992 |
| 1690 | 36,166 | 3400 | 72,760 | 1½ | 169,488 |
| 1700 | 36,380 | 3450 | 73,830 | 2 | 225,984 |
| 1710 | 36,594 | 3500 | 74,900 | 2½ | 282,480 |
| 1720 | 36,808 | 3550 | 75,970 | 3 | 338,976 |
| 1730 | 37,022 | 3600 | 77,040 | 3½ | 395,472 |
| 1740 | 37,236 | 3650 | 78,110 | 4 | 451,968 |
| 1750 | 37,450 | 3700 | 79,180 | 4½ | 508,464 |
| 1760 | 37,664 | 3750 | 80,250 | 5 | 564,960 |
| 1770 | 37,878 | 3800 | 81,320 | 5½ | 621,456 |
| 1780 | 38,092 | 3850 | 82,390 | 6 | 677,952 |
| 1790 | 38,306 | 3900 | 83,460 | 6½ | 734,448 |
| 1800 | 38,520 | 3950 | 84,530 | 7 | 790,944 |
| 1810 | 38,734 | 4000 | 85,600 | 7½ | 847,440 |
| 1820 | 38,948 | 4050 | 86,670 | 8 | 903,936 |
| 1830 | 39,162 | 4100 | 87,740 | 8½ | 960,432 |
| 1840 | 39,376 | 4150 | 88,810 | 9 | 1,016,928 |
| 1850 | 39,590 | | | 9½ | 1,073,424 |
| 1860 | 39,804 | | | 10 | 1,129,920 |

$$(A) \frac{\text{Feet} \times 2 \times 10.7 \times \text{amperes}}{\text{Volts lost}} = \text{circular mils.}$$

$$(B) \frac{\text{Feet} \times 2 \times 10.7 \times \text{amperes}}{\text{Circular mils}} = \text{volts lost.}$$

$$(C) \frac{\text{Circular mils} \times \text{volts lost}}{\text{Feet} \times 2 \times 10.7} = \text{amperes.}$$

actual length of circuit, multiply this product by the constant 10.7 and it will give the circular mils necessary for 1 ohm resistance, multiply this by the amperes and it gives the circular mils necessary for the loss of 1 volt. Divide this last result by the volts lost and it gives the circular mils necessary. Hence the formula *A*.

By simply transposing the terms we obtain formula *B*, which can be used to determine the volts lost in a given length of wire of certain size carrying a certain number of amperes.

Again, by another change in the terms, we obtain formula *C*, which shows the number of amperes which a wire of given size and length will carry at a given number of volts lost.

The table on pages 488, 489 has been arranged for the purpose of saving time in the use of these formulæ. It shows the result of $\text{Feet} \times 2 \times 10.7$ for various distances over which it may be desired to transmit current.

A few examples will assist in showing the use of the formulæ and tables.

Suppose we wish to distribute 300 16-candle-power 3.5 watt lamps of 110 volts at a distance of 490 feet with a loss of 10 per cent:

Using formula *A*,

$$490 \text{ feet} \times 2 \times 10.7 \text{ (find it in table on page 488)} = 10,486.$$

$$300 \text{ lamps of 110 volts} = 152.7 \text{ amperes.}$$

(See table, page 485, for amperes per lamp and multiply by 300.)

$$10 \text{ per cent loss on 110-volt system} = 12.22 \text{ volts. (See table on page 491.)}$$

$$10,486 \times 152.7 \text{ amperes} = 1,601,212 \text{ circular mils} \div 12.22 \text{ volts lost} = 131,030 \text{ circular mils.}$$

Table on page 482 shows the size of wire for this number of circular mils to be 00.

To check this and determine exactly the volts lost in this circuit by using No. 00 wire, use formula *B*, as follows:

$$10,486 \times 152.7 \text{ amperes} = 1,601,212 \div 133,079 \text{ circular mils} = 12.03 \text{ volts lost.}$$

VOLTS LOST AT DIFFERENT PER CENT DROP.
Voltage at Lamp or Distribution Point, Top Row.

| Volts. | 52 | 75 | 100 | 110 | 220 | 400 | 500 | 600 | 800 | 1000 | 1200 | 2000 |
|--------|-------|-------|-------|-------|-------|-------|-------|------|------|-------|-------|-------|
| 1% | .261 | .376 | .502 | .552 | 1.10 | 2.01 | 2.51. | 3.01 | 4.02 | 5.02 | 6.03 | 10.05 |
| 1% | .525 | .757 | 1.01 | 1.11 | 2.22 | 4.04 | 5.05 | 6.06 | 8.08 | 10.10 | 12.12 | 20.2 |
| 1½% | .2918 | 1.14 | 1.52 | 1.67 | 3.35 | 6.09 | 7.61 | 9.13 | 12.1 | 15.2 | 18.2 | 30.4 |
| 2% | 1.06 | 1.53 | 2.04 | 2.24 | 4.48 | 8.16 | 10.2 | 12.2 | 16.3 | 20.4 | 24.4 | 40.8 |
| 2½% | 1.33 | 1.92 | 2.56 | 2.82 | 5.64 | 10.25 | 12.8 | 15.3 | 20.5 | 25.6 | 30.7 | 51.2 |
| 3% | 1.61 | 2.31 | 3.09 | 3.40 | 6.80 | 12.37 | 15.4 | 18.5 | 24.7 | 30.9 | 37.1 | 61.8 |
| 4% | 2.16 | 3.12 | 4.16 | 4.58 | 9.16 | 16.66 | 20.8 | 24.9 | 33.3 | 41.6 | 49.9 | 83.3 |
| 5% | 2.73 | 3.94 | 5.26 | 5.78 | 11.57 | 21.05 | 26.3 | 31.5 | 42.1 | 52.6 | 63.1 | 105. |
| 6% | 3.31 | 4.78 | 6.38 | 7.02 | 14.04 | 25.53 | 31.9 | 38.2 | 51. | 63.8 | 76.5 | 127. |
| 7% | 3.91 | 5.64 | 7.52 | 8.27 | 16.55 | 30.10 | 37.6 | 45.1 | 60.2 | 75.2 | 90.3 | 150. |
| 8% | 4.52 | 6.52 | 8.69 | 9.56 | 19.13 | 34.78 | 43.4 | 52.1 | 69.5 | 86.9 | 104. | 173. |
| 9% | 5.14 | 7.41 | 9.89 | 10.87 | 21.75 | 39.56 | 49.4 | 59.3 | 79.1 | 98.9 | 118. | 197. |
| 10% | 5.77 | 8.33 | 11.11 | 12.22 | 24.44 | 44.44 | 55.5 | 66.6 | 88.8 | 111. | 133. | 222. |
| 12% | 7.09 | 10.22 | 13.63 | 14.99 | 29.99 | 54.54 | 61.7 | 74.1 | 98.8 | 123. | 148. | 247. |
| 13% | 7.76 | 11.10 | 14.94 | 16.43 | 32.87 | 59.76 | 68.1 | 81.8 | 109. | 136. | 163. | 272. |
| 14% | 8.46 | 12.20 | 16.27 | 17.90 | 35.81 | 65.1 | 74.7 | 89.6 | 119. | 149. | 179. | 298. |
| 15% | 9.17 | 13.23 | 17.64 | 19.41 | 38.82 | 70.5 | 81.3 | 97.6 | 130. | 162. | 195. | 325. |
| 20% | 13. | 18.75 | 25. | 27.50 | 55. | 100. | 88.2 | 105. | 141. | 176. | 211. | 352. |
| 25% | 17.33 | 25. | 33.33 | 36.66 | 73.33 | 133. | 125. | 150. | 200. | 250. | 300. | 400. |
| 30% | ..... | ..... | ..... | ..... | ..... | ..... | 166. | 200. | 266. | 333. | 400. | 666. |

The above table shows the loss in voltage between dynamos and distribution point at different per cents and for various voltages.

By adding the volts given in the table to the voltage at motor or lamp the result shows the voltage necessary at dynamo for voltage required at point of distribution

The following table is arranged to show the amperes per motor at different voltages for several sizes of motors at efficiencies obtained in ordinary practice.

AMPERES PER MOTOR.

| H.P. | Per Cent Efficiency. | Watts. | Volts. | | | | | | | | | |
|-------|----------------------|--------|--------|-------|-------|------|------|------|------|------|------|--|
| | | | 110 | 115 | 120 | 125 | 220 | 250 | 500 | 525 | 550 | |
| 1/4 | 65 | 860 | 7.82 | 7.48 | 7.17 | 6.88 | 3.91 | 3.44 | 1.72 | 1.64 | 1.56 | |
| 1 | 65 | 1148 | 10.4 | 9.98 | 9.57 | 9.18 | 5.22 | 4.59 | 2.30 | 2.19 | 2.09 | |
| 2 | 65 | 2295 | 20.8 | 20.0 | 19.1 | 18.4 | 10.4 | 9.18 | 4.59 | 4.37 | 4.17 | |
| 2 1/2 | 75 | 2487 | 22.6 | 21.6 | 20.7 | 19.9 | 11.3 | 9.95 | 4.97 | 4.74 | 4.52 | |
| 3 1/2 | 75 | 3480 | 31.6 | 30.3 | 29.0 | 27.8 | 15.8 | 13.9 | 6.96 | 6.63 | 6.33 | |
| 5 | 80 | 4662 | 42.4 | 40.5 | 38.8 | 37.3 | 21.2 | 18.6 | 9.32 | 8.88 | 8.48 | |
| 7 1/2 | 85 | 6994 | 63.6 | 60.8 | 58.3 | 56.0 | 31.8 | 28.0 | 14.0 | 13.3 | 12.7 | |
| 10 | 85 | 8776 | 79.8 | 76.3 | 73.1 | 70.2 | 39.9 | 35.1 | 17.6 | 16.7 | 16.0 | |
| 15 | 85 | 13165 | 120. | 114. | 110. | 105 | 59.8 | 52.6 | 26.3 | 25.1 | 23.9 | |
| 20 | 90 | 16578 | 151. | 144. | 138. | 133. | 75.4 | 66.3 | 33.2 | 31.6 | 30.1 | |
| 25 | 90 | 20722 | 188. | 180. | 173. | 166. | 94.2 | 82.9 | 41.4 | 39.5 | 37.7 | |
| 30 | 90 | 24867 | 226. | 216. | 207. | 199. | 113. | 99.4 | 49.7 | 47.4 | 45.2 | |
| 40 | 90 | 33155 | 301. | 288. | 276. | 265. | 151. | 133. | 66.3 | 63.2 | 60.3 | |
| 50 | 90 | 41444 | 377. | 360. | 345. | 332. | 188. | 166. | 82.9 | 79.0 | 75.4 | |
| 70 | 90 | 58022 | 528. | 505. | 484. | 464. | 264. | 232. | 116. | 111. | 106. | |
| 90 | 90 | 74600 | 678. | 649. | 622. | 597. | 339. | 298. | 149. | 142. | 136. | |
| 100 | 93 | 80215 | 729. | 697. | 668. | 642. | 365. | 321. | 160. | 153. | 146. | |
| 125 | 93 | 100269 | 912. | 872. | 836. | 802. | 456. | 401. | 200. | 191. | 182. | |
| 150 | 93 | 120323 | 1094. | 1046. | 1003. | 963. | 547. | 481. | 241. | 229. | 219. | |

Suppose it is desired to distribute 1000 lamps at a distance of 1950 feet by 3-wire system, viz., 220 volts, with a loss of 10 per cent:

Using formula *A*,

$$1950 \text{ feet} \times 2 \times 10.7 \text{ (see table on page 489)} = 41,730.$$

$$1000 \text{ lamps on 220-volt system} = 291 \text{ amperes.}$$

(See table on page 485 for amperes per lamp and multiply by 1000.)

10 per cent on 220-volt system = 24.44 volts lost. (See table on page 491.)

$$41,730 \times 291 \text{ amperes} = 12,143,430 \div 24.44 \text{ volts lost} = 496,867 \text{ circular mils.}$$

500,000 circular mils, the nearest commercial size, should be used.

Check this as before by formula *B*.

$$41,730 \times 291 \text{ amperes} = 12,143,430 \div 500,000 \text{ circular mils} = 24.29 \text{ volts lost.}$$

Suppose we wish to deliver 100 horse-power to a 500-volt motor at a distance of 4850 feet with 10 per cent loss:

Again using formula *A*,

$$4850 \text{ feet} \times 2 \times 10.7 = 103,790.$$

100 horse-power at 500 volts = 160 amperes. (See table on page 492.)

10 per cent loss on 500-volt system = 55.5 volts. (See table on page 491.)

$$103,790 \times 160 \text{ amperes} = 16,606,400 \div 55.5 \text{ volts} = 299,215 \text{ circular mils.}$$

300,000 circular mils cable should be used.

Check this as before by formula *B*.

$$103,790 \times 160 \text{ amperes} = 16,606,400 \div 300,000 \text{ circular mils} = 55.35 \text{ volts lost.}$$

To ascertain how many amperes could be carried to a distance of 4850 feet with 500 volts with 10 per cent loss, use formula *C*:

$$4850 \text{ feet} \times 2 \times 10.7 = 103,790.$$

10 per cent loss on 500-volt system = 55.5 volts.

300,000 circular mils \times 55.5 volts lost \div 103,790 = 160.42 amperes, which, as will appear by reference to table on page 492, will permit the use of 100-horse-power motor.

The following table gives the gauge and safe carrying capacity of copper wire

494 CARRYING CAPACITY OF COPPER WIRE.

GAUGES IN CIRCULAR MILS AND SAFE CARRYING CAPACITY

| d ² Circular Mils. | B. & S. Brown & Sharpe Gauge. | B.W.G. Birm- ingham Wire Gauge. | E.S.G. Edison Standard Gauge. | Safe Carrying Capacity. | | | |
|-------------------------------------|---|---|--|--|---|---|---|
| | | | | Wire heated to 30° F. above Tem- perature of Surrounding Air. | | | |
| | | | | Number of Am- peres. | Number of 55- volt Lamps, 16 C.P. | Number of 75- volt Lamps, 16 C.P. | Numbe of 110- volt Lamps, 16 C.P. |
| 220,000 | ..... | ..... | 220 | 203 | 203 | 278 | 406 |
| 211,600 | 0000 | ..... | ..... | 197.3 | 197 | 270 | 395 |
| 206,116 | ..... | 0000 | ..... | 193.5 | 193 | 264 | 387 |
| 200,000 | ..... | ..... | 200 | 189.15 | 189 | 259 | 378 |
| 190,000 | ..... | ..... | 190 | 182 | 182 | 249 | 364 |
| 180,625 | ..... | 000 | ..... | 179.3 | 179 | 245 | 359 |
| 180,000 | ..... | ..... | 180 | 174.8 | 175 | 240 | 330 |
| 170,000 | ..... | ..... | 170 | 167.4 | 167 | 229 | 335 |
| 167,805 | 000 | ..... | ..... | 165.8 | 166 | 227 | 332 |
| 160,000 | ..... | ..... | 160 | 160 | 160 | 219 | 320 |
| 150,000 | ..... | ..... | 150 | 152.5 | 152 | 208 | 305 |
| 144,400 | ..... | 00 | ..... | 148.2 | 148 | 203 | 296 |
| 140,000 | ..... | ..... | 140 | 114.8 | 145 | 199 | 290 |
| 133,079 | 00 | ..... | ..... | 139.4 | 139 | 190 | 279 |
| 130,000 | ..... | ..... | 130 | 136.9 | 137 | 188 | 274 |
| 120,000 | ..... | ..... | 120 | 129 | 129 | 177 | 258 |
| 115,600 | ..... | ..... | ..... | 125.4 | 125 | 171 | 251 |
| 110,000 | ..... | ..... | 110 | 120.8 | 121 | 166 | 242 |
| 105,592 | 0 | ..... | ..... | 117.2 | 117 | 160 | 234 |
| 100,000 | ..... | ..... | 100 | 112.5 | 112 | 153 | 225 |
| 95,000 | ..... | ..... | 95 | 108.2 | 108 | 148 | 216 |
| 90,000 | ..... | 1 | 90 | 103.9 | 104 | 142 | 208 |
| 85,000 | ..... | ..... | 85 | 99.5 | 99 | 136 | 199 |
| 83,694 | 1 | ..... | ..... | 98.4 | 98 | 134 | 197 |
| 80,656 | ..... | 2 | ..... | 95.7 | 96 | 131 | 191 |
| 80,000 | ..... | ..... | 80 | 95.1 | 95 | 130 | 190 |
| 75,000 | ..... | ..... | 75 | 90.6 | 91 | 125 | 181 |
| 70,000 | ..... | ..... | 70 | 86 | 86 | 118 | 172 |
| 67,081 | ..... | 3 | ..... | 84 | 84 | 115 | 168 |
| 66,373 | 2 | ..... | ..... | 83.1 | 83 | 114 | 166 |
| 65,000 | ..... | ..... | 65 | 81.4 | 81 | 111 | 163 |
| 60,000 | ..... | ..... | 60 | 78.4 | 78 | 107 | 157 |
| 56,644 | ..... | 4 | ..... | 73.4 | 73 | 100 | 147 |
| 55,000 | ..... | ..... | 55 | 71.8 | 72 | 99 | 144 |
| 52,634 | 3 | ..... | ..... | 69.5 | 69 | 94 | 139 |
| 50,000 | ..... | ..... | 50 | 66.8 | 67 | 92 | 134 |
| 48,400 | ..... | 5 | ..... | 65.2 | 65 | 89 | 131 |
| 45,000 | ..... | ..... | 45 | 61.7 | 62 | 85 | 123 |
| 41,742 | 4 | ..... | ..... | 58.4 | 58 | 79 | 117 |

GAUGES IN CIRCULAR MILS AND SAFE CARRYING CAPACITY—
(Continued).

| d ² Circular Mils. | B. & S. Brown & Sharpe Gauge. | B.W.G. Birm- ingham Wire Gauge. | E.S.G. Edison Standard Gauge. | Safe Carrying Capacity. | | | |
|-------------------------------------|--|---|--|--|---|---|--|
| | | | | Wire heated to 30° F. above Tem- perature of Surrounding Air. | | | |
| | | | | Number of Am- peres. | Number of 55- volt Lamps, 16 C.P. | Number of 75- volt Lamps, 16 C.P. | Number of 110- volt Lamps, 16 C.P. |
| 41,209 | .... | 6 | .... | 57.8 | 58 | 79 | 116 |
| 40,000 | .... | .... | 40 | 56.5 | 56 | 77 | 113 |
| 35,000 | .... | .... | 35 | 51.1 | 51 | 70 | 102 |
| 33,102 | 5 | .... | .... | 49.1 | 49 | 67 | 98 |
| 32,400 | .... | 7 | .... | 48.3 | 48 | 66 | 97 |
| 30,000 | .... | .... | 30 | 46.6 | 46 | 63 | 93 |
| 27,225 | .... | 8 | .... | 42.4 | 42 | 57 | 85 |
| 26,250 | 6 | .... | .... | 41.2 | 41 | 56 | 82 |
| 25,000 | .... | .... | 25 | 39.7 | 40 | 55 | 79 |
| 21,904 | .... | 9 | .... | 36 | 36 | 49 | 72 |
| 20,816 | 7 | .... | .... | 34.6 | 34 | 47 | 69 |
| 20,000 | .... | .... | 20 | 33.6 | 33 | 45 | 67 |
| 17,956 | .... | 10 | .... | 31 | 31 | 42 | 62 |
| 16,509 | 8 | .... | .... | 29.1 | 29 | 40 | 58 |
| 15,000 | .... | .... | 15 | 27.1 | 27 | 37 | 54 |
| 14,400 | .... | 11 | .... | 26.3 | 26 | 36 | 52 |
| 13,094 | 9 | .... | .... | 24.4 | 24 | 33 | 49 |
| 12,000 | .... | .... | 12 | 22.9 | 23 | 31 | 46 |
| 11,881 | .... | 12 | .... | 22.7 | 23 | 31 | 46 |
| 10,381 | 10 | .... | .... | 20.5 | 20 | 27 | 41 |
| 9,025 | .... | 13 | .... | 18.5 | 18 | 25 | 37 |
| 8,234 | 11 | .... | .... | 17.3 | 17 | 23 | 34 |
| 8,000 | .... | .... | 8 | 16.9 | 17 | 23 | 34 |
| 6,889 | .... | 14 | .... | 15.1 | 15 | 20 | 30 |
| 6,530 | 12 | .... | .... | 14.5 | 14 | 19 | 29 |
| 5,184 | .... | 15 | .... | 12.2 | 12 | 16 | 24 |
| 5,178 | 13 | .... | .... | 12.2 | 12 | 16 | 24 |
| 5,000 | .... | .... | 5 | 11.9 | 12 | 16 | 24 |
| 4,225 | .... | 16 | .... | 10.5 | 10 | 14 | 21 |
| 4,107 | 14 | .... | .... | 10.2 | 10 | 14 | 20 |
| 3,364 | .... | 17 | .... | 8.8 | 9 | 12 | 17 |
| 3,257 | 15 | .... | .... | 8.6 | 9 | 12 | 17 |
| 3,000 | .... | .... | 3 | 8.1 | 8 | 11 | 16 |
| 2,583 | 16 | .... | .... | 7.2 | 7 | 10 | 14 |
| 2,401 | .... | 18 | .... | 6.8 | 7 | 10 | 14 |

1. In this table it is estimated that 1 55-volt, 16-candle-power lamp requires about 1 ampere of current; 1 75-volt, 16-candle-power lamp requires about 0.73 ampere of current; 1 110-volt, 16-candle-power lamp requires about 0.5 ampere of current.

2. Lamps supposed to be in multiple arc. On the 3-wire system the same current in amperes will suffice for a series of two lamps. Hence twice the number of lamps as given in the above table can be safely carried on the same size wires.

CONDUCTORS AND INSULATORS.—Bodies in which the electric current moves freely are called conductors, and those in which it does not move freely are called insulators. There is, however, no substance so good a conductor as to be void of resistance, and there is no substance of so high a resistance as to be strictly a non-conductor.

In the following list the substances named are placed in order, each conducting better than those below it in the list:

| | | |
|----------------------------|---|-------------------------------|
| Silver (best conductor) | } | Good conductors. |
| Copper | | |
| Gold | | |
| Aluminum | | |
| Zinc | | |
| Platinum | | |
| Iron | | |
| Tin | | |
| Lead | | |
| Nickel | | |
| Mercury | | |
| Charcoal | | |
| Acids | | |
| Water | | |
| The body |  |  | } | Partial conductors. |
| Cotton | | |
| Dry wood | | |
| Marble | | |
| Paper | | |
| Oils | } | Non-conductors or insulators. |
| Porcelain | | |
| Wool | | |
| Silk | | |
| Resin | | |
| Gutta-percha | | |
| Shellac | | |
| Ebonite | | |
| Paraffine | | |
| Glass | | |
| Dry air (worst conductor). | | |

WIRING FORMULÆ AS GIVEN BY THE NATIONAL ELECTRIC CODE.

For a complete set of rules the superintendent should provide himself with this Code, which can be secured from the Mutual Fire Insurance Companies, Boston.

GENERAL WIRING FORMULÆ.

$$V = \frac{D \times W \times R \times B}{E \times A}, \text{ or } V = \frac{L \times E \times B}{100}.$$

$$A = \frac{D \times W \times R \times B}{E \times V}, \text{ or } A = \frac{D \times W \times R \times 100}{L \times E^2}.$$

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

$$L = \frac{D \times W \times R \times 100}{E^2 \times A}.$$

$$P = \frac{D^2 \times W \times R \times S}{L \times E^2 \times 10,000}, \text{ or } P = \frac{D \times S \times A}{1,000,000}.$$

V = volts drop in line.

D = distance between the two points, in feet along the wires.

W = total power *delivered*, in watts.

E = voltage at *receiving* end of line.

A = area of cross-section of wire, in circular mils.



The area in circular mils of B. & S. guage sizes from No. 10 to No. 0000 inclusive will be found in the table on page 500.

For wires smaller than these, see table on page 505.

C = current in each wire, in amperes.

L = loss in line, in per cent of W .

P = total pounds of copper in line.

R = a constant, for value of which see table on page 500.

S = " " " " " " " " " " " "

T = " " " " " " " " " " " "

B = " " " " " " " " " " " "

For direct-current systems, $R=21.6$, $B=1.00$, $T=1.00$, and $W=C \times E$, so that the first two of the above formulæ reduce

to $V = \frac{D \times C \times 21.6}{A}$, and $A = \frac{D \times C \times 21.6}{V}$.

In a balanced three-wire, two-phase, alternating-current system, the current in the middle wire is 1.41 times that in each

outside wire, the current in the outside wires being computed from the formula as if the system was a four-wire one.

When the power factor cannot be accurately determined, it may be assumed to be as follows for any alternating-current system operating under average conditions: lighting, with no motors, 95 per cent; lighting and motors together, 85 per cent; motors only, 80 per cent.

The values of B are for wires 18 inches apart, centre to centre, and are sufficiently accurate for all practical purposes, provided that the reactance of the line is not excessive or the line loss unusually high. They represent the true values at 10 per cent line loss; are close enough for all losses less than 10 per cent; and are often close enough for losses considerably above 10 per cent, at least for frequencies up to forty cycles. Where the conductors of a circuit are less than 18 inches apart, the value of B is less than that given in the table, and if they are close together, as with multiple conductor cable, B becomes equal to unity and can be omitted from the formula.

The following examples are given to show how the different formulæ are to be applied:

1. What size wire is needed to transmit current 200 feet to a centre of distribution for 60 incandescent lamps on a 110-volt direct-current system, with a drop of 3 per cent, which is an actual drop of 3.3 volts?

The table on page 485 shows that a 16 c. p. lamp at 110 volts takes 0.52 of an ampere, and 60 lamps would therefore take 31.2 amperes.

Hence $D=200$, $C=31.2$, and $V=3.3$, from which, using the simplified formula for direct-current, we have

$$A = \frac{200 \times 31.2 \times 21.6}{3.3} = 40,840.$$

From the table on page 500, we see that the nearest B. & S. gauge size above this is No. 4, which is the proper size to use.

2. What is the current in each wire of a three-phase circuit feeding two motors developing 20 H.P. each, the voltage at the motors being 550?

40 H.P. = 40×746 watts = 29,840 watts. Assuming a power factor of 85 per cent (see note above), we find from the table that the value of T for this power factor on a three-phase,

three-wire system is 0.68. Then from the formula, we have

$$C = \frac{29,840 \times 0.68}{550} = 36.9 \text{ amperes.}$$

3. In a two-phase, 60-cycle transmission line, with four No. 2 B. & S. gauge wires 18 inches apart, supplying lighting transformers at a point one and five-eighths miles from the generating station, what must be the voltage at the generator switchboard to give a voltage of 2080 at the transformers when the load on the transformers is 188 K.W.?

$1\frac{5}{8}$ miles = 8580 feet, and 188 K.W. = 188,000 watts. Hence $D = 8580$, $W = 188,000$, $E = 2080$; and from the table $R = 12.00$, $A = 66,600$, and $B = 1.18$, assuming a power factor of 95 per cent (see notes on page 498).

Inserting these values in the formulæ for L and V , we have

$$L = \frac{8580 \times 188,000 \times 12 \times 100}{(2080)^2 \times 66,600} = 6.72 \text{ and}$$

$$V = \frac{6.72 \times 2080 \times 1.18}{100} = 165 \text{ volts.}$$

Therefore the voltage at the generator must be $2080 + 165 = 2245$.

The following rules for electric wiring, etc., are taken from the "National Electric Code," and every superintendent should have a copy of this code, which can be obtained from the Mutual Fire Insurance Companies, Boston, Mass. The rules referred to in the following extract will be found in the above code.

OUTSIDE WORK.

12. WIRES.—*a.* Service wires must have an *approved* rubber insulating covering. (See Rule 41.) Line wires, other than services, must have an *approved* weather-proof or rubber insulating covering. (See Rules 41 and 44.) All tie wires must have an insulation equal to that of the conductors which they confine.

b. Must be so placed that moisture cannot form a cross connection between them not less than a foot apart, and not in contact with any substance other than their insulating supports

| System. | Values of <i>S</i> . | Values of <i>R</i> . Per Cent Power Factor. | | | | | Values of <i>T</i> . Per Cent Power Factor. | | | | |
|-------------------------------|----------------------|--|-------|-------|-------|-------|--|------|------|------|------|
| | | 100 | 95 | 90 | 85 | 80 | 100 | 95 | 90 | 85 | 80 |
| | | Single-phase..... | 6.04 | 24.00 | 26.60 | 30.00 | 33.80 | 1.00 | 1.05 | 1.11 | 1.17 | 1.25 |
| Two-phase (four-wire)..... | 12.08 | 12.00 | 13.30 | 15.00 | 16.90 | .50 | .53 | .55 | .59 | .62 | |
| Three-phase (three-wire)..... | 9.06 | 12.00 | 13.30 | 15.00 | 16.90 | .58 | .61 | .64 | .68 | .72 | |

| No. of Wire, B. & S. Gauge. | Area Wire, Cir- cular Mils. | Weight of Bare Wire per 1000 Feet, Pounds. | Resistance of Wire per 1000 Feet at 25° C. Ohms. | Values of <i>B</i> (for Wires 18 Inches Apart). | | | | | | | | | | | | | | | | | | | |
|--------------------------------|--------------------------------|--|--|---|------|------|------|------|---|------|------|------|------|---|------|------|------|------|--|--|--|--|--|
| | | | | 25 Cycles. Per Cent Power Factor. | | | | | 40 Cycles. Per Cent Power Factor. | | | | | 60 Cycles. Per Cent Power Factor. | | | | | 125 Cycles. Per Cent Power Factor. | | | | |
| | | | | 95 | 90 | 85 | 80 | 95 | 90 | 85 | 80 | 95 | 90 | 85 | 80 | 95 | 90 | 85 | 80 | | | | |
| 0000 | 212,000 | 641 | .0499 | 1.23 | 1.29 | 1.33 | 1.34 | 1.52 | 1.53 | 1.61 | 1.67 | 1.84 | 1.84 | 1.99 | 2.09 | 2.35 | 2.86 | 3.24 | 3.49 | | | | |
| 0000 | 168,000 | 509 | .0628 | 1.18 | 1.22 | 1.24 | 1.24 | 1.40 | 1.41 | 1.48 | 1.51 | 1.66 | 1.66 | 1.77 | 1.95 | 2.08 | 2.48 | 2.77 | 2.94 | | | | |
| 00 | 133,000 | 403 | .0794 | 1.14 | 1.16 | 1.16 | 1.16 | 1.25 | 1.32 | 1.35 | 1.37 | 1.52 | 1.52 | 1.60 | 1.66 | 1.86 | 2.18 | 2.40 | 2.57 | | | | |
| 0 | 106,000 | 320 | .0997 | 1.10 | 1.11 | 1.10 | 1.09 | 1.19 | 1.24 | 1.26 | 1.26 | 1.40 | 1.40 | 1.46 | 1.49 | 1.71 | 1.96 | 2.13 | 2.25 | | | | |
| 1 | 83,500 | 253 | .126 | 1.07 | 1.07 | 1.05 | 1.03 | 1.14 | 1.14 | 1.18 | 1.17 | 1.30 | 1.30 | 1.34 | 1.36 | 1.56 | 1.75 | 1.88 | 1.97 | | | | |
| 2 | 66,600 | 202 | .159 | 1.05 | 1.04 | 1.02 | 1.00 | 1.11 | 1.12 | 1.12 | 1.10 | 1.23 | 1.23 | 1.25 | 1.26 | 1.45 | 1.60 | 1.70 | 1.77 | | | | |
| 3 | 52,400 | 159 | .202 | 1.03 | 1.02 | 1.00 | 1.00 | 1.07 | 1.08 | 1.07 | 1.05 | 1.12 | 1.12 | 1.11 | 1.10 | 1.27 | 1.46 | 1.53 | 1.57 | | | | |
| 4 | 41,600 | 126 | .254 | 1.02 | 1.00 | 1.00 | 1.00 | 1.05 | 1.06 | 1.03 | 1.00 | 1.08 | 1.08 | 1.06 | 1.04 | 1.21 | 1.35 | 1.40 | 1.43 | | | | |
| 5 | 33,100 | 100 | .319 | 1.00 | 1.00 | 1.00 | 1.00 | 1.02 | 1.01 | 1.00 | 1.00 | 1.05 | 1.04 | 1.02 | 1.00 | 1.16 | 1.20 | 1.21 | 1.21 | | | | |
| 6 | 26,200 | 79.5 | .403 | 1.00 | 1.00 | 1.00 | 1.00 | 1.01 | 1.00 | 1.00 | 1.00 | 1.03 | 1.02 | 1.00 | 1.00 | 1.12 | 1.14 | 1.14 | 1.13 | | | | |
| 7 | 20,700 | 62.8 | .510 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.09 | 1.10 | 1.09 | 1.07 | | | | |
| 8 | 16,600 | 50.4 | .635 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.06 | 1.06 | 1.04 | 1.02 | | | | |
| 9 | 13,000 | 39.4 | .813 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.06 | 1.06 | 1.04 | 1.02 | | | | |
| 10 | 10,400 | 31.5 | 1.01 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.04 | 1.03 | 1.00 | 1.00 | | | | |

Wooden blocks to which insulators are attached must be covered over their entire surface with at least two coats of water-proof paint.

c. Must be at least seven feet above the highest point of flat roofs and at least one foot above the ridge of pitched roofs over which they pass or to which they are attached.

d. Must be protected by dead insulated guard irons or wires from possibility of contact with other conducting wires or substances to which current may leak. Especial precautions of this kind must be taken where sharp angles occur, or where wires of any other systems might possibly come in contact with electric-light or power wires.

e. Must be provided with petticoat insulators of glass or porcelain. Porcelain knobs or cleats or rubber hooks will not be approved.

f. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered to insure preservation, and covered with an insulation equal to that on the conductors.

g. Must, where they enter buildings, have drip loops outside, and the holes through which the conductors pass must be bushed with non-combustible, non-absorptive, insulating tubes, slanting upward toward the inside.

h. Telegraph, telephone, and other signal wires must not be placed on the same cross-arm with electric-light or power wires, and when placed on the same pole with such wires, the distance between the two inside pins on each cross-arm must not be less than twenty-six inches.

i. The metallic sheaths of cables must be permanently and effectively connected to "earth."

Trolley Wires.—j. Must not be smaller than No. 0 B. & S. gauge copper or No. 4 B. & S. gauge silicon bronze, and must readily stand the strain put upon them when in use.

k. Must have a double insulation from the ground. In wooden pole construction, the pole will be considered as one insulation.

l. Must be capable of being disconnected at the power plant, or of being divided into sections, so that in case of fire on the railway route the current may be shut off from the particular section to prevent its interfering with the work of the firemen. This also applies to feeders.

m. Must be safely protected against accidental contact where crossed by other conductors.

Ground Return Wires.—*n.* For the diminution of electrolytic corrosion of underground metal-work, ground return wires must be so arranged that the difference of potential between the grounded dynamo terminal and any point on the return circuit will not exceed twenty-five volts.

Transformers.—*a.* Must not be placed inside of any building excepting central stations, unless by special permission of the inspection department having jurisdiction.

b. Must not be attached to the outside walls of buildings, unless separated therefrom by substantial supports.

Grounding Low-potential Circuits.—The grounding of low-potential circuits under the following regulations is only allowed when such circuits are so arranged that under normal conditions of service there will be no passage of current over the ground wire.

Direct-current Three-wire Systems.—*a.* Neutral wire may be grounded, and when grounded the following rules must be complied with:

1. Must be grounded at the central station on a metal plate buried in coke beneath permanent-moisture level, and also through all available underground water- and gas-pipe systems.

2. In underground systems, the neutral wire must also be grounded at each distributing-box through the box.

3. In overhead systems the neutral wire must be grounded every 500 feet, as provided in §§ *c, e, f, and g.*

Alternating-current Secondary Systems.—*b.* The neutral points of transformers or the neutral wire of distributing systems may be grounded, and when grounded the following rules must be complied with:

1. Transformers feeding two-wire systems must be grounded at the centre of the secondary coils, as provided in §§ *d, e, f, and g.*

2. Transformers feeding systems with a neutral wire must have the neutral wire grounded as provided in §§ *d, e, f, and g* at the transformer, and at least every 250 feet for overhead systems and every 500 feet for underground systems.

Ground Connections.—*c.* The ground wire in direct-current three-wire systems must not at central stations be smaller than the neutral wire, and smaller than No. 6 B. & S. gauge elsewhere.

d. The ground wire in alternating-current systems must never be less than No. 6 B. & S. gauge, and must always have a

carrying capacity equal to that of the secondary lead of the transformer, or the combined leads where transformers are connected in parallel.

e. The ground wire must be kept outside of buildings, but may be directly attached to the building or pole. The wire must be carried as nearly in a straight line as possible, and kinks, coils, and sharp bends must be avoided.

f. The ground connections for central stations, transformer sub-stations, and banks of transformers must be made through metal plates buried in coke below permanent-moisture level, and connection should also be made to all available underground piping systems, including the lead sheaths of underground cables.

g. For individual transformers and building services, the ground connection may be made as in *F'*, or may be made to water or other piping systems running into the buildings. This connection may be made by carrying the ground wire into the cellar and connecting on the street side of meters, main cocks, etc., but connection must never be made to any lead pipes which form part of gas services.

INSIDE WORK.

ALL SYSTEMS AND VOLTAGES.

GENERAL RULES.

14. WIRES.—(For special cases, see Rules 18, 24, 35, 38, and 39.)

a. Must not be of smaller size than No. 14 B. & S. gauge, except as allowed under Rules 24, *v* and 45, *b*.

b. Tie wires must have an insulation equal to that of the conductors which they confine.

c. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered to insure preservation, and covered with an insulation equal to that on the conductors.

Stranded wires must be soldered before being fastened under clamps or binding-screws, and when they have a conductivity greater than that of No. 10 B. & S. gauge copper wire, they must be soldered into lugs.

d. Must be separated from contact with walls, floors, timbers, or partitions through which they may pass by non-combustible,

non-absorptive, insulating tubes, such as glass or porcelain except as provided in Rule 24, *u*.

e. Must be kept free from contact with gas, water, or other metallic piping, or any other conductors or conducting material which they may cross, by some continuous and firmly fixed non-conductor, creating a separation of at least one inch. Deviations from this rule may sometimes be allowed by special permission.

f. Must be so placed, in wet places, that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Wires should be run over rather than under pipes upon which moisture is likely to gather, or which by leaking might cause trouble on a circuit.

15. *Underground Conductors*.—*a*. Must be protected against moisture and mechanical injury where brought into a building and all combustible material must be kept removed from the immediate vicinity.

b. Must not be so arranged as to shunt the current through a building around any catch-box.

16. *Table of Carrying Capacity of Wires*.—*a*. The following table, showing the allowable carrying capacity of copper wires and cables of 98 per cent conductivity, according to the standard adopted by the American Institute of Electrical Engineers, must be followed in placing interior conductors.

For insulated aluminum wire the safe carrying capacity is 84 per cent of that given in the following tables for copper wire with the same kind of insulation.

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

The carrying capacity for No. 16 and No. 18 wire is given, but no smaller than No. 14 is to be used, except as allowed under Rules 24, *v* and 45, *b*.

There is a general agreement among those familiar with the effect of heat on rubber, that, if long life is desired, the temperature should not exceed 150° F.

In 1889, Mr. A. E. Kennelly made an elaborate series of careful experiments at the Edison Laboratory, to determine the temperature rise caused in wires under different conditions by currents of various strengths.

| B. & S. Gauge. | Table A. | Table B. | Circular Mils. |
|----------------|--|--|----------------|
| | Rubber-covered Wires. See Rule 41. Amperes. | Weather-proof Wires. See Rules 42 to 44. Amperes. | |
| 18..... | 3..... | 5..... | 1,624 |
| 16..... | 6..... | 8..... | 2,583 |
| 14..... | 12..... | 16..... | 4,107 |
| 12..... | 17..... | 23..... | 6,530 |
| 10..... | 24..... | 32..... | 10,380 |
| 8..... | 33..... | 46..... | 16,510 |
| 6..... | 46..... | 65..... | 26,250 |
| 5..... | 54..... | 77..... | 33,100 |
| 4..... | 65..... | 92..... | 41,740 |
| 3..... | 76..... | 110..... | 52,630 |
| 2..... | 90..... | 131..... | 66,370 |
| 1..... | 107..... | 156..... | 83,690 |
| 0..... | 127..... | 185..... | 105,500 |
| 00..... | 150..... | 220..... | 133,100 |
| 000..... | 177..... | 262..... | 167,800 |
| 0000..... | 210..... | 312..... | 211,600 |
| Circular Mils. | | | |
| 200,000..... | 200..... | 300 | |
| 300,000..... | 270..... | 400 | |
| 400,000..... | 330..... | 500 | |
| 500,000..... | 390..... | 590 | |
| 600,000..... | 450..... | 680 | |
| 700,000..... | 500..... | 760 | |
| 800,000..... | 550..... | 840 | |
| 900,000..... | 600..... | 920 | |
| 1,000,000..... | 650..... | 1,000 | |
| 1,100,000..... | 690..... | 1,080 | |
| 1,200,000..... | 730..... | 1,150 | |
| 1,300,000..... | 770..... | 1,220 | |
| 1,400,000..... | 810..... | 1,290 | |
| 1,500,000..... | 850..... | 1,360 | |
| 1,600,000..... | 890..... | 1,430 | |
| 1,700,000..... | 930..... | 1,490 | |
| 1,800,000..... | 970..... | 1,550 | |
| 1,900,000..... | 1,010..... | 1,610 | |
| 2,000,000..... | 1,050..... | 1,670 | |

The currents given in Table A are about 60 per cent of the currents which Mr. Kennelly found caused a rise of 75° F., or

a final temperature of about 150° F., assuming 75° F. as the average indoor temperature. This margin of 40 per cent is to allow for inevitable increase of current, such as that produced by the changing from one size lamp to those of a larger candle-power, the adding of more lamps to a circuit, the overloading of a motor, etc. The currents given in Table A cause a rise of temperature of about 29° F. above the surroundings, but varying somewhat with the size of the wire. It is well to remember in this connection that the heating effect increases about as the square of the current, i.e., if the current is doubled, for instance, the heating effect increases four times.

The limiting temperature for weather-proof insulation is about the same as for rubber, but a smaller factor of safety is allowable, as the covering on this class of wire is not greatly depended on for insulation, the insulation of the system being secured by the porcelain or glass supports to which the wire is attached. The currents in Table B, therefore, were obtained by taking 90 per cent of the currents which Mr. Kennelly found caused the wire to reach a temperature of 150° F., when the surrounding air was at 75° F. This allows a margin of only 10 per cent instead of the 40 per cent considered necessary in Table A.

It is interesting to note that, for any given size of wire, a current about three times as great as that given in Table A causes all ordinary insulations to begin to smoke.

Owing to the cooling effect of air-currents, the safe carrying capacity of outdoor conductors may be several times greater than the above, without causing any dangerous rise of temperature. As the conditions will vary so widely, and as such outdoor conductors are not at all liable to cause fire, no table has been made for them.

The following table shows, to the nearest one-hundredth of an ampere, the current consumed by incandescent lamps of various candle-powers, at the voltages in most common uses. This table is figured on the basis of an efficiency of 3.6 watt. per candle-power for the 52-, 104-, and 110-volt lamps, and 4.0 watts per candle-power for the 220-volt lamps.

17 *Switches, Cut-outs, Circuit-breakers etc.*—(For construction requirements, see Rules 51, 52, and 53.)

a. Must, whenever called for, unless otherwise provided (for exceptions see Rules 8, c and 22, c), be so arranged that the cut-outs will protect, and the opening of the switches or

| Volt- age. | 8 C.P. | 10 C.P. | 16 C.P. | 20 C.P. | 24 C.P. | 32 C.P. | 50 C.P. |
|---------------|--------|---------|---------|---------|---------|---------|---------|
| 52 | .55 | .69 | 1.11 | 1.38 | 1.66 | 2.22 | 3.46 |
| 104 | .28 | .35 | .55 | .69 | .83 | 1.11 | 1.73 |
| 110 | .26 | .33 | .52 | .65 | .78 | 1.05 | 1.64 |
| 220 | .15 | .18 | .29 | .36 | .44 | .58 | .91 |

circuit-breakers will disconnect, all of the wires; that is, in a two-wire system the two wires, and in a three-wire system the three wires, must be protected by the cut-out and disconnected by the operation of the switch or circuit-breaker.

b. Must not be placed in the immediate vicinity of easily ignitable material or where exposed to inflammable gases or dust or to combustible flyings.

c. Must, when exposed to dampness, be either inclosed in a water-proof box or mounted on porcelain knobs.

CONSTANT-CURRENT SYSTEMS.

PRINCIPALLY SERIES ARC LIGHTING.

18. WIRES.—*a.* Must have an approved rubber insulating covering. (See Rule 41.)

b. Must be arranged to enter and leave the building through an *approved* double-contact service switch (see Rule 51, *b*), mounted in a non-combustible case, kept free from moisture, and easy of access to police or firemen.

c. Must always be in plain sight, and never incased, except when *required* by the inspection department having jurisdiction.

d. Must be supported on glass or porcelain insulators which separate the wire at least one inch from the surface wired over, and must be kept *rigidly* at least eight inches from each other, except within the structure of lamps, on hanger-boards, or in cut-out boxes or like places, where a smaller distance is necessary.

e. Must, on side walls, be protected from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than seven feet from the floor. When crossing floor-timbers in cellars or rooms,

where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip, not less than one-half of an inch in thickness.

19. SERIES ARC LAMPS.—(For construction requirements, see Rule 57.)

a. Must be carefully isolated from inflammable material.

b. Must be provided at all times with a glass globe, surrounding the arc and securely fastened upon a closed base. Broken or cracked globes must not be used.

c. Must be provided with a wire netting (having a mesh not exceeding one and one-fourth inches) around the globe, and an *approved* spark-arrester (see Rule 58), when readily inflammable material is in the vicinity of the lamps, to prevent the escape of sparks of melted copper or carbon. It is recommended that plain carbons, not copper-plated, be used for lamps in such places.

d. Where hanger-boards (see Rule 56) are not used, lamps must be hung from insulating supports other than their conductors.

20. INCANDESCENT LAMPS IN SERIES CIRCUITS.—*a.* Must have the conductors installed as required in Rule 18, and each lamp must be provided with an automatic cut-out.

b. Must have each lamp suspended from a hanger-board by means of a rigid tube.

c. No electromagnetic device for switches and no multiple-series or series-multiple system of lighting will be approved.

d. Must not, under any circumstances, be attached to gas fixtures.

CONSTANT-POTENTIAL SYSTEMS.

GENERAL RULES—ALL VOLTAGES.

21. AUTOMATIC CUT-OUTS.—*Fuses and Circuit-breakers.*—(For construction requirements, see Rules 52 and 53.) (See also Rule 17.)

a. Must be placed on all service wires, either overhead or underground, as near as possible to the point where they enter the building, and inside the walls, and arranged to cut off the entire current from the building.

b. Must be placed at every point where a change is made

in the size of wire, unless the cut-out in the larger wire will protect the smaller. (See Rule 16.)

c. Must be in plain sight, or inclosed in an *approved* box (see Rule 54), and readily accessible. They must not be placed in the canopies or shells of fixtures.

d. Must be so placed that no set of incandescent lamps requiring more than 660 watts, whether grouped on one fixture or on several fixtures or pendants, will be dependent upon one cut-out. Special permission may be given in writing by the inspection department having jurisdiction for departure from this rule in the case of large chandeliers, stage borders, and illuminated signs.

e. The rated capacity of fuses must not exceed the allowable carrying capacity of the wire as given in Rule 16. Circuit-breakers must not be set more than 30 per cent above the allowable carrying capacity of the wire unless a fusible cut-out is also installed in the circuit.

22. SWITCHES.—a. Must be placed on all service wires, either overhead or underground, in a readily accessible place, as near as possible to the point where the wires enter the building and arrange to cut off the entire circuit.

b. Must always be placed in dry, accessible places, and should be grouped as far as possible. Knife switches must be so placed that gravity will tend to open rather than to close them.

c. Must not be single-pole when the circuits which they control supply devices which require over 660 watts of energy, or when the difference of potential is over 300 volts.

d. Where flush switches are used, whether with conduit systems or not, they must be inclosed in boxes constructed of or lined with fire-resisting material. No push-buttons for bells, gas-lighting circuits, or the like shall be placed in the same wall plate with switches controlling electric-light or power wiring.

e. Where possible, at all switch or fixture outlets, a seven-eighths-inch block must be fastened between studs or floor-timbers, flush with the back of lathing, to hold tubes and to support switches or fixtures. When this cannot be done, wooden base blocks not less than three-fourths of an inch in thickness, securely screwed to lathing, must be provided for switches, and also for fixtures which are not attached to gas-pipes or conduit tubing.

23. ELECTRIC HEATERS.—*a.* Must, if stationary, be placed in a safe situation, isolated from inflammable materials, and must be treated as sources of heat.

b. Must each have a cut-out and an *indicating* switch. (See Rule 17, *a.*)

c. The attachments of feed wires to the heaters must be in plain sight, easily accessible, and protected from interference, accidental or otherwise.

d. The flexible conductors for portable apparatus, such as irons, etc., must have an *approved* insulating covering. (See Rule 45, *g.*)

e. Must each be provided with a name-plate, giving the maker's name and the normal capacity in volts and amperes.

LOW-POTENTIAL SYSTEMS, 550 VOLTS OR LESS.

Any circuit attached to any machine or combination of machines which develops a difference of potential between any two wires of over 10 volts and less than 550 volts shall be considered as a low-potential circuit and as coming under this class, unless an approved transforming device is used which cuts the difference of potential down to 10 volts or less. The potential difference on the primary circuit must not exceed 3500 volts.

Before pressure is raised above 300 volts on any previously existing system of wiring, the whole must be strictly brought up to all of the requirements of the rules at date.

24. WIRES.

GENERAL RULES.

(See also Rules 14, 15, and 16.)

a. Must be so arranged that under no circumstances will there be a difference of potential of over 300 volts between any bare metal parts in any distributing switch or cut-out cabinet or equivalent centre of distribution.

b. Must not be laid in plaster, cement, or similar finish, and must never be fastened with staples.

c. Must not be fished for any great distance, and only in places where the inspector can satisfy himself that the rules have been complied with.

d. Twin wires must never be used, except in conduits or where flexible conductors are necessary.

f. When run immediately under roofs or in proximity to water tanks or pipes will be considered as exposed to moisture.

SPECIAL RULES FOR OPEN WORK.

IN DRY PLACES.—*g.* Must have an *approved* rubber or “slow-burning weather-proof” insulation. (See Rules 41 and 42.)

h. Must be rigidly supported on non-combustible, non-absorptive insulators, which will separate the wires from each other and from the surface wired over in accordance with the following table:

| Voltage. | Distance from Surface. | Distance between Wires. |
|------------|------------------------|-------------------------|
| 0 to 300 | $\frac{1}{2}$ inch | $2\frac{1}{2}$ inch |
| 300 to 550 | 1 “ | 4 “ |

Rigid supporting requires, under ordinary conditions, where wiring along flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports should be shortened. In buildings of mill construction, mains of No. 8 B. & S. gauge wire or over, where not liable to be disturbed, may be separated about four inches and run from timber to timber, not breaking around, and may be supported at each timber only.

This rule will not be interpreted to forbid the placing of the neutral of an Edison three-wire system in the centre of a three-wire cleat where the difference of potential between the outside wires is not over 300 volts, provided the outside wires are separated two and one-half inches.

In damp places, such as breweries, sugar-houses, packing-houses, stables, dye-houses, paper-mills, pulp-mills, or other buildings especially liable to moisture or to acid or other fumes which might injure the wires or their insulation:

i. Must have an *approved* rubber insulating covering. (See Rule 41.)

j. Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over, and must be kept apart at least two and one-half inches for voltages up to 300, and four inches for higher voltages.

k. Must have no joints or splices.

FOR MOULDING WORK.—*l.* Must have an *approved* rubber insulating covering. (See Rule 41.)

m. Must never be placed in moulding in concealed or damp places, or where the difference of potential between any two wires in the same moulding is over 300 volts.

FOR CONDUIT WORK.—*n.* Must have an *approved* rubber insulating covering. (See Rule 47.)

o. Must not be drawn in until all the mechanical work on the building has, as far as possible, been completed.

p. Must, for alternating-current systems, have the two or more wires of a circuit drawn into the same conduit.

FOR CONCEALED KNOB AND TUBE WORK.—*q.* Must have an *approved* rubber insulating covering. (See Rule 41.)

r. Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over. Must be kept at least ten inches apart, and, when possible, should be run singly on separate timbers or stud-dings. Must be separated from contact with the walls, floor-timbers, and partitions through which they may pass by non-combustible, non-absorptive insulating tubes, such as glass or porcelain.

s. When from the nature of the case it is impossible to place concealed wiring on non-combustible supports of glass or porcelain, an approved armored cable with single or twin conductors (see Rule 48) may be used, where the difference of potential between conductors is not over 300 volts, provided it is installed without joints between outlets, and that the cable armor properly enters all fittings and is rigidly secured in place; or, if the difference of potential between wires is not over 300 volts, and if the wires are not exposed to moisture, they may be fished on the loop system if separately incased throughout in approved flexible conduits.

t. Conduit used for mixed "concealed knob and tube" and "conduit" work must be continuous from outlet to outlet, and must comply throughout with rules for conduit work. (See Rules 24, *n* to 24, *p*, and 25.)

u. Must, at outlets for combination fixtures, be bushed with approved flexible insulating tubes, extending in continuous lengths from the last porcelain support to one inch beyond the outlet, except that an approved outlet insulator may be used. At outlets where there are no gas-pipes, either this class of construction or porcelain bushing tubes may be used.

v. Must have an *approved* rubber insulating covering (see Rule 46), and must not be smaller than No. 18 B. & S. gauge.

w. Supply conductors, and especially the splices to fixture wires, must be kept clear of the grounded part of gas-pipes, and where shells or outlet boxes are used, they must be made sufficiently large to allow the fulfilment of this requirement.

x. Must, when fixtures are wired outside, be so secured as not to be cut or abraded by the pressure of the fastenings or motion of the fixture.

25. INTERIOR CONDUITS.—*a.* No conduit tube having an internal diameter of less than five-eighths of an inch shall be used. With lined conduit, this measurement is to be taken inside the metal tube.

b. Must be continuous from one junction box to another, or to fixtures, and the conduit tube must properly enter all fittings.

c. Must first be installed as a complete conduit system, without the conductors.

d. Must be equipped at every outlet with an approved outlet box or plate.

e. Metal conduits, where they enter the junction boxes, and at all other outlets, etc., must be supplied with a capping of approved material, fitted so as to protect the wire from abrasion.

f. The metal of the conduit must be permanently and effectually grounded.

26. FIXTURES.—(See also Rules 22, *e*, and 24, *v* to 24, *x*.)—*a.* Must, when supported from the gas-piping or any grounded metal-work of a building, be insulated from such piping or metal-work by means of *approved* insulating joints (see Rule 59) placed as close as possible to the ceiling.

b. Must have all burrs, or fins, removed before the conductors are drawn into the fixtures.

c. Must be tested for “contacts” between conductors and fixtures, for “short circuits” and for ground connections, before they are connected to their supply conductors.

27. SOCKETS.—(For construction requirements, see Rule 55.)—

a. In rooms where inflammable gases may exist, the incandescent lamp and the socket must be inclosed in a vapor-tight globe and supported on a pipe-hanger, wired with *approved* rubber-covered wire (see Rule 41) soldered directly to the circuit.

b. In damp or wet places, or over especially inflammable material, water-proof sockets must be used.

28. FLEXIBLE CORD.—*a.* Must have an *approved* insulation and covering. (See Rule 45, *c.*)

b. Must not be used where the difference of potential between the two wires is over 300 volts.

c. Must not be used as a support for clusters.

d. Must not be used except for pendants, portable lamps, or motors, and portable heating apparatus.

e. Must not be used in show windows.

f. Must be protected by insulating bushings where it enters the socket.

g. Must be so suspended that the entire weight of the socket and lamp will be borne by knots under the bushing in the socket and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws.

29. ARC LIGHTS ON CONSTANT-POTENTIAL CIRCUITS.—*a.* Must have a cut-out (see Rule 17, *a*) for each lamp or each series of lamps.

b. All resistances or regulators must be inclosed in non-combustible material and must be treated as sources of heat. Incandescent lamps must not be used for this purpose.

c. Must be supplied with globes and protected by spark-arresters and wire netting around the globe, as in the case of series arc lamps. (See Rules 19 and 58.)

30. ECONOMY COILS.—*a.* Economy and compensator coils for arc lamps must be mounted on non-combustible, non-absorptive insulating supports, such as glass or porcelain, allowing an air space of at least one inch between frame and support, and must, in general, be treated as sources of heat.

Soldering Fluid.—The following formula for soldering fluid for electric wires is recommended by the National Board of Fire Underwriters, in the "National Electrical Code":

Saturated solution of zinc chloride. 5 parts.

Alcohol. 4 parts.

Glycerine. 1 part.

Heating.—During the progress of this part of the work, the superintendent must pay strict attention to the running of pipes, location of valves, registers, radiators, etc.

If the system to be used is a simple hot-air system, he must see that all hot-air pipes are run as direct as possible to their respective outlets; there should be as few bends or angles as possible, and where a turn is made it should be done with an easy elbow and not with a square turn, as is often done.

He should see that the pipes are so run that there will be no woodwork close enough to them to cause danger from fire.

LOCATION OF REGISTERS.—The bottom register when placed in the wall of a room should be just high enough to clear the base, and the one at the ceiling just low enough to clear the cornice or border.

A more evenly heated room will be the result if the registers are placed in an outside wall than if placed in an inside wall, but this point is often ignored, as it requires more pipe, and the hot-air pipes in the wall have to be covered to prevent the escape of the heat.

He should see that the outlets of all hot-air or vent pipes are so arranged that the register plate can be fastened on without any trouble, and he should also see that the flange of the outlet projects just far enough to receive the plaster; workmen are usually very careless regarding this point and often leave the flange project too far, and the plasterer will work to it and thus make a crooked job of plastering.

STEAM OR HOT-WATER SYSTEMS.—When either of the above systems are used the superintendent must see that the pipes are run and given the proper fall from the radiators, to carry back to the boiler the condensed steam, or the cold water. In a one-pipe system, which is the simplest form of steam heating, there is but one line of pipe from the boiler to the radiators and this pipe must be given fall enough to carry back the condensed steam. In the two-pipe system there are two lines of pipes, and the steam or hot water makes a circuit through the radiator and back to the boiler in the return pipe.

The superintendent must see that valves are placed where called for, or shown on the drawings, and he should see that all valves used are the full capacity or of equal area of the pipe which they control.

In taking branch lines from the main they should always be taken from the top of the pipe so that all drippings or condensation can run back without trapping the pipe.

All radiator connections, and all T or branch outlets, should

be plugged or capped as soon as put in place to prevent any dirt from getting in the pipe and possibly damaging the valves.

In running all pipes care must be taken to provide for expansion and contraction, and suitable provision made so there will be no danger of breaking a pipe or connection.

After the piping is all in place it should be tested before being covered up; this should be done by filling the pipes full of water and applying pressure with a force-pump to 100 or 150 pounds, then if possible a steam test should be made before covering the pipes.

All hot-water or steam pipes should be kept clear of all woodwork or other combustible material by about 4 inches.

PRESSURE OF SYSTEMS.—The high-pressure system is applied with steam at any pressure over 10 pounds.

The low-pressure system is operated with a pressure of from 2 to 5 pounds.

LOCATION OF RADIATORS.—Radiators should always be placed at outside walls, and near or under the window, so as to counteract the entrance of the cold air at the window. This will give a more even temperature in the room than if the radiator were located at the other side of the room.

In piping for a hot-water system all bends and angles should be made as easy as possible so as to prevent friction.

DATA FOR HOT-WATER HEATING.

TABLE OF RATIOS.

| Dwellings. | One Square Foot of Radiating Surface will Heat | |
|---|--|-------------|
| Living-rooms, one side exposed. | 30 | cubic feet. |
| “ , two sides exposed. | 28 | “ “ |
| “ , three sides exposed. | 28 | “ “ |
| Sleeping-room. | From 30 to 40 | “ “ |
| Hall-room. | “ 20 “ 30 | “ “ |
| Bath-room. | “ 20 “ 30 | “ “ |
| Public Buildings. | | |
| School-rooms. | “ 30 “ 50 | “ “ |
| Offices. | “ 30 “ 50 | “ “ |
| Factories. | “ 50 “ 70 | “ “ |
| Stores. | “ 50 “ 70 | “ “ |
| Auditoriums. | “ 80 “ 100 | “ “ |
| Churches. | “ 80 “ 100 | “ “ |

The above ratios are for direct heating and an average temperature of 168° Fahr. in the water.

If indirect radiators are used, allow not less than 50 per cent more surface and for direct-indirect 25 per cent more.

Due care must be exercised to provide for any special conditions, such as exposure of buildings, material of construction, location and length and size of mains governing plant under consideration.

Allowances should also be made for loose construction of doors and windows, which admit large volumes of cold air, and provide for outside doors which are used frequently and open directly into the room.

In estimating the radiating surface, it should be borne in mind that a large surface at a comparatively low temperature gives a much pleasanter atmosphere than a small surface at a high temperature.

LIST OF SIZES OF HOT-WATER MAINS.

| Radiation. | | | | |
|-------------|-----------------|-------------|---|--------------|
| 75 | | square feet | ..... | 1 inch pipe. |
| 75 to 125 | “ “ | “ “ | ..... | 1¼ “ “ |
| 125 “ 175 | “ “ | “ “ | ..... | 1½ “ “ |
| 175 “ 300 | “ “ | “ “ | ..... | 2 “ “ |
| 300 “ 475 | “ “ | “ “ | ..... | 2½ “ “ |
| 475 “ 700 | “ “ | “ “ | ..... | 3 “ “ |
| 700 “ 950 | “ “ | “ “ | ..... | 3½ “ “ |
| 950 “ 1200 | “ “ | “ “ | ..... | 4 “ “ |
| 1200 “ 1575 | “ “ | “ “ | ..... | 4½ “ “ |
| 1575 “ 1975 | “ “ | “ “ | ..... | 5 “ “ |
| 1975 “ 2375 | “ “ | “ “ | ..... | 5½ “ “ |
| 2375 “ 2850 | “ “ | “ “ | ..... | 6 “ “ |
| Inch Mains. | | Branches. | | |
| 1 | will supply two | ¾ in. | | |
| 1¼ | “ “ | “ 1 | “ | |
| 1½ | “ “ | “ 1¼ | “ | |
| 2 | “ “ | “ 1½ | “ | |
| 2½ | “ “ | “ 1½ | and one 1¼ in., or one 2 in. and one 1½ in. | |
| 3 | “ “ | one 2½ | and one 1 in., or two 2 in. and one 1½ in. | |
| 3½ | “ “ | two 2½ | or one 3 in. and one 2 in., or three 2 in. | |
| 4 | “ “ | one 3½ | and one 2½ in., or two 3 in., or four 2 in. | |
| 4½ | “ “ | “ 3½ | and one 3 in., or one 4 in. and one 2½ in. | |
| 5 | “ “ | “ 4 | and one 3 in., or one 4½ in. and one 2½ in. | |
| 6 | “ “ | two 4 | and one 3 in., or four 3 in. or ten 2 in. | |
| 7 | “ “ | one 6 | and one 4 in., or two 4 in. and one 2 in. | |
| 8 | “ “ | two 6 | and one 5 in., or five 4 in. and two 2 in. | |

APPROXIMATE NUMBER OF CUBIC FEET OF AIR ONE SQUARE FOOT OF RADIATION WILL HEAT. (Nason.)

| One Square Foot of Radiating Surface will Heat with | In Dwellings, Schoolrooms, Offices, etc. Cubic Feet. | In Halls, Stores, Lofts, Factories, etc. Cubic Feet. | In Churches, Large Auditoriums, etc. Cubic Feet. |
|---|--|--|--|
| Direct-steam radiation. | 60 to 80 | 75 to 100 | 150 to 200 |
| Indirect-steam radiation. | 40 to 50 | 50 to 70 | 100 to 140 |
| High temperature, direct hot-water radiation. | 50 to 70 | 65 to 90 | 130 to 180 |
| Low temperature, direct hot-water radiation. | 30 to 50 | 35 to 65 | 70 to 130 |
| High temperature, indirect hot-water radiation. | 30 to 60 | 35 to 75 | 70 to 150 |
| Low temperature, indirect hot-water radiation. | 20 to 40 | 25 to 50 | 50 to 100 |

The above proportions will give a temperature in the buildings described of 70° Fahr., the thermometer being at zero in the outside atmosphere.

While there is no iron-clad rule for computing the proper amount of radiation for heating buildings owing to the variable conditions that enter into the calculation, the above table will prove valuable if allowances are made for extreme cases.

It is well to remember that small rooms, rooms with large window surfaces or exposed sides, and rooms with exceptionally thick walls or fire-proof tiling require more radiating surface in proportion to space than is ordinarily needed. Frame buildings require more radiation than stone, and stone more than brick.

The following rules regarding heating by steam are given by Babcock & Wilcox:

Heating by Steam.—In heating buildings by steam, the amount of boiler and heating pipes depends largely on the kind of building and its location. Wooden buildings require more than stone, and stone more than brick. Iron fronts require still more, and glass in windows demands twenty times as much heat as the same surface in brick walls. Also if the heating be done by indirect radiation from 50 to 100 per cent more surface will be required than when direct radiation is used. No rules can be given which will not require a liberal application of “the coefficient of common sense.”

Radiating surface may be calculated by the rule: *Add together the square feet of glass in the windows, the number of cubic feet of air required to be changed per minute, and one-twentieth the*

surface of external wall and roof; multiply this sum by the difference between the required temperature of the room and that of the external air at its lowest point and divide the product by the difference in temperature between the steam in the pipes and the required temperature of the room. The quotient is the required radiating surface in square feet. Each square foot of radiating surface may be depended upon in average practice to give out three heat-units per hour for each degree of difference in temperature between the steam inside and the air outside, the range under different conditions being about 50 per cent above or below that figure. In *indirect* heating the efficiency of the radiating surface will increase, and the temperature of the air will diminish, when the quantity of the air caused to pass through the coil increases. Thus one square foot radiating surface, with steam at 212° , has been found to heat 100 cubic feet of air per hour from zero to 150° , or 300 cubic feet from zero to 100° in the same time.

The best results are attained by using indirect radiation to supply the necessary ventilation, and direct radiation for the balance of the heat. The best place for a radiator in a room is beneath a window. Heated air cannot be made to enter a room unless means are provided for permitting an equal amount to escape. The best place for such exit openings is near the floor.

Small pipes are more effective than large. When the diameter is doubled, 20 per cent additional surface should be allowed, and for three times the diameter 30 per cent additional is required. For indirect radiation that surface is most efficient which secures the most intimate contact of the current of air with the heated surface. Rooms on windward side of house require more radiating surface than those on sheltered side.

Where the condensed water is returned to the boiler, or where low pressure of steam is used, the diameter of mains leading from the boiler to the radiating surface should be equal, in inches, to *one-tenth the square root of the radiating surface, mains included*, in square feet. Thus a 1-inch pipe will supply 100 square feet of surface, itself included. Return pipes should be at least $\frac{3}{4}$ inch in diameter, and never less than one-half the diameter of the main—longer returns requiring larger pipes. A thorough drainage of steam-pipes will effectually prevent all cracking and pounding noises therein.

The amount of air required for ventilation is from 4 to 16 cubic feet per minute for each person, the larger amount being for prisons and hospitals. From $\frac{1}{2}$ to 1 cubic foot per minute should be allowed for each lamp or gas-burner employed.

One square foot of boiler surface will supply from 7 to 10 square feet of radiating surface, depending upon the size of boiler and the efficiency of its surface, as well as that of the radiating surface. Small boilers for house use should be much larger proportionately than large plants. Each horse-power of boiler will supply from 240 to 360 feet of 1-inch steam-pipe, or from 80 to 120 square feet of radiating surface.

Cubic feet of space has little to do with amount of steam or surface required, but is a convenient factor for rough calculations. Under ordinary conditions one horse-power will heat, approximately, in

| | |
|---|--------------------------|
| Brick dwellings, in blocks, as in cities. . . | 15,000 to 20,000 cu. ft. |
| Brick stores, in blocks. | 10,000 to 15,000 cu. ft. |
| Brick dwellings, exposed all round. . . . | 10,000 to 15,000 cu. ft. |
| Brick mills, shops, factories, etc. | 7,000 to 10,000 cu. ft. |
| Wooden dwellings, exposed | 7,000 to 10,000 cu. ft. |
| Foundries and wooden shops. | 6,000 to 10,000 cu. ft. |
| Exhibition buildings, largely glass, etc. | 4,000 to 15,000 cu. ft. |

The system of heating mills and manufactories by means of pipes placed overhead is being largely adopted, and is recommended by the Boston Manufacturers' Mutual Fire Insurance Company, in preference to radiators near the floor, particularly for rooms in which there are shafting and belting to circulate the air.

In heating buildings care should be taken to supply the necessary moisture to keep the air from becoming "dry" and uncomfortable. The capacity of air for moisture rises rapidly as it is heated, it being four times as great at 72° as at 32°. For comfort, air should be kept at about "50 per cent saturated." This would require one pound of vapor to be added to each 2,500 cubic feet heated from 32° to 70°.

A much-needed attachment has recently been introduced, which acts automatically upon the steam-valves of the radiators, or upon the hot-air registers and ventilators, and maintains the temperature in a room to within one-half a degree of any standard desired.

A "separator" acting by centrifugal force has been recently tested, and is very efficient, in trapping out all the water entrained in steam. It will be found valuable, particularly where the steam has to be carried a long distance from the boiler, and for the purpose of preventing "hammering" of water in the pipes.

RESISTANCE TO FLOW BY BENDS, VALVES, ETC.—Mr. Briggs states in "Warming Buildings by Steam," that the resistance at the entrance to a pipe consists of two parts, namely, the head, $\frac{v^2}{2g}$, which is necessary to create the velocity of flow and the head, $0.505\frac{v^2}{2g}$, which overcomes the resistance to entrance offered by the mouth of the pipe. The total loss of head at entrance then equals the sum of these, or $1.505\frac{v^2}{2g}$, in which v =velocity of flow of steam in the pipe, in feet per second, and g =acceleration due to gravity, or 32.2.

The Babcock & Wilcox Company state in "Steam" that the resistance at the opening and that at a globe valve are each about the same as that caused by an additional length of straight pipe, as computed by the formula

$$\text{Additional length of pipe} = \frac{114 \times \text{diameter of pipe}}{1 + (3.6 \div \text{diameter})}$$

from which has been computed the following table:

| | | | | | | | | |
|----------------------------------|----|----|----|-----|-----|-----|-----|-----|
| Diameter in inches. | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 | 7 |
| Additional length, feet. | 7 | 10 | 13 | 16 | 20 | 28 | 36 | 44 |
| Diameter in inches. | 8 | 10 | 12 | 15 | 18 | 20 | 22 | 24 |
| Additional length, feet. | 53 | 70 | 88 | 115 | 143 | 162 | 181 | 200 |

The resistance to flow at a right-angled elbow is about equal to $\frac{2}{3}$ that of a globe valve.

The above values are to be considered as being only approximations to the truth.

Example.—Find the discharge from a steam-pipe when the given length=120 feet and the diameter=8 inches, the pipe containing 6 right-angled elbows and two globe valves, the pressure at the two ends being respectively 105 and 103 pounds per square inch gauge.

The resistance to entrance, from the above table, for 8-inch pipe = 53 feet; the resistance of 6 elbows = $6 \times 53 \times \frac{2}{3} = 212$ feet; the resistance of two globe valves = $2 \times 53 = 106$ feet; making a total resistance = $53 + 212 + 106 = 371$ feet of additional length of pipe. Therefore the steam would encounter the same resistance flowing through a straight 8-inch pipe whose length equals $120 + 371$, or 491 feet, as it would in flowing through the given pipe with its various resistances.

Then in the formula

$$W = c \sqrt{\frac{w(p - p_2)d^5}{L}},$$

$L = 491$ feet; $p = 105$ pounds per square inch; $p_2 = 103$ pounds per square inch; $d = 8$ inches; c , for an 8-inch pipe, = 60.7; and w , from table of Properties of Saturated Steam, = 0.27.

Substituting in formula we get

$$W = 60.7 \sqrt{\frac{0.27(105 - 103)8^5}{491}} = 364.$$

The pipe, then, under the stated conditions, would discharge approximately 364 pounds of steam per minute, or 21,800 pounds per hour; which, on the basis of 30 pounds per horse-power hour, would have a capacity of 728 boiler horse-powers. Since one pound of steam at 104 pounds gauge has a volume of 3.7 cubic feet, the pipe would discharge 1,350 cubic feet per minute, or 81,000 cubic feet per hour.

NON-CONDUCTING COVERINGS FOR STEAM-PIPES.—A bare pipe carrying steam, and made of iron, steel, or other conducting material, loses heat by convection to the surrounding air and by radiation to the surrounding objects, both of which cause a loss of steam by condensation.

This loss is lessened in practice by covering the outer surface of the steam-pipe with a material that will offer a greater resistance to the flow of heat than that offered by the material of the pipe.

A good material for this purpose should not suffer serious deterioration from the heat or vibration to which it would be subjected in practice; and in all cases where damage from fire might result, it should never consist of combustible matter. Under the conditions of practice, especially in places where it

may become damp, a good pipe covering should consist of materials that will not rapidly deteriorate, and should contain nothing that will seriously corrode the pipe.

Since air does not take up heat by radiation, but receives heat by contact with a hot body only, it would appear that the greater the porosity of a material—that is, the greater the percentage of volume of finely divided air it contains—the greater will be its non-conducting qualities. This is noticeably the case in the commercial pipe coverings that consist substantially of the same materials, when these materials contain different percentages of still air. In every case the more porous the material, other things being equal, the greater will be its non-conducting properties.

The following table contains averages made up from results obtained by a number of carefully conducted tests, and represent approximately what may be expected when these materials are properly applied as steam-pipe coverings in practice. The table gives the quantity of heat transmitted through covered steam-pipes, when that transmitted through a naked pipe is taken as 100, the covering, except where otherwise indicated, being one inch thick.

| Kind of Covering. | Relative Amount of Heat Transmitted. |
|--|--------------------------------------|
| Naked pipe. | 100 |
| Hair-felt, asbestos lined and canvas covered. | 16 to 18 |
| Wool felt, " " " " " " | 20 " 22 |
| Two layers of asbestos paper. | 70 " 80 |
| Four " " " " " " | 45 " 55 |
| Asbestos mixed with some plaster of Paris. | 28 " 34 |
| Magnesia mixed with a little asbestos fibre, canvas covered. | 18 " 20 |
| Best mineral wool, lined and canvas covered. | 18 " 20 |
| Pipe painted with black asphaltum. | about 105 |
| " " " white glossy paint. | " 95 |

For coverings having values less than 25 in the above table, the values for thicknesses of covering of $1\frac{1}{2}$ and 2 inches (those in the table being for 1 inch, as noted) may be approximately obtained by multiplying respectively by 0.78 and 0.58. Thus a pipe covered with magnesia and canvas covered would transmit an amount, if $1\frac{1}{2}$ inches thick, = $(18 \text{ to } 20) \times 0.78 = 14 \text{ to } 15.5$; and if 2 inches thick an amount = $(18 \text{ to } 20) \times 0.58 = 10.5 \text{ to } 11.5$,

that transmitted by a similar bare pipe being 100 in the same length of time.

The following table gives the result of tests made by G. B. Dunford, of Hamilton, Ont., of various materials in regard to their quality as a non-conductor of heat.

| | | |
|--|------|-----------|
| Combination of asbestos, hair-felt, air space, and wood. | 100 | per cent. |
| Asbestos and hair-felt chopped and mixed with lime putty. | 87 | “ “ |
| A plastic cement manufactured by parties at Troy, N. Y., with $\frac{1}{2}$ inch hair-felt outside. . . | 86.6 | “ “ |
| Paper pulp mixed with lime putty, 1 inch, cov- ered with sheeting of wood pulp. | 85 | “ “ |
| Mineral wool cased with wood. | 81 | “ “ |
| Mineral wool cased with sheet iron. | 79 | “ “ |
| Charcoal. | 60 | “ “ |
| Sawdust. | 41 | “ “ |
| Loam and chopped straw sealed with wood. . . | 32 | “ “ |
| Asbestos. | 29 | “ “ |
| Coal ashes. | 24 | “ “ |
| Air space. | 20 | “ “ |
| Fire-brick. | 15 | “ “ |
| Red brick. | 12 | “ “ |
| Sand. | 9.3 | “ “ |

Steam.—Under the ordinary atmospheric pressure of 14.7 pounds per square inch, water boils at 212° F., passing off as steam, the temperature at which it boils varying with a variation in the pressure.

DRY STEAM is steam not containing any free moisture. It may be either saturated or superheated.

WET STEAM is steam containing free moisture in the form of spray or mist, and has the same temperature as dry saturated steam of the same pressure.

SATURATED STEAM is steam in its normal state, that is, steam whose temperature is that due its pressure; by which is meant steam at the same temperature as that of the water from which it was generated and upon which it rests.

SUPERHEATED STEAM is steam at a temperature above that due to its pressure.

A **BRITISH THERMAL UNIT** is the quantity of heat required

to raise one pound of water at $39^{\circ}.1$ F. through one degree of temperature.

THE TOTAL HEAT OF THE WATER is the number of British thermal units needed to raise one pound of water from 32° F. to the boiling-point under the given pressure.

THE LATENT HEAT OF STEAM is the number of British thermal units required to convert one pound of water, at the boiling-point, into steam of the same temperature.

THE TOTAL HEAT OF SATURATED STEAM is the number of heat-units required to raise a pound of water from 32° F. to the boiling-point, at the given pressure, plus the number required to evaporate the water at that temperature.

THE SPECIFIC HEAT OF STEAM is the quantity of heat required to raise the temperature of one pound of steam through one degree of temperature. In British units and near the saturation temperature it equals, at constant pressure, 0.48.

THE SPECIFIC GRAVITY OF STEAM at any temperature and pressure, as compared with air of same temperature and pressure, is approximately 0.622. One cubic inch of water evaporated into steam at 212° F. becomes 1646 cubic inches, that is, nearly 1 cubic foot.

Water in contact with saturated steam has the same temperature as the steam itself. Water introduced into superheated steam will be vaporized until the steam becomes saturated and its temperature becomes that due its pressure. Cold water, or water at a lower temperature than that of the steam, introduced into saturated steam will condense some of it, thus lowering both the temperature and pressure of the rest until the temperature again equals that due its pressure.

USEFUL RULES AND INFORMATION.—*Steam.*—A cubic inch of water evaporated under ordinary atmospheric pressure is converted into 1 cubic *foot* of steam (approximately).

The specific gravity of steam (at atmospheric pressure) is 0.411 that of air at 34° Fahr., and 0.0006 that of water at the same temperature.

27,222 cubic feet of steam weigh 1 pound; 13,817 cubic feet of air weigh 1 pound.

Locomotives average a consumption of 3,000 gallons of water per 100 miles run.

The best-designed boilers, well set, with good draft and skilful firing, will evaporate from 7 to 10 pounds of water per pound of first-class coal.

In calculating horse-power of tubular or flue boilers, consider 15 square feet of heating surface equivalent to one *nominal* horse-power.

On 1 square foot of grate can be burned on an average from 10 to 12 pounds of hard coal, or 18 to 20 pounds of soft coal, per hour, with natural draft. With forced draft nearly double these amounts can be burned.

Steam-engines, in economy, vary from 14 to 60 pounds of feed-water and from $1\frac{1}{2}$ to 7 pounds of coal per hour per indicated horse-power. See table below for duty of high-grade engines.

Condensing-engines require from 20 to 30 gallons of water, at an average low temperature, to condense the steam represented by every gallon of water evaporated in the boilers supplying engines—approximately for most engines, we say, from 1 to $1\frac{1}{2}$ gallons condensing water per minute per indicated horse-power.

Surface condensers should have about 2 square feet of tube (cooling) surface per horse-power for a compound steam-engine. Ordinary engines will require more surface according to their economy in the use of steam. It is absolutely necessary to place air-pumps below condensers to get satisfactory results.

RATIO OF VACUUM TO TEMPERATURE (FAHRENHEIT) OF FEED-WATER.

| | |
|-------------------------------|------|
| 00 inches vacuum | 212° |
| 11 " " | 190° |
| 18 " " | 170° |
| $22\frac{1}{2}$ " " | 150° |
| 25 * " " | 135° |
| $27\frac{1}{2}$ " " | 112° |
| $28\frac{1}{2}$ " " | 92° |
| 29 " " | 72° |
| $29\frac{1}{2}$ " " | 52° |

WEIGHT AND COMPARATIVE FUEL VALUE OF WOOD.

1 cord air-dried hickory or hard maple weighs about 4500 pounds, and is equal to about 2000 pounds coal.

1 cord air-dried white oak weighs about 3850 pounds, and is equal to about 1715 pounds coal.

1 cord air-dried beech, red oak, or black oak weighs about 3250 pounds, and is equal to about 1450 pounds coal.

* Usually considered the standard point of efficiency—condenser and air-pump being well proportioned.

1 cord air-dried poplar (whitewood), chestnut, or elm weighs about 2350 pounds, and is equal to about 1050 pounds coal.

1 cord air-dried average pine weighs about 2000 pounds, and is equal to about 925 pounds coal.

From the above it is safe to assume that 2½ pounds of dry wood is equal to 1 pound average quality of soft coal, and that the full value of the same *weight* of different woods is very nearly the same—that is, a pound of hickory is worth no more for fuel than a pound of pine, assuming both to be dry. It is important that the wood be dry, as each 10 per cent of water or moisture in wood will detract about 12 per cent from its value as fuel.

PIPE DATA.

| Inside Diameter Nominal. | Internal Area in Inches. | Circumference of Pipe in Inches. | Length of Pipe in Feet per Sq. Ft. of Radiating Surface. | Number of Sq. Feet in 1 Lineal Foot of Pipe. | Contents in Gallons per Foot. | Weight in Pounds per Lineal Foot. | Number of Threads per Inch of Screw. |
|--------------------------|--------------------------|----------------------------------|--|--|-------------------------------|-----------------------------------|--------------------------------------|
| 1 | .3048 | 2.652 | 4.502 | .221 | .0102 | 0.84 | 14 |
| 1 ¼ | .5333 | 3.299 | 3.637 | .274 | .0230 | 1.126 | 14 |
| 1 ½ | .8627 | 4.134 | 2.903 | .344 | .0408 | 1.670 | 11 ½ |
| 1 ¾ | 1.496 | 5.215 | 2.301 | .434 | .0638 | 2.258 | 11 ¼ |
| 2 | 2.038 | 5.969 | 2.010 | .497 | .0918 | 2.694 | 11 ¼ |
| 2 ¼ | 3.355 | 7.461 | 1.611 | .621 | .1632 | 3.667 | 11 ¼ |
| 2 ½ | 4.783 | 9.032 | 1.328 | .752 | .2550 | 5.773 | 8 |
| 3 | 7.368 | 10.99 | 1.091 | .916 | .3673 | 7.547 | 8 |
| 3 ½ | 9.837 | 12.56 | .955 | 1.044 | .4998 | 9.055 | 8 |
| 4 | 12.730 | 14.13 | .849 | 1.178 | .6528 | 10.728 | 8 |
| 4 ½ | 15.939 | 15.70 | .765 | 1.309 | .8263 | 12.492 | 8 |
| 5 | 19.990 | 17.47 | .629 | 1.656 | 1.0200 | 14.564 | 8 |
| 6 | 28.889 | 20.81 | .577 | 1.733 | 1.5500 | 18.767 | 8 |

DUTY OF STEAM-ENGINES.—A well-known engineer of high authority gives the following comparative figures, showing the economy of high-grade steam-engines in actual practice:

| Type of Engine. | Temperature of Feed-water. | Pounds of Water Evaporated per Pound of Cumberland Coal. | Pounds of Steam per I.H.P. Used per Hour. | Pounds of Cumberland Coal Used per I.H.P. per Hour. | Cost per I.H.P. per Hour, Supposing Coal at \$6 per Ton. |
|----------------------------|----------------------------|--|---|---|--|
| Non-condensing. | 210° | 10.5 | 29. | 2.75 | \$0.0073 |
| Condensing. | 100° | 9.4 | 20. | 2.12 | 0.0056 |
| Compound jacketed. | 100° | 9.4 | 17. | 1.81 | 0.0045 |
| Triple-expansion jacketed. | 100° | 9.4 | 13.6 | 1.44 | 0.0036 |

The effect of a good condenser and air-pump should be to make available about 10 pounds more mean effective pressure with the same terminal pressure; or to give the same mean effective pressure with a correspondingly less terminal pressure. When the load on the engine requires 20 pounds M.E.P., the condenser does half the work; at 30 pounds, one-third of the work; at 40 pounds, one-fourth, and so on. It is safe to assume that practically the condenser will save from one-fourth to one-third of the fuel, and it can be applied to any engine, cut-off, or throttling where a sufficient supply of water is available.

DATA FOR STEAM HEATING.—Under ordinary conditions, one square foot of direct radiating surface will heat approximately in

| | |
|---|-------------------|
| Bathroom, living-room, with two or three exposures and large amount of glass. | 40 cu. ft. |
| Living-room, one or two exposures, with large amount of glass. | 50 cu. ft. |
| Living-room, one exposure, amount of glass. . | 60 cu. ft. |
| Sleeping-rooms. | 55 to 70 cu. ft. |
| Halls. | 50 to 70 cu. ft. |
| Schoolrooms. | 60 to 80 cu. ft. |
| Churches and auditoriums of large cubic contents and high ceilings. | 65 to 100 cu. ft. |
| Lofts, workshops, and factories. | 75 to 150 cu. ft. |

If indirect radiators are used, allow not less than 50 per cent more surface than for direct, and for direct indirect, 25 per cent more.

In estimating the radiating surface make due allowance for exposure of building, material of construction, location, length and size of main location and capacity of boiler, also loose construction of doors and windows.

COMPARISON OF THERMOMETRIC SCALES.—To convert the degrees of Centigrade into those of Fahrenheit, multiply by 9 divide by 5, and add 32.

To convert degrees of Centigrade into those of Réaumur, multiply by 4 and divide by 5.

To convert degrees of Fahrenheit into those of Centigrade, deduct 32, multiply by 5, and divide by 9.

To convert degrees of Fahrenheit into those of Réaumur, deduct 32, divide by 9, and multiply by 4.

To convert degrees of Réaumur into those of Centigrade, multiply by 5 and divide by 4.

LIST OF SIZES OF STEAM MAINS.

| Radiation. | | One-pipe Work. | Two-pipe Work. |
|----------------------|-------|-------------------|--|
| 40 to 50 square feet | ..... | 1 inch | $\frac{3}{4} \times \frac{3}{4}$ inch. |
| 100 to 125 | ..... | 1 $\frac{1}{2}$ " | 1 \times $\frac{1}{2}$ " |
| 125 to 250 | ..... | 1 $\frac{1}{2}$ " | 1 $\frac{1}{2}$ \times 1 " |
| 250 to 400 | ..... | 2 " | 1 $\frac{1}{2}$ \times 1 $\frac{1}{2}$ " |
| 400 to 650 | ..... | 2 $\frac{1}{2}$ " | 2 \times 1 $\frac{1}{2}$ " |
| 650 to 900 | ..... | 3 " | 2 $\frac{1}{2}$ \times 2 " |
| 900 to 1250 | ..... | 3 $\frac{1}{2}$ " | 3 \times 2 $\frac{1}{2}$ " |
| 1250 to 1600 | ..... | 4 " | 3 $\frac{1}{2}$ \times 3 " |
| 1600 to 2050 | ..... | 4 $\frac{1}{2}$ " | 4 \times 3 $\frac{1}{2}$ " |
| 2050 to 2500 | ..... | 5 " | 4 $\frac{1}{2}$ \times 4 " |
| 2500 to 3600 | ..... | 6 " | 5 \times 4 $\frac{1}{2}$ " |
| 3600 to 5000 | ..... | 7 " | 6 \times 5 " |
| 5000 to 6500 | ..... | 8 " | 7 \times 6 " |
| 6500 to 8100 | ..... | 9 " | 8 \times 6 " |
| 8100 to 10000 | ..... | 10 " | 9 \times 6 " |

TABLE OF EXPANSION OF WROUGHT-IRON PIPE.

| Temperature of the Air when the Pipe is Fitted. | Length of Pipe when Fitted. | Length of Pipe when Heated. | | | | | |
|---|-----------------------------|-----------------------------|------|--------------|------|--------------|------|
| | | 160 Degrees. | | 180 Degrees. | | 200 Degrees. | |
| | | Feet. | In. | Feet. | In. | Feet. | In. |
| Degrees Fahr. | Feet. | Feet. | In. | Feet. | In. | Feet. | In. |
| 0 | 100 | 100 | 1.28 | 100 | 1.44 | 100 | 1.60 |
| 32 | 100 | 100 | 1.02 | 100 | 1.18 | 100 | 1.34 |
| 64 | 100 | 100 | .77 | 100 | .93 | 100 | 1.09 |

To convert degrees of Réaumur into those of Fahrenheit, multiply by 9, divide by 4, and add 32.

In De Lisle's thermometer, used in Russia, the graduation begins at boiling-point, which is marked zero, and the freezing-point is 150.

The following rules regarding the installation of heating apparatus are taken from the New York Building Code:

HEATING APPARATUS, DRYING-ROOMS, GAS- AND WATER-PIPES.

Sec. 84. *Heating-furnace and Boilers.* — A brick-set boiler shall not be placed on any wood or combustible floor or beams. Wood or combustible floors and beams under and not less than three feet in front and one foot on the sides of all portable boilers

shall be protected by a suitable brick foundation of not less than two courses of brick well laid in mortar on sheet iron; the said sheet iron shall extend at least twenty-four inches outside of the foundation at the sides and front. Bearing lines of bricks, laid on the flat, with air-spaces between them, shall be placed on the foundation to support a cast-iron ash-pan of suitable thickness, on which the base of the boiler shall be placed, and shall have a flange, turned up in the front and on the sides, four inches high; said pan shall be in width not less than the base of the boiler and shall extend at least two feet in front of it. If a boiler is supported on a cast-iron base with a bottom of the required thickness for an ash-pan, and is placed on bearing lines of brick in the same manner as specified for an ash-pan, then an ash-pan shall be placed in front of the said base and shall not be required to extend under it. All lath-and-plaster and wood ceilings and beams over and to a distance of not less than four feet in front of all boilers shall be shielded with metal. The distance from the top of the boiler to said shield shall be not less than twelve inches. No combustible partition shall be within four feet of the sides and back and six feet from the front of any boiler, unless said partition shall be covered with metal to the height of at least three feet above the floor, and shall extend from the end or back of the boiler to at least five feet in front of it; then the distance shall be not less than two feet from the sides and five feet from the front of the boiler. All brick hot-air furnaces shall have two covers, with an air-space of at least four inches between them; the inner cover of the hot-air chamber shall be either a brick arch or two courses of brick laid on galvanized iron or tin, supported on iron bars; the outside cover, which is the top of the furnace, shall be made of brick or metal supported on iron bars, and so constructed as to be perfectly tight, and shall be not less than four inches below any combustible ceiling or floor-beams. The walls of the furnace shall be built hollow in the following manner: One inner and one outer wall, each four inches in thickness, properly bonded together with an air-space of not less than three inches between them. Furnaces must be built at least four inches from all woodwork. The cold-air boxes of all hot-air furnaces shall be made of metal, brick, or other incombustible material, for a distance of at least ten feet from the furnace. All portable hot-air furnaces shall be placed at least two feet from any wood or combustible partition or ceiling,

unless the partitions and ceilings are properly protected by a metal shield, when the distance shall be not less than one foot. Wood floors under all portable furnaces shall be protected by two courses of brickwork well laid in mortar on sheet iron. Said brickwork shall extend at least two feet beyond the furnace in front of the ash-pan.

Sec. 85. *Registers*.—Registers located over a brick furnace shall be supported by a brick shaft built up from the cover of the hot-air chamber; said shaft shall be lined with a metal pipe, and all wood beams shall be trimmed away not less than four inches from it. Where a register is placed on any woodwork in connection with a metal pipe or duct the end of the said pipe or duct shall be flanged over on the woodwork under it. All registers for hot-air furnaces placed in any woodwork or combustible floors shall have stone or iron borders firmly set in plaster of Paris or gauged mortar. All register-boxes shall be made of tin plate or galvanized iron with a flange on the top to fit the groove in the frame, the register to rest upon the same; there shall be an open space of two inches on all sides of the register-box, extending from the under side of the border to and through the ceiling below. The said opening shall be fitted with a tight tin or galvanized-iron casing, the upper end of which shall be turned under the frame. When a register-box is placed in the floor over a portable furnace, the open space on all sides of the register-box shall be not less than three inches. When only one register is connected with a furnace said register shall have no valve.

Sec. 86. *Drying-rooms*.—All walls, ceilings, and partitions inclosing drying-rooms, when not made of fire-proof material, shall be wire-lathed and plastered, or covered with metal, tile, or other hard incombustible material.

Sec. 87. *Ranges and Stoves*.—Where a kitchen range is placed from twelve to six inches from a wood stud-partition, the said partition shall be shielded with metal from the floor to the height of not less than three feet higher than the range; if the range is within six inches of the partition, then the studs shall be cut away and framed three feet higher and one foot wider than the range, and filled in to the face of the said stud-partition with brick or fire-proof blocks, and plastered thereon. All ranges on wood or combustible floors and beams that are not supported on legs and have ash-pans three inches or more above their base, shall be set on suitable brick foundations,

consisting of not less than two courses of brick well laid in mortar on sheet iron, except small ranges such as are used in apartment houses that have ash-pans three inches or more above their base, which shall be placed on at least one course of brickwork on sheet iron or cement. No range shall be placed against a furred wall. All lath-and-plaster or wood ceilings over all large ranges, and ranges in hotels and restaurants, shall be guarded by metal hoods placed at least nine inches below the ceiling. A ventilating-pipe connected with a hood over a range shall be at least nine inches from all lath-and-plaster or wood work, and shielded. If the pipe is less than nine inches from lath-and-plaster and wood work, then the pipe shall be covered with one inch of asbestos plaster on wire mesh. No ventilating-pipe connected with a hood over a range shall pass through any floor. Laundry-stoves on wood or combustible floors shall have a course of bricks, laid on metal, on the floor under and extended twenty-four inches on all sides of them. All stoves for heating purposes shall be properly supported on iron legs resting on the floor three feet from all lath-and-plaster or wood work; if the lath-and-plaster or wood work is properly protected by a metal shield, then the distance shall be not less than eighteen inches. A metal shield shall be placed under and twelve inches in front of the ash-pan of all stoves that are placed on wood floors. All low gas-stoves shall be placed on iron stands, or the burners shall be at least six inches above the base of the stoves, and metal guard-plates placed four inches below the burners, and all wood work under them shall be covered with metal.

PART V.

DRAWING. LAYING OUT WORK. MENSURATION. GEOMETRICAL MENSURATION. VARIOUS ENGINEERING FORMULAS.

Drawing.—To BISECT A RIGHT ANGLE.—Take a as centre, Fig. 242, and any radius, and draw the arc bc . Now, with b and c as centres and the same radius, draw the arcs bisecting bc in 1 and 2; draw lines from a through 1 and 2.

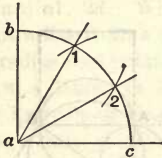


FIG. 242.

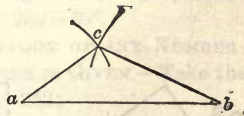


FIG. 243.

TO DRAW A TRIANGLE WHEN THE LENGTHS OF THE SIDES ARE GIVEN.—Draw the length of one side, as ab , Fig. 243; then, with a as centre and the length of one of the other sides, describe an arc, as shown; then, with b as centre, describe an arc, as shown, using the length of the third side as radius; then connect this intersection and ab .

TO DRAW THE FIVE-POINT STAR (Fig. 245).—Draw the circumference and divide it into 5 equal parts, 1, 2, 3, etc.; connect 1 and 3, 3 and 5, 5 and 2, 2 and 4, and 4 and 1.

TO DRAW A SQUARE WHEN THE DIAGONAL IS GIVEN.—Draw the diagonal, ab , Fig. 244; bisect it at c and draw the line de at right angles to ab ; then with ac as radius and c as centre strike

a circle; then connect ad , db , be , and ea , which is the square required.

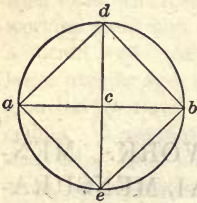


FIG. 244.



FIG. 245.

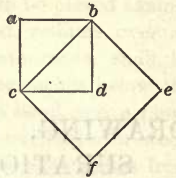


FIG. 246.

TO FIND A SQUARE TWICE THE AREA OF A GIVEN SQUARE.—Draw the given square, as $abcd$, Fig. 246; then, with the diagonal, cb , as one side, draw the square $cbef$, which will be twice the area of the first square.

TO DRAW A SQUARE HAVING THE AREA OF TWO GIVEN SQUARES.—Draw one side of each of the given squares so as to form a right angle, as ab and bc , Fig. 247; connect ac , and, with

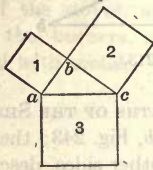


FIG. 247.

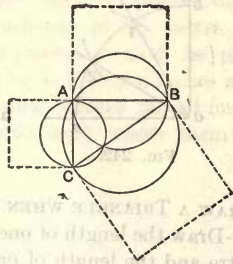


FIG. 248.

this line as one side, draw the square, 3, which is equal in area to 1 and 2.

The above rule applies to circles as well as squares; ab and AC , Fig. 248, represent the diameters of the smaller circles, and CB the diameter of a circle which is equal in area to the two small ones.

TO DRAW A TRIANGLE WHEN THE LENGTH OF ONE SIDE IS GIVEN.—Draw the side or base, as ab , Fig. 249; then, with ab

as radius, strike the arc ac ; then with the same radius and a as centre, find point d ; connect ad and db .

TO DRAW AN EQUILATERAL TRIANGLE WHEN THE PERPENDICULAR IS GIVEN.—Draw ab for the perpendicular, Fig. 250; then draw cd and gh at right angles to ab ; then, with any radius and

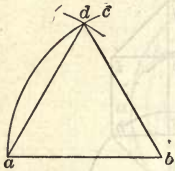


FIG. 249.

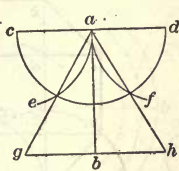


FIG. 250.

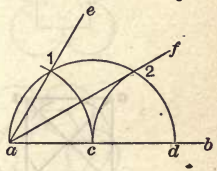


FIG. 251.

a as centre, draw the semicircle, $cefd$; then, with c as centre, find the point e ; then, with d as centre, find the point f ; then draw the line ah through the point f ; then draw the line ag through e .

TO DRAW AN ANGLE OF 60° OR 30° .—Draw the line ab , Fig. 251, and with any point on ab , as c , for centre and ca as radius, draw the arc $a1, 2d$. With a as centre and same radius find point 1; draw line from a through 1; $1ac = 60^\circ$; with d as centre and same radius find point 2; $2ad = 30^\circ$.

TO DRAW A REGULAR POLYGON OF ANY NUMBER OF SIDES, WHEN THE LENGTH OF ONE SIDE IS GIVEN.—Take the length of the side for a base, as ab , Fig. 252;

then with ab as radius and a as centre, draw the semicircle, db ; then divide the semicircle into as many equal parts as there are sides to the polygon, in this case 7; then, as we have one side, ab , we skip the first division and connect a and 2; then from the centre of $a2$ and ab draw lines at right angles until they meet at c , which is the centre of the polygon.

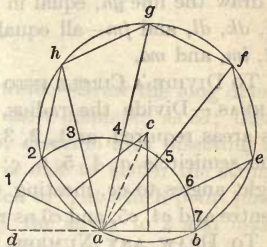


FIG. 252.

Then, with c at centre and ca as radius, draw the circle; then draw lines from a through points 3, 4, 5, and 6, striking the circle at $h, g, f,$ and e ; now connect $2h, hg, gf, fe,$ and eb .

TO DRAW AN OCTAGON.—When you have the distance from

one side to the other given, to draw the octagon, first draw a square, Fig. 253, of that size; then draw diagonal lines from each corner, as aa , aa ; then take the distance from the centre to the outside, as shown by the dotted line, and measure the same distance from the centre on the lines, aa ; then draw



FIG. 253.

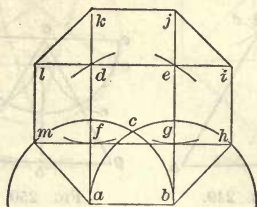


FIG. 254.

lines from this point at right angles to aa and you have the octagon.

TO DRAW AN OCTAGON WHEN THE SIDE OR BASE IS GIVEN.—Draw the line, ab , for the base, Fig. 254, and from a and b draw two indefinite perpendicular lines; then take the distance from a to b and describe the two half-circles; then, using the same radius, from point c find point d on the perpendicular, from which draw a horizontal line connecting at e ; then, with the same radius, find point f , from which draw a horizontal line connecting at g , thus forming the square, d, e, f, g . Then from g draw the line gh , equal in length to gb ; then the line ei , then ej , dk , dl , and fm —all equal to gb ; then connect bh , hi , ij , jk , kl , lm , and ma .

TO DIVIDE A CIRCLE INTO CONCENTRIC RINGS HAVING EQUAL AREAS.—Divide the radius, ac , Fig. 255, into as many parts as areas required, as 1, 2, 3, etc. With ac as a diameter draw the semicircle $a, 4, 5, 6, c$; draw lines from points 1, 2, 3 at right angles to ac , meeting the semicircle at 4, 5, 6; with c as centre and $c4$, $c5$, and $c6$ as radii draw the concentric circles.

TO DRAW ANY NUMBER OF TANGENTIAL ARCS OF CIRCLES HAVING A GIVEN DIAMETER.—Draw a polygon of as many sides as arcs required (four and six). With each angle as centre and half of one side as radius draw the arcs, as shown in Figs. 256 and 257.

TO DRAW AN ELLIPSE.—Draw the rectangle $abcd$, Fig. 258. ab represents the long diameter and ac half the short diam-

eter; divide ab into two equal parts, as ae and eb ; then divide ae and ac into the same number of equal parts, as 1, 2, 3, etc.;

FIG. 256.

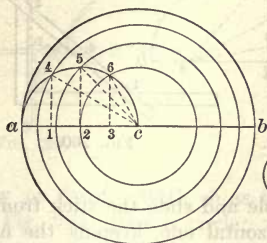


FIG. 255.

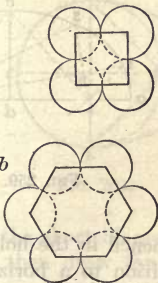


FIG. 257.

then draw lines from c to 5, 6, 7, etc.; then draw lines from e to 1, 2, 3, etc.; then draw the curved line through the intersections, as shown.

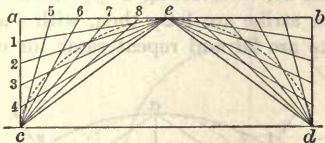


FIG. 258.

TO DRAW AN ELLIPSE WITH A STRING.—Draw the long diameter, Fig. 259, as ab ; then half the short diameter, as cd ; then, with c as centre and ad as radius, describe arcs bisecting ab at 1 and 2, at which points drive a nail to fasten the string; then fasten the string at 1 and stretch to c , at which point place a pencil inside the string and carry the string to 2 and make fast; then keep the string tight and run the pencil along on the inside of the string and the mark will be the ellipse; 3 and 4 show position of pencil and string on the curve.

TO DRAW AN ELLIPSE WITH THE SQUARE.—Take a strip of wood, as shown in Fig. 260, say $\frac{1}{2}'' \times 1''$, to use as a rule; then drive a nail through the stick about an inch from one end, as 1; then make the distance between 1 2 equal one-half the short

diameter of the ellipse and 2 3 equal to one-half the long diameter; drive another nail at 3 and at 2 make a hole for a pencil,

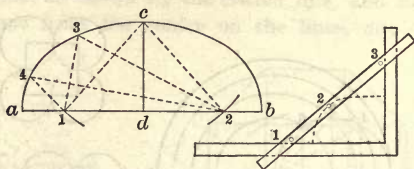


FIG. 259.

FIG. 260.

place the pencil in the hole and slide the stick from a perpendicular position to a horizontal one, keeping the nails against the inside of the square, and the pencil will describe an ellipse.

WHEN THE TWO AXES ARE GIVEN, TO DRAW A CURVE APPROXIMATING AN ELLIPSE.—With cd as the major axis and ag the minor axis, Fig. 261, draw lines connecting ad and ac ; then, with b as centre and ba as radius, draw the semicircle, finding points e and f , from which points draw lines at right angles to ad and ac , intersecting at g ; then, with ga as radius and g as centre strike arc 1 2; then, with i as centre and $i2$ as radius, strike arc 2 d and repeat same for other side.

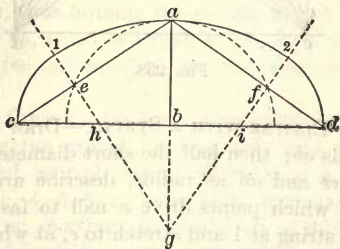


FIG. 261.

TO DRAW AN ELLIPSE WITH THE TRAMMEL.—Tack a frame to the floor or drawing-board, as shown by 1, 2, 3, Fig. 262, leaving a space between the strips of three-eighths of an inch; then, on the trammel, make de equal to the semi-minor axis and df equal to the semi-major axis; then put a $\frac{3}{8}$ -inch pin in the trammel at e and f and place the same on the frame with

the pins in the slot; then draw the trammel around and d will describe the ellipse.

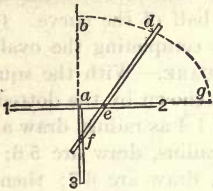


FIG. 262.

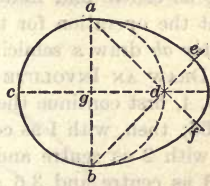


FIG. 263.

TO DRAW AN OVAL.—With ab as the short diameter and ag as radius, Fig. 263, draw a circle; then draw the line cd at right angles to ab through the centre g ; then draw the lines af and be through d ; then, with b as centre and ba as radius, draw the arc ae ; then, with a as centre and same radius, draw the arc bf ; then, with b as centre and de as radius, draw the arc ef .

UPON A GIVEN LINE, ab , TO DRAW AN OVAL.—Bisect ab at c , Fig. 264, and draw at right angles cd ; with b as centre and ba as

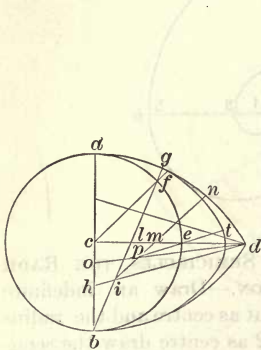


FIG. 264.

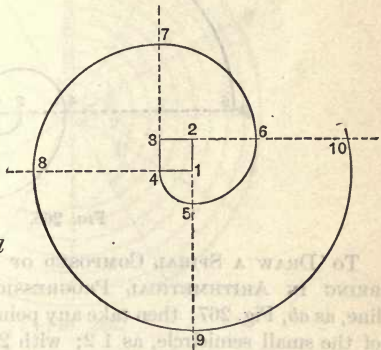


FIG. 265.

radius draw the arc ad . Bisect the quarter circle ae in f and through f draw bg , which gives ag as the first part of the curve. Now bisect cd in h and draw hd ; then the intersection i is the centre and ig the radius for the second part of the curve. Bisect el in m and through m draw in , which gives gn as the second part of the curve. Bisect ch in o and draw od ; the intersection

p is the centre and pn the radius for the third part of the curve. From p draw pet through e and nt is the third part of the curve; with e as centre and radius et draw the curve to the line cd . Repeat the operation for the other half of the curve. On the diameter ab draw a semicircle, thus completing the oval.

TO DRAW AN INVOLUTE OF A SQUARE.—With the square as 1, 2, 3, 4, first continue the sides, as shown by the dotted lines, Fig. 265; then, with 1 as centre and 1 4 as radius, draw arc 4 5; then, with 2 as centre and 2 5 as radius, draw arc 5 6; then, with 3 as centre and 3 6 as radius, draw arc 6 7; then, with 4 as centre and 4 7 as radius, draw arc 7 8, etc.

TO DRAW A SPIRAL COMPOSED OF SEMICIRCLES WHOSE RADII SHALL BE IN GEOMETRICAL PROGRESSION.—Draw an indefinite line, as ab ; Fig. 266. With 1 as centre and 1 2 as radius, draw first semicircle 2 3; then, with 2 as centre and 2 3 as radius, draw semicircle 3 4; then, with 3 as centre and 3 4 as radius, draw semicircle 4 5, etc.

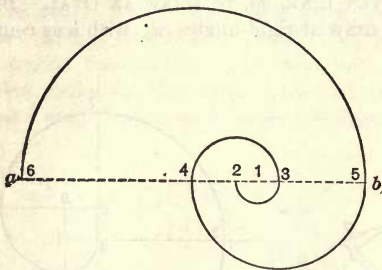


FIG. 266.

TO DRAW A SPIRAL COMPOSED OF SEMICIRCLES, THE RADII BEING IN ARITHMETICAL PROGRESSION.—Draw an indefinite line, as ab , Fig. 267; then take any point as centre and the radius of the small semicircle, as 1 2; with 2 as centre draw the semicircle 1 3; then, with 1 as centre and 1 3 as radius, draw the semicircle 3 4; then, with 2 as centre and 4 2 as radius, draw the semicircle 4 5, etc.

TO DRAW A SPIRAL OF ONE TURN.—First draw a circle, Fig. 268, as large as the spiral is to be; then divide it into any number of equal parts (in this case twelve), as lines abc , etc.; then divide any one of these lines into as many equal parts as the circle is divided; then with centre c and radius $c11$ draw

11e; then, with same centre and radius c10, draw arc 10f; then, with same centre and radius c9, draw arc 9g and continue until all the points are found; through these intersections draw the curves.

FIG. 267.

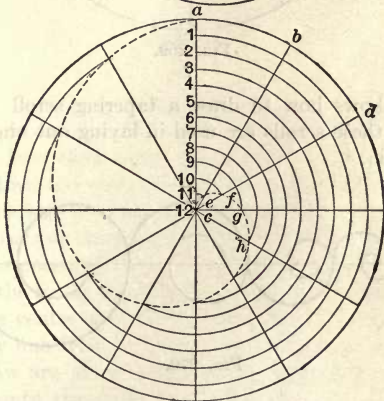
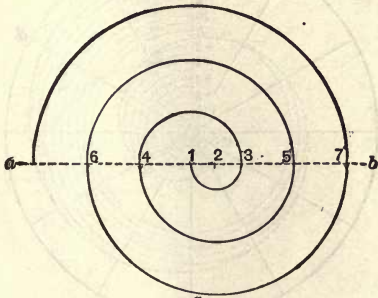


FIG. 268.

TO DRAW A SPIRAL OF ANY NUMBER OF TURNS (IN THIS CASE TWO).—Draw a circle the size of the spiral, Fig. 269, then divide it off into any number of equal spaces, say 12, as *a*, *e*, *d*, etc.; then divide any radius, as *ac*, into as many equal parts as there are turns to the spiral; then divide these spaces into as many equal parts as the circle, as 1, 2, 3, 4, etc.; then, with *c* as centre and *c2* as radius, draw arc intersecting *ec*; then, with *c* as centre and *c3* as radius, draw arc intersecting *dc*, etc.; continue up to

12; then commence with c as centre and $c+2$ as radius and draw arc to ec ; then through these points draw the curve.

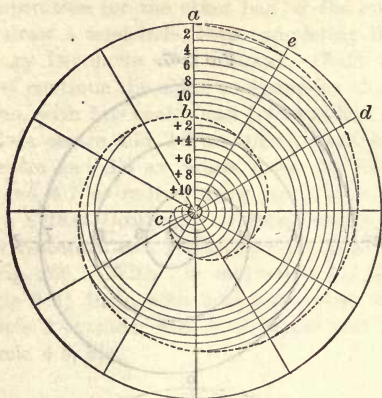


FIG. 269.

Fig. 270 shows how to draw a tapering scroll composed of semicircles; these scrolls are used in laying out vines and other ornamentation.

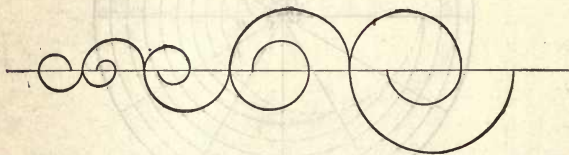


FIG. 270.

TO DRAW A SCROLL FOR A STAIR RAILING.—Draw the eye of the scroll, as the circle $abcd$, Fig. 271; draw the diameters ab and cd ; connect c and b ; bisect co at e and draw el parallel to ab ; draw a line from 6 parallel to cd , as $6k$; bisect eo at 3 and draw 32 ; make $o4$ equal to $o3$ and draw $j5$ parallel to ab ; bisect $o7$ and draw 12 ; with 1 as centre and $1f$ as radius draw arc fg ; with 2 as centre and $2g$ as radius draw arc gh ; with 3 as centre draw arc hi , etc. To draw the inner curve take 7 as centre and $7f$ as radius and draw arc fm ; with 6 as centre and $6m$ as radius draw arc mn .

TO DRAW A SPIRAL WHEN ITS GREATEST DIAMETER IS GIVEN (IN THIS CASE ONE OF THREE TURNS).—Divide the diameter

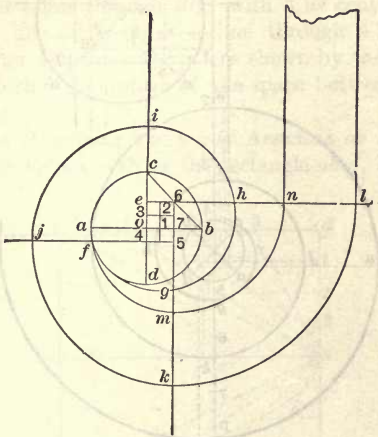


FIG. 271.

op, Fig. 272, into eight equal parts, as 1, 2, 3, etc.; with 4 5 as diameter draw the circle *abcd* for the eye of the spiral. Draw the two diameters *ab* and *cd* and divide them into twice as many equal parts as there are turns to the spiral, as 1, 2, 3, 4, 5, 6, etc., in the enlarged eye. Now, with 1 as centre and 1*b* as radius draw the arc *bf* to strike a horizontal line from 2 through 1; with 2 as centre and 2*f* as radius draw arc *fg* to strike a perpendicular line from 3 through 2; with 3 as centre and 3*g* as radius draw arc *gh* to strike a line from 4 through 3, and so continue until the spiral is completed.

In a spiral of one turn the diameter of the eye is about three-tenths of the length of the greatest diameter; in one of two turns, about one-sixth; in one of three turns, about one-eighth; in one of four turns, about one-tenth.

TO DRAW AN IONIC VOLUTE.—Let *ab* be the vertical measure of the volute, Fig. 273; divide *ab* into seven equal parts and from point 4 draw a line at right angles to *ab*; at any point on this line draw a circle whose diameter is equal to one of the divisions on *ab*. Draw the square *abcd*; bisect each of its sides and draw the square *e12*, *11f*; draw the diagonals *e11*, *f12*;

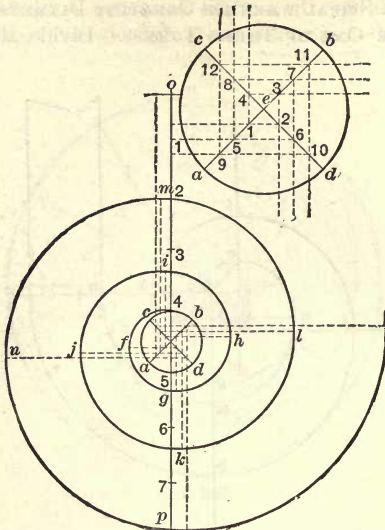


FIG. 272.

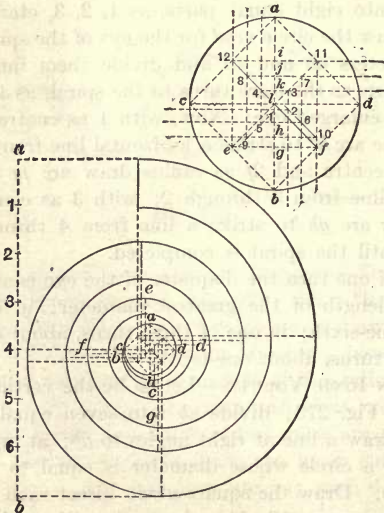


FIG. 273.

divide the diagonal $12l$ into three equal parts and draw 87 and 43 and continue the lines as shown, making hg equal to one-half ij ; with 1 as centre and $1a$ as radius draw arc ab to meet a line through 1 and 2; with 2 as centre and $2b$ as radius draw arc bc to meet a line through 23; with 3 as centre and $3c$ as radius draw arc cd to meet a line through 43, etc. The centres to draw the inner curve are shown by the dots on the diagonals, which is the centre of the space between the angles of the squares.

TO DRAW A PARABOLA WHEN THE ABSCISSA ab AND THE ORDINATE ac ARE GIVEN.—Draw the rectangle $abcd$, Fig. 274, and

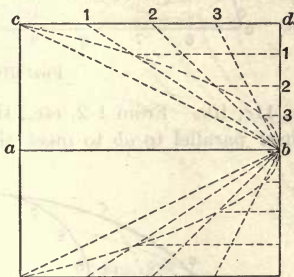


FIG. 274.

divide cd and db into the same number of equal parts; draw lines from b to meet points 1, 2, 3, etc., on cd ; then draw lines from points on db parallel to ab ; draw line 1 until it intersects $1b$; draw line 2 until it intersects $2b$, etc.; these intersections are points on the line of the curve.

TO DRAW AN HYPERBOLA WHEN THE DIAMETER, ab , THE ABSCISSA, bc , AND THE DOUBLE ORDINATE, de , ARE GIVEN.—Complete the rectangle $bcdf$, Fig. 275, and divide fd and dc into the same number of equal spaces, as 1, 2, 3, etc.; from b draw $b1, b2$, etc., and from a draw the intersecting lines $a1, a2$, etc.; through the intersections of these lines draw the curve bd . Repeat for the other half of the curve.

TO DRAW A CYCLOID.—Draw the rolling circle, as $b, 1, 2, 3$, etc., Fig. 276, and divide the semicircle into any number of equal parts, as 1, 2, 3, etc.; make the spaces on ab equal to those on the semicircle; draw a line from d parallel to ab ; draw lines from the points on ab perpendicular to meet the line ed at ooo ,

which are the centres of the rolling circle in its several positions; with these points as centres and the radius of the rolling circle

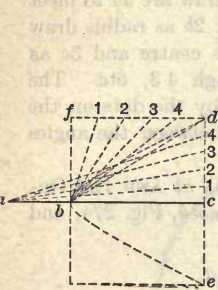


FIG. 275.

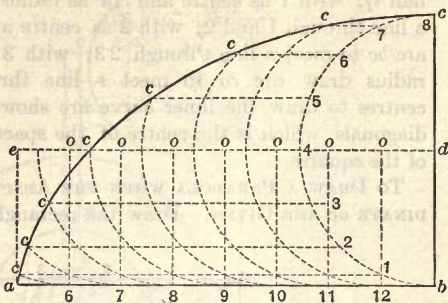


FIG. 276.

draw the arcs $12c$, $11c$, $10c$. From 1 2, etc., the points on the semicircle, draw lines parallel to ab to meet the arcs $12c$, $11c$,

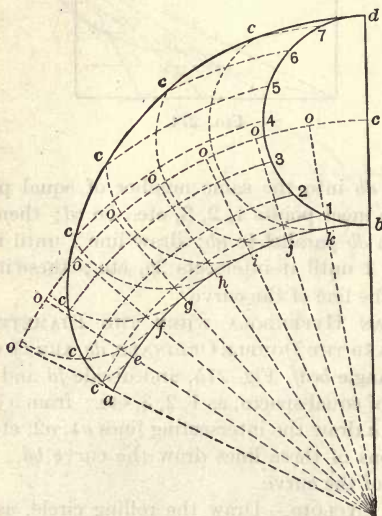


FIG. 277.

etc., at cc , etc.; draw the curve through points c , c , c , etc. For the other half of the curve reverse and proceed as above.

TO DRAW AN EPICYCLOID; ALSO TO DRAW A HYPOCYCLOID.— Draw the curve of the directing circle, as *ab*, Fig. 277, and the curve of the rolling circle, as *b, 1, 2*, etc.; divide the semicircle *bd* into any number of equal parts, as *1, 2, 3*, etc.; make the spaces on *ab* equal to those on the semicircle *bd*, spacing from

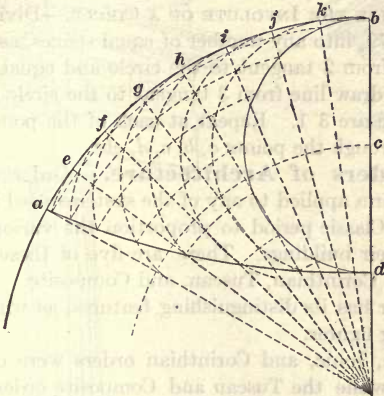


FIG. 278.

b; with the centre of the directing circle as a centre, draw an arc from *c*, giving the line of centres of the rolling circle. Draw lines from the centre of the directing circle radiating through

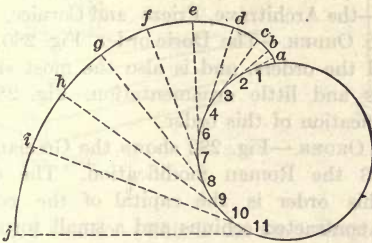


FIG. 279.

the points *k, j, i*, etc., thus finding the centres of the rolling circle in its several different positions, as *o, o, o*, etc.; with these points as centres and radius of the rolling circle draw the arcs *k, c, j, c*, etc.; with the centre of the directing circle as centre

draw arcs from 1, 2, 3, etc., to meet the arcs from *e*, *f*, *g*, etc.; the intersections of these arcs are points on the curve, as shown; draw the curve through the points *c*, *c*, *c*, etc. To draw the hypocycloid, see Fig. 278. When the diameter of the rolling circle is equal to the radius of the directing circle the hypocycloid becomes a straight line.

TO DESCRIBE THE INVOLUTE OF A CIRCLE.—Divide the given circle, Fig. 279, into any number of equal spaces, as 1, 2, 3, etc.; draw a line from 2 tangent to the circle and equal in length to the arc 1 2; draw line from 3 tangent to the circle and equal in length to the arc 3 1. Repeat at each of the points and draw the curve through the points *a*, *b*, *c*, *d*, etc.

The Orders of Architecture.—Order of Architecture is the term applied to any of the systems used by the architects of the Classic period to proportion the various parts and details of their buildings. There are five of these orders—the Doric, Ionic, Corinthian, Tuscan, and Composite.

Each order has its distinguishing features, as will be seen by the following figures.

The Doric, Ionic, and Corinthian orders were originated by the Greeks, while the Tuscan and Composite orders are modifications or improvements made by the Romans.

Each order consists principally of three divisions—the Stylobate, which forms the base or foundation; the Column, which is the shaft which supports the superstructure and which is usually composed of a base, shaft, and capital; and the Entablature, which is the superstructure proper. It consists of three principal divisions—the Architrave, Frieze, and Cornice.

THE DORIC ORDER.—The Doric order, Fig. 280, is the most ancient of all the orders, and is also the most simple; it has few members and little ornamentation. Fig. 281 shows the Roman modification of this order.

THE IONIC ORDER.—Fig. 282 shows the Grecian Ionic order, and Fig. 283 the Roman modification. The distinguishing feature of this order is the capital of the column, which consists of a contracted echinus and a small torus, over which the spirals or volutes are turned.

THE CORINTHIAN ORDER.—This order, shown by Fig. 284, is the most elaborate of the three Grecian orders; the column is more slender than the preceding orders and the capital has more enrichment. The ornament on the Corinthian capital consists of a number of caules, or husks, out of which the cauli-

culi, or twisted stems, spring, forming small spirals or volutes at the sides and angles of the abacus. Fig. 285 shows the Roman modification of the order.

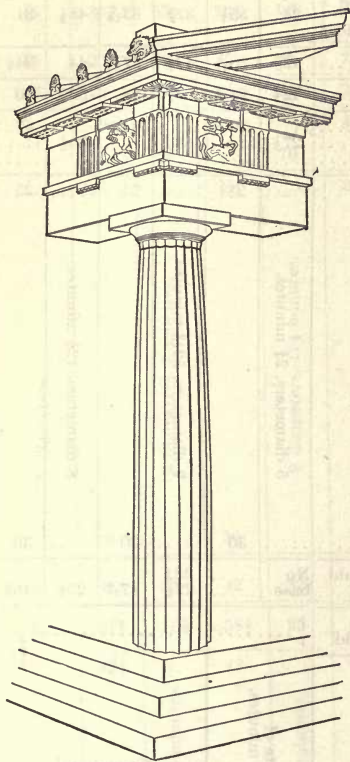


FIG. 280.

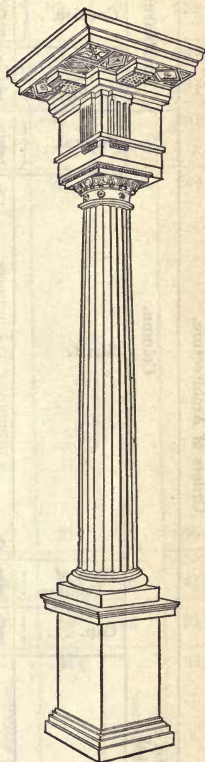


FIG. 281.

THE TUSCAN ORDER.—This is the most simple of the Roman orders, as is shown by Fig. 286. In the Roman orders the pedestal is always one-third and the entablature one-fourth the height of the column.

THE COMPOSITE ORDER.—This order, shown by Fig. 287, was invented by the Romans to secure something more elab-

| Name of Order. | | | Grecian Doric. | | Grecian Ionic. | | Grecian Corinthian. | | |
|-------------------------|-------------------|---|-------------------|---------------------------|----------------|---------------------------|---------------------|-----|-----|
| | | | H. | P. | H. | P. | H. | P. | |
| Entablature. | Cornice. . . { | Cymatium Corona Bed-mould } | 23 | 55½ | 37¾ | 63⅔ | 48½ | 81 | |
| | | | Frieze. | 42¾ | 28⅓ | 47¼ | 27⅒ | 44 | 31¼ |
| | | | Architrave. | Tænia. | 42¾ | 28⅓ | 50¼ | 28 | 52½ | 30 |
| Column. | Capital. . . { | Abacus. Echinus. Necking. | 27½ | 32 | 43⅔ | 34 | 85½ | 47 | |
| | | | Astragal. | 23½ | 25 | 25 | 25 | | |
| | Shaft. | 5 diameters, 2¼ minutes. | | 7 diameters, 52⅛ minutes. | | 8 diameters, 12½ minutes. | | | |
| | Cincture. | 30 | 30 | 30 | 30 | | | | |
| | Base of Column. } | Base mould. Plinth. | No base | 23⅝ | 22⅓ | 47⅒ | 22½ | 46¾ | |
| | | | Cap. { | Corona. Bed-mould. | } | | | | |
| Stylobate, or Pedestal. | Die. | Stylobate of 3 steps, 50⅓ minutes. | | No pedestal | | | | | |
| | Base. } | Base mould. Plinth. | | | | | | | |

| Roman Doric. | | Roman Ionic. | | Roman Corinthian. | | Composite. | | Tuscan. | |
|--------------|-------|---------------------------|-------|---------------------------|-------|---------------------------|-------|--------------------------|-------|
| H. | P. | H. | P. | H. | P. | H. | P. | H. | P. |
| 45 | 86½ | 52½ | 76½ | 60 | 88½ | 60 | 85 | 40 | 68½ |
| 45 | 25 | 45 | 25 | 45 | 25 | 45 | 25 | 35 | 23½ |
| 30 | 25 | 37½ | 25 | 45 | 25 | 45 | 25 | 30 | 23½ |
| ..... | 39½ | ..... | 33½ | ..... | 45 | ..... | 45 | ..... | 36½ |
| 30 | ..... | 25 | ..... | 70 | ..... | 70 | ..... | 30 | ..... |
| ..... | 25 | ..... | 25 | ..... | 25 | ..... | 25 | ..... | 23½ |
| 7 diameters. | | 8 diameters, 3 minutes. | | 8 diameters, 17½ minutes. | | 8 diameters, 17½ minutes. | | 6 diameters. | |
| ..... | 30 | ..... | 30 | ..... | 30 | ..... | 30 | ..... | 30 |
| 30 | 42½ | 32 | 42 | 32½ | 41½ | 32½ | 41½ | 30 | 41½ |
| 15 | 57½ | 16½ | 58½ | 25 | 55½ | 25 | 55 | 15 | 51½ |
| ..... | 42½ | ..... | 42 | ..... | 41½ | ..... | 41½ | ..... | 41½ |
| 2 diameters. | | 2 diameters, 26½ minutes. | | 2 diameters, 30 minutes. | | 2 diameters, 33½ minutes. | | 2 diameters, 50 minutes. | |
| 25 | 53½ | 16½ | 55½ | 25 | 54½ | 21½ | 55 | 15 | 51½ |

orate than the Corinthian order; as will be seen, it is a combination of the Ionic and Corinthian.

PROPORTIONS OF THE VARIOUS ORDERS OF ARCHITECTURE.—
All the different members of the various architectural orders

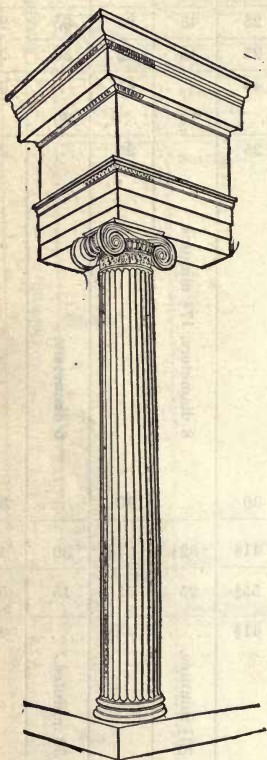


FIG. 282.

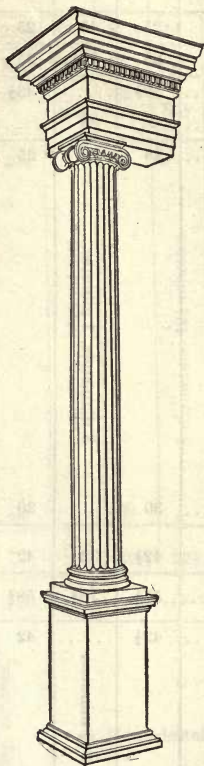


FIG. 283.

are proportioned from the large diameter of the column. For convenience we divide this diameter into sixty parts, called minutes or parts, and the different members are proportioned by this scale.

The chart on pp. 550, 551 shows the sizes of the members of the different orders, the figures denoting sixtieth parts of the diameter, or minutes. Those in the columns marked

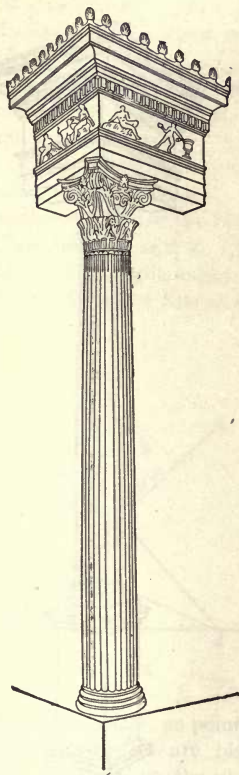


FIG. 284.

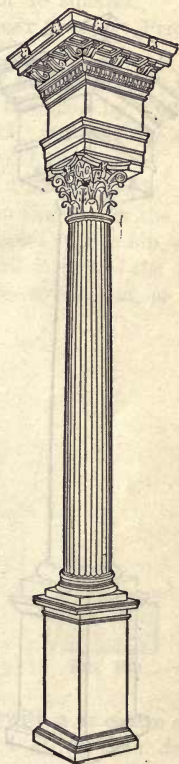


FIG. 285.

H are the heights, and those in the columns marked P give the projection of the member from the centre line or axis of the column.

The chart on pp. 550, 551 shows the sizes of the members of the different orders, the names denoting sixteen parts of the diameter, or number. Those in the columns marked

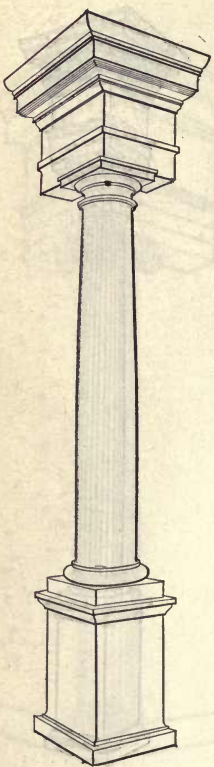


FIG 286.

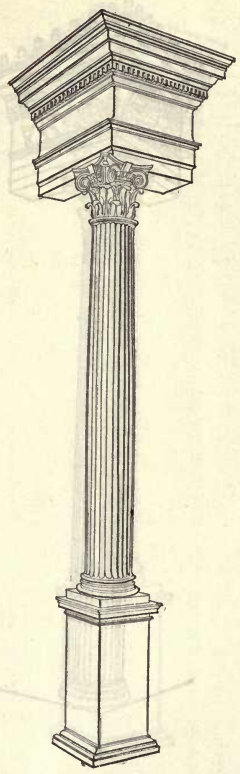


FIG 287.

It are the heights, and those in the columns marked 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, the projection of the member from the centre line or axis of the column.

Laying Out Work, etc.—To APPROXIMATE THE NUMBER OF SQUARES IN A ROOF.—If $\frac{1}{3}$ pitch, find the floor surface and multiply by $1\frac{1}{3}$; if $\frac{1}{2}$ pitch, multiply by $1\frac{1}{2}$; if $\frac{3}{4}$ pitch, multiply by $1\frac{3}{4}$, etc.

Example.—Find the number of squares in a roof 30×40 feet, $\frac{1}{2}$ pitch: $30 \times 40 = 1200$; $1200 \times 1\frac{1}{2} = 1800$, or 18 squares.

THE LENGTH OF RAFTERS FOR THE MOST COMMON PITCHES may be found as follows:

One-quarter pitch, multiply the span by 0.559; $\frac{1}{3}$ pitch, multiply the span by 0.6; $\frac{2}{3}$ pitch, multiply the span by 0.625; $\frac{1}{2}$ pitch, multiply the span by 0.71; $\frac{5}{8}$ pitch, multiply the span by 0.8; Gothic or full pitch, multiply by 1.12.

BACKING OF HIP-RAFTERS.—Draw 12 and 23, Fig. 288, to represent the plates of the building, then the seat of the hip, as 24; then the hip, as 25. Take any point of the hip, as *c*, and draw a line at right angles to 25 until it strikes the seat, 24; then continue the line at right angles to the scat, or 24,

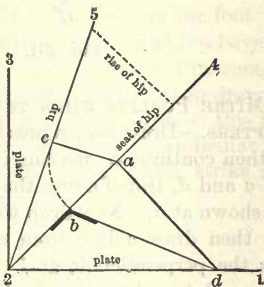


FIG. 288.



FIG. 289.

until it strikes the plate, as point *d*; then, with *a* as centre and *ac* as radius, strike an arc bisecting 24 at *b*; then draw line from *b* to point *d* on the plate; then the bevel at *b* is the bevel for backing the hip. Fig. 289 shows application.

TO FIND THE BEVEL FOR BACKING THE HIP-RAFTERS FOR AN OCTAGON ROOF.—Draw the plate as *ade*, Fig. 290; then draw the common rafter, as *ab*; then the seat and full size of hip, as *df*; then draw line from 5 to 6; then, with *d* as centre and *d1* as radius, describe arc 12; then draw line from 2 parallel to *ad* to point 3, and continue parallel to *ab*. Then lay off

the thickness of the rafter on 3 4, and draw the bevel lines as shown. This rule applies to any roof.

TO FIND THE BEVEL FOR BACKING HIP-RAFTERS.—Take the length of the hip on the blade of the square and the rise of the roof on the tongue and the tongue will give the desired bevel.

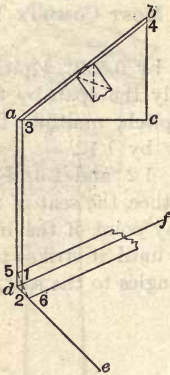


FIG. 290.

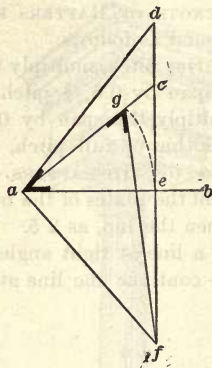


FIG. 291.

TO GET THE BEVELS TO MITRE PURLINS WHEN THE PURLIN SETS SQUARE WITH THE RAFTERS.—Draw ace , representing the slope of the roof, Fig. 291; then continue ce , making it equal in length to ac , as de ; connect a and d , thus finding the bevel for the top or face of purlins, as shown at a . Now drop the perpendicular from e indefinitely; then draw a line from a at right angles to ac until it strikes the perpendicular at j . Make ag on ac equal to ae ; connect g and j , and the bevel at g will be the bevel for the side of the purlin.

TO FIND THE LENGTHS AND BEVELS OF HIP- AND CRIPPLE-RAFTERS.—Draw the plates as ab and bc , Fig. 292, then the seat of the hip, as bd , then the seats of the cripples, as 1 1, 2 2, 3 3, etc.; then draw the rise of the common rafter, as de , then e to 1 is the length of the common rafters; then draw the rise of the hip, as df , then fb is the length of the hip; then continue the seat of the common rafter until it equals the length of the rafter as lg ; then draw gb , which is equal to the length of the hip, then continue the seats of the cripples until they strike the hip, gb , which gives the lengths of the cripples, also the top bevel, which is shown at h ; then draw line from g parallel to

TO LAY OUT A RAKE MOULDING TO JOIN THE MOULDING ON THE SQUARE SET ON A PLUMB FACIA.—Mark out the square moulding, as *a*, with *bc* as the facia, Fig. 294; then draw lines at right angles to the facia, joining all the breaks in the moulding, as 1, 2, 3, 4, etc.; then draw lines from these points on the moulding with the rake of the roof, as 1 1, 2 2, 3 3, etc., and draw a line at right angles to these, as 1 7 at *d*; make line 1 1 at *d* the same length as 1 1 at *a* and 2 2 at *d* same as at *a*, etc.; then join these points as shown, thus giving the profile of the rake moulding.

TO REDUCE A SQUARE STICK TO AN OCTAGON.—Place the blade of the square on the stick in the position shown in Fig. 295, and

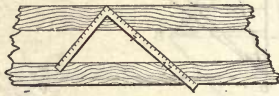


FIG. 295.

7 and 17 on the blade will give the chamfer lines, as shown.

TO LAY OUT PERPENDICULAR SHEATHING FOR A DOME ROOF.—Draw the spring of the roof, as *adb*, Fig. 296, and divide it in

half by *cd*; then divide *db* into equal parts (as many as desired), and from these points let fall perpendiculars to the base line *cb*; then with *c* as centre, continue these lines as semicircles, as shown by the dotted lines; then continue the line *dc* indefinitely; now on the outside of the circle lay off the width desired for the boards at the base, as 5 5, and draw a line from this point to *c*, as *c5*; this shows the ground plan and width of the board at the several different points. Now on the indefinite line make 5 11 equal to *db* on the circle; this is the length of the board. Then divide this line into as many equal parts as the

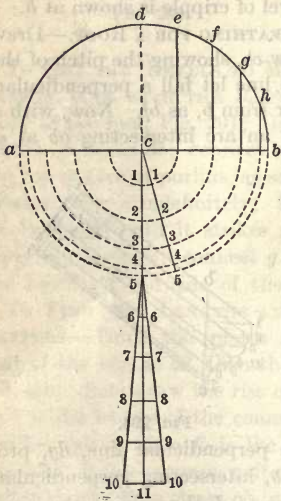


FIG. 296.

circle of the roof and make 6 6 equal to 1 1, 7 7 equal to 2 2,

8 8 equal to 3 3, etc.; now connect 5 6, 6 7, etc., which gives the pattern of the sheathing boards.

The same rule applies to any shape roof having a circular base.

TO LAY OUT HORIZONTAL SHEATHING FOR A DOME ROOF.—

Draw the roof as shown by *abc*, Fig. 297, and divide it in half by a perpendicular line, which continue up indefinitely; then divide *ab* into as many spaces as you desire boards, as 1, 2, 3, etc. Then draw a line from *a*, striking point 1, and continue until it bisects the perpendicular, which is the centre, and this point and *a* and this point and 1 is the radius for the first board; then draw a line from 1 through 2 and continue to the perpendicular, thus giving the centre and radius for second board; then draw the line 2 6 and repeat the operation, etc.

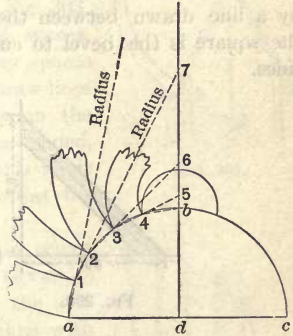


FIG. 297.

This rule applies to any shape roof of a circular base.

TO GET THE LENGTH AND CUT OF CRIPPLE-RAFTERS IN A CURVE ROOF.—Draw the plates, as *ab* and *bc*, Fig. 298, and the seat of the hip, as *ac*. Now draw the rise and profile of the common rafter, as *ce* and *eb*; lay off the seats of the cripples, as

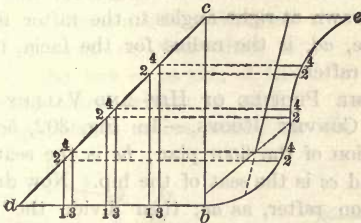


FIG. 298.

1 2, 3 4, etc., making 1 3 the thickness of the cripple rafter. Now continue these lines from where they strike the seat of the hip parallel to *ab* until they strike the profile of the common rafter; then *b4* will be the length of the cripple, 4 will be the

long length and 2 the short length, or 4 will be the line of the cut on one side and 2 the line of the cut on the other side.

TO GET THE CUT OF BRACES WHERE THEIR DIAGONAL IS PLUMB WHEN IN POSITION.—(As shown in Fig. 299.) Take the run of the brace, multiplied by 0.70711, on the blade of the square and the rise on the tongue, and the angle formed by a line drawn between these two points and the blade of the square is the bevel to cut the brace, applied on all four sides.

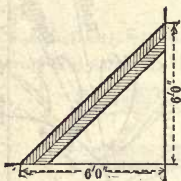


FIG. 299.

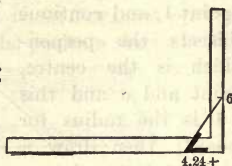


FIG. 300.

Example.—Find the cut of a brace 6 feet run and 6 feet rise. The run, 6 feet, by $0.70711 = 4.24266$. Now draw a line from 4.24+ on the blade to 6 on the tongue, and the bevel on the blade is the bevel to cut the brace, as shown in Fig. 300. For the top multiply the rise by 0.70711 and proceed as above.

TO LAY OUT THE PLANCHER FOR A CONICAL ROOF.—The following diagram, Fig. 301, will show how to lay out the plancher for a conical roof: a and b is the radius for the plancher, and cd , which is drawn at right angles to the rafter until it strikes the centre line, ad , is the radius for the facia, if it is put on square to the rafter.

TO FIND THE PROFILE OF HIP- AND VALLEY-RAFTERS FOR CONCAVE OR CONVEX ROOFS.—In Fig. 302, bcd represents a quarter section of the floor plan; bc is the seat of the common rafter and ce is the seat of the hip. Now draw the profile of the common rafter, as ac ; then divide the base, bc , into any number of spaces, 1, 2, 3, etc., and through these spaces draw lines at right angles to bc , continuing then to the profile of the common rafter, ac , and the seat of the hip, ec ; then from these intersections on the seat of the hip continue the lines at right angles to the seat of the hip, making the line 11 on the hip equal to 11 on the common

To find the side of an octagon bay when the length on the house is given: Divide the distance on the house by $2\frac{5}{12}$, and the answer will be the length of the side.

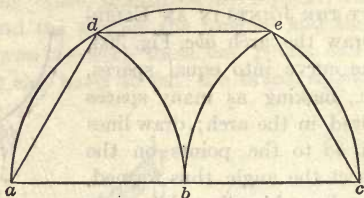


FIG. 305.

To find the distance on the house when the side is given: Multiply the side by $2\frac{5}{12}$, and the answer will be the diameter of the octagon.

TO STRIKE AN OGEE FOR A BRACKET.—Lay off the width and length of the bracket, as ac and ab , Fig. 306; then draw the line shown at the back of bracket an inch, or more if desired, from the edge of board; then draw the diagonal cd ; then divide



FIG. 306.

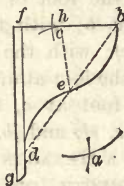


FIG. 307.

cd into two equal parts at 3; then, with 3 as centre and $3c$ as radius, strike arc at 1; then, with c as centre and same radius, strike arc intersecting at 1; then, with 1 as centre, strike arc $c3$; then, with $3d$ as centre, strike arcs intersecting at 2; then, with 2 as centre, strike arc $3d$.

ANOTHER WAY TO LAY OFF A BRACKET.—With fg as edge of board and fb as end or top of bracket, Fig. 307, draw the dotted line, as shown; then draw the diagonal ab and divide it into two equal parts at e ; then, with eb as centres and eh as radius, strike arcs intersecting at c ; then, with same radius and c as centre, strike arc be ; then, with same radius and ae as

centres, strike arcs intersecting at d ; then, with d as centre, strike arc ea .

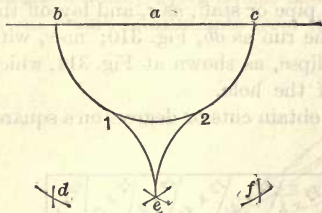


FIG. 308.

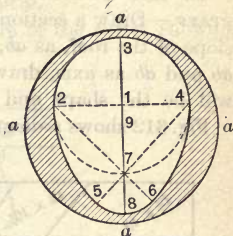


FIG. 309.

TO LAY OUT THE VENTILATING HOLE OF A PRIVY DOOR.— bac represents the top edge of the door, Fig. 308; with a as centre and the desired radius, draw the semicircle $b\ 1\ 2\ c$; now, with bc as radius and b and c as centres, draw arcs intersecting at e ; then, with same radius and a as centre, draw arcs at d and f ; now, with ac as radius and e as centre, draw arcs intersecting these at d and f , and with same radius and these intersections as centres, draw the arcs $1e$ and $2e$.

TO LAY OUT A PRIVY SEAT.—Draw two lines at right angles to each other, as $2\ 4$ and $3\ 8$, Fig. 309; make $2\ 4$ about

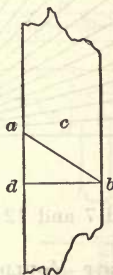


FIG. 310.

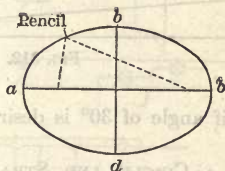


FIG. 311.

8 inches long; with 1 as centre and 1 4 as radius, draw a circle; now draw lines from 2 and 4 through 7; then, with 2 4 as radius and 2 4 as centre, draw the arcs 4 6 and 2 5; now, with 7 as centre and 7 6 as radius, draw the arc 5 6, completing the oval; now find the centre of the line 3 8, as 9, and with this

point as centre and 2 7 as radius, draw the circle *aaaa*; saw out to the oval line and round off to the circle.

TO LAY OUT A HOLE IN A ROOF FOR A STOVEPIPE OR FLAG-STAFF.—Draw a section of the pipe or staff, as *c*, and lay off the slope of the roof, as *ab*, and the run as *db*, Fig. 310; now, with *ab* and *db* as axis, draw an ellipse, as shown at Fig. 311, which will be the shape and size of the hole.

Fig. 312 shows a diagram to obtain cuts or degrees on a square;

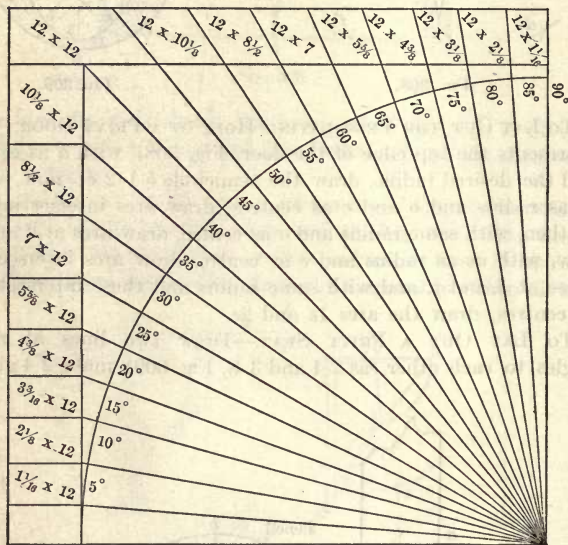


FIG. 312.

for instance, if angle of 30° is desired 7 and 12 on the square will give it.

TO MITRE A CIRCLE AND STRAIGHT MOULDING.—Draw a full-size plan of the two mouldings, as shown in Fig. 313; draw *abc*, as shown, in the centre of the space between the two outside lines; connect *d* and *b* and *b* and *c*; bisect *db* and *bc* and draw lines at right angles to them to meet at *f*; then *fd* is the radius of the mitre joint.

TO FIND MITRES ON THE STEEL SQUARE.— 12×12 equals square mitre; 7×4 equals triangle mitre; $13\frac{1}{4} \times 10$ equals

pentagon mitre; 4×7 equals hexagon mitre; $12\frac{1}{2} \times 6$ equals heptagon mitre; 7×17 equals octagon mitre; $22\frac{1}{2} \times 9$ equals nonagon mitre; $9\frac{1}{2} \times 3$ equals decagon mitre.

All plumb lines radiate from the centre of the earth, showing

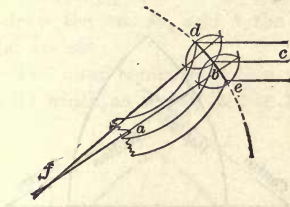


FIG. 313.

that if it were possible to make walls perfectly plumb they would not be parallel.

All level lines are at right angles to an imaginary line from the centre of the level to the centre of the earth. If a line

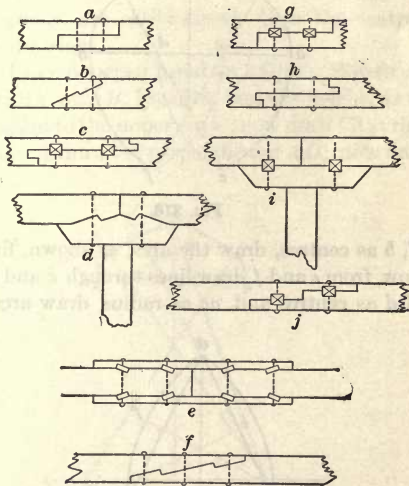


FIG. 314.

is drawn parallel to the earth's surface it has a curve of eight inches to the mile.

Fig. 314 shows some of the various methods of splicing or joining timber.

To Lay Out Arches.—LANCET GOTHIC ARCH.—A lancet Gothic arch is one whose radius is greater than its width, as shown in Fig. 315.

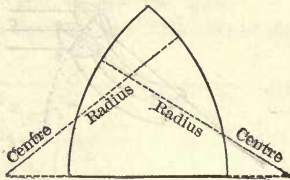


FIG. 315.

TO DRAW THE GOTHIC ELLIPTICAL ARCH.—Divide the span ab into three equal parts at c and d , Fig. 316; with bc as radius

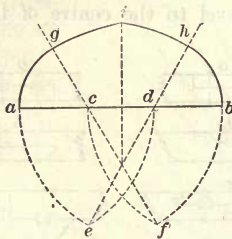


FIG. 316.

and a, c, d, b as centres, draw the arcs, as shown, finding points e and f ; now, from e and f draw lines through c and d , as shown; with c and d as centres and ac as radius draw arcs ag and hb ,

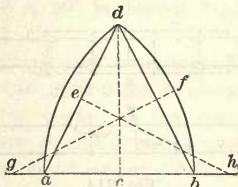


FIG. 317.

and with e and f as centres and eh as radius draw arcs gi and ih , completing the curve of the arch.

TO DRAW THE LANCET GOTHIC ARCH WHEN THE SPAN AND RISE ARE GIVEN.—On the base line, Fig. 317, mark the span ab and from the centre draw the rise cd ; now connect ad and db , and from the centre of these lines draw a line at right angles to strike the base line, as gf and eh ; now g is the centre and gb the radius to draw the arc db , and h the centre and same radius to draw the arc ad .

GOthic ARCH.—The most common Gothic arch is one whose radius is equal to its width, as shown in Fig. 318.

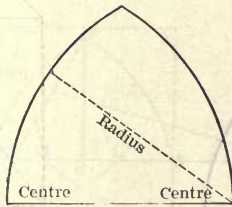


FIG. 318.

All Gothic arches are easily struck from the centre, usually shown on the drawings.

TO DRAW A FLAT-POINTED ARCH TO A GIVEN WIDTH AND RISE.—Draw the width, as AB , Fig. 319, and the height, as OC , while CD is a line tangent to the upper circle; now draw $C3$ at right angles to DC , and from A draw the perpendicular AD ; now find point I ,

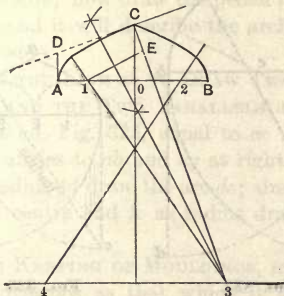


FIG. 319.

making AI equal to AD ; now find point E , making CE equal to AD , and connect I and E ; now bisect the line EI , as shown,

and draw a line to meet $C3$; now from 3 draw a line through point I as $3D$, and I and 3 will be the centres to strike the arch; then transfer the points across to 2 and 4 for the centres for the other half.

DROP ARCH.—A drop arch is one whose radius is less than its width, as shown in Fig. 320.

Another form of drop arch is shown in Fig. 321.

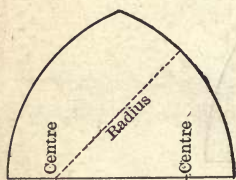


FIG. 320.

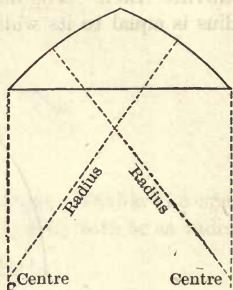


FIG. 321.

THREE-CENTRE ARCH.—With ab as width of arch and e as centre, Fig. 322, take ea as radius and strike semicircle ab ; then, with a as centre and ab as radius, strike arc bc ; then,

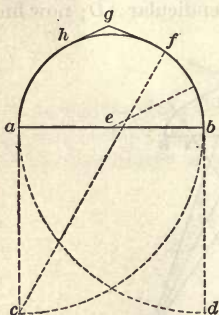


FIG. 322.

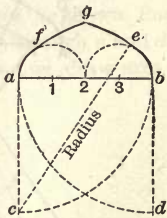


FIG. 323.

with b as centre and same radius, strike arc ad ; then, with c as centre and cf as radius, strike arc gf ; then, with d as centre and same radius, strike arc gh , thus completing the arch.

of the moulding marked *A* solid and bend the part marked *B* until the kerf or saw cut comes together. The distance the piece

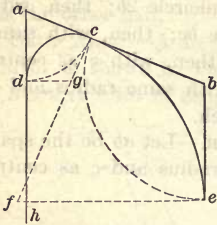


FIG. 325.

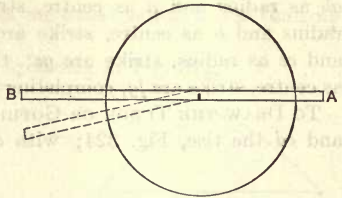


FIG. 326.

of moulding *B* has moved on the circle will be the distance apart to space the kerfs.

TO LAY OUT AN ARCH OR CURVE SIMILAR TO AN ELLIPSE, BUT WHOSE AXES DO NOT STAND AT RIGHT ANGLES.—Draw a parallelogram whose sides equal the axis, as *A, B, C,* and *D,* Fig. 327; now draw the two centre lines *EF* and *GH*;

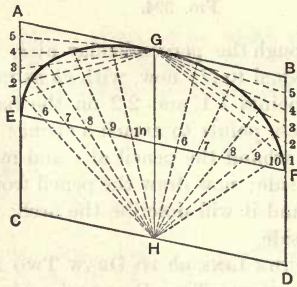


FIG. 327.

divide *AE* and *BF* into any number of equal parts, as 1, 2, 3, etc.; then divide *E1* and *1F* into the same number of parts and draw lines radiating from *G* to points 1, 2, 3, etc.; then draw lines radiating from *H* through points 6, 7, 8 etc., to strike the lines radiating from *G*, and through these intersections draw the curve as shown.

WHEN ANY THREE POINTS ARE GIVEN, TO DRAW A CIRCLE WHOSE CIRCUMFERENCE SHALL STRIKE EACH OF THE THREE POINTS.—With *a, b,* and *c* as the points, Fig. 328, join *a* and *b*

and *a* and *c* together, and draw lines at right angles from the centre of *ab* and *ac*, bisecting at *d*, which is the centre of the circle, and *da* the radius.

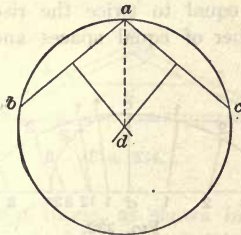


FIG. 328.

TO FIND THE CENTRE OF A CIRCLE.—Take any three points on the circumference and join them, as *a*, *b*, *c*, Fig. 329; then

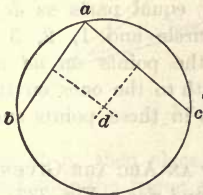


FIG. 329.

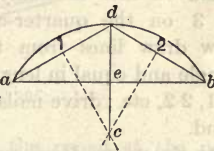


FIG. 330.

draw lines at right angles from the centre of *ab* and *ac* and the bisecting point *d* is the centre.

TO FIND THE DIAMETER OR RADIUS OF A CIRCLE WHEN THE CHORD AND RISE OF AN ARC ARE GIVEN.—Draw the chord as

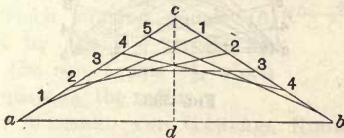


FIG. 331.

ab, then the rise *de*, Fig. 330; then connect *ad* and *db*; then draw lines *1c* and *2c* at right angles, and from the centre of

ad and db , until they intersect at c , which is the centre and cd the radius.

TO DRAW AN ARC BY INTERSECTING LINES WHEN THE CHORD AND RISE ARE GIVEN.—Draw the chord as ab , Fig. 331; then draw cd equal to twice the rise, divide ac and cb into the same number of equal spaces and draw the lines as shown.

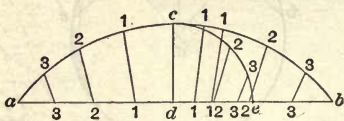


FIG. 332.

TO DRAW AN ARC BY BENDING A LATH OR STRIP.—Let ab be the span and cd the rise, Fig. 332; with cd as radius and d as centre, draw the quarter-circle ce ; now divide ce and ed into the same number of equal parts, as 1, 2, 3, etc.; now divide db and da into as many equal parts as de ; now connect 1, 2, 3 on the quarter-circle and 1, 2, 3 on de , as shown; now draw lines from the points on ad and db , at the same angle and equal in length to the ones on the quarter-circle, as 1 1, 2 2, etc.; drive nails in these points and bend the strips around.

WHEN THE SPAN AND RISE OF AN ARC ARE GIVEN, TO DRAW THE CURVE.—Draw the span ab and rise c , Fig. 333; then, with

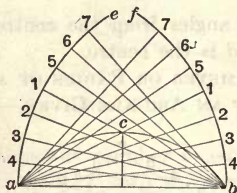


FIG. 333.

a and b as centres and ab as radius, draw arcs ae and bf ; now draw lines from a and b through c until they strike ae and bf , as $a1$ and $b1$; divide $a1$ on ae and $b1$ on bf into any number of equal spaces, as 1, 2, 3, etc.; make 5, 6, 7 equally distant

and draw the lines as shown; draw the curve through the intersections as shown.

WHEN THE CHORD AND RISE OF AN ARC ARE GIVEN, TO DRAW THE ARC.—Take two strips and joint the edges

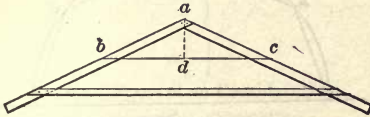


FIG. 334.

straight and make a frame, as shown in Fig. 334; *bc* is the chord and *ad* the rise of the arc. Drive a nail in the floor or drawing-board on the outside edge of the frame at *b* and

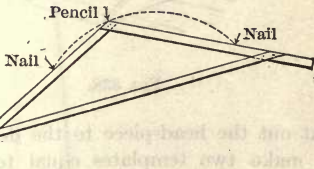


FIG. 335.

another one at *c*; then place the pencil at the point of the frame, *a*, and slide the frame around, keeping it tight against the nails, when the pencil will describe the curve, as shown in Fig. 335.

WHEN THE CHORD AND RISE OF AN ARC ARE GIVEN, TO FIND THE RADIUS.—Square one-half the chord, divide this product by the rise and to this answer add the rise and divide by 2; the answer is the radius. In Fig. 336, one-half the chord is 4, which squared equals 16, which divided by the rise equals $5\frac{1}{3}$, to which add the rise, equals $8\frac{1}{3}$, which divided by 2 equals $4\frac{1}{6}$, the radius.

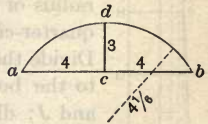


FIG. 336.

LAYING OUT MANSARD AND GAMBREL ROOFS.—To proportion a mansard or gambrel roof, draw a half-circle to a scale using the width of the building as the diameter, then draw the two slopes of the roof so that they intersect on the circle, as shown by Fig. 337.

LAYING OUT CIRCLE HEADS IN CIRCLE WALLS.—This can be done with lines and circles, but the quickest way for the work-

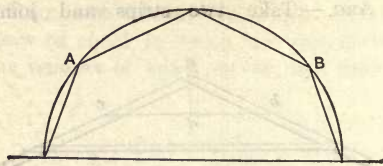


FIG. 337.

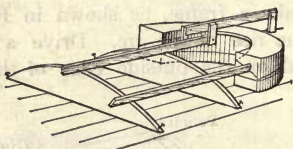


FIG. 338.

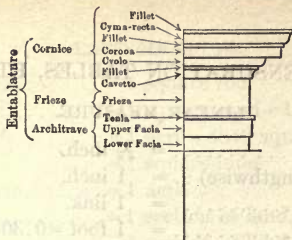
man is to cut out the head-piece to the desired circle for the frame; then make two templates equal to the circle of the wall and tack them on the drawing-board or floor, as shown by Fig. 338; now with a couple of straight-edges and pencil mark out the circle of the wall by sliding the strips over the templates.



FIG. 339.

TO LAY OUT ENTASIS OF COLUMNS, ETC.—Draw length of column, as AB , Fig. 339; then AC , the radius of the column at the bottom, and DB , the radius of the column at the top; now describe the quarter-circle CE , and let fall the perpendicular DF . Divide the length of the column into spaces equal to the bottom radius, spacing from E as G, H, I , and J ; divide the arc CF into the same number of equal spaces; now draw lines from the points on the centre line and at right angles to it, as $E6, G7$, etc., and draw perpendicular lines from points 1, 2, etc., on the arc to strike the lines from the centre line, as shown at 6, 7, 8, etc., and through

these points draw the curve. Fig. 339 is drawn with considerable swell, so that the lines can be seen more plainly.



Names of Parts of an Entablature.

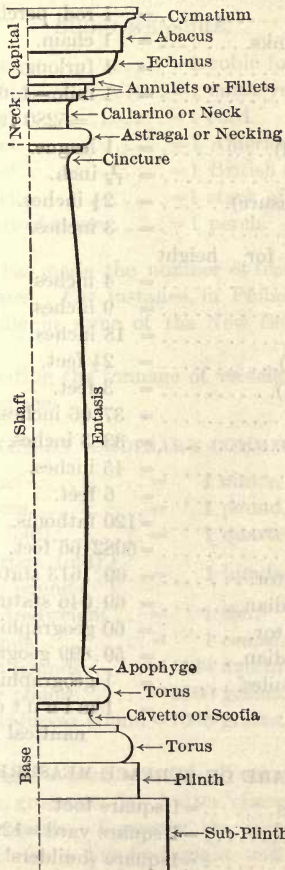


FIG. 340.—Names of Parts of a Column.

MENSURATION TABLES, ETC.

LINEAR MEASURE.

| | | |
|--|---|---|
| 1 hair's breadth. | = | $\frac{1}{48}$ inch. |
| 3 barleycorns (lengthwise) .. | = | 1 inch. |
| 7.92 inches. | = | 1 link. |
| 12 inches. | = | 1 foot = 0.3048 metre. |
| 3 feet. | = | 1 yard = 0.91438 metre. |
| 5½ yards. | = | 1 rod, perch, or pole. |
| 4 poles or 100 links. | = | 1 chain. |
| 10 chains. | = | 1 furlong. |
| 8 furlongs. | = | 1 mile = 1.6093 kilometres = 5280 ft. |
| 3 miles (nautical) | = | 1 league. |
| 1 line. | = | $\frac{1}{12}$ inch. |
| 1 nail (cloth measure). | = | 2¼ inches. |
| 1 palm. | = | 3 inches. |
| 1 hand (used for height of horses). | = | 4 inches. |
| 1 span. | = | 9 inches. |
| 1 cubit. | = | 18 inches. |
| 1 pace (military). | = | 2½ feet. |
| 1 pace (common). | = | 3 feet. |
| 1 Scotch ell. | = | 37.06 inches. |
| 1 vara (Spanish). | = | 33.3 inches. |
| 1 English ell. | = | 45 inches. |
| 1 fathom. | = | 6 feet. |
| 1 cable's length. | = | 120 fathoms. |
| 1 "knot" | = | 6082.66 feet. |
| 1 degree of equator. | = | 69.1613 statute miles. |
| 1 degree of meridian. | = | 69.046 statute miles |
| 1 degree of equator. | = | 60 geographical miles. |
| 1 degree of meridian. | = | 59.899 geographical miles. |
| 1.1527 statute miles. | = | 1 geographical mile. |
| 6086.07 feet. | = | 1 minute of longitude = 1 nautical mile. |

SQUARE OR SURFACE MEASURE.

| | | |
|----------------------------|---|-------------------------------------|
| 144 square inches. | = | 1 square foot. |
| 9 square feet. | = | 1 square yard = 1296 square inches. |
| 100 square feet. | = | 1 square (builders' measure). |

LAND MEASURE.

| | |
|--|--------------------------------------|
| 30 $\frac{1}{4}$ square yards. | = 1 square rod. |
| 40 square rods. | = 1 square rood = 1210 square yards. |
| 4 square roods. | = 1 acre = 4840 square yards. |
| 640 acres. | = 1 square mile. |
| 208.71 feet square. | = 1 acre. |
| 1 square mile. | = 1 section of land. |
| 160 acres. | = $\frac{1}{4}$ section of land. |

CUBIC MEASURE.

| | |
|------------------------------------|----------------------------|
| 1728 cubic inches. | = 1 cubic foot. |
| 27 cubic feet. | = 1 cubic yard. |
| 128 cubic feet. | = 1 cord. |
| 40 cubic feet. | = 1 American shipping ton. |
| 42 cubic feet. | = 1 British shipping ton. |
| 108 cubic feet. | = 1 stack of wood. |
| 24.75 cubic feet of stone. | = 1 perch. |

Note.—Custom has made the number of feet in a perch vary in different localities. For instance, in Philadelphia a perch is 22 cubic feet, while in some of the New England States it is 16.5 cubic feet.

A ton, in computing the tonnage of vessels, is 100 cubic feet of their internal space.

AVOIRDUPOIS WEIGHT (ORDINARY COMMERCIAL WEIGHT).

| | | |
|--------------------------|---|------------------|
| 16 drams. | = | 1 ounce, oz. |
| 16 ounces. | = | 1 pound, lb. |
| 28 lbs. (old). | = | 1 quarter, qr. |
| 4 quarters (old) } . . . | = | 1 hundredweight. |
| 100 lbs., pounds } . . . | | |
| 20 hundredweight . . . | = | 1 ton. |
| 100 pounds. | = | 1 cental. |
| 175 troy pounds. | = | 144 avoirdupois. |
| 1 troy pound. | = | 5760 grains. |
| 1 avoirdupois pound | = | 7000 grains. |

Avoirdupois weight is used to weigh all coarse articles, as hay, meat, fish, potash, groceries, flax, butter, cheese, etc., and metals, except precious metals. Formerly the usual custom was to allow 112 pounds for a hundredweight and 28 pounds for a

quarter, but this practice has very nearly passed away. The custom-house still adheres to the old usage.

APOTHECARIES' MEASURE—LIQUID.

| | |
|---------------------------|----------------------|
| 60 minims or drops, m., | =1 fluid drachm. |
| 8 fluid drachms. | =1 fluid ounce. |
| 16 fluid ounces | =1 pint (octarius). |
| 8 pints | =1 gallon (congius). |

These apothecarie ' weights and measures are used by apothecaries and physicians in compounding medicines, but drugs and medicines are bought and sold by avoirdupois weight.

The standard avoirdupois pound is the weight of 27.7015 cubic inches of distilled water weighed in air at 39.1°, the barometer at 30 inches.

APOTHECARIES' WEIGHT—DRY.

| | |
|--------------|-------------|
| 20 grains. . | =1 scruple. |
| 3 scruples | =1 dram. |
| 8 drams.. | =1 ounce. |
| 12 ounces | =1 pound. |

LIQUID OR WINE MEASURE.

| | |
|-------------------------------|-------------------|
| 4 gills. | =1 pint, pt. |
| 2 pints. | =1 quart, qt. |
| 4 quarts | =1 gallon, gal. |
| 42 gallons. | =1 tierce. |
| 1½ tierces or 63 gallons. . . | =1 hogshead, hhd. |
| 84 gallons. | =1 puncheon. |
| 1½ puncheons or 126 gallons | =1 pipe. |
| 2 pipes. | =1 tun. |
| 231 cubic inches. | =1 gallon. |
| 10 gallons. | =1 anker. |
| 18 " | =1 runlet. |
| 31½ " | =1 barrel. |

This measure is used to measure water, wine, spirits, cider, oil, honey, etc. In London the gill is usually called a quartern.

ALE OR BEER MEASURE.

| | |
|------------------------|----------------|
| 2 pints | = 1 quart. |
| 4 quarts | = 1 gallon. |
| 9 gallons | = 1 firkin. |
| 2 firkins | = 1 kilderkin. |
| 2 kilderkins | = 1 barrel. |
| 1½ barrels | = 1 hogshead. |
| 1½ hogsheads | = 1 puncheon. |
| 1½ puncheons | = 1 butt. |

Used to measure beer, ales, porter, etc. An ale gallon measures 282 cubic inches.

ENGLISH WINE MEASURE.

| | |
|------------------------------|---------------------|
| 18 U. S. gallons | = 1 runlet. |
| 25 English gallons | } = 1 tierce. |
| 42 U. S. gallons | |
| 7½ English gallons | = 1 firkin of beer. |
| 4 firkins | = 1 barrel. |
| 52¼ English gallons | } = 1 hogshead. |
| 63 U. S. gallons | |

DRY MEASURE.

| | | | |
|--------------------------|------------------------|-----------|---------------|
| 2 pints | = 1 quart | = 67.2 | cubic inches. |
| 4 quarts | = 1 gallon | = 288.8 | “ “ |
| 2 gallons | = 1 peck | = 537.6 | “ “ |
| 4 pecks | = 1 bushel | = 2150.42 | “ “ |
| 36 bushels | = 1 chaldron | = 57.244 | “ feet. |
| 4 bushels (in England) | = 1 coon. | | |
| 2 coons “ “ | = 1 quarter. | | |
| 5 quarters “ “ | = 1 wey. | | |
| 2 weys “ “ | = 1 last. | | |

A gallon, dry measure, measures 268½ cubic inches.

SURVEYORS' SQUARE MEASURE.

| | |
|---|--------------------------|
| 625 square links | = 1 square rod, sq. rd. |
| 16 “ rods | = 1 “ chain, sq. ch. |
| 10 “ chains | = 1 acre, A. |
| 640 acres | = 1 square mile, sq. mi. |
| 36 square miles or 6 miles square | = 1 township, tp. |

SURVEYORS' LONG MEASURE.

| | |
|----------------------|--------------|
| 7.92 inches . . . | = 1 link. |
| 25 links | = 1 pole. |
| 100 links | = 1 chain. |
| 10 chains | = 1 furlong. |
| 8 furlongs | = 1 mile. |

Used by surveyors, civil engineers, etc., in measuring distances.

MEASURE OF TIME.

| | |
|--------------------------------|------------------|
| 60 seconds, sec. | = 1 minute, min. |
| 60 minutes | = 1 hour, hr. |
| 24 hours | = 1 day, dy |
| 7 days | = 1 week, wk. |
| 2 weeks | = 1 fortnight. |
| 4 weeks | = 1 month, mo. |
| 13 months 1 day 6 hrs. | = 1 Julian year. |
| 365 days 6 hours | = 1 Julian year. |
| 366 days | = 1 leap year. |
| 12 calendar months | = 1 year. |

Used for computing time.

CIRCULAR MEASURE.

| | |
|-------------------------|--------------------------------|
| 60 seconds, " | = 1 minute, '. |
| 60 minutes | = 1 degree, °. |
| 30 degrees | = 1 sign, s. |
| 90 degrees | = 1 quadrant. |
| 12 signs | = a circle. |
| 4 quadrants } | = a circumference of a circle. |
| 360 degrees | |

Used in measuring latitude, longitude, etc.

TROY WEIGHT.

Used in Weighing Gold or Silver.

| | |
|---------------------------|------------------|
| 24 grains | = 1 pennyweight. |
| 20 pennyweights | = 1 ounce. |
| 12 ounces | = 1 pound. |

A carat of the jewellers, for precious stones, is, in the United States, 3.2 grains; in London, 3.17 grains; in Paris 3.18 grains are divided into 4 jewellers' grains. In troy, apothecaries', and avoirdupois weights the grain is the same.

MEASURES OF VALUE.

U. S. Standard.

- 10 mills. = 1 cent.
- 10 cents. = 1 dime.
- 10 dimes = 1 dollar.
- 10 dollars = 1 eagle.

The standard of gold and silver is 900 parts of pure metal and 100 parts of alloy to 1000 parts of coin.

WEIGHT OF COIN.

- Double eagle. = 516 troy grains.
- Eagle. = 258 troy grains.
- Dollar (gold). = 25.8 troy grains.
- Dollar (silver). = 412.5 troy grains.
- Half dollar. = 192 troy grains.
- 5-cent piece (nickel) = 77.16 troy grains.
- 3-cent piece (nickel) = 30 troy grains.
- Cent (copper). = 48 troy grains.

NUMBER OF ENGLISH OR UNITED STATES YARDS IN MILES OF DIFFERENT NATIONS.

| Name. | Yards. | Name. | Yards. |
|--------------------------------------|--------|------------------------------|--------|
| Arabian. | 2,148 | Luthenian. | 9,784 |
| Bohemian. | 10,187 | Oldenburg. | 10,820 |
| Brebant. | 6,082 | Persian (paisang). | 6,082 |
| Burgundy. | 6,183 | Polish (long). | 8,101 |
| Chinese (Hls). | 682 | Polish (short). | 6,095 |
| Dutch (Ure). | 6,395 | Portuguese (leguos). | 6,760 |
| Danish. | 8,244 | Prussian. | 8,498 |
| English (U. S.). | 1,760 | Roman (modern). | 2,035 |
| English (geographical). | 2,025 | Roman (ancient). | 1,613 |
| Flemish. | 6,869 | Russian (verst). | 1,167 |
| German (geographical) | 8,100 | Saxon. | 9,905 |
| Hamburg. | 8,244 | Scotch. | 1,984 |
| Hanover. | 11,559 | Silesian. | 7,083 |
| Hesse. | 10,547 | Spanish (leguas). | 4,630 |
| Hungarian. | 9,113 | Spanish (com.). | 7,416 |
| French (art leagues) | 4,860 | Swiss. | 9,166 |
| French (marine). | 6,075 | Swedish. | 11,704 |
| Legal Le'g'e (2000 toises) | 4,263 | Turkey. | 1,821 |
| Irish. | 3,338 | Tuscan. | 1,808 |
| Italian. | 2,025 | Vienna (post mile). | 8,296 |

TABLE OF MISCELLANEOUS WEIGHTS.

| | |
|--------------------------------------|------------------------------------|
| 14 pounds. | = 1 stone (horseman's weight). |
| 56 pounds. | = 1 firkin of butter. |
| 64 pounds. | = 1 firkin of soft soap. |
| 112 pounds. | = 1 barrel of raisins. |
| 256 pounds. | = 1 pack of soft soap. |
| 196 pounds. | = 1 barrel of flour. |
| 200 pounds. | = 1 barrel of beef, pork, or fish. |
| 280 pounds. | = 1 barrel of salt, New York. |
| 22 stones (301 lbs.). | = 1 sack of wool. |
| 17 stones 2 lbs. (240 lbs.). | = 1 pack of wool. |
| 60 pounds. | = 1 truss of hay (new). |
| 50 pounds. | = 1 truss of hay (old). |
| 40 pounds. | = 1 truss of straw. |
| 400 pounds. | = 1 bale of cotton. |
| 100 pounds. | = 1 quintal of fish. |

NUMBER OF POUNDS TO BUSHEL.

Recognized by the laws of the United States.

| | | | |
|--------------------------|----|-------------------------------|----|
| Wheat. | 60 | Dried apples. | 24 |
| Shelled corn. | 56 | Onions. | 57 |
| Corn in ear. | 70 | Salt. | 50 |
| Rye. | 56 | Stone coal. | 80 |
| Oats. | 32 | Coke. | 46 |
| Barley. | 48 | Malt. | 84 |
| Irish potatoes. | 60 | Bran. | 30 |
| Sweet potatoes. | 50 | Plastering hair. | 88 |
| White beans. | 60 | Turnips. | 57 |
| Castor-beans. | 46 | Unslacked lime. | 80 |
| Clover-seed. | 60 | Corn-meal. | 50 |
| Timothy-seed. | 45 | Fine salt. | 62 |
| Flaxseed. | 56 | Hungarian grass-seed. | 48 |
| Hempseed. | 44 | Ground peas. | 24 |
| Peas. | 60 | Onion-sets. | 14 |
| Blue-grass seed. | 14 | Onion tops. | 25 |
| Buckwheat. | 52 | Onion bottoms. | 35 |
| Dried peaches. | 33 | | |

METRIC SYSTEM OF WEIGHTS AND MEASURES.

The Metric System was legalized in the United States on July 28, 1866, when Congress enacted as follows:

“The tables in the schedule hereto annexed shall be recognized in the construction of contracts, and in all legal proceedings, as establishing, in terms of the weights and measures now in use in the United States, the equivalents of the weights and measures expressed therein in terms of the metric system, and the tables may lawfully be used for computing, determining, and expressing in customary weights and measures the weights and measures of the metric system.”

MEASURE OF LENGTH

| | |
|-------------------------------|------------------------|
| 10,000 metres = 1 myriametre. | 1 metre = 1 metre. |
| 1,000 “ = 1 kilometre. | .1 “ = 1 decimetre. |
| 100 “ = 1 hectometre. | .01 “ = 1 centimetre. |
| 10 “ = 1 decametre. | .001 “ = 1 millimetre. |

MEASURE OF SURFACE.

| | |
|--------------------------------|----------------------------|
| 10,000 sq. metres = 1 hectare. | Hectare = 2.471 acres. |
| 100 “ “ = 1 are. | Are = .119.6 square yards. |
| 1 “ “ = 1 centare. | Centare = 1550 sq. ins. |

MEASURE OF LENGTH.

| | |
|--|---------------------------|
| Myriametre = 6.2137 miles. | Metre = 39.37 inches. |
| Kilometre = 0.62137 mile = 3280 feet 10 inches. | Decimetre = 3.937 inches. |
| Hectometre = 328 feet 1 inch. | Centimetre = .3937 inch. |
| Decametre = 393.7 inches. | Millimetre = .0394 inch. |

MEASURES OF CAPACITY.

| |
|--|
| 1,000 litres = 1 kilolitre or 1 cubic metre. |
| 100 “ = 1 hectolitre or 0.1 cubic metre. |
| 10 “ = 1 decalitre or 10 cubic decimetres. |
| 1 litre = 1 litre or 1 cubic decimetre. |
| .1 “ = 1 decilitre or 0.1 cubic decimetre. |
| .01 “ = 1 centilitre or 10 cubic centimetres. |
| .001 “ = 1 millilitre or 0.1 cubic centimetre. |

584 EQUIVALENTS OF DENOMINATIONS IN USE.

EQUIVALENTS OF DENOMINATIONS IN USE.

DRY MEASURE.

| | |
|--------------|--------------------|
| 1 kilolitre | = 1.308 cu. yds. |
| 1 hectolitre | = 2 bu., 3.35 pks. |
| 1 decalitre | = 9.08 quarts. |
| 1 litre | = .908 quart. |
| 1 decilitre | = 6.1022 cu. in. |
| 1 centilitre | = .6102 cu. in. |
| 1 millilitre | = .061 cu. in. |

LIQUID MEASURE.

| | |
|--------------|------------------|
| 1 kilolitre | = 264.17 gal. |
| 1 hectolitre | = 26.417 " |
| 1 decalitre | = 2.6417 " |
| 1 litre | = 1.0567 qt. |
| 1 decilitre | = .845 gill. |
| 1 centilitre | = .368 fluid oz. |
| 1 millilitre | = .27 fluid dm. |

WEIGHTS.

| | |
|------------------|-------------------------|
| 1,000,000 grains | = 1 millier or tonneau. |
| 100,000 " | = 1 quintal. |
| 10,000 " | = 1 myriagram. |
| 1,000 " | = 1 kilogram. |
| 100 " | = 1 hectogram. |
| 10 " | = 1 decagram. |

1 gr. = 1 gram.

.1 " = 1 decigram.

.01 " = centigram.

.001 " = milligram.

| | |
|-------------|-----------------------------|
| 1 millier | = 2,204.6 lbs. avoirdupois. |
| 1 quintal | = 220.46 " " |
| 1 myriagram | = 22.046 " " |
| 1 kilogram | = 2.2046 " " |
| 1 hectogram | = 3.5274 ounces " |
| 1 decagram | = .3527 ounce " |
| 1 gram | = 15.432 grains " |
| 1 decigram | = 1.5432 " " |
| 1 centigram | = .1543 grain " |
| 1 milligram | = .0154 " " |

In the metric system the meter is the base of all weights and measures which it employs. The meter is one-ten-millionth part of the distance measured on a meridian of the earth from the equator to the pole, and equals about 39.37 inches, or nearly 3 ft. 3 $\frac{3}{8}$ inches.

COMMON WEIGHTS AND MEASURES AND THEIR METRIC EQUIVALENTS.

An inch = 2.54 centimetres.

A foot = .3048 metre.

A yard = .9144 metre.

A rod = 5.029 metres.

A mile = 1.6093 kilometres.

A square inch = 6.452 square centimetres.

A square foot = .0929 sq. m.

A square yard = .8361 sq. m.

An acre = .4047 hectare.

A square mile = 259 hectares.

A cubic foot = .02832 cu. m.

A cubic yard = .7646 cu. m.

A cord = 3.624 steres.

A liquid quart = .9465 litre.

A gallon = 3.786 litres.

A dry quart = 1.101 litres

A peck = 8.811 litres.

A bushel = 35.24 litres.

An ounce avoirdupois = 28.35 grams.

A pound avoirdupois = .4336 kilogram.

A ton = .9072 tonneau.

A grain troy = .0648 gram.

An ounce troy = 31.104 grms.

A pound troy = .3732 kgrm.

INTERCHANGEABLE TABLES BETWEEN UNITED STATES AND METRIC SYSTEMS.

1 Metre = 39.37 Inches. (Act of Congress.)

LONG MEASURE.

| Number. | 64ths of an Inch to Millimetres. | Millimetres to 64ths of an Inch. | Inches to Centimetres. | Centimetres to Inches. |
|---------|----------------------------------|----------------------------------|------------------------|------------------------|
| 1 | 0.3969 | 2.5197 | 2.54 | 0.3937 |
| 2 | 0.7938 | 5.0394 | 5.08 | 0.7874 |
| 3 | 1.1906 | 7.5590 | 7.62 | 1.1811 |
| 4 | 1.5875 | 10.0787 | 10.16 | 1.5748 |
| 5 | 1.9844 | 12.5984 | 12.70 | 1.9685 |
| 6 | 2.3813 | 15.1181 | 15.24 | 2.3622 |
| 7 | 2.7781 | 17.6378 | 17.78 | 2.7559 |
| 8 | 3.1750 | 20.1574 | 20.32 | 3.1496 |
| 9 | 3.5719 | 22.6771 | 22.86 | 3.5433 |

| Number. | Metres to Feet. | Feet to Metres. | Kilometres to Miles. | Miles to Kilometres. |
|---------|-----------------|-----------------|----------------------|----------------------|
| 1 | 3.2808 | 0.3048 | 0.62137 | 1.60935 |
| 2 | 6.5617 | 0.6096 | 1.24274 | 3.21869 |
| 3 | 9.8425 | 0.9144 | 1.86411 | 4.82804 |
| 4 | 13.1233 | 1.2192 | 2.48548 | 6.43739 |
| 5 | 16.4042 | 1.5240 | 3.10685 | 8.04674 |
| 6 | 19.6850 | 1.8288 | 3.72822 | 9.65608 |
| 7 | 22.9658 | 2.1336 | 4.34959 | 11.26543 |
| 8 | 26.2467 | 2.4384 | 4.97096 | 12.87478 |
| 9 | 29.5275 | 2.7432 | 5.59233 | 14.48412 |

SQUARE MEASURE.

| Number. | Square Inches to Square Centimetres. | Square Centimetres to Square Inches. | Square Feet to Square Metres. | Square Metres to Square Feet. | Square Yards to Square Metres. | Square Metres to Square Yards. |
|---------|--------------------------------------|--------------------------------------|-------------------------------|-------------------------------|--------------------------------|--------------------------------|
| 1 | 6.4516 | 0.155 | 0.0929 | 10.7639 | 0.8361 | 1.196 |
| 2 | 12.9032 | 0.310 | 0.1858 | 21.5278 | 1.6722 | 2.392 |
| 3 | 19.3548 | 0.465 | 0.2787 | 32.2917 | 2.5084 | 3.588 |
| 4 | 25.8064 | 0.620 | 0.3716 | 43.0556 | 3.3445 | 4.784 |
| 5 | 32.2581 | 0.775 | 0.4645 | 53.8194 | 4.1806 | 5.980 |
| 6 | 38.7097 | 0.930 | 0.5574 | 64.5833 | 5.0167 | 7.176 |
| 7 | 45.1613 | 1.085 | 0.6503 | 75.3472 | 5.8528 | 8.372 |
| 8 | 51.6129 | 1.240 | 0.7432 | 86.1111 | 6.6890 | 9.568 |
| 9 | 58.0645 | 1.395 | 0.8361 | 96.8750 | 7.5251 | 10.764 |

INTERCHANGEABLE TABLES BETWEEN UNITED STATES AND METRIC SYSTEMS.

SQUARE MEASURE.

| Number. | Acres to Hectares. | Hectares to Acres. | Square Miles to Square Kilometres. | Square Kilometres to Square Miles. | Square Miles to Hectares. | Hectares to Square Miles. |
|---------|--------------------|--------------------|------------------------------------|------------------------------------|---------------------------|---------------------------|
| 1 | 0.4047 | 2.471 | 2.59 | 0.3861 | 259.00 | 0.00386 |
| 2 | 0.8094 | 4.942 | 5.18 | 0.7722 | 518.00 | 0.00772 |
| 3 | 1.2141 | 7.413 | 7.77 | 1.1583 | 777.01 | 0.01158 |
| 4 | 1.6188 | 9.884 | 10.36 | 1.5444 | 1036.01 | 0.01544 |
| 5 | 2.0235 | 12.355 | 12.95 | 1.9305 | 1295.02 | 0.01930 |
| 6 | 2.4282 | 14.826 | 15.54 | 2.3166 | 1554.02 | 0.02317 |
| 7 | 2.8329 | 17.297 | 18.13 | 2.7027 | 1813.03 | 0.02703 |
| 8 | 3.2376 | 19.768 | 20.72 | 3.0887 | 2072.03 | 0.03089 |
| 9 | 3.6422 | 22.239 | 23.31 | 3.4748 | 2331.04 | 0.03475 |

1 Kilogram = 2.2046 Pounds. (Act of Congress.)

WEIGHTS.

| Number. | Kilograms to Ounces Troy. | Troy Ounces to Grams. | Grains to Milligrams. | Grams to Grains. | Gross Tons to Metric Tons. | Metric Tons to Gross Tons. |
|---------|---------------------------|-----------------------|-----------------------|------------------|----------------------------|----------------------------|
| 1 | 32.1507 | 31.1035 | 64.8004 | 15.432 | 1.0161 | 0.9842 |
| 2 | 64.3015 | 62.2070 | 129.6008 | 30.864 | 2.0321 | 1.9684 |
| 3 | 96.4522 | 93.3104 | 194.4012 | 46.296 | 3.0482 | 2.9526 |
| 4 | 128.6030 | 124.4139 | 259.2017 | 61.728 | 4.0642 | 3.9368 |
| 5 | 160.7537 | 155.5174 | 324.0021 | 77.160 | 5.0803 | 4.9210 |
| 6 | 192.9045 | 186.6209 | 388.8025 | 92.592 | 6.0963 | 5.9052 |
| 7 | 225.0552 | 217.7244 | 453.6029 | 108.024 | 7.1124 | 6.8894 |
| 8 | 257.2059 | 243.8278 | 518.4033 | 123.456 | 8.1285 | 7.8736 |
| 9 | 289.3567 | 279.9313 | 583.2037 | 138.888 | 9.1445 | 8.8578 |

| Number. | Avoirdupois Ounces to Grams. | Kilograms to Ounces Avoirdupois. | Avoirdupois Pounds to Kilograms. | Kilograms to Pounds Avoirdupois. | Net Tons to Metric Tons. | Metric Tons to Net Tons. |
|---------|------------------------------|----------------------------------|----------------------------------|----------------------------------|--------------------------|--------------------------|
| 1 | 28.3495 | 35.274 | 0.4536 | 2.2046 | 0.9072 | 1.1023 |
| 2 | 56.6990 | 70.548 | 0.9072 | 4.4092 | 1.8144 | 2.2046 |
| 3 | 85.0485 | 105.822 | 1.3603 | 6.6138 | 2.7216 | 3.3069 |
| 4 | 113.3980 | 141.096 | 1.8144 | 8.8184 | 3.6288 | 4.4092 |
| 5 | 141.7475 | 176.370 | 2.2680 | 11.0230 | 4.5360 | 5.5115 |
| 6 | 170.0970 | 211.644 | 2.7216 | 13.2276 | 5.4432 | 6.6138 |
| 7 | 198.4464 | 246.918 | 3.1752 | 15.4322 | 6.3504 | 7.7161 |
| 8 | 226.7959 | 282.192 | 3.6288 | 17.6368 | 7.2576 | 8.8184 |
| 9 | 255.1454 | 317.466 | 4.0824 | 19.8414 | 8.1647 | 9.9207 |

INTERCHANGEABLE TABLES BETWEEN UNITED STATES AND METRIC SYSTEMS.

1 Litre = $\left\{ \begin{array}{l} 1.0567 \text{ Quarts—Liquid Measure.} \\ 0.908 \text{ Quart —Dry Measure.} \end{array} \right\}$ (Act of Congress.)

LIQUID AND DRY MEASURE.

| Number. | Litres to Quarts. | | Quarts to Litres. | | Litres to Gallons, Liquid. | Gallons to Litres, Liquid. |
|---------|-------------------|-------|-------------------|--------|----------------------------|----------------------------|
| | Liquid. | Dry. | Liquid. | Dry. | | |
| 1 | 1.0567 | 0.908 | 0.9463 | 1.1013 | 0.2642 | 3.7854 |
| 2 | 2.1134 | 1.816 | 1.8927 | 2.2026 | 0.5284 | 7.5707 |
| 3 | 3.1701 | 2.724 | 2.8390 | 3.3040 | 0.7925 | 11.3561 |
| 4 | 4.2268 | 3.632 | 3.7854 | 4.4053 | 1.0567 | 15.1415 |
| 5 | 5.2835 | 4.540 | 4.7317 | 5.5066 | 1.3209 | 18.9268 |
| 6 | 6.3402 | 5.448 | 5.6781 | 6.6079 | 1.5851 | 22.7122 |
| 7 | 7.3969 | 6.356 | 6.6244 | 7.7093 | 1.8492 | 26.4976 |
| 8 | 8.4536 | 7.264 | 7.5707 | 8.8106 | 2.1134 | 30.2830 |
| 9 | 9.5103 | 8.172 | 8.5171 | 9.9119 | 2.3776 | 34.0683 |

| Number. | Cubic Metres to Gallons, Liquid. | Gallons to Cubic Metres, Liquid. | Hectolitres to Bushels, Dry. | Bushels to Hectolitres, Dry. |
|---------|----------------------------------|----------------------------------|------------------------------|------------------------------|
| 1 | 264.17 | 0.0038 | 2.8375 | 0.3524 |
| 2 | 528.34 | 0.0076 | 5.6750 | 0.7048 |
| 3 | 792.51 | 0.0114 | 8.5125 | 1.0573 |
| 4 | 1056.68 | 0.0151 | 11.3500 | 1.4097 |
| 5 | 1320.85 | 0.0189 | 14.1875 | 1.7621 |
| 6 | 1585.02 | 0.0227 | 17.0250 | 2.1145 |
| 7 | 1849.19 | 0.0265 | 19.8625 | 2.4670 |
| 8 | 2113.36 | 0.0303 | 22.7000 | 2.8194 |
| 9 | 2377.53 | 0.0341 | 25.5375 | 3.1718 |

CUBIC, HORSE-POWER, AND TON MEASURES.

| Number. | Cubic Centimetres to Cubic Inches. | Cubic Inches to Cubic Centimetres. | Cubic Metres to Cubic Feet. | Cubic Feet to Cubic Metres. | Cubic Metres to Cubic Yards. | Cubic Yards to Cubic Metres. |
|---------|------------------------------------|------------------------------------|-----------------------------|-----------------------------|------------------------------|------------------------------|
| 1 | 0.061 | 16.3934 | 35.316 | 0.0283 | 1.308 | 0.7645 |
| 2 | 0.122 | 32.7869 | 70.632 | 0.0566 | 2.616 | 1.5291 |
| 3 | 0.183 | 49.1803 | 105.948 | 0.0849 | 3.924 | 2.2936 |
| 4 | 0.244 | 65.5738 | 141.264 | 0.1133 | 5.232 | 3.0581 |
| 5 | 0.305 | 81.9672 | 176.580 | 0.1416 | 6.540 | 3.8226 |
| 6 | 0.366 | 98.3607 | 211.896 | 0.1699 | 7.848 | 4.5872 |
| 7 | 0.427 | 114.7541 | 247.212 | 0.1982 | 9.156 | 5.3517 |
| 8 | 0.488 | 131.1475 | 282.528 | 0.2265 | 10.464 | 6.1162 |
| 9 | 0.549 | 147.5410 | 317.844 | 0.2548 | 11.772 | 6.8807 |

INTERCHANGEABLE TABLES BETWEEN UNITED STATES AND METRIC SYSTEMS.

| Number. | Horse-power Metric to U. S. | Horse-power U. S. to Metric. | Foot-pounds to Kilogram-metres. | Kilogram-metres to Foot-pounds. | Gross Tons per Sq. Ft. to Metric Tons per Sq. Metre. | Metric Tons per Sq. Metre to Gross Tons per Sq. Foot. |
|---------|-----------------------------|------------------------------|---------------------------------|---------------------------------|--|---|
| 1 | 0.986 | 1.014 | 0.1383 | 7.2329 | 10.937 | 0.091 |
| 2 | 1.973 | 2.028 | 0.2765 | 14.4659 | 21.873 | 0.183 |
| 3 | 2.959 | 3.042 | 0.4148 | 21.6988 | 32.810 | 0.274 |
| 4 | 3.945 | 4.056 | 0.5530 | 28.9317 | 43.747 | 0.366 |
| 5 | 4.932 | 5.069 | 0.6913 | 36.1646 | 54.684 | 0.457 |
| 6 | 5.918 | 6.083 | 0.8295 | 43.3976 | 65.620 | 0.549 |
| 7 | 6.904 | 7.097 | 0.9678 | 50.6305 | 76.557 | 0.640 |
| 8 | 7.890 | 8.111 | 1.1061 | 57.8634 | 87.494 | 0.731 |
| 9 | 8.877 | 9.125 | 1.2443 | 65.0963 | 98.431 | 0.823 |

MISCELLANEOUS.

| Number. | Kilo. per Metre to Pounds per Foot. | Pounds per Foot to Kilo. per Metre. | Kilo. per Square Metre to Pounds per Square Foot. | Pounds per Square Foot to Kilo. per Square Metre. |
|---------|-------------------------------------|-------------------------------------|---|---|
| 1 | 0.6720 | 1.4882 | 0.2048 | 4.8825 |
| 2 | 1.3439 | 2.9764 | 0.4096 | 9.7649 |
| 3 | 2.0159 | 4.4645 | 0.6144 | 14.6474 |
| 4 | 2.6879 | 5.9527 | 0.8193 | 19.5299 |
| 5 | 3.3598 | 7.4409 | 1.0241 | 24.4123 |
| 6 | 4.0318 | 8.9291 | 1.2289 | 29.2948 |
| 7 | 4.7037 | 10.4172 | 1.4337 | 34.1773 |
| 8 | 5.3757 | 11.9054 | 1.6385 | 39.0597 |
| 9 | 6.0477 | 13.3936 | 1.8433 | 43.9422 |

| Number. | Kilo. per Cubic Metre to Pounds per Cubic Foot. | Pounds per Cubic Foot to Kilo. per Cubic Metre. | Kilo. per Square Centimetre to Pounds per Square Inch. | Pounds per Square Inch to Kilo. per Square Centimetre. |
|---------|---|---|--|--|
| 1 | 0.0624 | 16.0192 | 14.2232 | 0.0703 |
| 2 | 0.1248 | 32.0385 | 28.4465 | 0.1406 |
| 3 | 0.1873 | 48.0577 | 42.6697 | 0.2109 |
| 4 | 0.2497 | 64.0769 | 56.8929 | 0.2812 |
| 5 | 0.3121 | 80.0962 | 71.1161 | 0.3515 |
| 6 | 0.3745 | 96.1154 | 85.3394 | 0.4218 |
| 7 | 0.4370 | 112.1346 | 99.5626 | 0.4922 |
| 8 | 0.4994 | 128.1539 | 113.7858 | 0.5625 |
| 9 | 0.5618 | 144.1731 | 128.0090 | 0.6328 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS,
 RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS
 OF NOS. FROM 1 TO 1000.

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|--------|--------------|------------|---------|---------------|-----------------|---------|
| | | | | | | | Circum. | Area. |
| 1 | 1 | 1 | 1.0000 | 1.0000 | 0.00000 | 1000.000 | 3.142 | 0.7854 |
| 2 | 4 | 8 | 1.4142 | 1.2599 | 0.30103 | 500.000 | 6.283 | 3.1416 |
| 3 | 9 | 27 | 1.7321 | 1.4422 | 0.47712 | 333.333 | 9.425 | 7.0686 |
| 4 | 16 | 64 | 2.0000 | 1.5874 | 0.60206 | 250.000 | 12.566 | 12.5664 |
| 5 | 25 | 125 | 2.2361 | 1.7100 | 0.69897 | 200.000 | 15.708 | 19.6350 |
| 6 | 36 | 216 | 2.4495 | 1.8171 | 0.77815 | 166.667 | 18.850 | 28.2743 |
| 7 | 49 | 343 | 2.6458 | 1.9129 | 0.84510 | 142.857 | 21.991 | 38.4845 |
| 8 | 64 | 512 | 2.8284 | 2.0000 | 0.90309 | 125.000 | 25.133 | 50.2655 |
| 9 | 81 | 729 | 3.0000 | 2.0801 | 0.95424 | 111.111 | 28.274 | 63.6173 |
| 10 | 100 | 1000 | 3.1623 | 2.1544 | 1.00000 | 100.000 | 31.416 | 78.5398 |
| 11 | 121 | 1331 | 3.3166 | 2.2240 | 1.04139 | 90.9091 | 34.558 | 95.0332 |
| 12 | 144 | 1728 | 3.4641 | 2.2894 | 1.07918 | 83.3333 | 37.699 | 113.097 |
| 13 | 169 | 2197 | 3.6056 | 2.3513 | 1.11394 | 76.9231 | 40.841 | 132.732 |
| 14 | 196 | 2744 | 3.7417 | 2.4101 | 1.14613 | 71.4286 | 43.982 | 153.938 |
| 15 | 225 | 3375 | 3.8730 | 2.4662 | 1.17609 | 66.6667 | 47.124 | 176.715 |
| 16 | 256 | 4096 | 4.0000 | 2.5198 | 1.20412 | 62.5000 | 50.265 | 201.062 |
| 17 | 289 | 4913 | 4.1231 | 2.5713 | 1.23045 | 58.8235 | 53.407 | 226.980 |
| 18 | 324 | 5832 | 4.2426 | 2.6207 | 1.25527 | 55.5556 | 56.549 | 254.469 |
| 19 | 361 | 6859 | 4.3589 | 2.6684 | 1.27875 | 52.6316 | 59.690 | 283.529 |
| 20 | 400 | 8000 | 4.4721 | 2.7144 | 1.30103 | 50.0000 | 62.832 | 314.159 |
| 21 | 441 | 9261 | 4.5826 | 2.7589 | 1.32222 | 47.6190 | 65.973 | 346.361 |
| 22 | 484 | 10648 | 4.6904 | 2.8020 | 1.34242 | 45.4545 | 69.115 | 380.133 |
| 23 | 529 | 12167 | 4.7958 | 2.8439 | 1.36173 | 43.4783 | 72.257 | 415.476 |
| 24 | 576 | 13824 | 4.8990 | 2.8845 | 1.38021 | 41.6667 | 75.398 | 452.389 |
| 25 | 625 | 15625 | 5.0000 | 2.9240 | 1.39794 | 40.0000 | 78.540 | 490.874 |
| 26 | 676 | 17576 | 5.0990 | 2.9625 | 1.41497 | 38.4615 | 81.681 | 530.929 |
| 27 | 729 | 19683 | 5.1962 | 3.0000 | 1.43136 | 37.0370 | 84.823 | 572.555 |
| 28 | 784 | 21952 | 5.2915 | 3.0366 | 1.44716 | 35.7143 | 87.965 | 615.752 |
| 29 | 841 | 24389 | 5.3852 | 3.0723 | 1.46240 | 34.4828 | 91.106 | 660.520 |
| 30 | 900 | 27000 | 5.4772 | 3.1072 | 1.47712 | 33.3333 | 94.248 | 706.858 |
| 31 | 961 | 29791 | 5.5678 | 3.1414 | 1.49136 | 32.2581 | 97.389 | 754.768 |
| 32 | 1024 | 32768 | 5.6569 | 3.1748 | 1.50515 | 31.2500 | 100.531 | 804.248 |
| 33 | 1089 | 35937 | 5.7446 | 3.2075 | 1.51851 | 30.3030 | 103.673 | 855.299 |
| 34 | 1156 | 39304 | 5.8310 | 3.2396 | 1.53148 | 29.4118 | 106.814 | 907.920 |
| 35 | 1225 | 42875 | 5.9161 | 3.2711 | 1.54407 | 28.5714 | 109.956 | 962.113 |
| 36 | 1296 | 46656 | 6.0000 | 3.3019 | 1.55630 | 27.7778 | 113.097 | 1017.88 |
| 37 | 1369 | 50653 | 6.0828 | 3.3322 | 1.56820 | 27.0270 | 116.239 | 1075.21 |
| 38 | 1444 | 54872 | 6.1644 | 3.3620 | 1.57978 | 26.3158 | 119.381 | 1134.11 |
| 39 | 1521 | 59319 | 6.2450 | 3.3912 | 1.59106 | 25.6410 | 122.522 | 1194.59 |
| 40 | 1600 | 64000 | 6.3246 | 3.4200 | 1.60206 | 25.0000 | 125.66 | 1256.64 |
| 41 | 1681 | 68921 | 6.4031 | 3.4482 | 1.61278 | 24.3902 | 128.81 | 1320.25 |
| 42 | 1764 | 74088 | 6.4807 | 3.4760 | 1.62325 | 23.8095 | 131.95 | 1385.44 |
| 43 | 1849 | 79507 | 6.5574 | 3.5034 | 1.63347 | 23.2558 | 135.09 | 1452.20 |
| 44 | 1936 | 85184 | 6.6332 | 3.5303 | 1.64345 | 22.7273 | 138.23 | 1520.53 |
| 45 | 2025 | 91125 | 6.7082 | 3.5569 | 1.65321 | 22.2222 | 141.37 | 1590.43 |
| 46 | 2116 | 97336 | 6.7823 | 3.5830 | 1.66276 | 21.7391 | 144.51 | 1661.90 |
| 47 | 2209 | 103823 | 6.8557 | 3.6088 | 1.67210 | 21.2766 | 147.65 | 1734.94 |
| 48 | 2304 | 110592 | 6.9282 | 3.6342 | 1.68124 | 20.8333 | 150.80 | 1809.56 |
| 49 | 2401 | 117649 | 7.0000 | 3.6593 | 1.69020 | 20.4082 | 153.94 | 1885.74 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALs, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|--------|--------------|------------|---------|---------------|-----------------|---------|
| | | | | | | | Circum. | Area. |
| 50 | 2500 | 125000 | 7.0711 | 3.6840 | 1.69897 | 20.0000 | 157.08 | 1963.50 |
| 51 | 2601 | 132651 | 7.1414 | 3.7084 | 1.70757 | 19.6078 | 160.22 | 2042.82 |
| 52 | 2704 | 140608 | 7.2111 | 3.7325 | 1.71600 | 19.2308 | 163.36 | 2123.72 |
| 53 | 2809 | 148877 | 7.2801 | 3.7563 | 1.72428 | 18.8679 | 166.50 | 2206.18 |
| 54 | 2916 | 157464 | 7.3485 | 3.7798 | 1.73239 | 18.5185 | 169.65 | 2290.22 |
| 55 | 3025 | 166375 | 7.4162 | 3.8030 | 1.74036 | 18.1818 | 172.79 | 2375.83 |
| 56 | 3136 | 175616 | 7.4833 | 3.8259 | 1.74819 | 17.8571 | 175.93 | 2463.01 |
| 57 | 3249 | 185193 | 7.5498 | 3.8485 | 1.75587 | 17.5439 | 179.07 | 2551.76 |
| 58 | 3364 | 195112 | 7.6158 | 3.8709 | 1.76343 | 17.2414 | 182.21 | 2642.08 |
| 59 | 3481 | 205379 | 7.6811 | 3.8930 | 1.77085 | 16.9422 | 185.35 | 2733.97 |
| 60 | 3600 | 216000 | 7.7460 | 3.9149 | 1.77815 | 16.6667 | 188.50 | 2827.43 |
| 61 | 3721 | 226981 | 7.8102 | 3.9365 | 1.78533 | 16.3934 | 191.64 | 2922.47 |
| 62 | 3844 | 238328 | 7.8740 | 3.9579 | 1.79239 | 16.1290 | 194.78 | 3019.07 |
| 63 | 3969 | 250047 | 7.9373 | 3.9791 | 1.79934 | 15.8730 | 197.92 | 3117.25 |
| 64 | 4096 | 262144 | 8.0000 | 4.0000 | 1.80618 | 15.6250 | 201.06 | 3216.99 |
| 65 | 4225 | 274625 | 8.0623 | 4.0207 | 1.81291 | 15.3846 | 204.20 | 3318.31 |
| 66 | 4356 | 287496 | 8.1240 | 4.0412 | 1.81954 | 15.1515 | 207.35 | 3421.19 |
| 67 | 4489 | 300763 | 8.1854 | 4.0615 | 1.82607 | 14.9254 | 210.49 | 3525.65 |
| 68 | 4624 | 314432 | 8.2462 | 4.0817 | 1.83251 | 14.7059 | 213.63 | 3631.68 |
| 69 | 4761 | 328509 | 8.3066 | 4.1016 | 1.83885 | 14.4928 | 216.77 | 3739.28 |
| 70 | 4900 | 343000 | 8.3666 | 4.1213 | 1.84510 | 14.2857 | 219.91 | 3848.45 |
| 71 | 5041 | 357911 | 8.4261 | 4.1408 | 1.85126 | 14.0845 | 223.05 | 3959.19 |
| 72 | 5184 | 373248 | 8.4853 | 4.1602 | 1.85733 | 13.8889 | 226.19 | 4071.50 |
| 73 | 5329 | 389017 | 8.5440 | 4.1793 | 1.86332 | 13.6986 | 229.34 | 4185.39 |
| 74 | 5476 | 405224 | 8.6023 | 4.1983 | 1.86923 | 13.5135 | 232.48 | 4300.84 |
| 75 | 5625 | 421875 | 8.6603 | 4.2172 | 1.87506 | 13.3333 | 235.62 | 4417.86 |
| 76 | 5776 | 438976 | 8.7178 | 4.2358 | 1.88081 | 13.1579 | 238.76 | 4536.46 |
| 77 | 5929 | 456533 | 8.7750 | 4.2543 | 1.88649 | 12.9870 | 241.90 | 4656.63 |
| 78 | 6084 | 474552 | 8.8318 | 4.2727 | 1.89209 | 12.8205 | 245.04 | 4778.36 |
| 79 | 6241 | 493039 | 8.8882 | 4.2908 | 1.89763 | 12.6582 | 248.19 | 4901.67 |
| 80 | 6400 | 512000 | 8.9443 | 4.3089 | 1.90309 | 12.5000 | 251.33 | 5026.55 |
| 81 | 6561 | 531441 | 9.0000 | 4.3267 | 1.90849 | 12.3457 | 254.47 | 5153.00 |
| 82 | 6724 | 551368 | 9.0554 | 4.3445 | 1.91381 | 12.1951 | 257.61 | 5281.02 |
| 83 | 6889 | 571787 | 9.1104 | 4.3621 | 1.91908 | 12.0482 | 260.75 | 5410.61 |
| 84 | 7056 | 592704 | 9.1652 | 4.3795 | 1.92428 | 11.9048 | 263.89 | 5541.77 |
| 85 | 7225 | 614125 | 9.2195 | 4.3968 | 1.92942 | 11.7647 | 267.04 | 5674.50 |
| 86 | 7396 | 636056 | 9.2736 | 4.4140 | 1.93450 | 11.6279 | 270.18 | 5808.80 |
| 87 | 7569 | 658503 | 9.3274 | 4.4310 | 1.93952 | 11.4943 | 273.32 | 5944.68 |
| 88 | 7744 | 681472 | 9.3808 | 4.4480 | 1.94448 | 11.3636 | 276.46 | 6082.12 |
| 89 | 7921 | 704969 | 9.4340 | 4.4647 | 1.94939 | 11.2360 | 279.60 | 6221.14 |
| 90 | 8100 | 729000 | 9.4868 | 4.4814 | 1.95424 | 11.1111 | 282.74 | 6361.73 |
| 91 | 8281 | 753571 | 9.5394 | 4.4979 | 1.95904 | 10.9890 | 285.88 | 6503.88 |
| 92 | 8464 | 778688 | 9.5917 | 4.5144 | 1.96379 | 10.8696 | 289.03 | 6647.61 |
| 93 | 8649 | 804357 | 9.6437 | 4.5307 | 1.96848 | 10.7527 | 292.17 | 6792.91 |
| 94 | 8836 | 830584 | 9.6954 | 4.5468 | 1.97313 | 10.6383 | 295.31 | 6939.78 |
| 95 | 9025 | 857375 | 9.7468 | 4.5629 | 1.97772 | 10.5263 | 298.45 | 7088.22 |
| 96 | 9216 | 884736 | 9.7980 | 4.5789 | 1.98227 | 10.4167 | 301.59 | 7238.23 |
| 97 | 9409 | 912673 | 9.8489 | 4.5947 | 1.98677 | 10.3093 | 304.73 | 7389.81 |
| 98 | 9604 | 941192 | 9.8995 | 4.6104 | 1.99123 | 10.2041 | 307.88 | 7542.96 |
| 99 | 9801 | 970299 | 9.9499 | 4.6261 | 1.99564 | 10.1010 | 311.02 | 7697.69 |

592 SQUARES, CUBES, SQUARE ROOTS, ETC.

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|---------|--------------|------------|---------|---------------|-----------------|---------|
| | | | | | | | Circum. | Area. |
| 100 | 10000 | 1000000 | 10.0000 | 4.6416 | 2.00000 | 10.0000 | 314.16 | 7853.98 |
| 101 | 10201 | 1030301 | 10.0499 | 4.6570 | 2.00432 | 9.90099 | 317.30 | 8011.85 |
| 102 | 10404 | 1061208 | 10.0995 | 4.6723 | 2.00860 | 9.80392 | 320.44 | 8171.28 |
| 103 | 10609 | 1092727 | 10.1489 | 4.6875 | 2.01284 | 9.70874 | 323.58 | 8332.29 |
| 104 | 10816 | 1124864 | 10.1980 | 4.7027 | 2.01703 | 9.61538 | 326.73 | 8494.87 |
| 105 | 11025 | 1157625 | 10.2470 | 4.7177 | 2.02119 | 9.52381 | 329.87 | 8659.01 |
| 106 | 11236 | 1191016 | 10.2956 | 4.7326 | 2.02531 | 9.43396 | 333.01 | 8824.73 |
| 107 | 11449 | 1225043 | 10.3441 | 4.7475 | 2.02938 | 9.34579 | 336.15 | 8992.02 |
| 108 | 11664 | 1259712 | 10.3923 | 4.7622 | 2.03342 | 9.25926 | 339.29 | 9160.88 |
| 109 | 11881 | 1295029 | 10.4403 | 4.7769 | 2.03743 | 9.17431 | 342.43 | 9331.32 |
| 110 | 12100 | 1331000 | 10.4881 | 4.7914 | 2.04139 | 9.09091 | 345.58 | 9503.32 |
| 111 | 12321 | 1367631 | 10.5357 | 4.8059 | 2.04532 | 9.00901 | 348.72 | 9676.89 |
| 112 | 12544 | 1404928 | 10.5830 | 4.8203 | 2.04922 | 8.92857 | 351.86 | 9852.03 |
| 113 | 12769 | 1442897 | 10.6301 | 4.8346 | 2.05308 | 8.84956 | 355.00 | 10028.7 |
| 114 | 12996 | 1481544 | 10.6771 | 4.8488 | 2.05690 | 8.77193 | 358.14 | 10207.0 |
| 115 | 13225 | 1520875 | 10.7238 | 4.8629 | 2.06070 | 8.69565 | 361.28 | 10386.9 |
| 116 | 13456 | 1560896 | 10.7703 | 4.8770 | 2.06446 | 8.62069 | 364.42 | 10568.3 |
| 117 | 13689 | 1601613 | 10.8167 | 4.8910 | 2.06819 | 8.54701 | 367.57 | 10751.3 |
| 118 | 13924 | 1643032 | 10.8628 | 4.9049 | 2.07188 | 8.47458 | 370.71 | 10935.9 |
| 119 | 14161 | 1685159 | 10.9087 | 4.9187 | 2.07555 | 8.40336 | 373.85 | 11122.0 |
| 120 | 14400 | 1728000 | 10.9545 | 4.9324 | 2.07918 | 8.33333 | 376.99 | 11309.7 |
| 121 | 14641 | 1771561 | 11.0000 | 4.9461 | 2.08279 | 8.26446 | 380.13 | 11499.0 |
| 122 | 14884 | 1815848 | 11.0454 | 4.9597 | 2.08636 | 8.19672 | 383.27 | 11689.9 |
| 123 | 15129 | 1860867 | 11.0905 | 4.9732 | 2.08991 | 8.13008 | 386.42 | 11882.3 |
| 124 | 15376 | 1906624 | 11.1355 | 4.9866 | 2.09342 | 8.06452 | 389.56 | 12076.3 |
| 125 | 15625 | 1953125 | 11.1803 | 5.0000 | 2.09691 | 8.00000 | 392.70 | 12271.8 |
| 126 | 15876 | 2000376 | 11.2250 | 5.0133 | 2.10037 | 7.93651 | 395.84 | 12469.0 |
| 127 | 16129 | 2048383 | 11.2694 | 5.0265 | 2.10380 | 7.87402 | 398.98 | 12667.7 |
| 128 | 16384 | 2097152 | 11.3137 | 5.0397 | 2.10721 | 7.81250 | 402.12 | 12868.0 |
| 129 | 16641 | 2146689 | 11.3578 | 5.0528 | 2.11059 | 7.75194 | 405.27 | 13069.8 |
| 130 | 16900 | 2197000 | 11.4018 | 5.0658 | 2.11394 | 7.69231 | 408.41 | 13273.2 |
| 131 | 17161 | 2248091 | 11.4455 | 5.0788 | 2.11727 | 7.63359 | 411.55 | 13478.2 |
| 132 | 17424 | 2299968 | 11.4891 | 5.0916 | 2.12057 | 7.57576 | 414.69 | 13684.8 |
| 133 | 17689 | 2352637 | 11.5326 | 5.1045 | 2.12385 | 7.51880 | 417.83 | 13892.9 |
| 134 | 17956 | 2406104 | 11.5758 | 5.1172 | 2.12710 | 7.46269 | 420.97 | 14102.6 |
| 135 | 18225 | 2460375 | 11.6190 | 5.1299 | 2.13033 | 7.40741 | 424.12 | 14313.9 |
| 136 | 18496 | 2515456 | 11.6619 | 5.1426 | 2.13354 | 7.35294 | 427.26 | 14526.7 |
| 137 | 18769 | 2571353 | 11.7047 | 5.1551 | 2.13672 | 7.29927 | 430.40 | 14741.1 |
| 138 | 19044 | 2628072 | 11.7473 | 5.1676 | 2.13988 | 7.24638 | 433.54 | 14957.1 |
| 139 | 19321 | 2685619 | 11.7898 | 5.1801 | 2.14301 | 7.19424 | 436.68 | 15174.7 |
| 140 | 19600 | 2744000 | 11.8322 | 5.1925 | 2.14613 | 7.14286 | 439.82 | 15393.8 |
| 141 | 19881 | 2803221 | 11.8743 | 5.2048 | 2.14922 | 7.09220 | 442.96 | 15614.5 |
| 142 | 20164 | 2863288 | 11.9164 | 5.2171 | 2.15229 | 7.04255 | 446.11 | 15836.8 |
| 143 | 20449 | 2924207 | 11.9583 | 5.2293 | 2.15534 | 6.99301 | 449.25 | 16060.6 |
| 144 | 20736 | 2985984 | 12.0000 | 5.2415 | 2.15836 | 6.94444 | 452.39 | 16286.0 |
| 145 | 21025 | 3048625 | 12.0416 | 5.2536 | 2.16137 | 6.89655 | 455.53 | 16513.0 |
| 146 | 21316 | 3112136 | 12.0830 | 5.2656 | 2.16435 | 6.84932 | 458.67 | 16741.5 |
| 147 | 21609 | 3176523 | 12.1244 | 5.2776 | 2.16732 | 6.80272 | 461.81 | 16971.7 |
| 148 | 21904 | 3241792 | 12.1655 | 5.2896 | 2.17026 | 6.75676 | 464.96 | 17203.4 |
| 149 | 22201 | 3307949 | 12.2066 | 5.3015 | 2.17319 | 6.71141 | 468.10 | 17436.6 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|---------|--------------|------------|---------|---------------|-----------------|---------|
| | | | | | | | Circum. | Area. |
| 150 | 22500 | 3375000 | 12.2474 | 5.3133 | 2.17609 | 6.66667 | 471.24 | 17671.5 |
| 151 | 22801 | 3442951 | 12.2882 | 5.3251 | 2.17898 | 6.62252 | 474.38 | 17907.9 |
| 152 | 23104 | 3511808 | 12.3288 | 5.3368 | 2.18184 | 6.57895 | 477.52 | 18145.8 |
| 153 | 23409 | 3581577 | 12.3693 | 5.3485 | 2.18469 | 6.53595 | 480.66 | 18385.4 |
| 154 | 23716 | 3652264 | 12.4097 | 5.3601 | 2.18752 | 6.49351 | 483.81 | 18626.5 |
| 155 | 24025 | 3723875 | 12.4499 | 5.3717 | 2.19033 | 6.45161 | 486.95 | 18869.2 |
| 156 | 24336 | 3796416 | 12.4900 | 5.3832 | 2.19312 | 6.41026 | 490.09 | 19113.4 |
| 157 | 24649 | 3869893 | 12.5300 | 5.3947 | 2.19590 | 6.36943 | 493.23 | 19359.3 |
| 158 | 24964 | 3944312 | 12.5698 | 5.4061 | 2.19866 | 6.32911 | 496.37 | 19606.7 |
| 159 | 25281 | 4019679 | 12.6095 | 5.4175 | 2.20140 | 6.28931 | 499.51 | 19855.7 |
| 160 | 25600 | 4096000 | 12.6491 | 5.4288 | 2.20412 | 6.25000 | 502.65 | 20106.2 |
| 161 | 25921 | 4173281 | 12.6886 | 5.4401 | 2.20683 | 6.21118 | 505.80 | 20358.3 |
| 162 | 26244 | 4251528 | 12.7279 | 5.4514 | 2.20952 | 6.17284 | 508.94 | 20612.0 |
| 163 | 26569 | 4330747 | 12.7671 | 5.4626 | 2.21219 | 6.13497 | 512.08 | 20867.2 |
| 164 | 26896 | 4410944 | 12.8062 | 5.4737 | 2.21484 | 6.09756 | 515.22 | 21124.1 |
| 165 | 27225 | 4492125 | 12.8452 | 5.4848 | 2.21748 | 6.06061 | 518.36 | 21382.5 |
| 166 | 27556 | 4574296 | 12.8841 | 5.4959 | 2.22011 | 6.02410 | 521.50 | 21642.4 |
| 167 | 27889 | 4657463 | 12.9223 | 5.5069 | 2.22272 | 5.98802 | 524.65 | 21904.0 |
| 168 | 28224 | 4741632 | 12.9615 | 5.5178 | 2.22531 | 5.95238 | 527.79 | 22167.1 |
| 169 | 28561 | 4826809 | 13.0000 | 5.5288 | 2.22789 | 5.91716 | 530.93 | 22431.8 |
| 170 | 28900 | 4913000 | 13.0384 | 5.5397 | 2.23045 | 5.88235 | 534.07 | 22698.0 |
| 171 | 29241 | 5000211 | 13.0767 | 5.5505 | 2.23300 | 5.84795 | 537.21 | 22965.8 |
| 172 | 29584 | 5088448 | 13.1149 | 5.5613 | 2.23553 | 5.81395 | 540.35 | 23235.2 |
| 173 | 29929 | 5177717 | 13.1529 | 5.5721 | 2.23805 | 5.78035 | 543.50 | 23506.2 |
| 174 | 30276 | 5268024 | 13.1909 | 5.5828 | 2.24055 | 5.74713 | 546.64 | 23778.7 |
| 175 | 30625 | 5359375 | 13.2288 | 5.5934 | 2.24304 | 5.71429 | 549.78 | 24052.8 |
| 176 | 30976 | 5451776 | 13.2665 | 5.6041 | 2.24551 | 5.68182 | 552.92 | 24328.5 |
| 177 | 31329 | 5545233 | 13.3041 | 5.6147 | 2.24797 | 5.64972 | 556.06 | 24605.7 |
| 178 | 31684 | 5639752 | 13.3417 | 5.6252 | 2.25042 | 5.61798 | 559.20 | 24884.6 |
| 179 | 32041 | 5735339 | 13.3791 | 5.6357 | 2.25285 | 5.58659 | 562.35 | 25164.9 |
| 180 | 32400 | 5832000 | 13.4164 | 5.6462 | 2.25527 | 5.55556 | 565.49 | 25446.9 |
| 181 | 32761 | 5929741 | 13.4536 | 5.6567 | 2.25768 | 5.52486 | 568.63 | 25730.4 |
| 182 | 33124 | 6028568 | 13.4907 | 5.6671 | 2.26007 | 5.49451 | 571.77 | 26015.5 |
| 183 | 33489 | 6128487 | 13.5277 | 5.6774 | 2.26245 | 5.46448 | 574.91 | 26302.2 |
| 184 | 33856 | 6229504 | 13.5647 | 5.6877 | 2.26482 | 5.43478 | 578.05 | 26590.4 |
| 185 | 34225 | 6331625 | 13.6015 | 5.6980 | 2.26717 | 5.40541 | 581.19 | 26880.3 |
| 186 | 34596 | 6434856 | 13.6382 | 5.7083 | 2.26951 | 5.37634 | 584.34 | 27171.6 |
| 187 | 34969 | 6539203 | 13.6748 | 5.7185 | 2.27184 | 5.34759 | 587.48 | 27464.6 |
| 188 | 35344 | 6644672 | 13.7113 | 5.7287 | 2.27416 | 5.31915 | 590.62 | 27759.1 |
| 189 | 35721 | 6751269 | 13.7477 | 5.7388 | 2.27646 | 5.29101 | 593.76 | 28055.2 |
| 190 | 36100 | 6859000 | 13.7840 | 5.7489 | 2.27875 | 5.26316 | 596.90 | 28352.9 |
| 191 | 36481 | 6967871 | 13.8203 | 5.7590 | 2.28103 | 5.23560 | 600.04 | 28652.1 |
| 192 | 36864 | 7077888 | 13.8564 | 5.7690 | 2.28330 | 5.20833 | 603.19 | 28952.9 |
| 193 | 37249 | 7189057 | 13.8924 | 5.7790 | 2.28556 | 5.18135 | 606.33 | 29255.3 |
| 194 | 37636 | 7301384 | 13.9284 | 5.7890 | 2.28780 | 5.15464 | 609.47 | 29559.2 |
| 195 | 38025 | 7414875 | 13.9642 | 5.7989 | 2.29003 | 5.12821 | 612.61 | 29864.8 |
| 196 | 38416 | 7529536 | 14.0000 | 5.8088 | 2.29226 | 5.10204 | 615.75 | 30171.9 |
| 197 | 38809 | 7645373 | 14.0357 | 5.8186 | 2.29447 | 5.07614 | 618.89 | 30480.5 |
| 198 | 39204 | 7763392 | 14.0712 | 5.8285 | 2.29667 | 5.05051 | 622.04 | 30790.7 |
| 199 | 39601 | 7880599 | 14.1067 | 5.8383 | 2.29885 | 5.02513 | 625.18 | 31102.6 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|----------|--------------|------------|---------|---------------|-----------------|---------|
| | | | | | | | Circum. | Area. |
| 200 | 40000 | 8000000 | 14.1421 | 5.8480 | 2.30103 | 5.00000 | 628.32 | 31415.9 |
| 201 | 40401 | 8120601 | 14.1774 | 5.8578 | 2.30320 | 4.97512 | 631.46 | 31730.9 |
| 202 | 40804 | 8242408 | 14.2127 | 5.8675 | 2.30535 | 4.95050 | 634.60 | 32047.4 |
| 203 | 41209 | 8365427 | 14.2478 | 5.8771 | 2.30750 | 4.92611 | 637.74 | 32365.5 |
| 204 | 41616 | 8489664 | 14.2829 | 5.8868 | 2.30963 | 4.90196 | 640.89 | 32685.1 |
| 205 | 42025 | 8615125 | 14.3178 | 5.8964 | 2.31175 | 4.87805 | 644.03 | 33006.4 |
| 206 | 42436 | 8741816 | 14.3527 | 5.9059 | 2.31387 | 4.85437 | 647.17 | 33329.2 |
| 207 | 42849 | 8869743 | 14.3875 | 5.9155 | 2.31597 | 4.83092 | 650.31 | 33653.5 |
| 208 | 43264 | 8998912 | 14.4222 | 5.9250 | 2.31806 | 4.80769 | 653.45 | 33979.5 |
| 209 | 43681 | 9129329 | 14.4568 | 5.9345 | 2.32015 | 4.78469 | 656.59 | 34307.0 |
| 210 | 44100 | 9261000 | 14.4914 | 5.9439 | 2.32222 | 4.76190 | 659.73 | 34636.1 |
| 211 | 44521 | 9393931 | 14.5258 | 5.9533 | 2.32428 | 4.73934 | 662.88 | 34966.7 |
| 212 | 44944 | 9528128 | 14.5602 | 5.9627 | 2.32634 | 4.71698 | 666.02 | 35298.9 |
| 213 | 45369 | 9663597 | 14.5945 | 5.9721 | 2.32838 | 4.69484 | 669.16 | 35632.7 |
| 214 | 45796 | 9800344 | 14.6287 | 5.9814 | 2.33041 | 4.67290 | 672.30 | 35968.1 |
| 215 | 46225 | 9938375 | 14.6629 | 5.9907 | 2.33244 | 4.65116 | 675.44 | 36305.0 |
| 216 | 46656 | 10077696 | 14.6969 | 6.0000 | 2.33445 | 4.62963 | 678.58 | 36643.5 |
| 217 | 47089 | 1218313 | 14.7309 | 6.0092 | 2.33646 | 4.60829 | 681.73 | 36983.6 |
| 218 | 47524 | 10360232 | 14.7648 | 6.0185 | 2.33846 | 4.58716 | 684.87 | 37325.3 |
| 219 | 47961 | 10503459 | 14.7986 | 6.0277 | 2.34044 | 4.56621 | 688.01 | 37668.5 |
| 220 | 48400 | 10648000 | 14.8324 | 6.0368 | 2.34242 | 4.54545 | 691.15 | 38013.3 |
| 221 | 48841 | 10793861 | 14.8661 | 6.0459 | 2.34439 | 4.52489 | 694.29 | 38359.6 |
| 222 | 49284 | 10941048 | 14.8997 | 6.0550 | 2.34635 | 4.50450 | 697.43 | 38707.6 |
| 223 | 49729 | 11089567 | 14.9332 | 6.0641 | 2.34830 | 4.48431 | 700.58 | 39057.1 |
| 224 | 50176 | 11239424 | 14.9666 | 6.0732 | 2.35025 | 4.46429 | 703.72 | 39408.1 |
| 225 | 50625 | 11390625 | 15.0000 | 6.0822 | 2.35218 | 4.44444 | 706.86 | 39760.8 |
| 226 | 51076 | 11543176 | 15.0333 | 6.0912 | 2.35411 | 4.42478 | 710.00 | 40115.0 |
| 227 | 51529 | 11697083 | 15.0665 | 6.1002 | 2.35603 | 4.40529 | 713.14 | 40470.8 |
| 228 | 51984 | 11852352 | 15.0997 | 6.1091 | 2.35793 | 4.38596 | 716.28 | 40828.1 |
| 229 | 52441 | 12008989 | 15.1327 | 6.1180 | 2.35984 | 4.36681 | 719.42 | 41187.1 |
| 230 | 52900 | 12167000 | 15.1658 | 6.1269 | 2.36173 | 4.34783 | 722.57 | 41547.6 |
| 231 | 53361 | 12326391 | 15.1987 | 6.1358 | 2.36361 | 4.32900 | 725.71 | 41909.6 |
| 232 | 53824 | 12487168 | 15.2315 | 6.1446 | 2.36549 | 4.31034 | 728.85 | 42273.3 |
| 233 | 54289 | 12649337 | 15.2643 | 6.1534 | 2.36736 | 4.29185 | 731.99 | 42638.5 |
| 234 | 54756 | 12812904 | 15.2971 | 6.1622 | 2.36922 | 4.27350 | 735.13 | 43005.3 |
| 235 | 55225 | 12977875 | 15.3297 | 6.1710 | 2.37107 | 4.25532 | 738.27 | 43373.6 |
| 236 | 55696 | 13144256 | 15.3623 | 6.1797 | 2.37291 | 4.23729 | 741.42 | 43743.5 |
| 237 | 56169 | 13312053 | 15.3948 | 6.1885 | 2.37475 | 4.21941 | 744.56 | 44115.0 |
| 238 | 56644 | 13481272 | 15.4272 | 6.1972 | 2.37658 | 4.20168 | 747.70 | 44488.1 |
| 239 | 57121 | 13651919 | 15.4596 | 6.2058 | 2.37840 | 4.18410 | 750.84 | 44862.7 |
| 240 | 57600 | 13824000 | 15.4919 | 6.2145 | 2.38021 | 4.16667 | 753.98 | 45238.9 |
| 241 | 58081 | 13997521 | 15.5242 | 6.2231 | 2.38202 | 4.14938 | 757.12 | 45616.7 |
| 242 | 58564 | 14172488 | 15.5563 | 6.2317 | 2.38382 | 4.13223 | 760.27 | 45996.1 |
| 243 | 59049 | 14348907 | 15.5885 | 6.2403 | 2.38561 | 4.11523 | 763.41 | 46377.0 |
| 244 | 59536 | 14526784 | 15.6205 | 6.2488 | 2.38739 | 4.09836 | 766.55 | 46759.5 |
| 245 | 60025 | 14706125 | 15.6525 | 6.2573 | 2.38917 | 4.08163 | 769.69 | 47143.5 |
| 246 | 60516 | 14886936 | 15.6844 | 6.2658 | 2.39094 | 4.06504 | 772.83 | 47529.2 |
| 247 | 61009 | 15069223 | 15.7162 | 6.2743 | 2.39270 | 4.04858 | 775.97 | 47916.4 |
| 248 | 61504 | 15252992 | 15.7480 | 6.2828 | 2.39445 | 4.03226 | 779.12 | 48305.1 |
| 249 | 62001 | 15438249 | 15.7797 | 6.2912 | 2.39620 | 4.01606 | 782.26 | 48695.5 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|----------|--------------|------------|---------|---------------|-----------------|---------|
| | | | | | | | Circum. | Area. |
| 250 | 62500 | 15625000 | 15.8114 | 6.2996 | 2.39794 | 4.00000 | 785.40 | 49087.4 |
| 251 | 63001 | 15813251 | 15.8430 | 6.3080 | 2.39967 | 3.98406 | 788.54 | 49480.9 |
| 252 | 63504 | 16003008 | 15.8745 | 6.3164 | 2.40140 | 3.96825 | 791.68 | 49875.9 |
| 253 | 64009 | 16194277 | 15.9060 | 6.3247 | 2.40312 | 3.95257 | 794.82 | 50272.6 |
| 254 | 64516 | 16387064 | 15.9374 | 6.3330 | 2.40483 | 3.93701 | 797.96 | 50670.7 |
| 255 | 65025 | 16581375 | 15.9687 | 6.3413 | 2.40654 | 3.92157 | 801.11 | 51070.5 |
| 256 | 65536 | 16777216 | 16.0000 | 6.3496 | 2.40824 | 3.90625 | 804.25 | 51471.9 |
| 257 | 66049 | 16974593 | 16.0312 | 6.3579 | 2.40993 | 3.89105 | 807.39 | 51874.8 |
| 258 | 66564 | 17173512 | 16.0624 | 6.3661 | 2.41162 | 3.87597 | 810.53 | 52279.2 |
| 259 | 67081 | 17373979 | 16.0935 | 6.3743 | 2.41330 | 3.86100 | 813.67 | 52685.3 |
| 260 | 67600 | 17576000 | 16.1245 | 6.3825 | 2.41497 | 3.84615 | 816.81 | 53092.9 |
| 261 | 68121 | 17779581 | 16.1555 | 6.3907 | 2.41664 | 3.83142 | 819.96 | 53502.1 |
| 262 | 68644 | 17984723 | 16.1864 | 6.3988 | 2.41830 | 3.81679 | 823.10 | 53912.9 |
| 263 | 69169 | 18191447 | 16.2173 | 6.4070 | 2.41996 | 3.80228 | 826.24 | 54325.2 |
| 264 | 69696 | 18399744 | 16.2481 | 6.4151 | 2.42160 | 3.78788 | 829.38 | 54739.1 |
| 265 | 70225 | 18609625 | 16.2788 | 6.4232 | 2.42325 | 3.77358 | 832.52 | 55154.6 |
| 266 | 70756 | 18821096 | 16.3095 | 6.4312 | 2.42488 | 3.75940 | 835.66 | 55571.6 |
| 267 | 71239 | 19034163 | 16.3401 | 6.4393 | 2.42651 | 3.74532 | 838.81 | 55990.3 |
| 268 | 71824 | 19248832 | 16.3707 | 6.4473 | 2.42813 | 3.73134 | 841.95 | 56410.4 |
| 269 | 72361 | 19465109 | 16.4012 | 6.4553 | 2.42975 | 3.71747 | 845.09 | 56832.2 |
| 270 | 72900 | 19683000 | 16.4317 | 6.4633 | 2.43136 | 3.70370 | 848.23 | 57255.5 |
| 271 | 73441 | 19902511 | 16.4621 | 6.4713 | 2.43297 | 3.69004 | 851.37 | 57680.4 |
| 272 | 73984 | 20123648 | 16.4924 | 6.4792 | 2.43457 | 3.67647 | 854.51 | 58106.9 |
| 273 | 74529 | 20346417 | 16.5227 | 6.4872 | 2.43616 | 3.66300 | 857.66 | 58534.9 |
| 274 | 75076 | 20570824 | 16.5529 | 6.4951 | 2.43775 | 3.64964 | 860.80 | 58964.6 |
| 275 | 75625 | 20796875 | 16.5831 | 6.5030 | 2.43933 | 3.63636 | 863.94 | 59395.7 |
| 276 | 76176 | 21024576 | 16.6132 | 6.5108 | 2.44091 | 3.62319 | 867.08 | 59823.5 |
| 277 | 76729 | 21253933 | 16.6433 | 6.5187 | 2.44248 | 3.61011 | 870.22 | 60262.8 |
| 278 | 77284 | 21484952 | 16.6733 | 6.5265 | 2.44404 | 3.59712 | 873.36 | 60698.7 |
| 279 | 77841 | 21717639 | 16.7033 | 6.5343 | 2.44560 | 3.58423 | 876.50 | 61136.2 |
| 280 | 78400 | 21952000 | 16.7332 | 6.5421 | 2.44716 | 3.57143 | 879.65 | 61575.2 |
| 281 | 78961 | 22183041 | 16.7631 | 6.5499 | 2.44871 | 3.55872 | 882.79 | 62015.8 |
| 282 | 79524 | 22425768 | 16.7929 | 6.5577 | 2.45025 | 3.54610 | 885.93 | 62458.0 |
| 283 | 80089 | 22665187 | 16.8226 | 6.5654 | 2.45179 | 3.53357 | 889.07 | 62901.8 |
| 284 | 80656 | 22906304 | 16.8523 | 6.5731 | 2.45332 | 3.52113 | 892.21 | 63347.1 |
| 285 | 81225 | 23149125 | 16.8819 | 6.5808 | 2.45484 | 3.50877 | 895.35 | 63794.0 |
| 286 | 81796 | 23393656 | 16.9115 | 6.5885 | 2.45637 | 3.49650 | 898.50 | 64242.4 |
| 287 | 82369 | 23639903 | 16.9411 | 6.5962 | 2.45788 | 3.48432 | 901.64 | 64692.5 |
| 288 | 82944 | 23887872 | 16.9706 | 6.6039 | 2.45939 | 3.47222 | 904.78 | 65144.1 |
| 289 | 83521 | 24137569 | 17.0000 | 6.6115 | 2.46090 | 3.46021 | 907.92 | 65597.2 |
| 290 | 84100 | 24389000 | 17.0294 | 6.6191 | 2.46240 | 3.44828 | 911.06 | 66052.0 |
| 291 | 84681 | 24642171 | 17.0587 | 6.6267 | 2.46389 | 3.43643 | 914.20 | 66508.3 |
| 292 | 85264 | 24897088 | 17.0880 | 6.6343 | 2.46538 | 3.42466 | 917.35 | 66966.2 |
| 293 | 85849 | 25153757 | 17.1172 | 6.6419 | 2.46687 | 3.41297 | 920.49 | 67425.6 |
| 294 | 86436 | 25412184 | 17.1464 | 6.6494 | 2.46835 | 3.40136 | 923.63 | 67886.7 |
| 295 | 87025 | 25672375 | 17.1756 | 6.6569 | 2.46982 | 3.38983 | 926.77 | 68349.3 |
| 296 | 87616 | 25934336 | 17.2047 | 6.6644 | 2.47129 | 3.37838 | 929.91 | 68813.5 |
| 297 | 88209 | 26198073 | 17.2337 | 6.6719 | 2.47276 | 3.36700 | 933.05 | 69279.2 |
| 298 | 88804 | 26463592 | 17.2627 | 6.6794 | 2.47422 | 3.35570 | 936.19 | 69746.5 |
| 299 | 89401 | 26730899 | 17.2916 | 6.6869 | 2.47567 | 3.34448 | 939.34 | 70215.4 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS,
 RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS
 OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|----------|--------------|------------|---------|---------------|-----------------|---------|
| | | | | | | | Circum. | Area. |
| 300 | 90000 | 27000000 | 17.3205 | 6.6943 | 2.47712 | 3.33333 | 942.48 | 70685.8 |
| 301 | 90601 | 27270901 | 17.3494 | 6.7018 | 2.47857 | 3.32226 | 945.62 | 71157.9 |
| 302 | 91204 | 27543608 | 17.3781 | 6.7092 | 2.48001 | 3.31126 | 948.76 | 71631.5 |
| 303 | 91809 | 27818127 | 17.4069 | 6.7166 | 2.48144 | 3.30033 | 951.90 | 72106.6 |
| 304 | 92416 | 28094464 | 17.4356 | 6.7240 | 2.48287 | 3.28947 | 955.04 | 72583.4 |
| 305 | 93025 | 28372625 | 17.4642 | 6.7313 | 2.48430 | 3.27869 | 958.19 | 73061.7 |
| 306 | 93636 | 28652616 | 17.4929 | 6.7387 | 2.48572 | 3.26797 | 961.33 | 73541.5 |
| 307 | 94249 | 28934443 | 17.5214 | 6.7460 | 2.48714 | 3.25733 | 964.47 | 74023.0 |
| 308 | 94864 | 29218112 | 17.5499 | 6.7533 | 2.48855 | 3.24675 | 967.61 | 74506.0 |
| 309 | 95481 | 29503629 | 17.5784 | 6.7606 | 2.48996 | 3.23625 | 970.75 | 74990.6 |
| 310 | 96100 | 29791000 | 17.6068 | 6.7679 | 2.49136 | 3.22581 | 973.89 | 75476.8 |
| 311 | 96721 | 30080231 | 17.6352 | 6.7752 | 2.49276 | 3.21543 | 977.04 | 75964.5 |
| 312 | 97344 | 30371328 | 17.6635 | 6.7824 | 2.49415 | 3.20513 | 980.18 | 76453.8 |
| 313 | 97969 | 30664297 | 17.6918 | 6.7897 | 2.49554 | 3.19489 | 983.32 | 76944.7 |
| 314 | 98596 | 30959144 | 17.7200 | 6.7969 | 2.49693 | 3.18471 | 986.46 | 77437.1 |
| 315 | 99225 | 31255875 | 17.7482 | 6.8041 | 2.49831 | 3.17460 | 989.60 | 77931.1 |
| 316 | 99856 | 31554496 | 17.7764 | 6.8113 | 2.49969 | 3.16456 | 992.74 | 78426.7 |
| 317 | 100489 | 31855013 | 17.8045 | 6.8185 | 2.50106 | 3.15457 | 995.88 | 78923.9 |
| 318 | 101124 | 32157432 | 17.8326 | 6.8256 | 2.50243 | 3.14465 | 999.03 | 79422.6 |
| 319 | 101761 | 32461759 | 17.8606 | 6.8328 | 2.50379 | 3.13480 | 1002.2 | 79922.9 |
| 320 | 102400 | 32768000 | 17.8885 | 6.8399 | 2.50515 | 3.12500 | 1005.3 | 80424.8 |
| 321 | 103041 | 33076161 | 17.9165 | 6.8470 | 2.50651 | 3.11527 | 1008.5 | 80928.2 |
| 322 | 103684 | 33386248 | 17.9444 | 6.8541 | 2.50786 | 3.10559 | 1011.6 | 81433.2 |
| 323 | 104329 | 33698267 | 17.9722 | 6.8612 | 2.50920 | 3.09598 | 1014.7 | 81939.8 |
| 324 | 104976 | 34012224 | 18.0000 | 6.8683 | 2.51055 | 3.08642 | 1017.9 | 82448.0 |
| 325 | 105625 | 34328125 | 18.0278 | 6.8753 | 2.51188 | 3.07692 | 1021.0 | 82957.7 |
| 326 | 106276 | 34645976 | 18.0555 | 6.8824 | 2.51322 | 3.06749 | 1024.2 | 83469.0 |
| 327 | 106929 | 34965783 | 18.0831 | 6.8894 | 2.51455 | 3.05810 | 1027.3 | 83981.8 |
| 328 | 107584 | 35287552 | 18.1108 | 6.8964 | 2.51587 | 3.04878 | 1030.4 | 84496.3 |
| 329 | 108241 | 35611289 | 18.1384 | 6.9034 | 2.51720 | 3.03951 | 1033.6 | 85012.3 |
| 330 | 108900 | 35937000 | 18.1659 | 6.9104 | 2.51851 | 3.03030 | 1036.7 | 85529.9 |
| 331 | 109561 | 36264691 | 18.1934 | 6.9174 | 2.51983 | 3.02115 | 1039.9 | 86049.0 |
| 332 | 110224 | 36594368 | 18.2209 | 6.9244 | 2.52114 | 3.01205 | 1043.0 | 86569.7 |
| 333 | 110889 | 36926037 | 18.2483 | 6.9313 | 2.52244 | 3.00300 | 1046.2 | 87092.0 |
| 334 | 111556 | 37259704 | 18.2757 | 6.9382 | 2.52375 | 2.99401 | 1049.3 | 87615.9 |
| 335 | 112225 | 37595375 | 18.3030 | 6.9451 | 2.52504 | 2.98507 | 1052.4 | 88141.3 |
| 336 | 112896 | 37933056 | 18.3303 | 6.9521 | 2.52634 | 2.97619 | 1055.6 | 88668.3 |
| 337 | 113569 | 38272753 | 18.3576 | 6.9589 | 2.52763 | 2.96736 | 1058.7 | 89196.9 |
| 338 | 114244 | 38614472 | 18.3848 | 6.9658 | 2.52892 | 2.95858 | 1061.9 | 89727.0 |
| 339 | 114921 | 38958219 | 18.4120 | 6.9727 | 2.53020 | 2.94985 | 1065.0 | 90258.7 |
| 340 | 115600 | 39304000 | 18.4391 | 6.9795 | 2.53148 | 2.94118 | 1068.1 | 90792.0 |
| 341 | 116281 | 39651821 | 18.4662 | 6.9864 | 2.53275 | 2.93255 | 1071.3 | 91326.9 |
| 342 | 116964 | 40001688 | 18.4932 | 6.9932 | 2.53403 | 2.92398 | 1074.4 | 91863.3 |
| 343 | 117649 | 40353607 | 18.5203 | 7.0000 | 2.53529 | 2.91545 | 1077.6 | 92401.3 |
| 344 | 118336 | 40707584 | 18.5472 | 7.0068 | 2.53656 | 2.90698 | 1080.7 | 92940.9 |
| 345 | 119025 | 41063625 | 18.5742 | 7.0136 | 2.53782 | 2.89855 | 1083.8 | 93482.0 |
| 346 | 119716 | 41421736 | 18.6011 | 7.0203 | 2.53908 | 2.89017 | 1087.0 | 94024.7 |
| 347 | 120409 | 41781923 | 18.6279 | 7.0271 | 2.54033 | 2.88184 | 1090.1 | 94569.0 |
| 348 | 121104 | 42144192 | 18.6548 | 7.0338 | 2.54158 | 2.87356 | 1093.3 | 95114.9 |
| 349 | 121801 | 42508549 | 18.6815 | 7.0406 | 2.54283 | 2.86533 | 1096.4 | 95662.3 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALs, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 X Recip. | No. = Diameter. | |
|-----|--------|----------|--------------|------------|---------|---------------|-----------------|---------|
| | | | | | | | Circum. | Area. |
| 350 | 122500 | 42875000 | 18.7083 | 7.0473 | 2.54407 | 2.85714 | 1099.6 | 96211.3 |
| 351 | 123201 | 43243551 | 18.7350 | 7.0540 | 2.54531 | 2.84900 | 1102.7 | 96761.8 |
| 352 | 123904 | 43614208 | 18.7617 | 7.0607 | 2.54654 | 2.84091 | 1105.8 | 97314.0 |
| 353 | 124609 | 43986977 | 18.7883 | 7.0674 | 2.54777 | 2.83286 | 1109.0 | 97867.7 |
| 354 | 125316 | 44361864 | 18.8149 | 7.0740 | 2.54900 | 2.82486 | 1112.1 | 98423.0 |
| 355 | 126025 | 44738875 | 18.8414 | 7.0807 | 2.55023 | 2.81690 | 1115.3 | 98979.8 |
| 356 | 126736 | 45118016 | 18.8680 | 7.0873 | 2.55145 | 2.80899 | 1118.4 | 99538.2 |
| 357 | 127449 | 45499293 | 18.8944 | 7.0940 | 2.55267 | 2.80112 | 1121.5 | 100098 |
| 358 | 128164 | 45882712 | 18.9209 | 7.1006 | 2.55388 | 2.79330 | 1124.7 | 100660 |
| 359 | 128881 | 46268279 | 18.9473 | 7.1072 | 2.55509 | 2.78552 | 1127.8 | 101223 |
| 360 | 129600 | 46656000 | 18.9737 | 7.1138 | 2.55630 | 2.77778 | 1131.0 | 101788 |
| 361 | 130321 | 47045881 | 19.0000 | 7.1204 | 2.55751 | 2.77008 | 1134.1 | 102354 |
| 362 | 131044 | 47437928 | 19.0263 | 7.1269 | 2.55871 | 2.76243 | 1137.3 | 102922 |
| 363 | 131769 | 47832147 | 19.0526 | 7.1335 | 2.55991 | 2.75482 | 1140.4 | 103491 |
| 364 | 132496 | 48228544 | 19.0788 | 7.1400 | 2.56110 | 2.74725 | 1143.5 | 104062 |
| 365 | 133225 | 48627125 | 19.1050 | 7.1466 | 2.56229 | 2.73973 | 1146.7 | 104635 |
| 366 | 133956 | 49027896 | 19.1311 | 7.1531 | 2.56348 | 2.73224 | 1149.8 | 105209 |
| 367 | 134689 | 49430863 | 19.1572 | 7.1596 | 2.56467 | 2.72480 | 1153.0 | 105785 |
| 368 | 135424 | 49836032 | 19.1833 | 7.1661 | 2.56585 | 2.71739 | 1156.1 | 106362 |
| 369 | 136161 | 50243409 | 19.2094 | 7.1726 | 2.56703 | 2.71003 | 1159.2 | 106941 |
| 370 | 136900 | 50653000 | 19.2354 | 7.1791 | 2.56820 | 2.70270 | 1162.4 | 107521 |
| 371 | 137641 | 51064811 | 19.2614 | 7.1855 | 2.56937 | 2.69542 | 1165.5 | 108103 |
| 372 | 138384 | 51478848 | 19.2873 | 7.1920 | 2.57054 | 2.68817 | 1168.7 | 108687 |
| 373 | 139129 | 51895117 | 19.3132 | 7.1984 | 2.57171 | 2.68097 | 1171.8 | 109272 |
| 374 | 139876 | 52313624 | 19.3391 | 7.2048 | 2.57287 | 2.67380 | 1175.0 | 109858 |
| 375 | 140625 | 52734375 | 19.3649 | 7.2112 | 2.57403 | 2.66667 | 1178.1 | 110447 |
| 376 | 141376 | 53157376 | 19.3907 | 7.2177 | 2.57519 | 2.65957 | 1181.2 | 111036 |
| 377 | 142129 | 53582633 | 19.4165 | 7.2240 | 2.57634 | 2.65252 | 1184.4 | 111628 |
| 378 | 142884 | 54010152 | 19.4422 | 7.2304 | 2.57749 | 2.64550 | 1187.5 | 112221 |
| 379 | 143641 | 54439939 | 19.4679 | 7.2368 | 2.57864 | 2.63852 | 1190.7 | 112815 |
| 380 | 144400 | 54872000 | 19.4936 | 7.2432 | 2.57978 | 2.63158 | 1193.8 | 113411 |
| 381 | 145161 | 55306341 | 19.5192 | 7.2495 | 2.58093 | 2.62467 | 1196.9 | 114009 |
| 382 | 145924 | 55742968 | 19.5448 | 7.2558 | 2.58206 | 2.61780 | 1200.1 | 114608 |
| 383 | 146689 | 56181887 | 19.5704 | 7.2622 | 2.58320 | 2.61097 | 1203.2 | 115209 |
| 384 | 147456 | 56623104 | 19.5959 | 7.2685 | 2.58433 | 2.60417 | 1206.4 | 115812 |
| 385 | 148225 | 57066625 | 19.6214 | 7.2748 | 2.58546 | 2.59740 | 1209.5 | 116416 |
| 386 | 148996 | 57512456 | 19.6469 | 7.2811 | 2.58659 | 2.59067 | 1212.7 | 117021 |
| 387 | 149769 | 57960603 | 19.6723 | 7.2874 | 2.58771 | 2.58398 | 1215.8 | 117628 |
| 388 | 150544 | 58410172 | 19.6977 | 7.2936 | 2.58883 | 2.57732 | 1218.9 | 118237 |
| 389 | 151321 | 58863869 | 19.7231 | 7.2999 | 2.58995 | 2.57069 | 1221.1 | 118847 |
| 390 | 152100 | 59319000 | 19.7484 | 7.3061 | 2.59106 | 2.56410 | 1225.2 | 119459 |
| 391 | 152881 | 59776471 | 19.7737 | 7.3124 | 2.59218 | 2.55755 | 1228.4 | 120072 |
| 392 | 153664 | 60236288 | 19.7990 | 7.3186 | 2.59329 | 2.55102 | 1231.5 | 120687 |
| 393 | 154449 | 60698457 | 19.8242 | 7.3248 | 2.59439 | 2.54453 | 1234.6 | 121304 |
| 394 | 155236 | 61162984 | 19.8494 | 7.3310 | 2.59550 | 2.53807 | 1237.8 | 121922 |
| 395 | 156025 | 61629875 | 19.8746 | 7.3372 | 2.59660 | 2.53165 | 1240.9 | 122542 |
| 396 | 156816 | 62099136 | 19.8997 | 7.3434 | 2.59770 | 2.52525 | 1244.1 | 123163 |
| 397 | 157609 | 62570773 | 19.9249 | 7.3496 | 2.59879 | 2.51889 | 1247.2 | 123786 |
| 398 | 158404 | 63044792 | 19.9499 | 7.3558 | 2.59988 | 2.51256 | 1250.4 | 124410 |
| 399 | 159201 | 63521199 | 19.9750 | 7.3619 | 2.60097 | 2.50627 | 1253.5 | 125036 |

598 SQUARES, CUBES, SQUARE ROOTS, ETC.

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 400 | 160000 | 64000000 | 20.0000 | 7.3681 | 2.60206 | 2.50000 | 1256.6 | 125664 |
| 401 | 160801 | 64481201 | 20.0250 | 7.3742 | 2.60314 | 2.49377 | 1259.8 | 126293 |
| 402 | 161604 | 64964808 | 20.0499 | 7.3803 | 2.60423 | 2.48756 | 1262.9 | 126923 |
| 403 | 162409 | 65450827 | 20.0749 | 7.3864 | 2.60531 | 2.48139 | 1266.1 | 127556 |
| 404 | 163216 | 65939264 | 20.0998 | 7.3925 | 2.60638 | 2.47525 | 1269.2 | 128190 |
| 405 | 164025 | 66430125 | 20.1246 | 7.3986 | 2.60746 | 2.46914 | 1272.3 | 128825 |
| 406 | 164836 | 66923416 | 20.1494 | 7.4047 | 2.60853 | 2.46305 | 1275.5 | 129462 |
| 407 | 165649 | 67419143 | 20.1742 | 7.4108 | 2.60959 | 2.45700 | 1278.6 | 130100 |
| 408 | 166464 | 67917312 | 20.1990 | 7.4169 | 2.61066 | 2.45098 | 1281.8 | 130741 |
| 409 | 167281 | 68417929 | 20.2237 | 7.4229 | 2.61172 | 2.44499 | 1284.9 | 131382 |
| 410 | 168100 | 68921009 | 20.2485 | 7.4290 | 2.61278 | 2.43902 | 1288.1 | 132025 |
| 411 | 168921 | 69426531 | 20.2731 | 7.4350 | 2.61384 | 2.43309 | 1291.2 | 132670 |
| 412 | 169744 | 69934523 | 20.2978 | 7.4410 | 2.61490 | 2.42718 | 1294.3 | 133317 |
| 413 | 170569 | 70444997 | 20.3224 | 7.4470 | 2.61595 | 2.42131 | 1297.5 | 133965 |
| 414 | 171396 | 70957944 | 20.3470 | 7.4530 | 2.61700 | 2.41546 | 1300.6 | 134614 |
| 415 | 172225 | 71473375 | 20.3715 | 7.4590 | 2.61805 | 2.40964 | 1303.8 | 135265 |
| 416 | 173056 | 71991296 | 20.3961 | 7.4650 | 2.61909 | 2.40385 | 1306.9 | 135918 |
| 417 | 173889 | 72511713 | 20.4206 | 7.4710 | 2.62014 | 2.39808 | 1310.0 | 136572 |
| 418 | 174724 | 73034632 | 20.4450 | 7.4770 | 2.62118 | 2.39234 | 1313.2 | 137228 |
| 419 | 175561 | 73560059 | 20.4695 | 7.4829 | 2.62221 | 2.38664 | 1316.3 | 137885 |
| 420 | 176400 | 74088000 | 20.4939 | 7.4889 | 2.62325 | 2.38095 | 1319.5 | 138544 |
| 421 | 177241 | 74618461 | 20.5183 | 7.4948 | 2.62428 | 2.37530 | 1322.6 | 139205 |
| 422 | 178084 | 75151448 | 20.5426 | 7.5007 | 2.62531 | 2.36967 | 1325.8 | 139867 |
| 423 | 178929 | 75686967 | 20.5670 | 7.5067 | 2.62634 | 2.36407 | 1328.9 | 140531 |
| 424 | 179776 | 76225024 | 20.5913 | 7.5126 | 2.62737 | 2.35849 | 1332.0 | 141196 |
| 425 | 180625 | 76765625 | 20.6155 | 7.5185 | 2.62839 | 2.35294 | 1335.2 | 141863 |
| 426 | 181476 | 77308776 | 20.6398 | 7.5244 | 2.62941 | 2.34742 | 1338.3 | 142531 |
| 427 | 182329 | 77854483 | 20.6640 | 7.5302 | 2.63043 | 2.34192 | 1341.5 | 143201 |
| 428 | 183184 | 78402752 | 20.6882 | 7.5361 | 2.63144 | 2.33645 | 1344.6 | 143872 |
| 429 | 184041 | 78953589 | 20.7123 | 7.5420 | 2.63246 | 2.33100 | 1347.7 | 144545 |
| 430 | 184900 | 79507000 | 20.7364 | 7.5478 | 2.63347 | 2.32558 | 1350.9 | 145220 |
| 431 | 185761 | 80062991 | 20.7605 | 7.5537 | 2.63448 | 2.32019 | 1354.0 | 145896 |
| 432 | 186624 | 80621568 | 20.7846 | 7.5595 | 2.63548 | 2.31482 | 1357.2 | 146574 |
| 433 | 187489 | 81182737 | 20.8087 | 7.5654 | 2.63649 | 2.30947 | 1360.3 | 147254 |
| 434 | 188356 | 81746504 | 20.8327 | 7.5712 | 2.63749 | 2.30415 | 1363.5 | 147934 |
| 435 | 189225 | 82312875 | 20.8567 | 7.5770 | 2.63849 | 2.29885 | 1366.6 | 148617 |
| 436 | 190096 | 82881856 | 20.8806 | 7.5828 | 2.63949 | 2.29358 | 1369.7 | 149301 |
| 437 | 190969 | 83453453 | 20.9045 | 7.5886 | 2.64048 | 2.28833 | 1372.9 | 149987 |
| 438 | 191844 | 84027672 | 20.9284 | 7.5944 | 2.64147 | 2.28311 | 1376.0 | 150674 |
| 439 | 192721 | 84604519 | 20.9523 | 7.6001 | 2.64246 | 2.27790 | 1379.2 | 151363 |
| 440 | 193600 | 85184000 | 20.9762 | 7.6059 | 2.64345 | 2.27273 | 1382.3 | 152053 |
| 441 | 194481 | 85766121 | 21.0000 | 7.6117 | 2.64444 | 2.26757 | 1385.4 | 152745 |
| 442 | 195364 | 86350888 | 21.0238 | 7.6174 | 2.64542 | 2.26244 | 1388.6 | 153439 |
| 443 | 196249 | 86938307 | 21.0476 | 7.6232 | 2.64640 | 2.25734 | 1391.7 | 154134 |
| 444 | 197136 | 87528384 | 21.0713 | 7.6289 | 2.64738 | 2.25225 | 1394.9 | 154830 |
| 445 | 198025 | 88121125 | 21.0950 | 7.6346 | 2.64836 | 2.24719 | 1398.0 | 155528 |
| 446 | 198916 | 88716536 | 21.1187 | 7.6403 | 2.64933 | 2.24215 | 1401.2 | 156228 |
| 447 | 199809 | 89314623 | 21.1424 | 7.6460 | 2.65031 | 2.23714 | 1404.3 | 156930 |
| 448 | 200704 | 89915392 | 21.1660 | 7.6517 | 2.65128 | 2.23214 | 1407.4 | 157633 |
| 449 | 201601 | 90518849 | 21.1896 | 7.6574 | 2.65225 | 2.22717 | 1410.6 | 158337 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 450 | 202500 | 91125000 | 21.2132 | 7.6631 | 2.65321 | 2.22222 | 1413.7 | 159043 |
| 451 | 203401 | 91733851 | 21.2368 | 7.6688 | 2.65418 | 2.21730 | 1416.9 | 159751 |
| 452 | 204304 | 92345408 | 21.2603 | 7.6744 | 2.65514 | 2.21239 | 1420.0 | 160460 |
| 453 | 205209 | 92959677 | 21.2838 | 7.6801 | 2.65610 | 2.20751 | 1423.1 | 161171 |
| 454 | 206116 | 93576664 | 21.3073 | 7.6857 | 2.65706 | 2.20264 | 1426.3 | 161883 |
| 455 | 207025 | 94196375 | 21.3307 | 7.6914 | 2.65801 | 2.19780 | 1429.4 | 162597 |
| 456 | 207936 | 94818816 | 21.3542 | 7.6970 | 2.65896 | 2.19298 | 1432.6 | 163313 |
| 457 | 208849 | 95443993 | 21.3776 | 7.7026 | 2.65992 | 2.18818 | 1435.7 | 164030 |
| 458 | 209764 | 96071912 | 21.4009 | 7.7082 | 2.66087 | 2.18341 | 1438.9 | 164748 |
| 459 | 210681 | 96702579 | 21.4243 | 7.7138 | 2.66181 | 2.17865 | 1442.0 | 165468 |
| 460 | 211600 | 97336000 | 21.4476 | 7.7194 | 2.66276 | 2.17391 | 1445.1 | 166190 |
| 461 | 212521 | 97972181 | 21.4709 | 7.7250 | 2.66370 | 2.16920 | 1448.3 | 166914 |
| 462 | 213444 | 98611128 | 21.4942 | 7.7306 | 2.66464 | 2.16450 | 1451.4 | 167639 |
| 463 | 214369 | 99252847 | 21.5174 | 7.7362 | 2.66558 | 2.15983 | 1454.6 | 168365 |
| 464 | 215296 | 99897344 | 21.5407 | 7.7418 | 2.66652 | 2.15517 | 1457.7 | 169093 |
| 465 | 216225 | 100544625 | 21.5639 | 7.7473 | 2.66745 | 2.15054 | 1460.8 | 169823 |
| 466 | 217156 | 101194696 | 21.5870 | 7.7529 | 2.66839 | 2.14592 | 1464.0 | 170554 |
| 467 | 218089 | 101847563 | 21.6102 | 7.7584 | 2.66932 | 2.14133 | 1467.1 | 171287 |
| 468 | 219024 | 102503232 | 21.6333 | 7.7639 | 2.67025 | 2.13675 | 1470.3 | 172021 |
| 469 | 219961 | 103161709 | 21.6564 | 7.7695 | 2.67117 | 2.13220 | 1473.4 | 172757 |
| 470 | 220900 | 103823000 | 21.6795 | 7.7750 | 2.67210 | 2.12766 | 1476.5 | 173494 |
| 471 | 221841 | 104487111 | 21.7025 | 7.7805 | 2.67302 | 2.12314 | 1479.7 | 174234 |
| 472 | 222784 | 105154048 | 21.7256 | 7.7860 | 2.67394 | 2.11864 | 1482.8 | 174974 |
| 473 | 223729 | 105823817 | 21.7486 | 7.7915 | 2.67486 | 2.11417 | 1486.0 | 175716 |
| 474 | 224676 | 106496424 | 21.7715 | 7.7970 | 2.67578 | 2.10971 | 1489.1 | 176460 |
| 475 | 225625 | 107171875 | 21.7945 | 7.8025 | 2.67669 | 2.10526 | 1492.3 | 177205 |
| 476 | 226576 | 107850176 | 21.8174 | 7.8079 | 2.67761 | 2.10084 | 1495.4 | 177952 |
| 477 | 227529 | 108531333 | 21.8403 | 7.8134 | 2.67853 | 2.09644 | 1498.5 | 178701 |
| 478 | 228484 | 109215352 | 21.8632 | 7.8188 | 2.67945 | 2.09205 | 1501.7 | 179451 |
| 479 | 229441 | 109902239 | 21.8861 | 7.8243 | 2.68034 | 2.08768 | 1504.8 | 180203 |
| 480 | 230400 | 110592000 | 21.9089 | 7.8297 | 2.68124 | 2.08333 | 1508.0 | 180956 |
| 481 | 231361 | 111284641 | 21.9317 | 7.8352 | 2.68215 | 2.07900 | 1511.1 | 181711 |
| 482 | 232324 | 111980168 | 21.9545 | 7.8406 | 2.68305 | 2.07469 | 1514.3 | 182467 |
| 483 | 233289 | 112678587 | 21.9773 | 7.8460 | 2.68395 | 2.07039 | 1517.4 | 183225 |
| 484 | 234256 | 113379904 | 22.0000 | 7.8514 | 2.68485 | 2.06612 | 1520.5 | 183984 |
| 485 | 235225 | 114084125 | 22.0227 | 7.8568 | 2.68574 | 2.06186 | 1523.7 | 184745 |
| 486 | 236196 | 114791256 | 22.0454 | 7.8622 | 2.68664 | 2.05761 | 1526.8 | 185508 |
| 487 | 237169 | 115501303 | 22.0681 | 7.8676 | 2.68753 | 2.05339 | 1530.0 | 186272 |
| 488 | 238144 | 116214272 | 22.0907 | 7.8730 | 2.68842 | 2.04918 | 1533.1 | 187038 |
| 490 | 239121 | 116930169 | 22.1133 | 7.8784 | 2.68931 | 2.04499 | 1536.2 | 187805 |
| 490 | 240100 | 117649000 | 22.1359 | 7.8837 | 2.69020 | 2.04082 | 1539.4 | 188574 |
| 491 | 241081 | 118370771 | 22.1585 | 7.8891 | 2.69108 | 2.03666 | 1542.5 | 189345 |
| 492 | 242064 | 119095488 | 22.1811 | 7.8944 | 2.69197 | 2.03252 | 1545.7 | 190117 |
| 493 | 243049 | 119823157 | 22.2036 | 7.8998 | 2.69285 | 2.02840 | 1548.8 | 190890 |
| 494 | 244036 | 120553784 | 22.2261 | 7.9051 | 2.69373 | 2.02429 | 1551.9 | 191665 |
| 495 | 245025 | 121287375 | 22.2486 | 7.9105 | 2.69461 | 2.02020 | 1555.1 | 192442 |
| 496 | 246016 | 122023936 | 22.2711 | 7.9158 | 2.69548 | 2.01613 | 1558.2 | 193221 |
| 497 | 247009 | 122763473 | 22.2935 | 7.9211 | 2.69636 | 2.01207 | 1561.4 | 194000 |
| 498 | 248004 | 123505992 | 22.3159 | 7.9264 | 2.69723 | 2.00803 | 1564.5 | 194782 |
| 499 | 249001 | 124251499 | 22.3383 | 7.9317 | 2.69810 | 2.00401 | 1567.7 | 195565 |

600 SQUARES, CUBES, SQUARE ROOTS, ETC.

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALs, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 500 | 250000 | 125000000 | 22.3607 | 7.9370 | 2.69897 | 2.00000 | 1570.8 | 196350 |
| 501 | 251001 | 125751501 | 22.3830 | 7.9423 | 2.69984 | 1.99601 | 1573.9 | 197136 |
| 502 | 252004 | 126506008 | 22.4054 | 7.9476 | 2.70070 | 1.99203 | 1577.1 | 197923 |
| 503 | 253009 | 127263527 | 22.4277 | 7.9528 | 2.70157 | 1.98807 | 1580.2 | 198713 |
| 504 | 254016 | 128024064 | 22.4499 | 7.9581 | 2.70243 | 1.98413 | 1583.4 | 199504 |
| 505 | 255025 | 128787625 | 22.4722 | 7.9634 | 2.70329 | 1.98020 | 1586.5 | 200296 |
| 506 | 256036 | 129554216 | 22.4944 | 7.9686 | 2.70415 | 1.97629 | 1589.7 | 201090 |
| 507 | 257049 | 130323843 | 22.5167 | 7.9739 | 2.70501 | 1.97239 | 1592.8 | 201886 |
| 508 | 258064 | 131096512 | 22.5389 | 7.9791 | 2.70586 | 1.96850 | 1595.9 | 202683 |
| 509 | 259081 | 131872229 | 22.5610 | 7.9843 | 2.70672 | 1.96464 | 1599.1 | 202482 |
| 510 | 260100 | 132651000 | 22.5832 | 7.9896 | 2.70757 | 1.96078 | 1602.2 | 204282 |
| 511 | 261121 | 133432831 | 22.6053 | 7.9948 | 2.70842 | 1.95695 | 1605.4 | 205084 |
| 512 | 262144 | 134217728 | 22.6274 | 8.0000 | 2.70927 | 1.95312 | 1608.5 | 205887 |
| 513 | 263169 | 135005697 | 22.6495 | 8.0052 | 2.71012 | 1.94932 | 1611.6 | 206692 |
| 514 | 264196 | 135796744 | 22.6716 | 8.0104 | 2.71096 | 1.94553 | 1614.8 | 207499 |
| 515 | 265225 | 136590875 | 22.6936 | 8.0156 | 2.71181 | 1.94175 | 1617.9 | 208307 |
| 516 | 266256 | 137388096 | 22.7156 | 8.0208 | 2.71265 | 1.93798 | 1621.1 | 209117 |
| 517 | 267289 | 138188413 | 22.7376 | 8.0260 | 2.71349 | 1.93424 | 1624.2 | 209928 |
| 518 | 268324 | 138991832 | 22.7596 | 8.0311 | 2.71433 | 1.93050 | 1627.3 | 210741 |
| 519 | 269361 | 139798359 | 22.7816 | 8.0363 | 2.71517 | 1.92678 | 1630.5 | 211556 |
| 520 | 270400 | 140608000 | 22.8035 | 8.0415 | 2.71600 | 1.92308 | 1633.6 | 212372 |
| 521 | 271441 | 141420761 | 22.8254 | 8.0466 | 2.71684 | 1.91939 | 1636.8 | 213189 |
| 522 | 272484 | 142236648 | 22.8473 | 8.0517 | 2.71767 | 1.91571 | 1639.9 | 214008 |
| 523 | 273529 | 143055667 | 22.8692 | 8.0569 | 2.71850 | 1.91205 | 1643.1 | 214829 |
| 524 | 274576 | 143877824 | 22.8910 | 8.0620 | 2.71933 | 1.90840 | 1646.2 | 215651 |
| 525 | 275625 | 144703125 | 22.9129 | 8.0671 | 2.72016 | 1.90476 | 1649.3 | 216475 |
| 526 | 276676 | 145531576 | 22.9347 | 8.0723 | 2.72099 | 1.90114 | 1652.5 | 217301 |
| 527 | 277729 | 146363183 | 22.9565 | 8.0774 | 2.72181 | 1.89753 | 1655.6 | 218128 |
| 528 | 278784 | 147197952 | 22.9783 | 8.0825 | 2.72263 | 1.89394 | 1658.8 | 218956 |
| 529 | 279841 | 148035889 | 23.0000 | 8.0876 | 2.72346 | 1.89036 | 1661.9 | 219787 |
| 530 | 280900 | 148877000 | 23.0217 | 8.0927 | 2.72428 | 1.88679 | 1665.0 | 220618 |
| 531 | 281961 | 149721291 | 23.0434 | 8.0978 | 2.72509 | 1.88324 | 1668.2 | 221452 |
| 532 | 283024 | 150568768 | 23.0651 | 8.1028 | 2.72591 | 1.87970 | 1671.3 | 222287 |
| 533 | 284089 | 151419437 | 23.0868 | 8.1079 | 2.72673 | 1.87617 | 1674.5 | 223123 |
| 534 | 285156 | 152273304 | 23.1084 | 8.1130 | 2.72754 | 1.87266 | 1677.6 | 223961 |
| 535 | 286225 | 153130375 | 23.1301 | 8.1180 | 2.72835 | 1.86916 | 1680.8 | 224801 |
| 536 | 287296 | 153990656 | 23.1517 | 8.1231 | 2.72916 | 1.86567 | 1683.9 | 225642 |
| 537 | 288369 | 154854153 | 23.1733 | 8.1281 | 2.72997 | 1.86220 | 1687.0 | 226484 |
| 538 | 289444 | 155720872 | 23.1948 | 8.1332 | 2.73038 | 1.85874 | 1690.2 | 227329 |
| 539 | 290521 | 156590819 | 23.2164 | 8.1382 | 2.73159 | 1.85529 | 1693.3 | 228175 |
| 540 | 291600 | 157464000 | 23.2379 | 8.1433 | 2.73239 | 1.85185 | 1696.5 | 229022 |
| 541 | 292681 | 158340421 | 23.2594 | 8.1483 | 2.73320 | 1.84843 | 1699.6 | 229871 |
| 542 | 293764 | 159220088 | 23.2809 | 8.1533 | 2.73400 | 1.84502 | 1702.7 | 230722 |
| 543 | 294849 | 160103007 | 23.3024 | 8.1583 | 2.73480 | 1.84162 | 1705.9 | 231574 |
| 544 | 295936 | 160989184 | 23.3238 | 8.1633 | 2.73560 | 1.83824 | 1709.0 | 232428 |
| 545 | 297025 | 161878625 | 23.3452 | 8.1683 | 2.73640 | 1.83486 | 1712.2 | 233283 |
| 546 | 298116 | 162771336 | 23.3666 | 8.1733 | 2.73719 | 1.83150 | 1715.3 | 234140 |
| 547 | 299209 | 163667323 | 23.3880 | 8.1783 | 2.73799 | 1.82815 | 1718.5 | 234998 |
| 548 | 300304 | 164566592 | 23.4094 | 8.1833 | 2.73878 | 1.82482 | 1721.6 | 235858 |
| 549 | 301401 | 165469149 | 23.4307 | 8.1882 | 2.73957 | 1.82149 | 1724.7 | 236720 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 X Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 550 | 302500 | 166375000 | 23.4521 | 8.1932 | 2.74036 | 1.81818 | 1727.9 | 237583 |
| 551 | 303601 | 167284151 | 23.4734 | 8.1982 | 2.74115 | 1.81488 | 1731.0 | 238448 |
| 552 | 304704 | 168196608 | 23.4947 | 8.2031 | 2.74194 | 1.81159 | 1734.2 | 239314 |
| 553 | 305809 | 169112377 | 23.5160 | 8.2081 | 2.74273 | 1.80832 | 1737.3 | 240182 |
| 554 | 306916 | 170031464 | 23.5372 | 8.2130 | 2.74351 | 1.80505 | 1740.4 | 241051 |
| 555 | 308025 | 170953875 | 23.5584 | 8.2180 | 2.74429 | 1.80180 | 1743.6 | 241922 |
| 556 | 309136 | 171879616 | 23.5797 | 8.2229 | 2.74507 | 1.79856 | 1746.7 | 242795 |
| 557 | 310249 | 172808693 | 23.6008 | 8.2278 | 2.74586 | 1.79533 | 1749.9 | 243669 |
| 558 | 311364 | 173741112 | 23.6220 | 8.2327 | 2.74663 | 1.79211 | 1753.0 | 244545 |
| 559 | 312481 | 174676879 | 23.6432 | 8.2377 | 2.74741 | 1.78891 | 1756.2 | 245422 |
| 560 | 313600 | 175616000 | 23.6643 | 8.2426 | 2.74819 | 1.78571 | 1759.3 | 246301 |
| 561 | 314721 | 176558481 | 23.6854 | 8.2475 | 2.74896 | 1.78253 | 1762.4 | 247181 |
| 562 | 315844 | 177504328 | 23.7065 | 8.2524 | 2.74974 | 1.77936 | 1765.6 | 248063 |
| 563 | 316969 | 178453547 | 23.7276 | 8.2573 | 2.75051 | 1.77620 | 1768.7 | 248947 |
| 564 | 318096 | 179406144 | 23.7487 | 8.2621 | 2.75128 | 1.77305 | 1771.9 | 249832 |
| 565 | 319225 | 180362125 | 23.7697 | 8.2670 | 2.75205 | 1.76991 | 1775.0 | 250719 |
| 566 | 320356 | 181321496 | 23.7908 | 8.2719 | 2.75282 | 1.76678 | 1778.1 | 251607 |
| 567 | 321489 | 182284263 | 23.8118 | 8.2768 | 2.75358 | 1.76367 | 1781.3 | 252497 |
| 568 | 322624 | 183250432 | 23.8328 | 8.2816 | 2.75435 | 1.76056 | 1784.4 | 253388 |
| 569 | 323761 | 184220009 | 23.8537 | 8.2865 | 2.75511 | 1.75747 | 1787.6 | 254281 |
| 570 | 324900 | 185193000 | 23.8747 | 8.2913 | 2.75587 | 1.75439 | 1790.7 | 255176 |
| 571 | 326041 | 186169411 | 23.8956 | 8.2962 | 2.75664 | 1.75131 | 1793.9 | 256072 |
| 572 | 327184 | 187149248 | 23.9165 | 8.3010 | 2.75740 | 1.74825 | 1797.0 | 256970 |
| 573 | 328329 | 188132517 | 23.9374 | 8.3059 | 2.75815 | 1.74520 | 1800.1 | 257869 |
| 574 | 329476 | 189119224 | 23.9583 | 8.3107 | 2.75891 | 1.74216 | 1803.3 | 258770 |
| 575 | 330625 | 190109375 | 23.9792 | 8.3155 | 2.75967 | 1.73913 | 1806.4 | 259672 |
| 576 | 331776 | 191102976 | 24.0000 | 8.3203 | 2.76042 | 1.73611 | 1809.6 | 260576 |
| 577 | 332929 | 192100033 | 24.0208 | 8.3251 | 2.76118 | 1.73310 | 1812.7 | 261482 |
| 578 | 334084 | 193100552 | 24.0416 | 8.3300 | 2.76193 | 1.73010 | 1815.8 | 262389 |
| 579 | 335241 | 194104539 | 24.0624 | 8.3348 | 2.76268 | 1.72712 | 1819.0 | 263298 |
| 580 | 336400 | 195112000 | 24.0832 | 8.3396 | 2.76343 | 1.72414 | 1822.1 | 264208 |
| 581 | 337561 | 196122941 | 24.1039 | 8.3443 | 2.76418 | 1.72117 | 1825.3 | 265120 |
| 582 | 338724 | 197137368 | 24.1247 | 8.3491 | 2.76492 | 1.71821 | 1828.4 | 266033 |
| 583 | 339889 | 198155287 | 24.1454 | 8.3539 | 2.76567 | 1.71527 | 1831.6 | 266948 |
| 584 | 341056 | 199176704 | 24.1661 | 8.3587 | 2.76641 | 1.71233 | 1834.7 | 267865 |
| 585 | 342225 | 200201625 | 24.1868 | 8.3634 | 2.76716 | 1.70940 | 1837.8 | 268783 |
| 586 | 343396 | 201230056 | 24.2074 | 8.3682 | 2.76790 | 1.70649 | 1841.0 | 269701 |
| 587 | 344569 | 202262003 | 24.2281 | 8.3730 | 2.76864 | 1.70358 | 1844.1 | 270624 |
| 588 | 345744 | 203297472 | 24.2487 | 8.3777 | 2.76938 | 1.70068 | 1847.3 | 271547 |
| 589 | 346921 | 204336469 | 24.2693 | 8.3825 | 2.77012 | 1.69779 | 1850.4 | 272471 |
| 590 | 348100 | 205379000 | 24.2899 | 8.3872 | 2.77085 | 1.69492 | 1853.5 | 273397 |
| 591 | 349281 | 206425071 | 24.3105 | 8.3919 | 2.77159 | 1.69205 | 1856.7 | 274325 |
| 592 | 350464 | 207474688 | 24.3311 | 8.3967 | 2.77232 | 1.68919 | 1859.8 | 275254 |
| 593 | 351649 | 208527857 | 24.3516 | 8.4014 | 2.77305 | 1.68634 | 1863.0 | 276184 |
| 594 | 352836 | 209584584 | 24.3721 | 8.4061 | 2.77379 | 1.68350 | 1866.1 | 277117 |
| 595 | 354025 | 210644875 | 24.3926 | 8.4108 | 2.77452 | 1.68067 | 1869.3 | 278051 |
| 596 | 355216 | 211708736 | 24.4131 | 8.4155 | 2.77525 | 1.67785 | 1872.4 | 278986 |
| 597 | 356409 | 212776173 | 24.4336 | 8.4202 | 2.77597 | 1.67504 | 1875.5 | 279923 |
| 598 | 357604 | 213847192 | 24.4540 | 8.4249 | 2.77670 | 1.67224 | 1878.7 | 280862 |
| 599 | 358801 | 214921799 | 24.4745 | 8.4296 | 2.77743 | 1.66945 | 1881.8 | 281802 |

602 SQUARES, CUBES, SQUARE ROOTS, ETC.

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 600 | 360000 | 216000000 | 24.4949 | 8.4343 | 2.77815 | 1.66667 | 1885.0 | 282743 |
| 601 | 361201 | 217081801 | 24.5153 | 8.4390 | 2.77887 | 1.66389 | 1888.1 | 283687 |
| 602 | 362404 | 218167208 | 24.5357 | 8.4437 | 2.77960 | 1.66113 | 1891.2 | 284631 |
| 603 | 363609 | 219256227 | 24.5561 | 8.4484 | 2.78032 | 1.65837 | 1894.4 | 285578 |
| 604 | 364816 | 220348864 | 24.5764 | 8.4530 | 2.78104 | 1.65563 | 1897.5 | 286526 |
| 605 | 366025 | 221445125 | 24.5967 | 8.4577 | 2.78176 | 1.65289 | 1900.7 | 287475 |
| 606 | 367236 | 222545016 | 24.6171 | 8.4623 | 2.78247 | 1.65017 | 1903.8 | 288426 |
| 607 | 368449 | 223648543 | 24.6374 | 8.4670 | 2.78319 | 1.64745 | 1907.0 | 289379 |
| 608 | 369664 | 224755712 | 24.6577 | 8.4716 | 2.78390 | 1.64474 | 1910.1 | 290333 |
| 609 | 370881 | 225866529 | 24.6779 | 8.4763 | 2.78462 | 1.64204 | 1913.2 | 291289 |
| 610 | 372100 | 226981000 | 24.6982 | 8.4809 | 2.78533 | 1.63934 | 1916.4 | 292247 |
| 611 | 373321 | 228099131 | 24.7184 | 8.4856 | 2.78604 | 1.63666 | 1919.5 | 293206 |
| 612 | 374544 | 229220928 | 24.7386 | 8.4902 | 2.78675 | 1.63399 | 1922.7 | 294166 |
| 613 | 375769 | 230346397 | 24.7588 | 8.4948 | 2.78746 | 1.63132 | 1925.8 | 295128 |
| 614 | 376996 | 231475544 | 24.7790 | 8.4994 | 2.78817 | 1.62866 | 1928.9 | 296092 |
| 615 | 378225 | 232608375 | 24.7992 | 8.5040 | 2.78888 | 1.62602 | 1932.1 | 297057 |
| 616 | 379456 | 233744896 | 24.8193 | 8.5086 | 2.78958 | 1.62338 | 1935.2 | 298024 |
| 617 | 380689 | 234885113 | 24.8395 | 8.5132 | 2.79029 | 1.62075 | 1938.4 | 298992 |
| 618 | 381924 | 236029032 | 24.8596 | 8.5178 | 2.79099 | 1.61812 | 1941.5 | 299962 |
| 619 | 383161 | 237176659 | 24.8797 | 8.5224 | 2.79169 | 1.61551 | 1944.7 | 300934 |
| 620 | 384400 | 238328000 | 24.8998 | 8.5270 | 2.79239 | 1.61290 | 1947.8 | 301907 |
| 621 | 385641 | 239483061 | 24.9199 | 8.5316 | 2.79309 | 1.61031 | 1950.9 | 302882 |
| 622 | 386884 | 240641848 | 24.9399 | 8.5362 | 2.79379 | 1.60772 | 1954.1 | 303858 |
| 623 | 388129 | 241804367 | 24.9600 | 8.5408 | 2.79449 | 1.60514 | 1957.2 | 304836 |
| 624 | 389376 | 242970624 | 24.9800 | 8.5453 | 2.79518 | 1.60256 | 1960.4 | 305815 |
| 625 | 390625 | 244140625 | 25.0000 | 8.5499 | 2.79588 | 1.60000 | 1963.5 | 306796 |
| 626 | 391876 | 245314376 | 25.0200 | 8.5544 | 2.79657 | 1.59744 | 1966.6 | 307779 |
| 627 | 393129 | 246491833 | 25.0400 | 8.5590 | 2.79727 | 1.59490 | 1969.8 | 308763 |
| 628 | 394384 | 247673152 | 25.0599 | 8.5635 | 2.79796 | 1.59236 | 1972.9 | 309748 |
| 629 | 395641 | 248858189 | 25.0799 | 8.5681 | 2.79865 | 1.58983 | 1976.1 | 310736 |
| 630 | 396900 | 250047000 | 25.0998 | 8.5726 | 2.79934 | 1.58730 | 1979.2 | 311725 |
| 631 | 398161 | 251239591 | 25.1197 | 8.5772 | 2.80003 | 1.58479 | 1982.4 | 312715 |
| 632 | 399424 | 252435968 | 25.1396 | 8.5817 | 2.80072 | 1.58228 | 1985.5 | 313707 |
| 633 | 400689 | 253636137 | 25.1595 | 8.5862 | 2.80140 | 1.57978 | 1988.6 | 314700 |
| 634 | 401956 | 254840104 | 25.1794 | 8.5907 | 2.80209 | 1.57729 | 1991.8 | 315696 |
| 635 | 403225 | 256047875 | 25.1992 | 8.5952 | 2.80277 | 1.57480 | 1994.9 | 316692 |
| 636 | 404496 | 257259456 | 25.2190 | 8.5997 | 2.80346 | 1.57233 | 1998.1 | 317690 |
| 637 | 405769 | 258474853 | 25.2389 | 8.6043 | 2.80414 | 1.56986 | 2001.2 | 318690 |
| 638 | 407044 | 259694072 | 25.2587 | 8.6088 | 2.80482 | 1.56740 | 2004.3 | 319692 |
| 639 | 408321 | 260917119 | 25.2784 | 8.6132 | 2.80550 | 1.56495 | 2007.5 | 320695 |
| 640 | 409600 | 262144000 | 25.2982 | 8.6177 | 2.80618 | 1.56250 | 2010.6 | 321699 |
| 641 | 410881 | 263374721 | 25.3180 | 8.6222 | 2.80686 | 1.56006 | 2013.8 | 322705 |
| 642 | 412164 | 264609288 | 25.3377 | 8.6267 | 2.80754 | 1.55763 | 2016.9 | 323713 |
| 643 | 413449 | 265847707 | 25.3574 | 8.6312 | 2.80821 | 1.55521 | 2020.0 | 324722 |
| 644 | 414736 | 267089984 | 25.3772 | 8.6357 | 2.80889 | 1.55280 | 2023.2 | 325733 |
| 645 | 416025 | 268336125 | 25.3969 | 8.6401 | 2.80956 | 1.55039 | 2026.3 | 326745 |
| 646 | 417316 | 269586136 | 25.4165 | 8.6446 | 2.81023 | 1.54799 | 2029.5 | 327759 |
| 647 | 418609 | 270840023 | 25.4362 | 8.6490 | 2.81090 | 1.54560 | 2032.6 | 328775 |
| 648 | 419904 | 272097792 | 25.4558 | 8.6535 | 2.81158 | 1.54321 | 2035.8 | 329792 |
| 649 | 421201 | 273359449 | 25.4755 | 8.6579 | 2.81224 | 1.54083 | 2038.9 | 330810 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 650 | 422500 | 274625000 | 25.4951 | 8.6624 | 2.81291 | 1.53846 | 2042.0 | 331831 |
| 651 | 423801 | 275894451 | 25.5147 | 8.6668 | 2.81358 | 1.53610 | 2045.2 | 332853 |
| 652 | 425104 | 277167808 | 25.5343 | 8.6713 | 2.81425 | 1.53374 | 2048.3 | 333876 |
| 653 | 426409 | 278445077 | 25.5539 | 8.6757 | 2.81491 | 1.53139 | 2051.5 | 334901 |
| 654 | 427716 | 279726264 | 25.5734 | 8.6801 | 2.81558 | 1.52905 | 2054.6 | 335927 |
| 655 | 429025 | 281011375 | 25.5930 | 8.6845 | 2.81624 | 1.52672 | 2057.7 | 336955 |
| 656 | 430336 | 282300416 | 25.6125 | 8.6890 | 2.81690 | 1.52439 | 2060.9 | 337985 |
| 657 | 431649 | 283593393 | 25.6320 | 8.6934 | 2.81757 | 1.52207 | 2064.0 | 339016 |
| 658 | 432964 | 284890312 | 25.6515 | 8.6978 | 2.81823 | 1.51976 | 2067.2 | 340049 |
| 659 | 434281 | 286191179 | 25.6710 | 8.7022 | 2.81889 | 1.51745 | 2070.3 | 341084 |
| 660 | 435600 | 287496000 | 25.6905 | 8.7066 | 2.81954 | 1.51515 | 2073.5 | 342119 |
| 661 | 436921 | 288804781 | 25.7099 | 8.7110 | 2.82020 | 1.51286 | 2076.6 | 343157 |
| 662 | 438244 | 290117523 | 25.7294 | 8.7154 | 2.82086 | 1.51057 | 2079.7 | 344196 |
| 663 | 439569 | 291434247 | 25.7488 | 8.7198 | 2.82151 | 1.50830 | 2082.9 | 345237 |
| 664 | 440896 | 292754944 | 25.7682 | 8.7241 | 2.82217 | 1.50602 | 2086.0 | 346279 |
| 665 | 442225 | 294079625 | 25.7876 | 8.7285 | 2.82282 | 1.50376 | 2089.2 | 347323 |
| 666 | 443556 | 295408296 | 25.8070 | 8.7329 | 2.82347 | 1.50150 | 2092.3 | 348368 |
| 667 | 444889 | 296740963 | 25.8263 | 8.7373 | 2.82413 | 1.49925 | 2095.4 | 349415 |
| 668 | 446224 | 298077632 | 25.8457 | 8.7416 | 2.82478 | 1.49701 | 2098.6 | 350464 |
| 669 | 447561 | 299418309 | 25.8650 | 8.7460 | 2.82543 | 1.49477 | 2101.7 | 351514 |
| 670 | 448900 | 300763000 | 25.8844 | 8.7503 | 2.82607 | 1.49254 | 2104.9 | 352565 |
| 671 | 450241 | 302111711 | 25.9037 | 8.7547 | 2.82672 | 1.49031 | 2108.0 | 353618 |
| 672 | 451584 | 303464448 | 25.9230 | 8.7590 | 2.82737 | 1.48810 | 2111.2 | 354673 |
| 673 | 452929 | 304821217 | 25.9422 | 8.7634 | 2.82802 | 1.48588 | 2114.3 | 355730 |
| 674 | 454276 | 306182024 | 25.9615 | 8.7677 | 2.82866 | 1.48368 | 2117.4 | 356788 |
| 675 | 455625 | 307546875 | 25.9808 | 8.7721 | 2.82930 | 1.48148 | 2120.6 | 357847 |
| 676 | 456976 | 308915776 | 26.0000 | 8.7764 | 2.82995 | 1.47929 | 2123.7 | 358908 |
| 677 | 458329 | 310288733 | 26.0192 | 8.7807 | 2.83059 | 1.47711 | 2126.9 | 359971 |
| 678 | 459684 | 311665752 | 26.0384 | 8.7850 | 2.83123 | 1.47493 | 2130.0 | 361035 |
| 679 | 461041 | 313046839 | 26.0576 | 8.7893 | 2.83187 | 1.47275 | 2133.1 | 362101 |
| 680 | 462400 | 314432000 | 26.0768 | 8.7937 | 2.83251 | 1.47059 | 2136.3 | 363168 |
| 681 | 463761 | 315821241 | 26.0960 | 8.7980 | 2.83315 | 1.46843 | 2139.4 | 364237 |
| 682 | 465124 | 317214568 | 26.1151 | 8.8023 | 2.83378 | 1.46628 | 2142.6 | 365308 |
| 683 | 466489 | 318611987 | 26.1343 | 8.8066 | 2.83442 | 1.46413 | 2145.7 | 366380 |
| 684 | 467856 | 320013504 | 26.1534 | 8.8109 | 2.83506 | 1.46199 | 2148.9 | 367453 |
| 685 | 469225 | 321419125 | 26.1725 | 8.8152 | 2.83569 | 1.45985 | 2152.0 | 368528 |
| 686 | 470596 | 322828856 | 26.1916 | 8.8194 | 2.83632 | 1.45773 | 2155.1 | 369605 |
| 687 | 471969 | 324242703 | 26.2107 | 8.8237 | 2.83696 | 1.45560 | 2158.3 | 370684 |
| 688 | 473344 | 325660672 | 26.2298 | 8.8280 | 2.83759 | 1.45349 | 2161.4 | 371764 |
| 689 | 474721 | 327082769 | 26.2488 | 8.8323 | 2.83822 | 1.45138 | 2164.6 | 372845 |
| 690 | 476100 | 328509000 | 26.2679 | 8.8366 | 2.83885 | 1.44928 | 2167.7 | 373928 |
| 691 | 477481 | 329939371 | 26.2869 | 8.8408 | 2.83948 | 1.44718 | 2170.8 | 375013 |
| 692 | 478864 | 331373888 | 26.3059 | 8.8451 | 2.84011 | 1.44509 | 2174.0 | 376099 |
| 693 | 480249 | 332812557 | 26.3249 | 8.8493 | 2.84073 | 1.44300 | 2177.1 | 377187 |
| 694 | 481636 | 334255384 | 26.3439 | 8.8536 | 2.84136 | 1.44092 | 2180.3 | 378276 |
| 695 | 483025 | 335702375 | 26.3629 | 8.8578 | 2.84198 | 1.43885 | 2183.4 | 379367 |
| 696 | 484416 | 337153536 | 26.3818 | 8.8621 | 2.84261 | 1.43678 | 2186.6 | 380459 |
| 697 | 485809 | 338608873 | 26.4008 | 8.8663 | 2.84323 | 1.43472 | 2189.7 | 381554 |
| 698 | 487204 | 340068392 | 26.4197 | 8.8706 | 2.84386 | 1.43267 | 2192.8 | 382649 |
| 699 | 488601 | 341532099 | 26.4386 | 8.8748 | 2.84448 | 1.43062 | 2196.0 | 383746 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALs, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|-----------|-------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 700 | 490000 | 343000000 | 26.4575 | 8.8790 | 2.84510 | 1.42857 | 2199.1 | 384845 |
| 701 | 491401 | 344472101 | 26.4764 | 8.8833 | 2.84572 | 1.42653 | 2202.3 | 385945 |
| 702 | 492804 | 345948408 | 26.4953 | 8.8875 | 2.84634 | 1.42450 | 2205.4 | 387047 |
| 703 | 494209 | 347428927 | 26.5141 | 8.8917 | 2.84696 | 1.42248 | 2208.5 | 388151 |
| 704 | 495616 | 348913664 | 26.5330 | 8.8959 | 2.84757 | 1.42046 | 2211.7 | 389256 |
| 705 | 497025 | 350402625 | 26.5518 | 8.9001 | 2.84819 | 1.41844 | 2214.8 | 390363 |
| 706 | 498436 | 351895816 | 26.5707 | 8.9043 | 2.84880 | 1.41643 | 2218.0 | 391471 |
| 707 | 499849 | 353393243 | 26.5895 | 8.9085 | 2.84942 | 1.41443 | 2221.1 | 392580 |
| 708 | 501264 | 354894912 | 26.6083 | 8.9127 | 2.85003 | 1.41243 | 2224.3 | 393692 |
| 709 | 502681 | 356400829 | 26.6271 | 8.9169 | 2.85065 | 1.41044 | 2227.4 | 394805 |
| 710 | 504100 | 357911000 | 26.6458 | 8.9211 | 2.85126 | 1.40845 | 2230.5 | 395919 |
| 711 | 505521 | 359425431 | 26.6646 | 8.9253 | 2.85187 | 1.40647 | 2233.7 | 397035 |
| 712 | 506944 | 360944128 | 26.6833 | 8.9295 | 2.85248 | 1.40449 | 2236.8 | 398153 |
| 713 | 508369 | 362467097 | 26.7021 | 8.9337 | 2.85309 | 1.40253 | 2240.0 | 399272 |
| 714 | 509796 | 363994344 | 26.7208 | 8.9378 | 2.85370 | 1.40056 | 2243.1 | 400393 |
| 715 | 511225 | 365525875 | 26.7395 | 8.9420 | 2.85431 | 1.39860 | 2246.2 | 401515 |
| 716 | 512656 | 367061696 | 26.7582 | 8.9462 | 2.85491 | 1.39665 | 2249.4 | 402639 |
| 717 | 514089 | 368601813 | 26.7769 | 8.9503 | 2.85552 | 1.39470 | 2252.5 | 403765 |
| 718 | 515524 | 370146232 | 26.7955 | 8.9545 | 2.85612 | 1.39276 | 2255.7 | 404892 |
| 719 | 516961 | 371694959 | 26.8142 | 8.9587 | 2.85673 | 1.39082 | 2258.8 | 406020 |
| 720 | 518400 | 373248000 | 26.8328 | 8.9628 | 2.85733 | 1.38889 | 2261.9 | 407150 |
| 721 | 519841 | 374805361 | 26.8514 | 8.9670 | 2.85794 | 1.38696 | 2265.1 | 408282 |
| 722 | 521284 | 376367048 | 26.8701 | 8.9711 | 2.85854 | 1.38504 | 2268.2 | 409416 |
| 723 | 522729 | 377933067 | 26.8887 | 8.9752 | 2.85914 | 1.38313 | 2271.4 | 410550 |
| 724 | 524176 | 379503424 | 26.9072 | 8.9794 | 2.85974 | 1.38122 | 2274.5 | 411687 |
| 725 | 525625 | 381078125 | 26.9258 | 8.9835 | 2.86034 | 1.37931 | 2277.7 | 412825 |
| 726 | 527076 | 382657176 | 26.9444 | 8.9876 | 2.86094 | 1.37741 | 2280.8 | 413965 |
| 727 | 528529 | 384240583 | 26.9629 | 8.9918 | 2.86153 | 1.37552 | 2283.9 | 415106 |
| 728 | 529984 | 385828352 | 26.9815 | 8.9959 | 2.86213 | 1.37363 | 2287.1 | 416248 |
| 729 | 531441 | 387420489 | 27.0000 | 9.0000 | 2.86273 | 1.37174 | 2290.2 | 417393 |
| 730 | 532900 | 389017000 | 27.0185 | 9.0041 | 2.86332 | 1.36986 | 2293.4 | 418539 |
| 731 | 534361 | 390617891 | 27.0370 | 9.0082 | 2.86392 | 1.36799 | 2296.5 | 419686 |
| 732 | 535824 | 392223168 | 27.0555 | 9.0123 | 2.86451 | 1.36612 | 2299.7 | 420835 |
| 733 | 537289 | 393832837 | 27.0740 | 9.0164 | 2.86510 | 1.36426 | 2302.8 | 421986 |
| 734 | 538756 | 395446904 | 27.0924 | 9.0205 | 2.86570 | 1.36240 | 2305.9 | 423138 |
| 735 | 540225 | 397065375 | 27.1109 | 9.0246 | 2.86629 | 1.36054 | 2309.1 | 424293 |
| 736 | 541696 | 398688256 | 27.1293 | 9.0287 | 2.86688 | 1.35870 | 2312.2 | 425448 |
| 737 | 543169 | 400315553 | 27.1477 | 9.0328 | 2.86747 | 1.35685 | 2315.4 | 426604 |
| 738 | 544644 | 401947272 | 27.1662 | 9.0369 | 2.86806 | 1.35501 | 2318.5 | 427762 |
| 739 | 546121 | 403583419 | 27.1846 | 9.0410 | 2.86864 | 1.35318 | 2321.6 | 428922 |
| 740 | 547600 | 405224000 | 27.2029 | 9.0450 | 2.86923 | 1.35135 | 2324.8 | 430084 |
| 741 | 549081 | 406869021 | 27.2213 | 9.0491 | 2.86982 | 1.34953 | 2327.9 | 431247 |
| 742 | 550564 | 408518488 | 27.2397 | 9.0532 | 2.87040 | 1.34771 | 2331.1 | 432412 |
| 743 | 552049 | 410172407 | 27.2580 | 9.0572 | 2.87099 | 1.34590 | 2334.2 | 433578 |
| 744 | 553536 | 411830784 | 27.2764 | 9.0613 | 2.87157 | 1.34409 | 2337.3 | 434746 |
| 745 | 555025 | 413493625 | 27.2947 | 9.0654 | 2.87216 | 1.34228 | 2340.5 | 435916 |
| 746 | 556516 | 415160936 | 27.3130 | 9.0694 | 2.87274 | 1.34048 | 2343.6 | 437087 |
| 747 | 558009 | 416832723 | 27.3313 | 9.0735 | 2.87332 | 1.33869 | 2346.8 | 438259 |
| 748 | 559504 | 418508992 | 27.3496 | 9.0775 | 2.87390 | 1.33690 | 2349.9 | 439433 |
| 749 | 561001 | 420189749 | 27.3679 | 9.0816 | 2.87448 | 1.33511 | 2353.1 | 440609 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 750 | 562500 | 421875000 | 27.3861 | 9.0856 | 2.87506 | 1.33333 | 2356.2 | 441786 |
| 751 | 564001 | 423564751 | 27.4044 | 9.0896 | 2.87564 | 1.33156 | 2359.3 | 442965 |
| 752 | 565504 | 425259008 | 27.4226 | 9.0937 | 2.87622 | 1.32979 | 2362.5 | 444146 |
| 753 | 567009 | 426957777 | 27.4408 | 9.0977 | 2.87680 | 1.32802 | 2365.6 | 445328 |
| 754 | 568516 | 428661064 | 27.4591 | 9.1017 | 2.87737 | 1.32626 | 2368.8 | 446511 |
| 755 | 570025 | 430368875 | 27.4773 | 9.1057 | 2.87795 | 1.32450 | 2371.9 | 447697 |
| 756 | 571536 | 432081216 | 27.4955 | 9.1098 | 2.87852 | 1.32275 | 2375.0 | 448883 |
| 757 | 573049 | 433798093 | 27.5136 | 9.1138 | 2.87910 | 1.32100 | 2378.2 | 450072 |
| 758 | 574564 | 435519512 | 27.5318 | 9.1178 | 2.87967 | 1.31926 | 2381.3 | 451262 |
| 759 | 576081 | 437245479 | 27.5500 | 9.1218 | 2.88024 | 1.31752 | 2384.5 | 452453 |
| 760 | 577600 | 438976000 | 27.5681 | 9.1258 | 2.88081 | 1.31579 | 2387.6 | 453646 |
| 761 | 579121 | 440711081 | 27.5862 | 9.1298 | 2.88138 | 1.31406 | 2390.8 | 454841 |
| 762 | 580644 | 442450728 | 27.6043 | 9.1338 | 2.88196 | 1.31234 | 2393.9 | 456037 |
| 763 | 582169 | 444194947 | 27.6225 | 9.1378 | 2.88252 | 1.31062 | 2397.0 | 457234 |
| 764 | 583696 | 445943744 | 27.6405 | 9.1418 | 2.88309 | 1.30890 | 2400.2 | 458434 |
| 765 | 585225 | 447697125 | 27.6586 | 9.1458 | 2.88366 | 1.30719 | 2403.3 | 459635 |
| 766 | 586756 | 449455096 | 27.6767 | 9.1498 | 2.88423 | 1.30548 | 2406.5 | 460837 |
| 767 | 588289 | 451217663 | 27.6948 | 9.1537 | 2.88480 | 1.30378 | 2409.6 | 462042 |
| 768 | 589824 | 452984832 | 27.7128 | 9.1577 | 2.88536 | 1.30208 | 2412.7 | 463247 |
| 769 | 591361 | 454756609 | 27.7308 | 9.1617 | 2.88593 | 1.30039 | 2415.9 | 464454 |
| 770 | 592900 | 456533000 | 27.7489 | 9.1657 | 2.88649 | 1.29870 | 2419.0 | 465663 |
| 771 | 594441 | 458314011 | 27.7669 | 9.1696 | 2.88705 | 1.29702 | 2422.2 | 466873 |
| 772 | 595984 | 460099648 | 27.7849 | 9.1736 | 2.88762 | 1.29534 | 2425.3 | 468085 |
| 773 | 597529 | 461889917 | 27.8029 | 9.1775 | 2.88818 | 1.29366 | 2428.5 | 469298 |
| 774 | 599076 | 463684824 | 27.8209 | 9.1815 | 2.88874 | 1.29199 | 2431.6 | 470513 |
| 775 | 600625 | 465484375 | 27.8388 | 9.1855 | 2.88930 | 1.29032 | 2434.7 | 471730 |
| 776 | 602176 | 467288576 | 27.8568 | 9.1894 | 2.88986 | 1.28866 | 2437.9 | 472948 |
| 777 | 603729 | 469097433 | 27.8747 | 9.1933 | 2.89042 | 1.28700 | 2441.0 | 474168 |
| 778 | 605284 | 470910952 | 27.8927 | 9.1973 | 2.89098 | 1.28535 | 2444.2 | 475389 |
| 779 | 606841 | 472729139 | 27.9106 | 9.2012 | 2.89154 | 1.28370 | 2447.3 | 476612 |
| 780 | 608400 | 474552000 | 27.9285 | 9.2052 | 2.89209 | 1.28205 | 2450.4 | 477836 |
| 781 | 609961 | 476379541 | 27.9464 | 9.2091 | 2.89265 | 1.28041 | 2453.6 | 479062 |
| 782 | 611524 | 478211768 | 27.9643 | 9.2130 | 2.89321 | 1.27877 | 2456.7 | 480290 |
| 783 | 613089 | 480048687 | 27.9821 | 9.2170 | 2.89376 | 1.27714 | 2459.9 | 481519 |
| 784 | 614656 | 481890304 | 28.0000 | 9.2209 | 2.89432 | 1.27551 | 2463.0 | 482750 |
| 785 | 616225 | 483736625 | 28.0179 | 9.2248 | 2.89487 | 1.27389 | 2466.2 | 483982 |
| 786 | 617796 | 485587656 | 28.0357 | 9.2287 | 2.89542 | 1.27226 | 2469.3 | 485216 |
| 787 | 619369 | 487443403 | 28.0535 | 9.2326 | 2.89597 | 1.27065 | 2472.4 | 486451 |
| 788 | 620944 | 489303872 | 28.0713 | 9.2365 | 2.89653 | 1.26904 | 2475.6 | 487688 |
| 789 | 622521 | 491169069 | 28.0891 | 9.2404 | 2.89708 | 1.26743 | 2478.7 | 488927 |
| 790 | 624100 | 493039000 | 28.1069 | 9.2443 | 2.89763 | 1.26582 | 2481.9 | 490167 |
| 791 | 625681 | 494913671 | 28.1247 | 9.2482 | 2.89818 | 1.26422 | 2485.0 | 491409 |
| 792 | 627264 | 496793088 | 28.1425 | 9.2521 | 2.89873 | 1.26263 | 2488.1 | 492652 |
| 793 | 628849 | 498677257 | 28.1603 | 9.2560 | 2.89927 | 1.26103 | 2491.3 | 493897 |
| 794 | 630436 | 500566184 | 28.1780 | 9.2599 | 2.89982 | 1.25945 | 2494.4 | 495143 |
| 795 | 632025 | 502459875 | 28.1957 | 9.2638 | 2.90037 | 1.25786 | 2497.6 | 496391 |
| 796 | 633616 | 504358336 | 28.2135 | 9.2677 | 2.90091 | 1.25628 | 2500.7 | 497641 |
| 797 | 635209 | 506261573 | 28.2312 | 9.2716 | 2.90146 | 1.25471 | 2503.8 | 498892 |
| 798 | 636804 | 508169592 | 28.2489 | 9.2754 | 2.90200 | 1.25313 | 2507.0 | 50-145 |
| 799 | 638401 | 510082399 | 28.2666 | 9.2793 | 2.90255 | 1.25156 | 2510.1 | 501399 |

606 SQUARES, CUBES, SQUARE ROOTS, ETC.

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 800 | 640000 | 512000000 | 28.2843 | 9.2832 | 2.90309 | 1.25000 | 2513.3 | 502655 |
| 801 | 641601 | 513922401 | 28.3019 | 9.2870 | 2.90363 | 1.24844 | 2516.4 | 503912 |
| 802 | 643204 | 515849608 | 28.3196 | 9.2909 | 2.90417 | 1.24688 | 2519.6 | 505171 |
| 803 | 644809 | 517781627 | 28.3373 | 9.2948 | 2.90472 | 1.24533 | 2522.7 | 506432 |
| 804 | 646416 | 519718464 | 28.3549 | 9.2986 | 2.90526 | 1.24378 | 2525.8 | 507694 |
| 805 | 648025 | 521660125 | 28.3725 | 9.3025 | 2.90580 | 1.24224 | 2529.0 | 508958 |
| 806 | 649636 | 523606616 | 28.3901 | 9.3063 | 2.90634 | 1.24069 | 2532.1 | 510223 |
| 807 | 651249 | 525557943 | 28.4077 | 9.3102 | 2.90687 | 1.23916 | 2535.3 | 511490 |
| 808 | 652864 | 527514112 | 28.4253 | 9.3140 | 2.90741 | 1.23762 | 2538.4 | 512758 |
| 809 | 654481 | 529475129 | 28.4429 | 9.3179 | 2.90795 | 1.23609 | 2541.5 | 514028 |
| 810 | 656100 | 531441000 | 28.4605 | 9.3217 | 2.90849 | 1.23457 | 2544.7 | 515300 |
| 811 | 657721 | 533411731 | 28.4781 | 9.3255 | 2.90902 | 1.23305 | 2547.8 | 516573 |
| 812 | 659344 | 535387328 | 28.4956 | 9.3294 | 2.90956 | 1.23153 | 2551.0 | 517848 |
| 813 | 660969 | 537367797 | 28.5132 | 9.3332 | 2.91009 | 1.23001 | 2554.1 | 519124 |
| 814 | 662596 | 539353144 | 28.5307 | 9.3370 | 2.91062 | 1.22850 | 2557.3 | 520402 |
| 815 | 664225 | 541343375 | 28.5482 | 9.3408 | 2.91116 | 1.22699 | 2560.4 | 521681 |
| 816 | 665856 | 543338496 | 28.5657 | 9.3447 | 2.91169 | 1.22549 | 2563.5 | 522962 |
| 817 | 667489 | 545338513 | 28.5832 | 9.3485 | 2.91222 | 1.22399 | 2566.7 | 524245 |
| 818 | 669124 | 547343432 | 28.6007 | 9.3523 | 2.91275 | 1.22249 | 2569.8 | 525529 |
| 819 | 670761 | 549353259 | 28.6182 | 9.3561 | 2.91328 | 1.22100 | 2573.0 | 526814 |
| 820 | 672400 | 551368000 | 28.6356 | 9.3599 | 2.91381 | 1.21951 | 2576.1 | 528102 |
| 821 | 674041 | 553387661 | 28.6531 | 9.3637 | 2.91434 | 1.21803 | 2579.2 | 529391 |
| 822 | 675684 | 555412248 | 28.6705 | 9.3675 | 2.91487 | 1.21655 | 2582.4 | 530681 |
| 823 | 677329 | 557441767 | 28.6880 | 9.3713 | 2.91540 | 1.21507 | 2585.5 | 531973 |
| 824 | 678976 | 559476224 | 28.7054 | 9.3751 | 2.91593 | 1.21359 | 2588.7 | 533267 |
| 825 | 680625 | 561515625 | 28.7228 | 9.3789 | 2.91645 | 1.21212 | 2591.8 | 534562 |
| 826 | 682276 | 563559976 | 28.7402 | 9.3827 | 2.91698 | 1.21065 | 2595.0 | 535858 |
| 827 | 683929 | 565609283 | 28.7576 | 9.3865 | 2.91751 | 1.20919 | 2598.1 | 537157 |
| 828 | 685584 | 567663552 | 28.7750 | 9.3902 | 2.91803 | 1.20773 | 2601.2 | 538456 |
| 829 | 687241 | 569722789 | 28.7924 | 9.3940 | 2.91855 | 1.20627 | 2604.4 | 539758 |
| 830 | 688900 | 571787000 | 28.8097 | 9.3978 | 2.91908 | 1.20482 | 2607.5 | 541061 |
| 831 | 690561 | 573856191 | 28.8271 | 9.4016 | 2.91960 | 1.20337 | 2610.7 | 542365 |
| 832 | 692224 | 575930368 | 28.8444 | 9.4053 | 2.92012 | 1.20192 | 2613.8 | 543671 |
| 833 | 693889 | 578009537 | 28.8617 | 9.4091 | 2.92065 | 1.20048 | 2616.9 | 544979 |
| 834 | 695556 | 580093704 | 28.8791 | 9.4129 | 2.92117 | 1.19904 | 2620.1 | 546288 |
| 835 | 697225 | 582182875 | 28.8964 | 9.4166 | 2.92169 | 1.19760 | 2623.2 | 547599 |
| 836 | 698896 | 584277056 | 28.9137 | 9.4204 | 2.92221 | 1.19617 | 2626.4 | 548912 |
| 837 | 700569 | 586376253 | 28.9310 | 9.4241 | 2.92273 | 1.19474 | 2629.5 | 550226 |
| 838 | 702244 | 588480472 | 28.9482 | 9.4279 | 2.92324 | 1.19332 | 2632.7 | 551541 |
| 839 | 703921 | 590589719 | 28.9655 | 9.4316 | 2.92376 | 1.19189 | 2635.8 | 552858 |
| 840 | 705600 | 592704000 | 28.9828 | 9.4354 | 2.92428 | 1.19048 | 2638.9 | 554177 |
| 841 | 707281 | 594823321 | 29.0000 | 9.4391 | 2.92480 | 1.18906 | 2642.1 | 555497 |
| 842 | 708964 | 596947688 | 29.0172 | 9.4429 | 2.92531 | 1.18765 | 2645.2 | 556819 |
| 843 | 710649 | 599077107 | 29.0345 | 9.4466 | 2.92583 | 1.18624 | 2648.4 | 558142 |
| 844 | 712336 | 601211584 | 29.0517 | 9.4503 | 2.92634 | 1.18483 | 2651.5 | 559467 |
| 845 | 714025 | 603351125 | 29.0689 | 9.4541 | 2.92686 | 1.18343 | 2654.6 | 560794 |
| 846 | 715716 | 605495736 | 29.0861 | 9.4578 | 2.92737 | 1.18203 | 2657.8 | 562122 |
| 847 | 717409 | 607645423 | 29.1033 | 9.4615 | 2.92788 | 1.18064 | 2660.9 | 563452 |
| 848 | 719104 | 609800192 | 29.1204 | 9.4652 | 2.92840 | 1.17925 | 2664.1 | 564783 |
| 849 | 720801 | 611960049 | 29.1376 | 9.4690 | 2.92891 | 1.17786 | 2667.2 | 566116 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log | 1000 × Recip | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|--------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 850 | 722500 | 614125000 | 29.1548 | 9.4727 | 2.92942 | 1.17647 | 2670.4 | 567450 |
| 851 | 724201 | 616295051 | 29.1719 | 9.4764 | 2.92993 | 1.17509 | 2673.5 | 568786 |
| 852 | 725904 | 618470208 | 29.1890 | 9.4801 | 2.93044 | 1.17371 | 2676.6 | 570124 |
| 853 | 727609 | 620650477 | 29.2062 | 9.4838 | 2.93095 | 1.17233 | 2679.8 | 571463 |
| 854 | 729316 | 622835864 | 29.2233 | 9.4875 | 2.93146 | 1.17096 | 2682.9 | 572803 |
| 855 | 731025 | 625026375 | 29.2404 | 9.4912 | 2.93197 | 1.16959 | 2686.1 | 574146 |
| 856 | 732736 | 627222016 | 29.2575 | 9.4949 | 2.93247 | 1.16822 | 2689.2 | 575490 |
| 857 | 734449 | 629422793 | 29.2746 | 9.4986 | 2.93298 | 1.16686 | 2692.3 | 576835 |
| 858 | 736164 | 631628712 | 29.2916 | 9.5023 | 2.93349 | 1.16550 | 2695.5 | 578182 |
| 859 | 737881 | 633839779 | 29.3087 | 9.5060 | 2.93399 | 1.16414 | 2698.6 | 579530 |
| 860 | 739600 | 636056000 | 29.3258 | 9.5097 | 2.93450 | 1.16279 | 2701.8 | 580880 |
| 861 | 741321 | 638277381 | 29.3428 | 9.5134 | 2.93500 | 1.16144 | 2704.9 | 582232 |
| 862 | 743044 | 640503928 | 29.3598 | 9.5171 | 2.93551 | 1.16009 | 2708.1 | 583585 |
| 863 | 744769 | 642735647 | 29.3769 | 9.5207 | 2.93601 | 1.15875 | 2711.2 | 584940 |
| 864 | 746496 | 644972544 | 29.3939 | 9.5244 | 2.93651 | 1.15741 | 2714.3 | 586297 |
| 865 | 748225 | 647214625 | 29.4109 | 9.5281 | 2.93702 | 1.15607 | 2717.5 | 587655 |
| 866 | 749956 | 649461896 | 29.4279 | 9.5317 | 2.93752 | 1.15473 | 2720.6 | 589014 |
| 867 | 751689 | 651714363 | 29.4449 | 9.5354 | 2.93802 | 1.15340 | 2723.8 | 590375 |
| 868 | 753424 | 653972032 | 29.4618 | 9.5391 | 2.93852 | 1.15207 | 2726.9 | 591738 |
| 869 | 755161 | 656234909 | 29.4788 | 9.5427 | 2.93902 | 1.15075 | 2730.0 | 593102 |
| 870 | 756900 | 658503000 | 29.4958 | 9.5464 | 2.93952 | 1.14943 | 2733.2 | 594468 |
| 871 | 758641 | 660776311 | 29.5127 | 9.5501 | 2.94002 | 1.14811 | 2736.3 | 595835 |
| 872 | 760384 | 663054848 | 29.5296 | 9.5537 | 2.94052 | 1.14679 | 2739.5 | 597204 |
| 873 | 762129 | 665338617 | 29.5466 | 9.5574 | 2.94101 | 1.14548 | 2742.6 | 598575 |
| 874 | 763876 | 667627624 | 29.5635 | 9.5610 | 2.94151 | 1.14416 | 2745.8 | 599947 |
| 875 | 765625 | 669921875 | 29.5804 | 9.5647 | 2.94201 | 1.14286 | 2748.9 | 601320 |
| 876 | 767376 | 672221376 | 29.5973 | 9.5683 | 2.94250 | 1.14155 | 2752.0 | 602696 |
| 877 | 769129 | 674526133 | 29.6142 | 9.5719 | 2.94300 | 1.14025 | 2755.2 | 604073 |
| 878 | 770884 | 676836152 | 29.6311 | 9.5756 | 2.94349 | 1.13895 | 2758.3 | 605451 |
| 879 | 772641 | 679151439 | 29.6479 | 9.5792 | 2.94399 | 1.13766 | 2761.5 | 606831 |
| 880 | 774400 | 681472000 | 29.6648 | 9.5828 | 2.94448 | 1.13636 | 2764.6 | 608212 |
| 881 | 776161 | 683797841 | 29.6816 | 9.5865 | 2.94498 | 1.13507 | 2767.7 | 609595 |
| 882 | 777924 | 686128968 | 29.6985 | 9.5901 | 2.94547 | 1.13379 | 2770.9 | 610980 |
| 883 | 779689 | 688465387 | 29.7153 | 9.5937 | 2.94596 | 1.13250 | 2774.0 | 612366 |
| 884 | 781456 | 690807104 | 29.7321 | 9.5973 | 2.94645 | 1.13122 | 2777.2 | 613754 |
| 885 | 783225 | 693154125 | 29.7489 | 9.6010 | 2.94694 | 1.12994 | 2780.3 | 615143 |
| 886 | 784996 | 695506456 | 29.7658 | 9.6046 | 2.94743 | 1.12867 | 2783.5 | 616534 |
| 887 | 786769 | 697864103 | 29.7825 | 9.6082 | 2.94792 | 1.12740 | 2786.6 | 617927 |
| 888 | 788544 | 700227072 | 29.7993 | 9.6118 | 2.94841 | 1.12613 | 2789.7 | 619321 |
| 889 | 790321 | 702595369 | 29.8161 | 9.6154 | 2.94890 | 1.12486 | 2792.9 | 620717 |
| 890 | 792100 | 704969000 | 29.8329 | 9.6190 | 2.94939 | 1.12360 | 2796.0 | 622114 |
| 891 | 793881 | 707347971 | 29.8496 | 9.6226 | 2.94988 | 1.12233 | 2799.2 | 623513 |
| 892 | 795664 | 709732288 | 29.8664 | 9.6262 | 2.95036 | 1.12108 | 2802.3 | 624913 |
| 893 | 797449 | 712121957 | 29.8831 | 9.6298 | 2.95085 | 1.11982 | 2805.4 | 626315 |
| 894 | 799236 | 714516984 | 29.8998 | 9.6334 | 2.95134 | 1.11857 | 2808.6 | 627718 |
| 895 | 801025 | 716917375 | 29.9166 | 9.6370 | 2.95182 | 1.11732 | 2811.7 | 629124 |
| 896 | 802816 | 719323136 | 29.9333 | 9.6406 | 2.95231 | 1.11607 | 2814.9 | 630530 |
| 897 | 804609 | 721734273 | 29.9500 | 9.6442 | 2.95279 | 1.11483 | 2818.0 | 631938 |
| 898 | 806404 | 724150792 | 29.9666 | 9.6477 | 2.95328 | 1.11359 | 2821.2 | 633348 |
| 899 | 808201 | 726572699 | 29.9833 | 9.6513 | 2.95376 | 1.11235 | 2824.3 | 634760 |

608 SQUARES, CUBES, SQUARE ROOTS, ETC.

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS,
 RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS
 OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root. | Log. | 1000 × Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|------------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 900 | 810000 | 729000000 | 30.0000 | 9.6549 | 2.95424 | 1.11111 | 2827.4 | 636173 |
| 901 | 811801 | 731432701 | 30.0167 | 9.6585 | 2.95472 | 1.10988 | 2830.6 | 637587 |
| 902 | 813604 | 733870808 | 30.0333 | 9.6620 | 2.95521 | 1.10865 | 2833.7 | 639003 |
| 903 | 815409 | 736314327 | 30.0500 | 9.6656 | 2.95569 | 1.10742 | 2836.9 | 640421 |
| 904 | 817216 | 738763264 | 30.0666 | 9.6692 | 2.95617 | 1.10619 | 2840.0 | 641840 |
| 905 | 819025 | 741217625 | 30.0832 | 9.6727 | 2.95665 | 1.10497 | 2843.1 | 643261 |
| 906 | 820836 | 743677416 | 30.0998 | 9.6763 | 2.95713 | 1.10375 | 2846.3 | 644683 |
| 907 | 822649 | 746142643 | 30.1164 | 9.6799 | 2.95761 | 1.10254 | 2849.4 | 646107 |
| 908 | 824464 | 748613312 | 30.1330 | 9.6834 | 2.95809 | 1.10132 | 2852.6 | 647533 |
| 909 | 826281 | 751089429 | 30.1496 | 9.6870 | 2.95856 | 1.10011 | 2855.7 | 648960 |
| 910 | 828100 | 753571000 | 30.1662 | 9.6905 | 2.95904 | 1.09890 | 2858.8 | 650388 |
| 911 | 829921 | 756058031 | 30.1828 | 9.6941 | 2.95952 | 1.09769 | 2862.0 | 651818 |
| 912 | 831744 | 758550528 | 30.1993 | 9.6976 | 2.95999 | 1.09649 | 2865.1 | 653250 |
| 913 | 833569 | 761048497 | 30.2159 | 9.7012 | 2.96047 | 1.09529 | 2868.3 | 654684 |
| 914 | 835396 | 763551944 | 30.2324 | 9.7047 | 2.96095 | 1.09409 | 2871.4 | 656118 |
| 915 | 837225 | 766060875 | 30.2490 | 9.7082 | 2.96142 | 1.09290 | 2874.6 | 657555 |
| 916 | 839056 | 768575296 | 30.2655 | 9.7118 | 2.96190 | 1.09170 | 2877.7 | 658993 |
| 917 | 840889 | 771095213 | 30.2820 | 9.7153 | 2.96237 | 1.09051 | 2880.8 | 660433 |
| 918 | 842724 | 773620632 | 30.2985 | 9.7188 | 2.96284 | 1.08932 | 2884.0 | 661874 |
| 919 | 844561 | 776151559 | 30.3150 | 9.7224 | 2.96332 | 1.08814 | 2887.1 | 663317 |
| 920 | 846400 | 778688800 | 30.3315 | 9.7259 | 2.96379 | 1.08696 | 2890.3 | 664761 |
| 921 | 848241 | 781229961 | 30.3480 | 9.7294 | 2.96426 | 1.08578 | 2893.4 | 666207 |
| 922 | 850084 | 783777448 | 30.3645 | 9.7329 | 2.96473 | 1.08460 | 2896.5 | 667654 |
| 923 | 851929 | 786330467 | 30.3809 | 9.7364 | 2.96520 | 1.08342 | 2899.7 | 669103 |
| 924 | 853776 | 788889024 | 30.3974 | 9.7400 | 2.96567 | 1.08225 | 2902.8 | 670554 |
| 925 | 855625 | 791453125 | 30.4138 | 9.7435 | 2.96614 | 1.08108 | 2906.0 | 672006 |
| 926 | 857476 | 794022776 | 30.4302 | 9.7470 | 2.96661 | 1.07991 | 2909.1 | 673460 |
| 927 | 859329 | 796597983 | 30.4467 | 9.7505 | 2.96708 | 1.07875 | 2912.3 | 674915 |
| 928 | 861184 | 799178752 | 30.4631 | 9.7540 | 2.96755 | 1.07759 | 2915.4 | 676372 |
| 929 | 863041 | 801765089 | 30.4795 | 9.7575 | 2.96802 | 1.07643 | 2918.5 | 677831 |
| 930 | 864900 | 804357000 | 30.4959 | 9.7610 | 2.96848 | 1.07527 | 2921.7 | 679291 |
| 931 | 866761 | 806954491 | 30.5123 | 9.7645 | 2.96895 | 1.07411 | 2924.8 | 680752 |
| 932 | 868624 | 809557568 | 30.5287 | 9.7680 | 2.96942 | 1.07296 | 2928.0 | 682216 |
| 933 | 870489 | 812166237 | 30.5450 | 9.7715 | 2.96988 | 1.07181 | 2931.1 | 683680 |
| 934 | 872356 | 814780504 | 30.5614 | 9.7750 | 2.97035 | 1.07066 | 2934.2 | 685147 |
| 935 | 874225 | 817400375 | 30.5778 | 9.7785 | 2.97081 | 1.06952 | 2937.4 | 686615 |
| 936 | 876096 | 820025856 | 30.5941 | 9.7819 | 2.97128 | 1.06838 | 2940.5 | 688084 |
| 937 | 877969 | 822656953 | 30.6105 | 9.7854 | 2.97174 | 1.06724 | 2943.7 | 689555 |
| 938 | 879844 | 825293672 | 30.6268 | 9.7889 | 2.97220 | 1.06610 | 2946.8 | 691028 |
| 939 | 881721 | 827936019 | 30.6431 | 9.7924 | 2.97267 | 1.06496 | 2950.0 | 692502 |
| 940 | 883600 | 830584000 | 30.6594 | 9.7959 | 2.97313 | 1.06383 | 2953.1 | 693978 |
| 941 | 885481 | 833237621 | 30.6757 | 9.7993 | 2.97359 | 1.06270 | 2956.2 | 695455 |
| 942 | 887364 | 835896888 | 30.6920 | 9.8028 | 2.97405 | 1.06157 | 2959.4 | 696934 |
| 943 | 889249 | 838561807 | 30.7083 | 9.8063 | 2.97451 | 1.06045 | 2962.5 | 698415 |
| 944 | 891136 | 841232384 | 30.7246 | 9.8097 | 2.97497 | 1.05932 | 2965.7 | 699897 |
| 945 | 893025 | 843908625 | 30.7409 | 9.8132 | 2.97543 | 1.05820 | 2968.8 | 701380 |
| 946 | 894916 | 846590536 | 30.7571 | 9.8167 | 2.97589 | 1.05708 | 2971.9 | 702865 |
| 947 | 896809 | 849278123 | 30.7734 | 9.8201 | 2.97635 | 1.05597 | 2975.1 | 704352 |
| 948 | 898704 | 851971392 | 30.7896 | 9.8236 | 2.97681 | 1.05485 | 2978.2 | 705840 |
| 949 | 900601 | 854670349 | 30.8058 | 9.8270 | 2.97727 | 1.05374 | 2981.4 | 707330 |

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCAL, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(Continued).

| No. | Square | Cube. | Square Root. | Cube Root | Log. | 1000 X Recip. | No. = Diameter. | |
|-----|--------|-----------|--------------|-----------|---------|---------------|-----------------|--------|
| | | | | | | | Circum. | Area. |
| 950 | 902500 | 857375000 | 30.8221 | 9.8305 | 2.97772 | 1.05263 | 2984.5 | 708822 |
| 951 | 904401 | 860085351 | 30.8383 | 9.8339 | 2.97818 | 1.05152 | 2987.7 | 710315 |
| 952 | 906304 | 862801408 | 30.8545 | 9.8374 | 2.97864 | 1.05042 | 2990.8 | 711809 |
| 953 | 908209 | 865523177 | 30.8707 | 9.8408 | 2.97909 | 1.04932 | 2993.9 | 713306 |
| 954 | 910116 | 868250664 | 30.8869 | 9.8443 | 2.97955 | 1.04822 | 2997.1 | 714803 |
| 955 | 912025 | 870983875 | 30.9031 | 9.8477 | 2.98000 | 1.04712 | 3000.2 | 716303 |
| 956 | 913936 | 873722816 | 30.9192 | 9.8511 | 2.98046 | 1.04603 | 3003.4 | 717804 |
| 957 | 915849 | 876467493 | 30.9354 | 9.8546 | 2.98091 | 1.04493 | 3006.5 | 719306 |
| 958 | 917764 | 879217912 | 30.9516 | 9.8580 | 2.98137 | 1.04384 | 3009.6 | 720810 |
| 959 | 919681 | 881974079 | 30.9677 | 9.8614 | 2.98182 | 1.04275 | 3012.8 | 722316 |
| 960 | 921600 | 884736000 | 30.9839 | 9.8648 | 2.98227 | 1.04167 | 3015.9 | 723823 |
| 961 | 923521 | 887503681 | 31.0000 | 9.8683 | 2.98272 | 1.04058 | 3019.1 | 725332 |
| 962 | 925444 | 890277128 | 31.0161 | 9.8717 | 2.98318 | 1.03950 | 3022.2 | 726842 |
| 963 | 927369 | 893056347 | 31.0322 | 9.8751 | 2.98363 | 1.03842 | 3025.4 | 728354 |
| 964 | 929296 | 895841344 | 31.0483 | 9.8785 | 2.98403 | 1.03734 | 3028.5 | 729867 |
| 965 | 931225 | 898632125 | 31.0644 | 9.8819 | 2.98453 | 1.03627 | 3031.6 | 731382 |
| 966 | 933156 | 901428696 | 31.0805 | 9.8854 | 2.98498 | 1.03520 | 3034.8 | 732899 |
| 967 | 935089 | 904231063 | 31.0966 | 9.8888 | 2.98543 | 1.03413 | 3037.9 | 734417 |
| 968 | 937024 | 907039232 | 31.1127 | 9.8922 | 2.98588 | 1.03306 | 3041.1 | 735937 |
| 969 | 938961 | 909853209 | 31.1288 | 9.8956 | 2.98632 | 1.03199 | 3044.2 | 737458 |
| 970 | 940900 | 912673000 | 31.1448 | 9.8990 | 2.98677 | 1.03093 | 3047.3 | 738981 |
| 971 | 942841 | 915498611 | 31.1609 | 9.9024 | 2.98722 | 1.02987 | 3050.5 | 740506 |
| 972 | 944784 | 918330048 | 31.1769 | 9.9058 | 2.98767 | 1.02881 | 3053.6 | 742032 |
| 973 | 946729 | 921167317 | 31.1929 | 9.9092 | 2.98811 | 1.02775 | 3056.8 | 743559 |
| 974 | 948676 | 924010424 | 31.2090 | 9.9126 | 2.98856 | 1.02669 | 3059.9 | 745088 |
| 975 | 950625 | 926859375 | 31.2250 | 9.9160 | 2.98900 | 1.02564 | 3063.1 | 746619 |
| 976 | 952576 | 929714176 | 31.2410 | 9.9194 | 2.98945 | 1.02459 | 3066.2 | 748151 |
| 977 | 954529 | 932574833 | 31.2570 | 9.9227 | 2.98989 | 1.02354 | 3069.3 | 749685 |
| 978 | 956484 | 935441352 | 31.2730 | 9.9261 | 2.99034 | 1.02249 | 3072.5 | 751221 |
| 979 | 958441 | 938313739 | 31.2890 | 9.9295 | 2.99078 | 1.02145 | 3075.6 | 752758 |
| 980 | 960400 | 941192000 | 31.3050 | 9.9329 | 2.99123 | 1.02041 | 3078.8 | 754296 |
| 981 | 962361 | 944076141 | 31.3209 | 9.9363 | 2.99167 | 1.01937 | 3081.9 | 755837 |
| 982 | 964324 | 946966168 | 31.3369 | 9.9396 | 2.99211 | 1.01833 | 3085.0 | 757378 |
| 983 | 966289 | 949862087 | 31.3528 | 9.9430 | 2.99255 | 1.01729 | 3088.2 | 758922 |
| 984 | 968256 | 952763904 | 31.3688 | 9.9464 | 2.99300 | 1.01626 | 3091.3 | 760466 |
| 985 | 970225 | 955671625 | 31.3847 | 9.9497 | 2.99344 | 1.01523 | 3094.5 | 762013 |
| 986 | 972196 | 958585256 | 31.4006 | 9.9531 | 2.99388 | 1.01420 | 3097.6 | 763561 |
| 987 | 974169 | 961504803 | 31.4166 | 9.9565 | 2.99432 | 1.01317 | 3100.8 | 765111 |
| 988 | 976144 | 964430272 | 31.4325 | 9.9598 | 2.99476 | 1.01215 | 3103.9 | 766662 |
| 989 | 978121 | 967361669 | 31.4484 | 9.9632 | 2.99520 | 1.01112 | 3107.0 | 768214 |
| 990 | 980100 | 970299000 | 31.4643 | 9.9666 | 2.99564 | 1.01010 | 3110.2 | 769769 |
| 991 | 982081 | 973242271 | 31.4802 | 9.9699 | 2.99607 | 1.00908 | 3113.3 | 771325 |
| 992 | 984064 | 976191488 | 31.4960 | 9.9733 | 2.99651 | 1.00806 | 3116.5 | 772882 |
| 993 | 986049 | 979146657 | 31.5119 | 9.9766 | 2.99695 | 1.00705 | 3119.6 | 774441 |
| 994 | 988036 | 982107784 | 31.5278 | 9.9800 | 2.99739 | 1.00604 | 3122.7 | 776002 |
| 995 | 990025 | 985074875 | 31.5436 | 9.9833 | 2.99782 | 1.00503 | 3125.9 | 777564 |
| 996 | 992016 | 988047936 | 31.5595 | 9.9866 | 2.99826 | 1.00402 | 3129.0 | 779128 |
| 997 | 994009 | 991026973 | 31.5753 | 9.9900 | 2.99870 | 1.00301 | 3132.2 | 780693 |
| 998 | 996004 | 994011992 | 31.5911 | 9.9933 | 2.99913 | 1.00200 | 3135.3 | 782260 |
| 999 | 998001 | 997002999 | 31.6070 | 9.9967 | 2.99957 | 1.00100 | 3138.5 | 783828 |

DECIMALS OF A FOOT FOR EACH $\frac{1}{16}$ OF AN INCH.

| Inch. | 0" | 1" | 2" | 3" | 4" | 5" | 6" | 7" | 8" | 9" | 10" | 11" |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0 | 0 | .0833 | .1667 | .2500 | .3333 | .4167 | .5000 | .5833 | .6667 | .7500 | .8333 | .9167 |
| $\frac{1}{16}$ | .0013 | .0846 | .1680 | .2513 | .3346 | .4180 | .5013 | .5846 | .6680 | .7513 | .8346 | .9180 |
| $\frac{2}{16}$ | .0026 | .0859 | .1693 | .2526 | .3359 | .4193 | .5026 | .5859 | .6693 | .7526 | .8359 | .9193 |
| $\frac{3}{16}$ | .0039 | .0872 | .1706 | .2539 | .3372 | .4206 | .5039 | .5872 | .6706 | .7539 | .8372 | .9206 |
| $\frac{4}{16}$ | .0052 | .0885 | .1719 | .2552 | .3385 | .4219 | .5052 | .5885 | .6719 | .7552 | .8385 | .9219 |
| $\frac{5}{16}$ | .0065 | .0898 | .1732 | .2565 | .3398 | .4232 | .5065 | .5898 | .6732 | .7565 | .8398 | .9232 |
| $\frac{6}{16}$ | .0078 | .0911 | .1745 | .2578 | .3411 | .4245 | .5078 | .5911 | .6745 | .7578 | .8411 | .9245 |
| $\frac{7}{16}$ | .0091 | .0924 | .1758 | .2591 | .3424 | .4258 | .5091 | .5924 | .6758 | .7591 | .8424 | .9258 |
| $\frac{8}{16}$ | .0104 | .0937 | .1771 | .2604 | .3437 | .4271 | .5104 | .5937 | .6771 | .7604 | .8437 | .9271 |
| $\frac{9}{16}$ | .0117 | .0951 | .1784 | .2617 | .3451 | .4284 | .5117 | .5951 | .6784 | .7617 | .8451 | .9284 |
| $\frac{10}{16}$ | .0130 | .0964 | .1797 | .2630 | .3464 | .4297 | .5130 | .5964 | .6797 | .7630 | .8464 | .9297 |
| $\frac{11}{16}$ | .0143 | .0977 | .1810 | .2643 | .3477 | .4310 | .5143 | .5977 | .6810 | .7643 | .8477 | .9310 |
| $\frac{12}{16}$ | .0156 | .0990 | .1823 | .2656 | .3490 | .4323 | .5156 | .5990 | .6823 | .7656 | .8490 | .9323 |
| $\frac{13}{16}$ | .0169 | .1003 | .1836 | .2669 | .3503 | .4336 | .5169 | .6003 | .6836 | .7669 | .8503 | .9336 |
| $\frac{14}{16}$ | .0182 | .1016 | .1849 | .2682 | .3516 | .4349 | .5182 | .6016 | .6849 | .7682 | .8516 | .9349 |
| $\frac{15}{16}$ | .0195 | .1029 | .1862 | .2695 | .3529 | .4362 | .5195 | .6029 | .6862 | .7695 | .8529 | .9362 |
| 1 | .0208 | .1042 | .1875 | .2708 | .3542 | .4375 | .5208 | .6042 | .6875 | .7708 | .8542 | .9375 |
| $\frac{17}{16}$ | .0221 | .1055 | .1888 | .2721 | .3555 | .4388 | .5221 | .6055 | .6888 | .7721 | .8555 | .9388 |
| $\frac{18}{16}$ | .0234 | .1068 | .1901 | .2734 | .3568 | .4401 | .5234 | .6068 | .6901 | .7734 | .8568 | .9401 |
| $\frac{19}{16}$ | .0247 | .1081 | .1914 | .2747 | .3581 | .4414 | .5247 | .6081 | .6914 | .7747 | .8581 | .9414 |
| $\frac{20}{16}$ | .0260 | .1094 | .1927 | .2760 | .3594 | .4427 | .5260 | .6094 | .6927 | .7760 | .8594 | .9427 |
| $\frac{21}{16}$ | .0273 | .1107 | .1940 | .2773 | .3607 | .4440 | .5273 | .6107 | .6940 | .7773 | .8607 | .9440 |
| $\frac{22}{16}$ | .0286 | .1120 | .1953 | .2786 | .3620 | .4453 | .5286 | .6120 | .6953 | .7786 | .8620 | .9453 |
| $\frac{23}{16}$ | .0299 | .1133 | .1966 | .2799 | .3633 | .4466 | .5299 | .6133 | .6966 | .7799 | .8633 | .9466 |
| $\frac{24}{16}$ | .0312 | .1146 | .1979 | .2812 | .3646 | .4479 | .5312 | .6146 | .6979 | .7812 | .8646 | .9479 |
| $\frac{25}{16}$ | .0326 | .1159 | .1992 | .2826 | .3659 | .4492 | .5326 | .6159 | .6992 | .7826 | .8659 | .9492 |
| $\frac{26}{16}$ | .0339 | .1172 | .2005 | .2839 | .3672 | .4505 | .5339 | .6172 | .7105 | .7839 | .8672 | .9505 |
| $\frac{27}{16}$ | .0352 | .1185 | .2018 | .2852 | .3685 | .4518 | .5352 | .6185 | .7018 | .7852 | .8685 | .9518 |
| $\frac{28}{16}$ | .0365 | .1198 | .2031 | .2865 | .3698 | .4531 | .5365 | .6198 | .7031 | .7865 | .8698 | .9531 |
| $\frac{29}{16}$ | .0378 | .1211 | .2044 | .2878 | .3711 | .4544 | .5378 | .6211 | .7044 | .7878 | .8711 | .9544 |
| $\frac{30}{16}$ | .0391 | .1224 | .2057 | .2891 | .3724 | .4557 | .5391 | .6224 | .7057 | .7891 | .8724 | .9557 |
| $\frac{31}{16}$ | .0404 | .1237 | .2070 | .2904 | .3737 | .4570 | .5404 | .6237 | .7070 | .7904 | .8737 | .9570 |
| $\frac{32}{16}$ | .0417 | .1250 | .2083 | .2917 | .3750 | .4583 | .5417 | .6250 | .7083 | .7917 | .8750 | .9583 |
| $\frac{33}{16}$ | .0430 | .1263 | .2096 | .2930 | .3763 | .4596 | .5430 | .6263 | .7096 | .7930 | .8763 | .9596 |
| $\frac{34}{16}$ | .0443 | .1276 | .2109 | .2943 | .3776 | .4609 | .5443 | .6276 | .7109 | .7943 | .8776 | .9609 |
| $\frac{35}{16}$ | .0456 | .1289 | .2122 | .2956 | .3789 | .4622 | .5456 | .6289 | .7122 | .7956 | .8789 | .9622 |
| $\frac{36}{16}$ | .0469 | .1302 | .2135 | .2969 | .3802 | .4635 | .5469 | .6302 | .7135 | .7969 | .8802 | .9635 |
| $\frac{37}{16}$ | .0482 | .1315 | .2148 | .2982 | .3815 | .4648 | .5482 | .6315 | .7148 | .7982 | .8815 | .9648 |
| $\frac{38}{16}$ | .0495 | .1328 | .2161 | .2995 | .3828 | .4661 | .5495 | .6328 | .7161 | .7995 | .8828 | .9661 |
| $\frac{39}{16}$ | .0508 | .1341 | .2174 | .3008 | .3841 | .4674 | .5508 | .6341 | .7174 | .8008 | .8841 | .9674 |
| $\frac{40}{16}$ | .0521 | .1354 | .2188 | .3021 | .3854 | .4688 | .5521 | .6354 | .7188 | .8021 | .8854 | .9688 |
| $\frac{41}{16}$ | .0534 | .1367 | .2201 | .3034 | .3867 | .4701 | .5534 | .6367 | .7201 | .8034 | .8867 | .9701 |
| $\frac{42}{16}$ | .0547 | .1380 | .2214 | .3047 | .3880 | .4714 | .5547 | .6380 | .7214 | .8047 | .8880 | .9714 |
| $\frac{43}{16}$ | .0560 | .1393 | .2227 | .3060 | .3893 | .4727 | .5560 | .6393 | .7227 | .8060 | .8893 | .9727 |
| $\frac{44}{16}$ | .0573 | .1406 | .2240 | .3073 | .3906 | .4740 | .5573 | .6406 | .7240 | .8073 | .8906 | .9740 |
| $\frac{45}{16}$ | .0586 | .1419 | .2253 | .3086 | .3919 | .4753 | .5586 | .6419 | .7253 | .8086 | .8919 | .9753 |
| $\frac{46}{16}$ | .0599 | .1432 | .2266 | .3099 | .3932 | .4766 | .5599 | .6432 | .7266 | .8099 | .8932 | .9766 |
| $\frac{47}{16}$ | .0612 | .1445 | .2279 | .3112 | .3945 | .4779 | .5612 | .6445 | .7279 | .8112 | .8945 | .9779 |
| $\frac{48}{16}$ | .0625 | .1458 | .2292 | .3125 | .3958 | .4792 | .5625 | .6458 | .7292 | .8125 | .8958 | .9792 |

DECIMALS OF A FOOT FOR EACH 1/16 OF AN INCH—(Continued).

| Inch. | 0" | 1" | 2" | 3" | 4" | 5" | 6" | 7" | 8" | 9" | 10" | 11" |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| 1/16 | .0638 | .1471 | .2305 | .3138 | .3971 | .4805 | .5638 | .6471 | .7305 | .8138 | .8971 | .9805 |
| 1/8 | .0651 | .1484 | .2318 | .3151 | .3984 | .4818 | .5651 | .6484 | .7318 | .8151 | .8984 | .9818 |
| 3/16 | .0664 | .1497 | .2331 | .3164 | .3997 | .4831 | .5664 | .6497 | .7331 | .8164 | .8997 | .9831 |
| 1/4 | .0677 | .1510 | .2344 | .3177 | .4010 | .4844 | .5677 | .6510 | .7344 | .8177 | .9010 | .9844 |
| 5/16 | .0690 | .1523 | .2357 | .3190 | .4023 | .4857 | .5690 | .6523 | .7357 | .8190 | .9023 | .9857 |
| 3/8 | .0703 | .1536 | .2370 | .3203 | .4036 | .4870 | .5703 | .6536 | .7370 | .8203 | .9036 | .9870 |
| 7/16 | .0716 | .1549 | .2383 | .3216 | .4049 | .4883 | .5716 | .6549 | .7383 | .8216 | .9049 | .9883 |
| 1/2 | .0729 | .1562 | .2396 | .3229 | .4062 | .4896 | .5729 | .6562 | .7396 | .8229 | .9062 | .9896 |
| 9/16 | .0742 | .1576 | .2409 | .3242 | .4076 | .4909 | .5742 | .6576 | .7409 | .8242 | .9076 | .9909 |
| 5/8 | .0755 | .1589 | .2422 | .3255 | .4089 | .4922 | .5755 | .6589 | .7422 | .8255 | .9089 | .9922 |
| 11/16 | .0768 | .1602 | .2435 | .3268 | .4102 | .4935 | .5768 | .6602 | .7435 | .8268 | .9102 | .9935 |
| 3/4 | .0781 | .1615 | .2448 | .3281 | .4115 | .4948 | .5781 | .6615 | .7448 | .8281 | .9115 | .9948 |
| 13/16 | .0794 | .1628 | .2461 | .3294 | .4128 | .4961 | .5794 | .6628 | .7461 | .8294 | .9128 | .9961 |
| 7/8 | .0807 | .1641 | .2474 | .3307 | .4141 | .4974 | .5807 | .6641 | .7474 | .8307 | .9141 | .9974 |
| 1 | .0820 | .1654 | .2487 | .3320 | .4154 | .4987 | .5820 | .6654 | .7487 | .8320 | .9154 | .9987 |
| | | | | | | | | | | | | 1.0000 |

DECIMALS OF AN INCH FOR EACH 1/16TH.

| 1/2ds. | 1/4ths. | Decimal. | Fraction. | 1/2ds. | 1/4ths. | Decimal. | Fraction. |
|--------|---------|----------|-----------|--------|---------|----------|-----------|
| | 1 | .015625 | | | 33 | .515625 | |
| 1 | 2 | .03125 | | 17 | 34 | .53125 | |
| | 3 | .046875 | | | 35 | .546875 | |
| 2 | 4 | .0625 | 1/16 | 18 | 36 | .5625 | 9/16 |
| | 5 | .078125 | | | 37 | .578125 | |
| 3 | 6 | .09375 | | 19 | 38 | .59375 | |
| | 7 | .109375 | | | 39 | .609375 | |
| 4 | 8 | .125 | 1/8 | 20 | 40 | .625 | 5/8 |
| | 9 | .140625 | | | 41 | .640625 | |
| 5 | 10 | .15625 | | 21 | 42 | .65625 | |
| | 11 | .171875 | | | 43 | .671875 | |
| 6 | 12 | .1875 | 3/16 | 22 | 44 | .6875 | 11/16 |
| | 13 | .203125 | | | 45 | .703125 | |
| 7 | 14 | .21875 | | 23 | 46 | .71875 | |
| | 15 | .234375 | | | 47 | .734375 | |
| 8 | 16 | .25 | 1/4 | 24 | 48 | .75 | 3/4 |
| | 17 | .265625 | | | 49 | .765625 | |
| 9 | 18 | .28125 | | 25 | 50 | .78125 | |
| | 19 | .296875 | | | 51 | .796875 | |
| 10 | 20 | .3125 | 5/16 | 26 | 52 | .8125 | 13/16 |
| | 21 | .328125 | | | 53 | .828125 | |
| 11 | 22 | .34375 | | 27 | 54 | .84375 | |
| | 23 | .359375 | | | 55 | .859375 | |
| 12 | 24 | .375 | 3/8 | 28 | 56 | .875 | 7/8 |
| | 25 | .390625 | | | 57 | .890625 | |
| 13 | 26 | .40625 | | 29 | 58 | .90625 | |
| | 27 | .421875 | | | 59 | .921875 | |
| 14 | 28 | .4375 | 7/16 | 30 | 60 | .9375 | 15/16 |
| | 29 | .453125 | | | 61 | .953125 | |
| 15 | 30 | .46875 | | 31 | 62 | .96875 | |
| | 31 | .484375 | | | 63 | .984375 | |
| 16 | 32 | .5 | 1/2 | 32 | 64 | 1. | 1 |

GEOMETRICAL MENSURATION.

Definitions.—A point is a position without dimensions.

A line has one dimension—length.

A surface has two dimensions—length and breadth.

A solid has three dimensions—length, breadth, and thickness.

A right angle is one whose two sides make an angle of 90° with each other; an acute angle is less than a right angle; an obtuse angle is more than a right angle.

A plane figure is a plane bounded on all sides by lines. If the lines are straight the space which they contain is called a polygon.

Polygons are named according to the number of their sides, as: A triangle is a plane figure of three sides; a quadrilateral is a plane figure of four sides; a pentagon is a plane figure of five sides; a hexagon is a plane figure of six sides; a heptagon is a plane figure of seven sides; an octagon is a plane figure of eight sides; a nonagon is a plane figure of nine sides; a decagon is a plane figure of ten sides; an undecagon is a plane figure of eleven sides; a dodecagon is a plane figure of twelve sides.

A circle is a plane bounded by a curved line all points of which are equally distant from the centre.

A trapezium is a polygon of four sides of which no two sides are parallel.

A trapezoid is a polygon of four sides of which two are parallel.

A parallelogram is a polygon bounded by two pairs of parallel sides.

A rhomboid is a parallelogram whose sides are not equal and its angles not right angles.

A rhombus is a parallelogram whose sides are all equal, but whose angles are not right angles.

A rectangle is a parallelogram whose angles are right angles.

A square is a rectangle whose sides are all equal.

Polygons whose sides are all equal are called regular.

An equilateral triangle has all its sides and angles equal; an isosceles triangle has two of its sides and two of its angles equal; a scalene triangle has all its sides and angles unequal.

A quadrilateral is a plane figure bounded by four straight lines.

A diameter is any line drawn through the centre of a figure and terminated by the opposite boundaries.

Wedge.—Solidity of a wedge = area of base $\times \frac{1}{2}$ height
 Solidity of a frustum of a wedge = $\frac{1}{2}$ height \times sum of the areas of the two ends.

Prismoidal Formula.—A prismoid is a solid bounded by six plane surfaces only two of which are parallel.

To find the contents of a prismoid, add together the areas of the two parallel surfaces 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 surfaces.

Cycloid and Epicycloid.—The cycloid is the curve described by any point in the circumference of a circle when the circle rolls along a straight line.

An epicycloid is the curve described by point in the circumference of a circle when the circle rolls along the outside of another circle.

A hypocycloid is the path described by any point in the circumference of a circle when the circle rolls along the inside of another circle.

An involute is the curve described by the end of a string when unwinding the string from around a cylinder.

Area of cycloid = area of generating circle $\times 3$.

To Find Areas, etc.—Area of a square, a rectangle, a rhombus, or a rhomboid equals the height multiplied by the breadth.

Area of a triangle equals the base multiplied by one-half the height.

Area of a trapezium equals the diagonal multiplied by half the sum of the two perpendiculars.

Area of trapezoid equals one-half the sum of the two parallel sides multiplied by the distance between them.

Area of an irregular polygon is found by dividing it into triangles and adding together the areas of the triangles.

To find the area of a regular polygon when the length of one side is given: Multiply the square of the side by the multiplier opposite to the name of the polygon in column A of the following table.

To compute the radius of a circumscribing circle when the length of one side is given: Multiply the length of a side of the polygon by the number in column B.

To compute the length of a side of a polygon that is contained in a given circle when the radius of the circle is given: Multiply

| Name of Polygon | No. of Sides. | A Area. | B Radius of Circumscribed Circle. | C Length of the Side. | D Radius of Inscribed Circle. | Angle Contained between Two Sides. |
|-----------------|---------------|------------|--------------------------------------|--------------------------|----------------------------------|------------------------------------|
| Triangle..... | 3 | 0.433013 | 0.5773 | 1.732 | 0.2887 | 60° |
| Tetragon..... | 4 | 1 | 0.7071 | 1.4142 | 0.5 | 90° |
| Pentagon..... | 5 | 1.720477 | 0.8506 | 1.1756 | 0.6882 | 108° |
| Hexagon..... | 6 | 2.598076 | 1 | 1 | 0.866 | 120° |
| Heptagon..... | 7 | 3.633912 | 1.1524 | 0.8677 | 1.0383 | 128.57° |
| Octagon..... | 8 | 4.828427 | 1.3066 | 0.7653 | 1.2071 | 135° |
| Nonagon..... | 9 | 6.181824 | 1.4619 | 0.684 | 1.3737 | 140° |
| Decagon..... | 10 | 7.694209 | 1.618 | 0.618 | 1.5383 | 144° |
| Undecagon..... | 11 | 9.36564 | 1.7747 | 0.5634 | 1.7028 | 147.27° |
| Dodecagon..... | 12 | 11.196152 | 1.9319 | 0.5176 | 1.866 | 150° |

the radius of the circle by the number opposite the name of the desired polygon in column C.

To compute the radius of a circle that can be inscribed in a given polygon when the length of a side is given: Multiply the length of a side of the polygon by the number opposite the name of the polygon in column D.

Regular Polyhedrons.—DEFINITION.—A regular body is a solid contained within a certain number of similar and equal plane faces, all of which are equal regular polygons.

The whole number of regular bodies which can possibly be found is five.

1. The tetrahedron, or pyramid.
2. The hexahedron, or cube, which has six square faces.
3. The octahedron, which has eight triangular faces.
4. The dodecahedron, which has twelve pentagonal faces.
5. The icosahedron, which has twenty triangular faces.

To find the volume of a regular polyhedron when the radius of the circumscribing sphere is given: Multiply the cube of the radius of the sphere by the multiplier opposite to the body in column 1 of the following table.

Or when the radius of the inscribed sphere is given: Multiply the cube of the radius of the inscribed sphere by the multiplier opposite the body in column 2 of the following table.

Or when the surface is given: Cube the surface given, extract the square root, and multiply the root by the multiplier opposite the body in column 3 of the following table.

Side is length of linear edge of any side of the figure.

To find radius of circumscribed circle when side is given: Multiply the side by the multiplier opposite the body in column 4 of the following table.

To find the radius of inscribed circle when side is given: Multiply the side by the multiplier opposite the body in column 5 of the following table.

To find the area of surface when side is given: Multiply the side by the multiplier opposite the body in column 6 of the following table.

To find the volume when the side is given: Multiply the side by the multiplier opposite the body in column 7 of the following table.

| Number of Sides. | Name. | Volume by 1 Radius of Circumscrib- ing Sphere. | 2 | 3 | 4 | 5 | 6 | 7 |
|------------------|-----------------------------|---|-----------------------|---|---------------------------------------|-----------------------|--------------------------|--------|
| | | Volume by Radius of Inscribed Circle. | Volume by Surface. | Radius of Cir- cumscribed Circle. | Radius of In- scribed Cir- cle. | Area of Sur- face. | Volume by Given Side. | |
| 4 | Tetrahedron. | 0.5132 | 12.85641 | 0.0517 | 0.6124 | 0.2041 | 1.7320 | 0.1178 |
| 6 | Hexahedron. | 1.5396 | 8.0000 | 0.06804 | 0.866 | 0.5 | 6. | 1. |
| 8 | Octahedron | 1.33333 | 6.9282 | 0.07311 | 0.7071 | 0.4082 | 3.4641 | 0.4714 |
| 12 | Dodécahe- dron | 2.78517 | 5.5503 | 0.08169 | 1.4012 | 1.1135 | 20.6458 | 7.6631 |
| 20 | Icosahedron. | 2.53615 | 5.05406 | 0.0856 | 0.951 | 0.7558 | 86.602 | 2.1817 |

Parabola.—A parabola is one of the conic sections made by cutting the cone parallel to its slant.

A hyperbola is a section of a cone cut by a plane at a greater angle through the base than is made by the side of the cone.

To find the area of a parabola multiply the base by two-thirds the height.

Names of the parts of a circle (Fig. 341).

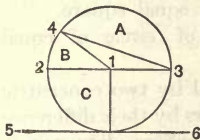


FIG. 341.

- A. Segment.
- B. Sector.
- C. Quadrant.
- 1 4. Radius.
- 2 3. Diameter.
- 4 3. Chord.
- 5 6. Tangent.

The Circle.—A circle is a plane figure bounded by a curve all points of which are equally distant from a point within, called the centre.

The circumference is the curve which bounds the circle.

The radius is a straight line drawn from the centre to the circumference.

The diameter is a straight line drawn through the centre to the circumference on either side.

An arc is any part of the circumference.

A chord is a straight line connecting two points on the circumference.

A segment is that part of the circle contained between the arc and its chord.

A sector is the space included between an arc and two radii drawn to the centre.

A tangent is a straight line which in passing a curve just touches it.

Diameter of a circle $\times 3.1416 =$ the circumference.

Radius of a circle $\times 6.283185 =$ the circumference.

Square of the radius of a circle $\times 3.1416 =$ area.

Square of the diameter of a circle $\times 0.7854 =$ area.

Square of the circumference of a circle $\times 0.07958 =$ area.

Half the circumference of a circle \times by half the diameter $=$ area.

Circumference of a circle $\times 0.159155 =$ radius.

Square root of the area of a circle $\times 0.56419 =$ radius.

Circumference of a circle $\times 0.31831 =$ diameter.

Square root of the area of a circle $\times 1.12838 =$ diameter.

Area of a circle $\div 0.7854$ and square root of the product $=$ the diameter.

Diameter of a circle $\times 0.86 =$ side of inscribed equilateral triangle.

Diameter of a circle $\times 0.7071 =$ side of inscribed square.

Circumference of a circle $\times 0.225 =$ side of an inscribed square.

Circumference of a circle $\times 0.285 =$ side of an equal square.

Diameter of a circle $\times 0.8862 =$ side of an equal square.

Side of a square $\times 1.128397 =$ diameter of circle of equal area.

To find the area of a circular ring formed by two concentric circles: Multiply the sum of the two diameters by their difference and the product by 0.7854. Any circle whose diameter is double that of another contains four times the area of the other.

The areas of all circles are to one another as the squares of their like dimensions. The area of a circle is equal to the area of a triangle whose base equals the circumference and perpendicular equals the radius.

TABLE GIVING AREA OF CIRCLES (IN SQUARE FEET).

| D. | 0 in. | 1 in. | 2 in. | 3 in. | 4 in. | 5 in. |
|----------|--------|--------|--------|--------|--------|--------|
| Ft. | | | | | | |
| 1. | .7854 | .922 | 1.07 | 1.23 | 1.40 | 1.58 |
| 2. | 3.14 | 3.41 | 3.69 | 3.98 | 4.28 | 4.59 |
| 3. | 7.07 | 7.47 | 7.88 | 8.30 | 8.73 | 9.17 |
| 4. | 12.58 | 13.10 | 13.64 | 14.19 | 14.75 | 15.32 |
| 5. | 19.64 | 20.39 | 20.97 | 21.65 | 22.34 | 23.04 |
| 6. | 28.27 | 29.06 | 29.87 | 30.68 | 31.50 | 32.34 |
| 7. | 38.48 | 39.41 | 40.34 | 41.28 | 42.24 | 43.20 |
| 8. | 50.27 | 51.32 | 52.37 | 53.46 | 54.54 | 55.64 |
| 9. | 63.62 | 64.80 | 66.00 | 67.20 | 68.42 | 69.64 |
| 10. | 78.54 | 79.85 | 81.18 | 82.52 | 83.86 | 85.22 |
| 11. | 95.03 | 96.48 | 97.93 | 99.40 | 100.88 | 102.37 |
| 12. | 113.10 | 114.67 | 116.26 | 117.86 | 119.47 | 121.09 |
| 13. | 132.73 | 134.44 | 136.16 | 137.89 | 139.63 | 141.38 |
| 14. | 153.94 | 155.78 | 157.63 | 159.49 | 161.36 | 163.24 |
| 15. | 176.72 | 178.68 | 180.66 | 182.65 | 184.66 | 186.67 |
| 16. | 201.06 | 203.16 | 205.27 | 207.39 | 209.53 | 211.67 |
| 17. | 226.98 | 229.21 | 231.45 | 233.71 | 235.97 | 238.24 |
| 18. | 254.47 | 256.83 | 259.20 | 261.59 | 263.98 | 266.39 |
| 19. | 283.53 | 286.06 | 288.52 | 291.04 | 293.56 | 296.11 |
| 20. | 314.16 | 316.78 | 319.42 | 322.06 | 324.72 | 327.39 |

| D. | 6 in. | 7 in. | 8 in. | 9 in. | 10 in. | 11 in. |
|----------|--------|--------|--------|--------|--------|--------|
| Ft. | | | | | | |
| 1. | 1.77 | 1.97 | 2.18 | 2.41 | 2.64 | 2.89 |
| 2. | 4.91 | 5.24 | 5.59 | 5.94 | 6.30 | 6.68 |
| 3. | 9.62 | 10.08 | 10.56 | 11.04 | 11.54 | 12.05 |
| 4. | 15.90 | 16.50 | 17.10 | 17.72 | 18.35 | 18.99 |
| 5. | 23.76 | 24.48 | 25.22 | 25.97 | 26.73 | 27.49 |
| 6. | 33.18 | 34.04 | 34.91 | 35.78 | 36.67 | 37.57 |
| 7. | 44.18 | 45.17 | 46.16 | 47.17 | 48.19 | 49.22 |
| 8. | 56.75 | 57.86 | 58.99 | 60.13 | 61.28 | 62.44 |
| 9. | 70.88 | 72.13 | 73.39 | 74.66 | 75.94 | 77.24 |
| 10. | 86.59 | 87.97 | 89.36 | 90.76 | 92.17 | 93.60 |
| 11. | 103.87 | 105.38 | 106.90 | 108.43 | 109.98 | 111.53 |
| 12. | 122.72 | 124.36 | 126.01 | 127.68 | 129.35 | 131.04 |
| 13. | 143.14 | 144.91 | 146.69 | 148.49 | 150.29 | 152.11 |
| 14. | 165.13 | 167.03 | 168.95 | 170.87 | 172.81 | 174.76 |
| 15. | 188.69 | 190.73 | 192.77 | 194.83 | 196.89 | 198.97 |
| 16. | 213.83 | 215.99 | 218.17 | 220.35 | 222.55 | 224.76 |
| 17. | 240.53 | 242.82 | 245.13 | 247.45 | 249.78 | 252.12 |
| 18. | 268.80 | 271.23 | 273.67 | 276.12 | 278.58 | 281.05 |
| 19. | 298.64 | 301.21 | 303.77 | 306.36 | 308.94 | 311.55 |
| 20. | 330.06 | 332.75 | 335.45 | 338.16 | 340.88 | 343.62 |

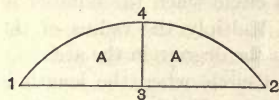


FIG. 342.

1 2 Chord.
 3 4 Rise, versed sine.
 1 4 2. Arc.
 A A Segment.

Arc, Segment, etc., of Circles (Fig. 342).—To find the radius of an arc when the chord and rise are given:

Rule.—Square one-half the chord, also square the rise; divide their sum by twice the rise and the answer will be the radius.

To find the rise of an arc when the chord and radius are given:

Rule.—Square the radius; also square one-half the chord; subtract the latter from the former and take the square root of the remainder. Subtract the result from the radius and the remainder will be the rise.

To find the chord of an arc when the chord of half the arc and the rise are given: From the square of the chord of half the arc subtract the square of the versed sine, or rise, and take twice the square root of the remainder.

To find the chord of an arc when the diameter and rise are given: Multiply the rise by 2 and subtract the product from the diameter; then subtract the square of the remainder from the square of the diameter and take the square root of that remainder.

To find the chord of half an arc when the chord of the arc and the rise are given: Take the square root of the sum of the squares of the rise and of half the chord of the arc.

To find the chord of half an arc when the diameter and rise are given: Multiply the diameter by the rise and take the square root of their product.

To find the diameter when the chord of half an arc and the rise are given: Divide the square of the chord of half the arc by the rise.

To find the rise when the chord of half an arc and the diameter are given: Divide the square of the chord of half the arc by the diameter.

To find the rise when the chord of an arc and the diameter are given: From the square of the diameter subtract the square of the chord and extract the square root of the remainder; subtract this root from the diameter and take half the remainder.

To find the length of an arc of a circle when the number of degrees and the radius are given: Multiply the radius of the circle by 0.01745 and the product by the degrees in the arc.

To find the length of an arc of a circle when the length is given in degrees, minutes, and seconds: Multiply the number of degrees by 0.01745329 and the product by the radius, and multiply the number of minutes by 0.00029 and that product by the radius, and multiply the number of seconds by 0.00000448 times the radius; add together the three results and the product will be the length of the arc.

To find the area of a sector of a circle when the degrees of the arc and the radius are given: Multiply the number of degrees in the arc by the area of the whole circle and divide by 360.

To find the area of a sector of a circle when the length of the arc is given in degrees and minutes and the radius is given: Reduce the length of the arc to minutes, multiply by the area of the whole circle, and divide by 21,600.

To find the area of a sector of a circle when the length of the arc and the radius are given: Multiply the length of the arc by half the length of the radius and the product is the area.

To find the area of a sector: Multiply one-half of the length of the arc by the radius, or divide the number of degrees in the arc of the sector by 360. Multiply the result by the area of the circle of which the sector is a part.

To find the area of a segment of a circle: Find the area of the sector of which the segment is a part, and from this area subtract the area of the triangle formed by the two radii and the chord of the segment.

Ellipse.—An ellipse is a plane figure bounded by a curved line, to any point of which the sum of the distances from two fixed points within, called the foci, is equal to the sum of the distances from the foci to any other point on the curve.

In Fig. 343, *A* and *B* are the foci and *C* and *D* any two points on the perimeter. $AC + CB = AD + DB$, and both these sums are equal to the major axis *EF*. The long diameter *EF* is called the major axis, and the short diameter *GD* the minor axis. The foci is located from *D* or *G* as a centre, making *DA* or *DB* equal to one-half the length of the long diameter.

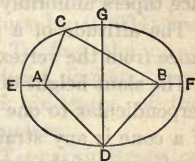


FIG. 343.

There is no exact method of finding the circumference or perimeter of an ellipse, but to approximate close enough for all practical purposes multiply the major axis by 1.82 and the minor axis by 1.315. The sum of the results will be the perimeter.

To find the area of an ellipse: Multiply the product of its two diameters by 0.7854.

When the length of the perimeter and one axis on an ellipse are given, to approximate the length of the other axis, divide the length of the perimeter by 1.6 and from this quotient subtract the length of the given axis.

The Frustum of a Pyramid or Cone.—If a pyramid or cone is cut by a plane parallel to the base, so as to form two parts, the lower part is called the frustum of the pyramid or cone. The upper end of the frustum is called the upper base and the lower end the lower base. The altitude is the perpendicular distance between the bases.

To find the convex area of a frustum of a pyramid or cone, multiply one-half the sum of the circumferences of the bases by the slant height. To find the entire area, add the area of the two bases.

To find the volume of the frustum of a pyramid or cone: Add the areas of the upper base, the lower base, and the square root of the product of the areas of the two bases; multiply this sum by one-third of the length.

Cylinder.—A cylinder is a solid whose ends are equal and similar curved figures.

To find the area of the convex surface of a cylinder: Multiply the circumference of the base by the height; and to find the entire area add the areas of the two ends.

To find the volume or solid contents of a cylinder: Multiply the area of the base by the height.

Pyramid and Cone.—A pyramid is a solid whose base is a polygon, and whose sides are triangles uniting at a common point called the vertex.

A cone is a solid whose base is a circle and whose convex surface tapers uniformly to a point called the vertex.

The altitude of a pyramid or cone is the perpendicular distance from the vertex to the base.

The slant height of a pyramid is a line drawn from the vertex perpendicular to one of the sides of the base. The slant height of a cone is any straight line drawn from the vertex to the circumference of the base.

To find the convex area of a pyramid or cone: Multiply the circumference of the base by one-half of the slant height.

To find the volume of a pyramid or cone: Multiply the area of the base by one-third of the altitude.

Sphere.—A sphere is a solid bounded by a uniformly curved surface every point of which is equally distant from a point within called the centre.

The square of the diameter of a sphere $\times 3.1416 =$ its surface.

Circumference of a sphere \times by its diameter $=$ its surface.

Square of the circumference of a sphere $\times 0.3183 =$ its surface.

Surface of a sphere \times by $\frac{1}{6}$ of its diameter $=$ its solidity.

Cube of the diameter of a sphere $\times 0.5236 =$ solidity.

Cube of the radius of a sphere $\times 4.1888 =$ solidity.

Cube of the circumference of a sphere $\times 0.016887 =$ solidity.

Square root of the surface of a sphere $\times 0.5236 =$ solidity.

Square root of the surface of a sphere $\times 1.772454 =$ the circumference.

Cube root of the solidity of a sphere $\times 1.2407 =$ the diameter.

Cube root of the solidity of a sphere $\times 3.8978 =$ the circumference.

Radius of a sphere $\times 1.1547 =$ side of inscribed cube.

Square root of ($\frac{1}{3}$ of the square of) the diameter of a sphere $=$ side of inscribed cube.

To find the solidity of a segment of a sphere: To three times the square of the radius of its base add the square of its height; multiply this sum by the height and the product by 0.5236.

SPHERICAL ZONE.—A spherical zone is the part of a sphere included between two parallel planes.

To find the solid contents of a spherical zone: To the sum of the squares of radii of the two ends add one-third of the square of the height of the zone; multiply this sum by the height, and this product by 1.5708.

Miscellaneous Mensuration.—To find the contents of a barrel or cask, multiply the square of the mean diameter by the length (both in inches) and this product by 0.0034; the answer will be the contents in gallons. To find the mean diameter of a barrel or cask, add to the head diameter two-thirds, or, if the staves are but little curved, six-tenths, of the difference between the head and bung diameters.

TO FIND THE CONTENTS OF A ROUND TAPERING STICK OF TIMBER.—Multiply the diameter of one end by the diameter of the other end, and to this product add one-third of the square of the difference of the diameters; then multiply this answer by 0.7854, which gives the mean area between the two ends, which multiplied by the height gives the cubical contents.

TO FIND THE CONTENTS OF TAPERING TIMBER.—Multiply the side of the large end by the side of the small end and to the product add one-third of the square of the difference of the sides, which gives the mean area between the two ends, which multiplied by the length gives the cubical contents.

TO FIND THE WEIGHT OF GRINDSTONES.—Multiply the square of the diameter (in inches) by the thickness (in inches), then by the decimal 0.06363; the product will be the weight of the stone in pounds.

SIZE OF BOXES.—A box 4"×4" square and 4½" deep will hold one quart; a box 7"×4" square and 4½" deep will hold half a gallon; a box 8"×8" square and 4½" deep will hold one gallon; a box 8"×8" square and 8½" deep will hold one peck; a box 16"×8½" square and 8" deep will hold half a bushel; a box 24"×16" square and 14" deep will hold half a barrel; a box 24"×16" square and 28" deep will hold one barrel, or three bushels.

TO FIND THE SOLID CONTENTS OF AN IRREGULAR BODY.—Immerse it in a vessel partly filled with water; then the contents of that part of the vessel filled by the rising water will be the cubical contents of the body.

Various Formulæ.—To find the horizontal thrust of an arch:

$$\text{Horizontal thrust} = \frac{\text{load on arch} \times \text{span}}{8 \times \text{rise of arch in feet}}$$

When tension rods are used the diameter of the rod can be found as follows:

$$\text{Diameter of rod in inches} = \frac{\text{total load on arch} \times \text{span}}{8 \times \text{rise of arch in feet} \times 7854}$$

If two rods are used substitute 16 in place of 8 in the formula, if three rods, 24.

To find the distance from the intrados to the extrados of an arch, in feet:

$$0.2 + \sqrt{\frac{\text{radius} + \text{half span}}{4}}$$

Strength of stone lintels:
Distributed breaking load

$$= \frac{2 \times \text{breadth in inches} \times \text{square of depth in inches}}{\text{span in feet}} \times C.$$

C for granite, 100; marble, 120; limestone, 83; sandstone, 70; slate, 300; bluestone flagging, 150.

Concentrated load at centre = one-half distributed load.

To find the power of a screw with lever: The power multi-

plied by the circumference which it describes is equal to the weight multiplied by the distance between threads.

To find the power of a lever:

Rule.—As the distance between the weight and the fulcrum is to the distance between the power and the fulcrum, so is the power to the weight.

To find the power of pulleys or set of blocks:

Rule.—As one is to twice the number of movable pulleys, so is the power to the weight.

STRENGTH OF WOODEN BEAMS.—To find the strength of a beam fixed at one end and load at other:

$$\text{Safe load in pounds} = \frac{\text{breadth} \times \text{square of depth} \times A}{4 \times \text{length in feet}}.$$

To find the strength of a beam fixed at one end and load uniformly distributed:

$$\text{Safe load in pounds} = \frac{\text{breadth} \times \text{square of depth} \times A}{2 \times \text{length in feet}}.$$

To find the strength of a beam supported at both ends and loaded at the centre:

$$\text{Safe load in pounds} = \frac{\text{breadth} \times \text{square of depth} \times A}{\text{span in feet}}.$$

To find the strength of a beam supported at both ends and uniformly distributed load:

$$\text{Safe load in pounds} = \frac{2 \times \text{breadth} \times \text{square of depth} \times A}{\text{span in feet}}.$$

To find the strength of a beam supported at both ends and with a concentrated load at any point but the centre:

$$\text{Safe load in pounds} = \frac{\text{breadth} \times \text{square of depth} \times \text{span} \times A}{4 \times B \times C}.$$

To find the strength of a beam supported at both ends and loaded with concentrated loads at two points equally distant from the supports:

$$\text{Safe load in pounds at each point} = \frac{\text{breadth} \times \text{square of depth} \times A}{4 \times C}.$$

In the last two formulæ C = the distance from the weight to the nearest support and B = the distance from the weight to the other support.

The values of the constant A in the above formula are as follows:

| | | | |
|------------------|-----|----------------------|-----|
| Ash. | 111 | White oak. | 75 |
| Beech. | 100 | White pine. | 80 |
| Birch. | 90 | Yellow pine. | 100 |
| Cedar. | 55 | Spruce. | 90 |
| Hemlock. | 66 | | |

FLITCH-PLATE GIRDERS.—To find the strength of flitch-plate girders in which the thickness of the iron plate is about $\frac{1}{8}$ of the breadth of the beam (which is about the correct proportion).

Beams supported at both ends:

$$\text{The safe load at centre in pounds} = \frac{D^2}{L}(FB + 750T).$$

$$\text{Safe distributed load in pounds} = \frac{2D^2}{L}(FB + 750T).$$

To find the depth of beam:

$$\text{For distributed load } D = \sqrt{\frac{WL}{2FB + 1500T}}$$

$$\text{For load at centre } D = \sqrt{\frac{WL}{FB + 750T}}$$

In the above formula

D = depth of beam.

B = total thickness of wood.

L = clear span in feet.

T = thickness of iron plate.

F = $\begin{cases} 100 \text{ pounds for hard pine,} \\ 73 \text{ pounds for spruce.} \end{cases}$

W = total load on girder.

HOGCHAINS, OR BELLY-ROD TRUSS.—Stresses in a beam with one strut, Fig. 344, with concentrated load at centre. To

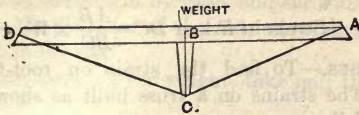


FIG. 344.

find the stress in AC or DC , divide the length of the line AC by the length of the line BC and then multiply this result by one-half the concentrated load.

To find the stress in the beam AD , divide the length of the line AB by the length of the line BC and multiply by one-half the concentrated load.

When the load is distributed over the entire beam, use $\frac{5}{8}$ of the entire load for the load on the strut, or concentrated at centre.

The length of the members in the above rules must be taken in the same unit of measurement. The rules may be expressed by the following formulæ, in which W = weight.

$$\text{Stress in } AC \text{ or } DC = \frac{AC}{BC} \times \frac{W}{2} = \text{tensile strength;}$$

$$\text{Stress in } AD = \frac{AB}{BC} \times \frac{W}{2} = \text{compression.}$$

Stresses in beams with two struts and load concentrated over the struts, Fig. 345.

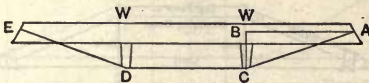


FIG. 345.

To obtain the stress in AC or ED , divide the length of AC by the length of BC and multiply this result by the load at W .

To find the stress in AE or DC , divide the length of the line AB by the length of the line BC and multiply this result by the load at W .

When a beam has two struts placed one-third of its distance from each end, and has a uniformly distributed load, the weight on each strut is $\frac{11}{30}$ of the total load.

The above rules may be expressed in formulæ as follows:

$$\text{Stress in } AC \text{ or } ED = \frac{AH}{BC} \times W;$$

$$\text{Stress in } EA \text{ or } DC = \frac{AB}{BC} \times W.$$

ROOF-TRUSSES.—To find the strain on roof-trusses with a single rod. The strains on a truss built as shown in Fig. 346 are found as follows:

Three-tenths of the distributed weight by half the length of the chord divided by the length of ab equals the tensile strain on the chord; five-eighths of weight equals tensile strain on the rod; three-tenths of the distributed weight by the length of the rafter divided by the length of ab equals the compression in the rafter. For concentrated weight at the centre: One-half the

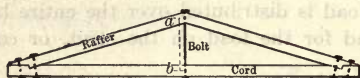


FIG. 346.

weight by half the length of the chord divided by the length of ab equals the strain on the chord; the strain on the rod is equal to the weight; one-half the weight by the length of the rafter divided by the length of ab equals the compression in the rafter.

TO FIND THE STRAIN ON ROOF-TRUSS WITH TWO RODS.—The strains on a truss built as shown in Fig. 347 are as follows: The distributed weight by 0.367 by one-third the length of the chord,

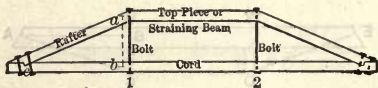


FIG. 347.

or cb , divided by the length of ab , equals the strain on the chord or the compression of top piece; the weight by 0.367 equals the strain on the rods; the distributed weight by 0.367 by the length of the rafter divided by the length of ab equals the compression in the rafter. When the weight is concentrated at 1 and 2: The weight by one-third the length of the chord, or cb , divided by the length of ab , equals the strain on the chord or the compression of the top piece; the weight equals the strain on the rods; the

weight by the length of the rafter divided by the length of *ab* equals the compression of the rafter.

The diameter of a single rod to carry a given weight may be found by dividing the weight by 9425, and the square root of the product will be the diameter of the rod, allowing 12,000 pounds per square inch in the rod.

When two rods carry a given weight, take half the weight and proceed as above.

TABLES FOR FINDING STRESSES IN MEMBERS FOR ROOF-TRUSSES OF THE DIFFERENT TYPES AND PITCHES AS GIVEN BELOW AND OF ANY SPAN.

Rule.—To find the stress in any member, multiply the coefficient given for that member by total dead load carried by truss (=span in feet × distance between trusses in feet × weight per square foot). If the truss is acted upon by wind forces of other unsymmetrical loading, the stresses in the members must be calculated accordingly and combined with the dead-load stresses as found below.

| Member of Truss | Pitch (Depth to Span). | | | |
|------------------|------------------------|------|---------------|---------------|
| | $\frac{1}{4}$ | 30° | $\frac{1}{2}$ | $\frac{3}{4}$ |
| Fig. 348. | | | | |
| <i>Aa</i> | .675 | .750 | .838 | 1.010 |
| <i>Bb</i> | .537 | .625 | .726 | .917 |
| <i>Ca</i> | .563 | .650 | .750 | .938 |
| <i>Cc</i> | .375 | .433 | .500 | .625 |
| <i>ab</i> | .208 | .217 | .224 | .232 |
| <i>bc</i> | .188 | .217 | .250 | .313 |
| Fig. 349. | | | | |
| <i>Aa</i> | .750 | .833 | .930 | 1.120 |
| <i>Bb</i> | .589 | .666 | .757 | .928 |
| <i>Cc</i> | .568 | .666 | .783 | .995 |
| <i>Da</i> | .625 | .721 | .833 | 1.042 |
| <i>Dd</i> | .375 | .433 | .500 | .625 |
| <i>ab</i> | .155 | .167 | .180 | .202 |
| <i>bc</i> | .155 | .167 | .180 | .202 |
| <i>cd</i> | .250 | .288 | .333 | .417 |
| Fig. 350. | | | | |
| <i>Aa</i> | .788 | .874 | .978 | 1.178 |
| <i>Bb</i> | .718 | .812 | .922 | 1.131 |
| <i>Cc</i> | .649 | .750 | .866 | 1.085 |
| <i>Dd</i> | .580 | .687 | .810 | 1.038 |
| <i>Ea</i> | .655 | .758 | .875 | 1.094 |
| <i>Ef</i> | .562 | .650 | .750 | .938 |
| <i>Ee</i> | .375 | .433 | .500 | .625 |
| <i>ab</i> | .104 | .108 | .112 | .116 |
| <i>bf</i> | .093 | .108 | .125 | .156 |
| <i>fg</i> | .208 | .216 | .224 | .232 |
| <i>gc</i> | .093 | .108 | .125 | .156 |
| <i>cd</i> | .104 | .108 | .112 | .116 |
| <i>ge</i> | .187 | .217 | .250 | .313 |
| <i>de</i> | .280 | .325 | .375 | .469 |

Note.—Heavy lines denote compression and light lines tension members. Loads are considered as concentrated at the joints.

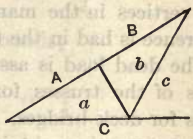


FIG. 348.

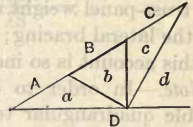


FIG. 349.

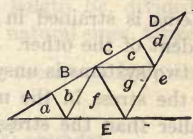


FIG. 350.

Explanation of Tables on Maximum Stresses in Pratt and Whipple Trusses (Pages 628 to 630, inclusive).

—These tables give the stress in each member of a Pratt (single quadrangular) or Whipple (double quadrangular) truss, for any number of panels not exceeding twelve in the former and twenty in the latter case, on the assumption that the load is uniform per foot and the panels are all of the same length. The stresses are given in terms of the truss-panel dead and moving loads, represented respectively by W and L . These are obtained by multiplying the dead load per foot of bridge, in the case of W , and the moving or live load per foot of bridge, in the case of L , by half the panel length.

The letters W and L are placed at the top of column in tables, and not next to the figures to which they belong, for want of space.

The stress in aB , for example, in a twelve-panel Pratt truss, $=5.5W + 5.5L$, and in $Bc = 4.5W + \frac{5}{4}\frac{5}{2}L$, both multiplied by the quotient specified in the last column.

The system of lettering employed is shown by Figs. 351 and 352, on page 627, and, it is believed, is the best in use. By making a sketch of the truss under consideration and lettering the vertices in the manner shown, the truss members to which reference is had in the tables can be readily identified.

The dead load is assumed as concentrated at the lower vertices of the trusses for through bridges and at the upper vertices for deck bridges. For through bridges of very large span, the stresses thus obtained for the posts must be increased by the truss-panel weight of the upper portion of the truss, including the lateral bracing; but in small spans, the increase of stress on this account is so inconsiderable that it is usually neglected.

Note.—In order to calculate the stresses in a Whipple or double quadrangular truss by statical methods, it is necessary to consider the truss as the combination of two Pratt trusses or single systems of bracing and assume that each of these two systems is strained in the same manner as if one were independent of the other. If the number of panels is odd, each of the two systems is unsymmetrical, which has the effect of making the stress in the middle panel of the lower chord slightly smaller than the stress in the corresponding panel of the top chord. The difference is, however, frequently neglected, and the stress in middle panel of bottom chord assumed the same as in middle panel of top chord.

Each of the two systems is assumed to carry one-half of the panel load at the top of the inclined end posts.

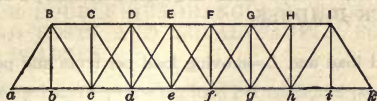


FIG. 351.—Pratt or Single Quadrangular Truss.

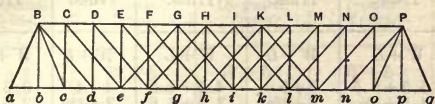


FIG. 352.—Whipple or Double Quadrangular Truss.

Illustration of Application of Tables, also of the Use of Table of Natural Sines, Tangents, and Secants.—A Pratt truss of 135 feet span and 18 feet depth is divided into nine panels of 15 feet each. Required the stress in first main tie Bc , and in middle panel DE of top chord, for a dead load of 1200 pounds and a moving load of 3000 pounds per lineal foot of bridge.

$$W = \frac{1200}{2} \times 15 = 9000 \text{ pounds;}$$

$$L = \frac{3000}{2} \times 15 = 22,500 \text{ " ;}$$

$$Bc = \left(3W + \frac{28}{9}L \right) \times \frac{\text{Length } Bc}{18};$$

$$DE = (10W + 10L) \frac{15}{18}.$$

The factor $\frac{15}{18}$, or panel length divided by depth of truss, is the tangent of the angle, for which the length Bc , divided by depth of truss, is the secant. By table of natural sines, tangents, and secants, for tangent = $\frac{15}{18} = 0.833$, the secant = 1.302; therefore

$$Bc = 97,000 \times 1.30 = 126,100 \text{ pounds;}$$

$$DE = 315,000 \times \frac{15}{18} = 262,500$$

MAXIMUM STRESSES UNDER DEAD AND MOVING LOADS IN PRATT OR SINGLE QUADRANGULAR TRUSSES, WITH INCLINED END POSTS AND EQUAL PANELS, FOR THROUGH AND DECK BRIDGES.

W = dead load and L = moving load per truss and per panel.

| Member. | 12-panel Truss. | 11-panel Truss. | 10-panel Truss. | 9-panel Truss. | 8-panel Truss. | Multiply by | |
|------------|-------------------------|----------------------|-----------------|--------------------|----------------------|---|---|
| | $W + L$ | $W + L$ | $W + L$ | $W + L$ | $W + L$ | Length of member divided by depth of truss. | |
| aB | $5.5 + 5.5$ | $5 + 5$ | $4.5 + 4.5$ | $4 + 4$ | $3.5 + 3.5$ | Length of member divided by depth of truss. | |
| Bc | $4.5 + 5\frac{5}{12}$ | $4 + 4\frac{5}{11}$ | $3.5 + 3.6$ | $3 + 2\frac{2}{9}$ | $2.5 + 2\frac{1}{8}$ | | |
| Cd | $3.5 + 4\frac{5}{12}$ | $3 + 3\frac{6}{11}$ | $2.5 + 2.8$ | $2 + 2\frac{1}{9}$ | $1.5 + 1\frac{5}{8}$ | | |
| De | $2.5 + 3\frac{5}{12}$ | $2 + 2\frac{8}{11}$ | $1.5 + 2.1$ | $1 + 1\frac{5}{9}$ | $0.5 + 1\frac{5}{8}$ | | |
| Ef | $1.5 + 2\frac{5}{12}$ | $1 + 2\frac{1}{11}$ | $0.5 + 1.5$ | $0 + 1\frac{5}{9}$ | $-0.5 + \frac{5}{8}$ | | |
| Fg | $0.5 + 2\frac{1}{12}$ | $0 + 1\frac{5}{11}$ | $-0.5 + 1.0$ | $-1 + \frac{5}{9}$ | $-1.5 + \frac{3}{8}$ | | |
| Gh | $-0.5 + 1\frac{5}{12}$ | $-1 + 1\frac{5}{11}$ | $-1.5 + 0.6$ | $-2 + \frac{3}{9}$ | | | |
| Hi | $-1.5 + 1\frac{10}{12}$ | $-2 + \frac{6}{11}$ | | | | | |
| abc | $5.5 + 5.5$ | $5 + 5$ | $4.5 + 4.5$ | $4 + 4$ | $3.5 + 3.5$ | | Panel length divided by depth of truss. |
| BC, cd | $10.0 + 10.0$ | $9 + 9$ | $8.0 + 8.0$ | $7 + 7$ | $6.0 + 6.0$ | | |
| CD, de | $13.5 + 13.5$ | $12 + 12$ | $10.5 + 10.5$ | $9 + 9$ | $7.5 + 7.5$ | | |
| DE, ef | $16.0 + 16.0$ | $14 + 14$ | $12.0 + 12.0$ | $10 + 10$ | $8.0 + 8.0$ | | |
| EF, fg | $17.5 + 17.5$ | $15 + 15$ | $12.5 + 12.5$ | | | | |
| FG | $18.0 + 18.0$ | | | | | | |
| Thro. Deck | | | | | | Unity. | |
| Cc | $4.5 + 5\frac{5}{12}$ | $4 + 4\frac{5}{11}$ | $3.5 + 3.6$ | $3 + 2\frac{2}{9}$ | $2.5 + 2\frac{1}{8}$ | | |
| Cc, Dd | $3.5 + 4\frac{5}{12}$ | $3 + 3\frac{6}{11}$ | $2.5 + 2.8$ | $2 + 2\frac{1}{9}$ | $1.5 + 1\frac{5}{8}$ | | |
| Dd, Ee | $2.5 + 3\frac{5}{12}$ | $2 + 2\frac{8}{11}$ | $1.5 + 2.1$ | $1 + 1\frac{5}{9}$ | $0.5 + 1\frac{5}{8}$ | | |
| Ee, Ff | $1.5 + 2\frac{5}{12}$ | $1 + 2\frac{1}{11}$ | $0.5 + 1.5$ | $0 + 1\frac{5}{9}$ | $-0.5 + \frac{5}{8}$ | | |
| Ff, Gg | $0.5 + 2\frac{1}{12}$ | $0 + 1\frac{5}{11}$ | $-0.5 + 1.0$ | | | | |
| Gg | $-0.5 + 1\frac{5}{12}$ | | | | | | |

| Member. | 7-panel Truss. | 6-panel Truss. | 5-panel Truss. | 4-panel Truss. | 3-panel Truss. | Multiply by |
|------------|---------------------|----------------------|----------------|----------------------|-------------------|---|
| | $W + L$ | $W + L$ | $W + L$ | $W + L$ | $W + L$ | Length of member divided by depth of truss. |
| aB | $3 + 3$ | $2.5 + 2.5$ | $2 + 2.0$ | $1.5 + 1.5$ | $1 + 1$ | Length of member divided by depth of truss. |
| Bc | $2 + 1\frac{5}{7}$ | $1.5 + 1\frac{5}{6}$ | $1 + 1.2$ | $0.5 + \frac{2}{3}$ | $0 + \frac{1}{3}$ | |
| Cd | $1 + 1\frac{10}{7}$ | $0.5 + 1.0$ | $0 + 0.6$ | $-0.5 + \frac{1}{3}$ | | |
| De | $0 + \frac{9}{7}$ | $-0.5 + 0.5$ | $-1 + 0.2$ | | | |
| Ef | $-1 + \frac{3}{7}$ | | | | | |
| abc | $3 + 3$ | $2.5 + 2.5$ | $2 + 2$ | $1.5 + 1.5$ | $1 + 1$ |  | Panel length divided by depth of truss. |
| BC, cd | $5 + 5$ | $4.0 + 4.0$ | $3 + 3$ | $2.0 + 2.0$ | $1 + 1$ | |
| CDE, de | $6 + 6$ | $4.5 + 4.5$ | | | | |
| Thro. Deck | | | | | | Unity. |
| Cc | $2 + 1\frac{5}{7}$ | $1.5 + 1\frac{5}{6}$ | $1 + 1.2$ | $0.5 + \frac{2}{3}$ | | |
| Cc, Dd | $1 + 1\frac{10}{7}$ | $0.5 + 1.0$ | $0 + 0.6$ | $-0.5 + \frac{1}{3}$ | | |
| Dd | $0 + \frac{9}{7}$ | $-0.5 + 0.5$ | | | | |

MAXIMUM STRESSES UNDER DEAD AND MOVING LOADS IN WHIPPLE OR DOUBLE QUADRANGULAR TRUSSES, WITH INCLINED END POSTS AND EQUAL PANELS, FOR THROUGH AND DECK BRIDGES.

W = dead load and L = moving load per truss and per panel.

| Member. | 20-panel Truss. | 19-panel Truss. | 18-panel Truss. | 17-panel Truss. | 16-panel Truss. |
|--------------|--|--|--|--|--|
| | $W+L$ | $W+L$ | $W+L$ | $W+L$ | $W+L$ |
| <i>aB</i> | ¹ 9.5 + 9.5 | 1 9 + 9 | ¹ 8.5 + 8.5 | 1 8 + 8 | ¹ 7.5 + 7.5 |
| <i>Bc</i> | 4.5 + 90 ⁵ / ₂₀ | 80 ¹ / ₁₉ + 80 ⁵ / ₁₉ | 4.0 + 72 ⁵ / ₁₈ | 63 ¹ / ₁₇ + 63 ⁵ / ₁₇ | 3.5 + 56 ⁵ / ₁₆ |
| <i>Bd</i> | 4.0 + 80 ⁵ / ₂₀ | 72 ¹ / ₁₉ + 72 ⁵ / ₁₉ | 3.5 + 63 ⁵ / ₁₈ | 56 ¹ / ₁₇ + 56 ⁵ / ₁₇ | 3.0 + 48 ⁵ / ₁₆ |
| <i>Ce</i> | 3.5 + 72 ⁵ / ₂₀ | 61 ¹ / ₁₉ + 63 ⁵ / ₁₉ | 3.0 + 56 ⁵ / ₁₈ | 46 ¹ / ₁₇ + 48 ⁵ / ₁₇ | 2.5 + 42 ⁵ / ₁₆ |
| <i>Df</i> | 3.0 + 63 ⁵ / ₂₀ | 53 ¹ / ₁₉ + 56 ⁵ / ₁₉ | 2.5 + 48 ⁵ / ₁₈ | 39 ¹ / ₁₇ + 42 ⁵ / ₁₇ | 2.0 + 35 ⁵ / ₁₆ |
| <i>Eg</i> | 2.5 + 56 ⁵ / ₂₀ | 42 ¹ / ₁₉ + 48 ⁵ / ₁₉ | 2.0 + 42 ⁵ / ₁₈ | 29 ¹ / ₁₇ + 35 ⁵ / ₁₇ | 1.5 + 30 ⁵ / ₁₆ |
| <i>Fh</i> | 2.0 + 48 ⁵ / ₂₀ | 34 ¹ / ₁₉ + 42 ⁵ / ₁₉ | 1.5 + 35 ⁵ / ₁₈ | 22 ¹ / ₁₇ + 30 ⁵ / ₁₇ | 1.0 + 24 ⁵ / ₁₆ |
| <i>Gi</i> | 1.5 + 42 ⁵ / ₂₀ | 23 ¹ / ₁₉ + 35 ⁵ / ₁₉ | 1.0 + 30 ⁵ / ₁₈ | 12 ¹ / ₁₇ + 24 ⁵ / ₁₇ | 0.5 + 20 ⁵ / ₁₆ |
| <i>Hk</i> | 1.0 + 35 ⁵ / ₂₀ | 15 ¹ / ₁₉ + 30 ⁵ / ₁₉ | 0.5 + 24 ⁵ / ₁₈ | 5 ¹ / ₁₇ + 20 ⁵ / ₁₇ | 0.0 + 15 ⁵ / ₁₆ |
| <i>Il</i> | 0.5 + 30 ⁵ / ₂₀ | 4 ¹ / ₁₉ + 24 ⁵ / ₁₉ | 0.0 + 20 ⁵ / ₁₈ | - 5 ¹ / ₁₇ + 15 ⁵ / ₁₇ | - 0.5 + 12 ⁵ / ₁₆ |
| <i>Km</i> | 0.0 + 24 ⁵ / ₂₀ | - 4 ¹ / ₁₉ + 20 ⁵ / ₁₉ | - 0.5 + 15 ⁵ / ₁₈ | - 12 ¹ / ₁₇ + 12 ⁵ / ₁₇ | - 1.0 + 8 ⁵ / ₁₆ |
| <i>Ln</i> | - 0.5 + 20 ⁵ / ₂₀ | - 15 ¹ / ₁₉ + 15 ⁵ / ₁₉ | - 1.0 + 12 ⁵ / ₁₈ | - 22 ¹ / ₁₇ + 8 ⁵ / ₁₇ | - 1.5 + 6 ⁵ / ₁₆ |
| <i>Mo</i> | - 1.0 + 15 ⁵ / ₂₀ | - 23 ¹ / ₁₉ + 12 ⁵ / ₁₉ | | | |
| <i>abc</i> | ² 9.5 + 9.5 | 2 9 + 9 | ² 8.5 + 8.5 | 2 8 + 8 | ² 7.5 + 7.5 |
| <i>cd</i> | 14 + 14 | 25 ¹ / ₁₉ + 25 ¹ / ₁₉ | 12.5 + 12.5 | 19 ¹ / ₁₇ + 19 ¹ / ₁₇ | 11 + 11 |
| <i>C, de</i> | 22 + 22 | 39 ⁵ / ₁₉ + 39 ⁵ / ₁₉ | 19.5 + 19.5 | 31 ¹ / ₁₇ + 31 ¹ / ₁₇ | 17 + 17 |
| <i>D, ef</i> | 29 + 29 | 51 ¹ / ₁₉ + 51 ¹ / ₁₉ | 25.5 + 25.5 | 40 ³ / ₁₇ + 40 ³ / ₁₇ | 22 + 22 |
| <i>E, fg</i> | 35 + 35 | 62 ³ / ₁₉ + 62 ³ / ₁₉ | 30.5 + 30.5 | 48 ¹ / ₁₇ + 48 ¹ / ₁₇ | 26 + 26 |
| <i>F, gh</i> | 40 + 40 | 70 ⁷ / ₁₉ + 70 ⁷ / ₁₉ | 34.5 + 34.5 | 53 ⁹ / ₁₇ + 53 ⁹ / ₁₇ | 29 + 29 |
| <i>G, hi</i> | 44 + 44 | 77 ⁵ / ₁₉ + 77 ⁵ / ₁₉ | 37.5 + 37.5 | 58 ³ / ₁₇ + 58 ³ / ₁₇ | 31 + 31 |
| <i>H, ik</i> | 47 + 47 | 82 ¹ / ₁₉ + 82 ¹ / ₁₉ | 39.5 + 39.5 | 60 ⁷ / ₁₇ + 60 ⁷ / ₁₇ | ¹ 32 + 32 |
| <i>I, kl</i> | 49 + 49 | 85 ¹ / ₁₉ + 85 ¹ / ₁₉ | 40.5 + 40.5 | 61 ⁷ / ₁₇ + 61 ⁷ / ₁₇ | <i>HI = GH</i> |
| <i>KL</i> | 50 + 50 | 85 ⁹ / ₁₉ + 85 ⁹ / ₁₉ | <i>IK = HI</i> | <i>IK = HI</i> | |
| | | ¹ <i>kl</i> = | | ¹ <i>ik</i> = | |
| | | 84 ³ / ₁₉ + 84 ³ / ₁₉ | | 59 ⁷ / ₁₇ + 59 ⁷ / ₁₇ | |
| Truss Deck | | | | | |
| <i>Cc</i> | ³ 4.5 + 90 ⁵ / ₂₀ | ³ 80 ¹ / ₁₉ + 80 ⁵ / ₁₉ | ³ 4.0 + 72 ⁵ / ₁₈ | ³ 63 ¹ / ₁₇ + 63 ⁵ / ₁₇ | ³ 3.5 + 56 ⁵ / ₁₆ |
| <i>Dd</i> | 4.0 + 80 ⁵ / ₂₀ | 72 ¹ / ₁₉ + 72 ⁵ / ₁₉ | 3.5 + 63 ⁵ / ₁₈ | 56 ¹ / ₁₇ + 56 ⁵ / ₁₇ | 3.0 + 48 ⁵ / ₁₆ |
| <i>c, Ee</i> | 3.5 + 72 ⁵ / ₂₀ | 61 ¹ / ₁₉ + 63 ⁵ / ₁₉ | 3.0 + 56 ⁵ / ₁₈ | 46 ¹ / ₁₇ + 48 ⁵ / ₁₇ | 2.5 + 42 ⁵ / ₁₆ |
| <i>d, Ff</i> | 3.0 + 63 ⁵ / ₂₀ | 53 ¹ / ₁₉ + 56 ⁵ / ₁₉ | 2.5 + 48 ⁵ / ₁₈ | 39 ¹ / ₁₇ + 42 ⁵ / ₁₇ | 2.0 + 35 ⁵ / ₁₆ |
| <i>e, Gg</i> | 2.5 + 56 ⁵ / ₂₀ | 42 ¹ / ₁₉ + 48 ⁵ / ₁₉ | 2.0 + 42 ⁵ / ₁₈ | 29 ¹ / ₁₇ + 35 ⁵ / ₁₇ | 1.5 + 30 ⁵ / ₁₆ |
| <i>f, Hh</i> | 2.0 + 48 ⁵ / ₂₀ | 34 ¹ / ₁₉ + 42 ⁵ / ₁₉ | 1.5 + 35 ⁵ / ₁₈ | 22 ¹ / ₁₇ + 30 ⁵ / ₁₇ | 1.0 + 24 ⁵ / ₁₆ |
| <i>g, Ii</i> | 1.5 + 42 ⁵ / ₂₀ | 23 ¹ / ₁₉ + 35 ⁵ / ₁₉ | 1.0 + 30 ⁵ / ₁₈ | 12 ¹ / ₁₇ + 24 ⁵ / ₁₇ | 0.5 + 20 ⁵ / ₁₆ |
| <i>h, Kk</i> | 1.0 + 35 ⁵ / ₂₀ | 15 ¹ / ₁₉ + 30 ⁵ / ₁₉ | 0.5 + 24 ⁵ / ₁₈ | 5 ¹ / ₁₇ + 20 ⁵ / ₁₇ | 0.0 + 15 ⁵ / ₁₆ |
| <i>i, Ll</i> | 0.5 + 30 ⁵ / ₂₀ | 4 ¹ / ₁₉ + 24 ⁵ / ₁₉ | 0.0 + 20 ⁵ / ₁₈ | - 5 ¹ / ₁₇ + 15 ⁵ / ₁₇ | - 0.5 + 12 ⁵ / ₁₆ |
| <i>j, k</i> | 0.0 + 24 ⁵ / ₂₀ | - 4 ¹ / ₁₉ + 20 ⁵ / ₁₉ | - 0.5 + 15 ⁵ / ₁₈ | | |
| <i>l</i> | - 0.5 + 20 ⁵ / ₂₀ | | | | |

¹ Multiply by: Length of member divided by depth of truss.

² Multiply by: Panel length divided by depth of truss.

³ Multiply by: Unity.

MAXIMUM STRESSES UNDER DEAD AND MOVING LOADS IN WHIPPLE OR DOUBLE QUADRANGULAR TRUSSES, WITH INCLINED END POSTS AND EQUAL PANELS, FOR THROUGH AND DECK BRIDGES—(Continued).

W = dead load and L = moving load per truss and per panel.

| Member. | 15-panel Truss. | 14-panel Truss. | 13-panel Truss. | 12-panel Truss. | 11-panel Truss. |
|--------------------------|--|--------------------------|--|--------------------------|-------------------------------------|
| | $W+L$ | $W+L$ | $W+L$ | $W+L$ | $W+L$ |
| <i>aB</i> | 17+7 | ¹ 6.5+6.5 | 16+6 | ¹ 5.5+5.5 | 15+5 |
| <i>Bc</i> | $48\frac{1}{15} + 48\frac{5}{15}$ | $3.0 + 42\frac{5}{14}$ | $85\frac{1}{13} + 85\frac{5}{13}$ | $2.5 + 30\frac{5}{12}$ | $24\frac{1}{11} + 24\frac{5}{11}$ |
| <i>Bd</i> | $42\frac{1}{15} + 42\frac{5}{15}$ | $2.5 + 85\frac{5}{14}$ | $80\frac{1}{13} + 80\frac{5}{13}$ | $2.0 + 24\frac{5}{12}$ | $20\frac{1}{11} + 20\frac{5}{11}$ |
| <i>Ce</i> | $33\frac{1}{15} + 35\frac{5}{15}$ | $2.0 + 80\frac{5}{14}$ | $22\frac{1}{13} + 24\frac{5}{13}$ | $1.5 + 20\frac{5}{12}$ | $13\frac{1}{11} + 15\frac{5}{11}$ |
| <i>Df</i> | $27\frac{1}{15} + 30\frac{5}{15}$ | $1.5 + 24\frac{5}{14}$ | $17\frac{1}{13} + 20\frac{5}{13}$ | $1.0 + 15\frac{5}{12}$ | $9\frac{1}{11} + 12\frac{5}{11}$ |
| <i>Eg</i> | $18\frac{1}{15} + 24\frac{5}{15}$ | $1.0 + 20\frac{5}{14}$ | $9\frac{1}{13} + 15\frac{5}{13}$ | $0.5 + 12\frac{5}{12}$ | $2\frac{1}{11} + 8\frac{5}{11}$ |
| <i>Fh</i> | $12\frac{1}{15} + 20\frac{5}{15}$ | $0.5 + 15\frac{5}{14}$ | $4\frac{1}{13} + 12\frac{5}{13}$ | $0.0 + 8\frac{5}{12}$ | $-\frac{2}{11} + 6\frac{5}{11}$ |
| <i>Gi</i> | $8\frac{1}{15} + 15\frac{5}{15}$ | $0.0 + 12\frac{5}{14}$ | $-\frac{4}{13} + 8\frac{5}{13}$ | $-0.5 + 6\frac{5}{12}$ | $-\frac{9}{11} + 3\frac{5}{11}$ |
| <i>Hk</i> | $-\frac{3}{15} + 12\frac{5}{15}$ | $-0.5 + 8\frac{5}{14}$ | $-\frac{9}{13} + 6\frac{5}{13}$ | $-1.0 + 3\frac{5}{12}$ | $-13\frac{1}{11} + 2\frac{5}{11}$ |
| <i>Il</i> | $-12\frac{1}{15} + 8\frac{5}{15}$ | $-1.0 + 6\frac{5}{14}$ | $-17\frac{1}{13} + 3\frac{5}{13}$ | | |
| <i>Km</i> | $-18\frac{1}{15} + 8\frac{5}{15}$ | | | | |
| <i>abc</i> | 27+7 | ² 6.5+6.5 | 26+6 | 25.5+5.5 | 25+5 |
| <i>cd</i> | $153\frac{1}{15} + 153\frac{1}{15}$ | 9.5+9.5 | $113\frac{1}{13} + 113\frac{1}{13}$ | 8.0+8.0 | $79\frac{1}{11} + 79\frac{1}{11}$ |
| <i>BC, de</i> | $237\frac{1}{15} + 237\frac{1}{15}$ | 14.5+14.5 | $173\frac{1}{13} + 173\frac{1}{13}$ | 12.0+12.0 | $119\frac{1}{11} + 119\frac{1}{11}$ |
| <i>CD, ef</i> | $303\frac{1}{15} + 303\frac{1}{15}$ | 18.5+18.5 | $217\frac{1}{13} + 217\frac{1}{13}$ | 15.0+15.0 | $145\frac{1}{11} + 145\frac{1}{11}$ |
| <i>DE, fg</i> | $357\frac{1}{15} + 357\frac{1}{15}$ | 21.5+21.5 | $251\frac{1}{13} + 251\frac{1}{13}$ | 17.0+17.0 | $163\frac{1}{11} + 163\frac{1}{11}$ |
| <i>EF, gh</i> | $393\frac{1}{15} + 393\frac{1}{15}$ | 23.5+23.5 | $269\frac{1}{13} + 269\frac{1}{13}$ ¹ | 18.0+18.0 | $167\frac{1}{11} + 167\frac{1}{11}$ |
| <i>FG, hi</i> | $417\frac{1}{15} + 417\frac{1}{15}$ ¹ | 24.5+24.5 | $277\frac{1}{13} + 277\frac{1}{13}$ | $FG = EF$ | $FG = EF$ |
| <i>GHI</i> | $423\frac{1}{15} + 423\frac{1}{15}$ | $GH = FG$ | $GH = FG$ | | $1 fg =$ |
| ¹ <i>hi</i> = | $411\frac{1}{15} + 411\frac{1}{15}$ | | $261\frac{1}{13} + 261\frac{1}{13}$ | | $159\frac{1}{11} + 159\frac{1}{11}$ |
| Thro. Deck | | | | | |
| <i>Cc</i> | $3 48\frac{1}{15} + 48\frac{5}{15}$ | $3 3.0 + 42\frac{5}{14}$ | $3 85\frac{1}{13} + 85\frac{5}{13}$ | $3 2.5 + 30\frac{5}{12}$ | $3 24\frac{1}{11} + 24\frac{5}{11}$ |
| <i>Dd</i> | $42\frac{1}{15} + 42\frac{5}{15}$ | $2.5 + 85\frac{5}{14}$ | $80\frac{1}{13} + 80\frac{5}{13}$ | $2.0 + 24\frac{5}{12}$ | $20\frac{1}{11} + 20\frac{5}{11}$ |
| <i>Cc, Ee</i> | $33\frac{1}{15} + 35\frac{5}{15}$ | $2.0 + 80\frac{5}{14}$ | $22\frac{1}{13} + 24\frac{5}{13}$ | $1.5 + 20\frac{5}{12}$ | $13\frac{1}{11} + 15\frac{5}{11}$ |
| <i>Dd, Ff</i> | $27\frac{1}{15} + 30\frac{5}{15}$ | $1.5 + 24\frac{5}{14}$ | $17\frac{1}{13} + 20\frac{5}{13}$ | $1.0 + 15\frac{5}{12}$ | $9\frac{1}{11} + 12\frac{5}{11}$ |
| <i>Ee, Gg</i> | $18\frac{1}{15} + 24\frac{5}{15}$ | $1.0 + 20\frac{5}{14}$ | $9\frac{1}{13} + 15\frac{5}{13}$ | $0.5 + 12\frac{5}{12}$ | $2\frac{1}{11} + 8\frac{5}{11}$ |
| <i>Ff, Hh</i> | $12\frac{1}{15} + 20\frac{5}{15}$ | $0.5 + 15\frac{5}{14}$ | $4\frac{1}{13} + 12\frac{5}{13}$ | $0.0 + 8\frac{5}{12}$ | $-\frac{2}{11} + 6\frac{5}{11}$ |
| <i>Gg</i> | $8\frac{1}{15} + 15\frac{5}{15}$ | $0.0 + 12\frac{5}{14}$ | $-\frac{4}{13} + 8\frac{5}{13}$ | $-0.5 + 6\frac{5}{12}$ | |
| <i>Hh</i> | $-\frac{3}{15} + 12\frac{5}{15}$ | $-0.5 + 8\frac{5}{14}$ | | | |

¹ Multiply by: Length of member divided by depth of truss.

² Multiply by: Panel length divided by depth of truss.

³ Multiply by: Unity.

Resistance to Shearing.—By shearing is meant the separating and pushing of one part of a piece by the other.

To find the working shearing strength of wood: Find the area to be sheared in inches and multiply by the strength given in table on page 317.

For the compression and tensile strength proceed in like manner.

TABLE SHOWING CAPACITIES OF CENTRIFUGAL PUMPS
TESTED DATA ROLLING MILL

| Flow (GPM) | Head (ft) | Efficiency (%) | Power (HP) | Speed (RPM) |
|------------|-----------|----------------|------------|-------------|
| 10 | 10 | 10 | 10 | 10 |
| 15 | 15 | 15 | 15 | 15 |
| 20 | 20 | 20 | 20 | 20 |
| 25 | 25 | 25 | 25 | 25 |
| 30 | 30 | 30 | 30 | 30 |
| 35 | 35 | 35 | 35 | 35 |
| 40 | 40 | 40 | 40 | 40 |
| 45 | 45 | 45 | 45 | 45 |
| 50 | 50 | 50 | 50 | 50 |
| 55 | 55 | 55 | 55 | 55 |
| 60 | 60 | 60 | 60 | 60 |
| 65 | 65 | 65 | 65 | 65 |
| 70 | 70 | 70 | 70 | 70 |
| 75 | 75 | 75 | 75 | 75 |
| 80 | 80 | 80 | 80 | 80 |
| 85 | 85 | 85 | 85 | 85 |
| 90 | 90 | 90 | 90 | 90 |
| 95 | 95 | 95 | 95 | 95 |
| 100 | 100 | 100 | 100 | 100 |

TABLE SHOWING CAPACITIES OF CENTRIFUGAL PUMPS

| Flow (GPM) | Head (ft) | Efficiency (%) | Power (HP) | Speed (RPM) |
|------------|-----------|----------------|------------|-------------|
| 10 | 10 | 10 | 10 | 10 |
| 15 | 15 | 15 | 15 | 15 |
| 20 | 20 | 20 | 20 | 20 |
| 25 | 25 | 25 | 25 | 25 |
| 30 | 30 | 30 | 30 | 30 |
| 35 | 35 | 35 | 35 | 35 |
| 40 | 40 | 40 | 40 | 40 |
| 45 | 45 | 45 | 45 | 45 |
| 50 | 50 | 50 | 50 | 50 |
| 55 | 55 | 55 | 55 | 55 |
| 60 | 60 | 60 | 60 | 60 |
| 65 | 65 | 65 | 65 | 65 |
| 70 | 70 | 70 | 70 | 70 |
| 75 | 75 | 75 | 75 | 75 |
| 80 | 80 | 80 | 80 | 80 |
| 85 | 85 | 85 | 85 | 85 |
| 90 | 90 | 90 | 90 | 90 |
| 95 | 95 | 95 | 95 | 95 |
| 100 | 100 | 100 | 100 | 100 |

PART VI.

HYDRAULICS AND DATA ON WATER. STRENGTHS, WEIGHTS, ETC., OF MA- TERIALS. VARIOUS MATERIALS AND DATA.

Hydraulics.

TABLE SHOWING CAPACITIES OF CENTRIFUGAL PUMPS, ALSO
USEFUL DATA REGARDING SAME.

| Size Pump (Diameter Discharge Pipe). | Size Pipe for Suction, Inches. | Economical Capacity, Gallons per Minute. | Horse-Power Required for each Foot Elevation. | Diameter and Face of Pulley in Inches. |
|--------------------------------------|--------------------------------|--|---|--|
| 1½ | 2 | 70 | .058 | 6 × 6 |
| 1¾ | 2 | 90 | .075 | 7 × 8 |
| 2 | 3 | 120 | .10 | 8 × 8 |
| 2½ | 3 | 180 | .15 | 8 × 8 |
| 3 | 4 | 260 | .22 | 8 × 8 |
| 4 | 5 | 470 | .30 | 10 × 10 |
| 5 | 6 | 735 | .45 | 12 × 12 |
| 6 | 8 | 1050 | .59 | 15 × 12 |
| 8 | 10 | 2000 | 1.00 | 20 × 12 |
| 10 | 12 | 3000 | 1.52 | 24 × 12 |
| 12 | 15 | 4200 | 2.00 | 30 × 14 |
| 15 | 18 | 7000 | 3.50 | 40 × 15 |
| 15 | 18 | 7000 | 3.50 | 30 × 15 |
| 18 | 20 | 10000 | 4.50 | 40 × 16 |
| 18 | 20 | 10000 | 4.50 | 30 × 16 |
| 20 | 22 | 12000 | 5.40 | 36 × 20 |
| 22 | 24 | 13000 | 5.50 | 48 × 20 |
| 24 | 24 | 15000 | 6.50 | 48 × 36 |

CAPACITY OF SAND AND DREDGING CENTRIFUGAL PUMPS.

| No. Pump (Diameter Discharge Opening) | Diameter Suction. | Cubic Yards Material per Hour, 10 to 20 Per Cent of Solids. | | | Horse-power Required for each 10 Feet Elevation. | Will Pass Solids: Diameter, Inches. | Diameter and Face of Pulley. |
|---------------------------------------|-------------------|---|--------------|--------------|--|-------------------------------------|------------------------------|
| | | 10 Per Cent. | 15 Per Cent. | 20 Per Cent. | | | |
| 4 | 4 | 14 | 21 | 28 | 4 | 2 | 12 × 12 |
| 6 | 6 | 30 | 45 | 60 | 8 | 4½ | 20 × 12 |
| 8 | 8 | 60 | 90 | 120 | 15 | 6 | 24 × 14 |
| 10 | 10 | 90 | 135 | 180 | 25 | 8 | 30 × 15 |
| 12 | 12 | 125 | 190 | 250 | 30 | 10 | 36 × 20 |
| 15 | 15 | 210 | 315 | 420 | 50 | 10 | 42 × 24 |
| 18 | 18 | 300 | 450 | 600 | 70 | 10 | 48 × 30 |

REVOLUTION TABLE

Speeds at which Standard Pumps should Run to Raise Water to Different Heights.

| No. | 5 Ft. | 10 Ft. | 15 Ft. | 25 Ft. | 35 Ft. | 50 Ft. | 70 Ft. | 100 Ft. |
|-----|-------|--------|--------|--------|--------|--------|--------|---------|
| 1½ | 428 | 604 | 739 | 955 | 1131 | 1351 | 1599 | 1911 |
| 1¾ | 348 | 491 | 601 | 777 | 920 | 1099 | 1301 | 1554 |
| 2 | 302 | 426 | 522 | 674 | 798 | 953 | 1128 | 1348 |
| 2½ | 302 | 426 | 522 | 674 | 798 | 953 | 1128 | 1348 |
| 3 | 302 | 426 | 522 | 674 | 798 | 953 | 1128 | 1348 |
| 4 | 285 | 402 | 493 | 637 | 754 | 901 | 1066 | 1274 |
| 5 | 256 | 362 | 443 | 572 | 678 | 810 | 958 | 1145 |
| 6 | 214 | 302 | 368 | 478 | 566 | 675 | 800 | 955 |
| 8 | 183 | 259 | 317 | 409 | 485 | 579 | 685 | 819 |
| 10 | 168 | 238 | 291 | 376 | 445 | 532 | 629 | 752 |
| 12 | 133 | 188 | 230 | 298 | 352 | 421 | 498 | 595 |
| 15 | 105 | 148 | 181 | 234 | 277 | 331 | 391 | 468 |
| 15 | 151 | 213 | 261 | 337 | 399 | 477 | 564 | 674 |
| 18 | 105 | 148 | 181 | 234 | 277 | 331 | 391 | 468 |
| 18 | 151 | 213 | 261 | 337 | 399 | 477 | 564 | 674 |
| 20 | 142 | 202 | 245 | 317 | 376 | 450 | 532 | 635 |
| 24 | 95 | 134 | 163 | 212 | 252 | 300 | 355 | 424 |

If water is to be forced through long pipes or through many elbows, speed must be increased to correspond.

Weir-dam Measurement for Flow of Water in Streams.—Cut a notch in a board deep enough to pass all the water and about two-thirds the width of the stream,

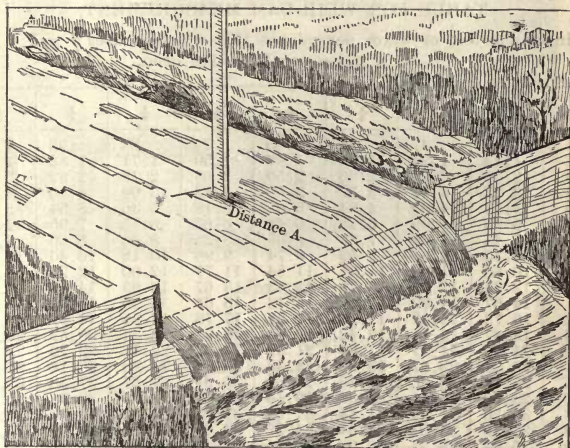


FIG. 353.

as shown by Fig. 353. Bevel the edges of the notch, then secure it in the position shown in the above view. Drive a stake

in the bottom of the stream about 4 or 5 feet from the board (shown as distance *A* in the view). The top of the stake must be exactly level with the bottom of the notch in the board. After the water has come to an even flow and reached its greatest depth, a careful measurement can be made of the depth of the water over the top of the stake. This measurement gives the true depth of water passing over notch. On the downward side, the water must have a drop of 10 to 15 inches after leaving the board to enable you to get the true flow.

The nature of the channel above the board should be such that the water will not rush over the board, but should be wide and deep enough to allow it to flow over quietly.

The Weir-dam table given below shows the number of cubic feet of water passing per minute over the notch for each inch in breadth. The figures in the first vertical column are the inches depth of water over the weir. The figures on first horizontal line show fractional parts of inches depth. The table shows cubic feet that will pass per minute per inch of width of notch in board.

Example.—Suppose the notch in the board is 20 inches wide and the water is $5\frac{1}{2}$ inches above top of stake. In the table

TABLE FOR WEIR-DAM MEASUREMENT,

Giving cubic feet of water per minute that will flow over a weir 1 inch wide and up to 25 inches deep.

| Inch. | | $\frac{1}{8}$ | $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ |
|-------|-------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| 1 | .40 | .47 | .55 | .65 | .74 | .83 | .93 | 1.03 |
| 2 | 1.14 | 1.24 | 1.36 | 1.47 | 1.59 | 1.71 | 1.83 | 1.96 |
| 3 | 2.09 | 2.23 | 2.36 | 2.50 | 2.63 | 2.78 | 2.92 | 3.07 |
| 4 | 3.22 | 3.37 | 3.52 | 3.68 | 3.83 | 3.99 | 4.16 | 4.32 |
| 5 | 4.50 | 4.67 | 4.84 | 5.01 | 5.18 | 5.36 | 5.54 | 5.72 |
| 6 | 5.90 | 6.09 | 6.28 | 6.47 | 6.65 | 6.85 | 7.05 | 7.25 |
| 7 | 7.44 | 7.64 | 7.84 | 8.05 | 8.25 | 8.45 | 8.66 | 8.86 |
| 8 | 9.10 | 9.31 | 9.52 | 9.74 | 9.96 | 10.18 | 10.40 | 10.62 |
| 9 | 10.86 | 11.08 | 11.31 | 11.54 | 11.77 | 12.00 | 12.23 | 12.47 |
| 10 | 12.71 | 12.95 | 13.19 | 13.43 | 13.67 | 13.93 | 14.16 | 14.42 |
| 11 | 14.67 | 14.92 | 15.18 | 15.43 | 15.67 | 15.96 | 16.20 | 16.46 |
| 12 | 16.73 | 16.99 | 17.26 | 17.52 | 17.78 | 18.05 | 18.32 | 18.58 |
| 13 | 18.87 | 19.14 | 19.42 | 19.69 | 19.97 | 20.24 | 20.52 | 20.80 |
| 14 | 21.09 | 21.37 | 21.65 | 21.94 | 22.22 | 22.51 | 22.79 | 23.08 |
| 15 | 23.38 | 23.67 | 23.97 | 24.26 | 24.56 | 24.86 | 25.16 | 25.46 |
| 16 | 25.76 | 26.06 | 26.36 | 26.66 | 26.97 | 27.27 | 27.58 | 27.89 |
| 17 | 28.20 | 28.51 | 28.82 | 29.14 | 29.45 | 29.76 | 30.08 | 30.39 |
| 18 | 30.70 | 31.02 | 31.34 | 31.66 | 31.98 | 32.31 | 32.63 | 32.96 |
| 19 | 33.29 | 33.61 | 33.94 | 34.27 | 34.60 | 34.94 | 35.27 | 35.60 |
| 20 | 35.94 | 36.27 | 36.60 | 36.94 | 37.28 | 37.62 | 37.96 | 38.31 |
| 21 | 38.65 | 39.00 | 39.34 | 39.69 | 40.04 | 40.39 | 40.73 | 41.09 |
| 22 | 41.43 | 41.78 | 42.13 | 42.49 | 42.84 | 43.20 | 43.56 | 43.92 |
| 23 | 44.28 | 44.64 | 45.00 | 45.38 | 45.71 | 46.08 | 46.43 | 46.81 |
| 24 | 47.18 | 47.55 | 47.91 | 48.28 | 48.65 | 49.02 | 49.39 | 49.76 |

$5\frac{1}{2}$ inches show that 5.18 cubic feet flow over 1 inch of width. Multiply this by 20 (width of notch), and you will have 103.6, which represents the cubic feet of water passing over the weir, or amount in the stream. This multiplied by $7\frac{1}{2}$ will give the gallons.

A "miners' inch" of water is approximately equal to a supply of 12 United States gallons per minute.

Measurements of Large Streams.—Where measurement by weir is impracticable, the amount of water can be calculated by ascertaining the average velocity of the current and the cross-section of the stream.

Select a place in the stream where there is a moderate current, or smooth, even flow of water, and measure the depth of the water at from 6 to 12 points across the stream at equal

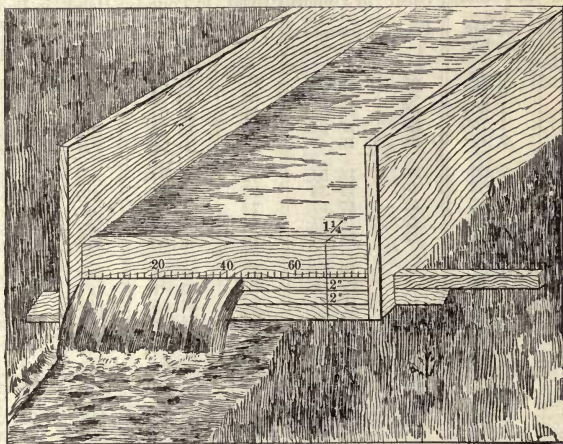


FIG. 354.

distances between. Add all the depths in feet together, and divide by the number of measurements made; this will be the average depth of the stream, which, multiplied by its width, will give its area or cross-section. Multiply this by the velocity of the stream in feet per minute, and the result will be the discharge in cubic feet per minute of the stream.

Miners' Inch Measurement.—The miners' inch is another method of measuring flow of water, and is commonly

used by the hydraulic companies in the western part of the United States.

The standard opening is 50 inches long by 2 inches wide in a 1½-inch board, top of said opening being 6 inches from level of water in stream, as shown by Fig. 354. This is equivalent to 100 miners' inches, and will discharge 157 cubic feet per minute, commonly taken as 150 cubic feet.

If there is not 150 cubic feet in the stream, it will be necessary to close part of the longitudinal 2-inch opening, so that the water will stand 6 inches above the upper edge of the slot at all times. The length of the opening multiplied by two gives the number of miners' inches.

PRESSURE OF WATER.

| Head in Feet. | Pressure in Pounds per Square Inch. | Head in Feet. | Pressure in Pounds per Square Inch. | Head in Feet. | Pressure in Pounds per Square Inch. | Head in Feet. | Pressure in Pounds per Square Inch. |
|---------------|-------------------------------------|---------------|-------------------------------------|---------------|-------------------------------------|---------------|-------------------------------------|
| 1 | 0.43 | 34 | 14.74 | 67 | 29.05 | 100 | 43.35 |
| 2 | 0.87 | 35 | 15.17 | 68 | 29.48 | 101 | 43.78 |
| 3 | 1.30 | 36 | 15.61 | 69 | 29.91 | 102 | 44.22 |
| 4 | 1.73 | 37 | 16.04 | 70 | 30.35 | 103 | 44.65 |
| 5 | 2.17 | 38 | 16.47 | 71 | 30.78 | 104 | 45.08 |
| 6 | 2.60 | 39 | 16.91 | 72 | 31.21 | 105 | 45.52 |
| 7 | 3.03 | 40 | 17.34 | 73 | 31.65 | 106 | 45.95 |
| 8 | 3.47 | 41 | 17.77 | 74 | 32.08 | 107 | 46.39 |
| 9 | 3.90 | 42 | 18.21 | 75 | 32.51 | 108 | 46.82 |
| 10 | 4.34 | 43 | 18.64 | 76 | 32.95 | 109 | 47.25 |
| 11 | 4.77 | 44 | 19.07 | 77 | 33.38 | 110 | 47.69 |
| 12 | 5.20 | 45 | 19.51 | 78 | 33.81 | 111 | 48.12 |
| 13 | 5.64 | 46 | 19.94 | 79 | 34.25 | 112 | 48.55 |
| 14 | 6.07 | 47 | 20.37 | 80 | 34.68 | 113 | 48.99 |
| 15 | 6.50 | 48 | 20.81 | 81 | 35.11 | 114 | 49.42 |
| 16 | 6.94 | 49 | 21.24 | 82 | 35.55 | 115 | 49.85 |
| 17 | 7.37 | 50 | 21.68 | 83 | 35.98 | 116 | 50.29 |
| 18 | 7.80 | 51 | 22.11 | 84 | 36.41 | 117 | 50.72 |
| 19 | 8.24 | 52 | 22.54 | 85 | 36.85 | 118 | 51.15 |
| 20 | 8.67 | 53 | 22.98 | 86 | 37.28 | 119 | 51.59 |
| 21 | 9.10 | 54 | 23.41 | 87 | 37.72 | 120 | 52.02 |
| 22 | 9.54 | 55 | 23.84 | 88 | 38.15 | 121 | 52.45 |
| 23 | 9.97 | 56 | 24.28 | 89 | 38.58 | 122 | 52.89 |
| 24 | 10.40 | 57 | 24.71 | 90 | 39.02 | 123 | 53.32 |
| 25 | 10.84 | 58 | 25.14 | 91 | 39.45 | 124 | 53.75 |
| 26 | 11.27 | 59 | 25.58 | 92 | 39.88 | 125 | 54.19 |
| 27 | 11.70 | 60 | 26.01 | 93 | 40.32 | 126 | 54.62 |
| 28 | 12.14 | 61 | 26.44 | 94 | 40.75 | 127 | 55.06 |
| 29 | 12.57 | 62 | 26.88 | 95 | 41.18 | 128 | 55.49 |
| 30 | 13.01 | 63 | 27.31 | 96 | 41.62 | 129 | 55.92 |
| 31 | 13.44 | 64 | 27.74 | 97 | 42.05 | 130 | 56.36 |
| 32 | 13.87 | 65 | 28.18 | 98 | 42.48 | 131 | 56.79 |
| 33 | 14.31 | 66 | 28.61 | 99 | 42.92 | 132 | 57.22 |

PRESSURE OF WATER—(Continued).

| Head in Feet. | Pressure in Pounds per Sq. Inch. | Head in Feet. | Pressure in Pounds per Sq. Inch. | Head in Feet. | Pressure in Pounds per Sq. Inch. | Head in Feet. | Pressure in Pounds per Sq. Inch. |
|---------------------|---|---------------------|---|---------------------|---|---------------------|---|
| 133 | 57.66 | 175 | 75.86 | 217 | 94.06 | 259 | 112.27 |
| 134 | 58.09 | 176 | 76.30 | 218 | 94.50 | 260 | 112.71 |
| 135 | 58.52 | 177 | 76.73 | 219 | 94.93 | 261 | 113.14 |
| 136 | 58.96 | 178 | 77.16 | 220 | 95.37 | 262 | 113.57 |
| 137 | 59.39 | 179 | 77.60 | 221 | 95.80 | 263 | 114.01 |
| 138 | 59.82 | 180 | 78.03 | 222 | 96.23 | 264 | 114.44 |
| 139 | 60.26 | 181 | 78.46 | 223 | 96.67 | 265 | 114.87 |
| 140 | 60.69 | 182 | 78.90 | 224 | 97.10 | 266 | 115.31 |
| 141 | 61.12 | 183 | 79.33 | 225 | 97.53 | 267 | 115.74 |
| 142 | 61.56 | 184 | 79.77 | 226 | 97.97 | 268 | 116.17 |
| 143 | 62.00 | 185 | 80.20 | 227 | 98.40 | 269 | 116.61 |
| 144 | 62.43 | 186 | 80.63 | 228 | 98.83 | 270 | 117.04 |
| 145 | 62.86 | 187 | 81.07 | 229 | 99.27 | 271 | 117.47 |
| 146 | 63.29 | 188 | 81.50 | 230 | 99.70 | 272 | 117.91 |
| 147 | 63.73 | 189 | 81.93 | 231 | 100.13 | 273 | 118.34 |
| 148 | 64.16 | 190 | 82.37 | 232 | 100.56 | 274 | 118.77 |
| 149 | 64.59 | 191 | 82.80 | 233 | 101.00 | 275 | 119.21 |
| 150 | 65.03 | 192 | 83.23 | 234 | 101.43 | 276 | 119.64 |
| 151 | 65.46 | 193 | 83.67 | 235 | 101.86 | 277 | 120.07 |
| 152 | 65.89 | 194 | 84.10 | 236 | 102.30 | 278 | 120.51 |
| 153 | 66.33 | 195 | 84.53 | 237 | 102.73 | 279 | 120.94 |
| 154 | 66.76 | 196 | 84.97 | 238 | 103.16 | 280 | 121.38 |
| 155 | 67.19 | 197 | 85.40 | 239 | 103.60 | 281 | 121.81 |
| 156 | 67.63 | 198 | 85.83 | 240 | 104.03 | 282 | 122.24 |
| 157 | 68.06 | 199 | 86.27 | 241 | 104.46 | 283 | 122.68 |
| 158 | 68.49 | 200 | 86.70 | 242 | 104.90 | 284 | 123.11 |
| 159 | 68.93 | 201 | 87.13 | 243 | 105.33 | 285 | 123.54 |
| 160 | 69.36 | 202 | 87.56 | 244 | 105.76 | 286 | 123.98 |
| 161 | 69.79 | 203 | 88.00 | 245 | 106.20 | 287 | 124.41 |
| 162 | 70.23 | 204 | 88.43 | 246 | 106.63 | 288 | 124.84 |
| 163 | 70.66 | 205 | 88.85 | 247 | 107.06 | 289 | 125.28 |
| 164 | 71.10 | 206 | 89.30 | 248 | 107.50 | 290 | 125.71 |
| 165 | 71.53 | 207 | 89.73 | 249 | 107.93 | 291 | 126.14 |
| 166 | 71.96 | 208 | 90.15 | 250 | 108.37 | 292 | 126.58 |
| 167 | 72.40 | 209 | 90.60 | 251 | 108.80 | 293 | 127.01 |
| 168 | 72.83 | 210 | 91.03 | 252 | 109.23 | 294 | 127.44 |
| 169 | 73.26 | 211 | 91.46 | 253 | 109.67 | 295 | 127.88 |
| 170 | 73.70 | 212 | 91.90 | 254 | 110.10 | 296 | 128.31 |
| 171 | 74.13 | 213 | 92.33 | 255 | 110.53 | 297 | 128.74 |
| 172 | 74.56 | 214 | 92.76 | 256 | 110.97 | 298 | 129.18 |
| 173 | 75.00 | 215 | 93.20 | 257 | 111.40 | 299 | 129.61 |
| 174 | 75.43 | 216 | 93.63 | 258 | 111.83 | 300 | 130.05 |

VELOCITY OF WATER.

Table giving velocity of water in feet per second, and the cubic feet of water per minute, to develop one horse-power at 80 per cent duty under heads from 1 to 108 feet.

| Head | Velocity. | Cubic Feet. | Head | Velocity. | Cubic Feet. | Head | Velocity. | Cubic Feet. |
|------|-----------|-------------|------|-----------|-------------|------|-----------|-------------|
| 1 | 8.02 | 661.765 | 37 | 48.78 | 17.886 | 73 | 68.53 | 9.065 |
| 2 | 11.34 | 330.883 | 38 | 49.44 | 17.415 | 74 | 69.00 | 8.943 |
| 3 | 13.89 | 220.589 | 39 | 50.09 | 16.968 | 75 | 69.46 | 8.822 |
| 4 | 16.04 | 165.441 | 40 | 50.72 | 16.544 | 76 | 69.92 | 8.707 |
| 5 | 17.92 | 132.353 | 41 | 51.35 | 16.141 | 77 | 70.38 | 8.594 |
| 6 | 19.65 | 110.294 | 42 | 54.98 | 15.756 | 78 | 70.84 | 8.484 |
| 7 | 21.22 | 94.538 | 43 | 52.59 | 15.390 | 79 | 71.29 | 8.377 |
| 8 | 22.68 | 82.720 | 44 | 53.20 | 15.040 | 80 | 71.74 | 8.272 |
| 9 | 24.06 | 73.529 | 45 | 53.80 | 14.706 | 81 | 72.19 | 8.170 |
| 10 | 25.36 | 66.177 | 46 | 54.40 | 14.368 | 82 | 72.63 | 8.070 |
| 11 | 26.60 | 60.160 | 47 | 54.99 | 14.080 | 83 | 73.07 | 7.973 |
| 12 | 27.78 | 55.147 | 48 | 55.57 | 13.787 | 84 | 73.51 | 7.878 |
| 13 | 28.92 | 50.905 | 49 | 56.14 | 13.505 | 85 | 73.95 | 7.785 |
| 14 | 30.01 | 47.269 | 50 | 56.71 | 13.236 | 86 | 74.38 | 7.695 |
| 15 | 31.06 | 44.118 | 51 | 57.27 | 12.976 | 87 | 74.81 | 7.606 |
| 16 | 32.08 | 41.360 | 52 | 57.84 | 12.726 | 88 | 75.24 | 7.520 |
| 17 | 33.07 | 38.927 | 53 | 58.39 | 12.486 | 89 | 75.67 | 7.436 |
| 18 | 34.03 | 36.765 | 54 | 58.93 | 12.255 | 90 | 76.09 | 7.353 |
| 19 | 34.96 | 34.830 | 55 | 59.48 | 12.032 | 91 | 76.51 | 7.272 |
| 20 | 35.87 | 33.088 | 56 | 60.01 | 11.817 | 92 | 76.93 | 7.193 |
| 21 | 36.75 | 31.513 | 57 | 60.56 | 11.610 | 93 | 77.35 | 7.116 |
| 22 | 37.61 | 30.080 | 58 | 61.08 | 11.410 | 94 | 77.76 | 7.040 |
| 23 | 38.46 | 28.772 | 59 | 61.61 | 11.216 | 95 | 78.18 | 6.966 |
| 24 | 39.29 | 27.574 | 60 | 62.12 | 11.029 | 96 | 78.59 | 6.893 |
| 25 | 40.10 | 26.471 | 61 | 62.71 | 10.849 | 97 | 79.00 | 6.822 |
| 26 | 40.89 | 25.453 | 62 | 63.15 | 10.674 | 98 | 79.40 | 6.753 |
| 27 | 41.67 | 24.510 | 63 | 63.66 | 10.504 | 99 | 79.81 | 6.685 |
| 28 | 42.44 | 23.634 | 64 | 64.16 | 10.340 | 100 | 80.22 | 6.618 |
| 29 | 43.19 | 22.819 | 65 | 64.66 | 10.181 | 101 | 80.61 | 6.552 |
| 30 | 43.93 | 22.059 | 66 | 65.16 | 10.027 | 102 | 81.01 | 6.487 |
| 31 | 44.65 | 21.347 | 67 | 65.65 | 9.877 | 103 | 81.40 | 6.425 |
| 32 | 45.37 | 20.680 | 68 | 66.14 | 9.732 | 104 | 81.80 | 6.363 |
| 33 | 46.07 | 20.053 | 69 | 66.62 | 9.591 | 105 | 82.19 | 6.303 |
| 34 | 46.77 | 19.464 | 70 | 67.11 | 9.454 | 106 | 82.58 | 6.243 |
| 35 | 47.45 | 18.908 | 71 | 67.58 | 9.321 | 107 | 82.97 | 6.185 |
| 36 | 48.12 | 18.382 | 72 | 68.06 | 9.191 | 108 | 83.35 | 6.127 |

TABLE SHOWING FLOW OF WATER THROUGH NOZZLES.

Quantity and Horse-power.

| Head, Feet. | Velocity per Second, Feet. | Diameters of Nozzles. | | | | | | | | | |
|-------------|----------------------------|------------------------|--------------|------------------------|--------------|------------------------|--------------|------------------------|--------------|------------------------|--------------|
| | | 1 Inch. | | 1.5 Inches. | | 2 Inches. | | 2.5 Inches. | | 3 Inches. | |
| | | Cubic Feet per Second. | Horse-power. | Cubic Feet per Second. | Horse-power. | Cubic Feet per Second. | Horse-power. | Cubic Feet per Second. | Horse-power. | Cubic Feet per Second. | Horse-power. |
| 5 | 17.95 | .091 | .051 | .205 | .113 | .364 | .204 | .56 | .315 | .820 | .452 |
| 10 | 25.38 | .129 | .146 | .290 | .329 | .516 | .584 | .805 | .915 | 1.16 | 1.32 |
| 15 | 31.08 | .158 | .269 | .355 | .505 | .632 | 1.08 | .985 | 1.68 | 1.42 | 2.42 |
| 20 | 35.89 | .182 | .414 | .410 | .931 | .728 | 1.66 | 1.14 | 2.58 | 1.64 | 3.72 |
| 25 | 40.13 | .204 | .578 | .458 | 1.30 | .816 | 2.31 | 1.27 | 3.61 | 1.83 | 5.20 |
| 30 | 43.95 | .228 | .760 | .513 | 1.71 | .912 | 3.04 | 1.42 | 4.75 | 2.05 | 6.84 |
| 35 | 47.47 | .241 | .958 | .542 | 2.15 | .964 | 3.83 | 1.51 | 5.98 | 2.17 | 8.60 |
| 40 | 50.75 | .257 | 1.17 | .579 | 2.63 | 1.03 | 4.68 | 1.61 | 7.31 | 2.32 | 10.52 |
| 45 | 53.83 | .273 | 1.40 | .614 | 3.14 | 1.09 | 5.60 | 1.71 | 8.23 | 2.46 | 12.56 |
| 50 | 56.75 | .288 | 1.64 | .648 | 3.68 | 1.15 | 6.56 | 1.79 | 10.22 | 2.59 | 14.72 |
| 60 | 62.16 | .385 | 2.15 | .709 | 4.84 | 1.26 | 8.60 | 1.97 | 13.43 | 2.84 | 19.36 |
| 70 | 67.14 | .341 | 2.71 | .766 | 6.10 | 1.36 | 10.84 | 2.13 | 16.93 | 3.06 | 24.40 |
| 80 | 71.78 | .364 | 3.31 | .819 | 7.45 | 1.46 | 13.24 | 2.27 | 20.69 | 3.28 | 20.80 |
| 90 | 76.13 | .386 | 3.95 | .864 | 8.88 | 1.54 | 15.80 | 2.44 | 24.68 | 3.46 | 35.52 |
| 100 | 80.25 | .407 | 4.63 | .916 | 10.41 | 1.63 | 18.52 | 2.54 | 28.90 | 3.66 | 41.64 |
| 125 | 89.72 | .455 | 6.47 | 1.02 | 14.55 | 1.82 | 25.88 | 2.81 | 40.40 | 4.08 | 58.20 |
| 150 | 98.28 | .499 | 8.50 | 1.12 | 19.12 | 2.00 | 34.00 | 3.11 | 53.12 | 4.48 | 76.48 |
| 175 | 106.1 | .539 | 10.70 | 1.21 | 24.07 | 2.16 | 42.80 | 3.36 | 66.86 | 4.84 | 96.28 |
| 200 | 113.5 | .576 | 13.1 | 1.29 | 29.43 | 2.30 | 52.4 | 3.50 | 81.75 | 5.10 | 117.7 |
| 250 | 127.1 | .644 | 18.3 | 1.45 | 41.13 | 2.58 | 73.2 | 4.02 | 114.2 | 5.80 | 164.5 |
| 300 | 139.0 | .705 | 24.0 | 1.59 | 54.07 | 2.82 | 96.0 | 4.40 | 150.2 | 6.36 | 216.3 |
| 350 | 150.1 | .762 | 30.3 | 1.71 | 68.15 | 3.05 | 121.2 | 4.76 | 189.3 | 6.84 | 272.6 |
| 400 | 160.5 | .814 | 37.0 | 1.83 | 83.25 | 3.26 | 148.0 | 5.09 | 231.2 | 7.32 | 323.0 |
| 450 | 170.2 | .864 | 44.2 | 1.94 | 99.34 | 3.46 | 176.8 | 5.40 | 276.0 | 7.76 | 397.4 |
| 500 | 179.4 | .910 | 51.7 | 2.05 | 116.5 | 3.64 | 206.8 | 5.60 | 323.2 | 8.20 | 406.0 |
| 550 | 188.2 | .955 | 59.7 | 2.10 | 134.2 | 3.82 | 238.8 | 5.96 | 372.7 | 8.40 | 536.8 |
| 600 | 196.6 | .999 | 68.0 | 2.23 | 152.9 | 3.99 | 272.0 | 6.23 | 475.0 | 8.92 | 611.0 |
| 700 | 212.3 | 1.06 | 85.7 | 2.46 | 192.8 | 4.36 | 342.8 | 6.79 | 535.5 | 9.84 | 771.2 |
| 800 | 226.9 | 1.15 | 104.7 | 2.58 | 235.5 | 4.60 | 418.8 | 7.19 | 654.0 | 10.32 | 942.0 |
| 900 | 240.7 | 1.22 | 124.9 | 2.75 | 281.0 | 4.88 | 499.6 | 7.63 | 780.5 | 11.00 | 1124 |
| 1000 | 253.8 | 1.29 | 146.2 | 2.89 | 329.0 | 5.16 | 584.8 | 8.04 | 914.0 | 11.56 | 1316 |

FIRE STREAMS.

Pressures required at nozzle and at pump, with quantity and pressure of water necessary to throw water various distances through different-sized nozzles—using 2½-inch rubber hose and smooth nozzles.—G. A. ELLIS, C.E.

| Size of Nozzles. | 1 Inch. | | | | 1½ Inch. | | | |
|---|---------------------------|-----|-----|-----|----------|-----|-----|-----|
| | Pressure at nozzle. . . . | 40 | 60 | 80 | 100 | 40 | 60 | 80 | 100 |
| * Pressure at pump or hydrant with 100 ft. 2½-inch rubber hose. | 48 | 73 | 97 | 121 | 54 | 81 | 108 | 135 |
| Gallons per minute. . . . | 155 | 189 | 219 | 245 | 196 | 240 | 277 | 310 |
| Horizontal distance thrown. | 109 | 142 | 168 | 186 | 113 | 148 | 175 | 193 |
| Vertical dist. thrown. . . | 79 | 108 | 131 | 148 | 81 | 112 | 137 | 157 |

| Size of Nozzles. | 1¼ Inch. | | | | 1¾ Inch. | | | |
|---|---------------------------|-----|-----|-----|----------|-----|-----|-----|
| | Pressure at nozzle. . . . | 40 | 60 | 80 | 100 | 40 | 60 | 80 | 100 |
| * Pressure at pump or hydrant with 100 ft. 2½-inch rubber hose. | 61 | 92 | 123 | 154 | 71 | 107 | 144 | 180 |
| Gallons per minute. . . . | 242 | 297 | 342 | 383 | 293 | 358 | 413 | 462 |
| Horizontal distance thrown. | 118 | 156 | 186 | 207 | 124 | 166 | 200 | 224 |
| Vertical dist. thrown. . . | 82 | 115 | 142 | 164 | 85 | 118 | 146 | 169 |

* For greater lengths of 2½ hose the increased friction can readily be obtained by noting the differences between the above given "pressure at nozzle" and "pressure at pump or hydrant with 100 feet of hose." For instance, if it requires at hydrant or pump 8 lbs. more pressure than it does at nozzle to overcome the friction when pumping through 100 feet of 2½-inch hose (using 1-inch nozzle, with 40 lbs. pressure at said nozzle), then it requires 16 lbs. pressure to overcome the friction in forcing through 200 feet of same size hose.

FLOW OF WATER THROUGH IRON PIPES. 643

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES.

| Fall in Feet per 100 Feet of Pipe. | Diameters. | | | | | | | | |
|------------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|-------------------|-------------------|-------------------|
| | 1 In. Cu. Ft. | 2 In. Cu. Ft. | 3 In. Cu. Ft. | 4 In. Cu. Ft. | 6 In. Cu. Ft. | 8 In. Cu. Ft. | 10 In. Cu. Ft. | 11 In. Cu. Ft. | 12 In. Cu. Ft. |
| .10 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1.265 |
| .12 | ..... | ..... | ..... | ..... | ..... | ..... | .878 | 1.120 | 1.402 |
| .14 | ..... | ..... | ..... | ..... | ..... | ..... | .960 | 1.221 | 1.489 |
| .16 | ..... | ..... | ..... | ..... | ..... | .573 | 1.047 | 1.320 | 1.634 |
| .18 | ..... | ..... | ..... | ..... | ..... | .611 | 1.110 | 1.394 | 1.728 |
| .20 | ..... | ..... | ..... | ..... | .298 | .639 | 1.194 | 1.490 | 1.846 |
| .22 | ..... | ..... | ..... | ..... | .314 | .659 | 1.265 | 1.580 | 1.940 |
| .24 | ..... | ..... | ..... | ..... | .330 | .703 | 1.325 | 1.653 | 2.026 |
| .26 | ..... | ..... | ..... | .1235 | .346 | .737 | 1.377 | 1.722 | 2.117 |
| .28 | ..... | ..... | ..... | .1298 | .359 | .768 | 1.423 | 1.788 | 2.207 |
| .30 | ..... | ..... | .0630 | .1335 | .377 | .808 | 1.470 | 1.854 | 2.297 |
| .35 | ..... | ..... | .0692 | .1465 | .395 | .876 | 1.587 | 1.996 | 2.466 |
| .40 | ..... | .02584 | .0749 | .1562 | .444 | .931 | 1.683 | 2.136 | 2.662 |
| .50 | ..... | .02924 | .0839 | .1771 | .496 | 1.045 | 1.865 | 2.397 | 3.020 |
| .60 | ..... | .03274 | .0915 | .1923 | .548 | 1.575 | 2.059 | 2.636 | 3.310 |
| .70 | ..... | .03492 | .0992 | .2146 | .589 | 1.262 | 2.222 | 2.858 | 3.601 |
| .80 | .00567 | .03776 | .1060 | .2339 | .631 | 1.344 | 2.383 | 3.062 | 3.856 |
| .90 | .00617 | .04081 | .1119 | .2460 | .672 | 1.424 | 2.514 | 3.232 | 4.072 |
| 1.00 | .00677 | .04321 | .1190 | .2582 | .721 | 1.496 | 2.662 | 3.419 | 4.305 |
| 1.20 | .00781 | .04843 | .1313 | .2893 | .784 | 1.644 | 2.932 | 3.760 | 4.728 |
| 1.40 | .00841 | .05150 | .1413 | .3036 | .858 | 1.782 | 3.210 | 4.016 | 5.094 |
| 1.60 | .00886 | .05456 | .1507 | .3237 | .922 | 1.916 | 3.450 | 4.390 | 5.482 |
| 1.80 | .00961 | .05740 | .1590 | .3412 | .975 | 2.033 | 3.679 | 4.679 | 5.839 |
| 2.00 | .00990 | .06111 | .1717 | .3607 | 1.022 | 2.155 | 3.856 | 5.251 | 6.160 |
| 3.00 | .01245 | .07399 | .2081 | .4503 | 1.263 | 2.667 | 4.762 | 6.086 | 7.630 |
| 4.00 | .01492 | .08734 | .2469 | .5331 | 1.484 | 3.145 | 5.563 | 7.022 | 8.860 |
| 5.00 | .01666 | .1095 | .2785 | .5954 | 1.665 | 3.513 | 6.704 | 8.244 | 9.967 |
| 6.00 | .01857 | .1200 | .3049 | .6390 | 1.929 | 3.847 | ..... | ..... | ..... |
| 7.00 | .01988 | .1288 | .3331 | .6967 | 1.976 | 4.196 | ..... | ..... | ..... |
| 8.00 | .02141 | .1375 | .3559 | .7506 | 2.144 | ..... | ..... | ..... | ..... |
| 9.00 | .02283 | .1442 | .3816 | .7960 | 2.274 | ..... | ..... | ..... | ..... |
| 10.00 | .02424 | .1523 | .4043 | .9464 | 2.399 | ..... | ..... | ..... | ..... |
| 12.00 | .02676 | .1634 | .4440 | .9270 | ..... | ..... | ..... | ..... | ..... |
| 14.00 | .02890 | .1748 | .4977 | 1.0060 | ..... | ..... | ..... | ..... | ..... |
| 15.98 | .03081 | .1855 | .5131 | 1.0810 | ..... | ..... | ..... | ..... | ..... |
| 18.00 | .03276 | .1955 | .5436 | ..... | ..... | ..... | ..... | ..... | ..... |
| 20.00 | .03458 | .2047 | .5832 | ..... | ..... | ..... | ..... | ..... | ..... |
| 25.00 | .03897 | .2276 | .6523 | ..... | ..... | ..... | ..... | ..... | ..... |
| 30.00 | .04316 | .2483 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 40.00 | .04987 | .2833 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 50.00 | .05648 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 60.00 | .06320 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 70.00 | .06943 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

To find the velocity in feet per second necessary to carry a given quantity of water in a pipe of given diameter, divide the quantity in cubic feet per second by the area of the pipe in square feet; the quotient will give the velocity.

644 FLOW OF WATER THROUGH IRON PIPES.

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES.

| Fall in Feet per 100 Feet of Pipe. | Diameter. | | | | | | | | | | | |
|------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | 14 In. Cu. Ft. | 15 In. Cu. Ft. | 16 In. Cu. Ft. | 18 In. Cu. Ft. | 20 In. Cu. Ft. | 22 In. Cu. Ft. | 24 In. Cu. Ft. | 26 In. Cu. Ft. | 30 In. Cu. Ft. | 36 In. Cu. Ft. | 40 In. Cu. Ft. | 48 In. Cu. Ft. |
| .02 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 10.29 | 13.88 | 22.98 | |
| .03 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 7.78 | 12.70 | 17.00 | 27.89 | |
| .04 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 8.99 | 14.56 | 19.68 | 32.93 | |
| .05 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 7.48 | 10.24 | 16.35 | 22.08 | 37.00 |
| .06 | ..... | ..... | ..... | ..... | 3.61 | 4.61 | 6.10 | 7.61 | 10.97 | 18.02 | 24.43 | 40.21 |
| .07 | ..... | ..... | 2.25 | 3.10 | 4.07 | 5.25 | 6.64 | 8.27 | 11.90 | 19.76 | 26.27 | 43.67 |
| .08 | 1.71 | 2.05 | 2.43 | 3.27 | 4.35 | 5.62 | 7.13 | 8.70 | 12.84 | 20.85 | 28.14 | 46.81 |
| .09 | 1.83 | 2.19 | 2.59 | 3.49 | 4.68 | 6.01 | 7.56 | 9.36 | 13.48 | 22.30 | 29.80 | 49.06 |
| .10 | 1.91 | 2.30 | 2.72 | 3.66 | 4.92 | 6.32 | 7.95 | 9.81 | 14.21 | 23.47 | 31.46 | 52.15 |
| .11 | 2.02 | 2.43 | 2.88 | 3.88 | 5.15 | 6.62 | 8.34 | 10.44 | 15.05 | 24.91 | 33.25 | 54.95 |
| .12 | 2.11 | 2.54 | 3.02 | 4.06 | 5.40 | 6.94 | 8.75 | 10.87 | 15.81 | 26.12 | 34.68 | 57.36 |
| .13 | 2.18 | 2.65 | 3.18 | 4.23 | 5.62 | 7.24 | 9.14 | 11.41 | 16.47 | 27.20 | 36.21 | 60.07 |
| .14 | 2.27 | 2.75 | 3.28 | 4.40 | 5.82 | 7.51 | 9.47 | 11.80 | 17.18 | 28.24 | 37.57 | 62.02 |
| .15 | 2.35 | 2.84 | 3.39 | 4.61 | 6.05 | 7.78 | 9.80 | 12.26 | 17.94 | 29.19 | 39.18 | 64.47 |
| .16 | 2.44 | 2.94 | 3.49 | 4.75 | 6.27 | 8.03 | 10.13 | 12.70 | 18.58 | 30.29 | 40.54 | 66.53 |
| .17 | 2.54 | 2.98 | 3.62 | 4.90 | 6.48 | 8.36 | 10.57 | 13.13 | 19.21 | 31.42 | 41.88 | 68.50 |
| .18 | 2.59 | 3.11 | 3.69 | 5.03 | 6.65 | 8.55 | 10.77 | 13.46 | 19.66 | 32.48 | 43.07 | 70.62 |
| .19 | 2.67 | 3.21 | 3.81 | 5.17 | 6.92 | 8.85 | 11.10 | 13.84 | 20.32 | 33.40 | 44.28 | 72.75 |
| .20 | 2.72 | 3.29 | 3.92 | 5.30 | 7.05 | 9.07 | 11.43 | 14.23 | 20.79 | 34.49 | 45.20 | 74.44 |
| .22 | 2.88 | 3.47 | 4.12 | 5.63 | 7.42 | 9.55 | 12.05 | 14.98 | 21.80 | 36.15 | 48.12 | 78.29 |
| .24 | 3.02 | 3.63 | 4.32 | 5.87 | 7.79 | 10.01 | 12.61 | 15.69 | 22.83 | 37.74 | 50.48 | 81.68 |
| .26 | 3.15 | 3.79 | 4.51 | 6.18 | 8.14 | 10.48 | 13.23 | 16.42 | 23.93 | 39.40 | 52.67 | 85.20 |
| .28 | 3.29 | 3.95 | 4.68 | 6.38 | 8.48 | 10.91 | 13.79 | 17.07 | 24.86 | 40.86 | 55.04 | 88.46 |
| .30 | 3.42 | 4.11 | 4.87 | 6.64 | 8.77 | 11.29 | 14.25 | 17.75 | 25.87 | 42.28 | 56.33 | 91.73 |
| .35 | 3.62 | 4.46 | 5.31 | 7.17 | 9.49 | 12.25 | 15.50 | 19.25 | 27.96 | 45.95 | 61.09 | 100.40 |
| .40 | 3.99 | 4.78 | 5.67 | 7.65 | 10.16 | 13.12 | 16.62 | 20.62 | 29.84 | 48.83 | 65.41 | 105.89 |
| .50 | 4.46 | 5.37 | 6.39 | 8.66 | 11.43 | 14.78 | 18.71 | 23.13 | 33.55 | 54.89 | 73.09 | 119.34 |
| .60 | 4.91 | 5.91 | 7.02 | 9.54 | 12.59 | 16.20 | 20.42 | 25.30 | 36.79 | 59.95 | 80.32 | 130.88 |
| .70 | 5.37 | 6.45 | 7.66 | 10.33 | 13.66 | 17.53 | 22.05 | 27.12 | 39.66 | 65.17 | 86.70 | 148.09 |
| .80 | 5.77 | 6.90 | 8.16 | 11.09 | 14.66 | 18.78 | 23.61 | 29.20 | 42.39 | 69.80 | 92.58 | 153.49 |
| .90 | 6.11 | 7.31 | 8.64 | 11.71 | 15.54 | 19.93 | 25.07 | 31.00 | 45.23 | 74.33 | 98.00 | ..... |
| 1.00 | 6.44 | 7.70 | 9.10 | 12.37 | 16.47 | 21.06 | 26.42 | 32.73 | 47.71 | 78.46 | 103.99 | ..... |
| 1.20 | 7.00 | 8.39 | 9.95 | 13.65 | 17.99 | 23.07 | 29.03 | 36.18 | 52.91 | 82.84 | ..... | ..... |
| 1.40 | 7.60 | 9.15 | 10.87 | 14.75 | 19.49 | 24.68 | 31.49 | 39.31 | 57.65 | ..... | ..... | ..... |
| 1.60 | 8.17 | 9.81 | 11.63 | 15.84 | 21.03 | 26.97 | 33.90 | 42.35 | ..... | ..... | ..... | ..... |
| 1.80 | 8.93 | 10.47 | 12.43 | 16.90 | 22.45 | 29.70 | 36.18 | 44.10 | ..... | ..... | ..... | ..... |
| 2.00 | 9.26 | 11.09 | 13.14 | 17.85 | 23.56 | 31.15 | 38.45 | ..... | ..... | ..... | ..... | ..... |
| 3.00 | 11.39 | 13.66 | 16.17 | 21.86 | 28.86 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 4.00 | 13.22 | 15.84 | 18.77 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

To find the area of a required pipe, the quantity and velocity being given, divide the quantity in a stated time by the velocity in the same period; the quotient will be the required area, from which the diameter may readily be calculated.

LOSS OF HEAD BY FRICTION.

The following tables give the friction head in pipe 1 to 12 inches diameter, per 100 feet length, with velocities from 2 to 7 feet per second.

INSIDE DIAMETER OF PIPE IN INCHES.

| Velocity in Feet per Sec. | 1 | | 2 | | 3 | | 4 | |
|---------------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|
| | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. |
| 2.0 | 2.37 | .65 | 1.185 | 2.62 | .791 | 5.89 | .593 | 10.4 |
| 2.2 | 2.80 | .73 | 1.404 | 2.88 | .936 | 6.48 | .702 | 11.5 |
| 2.4 | 3.27 | .79 | 1.639 | 3.14 | 1.093 | 7.07 | .819 | 12.5 |
| 2.6 | 3.78 | .86 | 1.891 | 3.40 | 1.26 | 7.65 | .945 | 13.6 |
| 2.8 | 4.32 | .92 | 2.16 | 3.66 | 1.44 | 8.24 | 1.08 | 14.6 |
| 3.0 | 4.89 | .99 | 2.44 | 3.92 | 1.62 | 8.83 | 1.22 | 15.7 |
| 3.2 | 5.47 | 1.06 | 2.73 | 4.18 | 1.82 | 9.42 | 1.37 | 16.7 |
| 3.4 | 6.09 | 1.12 | 3.05 | 4.45 | 2.04 | 10.00 | 1.52 | 17.8 |
| 3.6 | 6.76 | 1.19 | 3.38 | 4.71 | 2.26 | 10.60 | 1.69 | 18.8 |
| 3.8 | 7.48 | 1.26 | 3.74 | 4.97 | 2.49 | 11.20 | 1.87 | 19.9 |
| 4.0 | 8.20 | 1.32 | 4.10 | 5.23 | 2.73 | 11.80 | 2.05 | 20.9 |
| 4.2 | 8.97 | 1.39 | 4.49 | 5.49 | 2.98 | 12.30 | 2.24 | 22.0 |
| 4.4 | 9.77 | 1.45 | 4.89 | 5.76 | 3.25 | 12.90 | 2.43 | 23.0 |
| 4.6 | 10.60 | 1.52 | 5.30 | 6.02 | 3.53 | 13.50 | 2.64 | 24.0 |
| 4.8 | 11.45 | 1.58 | 5.72 | 6.28 | 3.81 | 14.10 | 2.85 | 25.1 |
| 5.0 | 12.33 | 1.65 | 6.17 | 6.54 | 4.11 | 14.70 | 3.08 | 26.2 |
| 5.2 | 13.24 | 1.72 | 6.62 | 6.80 | 4.41 | 15.30 | 3.31 | 27.2 |
| 5.4 | 14.20 | 1.78 | 7.10 | 7.06 | 4.73 | 15.90 | 3.55 | 28.2 |
| 5.6 | 15.16 | 1.85 | 7.58 | 7.32 | 5.06 | 16.50 | 3.79 | 29.3 |
| 5.8 | 16.17 | 1.91 | 8.09 | 7.58 | 5.40 | 17.10 | 4.04 | 30.3 |
| 6.0 | 17.23 | 1.98 | 8.61 | 7.85 | 5.74 | 17.70 | 4.31 | 31.4 |
| 7.0 | 22.89 | 2.31 | 11.45 | 9.16 | 7.62 | 20.60 | 5.72 | 36.6 |

INSIDE DIAMETER OF PIPE IN INCHES.

| Velocity in Feet per Sec. | 5 | | 6 | | 7 | | 8 | |
|---------------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|
| | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. |
| 2.0 | .474 | 16.3 | .395 | 23.5 | .338 | 32.0 | .96 | 41.9 |
| 2.2 | .561 | 18.0 | .468 | 25.9 | .401 | 35.3 | .351 | 46.1 |
| 2.4 | .650 | 19.6 | .547 | 28.2 | .468 | 38.5 | .410 | 50.2 |
| 2.6 | .757 | 21.3 | .631 | 30.6 | .540 | 41.7 | .473 | 54.4 |
| 2.8 | .864 | 22.9 | .720 | 32.9 | .617 | 44.9 | .540 | 58.6 |
| 3.0 | .978 | 24.5 | .815 | 35.3 | .698 | 48.1 | .611 | 62.8 |
| 3.2 | 1.098 | 26.2 | .915 | 37.7 | .785 | 51.3 | .686 | 67.0 |
| 3.4 | 1.22 | 27.8 | 1.021 | 40.0 | .875 | 54.5 | .765 | 71.2 |
| 3.6 | 1.35 | 29.4 | 1.131 | 42.4 | .969 | 57.7 | .848 | 75.4 |
| 3.8 | 1.49 | 31.0 | 1.25 | 44.7 | 1.070 | 60.9 | .936 | 79.6 |
| 4.0 | 1.64 | 32.7 | 1.37 | 47.1 | 1.175 | 64.1 | 1.027 | 83.7 |
| 4.2 | 1.79 | 34.3 | 1.49 | 49.5 | 1.28 | 67.3 | 1.122 | 87.9 |
| 4.4 | 1.95 | 36.0 | 1.62 | 51.8 | 1.39 | 70.5 | 1.22 | 92.1 |
| 4.6 | 2.11 | 37.6 | 1.76 | 54.1 | 1.51 | 73.7 | 1.32 | 96.3 |
| 4.8 | 2.27 | 39.2 | 1.90 | 56.5 | 1.63 | 76.9 | 1.43 | 100.0 |
| 5.0 | 2.46 | 40.9 | 2.05 | 58.9 | 1.76 | 80.2 | 1.54 | 105.0 |
| 5.2 | 2.65 | 42.5 | 2.21 | 61.2 | 1.89 | 83.3 | 1.65 | 109.0 |
| 5.4 | 2.84 | 44.2 | 2.37 | 63.6 | 2.03 | 86.6 | 1.77 | 113.0 |
| 5.6 | 3.03 | 45.8 | 2.53 | 65.9 | 2.17 | 89.8 | 1.89 | 117.0 |
| 5.8 | 3.24 | 47.4 | 2.70 | 68.3 | 2.31 | 93.0 | 2.01 | 121.0 |
| 6.0 | 3.45 | 49.1 | 2.87 | 70.7 | 2.46 | 96.2 | 2.15 | 125.0 |
| 7.0 | 4.57 | 57.2 | 3.81 | 82.4 | 3.26 | 112.0 | 2.85 | 146.0 |

LOSS OF HEAD BY FRICTION—(Continued).

INSIDE DIAMETER OF PIPE IN INCHES.

| Velocity in Feet per Sec. | 9 | | 10 | | 11 | | 12 | |
|---------------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|
| | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. |
| 2.0 | .264 | 53 | .237 | 65.4 | .216 | 79.2 | .198 | 94 |
| 2.2 | .312 | 58.3 | .281 | 72 | .255 | 87.1 | .234 | 103 |
| 2.4 | .365 | 63.6 | .327 | 78.5 | .297 | 95.0 | .273 | 113 |
| 2.6 | .420 | 68.9 | .378 | 85.1 | .344 | 103 | .315 | 122 |
| 2.8 | .480 | 74.2 | .432 | 91.6 | .392 | 111 | .360 | 132 |
| 3.0 | .544 | 79.5 | .488 | 98.2 | .444 | 119 | .407 | 141 |
| 3.2 | .609 | 84.8 | .549 | 105 | .499 | 127 | .457 | 151 |
| 3.4 | .680 | 90.1 | .612 | 111 | .557 | 134 | .510 | 160 |
| 3.6 | .755 | 95.4 | .679 | 118 | .617 | 142 | .566 | 169 |
| 3.8 | .831 | 101 | .749 | 124 | .680 | 150 | .624 | 179 |
| 4.0 | .913 | 106 | .822 | 131 | .747 | 158 | .685 | 188 |
| 4.2 | .998 | 111 | .897 | 137 | .816 | 166 | .749 | 198 |
| 4.4 | 1.086 | 116 | .977 | 144 | .888 | 174 | .815 | 207 |
| 4.6 | 1.177 | 122 | 1.059 | 150 | .963 | 182 | .883 | 217 |
| 4.8 | 1.27 | 127 | 1.145 | 157 | 1.040 | 190 | .954 | 226 |
| 5.0 | 1.37 | 132 | 1.23 | 163 | 1.122 | 198 | 1.028 | 235 |
| 5.2 | 1.47 | 138 | 1.32 | 170 | 1.20 | 206 | 1.104 | 245 |
| 5.4 | 1.57 | 143 | 1.41 | 177 | 1.28 | 214 | 1.183 | 254 |
| 5.6 | 1.68 | 148 | 1.51 | 183 | 1.37 | 222 | 1.26 | 264 |
| 5.8 | 1.80 | 154 | 1.61 | 190 | 1.46 | 229 | 1.34 | 273 |
| 6.0 | 1.92 | 159 | 1.71 | 196 | 1.56 | 237 | 1.43 | 283 |
| 7.0 | 2.52 | 185 | 2.28 | 229 | 2.07 | 277 | 1.91 | 330 |

The following tables give the friction head in pipe 13 to 36 inches' diameter, per 100 feet length with velocities of water from 2 to 7 feet per second.

INSIDE DIAMETER OF PIPE IN INCHES.

| Velocity in Feet per Sec. | 13 | | 14 | | 15 | | 16 | |
|---------------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|
| | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. |
| 2.0 | .183 | 110 | .169 | 128 | .158 | 147 | .147 | 167 |
| 2.2 | .216 | 121 | .200 | 141 | .187 | 162 | .175 | 184 |
| 2.4 | .252 | 133 | .234 | 154 | .218 | 176 | .205 | 201 |
| 2.6 | .290 | 144 | .270 | 167 | .252 | 191 | .236 | 218 |
| 2.8 | .332 | 156 | .308 | 179 | .288 | 206 | .270 | 234 |
| 3.0 | .375 | 166 | .349 | 192 | .325 | 221 | .306 | 251 |
| 3.2 | .422 | 177 | .392 | 205 | .366 | 235 | .343 | 268 |
| 3.4 | .471 | 188 | .438 | 218 | .408 | 250 | .383 | 284 |
| 3.6 | .522 | 199 | .485 | 231 | .452 | 265 | .425 | 301 |
| 3.8 | .576 | 210 | .535 | 243 | .499 | 280 | .468 | 318 |
| 4.0 | .632 | 221 | .587 | 256 | .548 | 294 | .513 | 335 |
| 4.2 | .691 | 232 | .641 | 269 | .598 | 309 | .561 | 352 |
| 4.4 | .751 | 243 | .698 | 282 | .651 | 324 | .611 | 368 |
| 4.6 | .815 | 254 | .757 | 295 | .707 | 339 | .662 | 385 |
| 4.8 | .881 | 265 | .818 | 308 | .763 | 353 | .715 | 402 |
| 5.0 | .949 | 276 | .881 | 321 | .822 | 368 | .770 | 419 |
| 5.2 | 1.020 | 287 | .947 | 333 | .883 | 383 | .828 | 435 |
| 5.4 | 1.092 | 298 | 1.014 | 346 | .947 | 397 | .888 | 452 |
| 5.6 | 1.167 | 309 | 1.083 | 359 | 1.011 | 412 | .949 | 469 |
| 5.8 | 1.245 | 321 | 1.155 | 372 | 1.078 | 427 | 1.011 | 486 |
| 6.0 | 1.325 | 332 | 1.229 | 385 | 1.148 | 442 | 1.076 | 502 |
| 7.0 | 1.75 | 387 | 1.630 | 449 | 1.520 | 515 | 1.430 | 586 |

LOSS OF HEAD BY FRICTION—(Continued).

INSIDE DIAMETER OF PIPE IN INCHES.

| Velocity in Feet per Sec. | 18 | | 20 | | 22 | | 24 | |
|---------------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|
| | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. |
| 2.0 | .132 | 212 | .119 | 262 | .108 | 316 | .098 | 377 |
| 2.2 | .156 | 233 | .140 | 288 | .127 | 348 | .116 | 414 |
| 2.4 | .182 | 254 | .164 | 314 | .149 | 380 | .136 | 452 |
| 2.6 | .210 | 275 | .189 | 340 | .171 | 412 | .157 | 490 |
| 2.8 | .240 | 297 | .216 | 366 | .195 | 443 | .180 | 528 |
| 3.0 | .271 | 318 | .245 | 393 | .222 | 475 | .204 | 565 |
| 3.2 | .305 | 339 | .275 | 419 | .249 | 507 | .229 | 603 |
| 3.4 | .339 | 360 | .306 | 445 | .278 | 538 | .255 | 641 |
| 3.6 | .377 | 382 | .339 | 471 | .308 | 570 | .283 | 678 |
| 3.8 | .416 | 403 | .374 | 497 | .340 | 601 | .312 | 716 |
| 4.0 | .456 | 424 | .410 | 523 | .373 | 633 | .342 | 754 |
| 4.2 | .499 | 445 | .449 | 550 | .408 | 665 | .374 | 791 |
| 4.4 | .542 | 466 | .488 | 576 | .444 | 697 | .407 | 829 |
| 4.6 | .588 | 488 | .529 | 602 | .482 | 728 | .441 | 867 |
| 4.8 | .636 | 509 | .572 | 628 | .521 | 760 | .476 | 905 |
| 5.0 | .685 | 530 | .617 | 654 | .561 | 792 | .513 | 942 |
| 5.2 | .736 | 551 | .662 | 680 | .602 | 823 | .552 | 980 |
| 5.4 | .788 | 572 | .710 | 707 | .645 | 855 | .591 | 1018 |
| 5.6 | .843 | 594 | .758 | 733 | .690 | 887 | .632 | 1055 |
| 5.8 | .899 | 615 | .809 | 759 | .735 | 918 | .674 | 1093 |
| 6.0 | .957 | 636 | .861 | 785 | .782 | 950 | .717 | 1131 |
| 7.0 | 1.270 | 742 | 1.143 | 916 | 1.040 | 1109 | .953 | 1319 |

INSIDE DIAMETER OF PIPE IN INCHES.

| Velocity in Feet per Sec. | 26 | | 28 | | 30 | | 36 | |
|---------------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|-----------------------|---------------------|
| | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. | Loss of Head in Feet. | Cubic Feet per Min. |
| 2.0 | .091 | 442 | .084 | 513 | .079 | 589 | .066 | 848 |
| 2.2 | .108 | 486 | .099 | 564 | .093 | 648 | .078 | 933 |
| 2.4 | .126 | 531 | .116 | 616 | .109 | 707 | .091 | 1018 |
| 2.6 | .145 | 575 | .134 | 667 | .126 | 766 | .104 | 1100 |
| 2.8 | .165 | 619 | .153 | 718 | .144 | 824 | .119 | 1188 |
| 3.0 | .188 | 663 | .174 | 770 | .163 | 883 | .135 | 1273 |
| 3.2 | .211 | 708 | .195 | 821 | .182 | 942 | .152 | 1357 |
| 3.4 | .235 | 752 | .218 | 872 | .204 | 1001 | .169 | 1442 |
| 3.6 | .261 | 796 | .242 | 923 | .226 | 1060 | .188 | 1527 |
| 3.8 | .288 | 840 | .267 | 974 | .249 | 1119 | .207 | 1612 |
| 4.0 | .315 | 885 | .293 | 1026 | .273 | 1178 | .228 | 1697 |
| 4.2 | .345 | 929 | .320 | 1077 | .299 | 1237 | .249 | 1782 |
| 4.4 | .375 | 973 | .348 | 1129 | .325 | 1296 | .271 | 1866 |
| 4.6 | .407 | 1017 | .378 | 1180 | .353 | 1355 | .294 | 1951 |
| 4.8 | .440 | 1062 | .409 | 1231 | .381 | 1414 | .318 | 2036 |
| 5.0 | .474 | 1106 | .440 | 1283 | .411 | 1472 | .342 | 2121 |
| 5.2 | .510 | 1150 | .473 | 1334 | .441 | 1531 | .368 | 2206 |
| 5.4 | .546 | 1194 | .507 | 1385 | .473 | 1590 | .394 | 2291 |
| 5.6 | .583 | 1239 | .542 | 1437 | .506 | 1649 | .421 | 2376 |
| 5.8 | .622 | 1283 | .578 | 1488 | .540 | 1708 | .450 | 2460 |
| 6.0 | .662 | 1327 | .615 | 1539 | .574 | 1767 | .479 | 2545 |
| 7.0 | .879 | 1548 | .817 | 1796 | .762 | 2061 | .636 | 2968 |

Example.—Have 200 feet head and 600 feet of 11-inch pipe, carrying 119 cubic feet of water per minute. To find effective head. In right-hand column under 11-inch pipe, find 119 cubic feet; opposite this will be found the coefficient of friction for this amount of water, which is 444. Multiply this by the number of hundred feet of pipe, which is 6, and you will have 2.66 feet, which is the loss of head. Therefore the effective head is 200—2.66=197.34.

648 CAPACITIES OF PIPES OF VARIOUS SIZES.

CONTENTS IN CUBIC FEET, U. S. GALLONS, AND WEIGHT OF WATER PER FOOT LENGTH FOR PIPE OF VARIOUS DIAMETERS, ALSO AREA IN SQUARE FEET AND INCHES, AND CIRCUMFERENCE IN INCHES.

| Diameter of Pipe in Inches. | Area in Sq. Feet or Contents in Cubic Feet per Foot of Length. | Contents in U. S. Gallons per Foot Length. | Weight of Water in One-foot Length, in Pounds. | Area in Sq. Inches. | Circumference in Inches. |
|-----------------------------|--|--|--|---------------------|--------------------------|
| 1 | .0055 | .0408 | .34 | .78 | 3.14 |
| 2 | .0218 | .1632 | 1.36 | 3.14 | 6.28 |
| 3 | .0491 | .3672 | 3.06 | 7.06 | 9.42 |
| 4 | .0873 | .6528 | 5.44 | 12.56 | 12.56 |
| 5 | .1364 | 1.020 | 8.51 | 19.63 | 15.70 |
| 6 | .1963 | 1.469 | 12.25 | 28.27 | 18.85 |
| 7 | .2673 | 1.999 | 16.68 | 38.48 | 21.99 |
| 8 | .3491 | 2.611 | 21.79 | 50.26 | 25.13 |
| 9 | .4418 | 3.305 | 27.57 | 63.61 | 28.27 |
| 10 | .5454 | 4.08 | 34.04 | 78.54 | 31.41 |
| 11 | .66 | 4.937 | 41.19 | 95.03 | 34.55 |
| 12 | .7854 | 5.875 | 49.02 | 113.10 | 37.69 |
| 13 | .9218 | 6.895 | 57.54 | 132.73 | 40.84 |
| 14 | 1.069 | 7.997 | 66.73 | 153.94 | 43.98 |
| 15 | 1.227 | 9.180 | 76.60 | 176.71 | 47.12 |
| 16 | 1.396 | 10.44 | 87.16 | 201.06 | 50.26 |
| 18 | 1.768 | 13.22 | 110.31 | 254.47 | 56.54 |
| 20 | 2.182 | 16.32 | 136.19 | 314.16 | 62.83 |
| 22 | 2.640 | 19.75 | 164.79 | 380.13 | 69.11 |
| 24 | 3.142 | 23.50 | 196.11 | 452.39 | 75.39 |
| 26 | 3.687 | 27.58 | 230.16 | 530.93 | 81.68 |
| 28 | 4.276 | 31.99 | 266.93 | 615.75 | 87.96 |
| 30 | 4.909 | 36.72 | 306.42 | 706.86 | 94.24 |
| 32 | 5.585 | 41.78 | 348.64 | 804.25 | 100.53 |
| 34 | 6.305 | 47.16 | 393.59 | 907.92 | 106.81 |
| 36 | 7.069 | 52.88 | 441.25 | 1017.9 | 113.09 |
| 38 | 7.876 | 58.92 | 491.64 | 1134.1 | 119.38 |
| 40 | 8.727 | 65.28 | 544.76 | 1256.6 | 125.66 |
| 42 | 9.621 | 71.97 | 600.59 | 1385.4 | 131.94 |
| 44 | 10.559 | 78.99 | 659.16 | 1520.5 | 138.23 |
| 46 | 11.541 | 86.33 | 720.44 | 1661.9 | 144.51 |
| 48 | 12.566 | 94.00 | 784.45 | 1809.6 | 150.79 |
| 50 | 13.635 | 102.00 | 851.18 | 1963.5 | 157.08 |
| 52 | 14.748 | 110.32 | 920.64 | 2123.7 | 163.36 |
| 54 | 15.90 | 118.97 | 992.82 | 2290.2 | 169.64 |
| 60 | 19.63 | 146.88 | 1225.71 | 2827.4 | 188.49 |
| 66 | 23.76 | 177.72 | 1483.11 | 3421.2 | 207.34 |
| 72 | 28.27 | 211.51 | 1765.02 | 4071.5 | 226.19 |

NUMBER OF GALLONS IN ROUND CISTERNS AND TANKS.

| Depth in Feet. | Diameter in Feet. | | | | | | | |
|----------------|-------------------|-------|-------|-------|-------|--------|--------|--------|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 5 | 735 | 1,060 | 1,440 | 1,875 | 2,380 | 2,925 | 3,550 | 4,237 |
| 6 | 881 | 1,270 | 1,728 | 2,250 | 2,855 | 3,510 | 4,260 | 5,084 |
| 7 | 1,028 | 1,480 | 2,016 | 2,625 | 3,330 | 4,095 | 4,970 | 5,931 |
| 8 | 1,175 | 1,690 | 2,304 | 3,000 | 3,805 | 4,680 | 5,680 | 6,778 |
| 9 | 1,322 | 1,900 | 2,592 | 3,375 | 4,280 | 5,265 | 6,390 | 7,625 |
| 10 | 1,469 | 2,110 | 2,880 | 3,750 | 4,755 | 5,850 | 7,100 | 8,472 |
| 11 | 1,616 | 2,320 | 3,168 | 4,125 | 5,250 | 6,435 | 7,810 | 9,319 |
| 12 | 1,762 | 2,530 | 3,456 | 4,500 | 5,705 | 7,020 | 8,520 | 10,166 |
| 13 | 1,909 | 2,740 | 3,744 | 4,875 | 6,180 | 7,605 | 9,230 | 11,013 |
| 14 | 2,056 | 2,950 | 4,032 | 5,250 | 6,655 | 8,190 | 9,940 | 11,860 |
| 15 | 2,203 | 3,160 | 4,320 | 5,625 | 7,130 | 8,775 | 10,650 | 12,707 |
| 16 | 2,356 | 3,370 | 4,608 | 6,000 | 7,605 | 9,360 | 11,360 | 13,554 |
| 17 | 2,497 | 3,580 | 4,896 | 6,375 | 8,080 | 9,945 | 12,070 | 14,401 |
| 18 | 2,644 | 3,790 | 5,184 | 6,750 | 8,535 | 10,530 | 12,780 | 15,248 |
| 19 | 2,791 | 4,000 | 5,472 | 7,125 | 9,010 | 11,115 | 13,490 | 16,095 |
| 20 | 2,938 | 4,210 | 5,760 | 7,500 | 9,490 | 11,700 | 14,200 | 16,942 |

| Depth in Feet. | Diameter in Feet. | | | | | | | |
|----------------|-------------------|--------|--------|--------|--------|--------|--------|--------|
| | 13 | 14 | 15 | 16 | 18 | 20 | 22 | 24 |
| 5 | 4,960 | 5,765 | 6,698 | 7,520 | 9,516 | 11,750 | 14,215 | 16,918 |
| 6 | 5,952 | 6,918 | 8,038 | 9,024 | 11,419 | 14,100 | 17,059 | 20,302 |
| 7 | 6,944 | 8,071 | 9,378 | 10,528 | 13,322 | 16,450 | 19,902 | 23,680 |
| 8 | 7,936 | 9,224 | 10,718 | 12,032 | 15,225 | 18,800 | 22,745 | 27,070 |
| 9 | 8,928 | 10,377 | 12,058 | 13,536 | 17,128 | 21,150 | 25,588 | 30,454 |
| 10 | 9,920 | 11,530 | 13,398 | 15,040 | 19,031 | 23,500 | 28,431 | 33,838 |
| 11 | 10,913 | 12,683 | 14,738 | 16,544 | 20,934 | 25,850 | 31,274 | 37,222 |
| 12 | 11,904 | 13,836 | 16,078 | 18,048 | 22,837 | 28,200 | 34,117 | 40,606 |
| 13 | 12,896 | 14,989 | 17,418 | 19,552 | 24,740 | 30,550 | 36,960 | 43,990 |
| 14 | 13,888 | 16,142 | 18,758 | 21,056 | 26,643 | 32,900 | 39,803 | 47,374 |
| 15 | 14,880 | 17,295 | 20,098 | 22,260 | 28,546 | 35,250 | 42,646 | 50,758 |
| 16 | 15,872 | 18,448 | 21,438 | 26,064 | 30,449 | 37,600 | 45,489 | 54,142 |
| 17 | 16,864 | 19,601 | 22,778 | 25,568 | 32,352 | 39,950 | 48,332 | 57,520 |
| 18 | 17,856 | 20,754 | 24,118 | 27,072 | 34,255 | 42,300 | 51,175 | 60,910 |
| 19 | 18,848 | 21,907 | 25,458 | 28,576 | 36,158 | 44,650 | 54,018 | 64,294 |
| 20 | 19,840 | 23,060 | 26,798 | 30,080 | 38,062 | 47,000 | 56,861 | 67,678 |

To find the number of gallons in a tank of unequal diameter multiply the inside bottom diameter in inches by the inside top diameter in inches, then this product by 34: point off four figures and the result will be the average number of gallons to one inch in depth of the tank.

Data Regarding Water.—Doubling the diameter of a pipe increases its capacity four times.

A gallon of water (United States standard) weighs 8.3311 pounds and contains 231 cubic inches.

A cubic foot of water contains $7\frac{1}{2}$ gallons, 1728 cubic inches, and weighs $62\frac{1}{2}$ pounds.

Cubic feet of water multiplied by 62.5 equals pounds avoirdupois; cubic inches of water multiplied by 0.03608 equals pounds avoirdupois.

Cubic feet multiplied by 7.48 equals United States gallons.

Cubic inches multiplied by 0.004329 equals United States gallons.

A column of water 1 inch square and 2.31 feet high weighs 1 pound.

A column of water 1 inch square and 1 foot high weighs 0.433 pound.

A column of water 33.947 feet high equals the pressure of the atmosphere at the sea-level.

Water is an almost universal solvent; consequently pure water does not occur in nature. Sea-water contains nearly every known substance in solution.

The latent heat of water is 79 thermal units. When water freezes it gives off its latent heat. The latent heat of steam is 536 thermal units. When steam condenses into water it gives off its latent heat.

Pure water consists of 2 parts hydrogen and 1 part oxygen. Chemical name, hydrogen oxide; chemical symbol, H_2O . Pure water is a colorless, odorless, tasteless, transparent liquid, and is practically incompressible. Water freezes at 32° Fahr. and boils at 212° Fahr. At its maximum density, 39.1° Fahr., it is the standard for specific gravities, and 1 cubic centimetre weighs 1 gram. Salt water boils at 224° Fahr.

$$1 \text{ U. S. gallon} = \begin{cases} 231 \text{ cubic inches.} \\ 0.13369 \text{ cubic foot.} \\ 8.3311 \text{ pounds of distilled water.} \\ 8.34 \text{ pounds in ordinary practice.} \end{cases}$$

1 cubic foot = { 62.425 pounds at 39.1° Fahr., maximum density.
62.418 pounds at 32° Fahr., freezing-point.
62.355 pounds at 62° Fahr., standard temperature.
59.64 pounds at 212° Fahr., boiling-point.
57.5 pounds at ice.
7.480 U. S. gallons.

1 pound = 27.7 cubic inches.
1 cubic inch = 0.03612-pound.

Data on Pumps.—DEPTH OF SUCTION.—Theoretically a perfect pump will lift water from a depth of nearly 34 feet, corresponding to a perfect vacuum (14.7 lbs. × 2.309 = 33.95 feet); but since a perfect vacuum cannot be obtained, on account of valve leakage, air contained in the water, and the vapor of the water itself, the actual height is generally less than 30 feet. In pumping hot water, the water must flow into the pump by gravity. The following table shows the theoretical maximum depth of suction for different temperatures, leakage not considered:

| Temperature, F. | Absolute Pressure of Vapor, Pounds per Sq. Inch. | Vacuum in Inches of Mercury. | Maximum Depth of Suction, Feet. | Temperature, F. | Absolute Pressure of Vapor, Pounds per Sq. Inch. | Vacuum in Inches of Mercury. | Maximum Depth of Suction, Feet. |
|-----------------|--|------------------------------|---------------------------------|-----------------|--|------------------------------|---------------------------------|
| 101.4 | 1 | 27.88 | 31.6 | 183.0 | 8 | 13.63 | 15.5 |
| 126.2 | 2 | 25.85 | 29.3 | 188.4 | 9 | 11.59 | 13.2 |
| 144.7 | 3 | 23.81 | 27.0 | 193.2 | 10 | 9.55 | 10.9 |
| 153.3 | 4 | 21.77 | 24.7 | 197.6 | 11 | 7.51 | 8.5 |
| 162.5 | 5 | 19.74 | 22.4 | 201.9 | 12 | 5.48 | 6.2 |
| 170.3 | 6 | 17.70 | 20.1 | 205.8 | 13 | 3.44 | 3.9 |
| 177.0 | 7 | 15.66 | 17.8 | 209.6 | 14 | 1.40 | 1.6 |

A suction-lift pump is one that raises water only to the level of the pump spout.

A force-pump is one that raises water to the pump and also forces it to any reasonable altitude above the pump

WEIGHT OF WATER PER CUBIC FOOT AT DIFFERENT TEMPERATURES.

| Temperature, Fahrenheit. | Weight, Pounds per Cubic Foot. | Temperature, Fahrenheit. | Weight, Pounds per Cubic Foot. | Temperature, Fahrenheit. | Weight, Pounds per Cubic Foot. | Temperature, Fahrenheit. | Weight, Pounds per Cubic Foot. | Temperature, Fahrenheit. | Weight, Pounds per Cubic Foot. |
|--------------------------|--------------------------------|--------------------------|--------------------------------|--------------------------|--------------------------------|--------------------------|--------------------------------|--------------------------|--------------------------------|
| 32° | 62.42 | 140° | 61.37 | 240° | 59.10 | 350° | 55.52 | 460° | 51.26 |
| 40 | 62.42 | 150 | 61.18 | 250 | 58.81 | 360 | 55.16 | 470 | 50.85 |
| 50 | 62.41 | 160 | 60.98 | 260 | 58.52 | 370 | 54.79 | 480 | 50.44 |
| 60 | 62.37 | 170 | 60.77 | 270 | 58.21 | 380 | 54.41 | 490 | 50.05 |
| 70 | 62.31 | 180 | 60.55 | 280 | 57.90 | 390 | 54.03 | 500 | 49.61 |
| 80 | 62.23 | 190 | 60.32 | 290 | 57.59 | 400 | 53.64 | 510 | 49.20 |
| 90 | 62.13 | 200 | 60.07 | 300 | 57.26 | 410 | 53.26 | 520 | 48.78 |
| 100 | 62.02 | 210 | 59.82 | 310 | 56.93 | 420 | 52.86 | 530 | 48.36 |
| 110 | 61.69 | 212 | 59.71 | 320 | 56.58 | 430 | 52.47 | 540 | 47.94 |
| 120 | 61.74 | 220 | 59.64 | 330 | 56.24 | 440 | 52.07 | 550 | 47.52 |
| 130 | 61.56 | 230 | 59.37 | 340 | 55.88 | 450 | 51.66 | 560 | 47.10 |

One ft. of water column at 39.1° F. = 62.425 lbs. on the square ft.

“ “ “ “ “ “ “ “ = 0.4335 lb. “ “ “ in.

“ “ “ “ “ “ “ “ = 0.0295 atmospheric pressure.

“ “ “ “ “ “ “ “ = 0.8826 in. mercury column at 32° F.

“ “ “ “ “ “ “ “ = 773.3 ft. of air column at 32° F. and atmospheric pressure.

One lb. pressure on sq. ft. = 0.01602 ft. water column at 39.1° F.

“ “ “ “ “ “ in. = 2.307 “ “ “ “ 39.1° F.

One atmospheric pressure = 29.92 in. mercury column = 33.9 ft. water column.

One inch of mercury column at 32° F. = 1.133 ft. water column.

One foot of air column at 32° F. and 1 atmospheric pressure = 0.001293 ft. water column.

Useful Information Regarding Water.—The mean pressure of the atmosphere is usually estimated at 14.7 pounds per square inch, so that with a perfect vacuum it will sustain a column of mercury 29.9 inches, or a column of water 33.9 feet high.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. Approximately, we say that every foot elevation is equal to

$\frac{1}{2}$ pound pressure per square inch; this allows for ordinary friction.

To find the diameter of a pump-cylinder to move a given quantity of water per minute (100 feet of piston being the standard of speed), divide the number of gallons by 4, then extract the square root, and the product will be the diameter in inches of the pump-cylinder.

To find quantity of water elevated in one minute running at 100 feet of piston speed per minute, square the diameter of the water-cylinder in inches and multiply by 4. Example: Capacity of a 5-inch cylinder is desired. The square of the diameter (5 inches) is 25, which, multiplied by 4, gives 100, the number of gallons per minute (approximately).

To find the horse-power necessary to elevate water to a given height, multiply the total weight of the water in pounds by the height in feet, and divide the product by 33,000 (an allowance of 25 per cent should be added for water-friction, and a further allowance of 25 per cent for loss in steam-cylinder).

The area of the steam-piston, multiplied by the steam pressure, gives the total amount of pressure that can be exerted. *The area of the water-piston*, multiplied by the pressure of water per square inch, gives the resistance. A margin must be made between the *power* and *resistance* to move the pistons at the required speed—say from 20 to 40 per cent, according to speed and other conditions.

To find the capacity of a cylinder in gallons. Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a United States gallon in inches), and product is the capacity in gallons.

To find the height in feet of a column of water corresponding with a given pressure, multiply the pressure in pounds by 2.3 feet.

The following table is arranged to show at a glance the equivalent pressure due to columns of water from 10 to 400 feet in height. Also more particularly to show the number of gallons of water delivered, and the height to which it will be projected through nozzles from $\frac{1}{4}$ inch to 2 inches in diameter.

Diameter of Nozzle in Inches.

| Height of Column in Feet. | Corresponding Pressure in Pounds per Square Inch. | | 1 | | 1 1/4 | | 1 1/2 | | 1 3/4 | | 2 | | 2 1/2 | | 3 | | 4 | | 5 | | 6 | | 8 | | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------------------|---|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|--------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|---------|-----|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| | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | Height of Jet in Feet. | Gallons Dis- charged per Minute. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 9.37 | 6 | 9.7 | 22.7 | 9.8 | 58.2 | 9.9 | 91 | 9.9 | 130.8 | 9.9 | 177.6 | 9.9 | 232.8 | 9.9 | 309.6 | 9.9 | 408 | 9.9 | 520.8 | 9.9 | 666.8 | 9.9 | 847.1 | 9.9 | 1043 | 9.9 | 1276.8 | 9.9 | 1514.4 | 9.9 | 1730.0 | 9.9 | 1945.6 | 9.9 | 2161.2 | 9.9 | 2376.8 | 9.9 | 2592.4 | 9.9 | 2808.0 | 9.9 | 3023.6 | 9.9 | 3239.2 | 9.9 | 3454.8 | 9.9 | 3670.4 | 9.9 | 3886.0 | 9.9 | 4101.6 | 9.9 | 4317.2 | 9.9 | 4532.8 | 9.9 | 4748.4 | 9.9 | 4964.0 | 9.9 | 5179.6 | 9.9 | 5395.2 | 9.9 | 5610.8 | 9.9 | 5826.4 | 9.9 | 6042.0 | 9.9 | 6257.6 | 9.9 | 6468.8 | 9.9 | 6680.0 | 9.9 | 6891.2 | 9.9 | 7102.4 | 9.9 | 7313.6 | 9.9 | 7524.8 | 9.9 | 7736.0 | 9.9 | 7947.2 | 9.9 | 8158.4 | 9.9 | 8369.6 | 9.9 | 8580.8 | 9.9 | 8792.0 | 9.9 | 9003.2 | 9.9 | 9214.4 | 9.9 | 9425.6 | 9.9 | 9636.8 | 9.9 | 9848.0 | 9.9 | 10059.2 | 9.9 | 10270.4 | 9.9 | 10481.6 | 9.9 | 10692.8 | 9.9 | 10904.0 | 9.9 | 11115.2 | 9.9 | 11326.4 | 9.9 | 11537.6 | 9.9 | 11748.8 | 9.9 | 11960.0 | 9.9 | 12171.2 | 9.9 | 12382.4 | 9.9 | 12593.6 | 9.9 | 12804.8 | 9.9 | 13016.0 | 9.9 | 13227.2 | 9.9 | 13438.4 | 9.9 | 13649.6 | 9.9 | 13860.8 | 9.9 | 14072.0 | 9.9 | 14283.2 | 9.9 | 14494.4 | 9.9 | 14705.6 | 9.9 | 14916.8 | 9.9 | 15128.0 | 9.9 | 15339.2 | 9.9 | 15550.4 | 9.9 | 15761.6 | 9.9 | 15972.8 | 9.9 | 16184.0 | 9.9 | 16395.2 | 9.9 | 16606.4 | 9.9 | 16817.6 | 9.9 | 17028.8 | 9.9 | 17240.0 | 9.9 | 17451.2 | 9.9 | 17662.4 | 9.9 | 17873.6 | 9.9 | 18084.8 | 9.9 | 18296.0 | 9.9 | 18507.2 | 9.9 | 18718.4 | 9.9 | 18929.6 | 9.9 | 19140.8 | 9.9 | 19352.0 | 9.9 | 19563.2 | 9.9 | 19774.4 | 9.9 | 19985.6 | 9.9 | 20196.8 | 9.9 | 20408.0 | 9.9 | 20619.2 | 9.9 | 20830.4 | 9.9 | 21041.6 | 9.9 | 21252.8 | 9.9 | 21464.0 | 9.9 | 21675.2 | 9.9 | 21886.4 | 9.9 | 22097.6 | 9.9 | 22308.8 | 9.9 | 22520.0 | 9.9 | 22731.2 | 9.9 | 22942.4 | 9.9 | 23153.6 | 9.9 | 23364.8 | 9.9 | 23576.0 | 9.9 | 23787.2 | 9.9 | 24000.0 | 9.9 | 24211.2 | 9.9 | 24422.4 | 9.9 | 24633.6 | 9.9 | 24844.8 | 9.9 | 25056.0 | 9.9 | 25267.2 | 9.9 | 25478.4 | 9.9 | 25689.6 | 9.9 | 25900.8 | 9.9 | 26112.0 | 9.9 | 26323.2 | 9.9 | 26534.4 | 9.9 | 26745.6 | 9.9 | 26956.8 | 9.9 | 27168.0 | 9.9 | 27379.2 | 9.9 | 27590.4 | 9.9 | 27801.6 | 9.9 | 28012.8 | 9.9 | 28224.0 | 9.9 | 28435.2 | 9.9 | 28646.4 | 9.9 | 28857.6 | 9.9 | 29068.8 | 9.9 | 29280.0 | 9.9 | 29491.2 | 9.9 | 29702.4 | 9.9 | 29913.6 | 9.9 | 30124.8 | 9.9 | 30336.0 | 9.9 | 30547.2 | 9.9 | 30758.4 | 9.9 | 30969.6 | 9.9 | 31180.8 | 9.9 | 31392.0 | 9.9 | 31603.2 | 9.9 | 31814.4 | 9.9 | 32025.6 | 9.9 | 32236.8 | 9.9 | 32448.0 | 9.9 | 32659.2 | 9.9 | 32870.4 | 9.9 | 33081.6 | 9.9 | 33292.8 | 9.9 | 33504.0 | 9.9 | 33715.2 | 9.9 | 33926.4 | 9.9 | 34137.6 | 9.9 | 34348.8 | 9.9 | 34560.0 | 9.9 | 34771.2 | 9.9 | 34982.4 | 9.9 | 35193.6 | 9.9 | 35404.8 | 9.9 | 35616.0 | 9.9 | 35827.2 | 9.9 | 36038.4 | 9.9 | 36249.6 | 9.9 | 36460.8 | 9.9 | 36672.0 | 9.9 | 36883.2 | 9.9 | 37094.4 | 9.9 | 37305.6 | 9.9 | 37516.8 | 9.9 | 37728.0 | 9.9 | 37939.2 | 9.9 | 38150.4 | 9.9 | 38361.6 | 9.9 | 38572.8 | 9.9 | 38784.0 | 9.9 | 38995.2 | 9.9 | 39206.4 | 9.9 | 39417.6 | 9.9 | 39628.8 | 9.9 | 39840.0 | 9.9 | 40051.2 | 9.9 | 40262.4 | 9.9 | 40473.6 | 9.9 | 40684.8 | 9.9 | 40896.0 | 9.9 | 41107.2 | 9.9 | 41318.4 | 9.9 | 41529.6 | 9.9 | 41740.8 | 9.9 | 41952.0 | 9.9 | 42163.2 | 9.9 | 42374.4 | 9.9 | 42585.6 | 9.9 | 42796.8 | 9.9 | 43008.0 | 9.9 | 43219.2 | 9.9 | 43430.4 | 9.9 | 43641.6 | 9.9 | 43852.8 | 9.9 | 44064.0 | 9.9 | 44275.2 | 9.9 | 44486.4 | 9.9 | 44697.6 | 9.9 | 44908.8 | 9.9 | 45120.0 | 9.9 | 45331.2 | 9.9 | 45542.4 | 9.9 | 45753.6 | 9.9 | 45964.8 | 9.9 | 46176.0 | 9.9 | 46387.2 | 9.9 | 46598.4 | 9.9 | 46809.6 | 9.9 | 47020.8 | 9.9 | 47232.0 | 9.9 | 47443.2 | 9.9 | 47654.4 | 9.9 | 47865.6 | 9.9 | 48076.8 | 9.9 | 48288.0 | 9.9 | 48499.2 | 9.9 | 48710.4 | 9.9 | 48921.6 | 9.9 | 49132.8 | 9.9 | 49344.0 | 9.9 | 49555.2 | 9.9 | 49766.4 | 9.9 | 49977.6 | 9.9 | 50188.8 | 9.9 | 50400.0 | 9.9 | 50611.2 | 9.9 | 50822.4 | 9.9 | 51033.6 | 9.9 | 51244.8 | 9.9 | 51456.0 | 9.9 | 51667.2 | 9.9 | 51878.4 | 9.9 | 52089.6 | 9.9 | 52300.8 | 9.9 | 52512.0 | 9.9 | 52723.2 | 9.9 | 52934.4 | 9.9 | 53145.6 | 9.9 | 53356.8 | 9.9 | 53568.0 | 9.9 | 53779.2 | 9.9 | 53990.4 | 9.9 | 54201.6 | 9.9 | 54412.8 | 9.9 | 54624.0 | 9.9 | 54835.2 | 9.9 | 55046.4 | 9.9 | 55257.6 | 9.9 | 55468.8 | 9.9 | 55680.0 | 9.9 | 55891.2 | 9.9 | 56102.4 | 9.9 | 56313.6 | 9.9 | 56524.8 | 9.9 | 56736.0 | 9.9 | 56947.2 | 9.9 | 57158.4 | 9.9 | 57369.6 | 9.9 | 57580.8 | 9.9 | 57792.0 | 9.9 | 58003.2 | 9.9 | 58214.4 | 9.9 | 58425.6 | 9.9 | 58636.8 | 9.9 | 58848.0 | 9.9 | 59059.2 | 9.9 | 59270.4 | 9.9 | 59481.6 | 9.9 | 59692.8 | 9.9 | 59904.0 | 9.9 | 60115.2 | 9.9 | 60326.4 | 9.9 | 60537.6 | 9.9 | 60748.8 | 9.9 | 60960.0 | 9.9 | 61171.2 | 9.9 | 61382.4 | 9.9 | 61593.6 | 9.9 | 61804.8 | 9.9 | 62016.0 | 9.9 | 62227.2 | 9.9 | 62438.4 | 9.9 | 62649.6 | 9.9 | 62860.8 | 9.9 | 63072.0 | 9.9 | 63283.2 | 9.9 | 63494.4 | 9.9 | 63705.6 | 9.9 | 63916.8 | 9.9 | 64128.0 | 9.9 | 64339.2 | 9.9 | 64550.4 | 9.9 | 64761.6 | 9.9 | 64972.8 | 9.9 | 65184.0 | 9.9 | 65395.2 | 9.9 | 65606.4 | 9.9 | 65817.6 | 9.9 | 66028.8 | 9.9 | 66240.0 | 9.9 | 66451.2 | 9.9 | 66662.4 | 9.9 | 66873.6 | 9.9 | 67084.8 | 9.9 | 67296.0 | 9.9 | 67507.2 | 9.9 | 67718.4 | 9.9 | 67929.6 | 9.9 | 68140.8 | 9.9 | 68352.0 | 9.9 | 68563.2 | 9.9 | 68774.4 | 9.9 | 68985.6 | 9.9 | 69196.8 | 9.9 | 69408.0 | 9.9 | 69619.2 | 9.9 | 69830.4 | 9.9 | 70041.6 | 9.9 | 70252.8 | 9.9 | 70464.0 | 9.9 | 70675.2 | 9.9 | 70886.4 | 9.9 | 71097.6 | 9.9 | 71308.8 | 9.9 | 71520.0 | 9.9 | 71731.2 | 9.9 | 71942.4 | 9.9 | 72153.6 | 9.9 | 72364.8 | 9.9 | 72576.0 | 9.9 | 72787.2 | 9.9 | 73000.0 | 9.9 | 73211.2 | 9.9 | 73422.4 | 9.9 | 73633.6 | 9.9 | 73844.8 | 9.9 | 74056.0 | 9.9 | 74267.2 | 9.9 | 74478.4 | 9.9 | 74689.6 | 9.9 | 74900.8 | 9.9 | 75112.0 | 9.9 | 75323.2 | 9.9 | 75534.4 | 9.9 | 75745.6 | 9.9 | 75956.8 | 9.9 | 76168.0 | 9.9 | 76379.2 | 9.9 | 76590.4 | 9.9 | 76801.6 | 9.9 | 77012.8 | 9.9 | 77224.0 | 9.9 | 77435.2 | 9.9 | 77646.4 | 9.9 | 77857.6 | 9.9 | 78068.8 | 9.9 | 78280.0 | 9.9 | 78491.2 | 9.9 | 78702.4 | 9.9 | 78913.6 | 9.9 | 79124.8 | 9.9 | 79336.0 | 9.9 | 79547.2 | 9.9 | 79758.4 | 9.9 | 79969.6 | 9.9 | 80180.8 | 9.9 | 80392.0 | 9.9 | 80603.2 | 9.9 | 80814.4 | 9.9 | 81025.6 | 9.9 | 81236.8 | 9.9 | 81448.0 | 9.9 | 81659.2 | 9.9 | 81870.4 | 9.9 | 82081.6 | 9.9 | 82292.8 | 9.9 | 82504.0 | 9.9 | 82715.2 | 9.9 | 82926.4 | 9.9 | 83137.6 | 9.9 | 83348.8 | 9.9 | 83560.0 | 9.9 | 83771.2 | 9.9 | 83982.4 | 9.9 | 84193.6 | 9.9 | 84404.8 | 9.9 | 84616.0 | 9.9 | 84827.2 | 9.9 | 85038.4 | 9.9 | 85249.6 | 9.9 | 85460.8 | 9.9 | 85672.0 | 9.9 | 85883.2 | 9.9 | 86094.4 | 9.9 | 86305.6 | 9.9 | 86516.8 | 9.9 | 86728.0 | 9.9 | 86939.2 | 9.9 | 87150.4 | 9.9 | 87361.6 | 9.9 | 87572.8 | 9.9 | 87784.0 | 9.9 | 87995.2 | 9.9 | 88206.4 | 9.9 | 88417.6 | 9.9 | 88628.8 | 9.9 | 88840.0 | 9.9 | 89051.2 | 9.9 | 89262.4 | 9.9 | 89473.6 | 9.9 | 89684.8 | 9.9 | 89896.0 | 9.9 | 90107.2 | 9.9 | 90318.4 | 9.9 | 90529.6 | 9.9 | 90740.8 | 9.9 | 90952.0 | 9.9 | 91163.2 | 9.9 | 91374.4 | 9.9 | 91585.6 | 9.9 | 91796.8 | 9.9 | 92008.0 | 9.9 | 92219.2 | 9.9 | 92430.4 | 9.9 | 92641.6 | 9.9 | 92852.8 | 9.9 | 93064.0 | 9.9 | 93275.2 | 9.9 | 93486.4 | 9.9 | 93697.6 | 9.9 | 93908.8 | 9.9 | 94120.0 | 9.9 | 94331.2 | 9.9 | 94542.4 | 9.9 | 94753.6 | 9.9 | 94964.8 | 9.9 | 95176.0 | 9.9 | 95387.2 | 9.9 | 95598.4 | 9.9 | 95809.6 | 9.9 | 96020.8 | 9.9 | 96232.0 | 9.9 | 96443.2 | 9.9 | 96654.4 | 9.9 | 96865.6 | 9.9 | 97076.8 | 9.9 | 97288.0 | 9.9 | 97499.2 | 9.9 | 97710.4 | 9.9 | 97921.6 | 9.9 | 98132.8 | 9.9 | 98344.0 | 9.9 | 98555.2 | 9.9 | 98766.4 | 9.9 | 98977.6 | 9.9 | 99188.8 | 9.9 | 99400.0 | 9.9 | 99611.2 | 9.9 | 99822.4 | 9.9 | 100033.6 | 9.9 | 100244.8 | 9.9 | 100456.0 | 9.9 | 100667.2 | 9.9 | 100878.4 | 9.9 | 101089.6 | 9.9 | 101300.8 | 9.9 | 101512.0 | 9.9 | 101723.2 | 9.9 | 101934.4 | 9.9 | 102145.6 | 9.9 | 102356.8 | 9.9 | 102568.0 | 9.9 | 102779.2 | 9.9 | 102990.4 | 9.9 | 103201.6 | 9.9 | 103412.8 | 9.9 | 103624.0 | 9.9 | 103835.2 | 9.9 | 104046.4 | 9.9 | 104257.6 | 9.9 | 104468.8 | 9.9 | 104680.0 | 9.9 | 104891.2 | 9.9 | 105102.4 | 9.9 | 105313.6 | 9.9 | 105524.8 | 9.9 | 105736.0 | 9.9 | 105947.2 | 9.9 | 106158.4 | 9.9 | 106369.6 | 9.9 | 106580.8 | 9.9 | 106792.0 | 9.9 | 107003.2 | 9.9 | 107214.4 | 9.9 | 107425.6 | 9.9 | 107636.8 | 9.9 | 107848.0 | 9.9 | 108059.2 | 9.9 | 108270.4 | 9.9 | 108481.6 | 9.9 | 108692.8 | 9.9 | 108904.0 | 9.9 | 109115.2 | 9.9 | 109326.4 | 9.9 | 109537.6 | 9.9 | 109748.8 | 9.9 | 109960.0 | 9.9 | 110171.2 | 9.9 | 110382.4 | 9.9 | 110593.6 | 9.9 | 110804.8 | 9.9 | 111016.0 | 9.9 | 111227.2 | 9.9 | 111438.4 | 9.9 | 111649.6 | 9.9 | 111860.8 | 9.9 | 112072.0 | 9.9 | 112283.2 | 9.9 | 112494.4 | 9.9 | 112705.6 | 9.9 | 112916.8 | 9.9 | 113128.0 | 9.9 | 113339.2 | 9.9 | 113550.4 | 9.9 | 113761.6 | 9.9 | 113972.8 | 9.9 | 114184.0 | 9.9 | 114395.2 | 9.9 | 114606.4 | 9.9 | 114817.6 | 9.9 | 115028.8 | 9.9 | 115240.0 | 9.9 | 115451.2 | 9.9 | 115662.4 | 9.9 | 115873.6 | 9.9 | 116084.8 | 9.9 | 116296.0 | 9.9 | 116507.2 | 9.9 | 116718.4 | 9.9 | 116929.6 | 9.9 | 117140.8 | 9.9 | 117352.0 | 9.9 | 117563.2 | 9.9 | 117774.4 | 9.9 | 117985.6 | 9.9 | 118196.8 | 9.9 | 118408.0 | 9.9 | 118619.2 | 9.9 | 118830.4 | 9.9 | 119041.6 | 9.9 | 119252.8 | 9.9 | 119464.0 | 9.9 | 119675.2 | 9.9 | 119886.4 | 9.9 | 120097.6 | 9.9 | 120308.8 | 9.9 | 120520.0 | 9.9 | 120731.2 | 9.9 | 120 |

WEIGHT AND CAPACITY OF DIFFERENT STANDARD GALLONS OF WATER.

| | Cubic Inches in a Gallon. | Weight of a Gallon in Pounds. | Gallons in a Cubic Foot. |
|------------------------------|------------------------------|-------------------------------------|-----------------------------|
| Imperial or English. | 277.274 | 10.00 | 6.232102 |
| United States. | 231 | 8.33111 | 7.480519 |

DISCHARGE OF WATER IN PIPES.

For any Length and Head, and for Diameters from 1 Inch to 10 Feet, in
Cubic Feet per Minute.—(BEARDMORE.)

| Diameter. | | Tabular Number. | Diameter. | | Tabular Number. | Diameter. | | Tabular Number. |
|-----------|------|--------------------|-----------|------|--------------------|-----------|------|--------------------|
| Ft. | Ins. | | Ft. | Ins. | | Ft. | Ins. | |
| | 1 | 4.71 | 1 | 7 | 7433 | 3 | 7 | 57265 |
| | 1.25 | 8.48 | 1 | 8 | 8449 | 3 | 8 | 60648 |
| | 1.5 | 13.02 | 1 | 9 | 9544 | 3 | 9 | 64156 |
| | 1.75 | 19.15 | 1 | 10 | 10722 | 3 | 10 | 67782 |
| | 2 | 26.69 | 1 | 11 | 11983 | 3 | 11 | 71526 |
| | 2.5 | 46.67 | 2 | | 13328 | 4 | | 75392 |
| | 3 | 73.5 | 2 | 1 | 14758 | 4 | 3 | 87730 |
| | 3.5 | 108.14 | 2 | 2 | 16278 | 4 | 6 | 101207 |
| | 4 | 151.02 | 2 | 3 | 17889 | 4 | 9 | 115854 |
| | 4.5 | 194.84 | 2 | 4 | 19592 | 5 | | 131703 |
| | 5 | 263.87 | 2 | 5 | 21390 | 5 | 3 | 148791 |
| | 6 | 416.54 | 2 | 6 | 23282 | 5 | 6 | 167139 |
| | 7 | 612.32 | 2 | 7 | 25270 | 5 | 9 | 186786 |
| | 8 | 654.99 | 2 | 8 | 27358 | 6 | | 207754 |
| | 9 | 1147.6 | 2 | 9 | 29547 | 6 | 6 | 253781 |
| | 10 | 1493.5 | 2 | 10 | 31834 | 7 | | 305437 |
| | 11 | 1894.9 | 2 | 11 | 34228 | 7 | 6 | 362935 |
| | 1 | 2356 | 3 | | 36725 | 8 | | 426481 |
| | 1 1 | 2376.7 | 3 | 1 | 39329 | 8 | 6 | 496275 |
| | 1 2 | 3463.3 | 3 | 2 | 42040 | 9 | | 572508 |
| | 1 3 | 4115.9 | 3 | 3 | 44863 | 9 | 6 | 655369 |
| | 1 4 | 4836.9 | 3 | 4 | 47794 | 10 | | 745038 |
| | 1 5 | 5628.5 | 3 | 5 | 50835 | | | |
| | 1 6 | 6493.1 | 3 | 6 | 53995 | | | |

This table is applicable to sewers and drains by taking same proportion of tabular numbers that area of cross-section of water in sewer or drain bears to whole area of sewer or drain.

To COMPUTE VOLUME DISCHARGED WHEN LENGTH OF PIPE, HEIGHT OR FALL, AND DIAMETER ARE GIVEN.—*Rule.*—Divide tabular number, opposite to diameter of tube, by square root of rate of inclination, and quotient will give volume required in cubic feet per minute.

Example.—A pipe has a diameter of 9 inches, and a length of 4750 feet; what is its discharge per minute under a head of 17.5 feet?

$$\text{Tab. No. 9 in.} = 1147.6, \text{ and } \frac{1147.61}{\sqrt{\frac{4750}{17.5}}} = \frac{1147.61}{16.47} = 69.67 \text{ cubic feet.}$$

TO COMPUTE DIAMETER WHEN LENGTH, HEAD, AND VOLUME ARE GIVEN.—*Rule.*—Multiply discharge per minute by square root of ratio of inclination; take nearest corresponding number in table, and opposite to it is diameter required.

Example.—Take elements of preceding case.

$$69.67 \times \sqrt{\frac{4750}{17.5}} = 1147.61, \text{ and opposite to this is 9 inches.}$$

Or, $\sqrt[5]{\frac{vl}{1542h}} = d$ in feet; v representing velocity in feet per second, and l length in feet.

TO COMPUTE HEAD WHEN LENGTH, DISCHARGE, AND DIAMETER ARE GIVEN.—*Rule.*—Divide tabular number for diameter by discharge per minute, square quotient, and divide length of pipe by it; quotient will give head necessary to force given volume of water through pipe in one minute.

Example.—Take elements of preceding cases:

$$\frac{1147.61}{69.67} = 16.47; 16.47^2 = 271.3; 4750 \div 271.2 = 17.5 \text{ feet.}$$

TO COMPUTE VELOCITY WHEN VOLUME AND DIAMETER ALONE ARE GIVEN.—*Rule.*—Divide volume when in feet per minute by area in feet, and quotient, divided by 60, will give velocity in feet per second.

Example.—Take elements of preceding case:

$$\frac{69.67}{0.75^2 \times 0.7854} \div 60 = 2.63 \text{ feet.}$$

WHEN VOLUME IS NOT GIVEN.—*Rule.*—Multiply square root of product of height of pipe by diameter in feet, divided by length in feet, by 50, and product will give velocity in feet per second. (Beardmore.)

TO COMPUTE INCLINATION OF PIPE WHEN VOLUME, DIAMETER,

AND LENGTH ARE GIVEN: $\left\{ \frac{V}{2356} \right\}^2 \frac{1}{D^5} = \frac{H}{L}$.

Illustration.—Take elements of preceding case:

$$\left\{ \frac{69.67}{2356} \right\}^2 \times \frac{1}{0.75^5} = 0.000847 \times 4.214 = 0.00368,$$

and

$$\frac{17.5}{4750} = 0.00368, \text{ or } 4750 \times 0.00368 = 17.49 \text{ ft. head.}$$

EQUATION OF PIPES.

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus, one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power (i.e., as the 2.5 power). The following table has been calculated on this basis. The figures opposite the intersection of any two sizes represent the number of the smaller-sized pipes required to equal one of the larger. Thus, one 4-inch pipe is equal to 5.7 2-inch pipes.

| Diameter, Inches. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 24 |
|----------------------|-------|-------|-------|-------|------|------|------|------|------|------|------|------|------|------|------|------|
| 2 | 5.7 | | | | | | | | | | | | | | | |
| 3 | 15.6 | 1 | | | | | | | | | | | | | | |
| 4 | 32 | 5.7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | 55.9 | 9.9 | 3.6 | 2.8 | 2.3 | 2.1 | 2.4 | 2.8 | 2.5 | 2.3 | 2.4 | 2.4 | 2.8 | 2.5 | 2.3 | 2.3 |
| 6 | 88.2 | 15.6 | 5.7 | 4.1 | 4.3 | 4.7 | 4.7 | 4.1 | 3.0 | 2.8 | 2.4 | 2.4 | 3.4 | 3 | 2.8 | 2.8 |
| 7 | 130 | 22.9 | 11.7 | 7.6 | 7.2 | 7.8 | 7.9 | 4.8 | 3.6 | 3.2 | 2.4 | 2.4 | 4.1 | 3.6 | 3.4 | 3.4 |
| 8 | 181 | 32 | 15.6 | 9.9 | 9.9 | 10.9 | 10.6 | 5.7 | 4.2 | 3.8 | 2.8 | 2.4 | 5.7 | 4.8 | 4.8 | 4.8 |
| 9 | 243 | 43 | 20.3 | 12.5 | 11.7 | 13.5 | 12.5 | 6.6 | 4.9 | 3.8 | 2.8 | 2.4 | 7.1 | 6.6 | 6.6 | 6.6 |
| 10 | 316 | 55.9 | 25.7 | 15.6 | 13.5 | 15.6 | 13.8 | 7.6 | 5.7 | 4.3 | 3.2 | 2.4 | 8.3 | 7.6 | 7.6 | 7.6 |
| 11 | 401 | 70.9 | 32 | 19 | 18.3 | 17.8 | 17.5 | 8.7 | 6.5 | 5.7 | 4.3 | 3.2 | 9.9 | 8.9 | 8.9 | 8.9 |
| 12 | 499 | 88.2 | 39.1 | 22.9 | 21.3 | 20.3 | 21.8 | 9.9 | 7.4 | 6.5 | 5.7 | 4.3 | 11.7 | 10.9 | 10.9 | 10.9 |
| 13 | 609 | 108 | 47 | 27.2 | 24.6 | 23.7 | 26.6 | 12.5 | 9.3 | 7.7 | 6.5 | 5.7 | 13.8 | 13.1 | 13.1 | 13.1 |
| 14 | 733 | 130 | 55.9 | 32 | 28.1 | 25.7 | 32 | 15.6 | 11.6 | 9.9 | 8.3 | 7.1 | 15.6 | 15.6 | 15.6 | 15.6 |
| 15 | 787 | 154 | 65.7 | 37.2 | 32 | 29.1 | 32 | 18.3 | 14.2 | 10.9 | 8.9 | 7.7 | 18.3 | 18.3 | 18.3 | 18.3 |
| 16 | ..... | 181 | 76.4 | 43 | 32 | 30.5 | 32 | 21.3 | 17.1 | 13.1 | 10.6 | 9.3 | 21.3 | 21.3 | 21.3 | 21.3 |
| 17 | ..... | 211 | 88.2 | 49 | 37.2 | 32 | 43 | 24.6 | 19.6 | 15.6 | 12.5 | 10.6 | 24.6 | 24.6 | 24.6 | 24.6 |
| 18 | ..... | 243 | 101 | 55.9 | 43 | 38.1 | 43 | 28.1 | 22.9 | 18.3 | 15.6 | 12.5 | 28.1 | 28.1 | 28.1 | 28.1 |
| 19 | ..... | 278 | 115 | 65.7 | 49 | 40.6 | 49 | 32 | 27.2 | 22.9 | 20.3 | 18.3 | 32 | 32 | 32 | 32 |
| 20 | ..... | 316 | 130 | 76.4 | 55.9 | 46 | 55.9 | 37.2 | 32 | 27.2 | 23.7 | 21.8 | 37.2 | 37.2 | 37.2 | 37.2 |
| 22 | ..... | 401 | 146 | 88.2 | 70.9 | 52.7 | 88.2 | 43 | 38.1 | 32 | 29.1 | 26.6 | 43 | 43 | 43 | 43 |
| 24 | ..... | 499 | 181 | ..... | 88.2 | 61.7 | 108 | 50.5 | 44.2 | 38.1 | 32 | 32 | 50.5 | 50.5 | 50.5 | 50.5 |
| 26 | ..... | 609 | 221 | ..... | 74.2 | 74.2 | 130 | 61.7 | 47 | 43 | 38.1 | 32 | 61.7 | 61.7 | 61.7 | 61.7 |
| 28 | ..... | 733 | 266 | ..... | 88.2 | 88.2 | 154 | 74.2 | 55.9 | 47 | 43 | 38.1 | 88.2 | 88.2 | 88.2 | 88.2 |
| 30 | ..... | 787 | 316 | ..... | 130 | 130 | 181 | 88.2 | 60 | 55.9 | 47 | 43 | 130 | 130 | 130 | 130 |
| 36 | ..... | ..... | 499 | ..... | 205 | 205 | 243 | 130 | 88.2 | 60 | 55.9 | 47 | 205 | 205 | 205 | 205 |
| 42 | ..... | ..... | 733 | ..... | 286 | 286 | 316 | 181 | 123 | 88.2 | 62.7 | 50.5 | 286 | 286 | 286 | 286 |
| 48 | ..... | ..... | ..... | ..... | 383 | 383 | 499 | 243 | 165 | 118 | 88.2 | 67.8 | 383 | 383 | 383 | 383 |
| 54 | ..... | ..... | ..... | ..... | 499 | 499 | 670 | 316 | 215 | 154 | 115 | 88.2 | 499 | 499 | 499 | 499 |
| 60 | ..... | ..... | ..... | ..... | 787 | 787 | 88.2 | 499 | 215 | 154 | 115 | 88.2 | 787 | 787 | 787 | 787 |



TABLES OF WEIGHTS, STRENGTHS, ETC.

SPECIFIC GRAVITY OF VARIOUS SUBSTANCES.

| Names of Substances. | Specific Gravity. | Names of Substances. | Specific Gravity. |
|------------------------------------|-------------------|------------------------------------|-------------------|
| Aluminum { cast. | 2.60 | Mahogany. | 0.56-1.09 |
| { hammered. | 2.75 | Maple, dry. | 0.70 |
| Amber. | 1.08 | Marble. | 2.52-2.85 |
| Anthracite. | 1.40-1.70 | Masonry, stone, dry. | 2.00-2.55 |
| Asphaltum. | 1.10-1.20 | brick. | 1.50-1.60 |
| Brass { cast. | 8.40-8.70 | Mercury at 32° Fahr. | 13.596 |
| { rolled. | 8.57 | Mica. | 2.80 |
| Brick, common, hard. | 1.53-2.30 | Nickel. | 8.8 |
| Cement, ground, loose. | 1.85 | Oak, dry. | 0.69-1.03 |
| Charcoal. | 0.44 | Petroleum at 59° Fahr. | 0.80 |
| Cherry, dry. | 0.76-0.84 | Pine. | 0.35-0.60 |
| Clay, dry. | 1.80-2.60 | Platinum { cast. | 21.15 |
| Coal, bituminous. | 1.20-1.50 | { hammered. | 21.3-21.5 |
| Coke, loose. | 0.55 | Quartz. | 2.5-2.80 |
| Concrete. | 2.47 | Saltpetre, Chili. | 2.26 |
| Copper { cast. | 8.79 | Kali. | 1.95-2.08 |
| { rolled. | 8.78-9.00 | Sand, fine, dry. | 1.40-1.65 |
| Diamond. | 3.52 | wet. | 1.90-2.05 |
| Earth, humus. | 1.30-1.80 | coarse. | 1.40-1.50 |
| Glass, common window. | 2.64 | Sandstone. | 2.20-2.50 |
| Gneiss, common. | 2.40-2.70 | Silver { cast. | 10.48 |
| Gold { cast, pure, or 24 | 19.28 | { hammered. | 10.62 |
| { pure, hammered. | 19.33 | Slate. | 2.60-2.70 |
| Granite. | 2.50-3.00 | Snow, freshly fallen. | 0.19 |
| Gypsum, cast, dry. | 0.97 | Steel. | 7.26-7.86 |
| Hornblende. | 3.00 | Sulphur. | 1.93-2.07 |
| Ice. | 0.88-0.92 | Sodium. | 0.978 |
| Iron { cast. | 7.10-7.50 | Tin { cast. | 7.20 |
| { wrought. | 7.79 | { rolled. | 7.30 |
| Ivory. | 1.82 | Water, pure rain or dis- | 1.00 |
| Lead. | 11.37 | tilled, at 39° F. | 1.03 |
| Lime. | 2.30-3.20 | Water, sea. | 1.03 |
| Lime, slaked. | 1.30-1.40 | Walnut, dry. | 0.60-0.81 |
| Limestones. | 2.46-2.84 | Wax. | 0.95-0.98 |
| Magnesium. | 1.74 | Zinc { cast. | 6.90 |
| | | { rolled. | 7.20 |

WEIGHT OF A CUBIC FOOT OF SUBSTANCES.

| Names of Substances. | Average Weight, Pounds. |
|---|-------------------------|
| Aluminum. | 162 |
| Anthracite, solid, of Pennsylvania. | 93 |
| " broken, loose. | 54 |
| " " moderately shaken. | 58 |
| " heaped bushel, loose. | (80) |
| Ash, American, white, dry. | 38 |
| Asphaltum. | 87 |

WEIGHT OF SUBSTANCES—(Continued).

| Names of Substances. | Average Weight, Pounds. |
|---|-------------------------|
| Brass (copper and zinc), cast. | 504 |
| “ rolled. | 524 |
| Brick, best pressed. | 150 |
| “ common, hard. | 125 |
| “ soft, inferior. | 100 |
| Brickwork, pressed brick. | 140 |
| “ ordinary. | 112 |
| Cement, hydraulic, ground, loose, American Rosendale. . | 56 |
| “ “ “ “ “ Louisville. . | 50 |
| “ “ “ “ English, Portland. . . . | 90 |
| Cherry, dry. | 42 |
| Chestnut, dry. | 41 |
| Clay, potters' dry. | 119 |
| “ in lump, loose. | 63 |
| Coal, bituminous, solid. | 84 |
| “ “ broken, loose. | 49 |
| “ “ heaped bushel, loose. | (74) |
| Coke, loose, of good coal. | 26.3 |
| “ “ heaped bushel. | (40) |
| Copper, cast. | 542 |
| “ rolled. | 548 |
| Earth, common loam, dry, loose. | 76 |
| “ “ “ “ moderately rammed. | 95 |
| “ as a soft, flowing mud. | 108 |
| Ebony, dry. | 76 |
| Elm, dry. | 35 |
| Flint. | 162 |
| Glass, common window. | 157 |
| Gneiss, common. | 168 |
| Gold, cast, pure, or 24 carat. | 1204 |
| “ pure, hammered. | 1217 |
| Grain, at 60 lbs. per bushel. | 48 |
| Granite. | 170 |
| Gravel, about the same as sand, which see. | |
| Gypsum (plaster of Paris). | 142 |
| Hemlock, dry. | 25 |
| Hickory, dry. | 53 |
| Hornblende, black. | 203 |
| Ice. | 58.7 |

WEIGHT OF SUBSTANCES—(Continued).

| Names of Substances. | Average Weight, Pounds. |
|---|-------------------------|
| Iron, cast. | 450 |
| " wrought, purest. | 485 |
| " " average. | 480 |
| Ivory. | 114 |
| Lead. | 711 |
| Lignum vitæ, dry. | 83 |
| Lime, quick, ground, loose, or in small lumps. | 53 |
| " " " " thoroughly shaken. | 75 |
| " " " " per struck bushel. | 66 |
| Limestones and marbles. | 168 |
| " " " loose, in irregular fragments. | 96 |
| Magnesium | 109 |
| Mahogany, Spanish, dry. | 53 |
| " Honduras, dry. | 35 |
| Maple, dry. | 45 |
| Marbles, see Limestones. | |
| Masonry, of granite or limestone, well dressed. | 165 |
| " " mortar rubble. | 154 |
| " " dry " (well scabbled). | 138 |
| " " sandstone, well dressed. | 144 |
| Mercury, at 32° Fahrenheit. | 849 |
| Mica. | 183 |
| Mortar, hardened. | 103 |
| Mud, dry, close. | 80 to 110 |
| Mud, wet, fluid, maximum. | 120 |
| Oak, live, dry. | 59 |
| Oak, white, dry. | 50 |
| " other kinds. | 32 to 45 |
| Petroleum. | 55 |
| Pine, white, dry. | 25 |
| " yellow, Northern. | 34 |
| " " Southern. | 45 |
| Platinum. | 1342 |
| Quartz, common, pure. | 165 |
| Rosin. | 69 |
| Salt, coarse, Syracuse, N. Y. | 45 |
| " Liverpool, fine, for table use. | 49 |
| Sand, of pure quartz, dry, loose. | 90 to 106 |
| " well shaken. | 99 to 117 |

WEIGHT OF SUBSTANCES—(Continued).

| Names of Substances. | Average Weight, Pounds. |
|---|-------------------------|
| Sand, perfectly wet. | 120 to 140 |
| Sandstones, fit for building. | 151 |
| Shales, red or black. | 162 |
| Silver. | 655 |
| Slate. | 175 |
| Snow, freshly fallen. | 5 to 12 |
| " moistened and compacted by rain. | 15 to 50 |
| Spruce, dry. | 25 |
| Steel. | 490 |
| Sulphur. | 125 |
| Sycamore, dry. | 37 |
| Tar. | 62 |
| Tin, cast. | 459 |
| Turf or peat, dry, unpressed. | 20 to 30 |
| Walnut, black, dry. | 38 |
| Water, pure rain or distilled, at 60° Fahrenheit. | 62½ |
| " sea. | 64 |
| Wax, bees. | 60.5 |
| Zinc or spelter. | 437.5 |

Green timbers usually weigh from one-fifth to one-half more than dry.

WEIGHT OF DIFFERENT MATERIALS.

| | Pounds. |
|--|------------|
| 1 barrel of lime. | 200 to 230 |
| 1 " " cement (hydraulic or Rosendale). | 300 |
| 1 " " " (Portland). | 400 |
| 1 " " " (Scotch, Roman) | 350 |
| 1 " " fire-clay (American). | 300 |
| 1 " " " (English). | 350 |
| 1 " " brick-dust. | 350 |
| 1 " " marble-dust. | 350 |
| 1 " " plaster, California | 260 |
| 1 " " " Wotherspoon (Eastern). | 275 |
| 1 " " " (ground gypsum or land) | 320 |
| Fire-brick 6½ to 7 pounds each. | |

LINEAR EXPANSION OF SUBSTANCES BY HEAT.

To find the increase in the length of a bar of any material due to an increase of temperature, multiply the number of degrees of increase of temperature by the coefficient for 100 degrees and by the length of the bar and divide by 100.

| Name of Substance. | Coefficient for 100° Fahrenheit. | Coefficient for 180° Fahrenheit, or 100° Centigrade. |
|---|----------------------------------|--|
| Baywood (in the direction of the grain, dry)..... | .00026 to .00031 | .00046 to .00057 |
| Brass (cast)..... | .00104 | .00188 |
| " (wire)..... | .00107 | .00193 |
| Brick (fire)..... | .0003 | .0005 |
| Cement (Roman)..... | .0008 | .0014 |
| Copper..... | .0009 | .0017 |
| Deal (in the direction of the grain, dry)..... | .00024 | .00044 |
| Glass (English flint)..... | .00045 | .00081 |
| " (French white lead)..... | .00048 | .00087 |
| Gold..... | .0008 | .0015 |
| Granite (average)..... | .00047 | .00085 |
| Iron (cast)..... | .0006 | .0011 |
| " (soft forged)..... | .0007 | .0012 |
| " (wire)..... | .0008 | .0014 |
| Lead..... | .0016 | .0029 |
| Marble (Carrara)..... | .00036 to .0006 | .00065 to .0011 |
| Mercury..... | .0033 | .0060 |
| Platinum..... | .0005 | .0009 |
| Sandstone..... | .0005 to .0007 | .0009 to .0012 |
| Silver..... | .0011 | .002 |
| Slate (Wales)..... | .0006 | .001 |
| Water (varies considerably with the temperature)..... | .0086 | .0155 |
| Tin..... | .0003 | .0069 |
| Zinc..... | .0004 | .0088 |

STRENGTH OF MATERIALS.

Ultimate resistance to tension, in pounds per square inch.

METALS AND ALLOYS.

| | Average. |
|---|-------------------|
| Aluminum bronze: | |
| 10 per cent Al and 90 per cent copper..... | 85,000 |
| 1¼ " " " 98½ " " | 28,000 |
| Brass, cast..... | 18,000 |
| Brass wire..... | 49,000 |
| Bronze or gun metal..... | 36,000 |
| Copper, cast..... | 19,000 |
| Copper, sheet..... | 30,000 |
| Copper, bolts..... | 36,000 |
| Copper wire (unannealed)..... | 60,000 |
| Iron, cast, 13,400 to 29,000..... | 16,500 |
| Iron wire, black or annealed..... | 56,000 |
| Iron wire, bright, hard drawn..... | 78,400 |
| Lead, sheet..... | 3,300 |
| Steel..... | 45,000 to 120,000 |
| Steel aluminum, 2½ per cent aluminum..... | 70,000 |
| Steel copper, 35 per cent copper..... | 60,000 |
| Steel nickel, 3¼ per cent nickel..... | 86,000 |
| Steel cast, wire Bessemer..... | 2,896,000 |
| Steel cast, wire high carbon..... | 179,200 |
| Steel cast, wire mild O. H..... | 134,000 |
| The modulus of elasticity of steel from recent tests is from 27,000,000 to 31,000,000. Average, 29,000,000. | |
| Tin, cast..... | 4,600 |
| Zinc..... | 7,000 to 8,000 |

STONE, NATURAL AND ARTIFICIAL.

| | |
|----------------------------|----------------|
| Brick and cement..... | 280 to 300 |
| Glass..... | 2,560 |
| Slate..... | 2,400 to 4,600 |
| Mortar, ordinary lime..... | 10 to 20 |

ULTIMATE RESISTANCE TO COMPRESSION.

Metals.

| | |
|------------------|-------------------|
| Brass, cast..... | 10,300 |
| Iron, "..... | 85,000 to 125,000 |
| Steel..... | 45,000 to 120,000 |

STONE, NATURAL AND ARTIFICIAL.

| | Average. |
|-------------------------------------|-----------------|
| Brick, weak..... | 550 to 800 |
| “ strong..... | 1,100 |
| “ fire..... | 1,700 |
| Brickwork, ordinary, in cement..... | 300 to 600 |
| “ best..... | 1,000 |
| Glass..... | 30,000 |
| Granite..... | 5,000 to 18,000 |
| Limestone..... | 4,000 to 16,000 |
| Marble..... | 4,000 to 18,000 |
| Sandstone, ordinary..... | 2,500 to 10,000 |

ULTIMATE RESISTANCE TO SHEARING.

Metals.

| | |
|-----------------|--------|
| Iron, cast..... | 25,000 |
| Steel..... | 50,000 |

MODULI OF ELASTICITY.

Metals.

| | |
|----------------------------|------------|
| Iron (cast)..... | 12,000,000 |
| Iron (wrought shapes)..... | 27,000,000 |
| Iron (rerolled bars)..... | 26,000,000 |
| Steel (casting)..... | 30,000,000 |
| Steel (structural)..... | 29,000,000 |

WEIGHT, STRENGTH, ETC., OF STANDARD HOISTING ROPE
 Composed of Six Strands and a Hemp Centre, Nineteen Wires to the Strand
 SWEDISH IRON.

| Trade Number. | Diameter in Inches. | Approximate Circumference in Inches. | Weight per Foot in Pounds. | Approximate Breaking Strain in Tons of 2000 Pounds. | Allowable Working Strain in Tons of 2000 Pounds. | Minimum Size of Drum or Sheave in Feet. |
|------------------|---------------------|--------------------------------------|----------------------------|---|--|---|
| .. | 2 $\frac{3}{4}$ | 8 $\frac{5}{8}$ | 11.95 | 114 | 22.8 | 16 |
| ... | 2 $\frac{1}{2}$ | 7 $\frac{7}{8}$ | 9.85 | 95 | 18.9 | 15 |
| 1 | 2 $\frac{1}{4}$ | 7 $\frac{1}{8}$ | 8.00 | 78 | 15.60 | 13 |
| 2 | 2 | 6 $\frac{1}{2}$ | 6.30 | 62 | 12.40 | 12 |
| 3 | 1 $\frac{3}{4}$ | 5 $\frac{1}{2}$ | 4.85 | 48 | 9.60 | 10 |
| 4 | 1 $\frac{5}{8}$ | 5 | 4.15 | 42 | 8.40 | 8 $\frac{1}{2}$ |
| 5 | 1 $\frac{1}{2}$ | 4 $\frac{3}{4}$ | 3.55 | 36 | 7.20 | 7 $\frac{1}{2}$ |
| 5 $\frac{1}{2}$ | 1 $\frac{3}{8}$ | 4 $\frac{1}{4}$ | 3.00 | 31 | 6.20 | 7 |
| 6 | 1 $\frac{1}{4}$ | 4 | 2.45 | 25 | 5.00 | 6 $\frac{1}{2}$ |
| 7 | 1 $\frac{1}{8}$ | 3 $\frac{1}{2}$ | 2.00 | 21 | 4.20 | 6 |
| 8 | 1 | 3 | 1.58 | 17 | 3.40 | 5 $\frac{1}{2}$ |
| 9 | $\frac{7}{8}$ | 2 $\frac{3}{4}$ | 1.20 | 13 | 2.60 | 4 $\frac{1}{2}$ |
| 10 | $\frac{3}{4}$ | 2 $\frac{1}{4}$ | 0.89 | 9.7 | 1.94 | 4 |
| 10 $\frac{1}{4}$ | $\frac{5}{8}$ | 2 | 0.62 | 6.8 | 1.36 | 3 $\frac{1}{2}$ |
| 10 $\frac{1}{2}$ | $\frac{9}{16}$ | 1 $\frac{3}{4}$ | 0.50 | 5.5 | 1.10 | 2 $\frac{3}{4}$ |
| 10 $\frac{3}{4}$ | $\frac{1}{2}$ | 1 $\frac{1}{2}$ | 0.39 | 4.4 | 0.88 | 2 $\frac{1}{2}$ |
| 10a | $\frac{7}{16}$ | 1 $\frac{1}{4}$ | 0.30 | 3.4 | 0.68 | 2 |
| 10b | $\frac{3}{8}$ | 1 $\frac{1}{8}$ | 0.22 | 2.5 | 0.50 | 1 $\frac{1}{2}$ |
| 10c | $\frac{5}{16}$ | 1 | 0.15 | 1.7 | 0.34 | 1 |
| 10d | $\frac{1}{4}$ | $\frac{3}{4}$ | 0.10 | 1.2 | 0.24 | $\frac{3}{4}$ |

CAST STEEL.

| | | | | | | |
|------------------|-----------------|-----------------|-------|------|------|-----------------|
| .. | 2 $\frac{3}{4}$ | 8 $\frac{5}{8}$ | 11.95 | 228 | 45.6 | 10 |
| ... | 2 $\frac{1}{2}$ | 7 $\frac{7}{8}$ | 9.85 | 190 | 37.9 | 9 $\frac{1}{2}$ |
| 1 | 2 $\frac{1}{4}$ | 7 $\frac{1}{8}$ | 8.00 | 156 | 31.2 | 8 $\frac{1}{2}$ |
| 2 | 2 | 6 $\frac{1}{2}$ | 6.30 | 124 | 24.8 | 8 |
| 3 | 1 $\frac{3}{4}$ | 5 $\frac{1}{2}$ | 4.85 | 96 | 19.2 | 7 $\frac{1}{2}$ |
| 4 | 1 $\frac{5}{8}$ | 5 | 4.15 | 84 | 16.8 | 6 $\frac{1}{2}$ |
| 5 | 1 $\frac{1}{2}$ | 4 $\frac{3}{4}$ | 3.55 | 72 | 14.4 | 5 $\frac{3}{4}$ |
| 5 $\frac{1}{2}$ | 1 $\frac{3}{8}$ | 4 $\frac{1}{4}$ | 3.00 | 62 | 12.4 | 5 $\frac{1}{2}$ |
| 6 | 1 $\frac{1}{4}$ | 4 | 2.45 | 50 | 10.0 | 5 |
| 7 | 1 $\frac{1}{8}$ | 3 $\frac{1}{2}$ | 2.00 | 42 | 8.40 | 4 $\frac{1}{2}$ |
| 8 | 1 | 3 | 1.58 | 34 | 6.80 | 4 |
| 9 | $\frac{7}{8}$ | 2 $\frac{3}{4}$ | 1.20 | 26 | 5.20 | 3 $\frac{1}{2}$ |
| 10 | $\frac{3}{4}$ | 2 $\frac{1}{4}$ | 0.89 | 19.4 | 3.88 | 3 |
| 10 $\frac{1}{4}$ | $\frac{5}{8}$ | 2 | 0.62 | 13.6 | 2.72 | 2 $\frac{1}{2}$ |
| 10 $\frac{1}{2}$ | $\frac{9}{16}$ | 1 $\frac{3}{4}$ | 0.50 | 11.0 | 2.20 | 1 $\frac{3}{4}$ |
| 10 $\frac{3}{4}$ | $\frac{1}{2}$ | 1 $\frac{1}{2}$ | 0.39 | 8.8 | 1.76 | 1 $\frac{1}{2}$ |
| 10a | $\frac{7}{16}$ | 1 $\frac{1}{4}$ | 0.30 | 6.8 | 1.36 | 1 $\frac{1}{4}$ |
| 10b | $\frac{3}{8}$ | 1 $\frac{1}{8}$ | 0.22 | 5.0 | 1.00 | 1 |
| 10c | $\frac{5}{16}$ | 1 | 0.15 | 3.4 | 0.68 | $\frac{3}{4}$ |
| 10d | $\frac{1}{4}$ | $\frac{3}{4}$ | 0.10 | 2.4 | 0.48 | $\frac{1}{2}$ |

WEIGHT, STRENGTH, ETC., OF EXTRA STRONG CRUCIBLE CAST-STEEL ROPE.

Composed of Six Strands and a Hemp Centre, Nineteen Wires to the Strand.

| Trade Number. | Diameter in Inches. | Approximate Circumference in Inches. | Weight per Foot in Pounds. | Approximate Breaking Strain in Tons of 2000 Pounds. | Allowable Working Strain in Tons of 2000 Pounds. | Minimum Size of Drum or Sheave in Feet. |
|------------------|---------------------|--------------------------------------|----------------------------|---|--|---|
| .. | 2 $\frac{1}{8}$ | 8 $\frac{3}{8}$ | 11.95 | 266 | 53 | 10 |
| 1 | 2 $\frac{1}{4}$ | 7 $\frac{7}{8}$ | 9.85 | 222 | 45 | 9 $\frac{1}{2}$ |
| 2 | 2 $\frac{1}{2}$ | 7 $\frac{1}{8}$ | 8.00 | 182 | 36.4 | 8 $\frac{1}{2}$ |
| 3 | 2 | 6 $\frac{1}{4}$ | 6.30 | 144 | 28.8 | 8 |
| | 1 $\frac{3}{4}$ | 5 $\frac{1}{2}$ | 4.85 | 112 | 22.4 | 7 $\frac{1}{4}$ |
| 4 | 1 $\frac{5}{8}$ | 5 | 4.15 | 97 | 19.4 | 6 $\frac{1}{2}$ |
| 5 | 1 $\frac{1}{2}$ | 4 $\frac{3}{4}$ | 3.55 | 84 | 16.8 | 5 $\frac{3}{4}$ |
| 5 $\frac{1}{2}$ | 1 $\frac{3}{8}$ | 4 $\frac{1}{4}$ | 3.00 | 72 | 14.4 | 5 $\frac{1}{2}$ |
| 6 | 1 $\frac{1}{4}$ | 4 | 2.45 | 58 | 11.6 | 5 |
| 7 | 1 $\frac{1}{8}$ | 3 $\frac{3}{4}$ | 2.00 | 49 | 9.80 | 4 $\frac{1}{2}$ |
| 8 | 1 | 3 | 1.58 | 39 | 7.80 | 4 |
| 9 | $\frac{7}{8}$ | 2 $\frac{3}{4}$ | 1.20 | 30 | 6.00 | 3 $\frac{1}{2}$ |
| 10 | $\frac{3}{4}$ | 2 $\frac{1}{4}$ | 0.89 | 22 | 4.40 | 3 |
| 10 $\frac{1}{2}$ | $\frac{5}{8}$ | 2 | 0.62 | 15.8 | 3.16 | 2 $\frac{1}{2}$ |
| 10 $\frac{3}{4}$ | $\frac{7}{16}$ | 1 $\frac{1}{2}$ | 0.50 | 12.7 | 2.54 | 1 $\frac{3}{4}$ |
| 10 $\frac{1}{2}$ | $\frac{1}{2}$ | 1 $\frac{1}{4}$ | 0.39 | 10.1 | 2.02 | 1 $\frac{1}{2}$ |
| 10a | $\frac{7}{16}$ | 1 $\frac{1}{4}$ | 0.30 | 7.8 | 1.56 | 1 $\frac{1}{4}$ |
| 10b | $\frac{3}{8}$ | 1 $\frac{1}{8}$ | 0.22 | 5.78 | 1.15 | 1 |
| 10c | $\frac{5}{16}$ | 1 | 0.15 | 4.05 | 0.81 | $\frac{3}{4}$ |
| 10d | $\frac{3}{16}$ | $\frac{3}{4}$ | 0.10 | 2.70 | 0.54 | $\frac{1}{2}$ |

Seven Wires to the Strand.

| | | | | | | |
|----|-----------------|-----------------|-------|------|------|-----------------|
| 11 | 1 $\frac{1}{2}$ | 4 $\frac{3}{4}$ | 3.55 | 79 | 15.8 | 8 $\frac{1}{2}$ |
| 12 | 1 $\frac{3}{8}$ | 4 $\frac{1}{4}$ | 3.00 | 68 | 13.6 | 8 |
| 13 | 1 $\frac{1}{4}$ | 4 | 2.45 | 56 | 11.2 | 7 $\frac{1}{2}$ |
| 14 | 1 $\frac{1}{8}$ | 3 $\frac{1}{2}$ | 2.00 | 46 | 9.20 | 6 $\frac{1}{2}$ |
| 15 | 1 | 3 | 1.58 | 37 | 7.40 | 5 $\frac{1}{2}$ |
| 16 | $\frac{7}{8}$ | 2 $\frac{3}{4}$ | 1.20 | 28 | 5.60 | 5 |
| 17 | $\frac{3}{4}$ | 2 $\frac{1}{4}$ | 0.89 | 21 | 4.20 | 4 $\frac{1}{2}$ |
| 18 | $\frac{11}{16}$ | 2 $\frac{1}{8}$ | 0.75 | 18.4 | 3.68 | 4 |
| 19 | $\frac{3}{8}$ | 2 | 0.62 | 15.1 | 3.02 | 3 $\frac{1}{2}$ |
| 20 | $\frac{9}{16}$ | 1 $\frac{3}{4}$ | 0.50 | 12.3 | 2.46 | 3 |
| 21 | $\frac{7}{16}$ | 1 $\frac{1}{4}$ | 0.39 | 9.70 | 1.94 | 2 $\frac{1}{2}$ |
| 22 | $\frac{7}{16}$ | 1 $\frac{1}{4}$ | 0.30 | 7.50 | 1.50 | 2 $\frac{1}{4}$ |
| 23 | $\frac{3}{8}$ | 1 $\frac{1}{8}$ | 0.22 | 5.58 | 1.11 | 2 |
| 24 | $\frac{5}{16}$ | 1 | 0.15 | 3.88 | 0.77 | 1 $\frac{3}{4}$ |
| 25 | $\frac{3}{16}$ | $\frac{7}{8}$ | 0.125 | 3.22 | 0.64 | 1 $\frac{1}{4}$ |

WEIGHT, STRENGTH, ETC., OF COPPER, IRON, TINNED AND GALVANIZED SASH-CORDS.

Composed of Six Strands and a Cotton Centre, Seven Wires to the Strand.

| Trade Number. | Diameter in Inches. | Weight per Foot in Pounds. | | Approximate Breaking Strain in Pounds. | | |
|------------------|---------------------|----------------------------|---------|--|-----------|----------------|
| | | Iron. | Copper. | Iron. | | Bright Copper. |
| | | | | Bright. | Annealed. | |
| 26 | $\frac{1}{4}$ | 0.100 | 0.115 | 2200 | 1600 | 1265 |
| 27 | $\frac{3}{32}$ | 0.076 | 0.087 | 1809 | 1254 | 1022 |
| 27 $\frac{1}{2}$ | $\frac{1}{16}$ | 0.056 | 0.064 | 1417 | 947 | 792 |
| 28 | $\frac{1}{8}$ | 0.025 | 0.029 | 790 | 467 | 435 |
| 28 $\frac{1}{2}$ | $\frac{3}{32}$ | 0.014 | 0.016 | 510 | 280 | 272 |
| 29 | $\frac{1}{16}$ | 0.006 | 0.007 | 262 | 132 | 140 |

APPROXIMATE WEIGHT AND STRENGTH OF MANILA ROPE.

Manila, Sisal, New Zealand, and Jute Ropes weigh (about) alike. Tared Hemp Cordage will weigh (about) one-fourth more. Manila is about 25 per cent stronger than Sisal. Working load about one-fourth of breaking strain.

| Circumference in Inches. | Diameter in Inches. | Weight of 1000 Feet in Pounds. | Number of Feet and Inches in One Pound. | | Strength of New Manila Rope in Pounds. |
|--------------------------|---------------------|--------------------------------|---|-----------------|--|
| | | | Ft. | Ins. | |
| $\frac{1}{4}$ | $\frac{1}{16}$ | 23 | 50 | | 450 |
| 1 | $\frac{1}{8}$ | 33 | 33 | | 780 |
| 1 $\frac{1}{8}$ | $\frac{3}{32}$ | 42 | 25 | | 1,000 |
| 1 $\frac{1}{4}$ | $\frac{1}{16}$ | 52 | 19 | | 1,280 |
| 1 $\frac{3}{8}$ | $\frac{3}{32}$ | 74 | 11 | | 1,760 |
| 1 $\frac{1}{2}$ | $\frac{1}{8}$ | 101 | 9 | | 2,400 |
| 2 | $\frac{3}{16}$ | 132 | 7 | | 3,140 |
| 2 $\frac{1}{8}$ | $\frac{1}{8}$ | 167 | 6 | | 3,970 |
| 2 $\frac{1}{4}$ | $\frac{3}{16}$ | 207 | 5 | | 4,900 |
| 2 $\frac{3}{8}$ | $\frac{1}{8}$ | 250 | 4 | | 5,900 |
| 3 | $\frac{1}{4}$ | 297 | 3 | 6 | 7,000 |
| 3 $\frac{1}{8}$ | $\frac{3}{16}$ | 349 | 2 | 10 | 8,200 |
| 3 $\frac{1}{4}$ | $\frac{1}{8}$ | 405 | 2 | 4 | 9,600 |
| 3 $\frac{3}{8}$ | $\frac{3}{16}$ | 465 | 2 | 1 | 11,000 |
| 4 | $\frac{1}{4}$ | 529 | 1 | 10 | 12,500 |
| 4 $\frac{1}{8}$ | $\frac{3}{16}$ | 597 | 1 | 8 | 14,000 |
| 4 $\frac{1}{4}$ | $\frac{1}{8}$ | 669 | 1 | 5 | 15,800 |
| 4 $\frac{3}{8}$ | $\frac{3}{16}$ | 746 | 1. | 4 | 17,600 |
| 5 | $\frac{1}{4}$ | 826 | 1 | 2 | 19,500 |
| 5 $\frac{1}{8}$ | $\frac{3}{16}$ | 1000 | 1 | | 23,700 |
| 6 | $\frac{1}{4}$ | 1190 | | 10 | 28,000 |
| 6 $\frac{1}{8}$ | 2 | 1291 | | 9 $\frac{1}{2}$ | 33,000 |
| 6 $\frac{1}{4}$ | 2 $\frac{1}{8}$ | 1397 | | 8 $\frac{1}{2}$ | 38,000 |
| 7 | 2 $\frac{1}{4}$ | 1620 | | 7 | 44,000 |
| 7 $\frac{1}{8}$ | 2 $\frac{3}{8}$ | 1860 | | 6 $\frac{1}{2}$ | 50,000 |
| 8 | 2 $\frac{1}{2}$ | 2116 | | 5 $\frac{1}{2}$ | 60,000 |
| 8 $\frac{1}{8}$ | 2 $\frac{3}{8}$ | 2388 | | 5 | 63,000 |
| 9 | 2 $\frac{7}{8}$ | 2673 | | 4 $\frac{1}{2}$ | 67,700 |
| 9 $\frac{1}{8}$ | 3 | 2983 | | 4 | 70,000 |
| 10 | 3 $\frac{1}{16}$ | 3306 | | 3 $\frac{3}{8}$ | 78,000 |

WIRE ROPE FOR INCLINE PLANES.

For inclines and other places where wire cables are subject to friction, coarse wires are preferable to fine, since the latter wear in two more rapidly.

This table gives only the strain produced on a rope by a load of one ton of 2000 pounds, an allowance for rolling friction being made. An additional allowance for the weight of the rope will have to be made.

Example.—For an inclination of 100 feet in 100 feet, corresponding to an angle of 45°, a load of 2000 pounds will produce a strain on the rope of 1419 pounds, and for a load of 9000 pounds the strain on the rope will be $(1419 \times 9000) + 200 = 6,385\frac{1}{2}$ pounds, or $3^{885/2000}$ tons.

| Elevation in 100 Feet. | Corresponding Angle in Degrees of Inclination. | Strain in Pounds on Rope from a Load of 2000 Pounds. | Elevation in 100 Feet. | Corresponding Angle in Degrees of Inclination. | Strain in Pounds on Rope from a Load of 2000 Pounds. |
|------------------------|--|--|------------------------|--|--|
| 5 | 2 $\frac{1}{4}$ | 112 | 70 | 35 | 1156 |
| 10 | 5 $\frac{1}{2}$ | 211 | 75 | 37 | 1210 |
| 15 | 8 $\frac{1}{2}$ | 308 | 80 | 38 $\frac{1}{2}$ | 1260 |
| 20 | 11 $\frac{1}{2}$ | 404 | 85 | 40 $\frac{1}{2}$ | 1304 |
| 25 | 14 $\frac{1}{2}$ | 497 | 90 | 42 | 1347 |
| 30 | 16 $\frac{1}{2}$ | 586 | 95 | 43 $\frac{1}{2}$ | 1385 |
| 35 | 19 $\frac{1}{2}$ | 673 | 100 | 45 | 1419 |
| 40 | 21 $\frac{3}{8}$ | 754 | 105 | 46 $\frac{1}{4}$ | 1457 |
| 45 | 24 $\frac{1}{4}$ | 832 | 110 | 47 $\frac{1}{4}$ | 1487 |
| 50 | 26 $\frac{1}{4}$ | 905 | 115 | 49 | 1516 |
| 55 | 28 $\frac{3}{8}$ | 975 | 120 | 50 $\frac{1}{2}$ | 1544 |
| 60 | 31 | 1040 | 125 | 51 $\frac{1}{2}$ | 1570 |
| 65 | 33 $\frac{1}{2}$ | 1100 | | | |

A factor of safety of five to seven times should be taken; that is, the working load on the rope should only be one-fifth to one-seventh of its breaking strength. As a rule, ropes for shafts should have a factor of safety of five, and on inclined planes, where the wear is much greater, the factor of safety should be seven.

TABLE SHOWING HOW THE LIFE OF AN INCLINE STEEL-WIRE ROPE IS AFFECTED BY REDUCING THE SIZE OF SHEAVES AND DRUMS.

Computed for Ropes of Seven Wires to the Strand.

| Diameter of Rope in Ins. | Diameter of Sheaves or Drums in Feet, showing Percentages of Life for Various Diameters. | | | | | | |
|--------------------------|--|--------------|--------------|--------------|--------------|--------------|--------------|
| | 100 Per Cent. | 90 Per Cent. | 80 Per Cent. | 75 Per Cent. | 60 Per Cent. | 50 Per Cent. | 25 Per Cent. |
| | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. |
| 1 $\frac{1}{4}$ | 16 | 14 | 12 | 11 | 9 | 7 | 4.75 |
| 1 $\frac{3}{8}$ | 14 | 12 | 10 | 8.5 | 7 | 6 | 4.5 |
| 1 $\frac{1}{2}$ | 12 | 10 | 8 | 7.25 | 6.5 | 5.5 | 4.25 |
| 1 $\frac{3}{4}$ | 10 | 8.5 | 7.75 | 7 | 6 | 5 | 4 |
| 1 | 8.5 | 7.75 | 6.75 | 6 | 5 | 4.5 | 3.75 |
| $\frac{7}{8}$ | 7.75 | 7 | 6.25 | 5.75 | 4.5 | 3.75 | 3.25 |
| $\frac{3}{4}$ | 7 | 6.25 | 5.5 | 5 | 4.25 | 3.5 | 2.75 |
| $\frac{5}{8}$ | 6 | 5.25 | 4.5 | 4 | 3.26 | 3 | 2.5 |
| $\frac{3}{8}$ | 5 | 4.5 | 4 | 3.5 | 2.75 | 2.25 | 1.75 |

General Information Relating to Wire Rope.—

Wire rope is made of wires either twisted together or laid parallel to each other. The latter kind is only employed on large suspension bridges, while the former is in general use.

There are two classes of twisted, or, as it is usually called, *stranded wire rope*—*flat and round*.

Flat wire ropes consist of a number of wire strands which have been laid side by side and sewed together with annealed wire.

Round wire ropes are composed of a number of wire strands twisted around a core of hemp or around a wire strand or wire rope.

The *standard wire rope* is made of six wire strands and a hemp core. This arrangement affords the most convenient and compact form, as the strands and the core are practically all of the same size. For special purposes, however, four, five, seven, eight, nine, or any reasonable number of strands may be utilized.

Wire strands are twisted around the core, either to the right or left, and the resulting rope is thereby designated as *right lay* or *left lay*. The twist may be long or short, according to requirements. The shorter twist forms the more flexible rope, the longer twist the more rigid rope.

The *core* of a wire rope is, as a rule, hemp saturated with tar. It provides little additional strength, but acts as a cushion to preserve the shape of the rope and helps to lubricate the wires.

When the core is a *wire strand* or *rope*, it adds from 7 to 10 per cent to the strength of the rope, but will wear from the friction between it and the outer strands as rapidly as the outside of the rope. This does not apply to stationary ropes.

Wire strands are made of wires twisted together. The number of wires commonly used are four, seven, twelve, nineteen, and thirty-seven, and depends upon the nature of the work for which the strands are intended. Ordinarily the wires are twisted into strands in the *opposite direction* to the twist of the strands into rope.

When wires and strands are twisted in the *same direction*, the rope is known as "*Lang*" rope. For great flexibility, the strands of a wire rope sometimes consist of wire ropes, which in turn are made of strands composed of wires, as in tiller ropes.

When considerable outside friction and corrosion are to be resisted and pliability is also demanded, strands are made of twelve or eighteen wires, twisted about a hemp centre, as in ships' hawsers and running ropes.

Individual strands of wires are employed as smoke-stack guys, span wires for trolley roads, and wherever only moderate flexibility is needed.

Iron, open-hearth steel, crucible steel, and plough steel possess qualities which cover almost every demand upon the material of a wire rope. Copper, bronze, etc., are, however, used for a few special purposes:

In order to provide a protection against the action of salt air, rust, etc., wire is often galvanized or tinned, as for ships' rigging, etc. Ropes subject to constant bending around drums and sheaves are not usually so treated.

The *strength* of wire ropes depends primarily upon the material of which the wires are made. It is hard to obtain from a sample of wire rope more than 90 per cent of the aggregate strength of all of its wires in a testing-machine, the average being about 82½ per cent. This is due to the difficulty in making perfect attachments to the ends of the test-piece, in order that every wire shall carry its share of the load; to the fact that the inside wires of the strands are shorter than the outside wires and tend to break before them, and to the construction of the rope, which causes the adjacent strands to nick each other. While the last-mentioned action reduces the breaking strain of a rope, it occurs only at stresses far above those employed in practice. On account of the nicking, ropes with a short twist, or ropes made of hard steel break at a lower percentage of the aggregate strength of their wires than ropes with a long twist or ropes made of soft wire. So that, while it may be advisable in certain cases to use a rope with a short twist, its breaking strain will be lower than if the twist were long.

The *strength of iron wire* ranges from 45,000 to 100,000 pounds per square inch; *open-hearth steel* from 50,000 to 130,000 pounds per square inch; *crucible steel* from 130,000 to 190,000 pounds per square inch; and *plough steel* from 190,000 to 350,000 pounds per square inch, according to quality, treatment, size of wire, etc.

The *breaking strains* given in the preceding tables were determined by means of our own testing-machine, which has a capacity of 300,000 pounds, and those at Watertown Arsenal and Phoenixville. They represent fair averages of the rope usually supplied.

The *working loads* were calculated at *one-fifth* the *breaking strains*, but it should be understood that this factor of safety

is not recommended for all cases, as it is imperative to determine for every set of conditions a reasonable factor of safety. For instance, elevator ropes seldom have a load of more than one-tenth or one-fifteenth of their breaking strain.

The *minimum sizes of drums or sheaves* given in the tables were calculated on a basis of a working load of one-fifth the breaking strain, and provide that ropes shall not have their wires strained beyond the elastic limit when passing around the drums or sheaves indicated. While the theoretical sizes for cast-steel ropes are smaller than for the corresponding iron ropes, because the elastic limit of the former is much higher than of the latter, and the modulus of elasticity is nearly the same for both, still it is better to use the larger sizes of drums and sheaves for steel ropes, because when steel wire becomes worn or nicked it cracks very easily.

When high speeds are used, much larger drums and sheaves must be employed.

When working loads less than those given in the tables are used, or when the bending around sheaves and drums is very occasional, slightly smaller dimensions may be adopted.

In general, however, the *larger* the drum or sheave, the *longer* the rope will last, and the use of diameters less than those stated in the tables will often result in a rapid deterioration of the rope.

Wire rope should be *protected* from all unnecessary wear, and should be *lubricated* and kept as *dry* as possible. Wear increases with speed; it is therefore better to increase the load, within certain limits, than the speed.

For *lubrication* and to *prevent rusting*, linseed-oil, tar, or other similar materials free from acids or corrosive substances should be used. This is of the utmost importance, and is a large factor in the life of a wire rope. Applications of lubricants should be frequent, and in most cases the spaces between the strands of a wire rope should be gradually so filled that the rope eventually presents the appearance of a round iron bar. Many operators prefer to apply compositions of their own when the rope is put on, and for this reason we usually apply a coating of oil or paint merely to prevent the rope rusting while in transit or storage. We, however, are prepared upon request not only to apply any of the many commercial rope coatings and preservers, but if notified in time can lay the rope up in the same, thus insuring a thorough protection and lubrication.

Wire rope must not be coiled or uncoiled like hemp rope. When it is received upon a reel, the latter should be mounted upon a spindle or turntable and the rope then run off.

When shipped in a coil, it should be rolled along the ground like a wheel. All untwisting and kinking must be avoided. When a wire rope is to be cut, soft iron wire should be served on each side of the place where the division is to be made to prevent the rope from untwisting.

The Right and Wrong Ways to Measure Wire Rope.—The diameter of a wire rope is that of a true circle. Note where the dotted line touches the strands in Fig. 355.



FIG. 355.

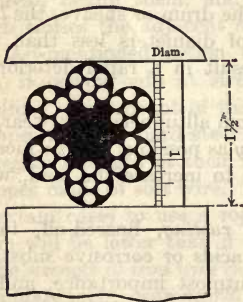


FIG. 356.

Right way to measure.
(A true circle.)

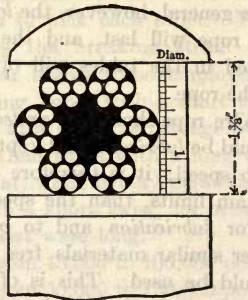


FIG. 357.

Wrong way to measure.
(Not a true circle.)

We always understand the diameter of a wire rope to be that of a circle inclosing the rope. Care should be taken in measuring to obtain this diameter. If a rope is measured the wrong way (see cut) and a wheel is ordered grooved to take the rope, the groove would be too small.

WEIGHT, LENGTH, AND STRENGTH OF STEEL WIRE.

| Number, Roebling Gauge. | Diameter in Inches. | Area in Square Inches. | Breaking Strain at Rate of 100,000 Pounds per Square Inch. | Weight in Pounds. | | Number of Feet in 2000 Pounds. |
|-------------------------|---------------------|------------------------|--|-------------------|-----------|--------------------------------|
| | | | | Per 1000 Feet. | Per Mile. | |
| 000000 | .460 | .166191 | 16,619 | 558.4 | 2948 | 3,582 |
| 00000 | .430 | .145221 | 14,522 | 487.9 | 2576 | 4,099 |
| 0000 | .393 | .121304 | 12,130 | 407.6 | 2152 | 4,907 |
| 000 | .362 | .102922 | 10,292 | 345.8 | 1826 | 5,783 |
| 00 | .331 | .086049 | 8,605 | 289.1 | 1527 | 6,917 |
| 0 | .307 | .074023 | 7,402 | 248.7 | 1313 | 8,041 |
| 1 | .283 | .062902 | 6,290 | 211.4 | 1116 | 9,463 |
| 2 | .263 | .054325 | 5,433 | 182.5 | 964 | 10,957 |
| 3 | .244 | .046760 | 4,676 | 157.1 | 830 | 12,730 |
| 4 | .225 | .039761 | 3,976 | 133.6 | 705 | 14,970 |
| 5 | .207 | .033654 | 3,365 | 113.1 | 597 | 17,687 |
| 6 | .192 | .028953 | 2,895 | 97.3 | 514 | 20,559 |
| 7 | .177 | .024606 | 2,461 | 82.7 | 437 | 24,191 |
| 8 | .162 | .020612 | 2,061 | 69.3 | 366 | 28,878 |
| 9 | .148 | .017203 | 1,720 | 57.8 | 305 | 34,600 |
| 10 | .135 | .014314 | 1,431 | 48.1 | 254 | 41,584 |
| 11 | .120 | .011310 | 1,131 | 38.0 | 201 | 52,631 |
| 12 | .105 | .008659 | 866 | 29.1 | 154 | 68,752 |
| 13 | .092 | .006648 | 665 | 22.3 | 118 | 89,525 |
| 14 | .080 | .005027 | 503 | 16.9 | 89.2 | 118,413 |
| 15 | .072 | .004071 | 407 | 13.7 | 72.2 | 146,198 |
| 16 | .063 | .003117 | 312 | 10.5 | 55.3 | 191,022 |
| 17 | .054 | .002290 | 229 | 7.70 | 40.6 | 259,909 |
| 18 | .047 | .001735 | 174 | 5.83 | 30.8 | 343,112 |
| 19 | .041 | .001320 | 132 | 4.44 | 23.4 | 450,856 |
| 20 | .035 | .000962 | 96 | 3.23 | 17.1 | 618,620 |
| 21 | .032 | .000804 | 80 | 2.70 | 14.3 | 740,193 |
| 22 | .028 | .000616 | 62 | 2.07 | 10.9 | 966,651 |
| 23 | .025 | .000491 | 49 | 1.65 | 8.71 | ..... |
| 24 | .023 | .000415 | 42 | 1.40 | 7.37 | ..... |
| 25 | .020 | .000314 | 31 | 1.06 | 5.58 | ..... |
| 26 | .018 | .000254 | 25 | .855 | 4.51 | ..... |
| 27 | .017 | .000227 | 23 | .763 | 4.03 | ..... |
| 28 | .016 | .000201 | 20 | .676 | 3.57 | ..... |
| 29 | .015 | .000177 | 18 | .594 | 3.14 | ..... |
| 30 | .014 | .000154 | 15 | .517 | 2.73 | ..... |
| 31 | .0135 | .000143 | 14 | .481 | 2.54 | ..... |
| 32 | .013 | .000133 | 13 | .446 | 2.36 | ..... |
| 33 | .011 | .000095 | 9.5 | .319 | 1.69 | ..... |
| 34 | .010 | .000079 | 7.9 | .264 | 1.39 | ..... |
| 35 | .0095 | .000071 | 7.1 | .238 | 1.26 | ..... |
| 36 | .009 | .000064 | 6.4 | .214 | 1.13 | ..... |

This table was calculated on a basis of 483.84 pounds per cubic foot for steel wire. Iron wire is a trifle lighter.

The breaking strains were calculated for 100,000 pounds per square inch throughout, simply for convenience, so that the breaking strains of wires of any strength per square inch may be quickly determined by multiplying the values given in the table by the ratio between the strength per square inch and 100,000. Thus a No. 15 wire with a strength per square inch of

$$150,000 \text{ pounds has a breaking strain of } 407 \times \frac{150,000}{100,000} = 610.5 \text{ pounds.}$$

It must not be thought from this table that steel wire invariably has a strength of 100,000 pounds per square inch. As a matter of fact it ranges from 45,000 pounds for soft annealed to over 400,000 pounds per square inch for hard wire.

STANDARD GAUGES.

| No. of Gauge. | Thickness in Decimals of an Inch. | | | | | | No. of Gauge. | |
|---------------|-----------------------------------|-----------------|--------------------------------------|-------------------|---------------------|------------------|---------------|-------------------|
| | Birmingham. | Browne & Sharpe | U. S. Standard Plate Iron and Steel. | British Imperial. | Washburn & Moen Co. | Trenton Iron Co. | | Stubs Steel Wire. |
| 7° | ..... | ..... | .500 | .500 | ..... | ..... | ..... | 7° |
| 6° | ..... | ..... | .46875 | .464 | ..... | ..... | ..... | 6° |
| 5° | ..... | ..... | .4375 | .432 | ..... | .45 | ..... | 5° |
| 4° | .454 | .46 | .40625 | .400 | .3938 | .40 | ..... | 4° |
| 3° | .425 | .40964 | .375 | .372 | .3625 | .36 | ..... | 3° |
| 2° | .380 | .3648 | .34375 | .348 | .3310 | .33 | ..... | 2° |
| 0 | .340 | .32486 | .3125 | .324 | .3065 | .305 | ..... | 0 |
| 1 | .300 | .2893 | .28125 | .300 | .2830 | .285 | .227 | 1 |
| 2 | .284 | .25763 | .265625 | .276 | .2625 | .265 | .219 | 2 |
| 3 | .259 | .22942 | .25 | .252 | .2437 | .245 | .212 | 3 |
| 4 | .238 | .20431 | .234375 | .232 | .2253 | .225 | .207 | 4 |
| 5 | .220 | .18194 | .21875 | .212 | .2070 | .205 | .204 | 5 |
| 6 | .203 | .16202 | .203125 | .192 | .1920 | .190 | .201 | 6 |
| 7 | .180 | .14428 | .1875 | .176 | .1770 | .175 | .199 | 7 |
| 8 | .165 | .12849 | .171875 | .160 | .1620 | .160 | .197 | 8 |
| 9 | .148 | .11443 | .15625 | .144 | .1483 | .145 | .194 | 9 |
| 10 | .134 | .10189 | .140625 | .128 | .1350 | .130 | .191 | 10 |
| 11 | .120 | .090742 | .125 | .116 | .1205 | .1175 | .188 | 11 |
| 12 | .109 | .080808 | .109375 | .104 | .1055 | .1050 | .185 | 12 |
| 13 | .095 | .071961 | .09375 | .092 | .0915 | .0925 | .182 | 13 |
| 14 | .083 | .064084 | .078125 | .080 | .0800 | .0800 | .180 | 14 |
| 15 | .072 | .057068 | .0703125 | .072 | .0720 | .0700 | .178 | 15 |
| 16 | .065 | .05082 | .0625 | .064 | .0625 | .0610 | .175 | 16 |
| 17 | .058 | .045257 | .05625 | .056 | .0540 | .0525 | .172 | 17 |
| 18 | .049 | .040303 | .05 | .048 | .0475 | .0450 | .168 | 18 |
| 19 | .042 | .03589 | .04375 | .040 | .0410 | .0400 | .164 | 19 |
| 20 | .035 | .031961 | .0375 | .036 | .0348 | .0350 | .161 | 20 |
| 21 | .032 | .028462 | .034375 | .032 | .03175 | .0310 | .157 | 21 |
| 22 | .028 | .025347 | .03125 | .028 | .0286 | .0280 | .155 | 22 |
| 23 | .025 | .022571 | .028125 | .024 | .0258 | .0250 | .153 | 23 |
| 24 | .022 | .0201 | .025 | .022 | .0230 | .0225 | .151 | 24 |
| 25 | .020 | .0179 | .021875 | .020 | .0204 | .0200 | .148 | 25 |
| 26 | .018 | .01594 | .01875 | .018 | .0181 | .0180 | .146 | 26 |
| 27 | .016 | .014195 | .0171875 | .0164 | .0173 | .0170 | .143 | 27 |
| 28 | .014 | .012641 | .015625 | .0148 | .0162 | .0160 | .139 | 28 |
| 29 | .013 | .011257 | .0140625 | .0136 | .0150 | .0150 | .134 | 29 |
| 30 | .012 | .010025 | .0125 | .0124 | .0140 | .0140 | .127 | 30 |
| 31 | .010 | .008928 | .0109375 | .0116 | .0132 | .0130 | .120 | 31 |
| 32 | .009 | .00795 | .01015625 | .0108 | .0120 | .0120 | .115 | 32 |
| 33 | .008 | .00708 | .009375 | .0100 | .0118 | .0110 | .112 | 33 |
| 34 | .007 | .006304 | .00859375 | .0092 | .0104 | .0100 | .110 | 34 |
| 35 | .005 | .005614 | .0078125 | .0084 | .0095 | .0095 | .108 | 35 |
| 36 | .004 | .005 | .00703125 | .0076 | .0090 | .0090 | .106 | 36 |
| 37 | ..... | .004453 | .006640625 | .0068 | ..... | .0085 | .103 | 37 |
| 38 | ..... | .003965 | .00625 | .0060 | ..... | .0080 | .101 | 38 |
| 39 | ..... | .003531 | ..... | ..... | ..... | .0075 | .099 | 39 |
| 40 | ..... | .003144 | ..... | ..... | ..... | .0070 | .097 | 40 |

| Size, Inches. | Stud Link. | | B. B. Crane. | | | B. B. B. Crane. | | | Best Special Dredge. | | | |
|------------------|-------------------------|-------------------|--------------------------------|------------------------|-------------------|--------------------------------|------------------------|-------------------|--------------------------------|------------------------|-------------------|--------------------------------|
| | Weight per Fathom | Proof, Pounds. | Breaking Strain, Pounds. | Weight per Foot. | Proof, Pounds. | Breaking Strain, Pounds. | Weight per Foot. | Proof, Pounds. | Breaking Strain, Pounds. | Weight per Foot. | Proof, Pounds. | Breaking Strain, Pounds. |
| $\frac{1}{8}$ | 600 | ..... | ..... | $\frac{1}{8}$ | 1,000 | 1,750 | $\frac{1}{8}$ | 1,250 | 2,000 | $\frac{1}{8}$ | 1,750 | 3,500 |
| $\frac{1}{4}$ | 940 | ..... | ..... | $\frac{1}{4}$ | 1,500 | 3,000 | $\frac{1}{4}$ | 2,000 | 4,000 | 1 | 2,500 | 5,000 |
| $\frac{3}{8}$ | 1300 | ..... | ..... | 1 | 2,500 | 5,000 | 1 | 3,000 | 6,000 | 1 | 3,500 | 7,000 |
| $\frac{1}{2}$ | 2100 | ..... | ..... | 1 $\frac{1}{2}$ | 4,000 | 8,000 | 1 $\frac{1}{2}$ | 4,500 | 9,000 | 1 $\frac{1}{2}$ | 5,000 | 10,000 |
| $\frac{5}{8}$ | 3000 | ..... | ..... | 2 | 6,000 | 12,000 | 2 | 6,500 | 13,000 | 2 | 7,000 | 14,000 |
| $\frac{3}{4}$ | 4000 | ..... | ..... | 2 $\frac{1}{2}$ | 7,000 | 15,500 | 2 $\frac{1}{2}$ | 8,000 | 17,000 | 2 $\frac{1}{2}$ | 9,000 | 18,000 |
| $\frac{7}{8}$ | 5000 | ..... | ..... | 3 $\frac{1}{2}$ | 9,000 | 18,000 | 3 $\frac{1}{2}$ | 10,000 | 20,000 | 3 $\frac{1}{2}$ | 11,000 | 22,000 |
| 1 | 6000 | ..... | ..... | 4 $\frac{1}{2}$ | 11,000 | 22,000 | 4 $\frac{1}{2}$ | 12,000 | 26,000 | 4 $\frac{1}{2}$ | 14,000 | 27,000 |
| $1 \frac{1}{8}$ | 7000 | ..... | ..... | 5 $\frac{1}{2}$ | 14,000 | 28,000 | 5 $\frac{1}{2}$ | 14,500 | 30,000 | 5 $\frac{1}{2}$ | 17,000 | 32,500 |
| $1 \frac{1}{4}$ | 8000 | ..... | ..... | 6 $\frac{1}{2}$ | 16,000 | 32,000 | 6 $\frac{1}{2}$ | 17,500 | 36,000 | 6 $\frac{1}{2}$ | 20,000 | 40,000 |
| $1 \frac{3}{8}$ | 9000 | ..... | ..... | 7 | 19,000 | 38,000 | 7 | 19,000 | 40,000 | 7 | 23,000 | 42,000 |
| $1 \frac{1}{2}$ | 10000 | ..... | ..... | 8 | 20,000 | 40,000 | 8 | 22,000 | 44,000 | 8 | 26,000 | 48,000 |
| $1 \frac{5}{8}$ | 11000 | ..... | ..... | 9 $\frac{1}{2}$ | 24,000 | 48,000 | 9 $\frac{1}{2}$ | 25,000 | 50,000 | 9 $\frac{1}{2}$ | 29,000 | 54,000 |
| $1 \frac{3}{4}$ | 12000 | ..... | ..... | 10 $\frac{1}{2}$ | 26,000 | 52,000 | 10 $\frac{1}{2}$ | 28,000 | 57,000 | 10 $\frac{1}{2}$ | 32,000 | 61,000 |
| $1 \frac{7}{8}$ | 13000 | ..... | ..... | 12 | 28,000 | 56,000 | 12 | 32,000 | 65,000 | 12 | 35,000 | 69,000 |
| 2 | 14000 | ..... | ..... | 13 $\frac{1}{2}$ | 32,000 | 60,000 | 13 $\frac{1}{2}$ | 36,000 | 72,000 | 13 $\frac{1}{2}$ | 40,000 | 78,000 |
| $2 \frac{1}{8}$ | 15000 | ..... | ..... | 14 $\frac{1}{2}$ | 36,000 | 72,000 | 14 $\frac{1}{2}$ | 40,000 | 80,000 | 14 $\frac{1}{2}$ | 46,000 | 88,000 |
| $2 \frac{1}{4}$ | 16000 | ..... | ..... | 16 $\frac{1}{2}$ | 42,000 | 84,000 | 16 $\frac{1}{2}$ | 44,000 | 88,000 | 16 $\frac{1}{2}$ | 51,000 | 95,000 |
| $2 \frac{3}{8}$ | 17000 | ..... | ..... | 17 $\frac{1}{2}$ | 46,000 | 92,000 | 17 $\frac{1}{2}$ | 48,000 | 96,000 | 17 $\frac{1}{2}$ | 54,000 | 104,000 |
| $2 \frac{1}{2}$ | 18000 | ..... | ..... | 19 $\frac{1}{2}$ | 50,000 | 100,000 | 19 $\frac{1}{2}$ | 53,000 | 104,000 | 19 $\frac{1}{2}$ | 58,000 | 114,000 |
| $2 \frac{5}{8}$ | 19000 | ..... | ..... | 21 $\frac{1}{2}$ | 54,000 | 108,000 | 21 $\frac{1}{2}$ | 58,000 | 116,000 | 21 $\frac{1}{2}$ | 62,000 | 122,000 |
| $2 \frac{3}{4}$ | 20000 | ..... | ..... | 23 | 60,000 | 120,000 | 23 | 62,000 | 124,000 | 23 | 67,000 | 134,000 |



NOTES ON ROOFS.

APPROXIMATE WEIGHT OF VARIOUS ROOF COVERINGS.

| Material. | Weight in Pounds per Square of Roof. |
|--|--------------------------------------|
| Yellow pine (Northern) sheathing 1 inch thick. | 300 |
| “ “ (Southern). | 400 |
| Spruce. | 200 |
| Chestnut or maple. | 400 |
| Ash or oak. | 500 |
| Shingles, pine. | 200 |
| Slate $\frac{1}{4}$ inch thick. | 900 |
| Sheet iron $\frac{1}{8}$ inch thick. | 300 |
| “ “ $\frac{1}{8}$ inch “ and laths. | 500 |
| Iron, corrugated. | 100 to 375 |
| “ galvanized, flat. | 100 to 350 |
| Tin. | 70 to 125 |
| Felt and asphalt. | 100 |
| “ “ gravel. | 800 to 1000 |
| Skylights, glass, $\frac{3}{16}$ inch to $\frac{1}{2}$ inch thick. | 250 to 700 |
| Sheet lead. | 500 to 800 |
| Copper. | 80 to 125 |
| Zinc. | 100 to 200 |
| Tiles, flat. | 1500 to 2000 |
| “ “ with mortar. | 2000 to 3000 |
| “ pan. | 1000 |

ANGLES OF ROOFS AS COMMONLY USED.

| Proportion of Rise to Span. | Angle. | | Length of Rafter to Rise. | Proportion of Rise to Span. | Angle. | | Length of Rafter to Rise. |
|-----------------------------|--------|------|---------------------------|-----------------------------|--------|------|---------------------------|
| | Deg. | Min. | | | Deg. | Min. | |
| $\frac{1}{4}$ | 45 | .. | 1.4142 | $\frac{1}{4}$ | 26 | 34 | 2.2361 |
| $\frac{1}{3}$ | 33 | 41 | 1.8028 | $\frac{1}{3}$ | 21 | 48 | 2.6926 |
| $\frac{1}{2}$ | 30 | .. | 2.0000 | $\frac{1}{2}$ | 18 | 26 | 3.1623 |
| $2\sqrt{3}$ | | | | | | | |

APPROXIMATE LOADS PER SQUARE FOOT FOR ROOFS OF SPANS UNDER SEVENTY-FIVE FEET, INCLUDING WEIGHT OF TRUSS.

| | |
|---|-----------|
| Roof covered with corrugated sheets, unboarded... | 8 pounds. |
| “ “ “ “ “ “ on boards.... | 11 “ |
| “ “ “ slate, on laths..... | 13 “ |
| Same, on boards 1¼ in. thick..... | 16 “ |
| Roof covered with shingles, on laths..... | 10 “ |
| Add to above, if plastered below rafters..... | 10 “ |
| Snow, light, weighs per cubic foot..... | 5 to 12 “ |

For spans over 75 feet add 4 pounds to the above loads per square foot.

It is customary to add 30 pounds per square foot to the above for snow and wind when separate calculations are not made.

PRESSURE OF WIND ON ROOFS. (UNWIN.)

a = angle of surface of roof with direction of wind;

F = force of wind in pounds per square foot;

A = pressure normal to surface of roof = $F \sin a^{1.84 \cos a - 1}$.

B = pressure perpendicular to direction of wind = $F \cot a \sin a^{1.84 \cos a}$.

C = pressure parallel to direction of wind = $F \sin a^{1.84 \cos a}$.

| Angle of roof = a | 5° | 10° | 20° | 30° | 40° | 50° | 60° | 70° | 80° | 90° |
|---------------------------|------|-----|-----|-----|-----|-----|------|------|------|------|
| $A = F \times$ | .125 | .24 | .45 | .66 | .83 | .95 | 1.00 | 1.02 | 1.01 | 1.00 |
| $B = F \times$ | .122 | .24 | .42 | .57 | .64 | .61 | .50 | .35 | .17 | .00 |
| $C = F \times$ | .01 | .04 | .15 | .33 | .53 | .73 | .85 | .96 | .99 | 1.00 |

MISCELLANEOUS DATA.

FORCE OF THE WIND.

| Description. | Miles per Hour. | Feet per Minute. | Feet per Second. | Force in Pounds per Sq. Foot. |
|-------------------------|-----------------|------------------|------------------|-------------------------------|
| Hardly perceptible..... | 1 | 88 | 1.47 | 0.005 |
| Just perceptible..... | 2 | 176 | 2.93 | 0.02 |
| | 3 | 264 | 4.4 | 0.044 |
| | 4 | 352 | 5.87 | 0.079 |
| Gentle breeze..... | 5 | 440 | 7.33 | 0.123 |
| | 10 | 880 | 14.67 | 0.492 |
| Pleasant breeze..... | 15 | 1320 | 22 | 1.107 |
| | 20 | 1760 | 29.3 | 1.968 |
| Brisk gale..... | 25 | 2200 | 36.6 | 3.075 |
| | 30 | 2640 | 44 | 4.428 |
| High wind..... | 35 | 3080 | 51.3 | 6.027 |
| | 40 | 3220 | 58.6 | 7.872 |
| Very high wind..... | 45 | 3960 | 66 | 9.963 |
| | 50 | 4400 | 73.3 | 12.300 |
| Storm..... | 60 | 5280 | 88 | 17.712 |
| | 70 | 6160 | 102 | 24.108 |
| Great storm..... | 80 | 7040 | 117.3 | 31.488 |
| | 100 | 8800 | 146.6 | 49.200 |

MELTING-POINTS OF METALS.

| Metals. | Centi-grade, Degrees. | Fahren-heit, Degrees. | Metals. | Centi-grade, Degrees. | Fahren-heit, Degrees. |
|---------------------|-----------------------|-----------------------|----------------|-----------------------|-----------------------|
| Aluminum..... | 700 | 1292 | Lead..... | 334 | 617 |
| Antimony..... | 425 | 797 | Magnesium..... | 235 | 455 |
| Arsenic..... | 185 | 365 | Mercury..... | 40 | 40 |
| Bismuth..... | 264 | 507 | Nickel..... | 1600 | 2912 |
| Cadmium..... | 320 | 608 | Potassium..... | 62 | 143 |
| Cobalt..... | 1200 | 2192 | Platinum..... | 2600 | 4712 |
| Copper..... | 1091 | 1995 | Silver..... | 1040 | 1944 |
| Gold..... | 1381 | 2485 | Steel..... | 1400 | 2552 |
| Indium..... | 176 | 348 | Sodium..... | 96 | 173 |
| Iron, wrought... .. | 1500 | 2786 | Tin..... | 235 | 455 |
| Iron, cast..... | 1200 | 2192 | Zinc..... | 412 | 774 |

COLOR OF HOT METALS AND TEMPERATURE AT CERTAIN COLORS.

| Color. | Corresponds to | |
|---------------------------|----------------------|----------------------|
| | Centigrade, Degrees. | Fahrenheit, Degrees. |
| Incipient red heat..... | 525 | 977 |
| Dull red..... | 700 | 1292 |
| Incipient cherry-red..... | 800 | 1472 |
| Cherry-red..... | 900 | 1652 |
| Clear cherry-red..... | 1000 | 1832 |
| Deep orange..... | 1100 | 2012 |
| Clear orange..... | 1200 | 2192 |
| White..... | 1300 | 2372 |
| Bright white..... | 1400 | 2552 |
| Dazzling white..... | 1500 | 2732 |

To find the weight of metal objects: Measure the number of cubic inches contained in the piece and multiply by 0.2816 for wrought iron, 0.2607 for cast iron, 0.32418 for copper, 0.41015 for lead, 0.3112 for brass, and the answer will be the number of pounds in the piece.

MOULDERS AND PATTERN-MAKERS' TABLE.

| White Pine being 1. | | Cast Iron being 1. | | Bar Iron being 1. | |
|---------------------|------|--------------------|------|--------------------|------|
| Cast iron. | 13 | Bar iron. | 1.07 | Cast iron. | .95 |
| Copper. | 13.4 | Steel. | 1.08 | Steel. | 1.03 |
| Brass. | 12.7 | Brass. | 1.16 | Copper. | 1.16 |
| Lead. | 18.1 | Copper. | 1.21 | Brass. | 1.09 |
| Steel. | 14 | Lead. | 1.55 | Lead. | 1.48 |

SHRINKAGE IN CASTINGS.

| | | |
|-----------------------|--------------------|-------------------------------|
| Pattern-makers' rule. | Aluminum. | $\frac{3}{16}$ inch per foot. |
| | Cast iron. | $\frac{1}{8}$ " " " |
| | Brass. | $\frac{3}{16}$ " " " |
| | Copper. | $\frac{3}{16}$ " " " |
| | Lead. | $\frac{1}{8}$ " " " |
| | Steel. | $\frac{1}{4}$ " " " |
| | Tin. | $\frac{1}{12}$ " " " |
| | Zinc. | $\frac{3}{16}$ " " " |

REDUCTION FOR ROUND CORES AND CORE-PRINTS.—Rule.—Multiply the square of the diameter by the length of the core in inches and the product multiplied by 0.017 is the weight of the pine core to be deducted from the weight of the pattern

WEIGHT OF CAST-IRON SASH-WEIGHTS.

| Length in Inches. | Round. | | | | | | | | |
|-------------------------|---------------------|-----------------|-----------------|-----------------|------|-----------------|-----------------|-----------------|-------|
| | Inches in Diameter. | | | | | | | | |
| | 1 | 1 $\frac{1}{4}$ | 1 $\frac{1}{2}$ | 1 $\frac{3}{4}$ | 2 | 2 $\frac{1}{4}$ | 2 $\frac{1}{2}$ | 2 $\frac{3}{4}$ | 3 |
| | Weight in Pounds. | | | | | | | | |
| 1 | .20 | .31 | .45 | .62 | .81 | 1.04 | 1.27 | 1.53 | 1.83 |
| 2 | .40 | .62 | .90 | 1.24 | 1.62 | 2.08 | 2.54 | 3.06 | 3.66 |
| 3 | .60 | .93 | 1.35 | 1.86 | 2.43 | 3.12 | 3.81 | 4.59 | 5.41 |
| 4 | .80 | 1.24 | 1.80 | 2.48 | 3.24 | 4.16 | 5.08 | 6.12 | 7.32 |
| 5 | 1.00 | 1.55 | 2.25 | 3.10 | 4.05 | 5.20 | 6.35 | 7.65 | 9.15 |
| 6 | 1.20 | 1.86 | 2.70 | 3.72 | 4.86 | 6.24 | 7.62 | 9.18 | 10.98 |
| 7 | 1.40 | 2.17 | 3.15 | 4.34 | 5.67 | 7.28 | 8.89 | 10.71 | 12.81 |
| 8 | 1.60 | 2.48 | 3.60 | 4.96 | 6.48 | 8.32 | 10.16 | 12.24 | 14.64 |
| 9 | 1.80 | 2.79 | 4.05 | 5.58 | 7.29 | 9.36 | 11.43 | 13.77 | 16.47 |
| 10 | 2.00 | 3.10 | 4.50 | 6.20 | 8.10 | 10.40 | 12.70 | 15.30 | 18.30 |
| 11 | 2.20 | 3.41 | 4.96 | 6.88 | 9.91 | 11.44 | 13.97 | 16.83 | 20.13 |
| 12 | 2.43 | 3.72 | 5.40 | 7.44 | 9.72 | 12.48 | 15.24 | 18.36 | 21.96 |

| Length in Inches. | Square. | | | | | | | | |
|-------------------------|-------------------|-----------------|-----------------|-----------------|-------|-----------------|-----------------|-----------------|-------|
| | Inches Square. | | | | | | | | |
| | 1 | 1 $\frac{1}{4}$ | 1 $\frac{1}{2}$ | 1 $\frac{3}{4}$ | 2 | 2 $\frac{1}{4}$ | 2 $\frac{1}{2}$ | 2 $\frac{3}{4}$ | 3 |
| | Weight in Pounds. | | | | | | | | |
| 1 | .26 | .40 | .58 | .79 | 1.04 | 1.31 | 1.62 | 1.96 | 2.34 |
| 2 | .52 | .80 | 1.16 | 1.58 | 2.08 | 2.62 | 3.24 | 3.92 | 4.68 |
| 3 | .78 | 1.20 | 1.74 | 2.37 | 3.12 | 3.93 | 4.86 | 5.88 | 7.02 |
| 4 | 1.04 | 1.60 | 2.32 | 3.16 | 4.16 | 5.24 | 6.48 | 7.84 | 9.36 |
| 5 | 1.30 | 2.00 | 2.90 | 3.95 | 5.20 | 6.55 | 8.10 | 9.88 | 11.70 |
| 6 | 1.56 | 2.40 | 3.48 | 4.74 | 6.24 | 7.86 | 9.72 | 11.76 | 14.04 |
| 7 | 1.82 | 2.80 | 4.06 | 5.53 | 7.28 | 9.17 | 11.34 | 13.72 | 16.38 |
| 8 | 2.08 | 3.20 | 4.64 | 6.32 | 8.32 | 10.48 | 12.96 | 15.68 | 18.72 |
| 9 | 2.34 | 3.60 | 5.22 | 7.11 | 9.36 | 11.79 | 14.58 | 17.64 | 21.06 |
| 10 | 2.60 | 4.00 | 5.88 | 7.90 | 10.40 | 13.10 | 16.20 | 19.60 | 23.40 |
| 11 | 2.86 | 4.40 | 6.38 | 8.69 | 11.44 | 14.41 | 17.82 | 21.56 | 25.74 |
| 12 | 3.12 | 4.80 | 6.96 | 9.48 | 12.48 | 15.72 | 19.44 | 23.52 | 28.08 |

WEIGHT OF CROWDS.—The weight of crowds on floors per square foot varies from 100 to 145 pounds. Prof. Kernot of Victoria made some experiments with a crowd of persons in which he packed them close enough to give a weight on the floor of 147.4 pounds per square foot.

Miscellaneous Materials.—**GLUE.**—This valuable product consists essentially of gelatine and is prepared from a variety of animal products. It varies in purity and in quality

TABLE OF LEAD SASH-WEIGHTS.

| Size. | Round Weights, Weight per Lineal Foot. | Square Weights, Weight per Lineal Foot. |
|--------|---|--|
| 1 inch | 3½ pounds | 4.93 pounds |
| 1½ " | 6 " | 7.68 " |
| 1¾ " | 8½ " | 10.27 " |
| 2 " | 11½ " | 15.08 " |
| 2½ " | 15½ " | 19.02 " |
| 2¾ " | 18½ " | 24 " |
| 3 " | 23 " | 30.82 " |
| 3¼ " | 28.93 " | 37.27 " |
| 3½ " | 34.81 " | 44.38 " |
| 3¾ " | 40.52 " | 52.07 " |
| 4 " | 47.26 " | 60.82 " |
| | 54 " | 69.33 " |
| | 61.93 " | |

from the almost colorless varieties of gelatine or fish glue to the dark-brown color.

Glue is made by digesting bones and other animal tissues at a low temperature (best in a vacuum apparatus), then clarifying the liquid from any insoluble portions, and setting this in moulds to cool; when cold, cutting it into thin slices and exposing these on netting until dry. The palest glues are made from the best materials, and the hot liquids are bleached. The darkest glues are usually made from bones and are not treated before drying.

The best glues are transparent and of a clear amber color. When glue is prepared it should be broken up and allowed to stand overnight in cold water. It should be melted in a double pot and covered to keep out all dirt. The water in the outer pot should always be high enough to be above the glue in the small pot.

Glue that has been remelted several times loses its strength. Glue should be used when it is boiling hot, and the pieces to be glued together should be heated and the glue spread on them in a thin film; then the pieces should be clamped together tight enough to force out all surplus glue.

ALUM.—Alum is a whitish, astringent, saline substance; properly it is a double salt, being composed of sulphate of potash and sulphate of alumina, which, along with a certain proportion of water, crystallize together in cubes.

It is soluble in eighteen times its weight in cold water, and in its own weight of hot water. The solution thus obtained has a peculiar astringent taste, and is strongly acid to colored test-papers.

STANDARD SCREW-THREADS, NUTS, AND BOLT-HEADS.

Recommended by the Franklin Institute.

SCREW-THREADS.



Angle of thread 60°. Flat at top and bottom = $\frac{1}{8}$ of pitch.

| Diameter of Screw, Inches. | Diameter at Root of Thread, Inches. | Threads per Inch, Number. |
|----------------------------|-------------------------------------|---------------------------|
| $\frac{1}{16}$ | .185 | 20 |
| $\frac{1}{8}$ | .240 | 18 |
| $\frac{3}{16}$ | .294 | 16 |
| $\frac{1}{4}$ | .344 | 14 |
| $\frac{5}{16}$ | .400 | 13 |
| $\frac{3}{8}$ | .454 | 12 |
| $\frac{7}{16}$ | .507 | 11 |
| $\frac{1}{2}$ | .620 | 10 |
| $\frac{5}{8}$ | .731 | 9 |
| 1 | .837 | 8 |
| $1\frac{1}{8}$ | .940 | 7 |
| $1\frac{1}{4}$ | 1.065 | 7 |
| $1\frac{3}{8}$ | 1.160 | 6 |
| $1\frac{1}{2}$ | 1.284 | 6 |
| $1\frac{5}{8}$ | 1.389 | 5 $\frac{1}{2}$ |
| $1\frac{3}{4}$ | 1.490 | 5 |
| $1\frac{7}{8}$ | 1.615 | 5 |
| 2 | 1.712 | 4 $\frac{1}{2}$ |
| $2\frac{1}{4}$ | 1.962 | 4 $\frac{1}{2}$ |
| $2\frac{1}{2}$ | 2.175 | 4 |
| $2\frac{3}{4}$ | 2.425 | 4 |
| 3 | 2.629 | 3 $\frac{1}{2}$ |
| $3\frac{1}{4}$ | 2.879 | 3 $\frac{1}{2}$ |
| $3\frac{1}{2}$ | 3.100 | 3 $\frac{1}{2}$ |
| $3\frac{3}{4}$ | 3.317 | 3 |
| 4 | 3.567 | 3 |
| $4\frac{1}{4}$ | 3.798 | 2 $\frac{7}{8}$ |
| $4\frac{1}{2}$ | 4.028 | 2 $\frac{7}{8}$ |
| $4\frac{3}{4}$ | 4.255 | 2 $\frac{3}{8}$ |
| 5 | 4.480 | 2 $\frac{1}{2}$ |
| $5\frac{1}{4}$ | 4.730 | 2 $\frac{1}{2}$ |
| $5\frac{1}{2}$ | 4.953 | 2 $\frac{1}{2}$ |
| $5\frac{3}{4}$ | 5.203 | 2 $\frac{1}{2}$ |
| 6 | 5.423 | 2 $\frac{1}{2}$ |

Nuts and bolt-heads are determined by the following rules, which apply to both square and hexagon nuts:

Short dia. of rough nut = $1\frac{1}{2} \times$ dia. of bolt + $\frac{1}{8}$ in.

Short dia. of finished nut = $1\frac{1}{2} \times$ dia. of bolt + $\frac{1}{16}$ in.

Thickness of rough nut = dia. of bolt.

Thickness of finished nut = dia. of bolt - $\frac{1}{16}$ in.

Short dia. of rough head = $1\frac{1}{2} \times$ dia. of bolt + $\frac{1}{8}$ in.

Short dia. of finished head = $1\frac{1}{2} \times$ dia. of bolt + $\frac{1}{16}$ in.

Thickness of rough head = $\frac{1}{2}$ short dia. of head.

Thickness of finished head = dia. of bolt - $\frac{1}{16}$ in.

The long diameter of a hexagon nut may be obtained by multiplying the short diameter by 1.155 and the long diameter of a square nut by multiplying the short diameter by 1.414.

The above standards for screw-threads, nuts, and bolt-heads were recommended by the Franklin Institute in December, 1864. The standard for screw-threads has been very generally adopted in the United States, but the proportions recommended for nuts and bolt-heads have not found general acceptance because of the odd sizes of bar—not usually rolled by the mills—required to make the nut.

Alum is made by digesting aluminous earths with sulphuric acid, treating the mass with water, and adding to the solution potassium sulphate, after which it is allowed to crystallize out.

The manufacture of the colors or paints called lakes depends on this property of alumina to attach to itself certain coloring-matters.

Thus, if a solution of alum is colored with cochineal or madder, and ammonia or carbonate of soda is added, the alumina in the alum is precipitated with the color attached to it, and the liquid is left colorless.

It is commonly used by paperhangers to keep paste sweet.

AMMONIA.—Ammonia is the solution of gas ammonia in water. Ammonia gas is composed of 1 part nitrogen and 3 parts hydrogen.

Ammonia is a volatile liquid, characterized by a strong, peculiar odor, and evaporates completely away when exposed to air or boiled. It is a powerful base, uniting with and neutralizing all acids, and will dissolve many gums and acids.

It is used as a powerful cleaner for glass or woodwork when diluted to a light solution. Especially useful in fairly strong solution, cleaning floors where revarnishing is to be done.

WHITING.—This pigment is prepared from chalk. Chalk is a natural deposit of calcium carbonate, found extensively in England and France. When chalk is examined under a microscope it is seen to consist of minute shells, the remains of a group of animals known as Foraminifera, of which there are many species. These form a skeleton of calcium carbonate. They live on the surface of the sea. Whiting is nothing more than chalk ground up with water. Whiting is largely used as a body color in distemper work, using water as a vehicle. It is quite permanent when used as a pigment, resisting exposure to all ordinary atmospheric conditions.

ASPHALTUM.—This substance is employed in the preparation of varnishes such as black japan. It was originally obtained from the shores of the Dead Sea. It is imported from Egypt, South America, and is found in a few places in the United States. The exact chemical composition has not yet been ascertained; presumably allied to petroleum and the paraffines.

Artificial asphaltum is made by melting or mixing together rosin, coal-tar, wood, and other pitches, and is used in preparing cheap black varnishes.

BEESWAX.—This is the best known of waxes and is the prod-

uct of various species of insects belonging to the genus *Apis* which are found in every quarter of the globe.

The wax is obtained by melting the combs in water and then allowing the molten wax to cool.

ALCOHOL.—It is a limpid, colorless liquid of a hot, pungent taste, and having a slight but agreeable smell. Owing to its extensive application, it becomes one of the most important substances produced by art.

There is only one source of alcohol, namely, the fermentation of sugar and other saccharine matter. The best vegetable substances for yielding it are those that contain the greatest abundance of sugar or starch.

Owing to the attraction of alcohol for water, it is impossible to procure pure alcohol by distillation alone.

Alcohol has the property of non-freezing. This property of non-freezing at any degree of cold to which the earth is subjected has led to the employment of alcohol colored by red cochineal in the thermometers sent out to the Arctic regions.

It is a powerful solvent for acids, resins, gums, oils, and waxes, and hence is employed in the preparation of varnishes. On account of rapid evaporation it is especially used in making shellac varnish.

It acts as a poison by abstracting the water from the parts it touches. It is highly inflammable, its combustion yielding only carbonic acid and water.

GRAPHITE.—Silica-graphite is as pure and sweet as charcoal, is mined at Ticonderoga, N. Y., and is an ideal pigment in flake form.

Graphite possesses greater affinity for iron and steel than any other pigment. Silica-graphite, while smooth and slippery and apparently oily to touch, is absolutely free from any oil or grease. In this respect it differs entirely from lampblack and similar products.

It is an ideal protective coating for all kinds of metal or wood. It lasts four or five times longer than any other paint, and covers two or three times more surface. It is also easier to apply than any other paint and wears brushes less.

This silica-graphite is used on new and old work, should be used for all priming or first coats, and can be used on top of any old paint. This paint has no bad odor, and will not taint water, and is as pure and sweet and healthful as charcoal, containing nothing poisonous. Good for inside of water-tanks.

It has twice the bulk of mineral paint, therefore covers just so much more surface, and is applied and used the same as linseed-oil paint.

Graphite is equally useful for wood or metal, and never fades, therefore stands without a rival for durability, economy, and for beauty of finish.

MURIATIC ACID.—Muriatic acid is prepared by heating common salt with sulphuric acid, dissolving the evolved gas in water. When pure it is a colorless liquid, fuming slightly and having a strong acid smell.

Muriatic acid is a powerful acid. It dissolves in the cold such metals as zincs, iron magnesium, nickel, and aluminum. When boiling it dissolves tin, lead, copper, bismuth, and many other metals. Muriatic acid is used largely in cleaning the alkali collecting on brick or stone buildings.

OXALIC ACID.—Oxalic acid was first discovered in the juice of the *Oxalis acetosella*. It is widely distributed in the vegetable kingdom in the form of potassium, sodium, and calcium salts, and is made artificially by heating sawdust with a mixture of caustic potash and soda. It forms white crystals, is readily soluble in water and alcohol, has an intensely acid taste, and is violently poisonous. It is often sold under the erroneous name of salts of lemon. Oxalic acid is largely used in calico-printing dyeing, and in bleaching flax and straw. It is used by painters in bleaching floors and woodwork.

GYPSUM.—Gypsum is used principally for wall plaster, and the most important markets are the large cities in which modern buildings are being constructed. Gypsum plaster is largely displacing lime mortar as wall finish. Not only is it found to be more suitable and durable, but its strength and hardness, and the fact that construction can be completed more quickly when it is used, have brought it into favor.

In the Rocky Mountain States and the region westward to the Pacific coast, the gypsum industry is in its infancy. There are plants in Montana, in the Black Hills of South Dakota, in Wyoming, Colorado, New Mexico, Utah, Nevada, California, and Oregon. Some of them have a large capacity, and their product is finding a ready market. This is more particularly true of those which supply the larger cities. The deposits are well distributed in these States, and the character of the gypsum is such that they can meet any requirements of the trade. No doubt the industry will advance with the growth of the country, and when the value of gypsum plaster is better appreciated

it will displace the lime and sand plaster in these States, as it is doing in the East.

STAFF.—This composition, which was used so extensively in the construction of buildings for the Chicago Exposition, and has been employed even more extensively in the buildings for the St. Louis Exposition, is a mixture of ordinary plaster of Paris with a suitable binding material. The latter must be rather coarse and loose, to allow the plaster to percolate through it and afford the necessary surface for adhesion. Manila fibre, hemp, etc., are commonly used for a binder. As a building material staff is well-nigh fire-proof. Frost does not hurt it. Rain has little effect upon it. A drip injures it. The short durability of staff plaster on exposition buildings in some instances has been due to their inadequate foundations and the shrinkage of the sheeting to which the plaster is applied. If spread on expanded metal lathing, staff plaster would doubtless prove durable. Staff and cement do not give a good mixture.

SILICATE STONE.—This is an English invention and consists essentially of silica and lime. The proportion of lime used is from 5 to 10 per cent, the purity of the silica regulating the quantity. When the proper mixture has been made it is put into moulds, water and steam are injected, and the whole subjected to a high heat and pressure. In this way, it is stated, the lime combines with part of the sand and forms a silicate of lime, to the presence of which the mechanical strength of the stone is principally due. The crushing strength is given as 10,776 pounds per square inch. The process takes six hours from the time the mixture enters the moulds until it is ready for shipment. In appearance the stone resembles granite, though the color can be changed in manufacturing to suit the taste of customers. It is adapted to working in intricate ornamental designs, and is claimed to have the property of resisting the injurious action of salt or fresh water and varying atmospheric conditions.

BUILDING PAPERS.—There are a number of different building papers on the market, such as asbestos, parchment, felt, rosin-sized, asphalt, tar, etc.

They are usually graded as to weight or thickness.

The felt or deafening papers are usually graded as to weight per square yard, and generally come in three weights, viz.: 9 square feet to a pound, and which is about $\frac{3}{8}$ inch in thickness; 6

square feet to a pound, and which is about $\frac{1}{16}$ inch in thickness; $4\frac{1}{2}$ square feet to a pound, and which is about $\frac{5}{8}$ inch in thickness.

The asbestos papers usually run in three thicknesses as follows: Thin, which weighs 6 pounds per 100 square feet and which is about $\frac{1}{100}$ inch in thickness; medium, which weighs 10 pounds per 100 square feet, and which is about $\frac{1}{84}$ inch in thickness; and heavy, weighing 14 pounds per 100 square feet, and which is about $\frac{1}{60}$ inch in thickness.

Rosin-sized papers also come in various thicknesses, but are usually very thin; they are made by immersing Manila or other paper in a mixture of rosin, glue, and ochre.

Asphalt papers are made by saturating felt paper with asphaltum, either alone or mixed with petroleum residuum.

The various tar and roofing papers are made in one, two, or three thicknesses, and are designated as "one-ply," "two-ply," etc.

ASBESTOS.—This is a mineral of so fibrous a nature that it can be woven into a textile fabric, which is naturally incombustible, having also the quality of slow conduction of heat. Its chief use in building has been for covering of steam-pipes, deafening for floors, sheathing paper, etc.

Its color ranges from white, through many shades of yellow to a dull brown.

COAL-TAR.—Coal-tar is a by-product produced in the manufacture of coal-gas. When distilled it produces, in various stages, coal-naphtha, dead oil or creosote, and tar or pitch; this last is used for roofing, waterproofing, etc. Coal-tar after being distilled is very brittle at the freezing-point, and softens and flows between 70° and 115° Fahr.

Paving pitch is the residue obtained from distilling coal-tar.

Creosote-oil is a product obtained in distilling coal-tar. It is mostly used for preserving timber.

ASPHALTUM AND BITUMINOUS ROCK.—The general term "asphaltum" may be applied to the numerous varieties of hydrocarbons of an asphaltic base which exist in all conditions, from the liquid to the solid state. The general rule has been to include under asphaltum only material used as such, for instance, the residuum from petroleum-refining processes which is sold and used as asphalt.

The term "bituminous rock" includes sandstones and limestones impregnated with asphaltum or bitumen which are shipped and sold without previous mixing. This rock is used prin-

pally for street pavement, and is either used in its natural state or mixed with other ingredients.

Bituminous rock is also treated to obtain asphaltum or bitumen, the product being sold as refined or gum asphalt.

Asphaltum is much used for roofing purposes, and is much superior to the ordinary tar or pitch, as the sun and weather does not affect it.

When there is any doubt as to the composition of either asphaltum or bituminous rock, a careful analysis should be made.

MINERAL WOOL is essentially a vitreous substance converted to a fibrous condition. In appearance it consists of a mass of very fine fibres interlacing each other in every direction, thus forming an innumerable number of minute air-cells. The resemblance of these fibres to those of wool or cotton has given to the material the name of mineral wool in this country, and of silicate cotton elsewhere; but it is only in appearance and softness that any similarity exists between the mineral and organic fibres.

Mineral wool partakes of the nature of glass without its brittleness, the fibres being soft, pliant, and inelastic. They are of irregular thickness, and cross each other in all possible directions. It is made by converting scoria and certain rocks, while in a melted condition, to a fibrous state.

| Average Weight. | Pounds per Cubic Foot. | Square Foot One Inch Thick. | Cubic Feet to Ton. |
|-------------------------|------------------------|-----------------------------|--------------------|
| Ordinary slag wool..... | 12 | 1 pound | 166 |
| Selected " "..... | 9 | $\frac{2}{3}$ " | 223 |
| Extra " "..... | 6 | $\frac{1}{2}$ " | 333 |
| Ordinary rock wool..... | 12 | 1 " | 166 |
| Selected " "..... | 8 | $\frac{2}{3}$ " | 250 |
| Extra " "..... | 6 | $\frac{1}{2}$ " | 333 |

LITHARGE.—Obtained by melting lead and passing a current of air over the molten lead. The oxygen is absorbed; the resulting oxide is allowed to melt and run into suitable vessels. On cooling it breaks into fragments, which are again broken into flakes or powdered, as the case may be, and ready for the market.

Litharge is used for a great variety of purposes: in making glass, cements, colors, pottery, calico-printing, and as a dryer in paints and oils, etc.

MICA.—Common mica is a double silicate of potash and

alumina. A characteristic feature of mica is that it occurs in plates which are readily split into thin transparent slices, with great power of resisting heat. Mica forms one of the constituents of a typical granite, and it appears in small flakes throughout the stone.

Miscellaneous Receipts. — **TEST FOR SEWER-GAS.** — Saturate unglazed paper with a solution of 1 ounce pure lead acetate in half a pint of rain-water; let it partially dry, then expose in the room suspected of containing sewer-gas.

The presence of gas in any considerable quantity soon darkens or blackens the test-paper. A suspected joint of a pipe can be tested by wrapping with a single layer of white muslin, moistened with the above solution, and if gas is escaping it will darken the cloth.

TO CLEAN COPPER. — Take 1 ounce of oxalic acid, 6 ounces of rotten stone, $\frac{1}{2}$ ounce of gum arabic, all in powder, 1 ounce of sweet-oil, and sufficient water to make a paste. Apply a small portion and rub dry with a flannel or leather.

REMOVAL OF STAINS FROM GRANITE. — A paste of 1 ounce of ox-gall, 1 gill of strong solution of caustic soda, $1\frac{1}{2}$ tablespoonfuls of turpentine, with enough pipe-clay to make it thick, and scour well.

Or, mix together $\frac{1}{4}$ pound soft soap, 1 ounce washing-soda, and a piece of sulphate of soda as big as a walnut. Rub it over the surface proposed to clean, let it stand twenty-four hours, and then wash off; or, smoke and soot stains can be removed with a hard scrubbing-brush and fine sharp sand, to which add a little potash.

Or, use strong lye, or make a hot solution of 3 pounds of common washing-soda dissolved in 1 gallon of water. Lay it on the granite with a paint-brush.

TO CLEAN MARBLE. — Mix 2 parts by weight of sal-soda, 1 part powdered chalk or fine bolted whiting, and 1 part powdered pumice-stone with enough water to make a thin batter, and by the means of a scrubbing-brush apply it to the spots; then wash off with soap and water.

Or, to remove grease spots from marble, moisten fine whiting or fullers' earth with benzine, apply it in a thick layer to the spots, and let it remain for some time; then remove the dry paste and wash the spot with soap and water.

To extract oil stains from marble, make a paste by mixing 2 parts of fullers' earth, 1 part soft soap, and 1 part potash with

boiling water. Apply this paste to the spots and let it remain three or four hours.

TO REMOVE PAINT FROM WINDOW GLASS.—Put sufficient saleratus into hot water to make a strong solution, and with this saturate the paint which adheres to the glass. Let it remain until nearly dry, then rub it off with a woollen cloth.

TO MAKE MODELLING CLAY.—Knead dry clay with glycerine instead of water, work thoroughly with the hands, moisten work at intervals of two or three days, and keep covered to prevent evaporation of moisture.

TO CLEAN PAINT.—When paint is washed with any strong alkaline solution, such as soda or strong soap, the oil of the paint is liable to be changed to soap and the paint is seriously injured. To avoid this, take some of the best whiting, and have ready some clean warm water and a piece of flannel, which dip into the water and squeeze nearly dry; then take up as much whiting as will adhere to it, apply it to the painted surface, when a little rubbing will quickly remove any dirt or grease stains. After this wash the part well with clean water, rubbing it dry with a soft chamois. Paint thus cleaned will look as well as when first put on, and the operation may be tried without fear of injury to the most delicate colors. It answers far better than the use of soap, and does not require more than one-half the time and labor. Another simple method is the following: Put a tablespoonful of aqua ammonia in a quart of moderately hot water, dip in a flannel cloth, and with this merely wipe over the surface of the woodwork. No rubbing is necessary. The first recipe is preferable, except where the paint is badly discolored.

TO AGE OR COLOR COPPER.—Add about 1 pound of powdered sal ammoniac to 5 gallons of water, dissolve it thoroughly, and let it stand at least twenty-four hours before putting it on the copper. Apply it to the copper with a brush, being sure to cover every place; let it stand for a day and sprinkle with water, using a brush to sprinkle the water on so that it will not run and streak the copper. After standing overnight the color will be as desired. The same effect can be produced by using vinegar and salt instead of the sal ammoniac, using $\frac{1}{2}$ pound of salt to 2 gallons of vinegar.

TO REMOVE OLD GLASS FROM SASH.—Take a hot iron and run along the surface of the putty, when it can easily be removed with a chisel.

TO REMOVE RUST STAINS.—To remove rust stains from wood, wash the disfigured parts with a solution of 2 ounces of oxalic acid to 1 pint of hot water.

In fitting doors, always keep the hollow side next the stop or rebate strip.

A flour barrel is 28 to 30 inches high and 20 to 21 inches in diameter.

When hanging transoms, where possible, if the transom is to be hung at the top, hang them so that when they are open the glass will lay on the wood and not on the putty.

Wash-stands are usually set 2 feet 6 inches from the floor.

The relative strength of timbers is estimated by multiplying the breadth by the square of the depth. *Example.*—How many times as strong is a joist $2\frac{1}{2}'' \times 15''$ when supported on its narrow side as when supported on its broad side: $2\frac{1}{2} \times 2\frac{1}{2} = 6\frac{1}{4}$, $6\frac{1}{4} \times 15 = 93\frac{7}{8}$, $15 \times 15 = 225$, $225 \times 2\frac{1}{2} = 562\frac{1}{2}$, $562\frac{1}{2} \div 93\frac{7}{8} = 6$, or six times stronger.

GLOSSARY OF NAMES OF SOME NEW MATERIALS USED IN BUILDING.

ALASTER. A fire-proof paint, manufactured by the National Fireproof Paint Corporation, Chicago, Ill.

ÆOLIPILE. A patent damper for use in the smoke-collar of a furnace, manufactured by the Æolipile Co., New York.

AB-LU-ENT. A paint and varnish remover, manufactured by the Detroit White Lead Works, Detroit, Mich.

ANHYDROSAL. A water-proof coating for concrete and brick, manufactured by Toch Bros., New York.

ASBESTOLITH. A plastic sanitary floor covering, manufactured by the Asbestolith Co., New York.

ASBESTOSIDE. A siding for buildings, manufactured by H. W. Johns-Manville Co., New York

ALABASTINE. An interior-wall paint, manufactured by the Alabastine Co., Grand Rapids, Mich.

ALPHADUCT. A flexible conduit for electric wires, manufactured by the Alphaduct Mfg. Co., New York.

ASBESTINE. A fire-proof paint, manufactured by the Alden Spears Sons Co., New York.

ANAGLYPTA. An embossed-paper wall covering, for sale by W. H. S. Lloyd Co., New York.

- APADAC.** A structural-meal paint, manufactured by the Chilton Paint Co., New York.
- BITULITHIC PAVEMENT.** A pavement put down by Warren Bros., New York.
- BESSEMER PAINT.** A paint for the protection of iron and steel, manufactured by Rinald Bros., Philadelphia, Pa.
- CARBOLINEUM AVENARIUS.** A wood-preserving paint, manufactured by the Carbolineum Wood-preserving Co., New York.
- CEMENTICO.** A cold-water paint, manufactured by the U. S. Gypsum Co.
- CONSERVO.** A wood preservative, manufactured by Samuel Cabot, Boston, Mass.
- CALSOM FINISH.** A kalsomine for interior walls, manufactured by B. Moore, Chicago, Ill.
- DULL-EINE.** A dull varnish, manufactured by Samuel F. Woodhouse, Philadelphia, Pa.
- FLINTKOTE.** A prepared roof covering, manufactured by J. A. Bird & Co., Boston, Mass.
- FLINTOLINE.** A floor paint, manufactured by F. W. Devoe Co., Chicago, Ill.
- FLUATE (Lockpore).** A coating for the preservation of marble, stone, terra-cotta, etc., manufactured by Toch Bros., New York.
- GRAINOLETTE.** A transfer graining paper, manufactured by the Stencil Treasury, 209 E. 59th St., New York.
- HYDREX.** A water-proofing compound, manufactured by F. W. Bird & Son, East Walpole, Mass.
- INDURINE.** A cold-water paint, manufactured by L. A. Moore & Co., St. Paul, Minn.
- JAP-A-LAC.** A floor finish or varnish, manufactured by the Gildden Varnish Co., Cleveland, Ohio.
- KALLIGRAIN.** A transfer graining paper, manufactured by Emil Majert, New York.
- KONKERIT COATING.** A water-proof paint for concrete or brick walls, manufactured by Toch Bros., New York.
- LINOFELT.** A sheathing fibre felt, manufactured by Union Fibre Co., Winona, Minn.
- LYTHITE.** A white enamel paint, manufactured by Frank S. De Ronde Co., New York.
- LETHEROID.** A wool-felt roof covering, manufactured by the Union Paper Co., Cleveland, Ohio.

- MARBELITHIC.** An artificial marble, made by the Marbelithic Co., Dayton, Ohio.
- MONOLITH.** A sanitary plastic flooring, base, etc., manufactured by the American Monolith Co., Milwaukee, Wis.
- MALTHOID.** A ready roofing, manufactured by the Paraffine Paint Co., San Francisco, Cal.
- MIRAC.** A varnish and paint remover, manufactured by J. Lucas & Co., Philadelphia, Pa.
- MURA-KALSO.** A kalsomine, manufactured by American Lucol Co., New York.
- METILE.** A metal wall covering in imitation of tile, manufactured by Wisconsin Mantel Co., Milwaukee, Wis.
- NOVUS GLASS.** A glass wainscot, etc., manufactured by the Penn-American Plate Glass Co., Pittsburg, Pa.
- OKONITE.** A brand of insulated electric-light wire, manufactured by the Okonite Co., Broadway, New York.
- PORCELITE.** A white-enamel paint, manufactured by the Thomson Wood Finishing Co., Philadelphia, Pa.
- PHENOID.** A varnish and paint remover, manufactured by Ellis Chambers, Dedham, Mass.
- ROOF-LEAK.** An asphalt roof coating, manufactured by the Elliot Varnish Co., Chicago, Ill.
- SUPERBA.** A cold-water paint, or kalsomine for interior walls, manufactured by the Dry Kalsomine and Paint Works, New York.
- SIAMLAC.** A substitute for shellac, sold by J. B. Moffett, Minneapolis, Minn.
- SILICATED CARBON.** A transparent waterproofing for concrete and brick, manufactured by the Standard Specialty Co., Cleveland, Ohio.
- SPHINX GUM.** A strengthener to add to flour paste, manufactured by the Arabol Manufacturing Co., 100 William Street, New York.
- SALSEE.** A plastering fibre used in place of hair, manufactured by C. R. Weeks, 14th Street, New York.
- SACKET'S PLASTER BOARD.** A plaster board made in sheets 32"×36" and nailed to the studs, and then finished with a coat of hard plaster, sold by the Garden City Sand Co., Chicago, Ill.
- SANTAS.** A cloth wall covering, manufactured by the Standard Table Oil Cloth Co., New York.

- TAPESTROLA.** A burlap decoration, manufactured by Richter Manufacturing Co., Tenafly, N. J.
- TITEKOTE.** An iron-preservative paint, manufactured by the Barber Asphalt Co., Philadelphia, Pa.
- TEX-TA-DOR-NA.** A burlap wall covering, manufactured by the Tex-ta-dor-na Manufacturing Co., Columbus, Ohio.
- TRANSITE.** A fire-proof lumber, manufactured by H. W. Johns-Manville Co.

INDEX.

| | PAGE |
|----------------------------------|------|
| Abacus..... | 575 |
| Absorptive power of brick..... | 43 |
| granite..... | 43 |
| limestone..... | 43 |
| marble..... | 43 |
| mortar..... | 43 |
| sandstone..... | 43 |
| slate..... | 70 |
| Ab-u-lent..... | 692 |
| Acid, muriatic..... | 686 |
| oxalic..... | 686 |
| tests for iron and steel..... | 426 |
| Activity of cement..... | 128 |
| Adulteration of linseed-oil..... | 397 |
| red lead..... | 403 |
| turpentine..... | 399 |
| white lead..... | 402 |
| Aeolipile..... | 692 |
| Aggregate for concrete..... | 167 |
| Air-slaked lime..... | 111 |
| Alabastine..... | 692 |
| Alaster..... | 692 |
| Alcohol..... | 685 |
| Alphaduct..... | 692 |
| Alum..... | 682 |
| Aluminum, weight of... .. | 658 |
| to solder..... | 388 |
| Ammonia..... | 684 |
| Ampere, electric..... | 480 |
| Anchors to beams, etc..... | 307 |
| Anchor-joist..... | 260 |
| Anhydrosal..... | 692 |
| Anaglypta..... | 692 |
| Angle, to draw..... | 535 |
| Angle-beads..... | 293 |
| Angles in partitions..... | 299 |
| Annealing, steel..... | 447 |
| Annulet..... | 575 |

| | PAGE |
|--------------------------------------|------|
| Antimony vermilion..... | 403 |
| Apadac..... | 693 |
| Apophyge..... | 575 |
| Apothecaries, measure, liquid..... | 578 |
| dry..... | 578 |
| Arc..... | 617 |
| area of..... | 619 |
| measurement of..... | 618 |
| of circle..... | 571 |
| to draw curve of..... | 572 |
| to find radius of..... | 617 |
| Arc lamps..... | 514 |
| Arc-lighting..... | 507 |
| Arch: | |
| brick floor..... | 194 |
| composed of two arcs of circles..... | 569 |
| concrete floor..... | 195 |
| drop..... | 568 |
| elliptical, not level..... | 570 |
| flat-pointed..... | 567 |
| four-centre..... | 569 |
| Gothic..... | 567 |
| hearth..... | 86 |
| inverted, in footings..... | 27 |
| lancet Gothic..... | 567 |
| lintel..... | 59 |
| lintel, brick..... | 85 |
| size of ring..... | 622 |
| three-center..... | 568 |
| to find thrust of..... | 622 |
| Tudor..... | 569 |
| Arch brick..... | 74 |
| Architectural terra-cotta..... | 226 |
| Architecture, orders of..... | 548 |
| table of orders..... | 553 |
| Arcs of circles, tangential..... | 536 |
| Area: | |
| arc..... | 619 |
| circles, to find..... | 692 |
| circles..... | 616 |
| cone..... | 697 |
| cycloid..... | 613 |
| cylinder..... | 620 |
| ellipse..... | 619 |
| frustum of cone or pyramid..... | 620 |
| polygon..... | 613 |
| pyramid..... | 697 |
| sector..... | 619 |
| segment..... | 619 |
| sphere..... | 621 |
| square..... | 613 |

| Area: | PAGE |
|---------------------------------------|---------|
| trapezium. | 613 |
| triangle. | 613 |
| Area covered by concrete. | 144 |
| Artificial foundations. | 9 |
| stone sidewalks. | 180 |
| Asbestos. | 688 |
| paper. | 688 |
| Asbestolith. | 692 |
| Asbestoside. | 692 |
| Ash, description of. | 314 |
| Ash boxes and pits. | 253 |
| Ashlar: | |
| backing of. | 83 |
| coursed, two sizes stone. | 49 |
| irregular coursed. | 49 |
| joints in. | 64 |
| level and broken. | 49 |
| random. | 50 |
| random in courses. | 50 |
| regular coursed. | 49 |
| rusticated. | 51 |
| Asphalt paper. | 688 |
| Asphaltum. | 684-688 |
| Astragal. | 575 |
| Atmosphere, effects on stone. | 43 |
| tests for effects on stone. | 43 |
| Automatic sprinklers. | 287 |
| Avoirdupois measure. | 577 |
| Barrel, contents of. | 621 |
| size of. | 692 |
| Basalt, description of. | 29 |
| Batter-boards. | 4 |
| Beams: | |
| belly-rod. | 675 |
| bending moments of. | 478 |
| deflection of. | 478 |
| formula on iron and steel. | 476 |
| in footings. | 21 |
| properties of I beams. | 468 |
| roof and floor. | 439 |
| safe load. | 463 |
| size of. | 468 |
| steel. | 468 |
| strength of wooden. | 318 |
| to find stress of wooden. | 623 |
| various loading of. | 478 |
| weight of. | 468 |
| wooden. | 306 |
| Bed of foundations. | 8 |
| Bench-marks. | 4 |

| | PAGE |
|---|---------|
| Beeswax..... | 684 |
| Behrend steel sheet-piling..... | 19 |
| Belly-rod truss, strength of..... | 675 |
| Bessemer paint..... | 693 |
| Bevel for backing hip-rafters..... | 555 |
| octagon roof-..... | 555 |
| Bevel to mitre purlins..... | 556 |
| Birch, description of..... | 315 |
| Bitulithic pavement..... | 693 |
| Bituminous rock..... | 688 |
| Black walnut, description of..... | 315 |
| Blind bond in brickwork..... | 80 |
| Block and tackle, power of..... | 623 |
| Block-tin pipe..... | 367 |
| Blue black..... | 405 |
| pigments..... | 405 |
| lead..... | 405 |
| sap..... | 315 |
| Board measure..... | 322 |
| Boilers, setting of..... | 245 |
| Bond in brickwork..... | 79 |
| stonework..... | 48 |
| Bolting of structural iron and steel..... | 427-440 |
| Bolts, etc., in woodwork..... | 308 |
| Bond iron in buildings..... | 262 |
| Boneblack..... | 405 |
| Boston hip in shingling..... | 299 |
| Boxes, size of..... | 622 |
| Braces, to get cut of..... | 560 |
| Brass: | |
| expansion of..... | 662 |
| rods, weight of..... | 395 |
| specific gravity of..... | 658 |
| weight of sheets..... | 393 |
| weight of tubing..... | 369 |
| Bremen blue..... | 405 |
| Bricks: | |
| absorptive power..... | 43-75 |
| expansion of fire-brick..... | 662 |
| fire-brick..... | 76 |
| iron in..... | 73 |
| lime in..... | 73 |
| names of..... | 74 |
| quality of..... | 75 |
| shale in..... | 73 |
| size of..... | 74 |
| tests of..... | 75 |
| weight of..... | 75 |
| weight and strength of..... | 75 |
| working strength..... | 75 |
| vitrified..... | 76 |

| | PAGE |
|--|------|
| Brick-laying. | 76 |
| arch lintels. | 85 |
| backing up ashlar. | 83 |
| beds in brickwork. | 78 |
| bond in. | 79 |
| bond course to mark. | 82 |
| bracing of walls. | 85 |
| chimneys. | 86 |
| efflorescence on. | 100 |
| English bond. | 81 |
| English cross bond. | 81 |
| estimating of. | 100 |
| Flemish bond. | 81 |
| floor-arches. | 194 |
| footings. | 26 |
| headers. | 83 |
| hearth-arches. | 86 |
| hollow walls. | 86 |
| joints in. | 78 |
| nogging. | 87 |
| pointing. | 98 |
| projecting courses. | 84 |
| rules for. | 87 |
| secrete bond. | 80 |
| wall ties in. | 80 |
| washing down. | 86 |
| wet when layed. | 76 |
| Brick-dust, weight of. | 661 |
| Brick footings. | 26 |
| nogging. | 87 |
| British thermal unit (B.T.U.). | 524 |
| Bridging. | 298 |
| Broken-stone drain. | 5 |
| Brown colors. | 406 |
| Buckeye fire-proof floor construction. | 210 |
| Building paper. | 687 |
| Bushel, weight of. | 582 |
| Butternut, description of. | 315 |
| Buttresses. | 61 |
| Calcareous stones. | 30 |
| Calking joints in cast-iron pipes. | 359 |
| Callarino. | 575 |
| Calson finish. | 693 |
| Camber in joist. | 297 |
| Capping, concrete. | 19 |
| granite. | 20 |
| Carbon in steel. | 426 |
| Carbolineum avenarius. | 693 |
| Carpentry: | |
| anchorage of beams. | 307 |

| Carpentry: | PAGE |
|--|------|
| angles in partitions. | 299 |
| base, fastening of. | 305 |
| bracing, etc. | 299 |
| bridging floors. | 298 |
| partitions. | 298 |
| camber in joist. | 297 |
| description of woods. | 313 |
| doors. | 302 |
| doors, hand of. | 305 |
| to hang. | 692 |
| fastening finish, etc. | 304 |
| finish, nailing of. | 303 |
| flag-pole, to make. | 302 |
| floor-strips. | 297 |
| grounds. | 298 |
| hardware, placing of. | 305 |
| joins in timber. | 565 |
| kerfing of mouldings. | 569 |
| lumber measure. | 322 |
| metal plugs. | 305 |
| mouldings, nailing of. | 303 |
| nailing blocks. | 303 |
| in T. C. walls. | 304 |
| panels, etc. | 303 |
| partitions. | 298 |
| pitch of stairs. | 302 |
| reducing timber to octagon. | 558 |
| sash. | 302 |
| securing trim, etc. | 303 |
| sheathing. | 302 |
| shingling. | 299 |
| strength of wood columns. | 319 |
| of beams. | 318 |
| transoms, to hang. | 692 |
| trimmer-beams. | 306 |
| wainscot, fastening of. | 305 |
| washstands, height of. | 692 |
| wood beams, etc. | 306 |
| frames. | 304 |
| Castings, shrinkage of. | 680 |
| Cast-iron pipe, safe pressure. | 364 |
| Cast iron: | |
| appearance of. | 422 |
| color of. | 422 |
| defects in. | 421 |
| expansion of. | 662 |
| fittings, weight of. | 368 |
| inspection of columns. | 422 |
| lintels. | 438 |
| malleable. | 423 |
| melting-point. | 423 |

| | PAGE |
|---|---------|
| Cast iron: | |
| pipes, weight of. | 380 |
| pressure in cast-iron pipes. | 364 |
| sand-holes in. | 421 |
| shrinkage of. | 423 |
| specifications for. | 423 |
| strength of. | 423 |
| of columns. | 424 |
| of malleable. | 423 |
| weight of. | 423 |
| Carving, stone. | 61 |
| Cavetto. | 575 |
| Cedar. | 314 |
| Cement: | |
| activity of. | 128 |
| amount for test. | 3 |
| analysis of Portland. | 116 |
| of various brands of Portland. | 145 |
| color, etc. | 116 |
| expansion of. | 142 |
| Keene's. | 296 |
| Lafarge. | 296 |
| magnesia in. | 116 |
| manufacturers' guarantee. | 116 |
| natural. | 112 |
| non-staining. | 142 |
| notes on. | 142 |
| porosity of. | 142 |
| Portland. | 115 |
| Puzzolan. | 120 |
| use of. | 121 |
| Rosendale. | 112 |
| silica. | 124 |
| size of sieves for testing fineness. | 142 |
| slag. | 120 |
| strength of various brands of Portland. | 147 |
| of natural. | 146 |
| specifications for. | 125 |
| Portland. | 117 |
| natural. | 113 |
| Puzzolan. | 122 |
| specific gravity. | 143 |
| tests of various brands of natural. | 146 |
| of Portland. | 147 |
| tests of. | 126 |
| for expansion. | 142 |
| of mortar. | 158-171 |
| for soundness. | 142 |
| use of, in freezing weather. | 156 |
| weight of. | 658 |
| weight, etc., of natural. | 112 |
| what one barrel will do. | 144 |

| | PAGE |
|---|------|
| Cement: | |
| water-proof wash..... | 154 |
| Cementico..... | 693 |
| Centrifugal pumps, capacity of..... | 634 |
| revolutions of..... | 635 |
| Chain, strength of..... | 675 |
| Chases in walls..... | 85 |
| Channels, properties of..... | 472 |
| safe load..... | 466 |
| sizes of..... | 472 |
| weights of..... | 472 |
| Cherry..... | 315 |
| Chestnut, description of..... | 315 |
| Chimneys, flues, etc., fire protection of..... | 235 |
| height of flue-lining..... | 235 |
| supports..... | 240 |
| thickness of brick walls..... | 231 |
| wood plugs in..... | 236 |
| and flues in frame buildings..... | 231 |
| Chimneys..... | 86 |
| Chord..... | 615 |
| Chrome yellow..... | 404 |
| Cincture..... | 575 |
| Circle: | |
| arc, to draw..... | 572 |
| area, to find..... | 616 |
| circumference of..... | 616 |
| involute of..... | 548 |
| heads, to lay out..... | 574 |
| measurements of..... | 616 |
| parts of..... | 615 |
| to draw diameter when chord and rise of arc is given..... | 572 |
| to find centre..... | 571 |
| to draw to strike three given points..... | 570 |
| Circular areas..... | 590 |
| Circuit-breaker, electric..... | 506 |
| circular measure..... | 580 |
| Circumferences, table of..... | 590 |
| Cisterns, capacity of..... | 649 |
| Classification of brick..... | 74 |
| of fire-proof structures..... | 253 |
| Clay: | |
| carrying power..... | 10 |
| foundation..... | 9 |
| in concrete..... | 168 |
| in sand..... | 110 |
| shrinkage of..... | 6 |
| Cleaning of brick masonry..... | 86 |
| of granite..... | 690 |
| of marble..... | 690 |
| of stone masonry..... | 68 |
| of paint..... | 691 |

| | PAGE |
|--|---------|
| Closets as fire-traps. | 235 |
| Coal-tar. | 688 |
| paint. | 417 |
| Cobalt blue. | 405 |
| Coins, weight of. | 581 |
| Colors: | |
| compound. | 406 |
| contrast in. | 418 |
| harmony in. | 418 |
| to mix. | 406 |
| Color of bricks. | 73 |
| Columbian fire-proof floor construction. | 216 |
| Columns: | |
| cast-iron. | 424-436 |
| double. | 437 |
| encasing of steel. | 197 |
| entasis of. | 574 |
| filling with concrete. | 480 |
| iron and steel. | 435 |
| names of parts. | 575 |
| wood. | 319 |
| Comparison of thermometric scales. | 628 |
| Composite order of architecture. | 549 |
| proportions of. | 554 |
| Concentric rings, to divide circle. | 536 |
| Concrete: | |
| aggregate for. | 167 |
| building blocks. | 191 |
| compositions for various uses. | 184 |
| construction. | 190 |
| defects in. | 191 |
| depositing. | 174 |
| dry. | 164 |
| filling hollow columns. | 480 |
| floor-arches. | 194 |
| floor-arches, tests of. | 194 |
| floor construction. | 194 |
| rules for. | 194 |
| forms for. | 190 |
| inspection of. | 164 |
| lime. | 186 |
| mixing. | 165 |
| notes on. | 187 |
| plastering, composition of. | 184 |
| proportions of. | 168 |
| of cinder. | 194 |
| protection of steel by. | 173 |
| reinforced construction. | 190 |
| salt in. | 190 |
| sand for. | 168 |
| sidewalks. | 180 |

| | PAGE |
|---|----------|
| Concrete: | |
| sidewalks, specifications for. | 181 |
| strength of. | 240 |
| specifications for. | 175 |
| tests of | 171, 172 |
| of mortar in. | 158 |
| voids in. | 169 |
| volume of. | 188 |
| wash. | 184 |
| weight of. | 183 |
| wet. | 164 |
| Cone or pyramid, frustum of | 620 |
| volume of. | 620 |
| area of. | 620 |
| Contents of pipes. | 648 |
| of irregular body. | 622 |
| Conventional signs for riveting. | 434 |
| Conservo. | 693 |
| Conductor, electric. | 496 |
| Conduits, electric. | 480 |
| interior electric. | 513 |
| Corinthian order of architecture. | 548 |
| proportions of. | 554 |
| Cornices of fire-proof structures. | 277 |
| Cornice, plaster. | 295 |
| Corner beads, metal. | 293 |
| Corona. | 575 |
| Coping, stone. | 61 |
| Copper: | |
| amount required for test. | 3 |
| capacity, electrical. | 494 |
| expansion of. | 662 |
| nails. | 312 |
| rods, weight of. | 395 |
| roofing. | 384 |
| specific gravity. | 658 |
| to clean. | 690 |
| to age. | 691 |
| weight of sheet. | 393 |
| wire, resistance of, electric. | 482 |
| Covering for steam-pipes. | 522-524 |
| Creosote. | 688 |
| Crowds, weight of. | 681 |
| Cubic measure. | 577 |
| Cube roots, etc. | 590 |
| Cummings's system of reinforced concrete. | 219 |
| Curb, stone. | 61 |
| Curbs, to set. | 67 |
| Cut-outs, electric. | 506 |
| Curve approximating an ellipse. | 338 |
| Cycloid. | 613 |
| area of. | 613 |

| | PAGE |
|---------------------------------------|----------|
| Cylinder..... | 620 |
| area of..... | 620 |
| volume of..... | 620 |
| Cymatium..... | 575 |
| Cyma-recta..... | 575 |
| Cypress, description of..... | 314 |
| inspection of..... | 334 |
| Dam measurements..... | 635 |
| Decimals of a foot..... | 610 |
| of an inch..... | 611 |
| Defects in: | |
| cast iron..... | 421 |
| concrete..... | 191 |
| glass..... | 420 |
| granite..... | 29 |
| limestone..... | 39 |
| plastering..... | 293, 294 |
| sandstone..... | 34 |
| steel..... | 426 |
| timber..... | 315 |
| wrought iron..... | 426 |
| Degrees from steel square..... | 564 |
| Diary, superintendents..... | 2 |
| Dismissal of workman..... | 2 |
| Dodecahedron..... | 614 |
| Dome, perpendicular sheathing on..... | 558 |
| horizontal sheathing on..... | 559 |
| Doors, to fit..... | 692 |
| to hang..... | 692 |
| hand of..... | 342 |
| Doric order of architecture..... | 548 |
| proportions of..... | 553 |
| Douglas fir, inspection of..... | 344 |
| Ducts for ventilation..... | 385 |
| Drains, tile..... | 5 |
| broken-stone..... | 5 |
| Drawing: | |
| arcs of circles, tangential..... | 536 |
| cycloid..... | 545 |
| ellipse..... | 537 |
| epicycloid..... | 547 |
| hyperbola..... | 545 |
| hypocycloid..... | 547 |
| involute of circle..... | 548 |
| Ionic involute..... | 543 |
| octagon..... | 535 |
| oval..... | 539 |
| parabola..... | 545 |
| polygon..... | 535 |
| spiral..... | 540 |

| | PAGE |
|--|----------|
| Drawing: | |
| spiral, when greatest diameter is given..... | 543 |
| stair scroll | 542 |
| tapering scroll..... | 542 |
| triangle..... | 533 |
| Drop arch..... | 568 |
| Ducts for ventilators..... | 241 |
| Dull-ine..... | 693 |
| Dutch pink..... | 404 |
| Duties of superintendent..... | 1 |
| Echinus..... | 575 |
| Efflorescence on brickwork..... | 100 |
| concrete..... | 189 |
| Electric work: | |
| ampere..... | 480 |
| amperes per lamp..... | 485 |
| per motor..... | 492 |
| arc lighting..... | 507 |
| lamps..... | 514 |
| automatic cut-outs..... | 508 |
| bends in conduits..... | 480 |
| broken circuit..... | 480 |
| capacity of wire..... | 494, 495 |
| circuit, broken..... | 480 |
| concealed knob work..... | 512 |
| tube work..... | 512 |
| conduits..... | 480 |
| conductors..... | 496 |
| constant-potential system..... | 508 |
| cut-outs..... | 506 |
| economy coils..... | 514 |
| electric heaters..... | 510 |
| terms..... | 480 |
| equivalents of electrical units..... | 484 |
| fixtures..... | 513 |
| flexible cord..... | 514 |
| grounded circuit..... | 480 |
| grounding circuits..... | 502 |
| ground connections..... | 502 |
| horse-power..... | 484 |
| incandescent lamps..... | 508 |
| wiring table..... | 488, 489 |
| insulators..... | 496 |
| interior conduits..... | 513 |
| low-potential system..... | 510 |
| moulding work..... | 511 |
| ohm..... | 480 |
| resistance of wire..... | 482, 483 |
| rules for..... | 499 |
| sockets..... | 513 |
| soldering fluid..... | 514 |

| | PAGE |
|---|---------|
| Electric work: | |
| switches. | 506-509 |
| transformers. | 502 |
| trolley wires. | 501 |
| underground conductors. | 504 |
| volt. | 484 |
| watt. | 484 |
| wires, inside. | 503 |
| outside. | 499 |
| wiring formula. | 497 |
| table. | 485 |
| Elevator shafts. | 270 |
| Ellipse: | |
| curve approximating. | 538 |
| draw with trammel. | 538 |
| foci of. | 619 |
| joints in arch. | 561 |
| perimeter of. | 619 |
| to draw. | 536 |
| to find area. | 619 |
| Elliptical arch, joints in. | 561 |
| English bond in brickwork. | 81 |
| cross bond in brickwork. | 81 |
| Entablature, names of parts. | 575 |
| Entasis of column. | 574 |
| Encasing of columns. | 197 |
| Epicycloid. | 613 |
| to draw. | 547 |
| Equivalent of electrical units. | 484 |
| Estimate of superintendent. | 2 |
| Estimating brickwork. | 100 |
| stonework. | 51 |
| Excavating. | 5 |
| shrinkage of material. | 6 |
| Expanded metal construction. | 198 |
| Expansion of: | |
| brick, fire. | 662 |
| brass. | 662 |
| cast iron. | 662 |
| copper. | 662 |
| granite. | 662 |
| lead. | 662 |
| steel. | 448 |
| table of. | 662 |
| tin. | 662 |
| wrought iron. | 448 |
| wrought-iron pipe. | 529 |
| zinc. | 662 |
| Facia. | 575 |
| Felt paper. | 687 |
| Fencing, grade of lumber. | 327 |

| | PAGE |
|---|------|
| Ferroinclave fire-proof floor system. | 211 |
| Fibre, plastering. | 293 |
| Fillers, wood. | 414 |
| Fillets. | 575 |
| Filling, fire-proof floor. | 220 |
| around walls. | 28 |
| Fineness of cement. | 142 |
| of sieves. | 142 |
| Finishing lumber, sizes of. | 333 |
| Fire-brick. | 76 |
| weight of. | 661 |
| Fire-clay, weight of. | 661 |
| Fire-escapes, erection of. | 288 |
| Fireproofing of columns. | 197 |
| Fire-proof floor construction: | |
| Buckeye. | 210 |
| Columbian. | 216 |
| Cummings. | 219 |
| expanded metal. | 198 |
| tests of. | 200 |
| ferroinclave. | 211 |
| filling of. | 220 |
| Hennebique. | 214 |
| Herculean arch. | 222 |
| International. | 207 |
| Johnston. | 220 |
| Kahn. | 210 |
| Kuhnes sheet-metal. | 206 |
| Metropolitan. | 210 |
| Multiplex. | 217 |
| New York arch. | 220 |
| Ransome. | 214 |
| Renton. | 203 |
| Roebing. | 200 |
| terra-cotta. | 220 |
| Thacher. | 218 |
| vulcanite. | 211 |
| Fire protection of buildings. | 229 |
| anchors, etc. | 260 |
| ash-boxes and pits. | 253 |
| automatic sprinklers. | 287 |
| boilers, setting of. | 245 |
| bond iron in buildings. | 262 |
| bridging in partitions. | 236 |
| cement mortar. | 278 |
| chimneys, flues, etc. | 235 |
| chimney supports. | 240 |
| closets as fire-traps. | 235 |
| columns, casing of. | 267 |
| concrete fire-proof construction. | 266 |
| aggregate in. | 266 |

| | PAGE |
|--|----------|
| Fire concrete, preparing and placing..... | 167-174 |
| cornices..... | 277 |
| ducts for ventilators..... | 241-243 |
| elevator shafts..... | 270 |
| encasing of columns..... | 276 |
| fire-escapes, erection of..... | 288 |
| fire-proof structures classified..... | 253 |
| fire protection of fire-proof structures..... | 262 |
| fire-resistant devices..... | 286 |
| fire-shutters, address concerning..... | 281 |
| fire-stops in furred walls..... | 236 |
| stud walls..... | 238 |
| floor construction in fire-proof buildings..... | 263 |
| flues, etc..... | 231 |
| flue connections..... | 244 |
| frame house protection..... | 231 |
| furnaces, setting of..... | 246 |
| hearths..... | 233 |
| hearth bottoms..... | 233 |
| hollow-tile construction..... | 264 |
| mortar in..... | 264 |
| setting tile..... | 264 |
| shoe tile..... | 265 |
| wetting tile..... | 265 |
| hot-air pipes, etc..... | 241-249 |
| in walls..... | 242 |
| lining, height of..... | 235 |
| materials prohibited..... | 266 |
| metal frames..... | 278, 279 |
| sash..... | 278, 279 |
| mill or slow-burning construction..... | 256 |
| National Board of Underwriters' rules..... | 270 |
| cinder filling on top..... | 275 |
| concrete arches..... | 273 |
| encasing of beams..... | 275 |
| of columns..... | 276 |
| fire-proof buildings..... | 270 |
| floor filling..... | 271 |
| hall partitions..... | 271 |
| hollow-tile arches..... | 272 |
| pipe openings..... | 275 |
| protection against freezing..... | 275 |
| strength for floors..... | 275 |
| temporary centring..... | 275 |
| various fillings..... | 273 |
| pipe covering..... | 244-251 |
| pipes, wires, etc..... | 269 |
| plaster of Paris, use of, in fire-proof buildings..... | 266 |
| plumbing pipes..... | 244 |
| pointing..... | 277 |
| protection against hot metal, etc..... | 252 |

| | PAGE |
|--|---------|
| Fire protection of buildings from outside fires. | 276 |
| of external openings | 278 |
| ranges, setting of. | 246 |
| registers. | 251 |
| secrete bond in brick wall of buildings. | 277 |
| selection of materials. | 277 |
| shutters, metal. | 278 |
| sills and lintels. | 277 |
| smoke-pipes. | 248 |
| smoke-pipe shields. | 249 |
| stairways. | 269 |
| steam and hot-water heating pipes. | 250 |
| studded fireplaces. | 234 |
| terra-cotta. | 277 |
| tile partitions, etc. | 267 |
| tower fire-escapes, erection of. | 290 |
| trimmer-arches. | 239 |
| wall ties. | 277 |
| wire-glass. | 284 |
| wood-framing for fire protection. | 237 |
| wood in fire-proof structures. | 268 |
| plug in chimneys | 236 |
| Fire-proof structures classified. | 253 |
| Fire protection of fire-proof structures. | 262 |
| Fire-resistant devices. | 286 |
| Fire shutters, address concerning. | 281 |
| stops in furred walls. | 236 |
| Fittings, weight of pipe. | 368 |
| Fixtures, electric. | 513 |
| Flagpole, to make. | 302 |
| Flagging, stone. | 61 |
| Flashing. | 384 |
| projecting brick courses. | 84 |
| Flat-pointed arch. | 567 |
| Flemish bond in brickwork. | 81 |
| Flintoline. | 693 |
| Flintkote. | 693 |
| Flitch plate-girder. | 624 |
| Floor-arches, tests of. | 194 |
| Floor construction in fire-proof buildings. | 263 |
| Floors, concrete. | 194 |
| Floor levels, to check. | 4 |
| strips, wood. | 297 |
| Flooring, trough plate. | 479 |
| Flow of water. | 641-643 |
| Fluate (lockpore). | 693 |
| Flue linings, height of. | 235 |
| weight of. | 371 |
| connections. | 244 |
| Flues, testing of. | 86 |
| etc. | 231 |

| | PAGE |
|--|------|
| Flux for soldering. | 387 |
| Foot, decimals of | 610 |
| Footing: | |
| inverted arch in. | 27 |
| brick. | 26 |
| courses. | 25 |
| spread. | 21 |
| calculations of. | 22 |
| stone. | 25 |
| Forms for concrete, wood to use. | 190 |
| Force-pump. | 651 |
| Force of wind. | 679 |
| Formulas: | |
| area of piston. | 653 |
| diameter of pipe. | 656 |
| diameter of pump cylinder. | 653 |
| flow of gas in pipes. | 409 |
| for electric wiring. | 497 |
| head of water. | 656 |
| horse-power to elevate water. | 653 |
| inclination of pipe. | 556 |
| power of lever. | 623 |
| power of pulleys. | 623 |
| screw. | 622 |
| pressure of water. | 652 |
| prismoidal. | 613 |
| quantity of water discharged. | 655 |
| size or arch ring. | 622 |
| steel beams. | 476 |
| strength of fitch plate-girders. | 624 |
| of stone lintels. | 622 |
| of wooden beams. | 623 |
| stress in belly-rod truss. | 625 |
| hog-chains. | 625 |
| thickness of cast-iron water-pipe. | 367 |
| thrust of arch. | 622 |
| trusses, strength of common. | 626 |
| stress in members of. | 627 |
| Pratt. | 628 |
| Whipple. | 628 |
| velocity of water. | 656 |
| volume of water discharged. | 655 |
| Foundations: | |
| artificial. | 9 |
| bed of. | 8 |
| clay. | 9 |
| gravel. | 9 |
| laying out. | 4 |
| pile. | 10 |
| rock. | 8 |
| sand. | 9 |

| | PAGE |
|--|------|
| Foundations: | |
| silt, etc. | 9 |
| walls. | 27 |
| Frame-house fire protection. | 231 |
| Frankfort black. | 405 |
| Frieze. | 575 |
| Fronts, iron. | 442 |
| Furnaces, setting of. | 246 |
| Furring, metal. | 225 |
| Fusibility of metals. | 679 |
| Gallons in cisterns. | 649 |
| Galvanized iron sheets, weight of. | 391 |
| Gas-piping. | 371 |
| Gas pipes, capacity of. | 373 |
| flow in pipes. | 373 |
| Gauges, standard. | 674 |
| Gauge, U. S. standard. | 389 |
| decimal equivalents. | 389 |
| Geometrical definitions. | 612 |
| Georgia pine. | 313 |
| Girders: | |
| fitch plate. | 624 |
| steel and iron. | 463 |
| wood. | 623 |
| Glass, defects in. | 420 |
| expansion of. | 662 |
| how made. | 420 |
| quality of. | 420 |
| to remove. | 691 |
| thickness of. | 421 |
| weight of. | 421 |
| Glazing. | 421 |
| Glue. | 683 |
| Gneiss. | 29 |
| Gothic arch. | 567 |
| Grainolette. | 693 |
| Granite: | |
| absorptive power. | 43 |
| amount produced. | 33 |
| analysis of. | 32 |
| buildings used in. | 30 |
| capping. | 20 |
| color of. | 30 |
| defects in. | 29 |
| description of. | 28 |
| expansion of. | 662 |
| strength. | 31 |
| to clean. | 690 |
| weight of. | 31 |
| working strength. | 30 |
| Graphite. | 685 |

| | PAGE |
|---|------|
| Graphite paint. | 417 |
| Greek orders of architecture. | 548 |
| Green colors. | 406 |
| Grillage on piles. | 19 |
| steel. | 16 |
| wood. | 19 |
| Grindstones, weight of. | 622 |
| Grounds, plastering. | 298 |
| Grouting. | 163 |
| composition of. | 177 |
| Gravel: | |
| carrying power. | 10 |
| foundations. | 9 |
| shrinkage of. | 6 |
| Gravity, specific, of materials. | 658 |
| Gutters, tin. | 386 |
| Gypsum. | 686 |
| Hair, plastering. | 293 |
| Hand of doors. | 305 |
| Hardness of woods, relative. | 352 |
| Hard-pan, carrying power. | 10 |
| Hardware, placing of. | 305 |
| Headers in brickwork. | 83 |
| stonework. | 48 |
| Hearth bottoms for fire protection. | 233 |
| arch. | 86 |
| Hearths. | 233 |
| Heaters, electric. | 510 |
| Heating: | |
| capacity of radiators. | 518 |
| comparison of thermometric scales. | 528 |
| calculating radiating surface. | 518 |
| data for steam-heating. | 527 |
| on hot-water heating. | 516 |
| duty of steam-engines. | 527 |
| expansion of wrought-iron pipes. | 529 |
| fuel value of wood. | 526 |
| heating furnaces and boilers. | 530 |
| location of radiators. | 516 |
| of registers. | 516 |
| non-conductive covering. | 522 |
| table of. | 524 |
| outlets of vent and hot-air pipes. | 515 |
| pipe data. | 527 |
| pressure of systems. | 516 |
| ranges and stoves. | 531 |
| registers. | 531 |
| location of. | 515 |
| resistance to flow in pipes. | 521 |
| rules for installing heating systems. | 530 |

| | PAGE |
|---|---------|
| Heating: | |
| running of pipes, hot-air..... | 515 |
| steam and hot water..... | 567 |
| size of steam-mains..... | 529 |
| steam, data on..... | 524 |
| steam or hot-water pipes..... | 515 |
| systems..... | 515 |
| steam, rules and information on..... | 525 |
| testing..... | 516 |
| value for horse-power..... | 526 |
| Hemlock..... | 313 |
| Hennebique fire-proof floor construction..... | 214 |
| Herculean arch..... | 222 |
| Hexagon bay..... | 561 |
| Hexahedron..... | 614 |
| Hickory..... | 314 |
| Hip-rafters, bevels for backing..... | 555 |
| Hog-chain girders, strength of..... | 675 |
| Hole in roof for pipes, etc..... | 563 |
| Hollow walls..... | 86 |
| Horse-power, electric..... | 484 |
| heating value..... | 520 |
| to elevate water..... | 653 |
| Hot-air pipes..... | 241-249 |
| Hot-water system of heating..... | 515 |
| Hydraulics..... | 634 |
| capacity of centrifugal pumps..... | 634 |
| cisterns, capacity of..... | 649 |
| contents of pipes..... | 648 |
| fire-streams..... | 642 |
| flow of water..... | 641-643 |
| gallons in cisterns..... | 649 |
| lift of pumps..... | 651 |
| measurement of streams..... | 637 |
| miners' inch, measurement of..... | 637 |
| pressure of water..... | 638 |
| pump data..... | 651 |
| velocity of water..... | 640 |
| revolution of centrifugal pumps..... | 635 |
| Water: | |
| boiling-point..... | 605 |
| data on..... | 650 |
| discharge in pipes..... | 655 |
| freezing-point..... | 650 |
| heat of..... | 650 |
| loss by friction..... | 645 |
| pressure of..... | 638 |
| pure..... | 650 |
| sea..... | 650 |
| to compute velocity..... | 656 |
| discharge..... | 655 |
| head..... | 656 |

| | PAGE |
|--|---------|
| Hydraulics—water: to compute diameter of pipe. | 656 |
| to find pressure. | 652 |
| velocity of. | 640 |
| weight at different temperatures. | 652 |
| of column. | 650 |
| of cubic foot. | 651 |
| of gallon. | 650 |
| weir-dam measurements. | 635 |
| Hydraulic lime. | 111 |
| Hydrex. | 693 |
| Hyperbola. | 615 |
| to draw. | 545 |
| Hypocycloid. | 613 |
| to draw. | 547 |
| Icosahedron. | 614 |
| Incandescent lamps. | 508 |
| wiring table. | 488 |
| Inch, decimals of. | 611 |
| Incompetent workman, dismissal of. | 2 |
| Indian red. | 403 |
| Indigo blue. | 405 |
| Indurine. | 693 |
| Insulators. | 496 |
| International system of fireproofing. | 207 |
| Interpretations of specifications. | 3 |
| Inverted arch. | 27 |
| Involute. | 613 |
| of square. | 540 |
| of circle. | 548 |
| Ionic involute, to draw. | 543 |
| Ionic order of architecture. | 548 |
| proportions of. | 553 |
| Iron in brick. | 73 |
| sheets, weight of. | 390-461 |
| Ironwork: | |
| annealing of. | 447 |
| beams, strength of. | 463 |
| properties of. | 468 |
| weight per foot. | 468 |
| cast-iron pipe, weight of. | 368-380 |
| channels, properties of. | 472 |
| safe load. | 466 |
| sizes of. | 472 |
| weight of. | 472 |
| expansion of. | 448 |
| melting-point. | 448 |
| modulus of elasticity. | 664 |
| notes on. | 447 |
| painting of. | 408 |
| pipes, weight of wrought-iron. | 376 |

| | PAGE |
|---|------------|
| Ironwork: | |
| trough-plate floors..... | 479 |
| weight of sheets..... | 390 |
| Iron, structural: | |
| beams, strength of..... | 463 |
| bolting of..... | 427-440 |
| cast-iron columns..... | 424 |
| columns..... | 435 |
| connecting of..... | 439 |
| erection of..... | 427 |
| framing of..... | 439 |
| fronts..... | 442 |
| girders..... | 438 |
| inspection of..... | 426 |
| lintels, cast-iron..... | 438 |
| punching of..... | 446 |
| requirements for..... | 435 |
| riveting of..... | 427-440 |
| roof-beams..... | 439 |
| skeleton construction..... | 435 |
| specifications for..... | 442 |
| strength of floor-beams..... | 463 |
| tests of..... | 426 |
| trusses..... | 441 |
| working strength of..... | 449 |
| Iron, wrought: | |
| strength of..... | 426 |
| specific gravity of..... | 426 |
| weight of..... | 426 |
| working strength..... | 426 |
| Irregular body, to find contents of..... | 622 |
| Ivory-black..... | 404 |
| Japalac..... | 693 |
| Johnson system of fire-proof floors..... | 220 |
| Joints in: | |
| brickwork..... | 78 |
| elliptical arch..... | 561 |
| stonework..... | 64 |
| timber..... | 565 |
| Joist: | |
| camber in..... | 297 |
| bevelling ends in walls..... | 297 |
| bridging of..... | 298 |
| levelling of..... | 297 |
| Kahn system of fire-proof floors..... | 210 |
| Kalligrain..... | 693 |
| Keene's cement..... | 296 |
| Kerfing of mouldings..... | 569 |
| King s yellow..... | 404 |
| Knots: | |
| killing, in painting..... | 407 |

| | PAGE |
|--|------|
| Knots: | |
| in stone. | 29 |
| in timber. | 315 |
| Konkerit coating. | 693 |
| Kuhne's fire-proof floor construction. | 206 |
| Lafarge cement. | 296 |
| Lakes. | 404 |
| Land measure. | 577 |
| Lampblack. | 404 |
| Lasting quality of woods. | 217 |
| Latent heat of steam. | 525 |
| Lathing: | |
| data on. | 292 |
| metal. | 293 |
| nails required. | 292 |
| Laying out work: | |
| approximating roof surface. | 555 |
| arc of circle. | 572 |
| arc, to draw curve of. | 572 |
| Arch; | |
| drop. | 568 |
| elliptical, not level. | 570 |
| flat-pointed. | 567 |
| four-centre. | 569 |
| Gothic. | 567 |
| Gothic, elliptical. | 566 |
| lancet Gothic | 566 |
| to give rise and span. | 567 |
| of two arcs of circles. | 569 |
| three-centre. | 568 |
| Tudor. | 569 |
| braces, cut of. | 560 |
| circle, to strike three given points. | 570 |
| to find centre. | 571 |
| heads. | 574 |
| degrees from a square. | 564 |
| diameter of circle when chord and rise of arc are given. | 571 |
| entasis of column. | 574 |
| foundations. | 4 |
| gambrel roof. | 573 |
| hexagon bay. | 561 |
| joints in elliptical arch. | 561 |
| timber. | 565 |
| mansard roof. | 573 |
| mitre circle and straight moulding. | 564 |
| octagon bay. | 561 |
| ogee bracket. | 562 |
| pipe hole in roof. | 563 |
| plancher for conical roof. | 560 |
| privy seat. | 563 |
| purlins, to mitre. | 556 |

| | PAGE |
|---|----------|
| Laying out work: | |
| rafters, bevels for backing. | 555 |
| cripples, lengths, etc. | 556 |
| for curve roof. | 559 |
| in concave roof. | 560 |
| in convex roof. | 560 |
| lengths and bevels. | 555, 556 |
| rake mould, to lay out. | 558 |
| sheathing, bevel for. | 557 |
| on dome perpendicular. | 558 |
| horizontal. | 559 |
| ventilating hole in privy door. | 563 |
| Lead: | |
| expansion of. | 662 |
| weight of. | 658 |
| sheet. | 368 |
| sash-weights, weight of. | 682 |
| Leatheroid. | 693 |
| Length of miles. | 581 |
| Level, to use. | 4 |
| line, curve of. | 565 |
| Lever, power of. | 623 |
| Liquid measure. | 578 |
| Lime: | |
| amount for stonework. | 52 |
| air-slaked. | 111 |
| concrete. | 186 |
| for plastering. | 293 |
| hydrate of. | 111 |
| hydraulic | 111 |
| analysis of. | 112 |
| in brick. | 73 |
| mortar. | 150 |
| preservation of. | 111 |
| putty. | 111 |
| quality of. | 111 |
| weight of. | 660 |
| what one barrel will do. | 111 |
| Limestone: | |
| analysis of. | 40 |
| absorptive power. | 43 |
| defects in. | 39 |
| description of. | 36 |
| production in the U. S. | 38 |
| strength of. | 39 |
| weight of. | 39 |
| Limnoria terebrans. | 14 |
| Line. | 612 |
| Linear measure. | 576 |
| Linofelt. | 693 |
| Linseed-oil. | 396 |
| amount for test | 3 |

| | PAGE |
|----------------------------------|------|
| Linseed-oil: | |
| boiled..... | 396 |
| bung-hole process..... | 397 |
| raw..... | 396 |
| substitutes for..... | 397 |
| tests for..... | 398 |
| Lintels: | |
| cast iron..... | 438 |
| strength of stone..... | 622 |
| in fire-proof structures..... | 277 |
| Litharge..... | 689 |
| Load on roofs, weight of..... | 677 |
| Locust..... | 314 |
| Loam, shrinkage of..... | 6 |
| carrying power..... | 10 |
| Logarithms..... | 590 |
| Lumber: | |
| inspection of cypress..... | 334 |
| of Douglas fir..... | 344 |
| of Eastern Oregon pine..... | 337 |
| of Oregon pine..... | 342 |
| of redwood..... | 349 |
| of yellow pine..... | 322 |
| measure..... | 323 |
| woods, where found..... | 350 |
| Lythite..... | 693 |
| Magnesia in brick clay..... | 74 |
| cement..... | 116 |
| Mahogany..... | 315 |
| Malthoid..... | 694 |
| Manila rope, strength of..... | 667 |
| Maple, description of..... | 315 |
| Marble: | |
| absorptive power of..... | 43 |
| analysis of..... | 42 |
| anchors for..... | 69 |
| cutting..... | 68 |
| description of..... | 40 |
| dust, weight of..... | 661 |
| expansion of..... | 662 |
| Georgia..... | 41 |
| mosaic..... | 70 |
| polishing of..... | 68 |
| production in United States..... | 41 |
| setting..... | 68 |
| strength of..... | 42 |
| Terrazza..... | 70 |
| to clean..... | 690 |
| weight of..... | 42 |
| Marbleitic..... | 694 |
| Materials, rejected..... | 1 |

| | PAGE |
|---|------|
| Materials, rejected, removal of | 1 |
| prohibited in fire-proof structures | 266 |
| specific gravity of | 658 |
| strength of | 663 |
| weight of | 658 |
| Measures of miscellaneous weights | 582 |
| Measurement of— | |
| arcs of circles | 618 |
| barrel | 621 |
| brickwork | 100 |
| circle | 616 |
| ellipse | 619 |
| miner's inch | 637 |
| roof | 555 |
| sphere | 620 |
| spherical zone | 621 |
| stonework | 51 |
| streams | 637 |
| tapering timber | 621 |
| weir dams | 635 |
| Melting-point of metals | 679 |
| cast iron | 448 |
| steel | 448 |
| wrought iron | 448 |
| Mensuration: | |
| ale or beer | 579 |
| apothecaries', dry | 578 |
| liquid | 578 |
| avoirdupois | 577 |
| circular | 580 |
| cubic | 577 |
| dry | 579 |
| land | 577 |
| linear | 576 |
| liquid | 578 |
| square | 576 |
| standard pound | 578 |
| surveyors', long | 580 |
| square | 579 |
| time | 580 |
| troy | 580 |
| value, U. S. standard | 581 |
| weight of coins | 581 |
| wine | 579 |
| Metals, color at different temperatures | 679 |
| Metal frames | 278 |
| fronts | 442 |
| sash | 278 |
| Metals, melting-point | 679 |
| Metal nailing plugs | 305 |
| Metals, strength of | 664 |

| | PAGE |
|---|---------|
| Metals, specific gravity of. | 658 |
| Metal wall ties. | 80 |
| Metile. | 694 |
| Metal beams. | 225 |
| corner beads. | 293 |
| furring. | 225 |
| lathing. | 293 |
| Metallic paint. | 417 |
| Metal, painting of. | 408 |
| Metric system | 583 |
| common equivalents. | 585 |
| equivalents. | 584 |
| interchangeable table. | 586 |
| Metropolitan fire-proof construction. | 210 |
| Mica | 689 |
| Miles, length of various. | 581 |
| Mill construction. | 256 |
| Mineral wool. | 689 |
| Mirac. | 694 |
| Miscellaneous weights. | 582 |
| Miscellaneous materials: | |
| alcohol. | 685 |
| alum. | 682 |
| ammonia. | 684 |
| asbestos. | 688 |
| asphaltum. | 684-688 |
| beeswax. | 684 |
| bituminous rocks. | 688 |
| building papers. | 687 |
| coal-tar. | 688 |
| creosote. | 688 |
| glue. | 681 |
| graphite. | 685 |
| gypsum. | 686 |
| litharge. | 689 |
| mica. | 689 |
| mineral wool. | 689 |
| muriatic acid. | 686 |
| oxalic acid. | 686 |
| pitch. | 688 |
| silicate stone. | 687 |
| staff. | 687 |
| whiting. | 684 |
| Mitres, to find, on square. | 564 |
| Modelling-clay, to make. | 691 |
| Modulus of elasticity of metals. | 664 |
| Monolith. | 694 |
| Mouldings, kerfing of. | 569 |
| Mortar: | |
| absorptive power of. | 43-142 |
| cement. | 153 |

| | PAGE |
|--|------|
| Mortar: | |
| cement-lime..... | 512 |
| cement: | |
| amount for plastering..... | 144 |
| stonework..... | 144 |
| brickwork..... | 144 |
| strength of..... | 157 |
| coloring of cement..... | 155 |
| effect of temperature on..... | 155 |
| for press brickwork..... | 151 |
| grouting..... | 163 |
| lime: | |
| amount for brickwork..... | 111 |
| stonework..... | 111 |
| plastering..... | 111 |
| lime..... | 150 |
| mosaic, marble..... | 70 |
| lime putty in cement..... | 152 |
| mixing..... | 154 |
| sugar in..... | 151 |
| tests of..... | 158 |
| tests of cement..... | 170 |
| use of in freezing weather..... | 151 |
| volume of..... | 186 |
| water-tight..... | 154 |
| Mouldings, fastening of..... | 303 |
| Moulding, kerfing of..... | 569 |
| Moulder's table..... | 680 |
| Mouldings, to mitre straight and circle..... | 564 |
| Multiplex fire-proof floor construction..... | 217 |
| Mura-kalso..... | 694 |
| Muriatic acid..... | 686 |
| Nails: | |
| flooring, number required to lay..... | 311 |
| lath, number required..... | 292 |
| requirements of..... | 308 |
| resistance of..... | 309 |
| shingles, number required..... | 301 |
| sheathing, number required..... | 311 |
| siding, number required..... | 311 |
| size, length, etc..... | 311 |
| slate, number required..... | 73 |
| term of penny..... | 311 |
| tests of strength..... | 310 |
| weight of copper..... | 312 |
| Names of parts of a column..... | 575 |
| Naples yellow..... | 404 |
| National Board of Underwriters' rules..... | 270 |
| Natural cement..... | 112 |
| tests of..... | 146 |
| New York terra-cotta floor-arch..... | 220 |

| | PAGE |
|-----------------------------------|---------|
| Non-conductive pipe covering..... | 522-524 |
| Nogging, brick..... | 87 |
| Novous glass..... | 694 |
| Oak: | |
| black, coloring of..... | 418 |
| coloring of..... | 418 |
| description of..... | 314 |
| red..... | 314 |
| verde finish..... | 418 |
| weathered..... | 418 |
| white..... | 314 |
| Ochres..... | 404 |
| Octahedron..... | 614 |
| Octagon bay..... | 561 |
| to draw..... | 535 |
| when base is given..... | 536 |
| to find side..... | 561 |
| diameter..... | 562 |
| reduce square timber to..... | 558 |
| Ogee bracket..... | 562 |
| Ohm, electric..... | 480 |
| Oil, linseed..... | 396 |
| amount for testing..... | 3 |
| Okonite..... | 694 |
| Onyx..... | 41 |
| Orders of architecture: | |
| composite..... | 549 |
| Corinthian..... | 548 |
| Doric..... | 548 |
| Ionic..... | 548 |
| Tuscan..... | 549 |
| Oregon pine, description of..... | 313 |
| * inspection of..... | 342 |
| Eastern..... | 337 |
| Oval, to draw..... | 539 |
| on given line..... | 539 |
| Ovalo..... | 575 |
| Oxalic acid..... | 686 |
| Oxide of iron..... | 403 |
| æds..... | 404 |
| P. & B. paint..... | 417 |
| Paint, to remove from glass..... | 691 |
| cleaning of..... | 691 |
| Painting: | |
| applying paint..... | 407 |
| antimony vermilion..... | 403 |
| adulteration of white lead..... | 402 |
| of red lead..... | 403 |
| of turpentine..... | 399 |
| bituminous paints..... | 417 |

| Painting: | PAGE |
|---------------------------------|------|
| birch-coloring of..... | 416 |
| black pigments..... | 404 |
| blue-black..... | 405 |
| boneblack..... | 405 |
| blue lead..... | 405 |
| Bremen blue..... | 405 |
| brown umber..... | 406 |
| burnt sienna..... | 406 |
| blue pigments..... | 405 |
| cobalt blue..... | 405 |
| compound colors..... | 406 |
| cleaning old work..... | 409 |
| coloring oak..... | 418 |
| coloring birch..... | 416 |
| contrast in colors..... | 418 |
| chrome yellow..... | 404 |
| ceilings, painting of..... | 408 |
| data on painting..... | 417 |
| Dutch pink..... | 404 |
| filling hardwoods..... | 414 |
| finishing redwood..... | 410 |
| Frankfort black..... | 405 |
| greens..... | 406 |
| harmony in colors..... | 418 |
| Indian red..... | 403 |
| ivory-black..... | 404 |
| indigo blue..... | 405 |
| ironwork, painting of..... | 408 |
| King's yellow..... | 404 |
| Lake's..... | 404 |
| lampblack..... | 404 |
| litharge..... | 689 |
| linseed-oil, boiled..... | 396 |
| bung-hole process..... | 397 |
| raw..... | 396 |
| substitutes for..... | 397 |
| tests for..... | 398 |
| materials for..... | 396 |
| metallic paint..... | 417 |
| Naples yellow..... | 404 |
| oxide of iron..... | 403 |
| reds..... | 404 |
| ochres..... | 404 |
| pumice..... | 414 |
| Prince's metallic paint..... | 417 |
| paint, to remove..... | 409 |
| Prussian blue..... | 405 |
| preparing for..... | 407 |
| rosin..... | 414 |
| raw Sienna..... | 406 |
| red lead, adulterates used..... | 403 |

| | PAGE |
|----------------------------------|------|
| Painting: | |
| red lead, tests of..... | 403 |
| removing old paint..... | 409 |
| sublimed lead..... | 401 |
| shellac..... | 413 |
| stains..... | 416 |
| scarlet red..... | 403 |
| turpentine, adulteration of..... | 399 |
| tests for..... | 399 |
| to mix paints..... | 406 |
| tinwork, to paint..... | 408 |
| ultramarine blue..... | 405 |
| vermilion..... | 403 |
| Venetian red..... | 404 |
| varnish..... | 409 |
| wood fillers..... | 414 |
| weathered oak..... | 418 |
| white lead..... | 402 |
| tests of..... | 402 |
| walls, painting of..... | 408 |
| yellow ochre..... | 404 |
| zinc white..... | 402 |
| tests for..... | 403 |
| Paints: | |
| asphalt..... | 417 |
| bituminous..... | 417 |
| coal-tar..... | 417 |
| graphite..... | 417 |
| lead and oil..... | 406 |
| metallic..... | 417 |
| ready-mixed..... | 417 |
| Paper: | |
| asbestos..... | 688 |
| asphalt..... | 688 |
| building..... | 687 |
| felt..... | 687 |
| parchment..... | 687 |
| tar..... | 688 |
| Paper-hanging..... | 422 |
| Parabola..... | 615 |
| to draw..... | 545 |
| Parchment paper..... | 687 |
| Partitions: | |
| angles in..... | 299 |
| Berger..... | 225 |
| bracing of..... | 298 |
| expanded metal..... | 223 |
| fire-proof..... | 223 |
| Metropolitan..... | 223 |
| Phoenix..... | 225 |
| rabbit..... | 223 |
| Roebing..... | 223 |

| | PAGE |
|--------------------------------------|------|
| Partitions: | |
| wood..... | 298 |
| Pattern-makers' table..... | 680 |
| Pavement, bitulithic..... | 693 |
| Paving: | |
| asphalt..... | 107 |
| brick..... | 102 |
| concrete foundation for..... | 104 |
| cross-walks..... | 109 |
| grouting of..... | 107 |
| gutters..... | 103 |
| specifications for..... | 102 |
| Phenoid..... | 694 |
| Piles: | |
| bearing value..... | 15 |
| capping of..... | 19 |
| concrete..... | 16 |
| concrete capping of..... | 19 |
| driving..... | 13 |
| eaten by terredo..... | 13 |
| limnoria..... | 13 |
| for foundations..... | 10 |
| friestedt sheet..... | 18 |
| granite capping..... | 19 |
| grillage on..... | 19 |
| material for..... | 11 |
| pointing of..... | 12 |
| preserving of..... | 14 |
| Raymond..... | 16 |
| sheet..... | 17 |
| simplex..... | 16 |
| specifications for..... | 10 |
| testing of..... | 14 |
| tests of concrete..... | 16 |
| Wittekind sheet..... | 18 |
| Pitch, paving..... | 688 |
| Pipes: | |
| cast-iron, weight of..... | 380 |
| contents of..... | 648 |
| covering..... | 522 |
| data on..... | 527 |
| equation of..... | 657 |
| expansion of..... | 529 |
| fittings, weight of..... | 368 |
| how made..... | 370 |
| in fire-proof structures..... | 269 |
| running of steam- and hot-water..... | 515 |
| resistance to flow in steam..... | 521 |
| size and weight of iron..... | 376 |
| lead..... | 366 |
| Plancher in conical roof..... | 560 |
| Plane figure..... | 612 |

| | PAGE |
|--------------------------------------|----------|
| Plans as guide..... | 3 |
| Plaster, weight of..... | 661 |
| Plaster of Paris | 293 |
| in fire-proof structures..... | 266 |
| Plastering: | |
| cement, composition of..... | 153 |
| cornices and mouldings..... | 295 |
| covering capacity of patent..... | 295 |
| lime..... | 295 |
| data..... | 295 |
| hair..... | 293 |
| Keene's cement..... | 296 |
| Lafarge cement..... | 296 |
| lime for..... | 293 |
| outside stucco..... | 295 |
| patent plasters..... | 294 |
| protection of cement..... | 295 |
| sand for..... | 293 |
| scagliola..... | 295 |
| staff..... | 687 |
| stucco..... | 295 |
| weight of plaster..... | 661 |
| Plinth..... | 575 |
| Plumbing: | |
| air-inlets..... | 356 |
| block-tin pipes..... | 367 |
| conductors..... | 361 |
| connecting lead and iron pipes..... | 359 |
| drain connections..... | 354 |
| drain-pipes..... | 358 |
| drain-pipes, weight of..... | 358 |
| fall of soil-pipes..... | 351 |
| fastening of pipes..... | 351 |
| flow of water in pipes..... | 363 |
| galvanized boilers, capacity of..... | 369 |
| gas, flow of, in pipes..... | 374 |
| gas-pipes, capacity of..... | 372, 373 |
| increase of pressure..... | 372 |
| to compute pressure..... | 372 |
| gas-piping..... | 371 |
| hand-holes in traps..... | 356 |
| house-drains..... | 355 |
| joints in sewer-pipes..... | 353 |
| soil-pipes..... | 353 |
| latrines..... | 361 |
| lead pipe, size and weight..... | 366 |
| location of traps..... | 356 |
| materials used..... | 354 |
| pressure in cast-iron pipes..... | 364 |
| rules for..... | 354 |
| sheet lead..... | 368 |

| | PAGE |
|---|------|
| Plumbing: | |
| soil-pipes | 356 |
| weight of. | 368 |
| stop-cocks in pipes. | 354 |
| tests of pipes. | 353 |
| for sewer-gas. | 690 |
| vault, privy. | 362 |
| wash-stands, height to set. | 692 |
| waste-pipes. | 357 |
| water-closets. | 360 |
| Plumb-lines, radiating. | 565 |
| Point. | 612 |
| Pointing, brickwork. | 98 |
| stonework. | 67 |
| walls of fire-proof structures. | 277 |
| Pole for setting stonework. | 66 |
| Polyhedrons. | 614 |
| Polygons. | 612 |
| to draw. | 535 |
| Poplar, description of. | 315 |
| Porcelite. | 694 |
| Portland cement | 115 |
| analysis of. | 145 |
| tests of. | 147 |
| Posts, party-wall. | 438 |
| Pound, standard. | 578 |
| Power of lever. | 623 |
| of screw. | 622 |
| of pulleys. | 623 |
| Pratt truss. | 630 |
| Pressure of water. | 638 |
| of wind on roofs. | 678 |
| of heating systems. | 516 |
| Pressures, to compute various. | 372 |
| Prince's metallic paint. | 417 |
| Prismoidal formula. | 613 |
| Privy-door ventilating-hole. | 563 |
| Privy seat, to lay out. | 563 |
| Protection of buildings from outside fires. | 276 |
| of external openings of fire-proof buildings. | 278 |
| Prussian blue. | 405 |
| Pulley, power of. | 623 |
| Pumice. | 414 |
| Purlins, bevel to mitre. | 556 |
| Puzzolan cement. | 120 |
| Quadrant. | 615 |
| Quadrilateral. | 612 |
| Quoins, chamfered. | 51 |
| Radiation, to compute. | 518 |
| Radiators, capacity of. | 518 |
| location of. | 517 |

| | PAGE |
|---|---------|
| Radius of arc, to find. | 617 |
| Rafters: | |
| bevels to back hips. | 555 |
| in octagon roof. | 555 |
| in concave roof. | 560 |
| convex roof. | 560 |
| curve roof. | 559 |
| length of cripples. | 556 |
| lengths, bevels, etc. | 556 |
| to find length of. | 555 |
| Rake moulding, to lay out. | 558 |
| Random range stonework. | 47 |
| broken courses. | 47 |
| coursed. | 47 |
| Ranges, setting of. | 246 |
| Ransome system of concrete construction. | 214 |
| Receipts, etc.: | |
| copper, to age. | 691 |
| to clean. | 690 |
| glass, to remove. | 691 |
| marble, to clean. | 690 |
| modelling-clay, to make. | 691 |
| paint on glass, to remove. | 691 |
| rust-stains, to remove. | 692 |
| sewer-gas, to test for. | 690 |
| stains on granite, to remove. | 690 |
| Reciprocals. | 590 |
| Rectangle. | 612 |
| Red lead: | |
| adulteration of. | 403 |
| amount required for tests. | 3 |
| tests for. | 403 |
| Red oak. | 314 |
| Redwood. | 314 |
| finishing of. | 410 |
| inspection of. | 349 |
| Registers, heating. | 531 |
| location of. | 515 |
| Reinforced-concrete construction. | 260 |
| Rejected materials. | 2 |
| Renton system of fire-proof floor construction. | 203 |
| Requirements for iron and steel. | 435 |
| Resistance to shearing of wood. | 317 |
| Rhomboid. | 612 |
| Rhombus. | 612 |
| Right angle. | 612 |
| to bisect. | 533 |
| Riveting | 440 |
| careless. | 428 |
| instructural steelwork. | 427 |
| of structural steel and iron. | 427-440 |

| | PAGE |
|--------------------------------------|------|
| Riveting, perfect..... | 430 |
| signs for..... | 434 |
| Rivets, strength of..... | 432 |
| Rock foundations..... | 8 |
| Rock-carrying power..... | 10 |
| Roebing fire-proof floor system..... | 200 |
| Roman orders of architecture..... | 548 |
| Roofing, etc.: | |
| angles of roofs..... | 677 |
| copper..... | 384 |
| flashing..... | 384 |
| loads on..... | 678 |
| pressure of wind on..... | 678 |
| tin..... | 382 |
| weight of covering..... | 677 |
| zinc..... | 384 |
| Roof, to measure..... | 555 |
| Roof leak..... | 694 |
| Rope: | |
| information on wire..... | 669 |
| strength of wire..... | 665 |
| of manila..... | 667 |
| Rosendale cement..... | 112 |
| Rosin..... | 414 |
| Rubble: | |
| stonework..... | 46 |
| coursed..... | 46 |
| random..... | 46 |
| Rust-stains, to remove..... | 692 |
| Sacket's plaster-board..... | 694 |
| Salsee..... | 694 |
| Salt in cement mortar..... | 156 |
| concrete..... | 190 |
| sand..... | 110 |
| Sand: | |
| carrying power of..... | 10 |
| clay in..... | 110 |
| for concrete..... | 168 |
| for plastering..... | 293 |
| salt in..... | 110 |
| shrinkage of..... | 6 |
| quality of..... | 110 |
| weight of..... | 660 |
| Sandstone: | |
| absorptive power of..... | 43 |
| analysis of..... | 37 |
| buildings used in..... | 34 |
| color of..... | 34 |
| defects in..... | 34 |
| description of..... | 30 |

| | PAGE |
|---------------------------------------|---------|
| Sandstone: | |
| expansion of. | 662 |
| production in United States. | 35 |
| strength of. | 35 |
| weight of. | 36 |
| working strength. | 35 |
| Sanitas. | 694 |
| Sash-cord, strength of wire. | 667 |
| Sash, to fit. | 302 |
| Sash-weights, weight of lead. | 682 |
| of cast-iron. | 681 |
| size of cast-iron. | 681 |
| Scagliola. | 295 |
| Scarlet red. | 403 |
| Scotia. | 575 |
| Screws, length and number. | 313 |
| Screw, power of. | 622 |
| Screw-threads, standard. | 683 |
| Sector. | 616 |
| area of. | 619 |
| Segment. | 616 |
| area of. | 619 |
| Sewers. | 353 |
| Sewer-gas, test for. | 690 |
| Sewers, main, laid. | 5 |
| Sewer-pipe, weight of. | 370 |
| Sheathing, to cut. | 557 |
| on dome, horizontal. | 559 |
| perpendicular. | 558 |
| Shearing, resistance to. | 633 |
| Sheet lead, weight of. | 368 |
| Sheet-metal gauge. | 389 |
| Shellac. | 413 |
| amount for testing. | 3 |
| Shingling: | |
| Boston hip. | 300 |
| nails required for. | 301 |
| number in a bundle. | 302 |
| number per square of roof. | 301 |
| sides and corners. | 301 |
| valleys. | 300 |
| Shrinkage of castings. | 680 |
| of timber. | 316 |
| Shutters, metal. | 278 |
| fire address concerning. | 281 |
| Siamlac. | 694 |
| Sidewalks: | |
| construction of. | 180 |
| defects in. | 181 |
| laid in freezing weather. | 181 |
| hot weather. | 181 |
| specifications for. | 181-183 |

| | PAGE |
|--|---------|
| Sienna | 406 |
| burnt. | 406 |
| Silicated carbon. | 694 |
| Silicious stones. | 30 |
| Silt foundations. | 9 |
| Sills and lintels of fire-proof structures. | 277 |
| Silicate stone. | 687 |
| Size of boxes. | 622 |
| Slate: | |
| absorptive power of. | 70 |
| laying of. | 71 |
| nails required for. | 73 |
| roofing. | 70 |
| strength of. | 72 |
| tests of. | 70 |
| weight of. | 72 |
| of various thicknesses. | 72 |
| Slow-burning construction | 256 |
| rules for. | 259 |
| Smoke-pipes. | 248 |
| Sockets, electrical. | 513 |
| Soil: | |
| carrying power of. | 10 |
| foundations. | 9 |
| shrinkage of. | 6 |
| testing of. | 7 |
| Soil-pipe, weight of. | 368 |
| Solder, composition of. | 387 |
| to test. | 387 |
| for aluminum. | 388 |
| Soldering, flux for. | 387 |
| fluid for electric wires. | 514 |
| Solid. | 612 |
| Specifications for— | |
| concrete. | 175 |
| constructural steel. | 444 |
| iron. | 442 |
| concrete foundations, etc. | 177 |
| natural cement. | 113 |
| Portland cement. | 117 |
| Puzzolan cement. | 120 |
| reinforced concrete construction. | 191 |
| sidewalks. | 180-183 |
| piles. | 11 |
| structural cast iron. | 423 |
| Specific gravity of substances. | 658 |
| of steam. | 525 |
| Sphere, area of. | 620 |
| contents of. | 621 |
| Spherical zone | 621 |
| contents of. | 621 |

| | PAGE |
|---|------|
| Sphinx gum..... | 694 |
| Spikes, length, etc. | 312 |
| Spiral composed of semicircles..... | 540 |
| in arithmetrical progression..... | 540 |
| of any number of turns..... | 541 |
| of one turn..... | 540 |
| Spiral, to draw when great diameter is given..... | 543 |
| Spread footings..... | 22 |
| Sprinklers, automatic fire-..... | 287 |
| Spruce..... | 313 |
| Square, involute of..... | 540 |
| measure..... | 576 |
| to draw..... | 533 |
| Squares, etc., table of..... | 590 |
| Staff..... | 687 |
| Stains..... | 416 |
| Stairs, pitch of..... | 302 |
| Stair scroll, to draw..... | 542 |
| Stairways in fire-proof structures..... | 269 |
| Standard screw-threads..... | 683 |
| Star, to draw..... | 533 |
| Steam and hot-water pipes in fire-proof structures..... | 250 |
| data on..... | 524 |
| latent heat of..... | 525 |
| rules and information on..... | 518 |
| specific gravity of..... | 525 |
| Steam-engine, duty of..... | 527 |
| Steam-heating, data on..... | 524 |
| system..... | 515 |
| Steam-mains, size of..... | 529 |
| Steam-pipes..... | 515 |
| Steel: | |
| beams..... | 439 |
| bending moments of..... | 479 |
| deflection of..... | 479 |
| formula for..... | 476 |
| safe load..... | 563 |
| various loading..... | 479 |
| channels, properties of..... | 472 |
| safe load..... | 466 |
| sizes of..... | 472 |
| weight of..... | 472 |
| columns..... | 435 |
| expansion of..... | 448 |
| girders..... | 438 |
| I beams, properties of..... | 468 |
| size of..... | 468 |
| strength of..... | 463 |
| weight of..... | 468 |
| melting-point..... | 448 |
| modulus of elasticity..... | 664 |

| Steel: | PAGE |
|-------------------------------------|---------|
| pipe, how made. | 379 |
| weight of. | 376 |
| protection of, by concrete. | 173 |
| sheets, weight of. | 390 |
| skeleton construction. | 435 |
| specific gravity. | 658 |
| specifications for. | 442-444 |
| trusses. | 441 |
| weight of flat bars. | 450 |
| of round bars. | 456 |
| of square bars. | 456 |
| of sheet. | 461 |
| working strength. | 448 |
| Steps, stone. | 61 |
| to set stone. | 66 |
| Stone: | |
| cutting. | 52 |
| iron in. | 33 |
| laying. | 46 |
| setting. | 62 |
| strength of. | 664 |
| testing of. | 41 |
| tests and analysis of. | 44 |
| Stone-cutting: | |
| bush-hammered. | 54 |
| carving. | 61 |
| crandalled work. | 54 |
| cross-crandalled work. | 54 |
| defects in. | 57 |
| drip on sills, etc. | 58 |
| drove work. | 55 |
| fine-pointed. | 52 |
| inspection of. | 57 |
| lintels. | 59 |
| mouldings. | 57 |
| patent hammered. | 54 |
| picked work. | 54 |
| rock face | 55 |
| with draft. | 55 |
| rough-pointed. | 55 |
| tools used. | 52 |
| tooled work. | 55 |
| template for droved work. | 56 |
| wash on sills. | 58 |
| Stone lintels, strength of. | 622 |
| Stone-setting: | |
| area coping. | 61 |
| backing-up. | 63 |
| curbs. | 61 |
| flagging. | 67 |
| height pole. | 66 |

| | PAGE |
|--------------------------------------|----------|
| Stone-setting: | |
| lead filling in joints. | 65 |
| tool for. | 65 |
| size of joints. | 64 |
| steps. | 66 |
| tool for slushing joints. | 64 |
| wedges used for. | 62 |
| Stonework: | |
| amount of lime and sand for. | 52 |
| area coping. | 61 |
| ashlar, coursed two sizes. | 49 |
| irregular coursed. | 49 |
| level and broken. | 49 |
| random | 50 |
| random in courses. | 50 |
| rusticated. | 51 |
| block-coursed. | 47 |
| buttresses. | 61 |
| chamfered quoins. | 51 |
| coping. | 61 |
| curbs. | 61 |
| cut-stone work. | 46 |
| flagging. | 61 |
| footings. | 25 |
| granite | 28 |
| irregular form of. | 47 |
| joints in. | 64 |
| measurement of | 51 |
| natural stones. | 28 |
| one-man rubble. | 48 |
| pointing. | 67 |
| random range. | 47 |
| coursed. | 47 |
| regular coursed ashlar. | 49 |
| rubble-work. | 46 |
| rubble, coursed. | 46 |
| random. | 46 |
| washing down. | 68 |
| Stone, silicate. | 687 |
| Streams, measurement of. | 637 |
| Strength of— | |
| brick. | 75 |
| cast iron | 423 |
| columns. | 424 |
| chains. | 675 |
| concrete. | 171, 172 |
| fitch-plate girders | 624 |
| granite. | 31 |
| hog-chains. | 675 |
| limestone. | 39 |
| malleable cast iron. | 423 |
| Manila rope | 667 |

| | PAGE |
|-----------------------------------|---------|
| Strength of— | |
| marble. | 42 |
| materials. | 663 |
| metals. | 664 |
| mortar. | 158 |
| rivets. | 432 |
| slate. | 72 |
| steel beams. | 463 |
| wire. | 673 |
| stones. | 664 |
| timber, working. | 317 |
| trusses. | 709-711 |
| wire sash-cord. | 667 |
| rope. | 665 |
| wooden beams. | 318 |
| columns. | 319 |
| wrought iron. | 426 |
| Structural steel and iron: | |
| annealing of. | 447 |
| beams. | 439 |
| bolting of. | 427-440 |
| columns. | 424 |
| connecting. | 439 |
| erection of. | 427 |
| expansion of. | 448 |
| framing of. | 439 |
| girders. | 438 |
| inspection of. | 426 |
| melting-point. | 448 |
| notes on. | 447 |
| plates in joints. | 438 |
| punching. | 446 |
| requirements for. | 435 |
| riveting of. | 427-440 |
| signs for riveting. | 434 |
| skeleton construction. | 435 |
| specifications. | 442 |
| tests of. | 426 |
| trough plate flooring. | 479 |
| trusses. | 441 |
| working strength. | 449 |
| Studded fireplaces. | 234 |
| Stucco-work. | 295 |
| Sublimed white lead. | 401 |
| Substances, expansion of. | 662 |
| Sugar in mortar. | 151 |
| Superintendent | 1 |
| decision of. | 1 |
| diary of | 2 |
| duties of | 1 |
| estimate of | 2 |
| personality of. | 1 |

| Timber: | PAGE |
|----------------------------------|---------|
| inspection of cypress..... | 334 |
| of Douglas fir..... | 342 |
| of Eastern Oregon pine..... | 337 |
| of Oregon pine..... | 342 |
| of redwood..... | 349 |
| of yellow pine..... | 322 |
| knots in..... | 315 |
| lasting qualities of..... | 317 |
| relative strength of..... | 692 |
| rot in..... | 315 |
| sap in..... | 315 |
| seasoning of..... | 316 |
| shrinkage of..... | 316 |
| sound, indication of..... | 316 |
| splits in..... | 316 |
| to reduce to octagon..... | 558 |
| wind-shakes..... | 316 |
| working strength of..... | 317 |
| Time measure..... | 580 |
| Tin and sheet-metal work: | |
| double-lock joint..... | 383 |
| flashing..... | 384 |
| flux for soldering..... | 387 |
| gutters..... | 386 |
| hot-air pipes..... | 385 |
| joints in..... | 383 |
| laid between strips..... | 384 |
| method of laying..... | 383 |
| painting of..... | 385 |
| single-lock joint..... | 384 |
| solder for..... | 387 |
| soldering aluminum..... | 391 |
| standing seam..... | 383 |
| tin plate..... | 386 |
| ventilators..... | 386 |
| Tin plate: | |
| amount for test..... | 3 |
| brand of..... | 386 |
| number of sheets required..... | 388-391 |
| size and weight of sheets..... | 390 |
| thickness of..... | 386 |
| vent-pipes..... | 385 |
| ventilators..... | 386 |
| weight of..... | 386 |
| Tin, modulus of elasticity..... | 664 |
| Titekote..... | 695 |
| Torus..... | 575 |
| Tower fire-escapes..... | 290 |
| Transoms, to hang..... | 692 |
| Transit..... | 695 |
| Transformers, electric..... | 502 |

| | PAGE |
|--|----------|
| Trapezium..... | 612 |
| Trapezoid..... | 612 |
| Trap-rock..... | 29 |
| Triangle, to draw..... | 533, 534 |
| Trough-plate floors..... | 479 |
| Trusses: | |
| iron..... | 441 |
| pin-connected..... | 441 |
| riveted..... | 441 |
| steel..... | 441 |
| strength of common..... | 628 |
| stress in members of roof..... | 627 |
| Pratt..... | 630 |
| Whipple..... | 631 |
| Tudor arch..... | 569 |
| Tuscan order of architecture..... | 549 |
| proportions of..... | 551 |
| Turpentine: | |
| adulteration of..... | 399 |
| tests for..... | 399 |
| Two-centre arch..... | 568 |
| Ultramarine blue..... | 405 |
| Umber..... | 406 |
| burnt..... | 406 |
| Varnish..... | 409 |
| amount required for testing..... | 3 |
| Velocity of water..... | 640 |
| Venetian red..... | 404 |
| Ventilator..... | 386 |
| Vent-pipes..... | 250-385 |
| outlets of..... | 385 |
| and ducts..... | 251 |
| Vermilion..... | 403 |
| Versed sine..... | 617 |
| Vitrified brick..... | 76 |
| Voids in broken stone..... | 169 |
| in concrete..... | 169 |
| Volume of concrete..... | 188 |
| of mortar..... | 186 |
| Volt, electric..... | 484 |
| Vulcanite fire-proof floor system..... | 211 |
| Walls, foundation..... | 27 |
| hollow..... | 86 |
| Walnut, black..... | 315 |
| white..... | 315 |
| Wall ties, metal..... | 80 |
| in brick walls..... | 80 |
| in fire-proof structures..... | 277 |
| Wainscot, fastening of..... | 305 |

| | PAGE |
|---|---------|
| Wash, cement. | 184 |
| Wash-stands, height of. | 692 |
| Water: | |
| boiling-point of. | 650 |
| data on. | 650 |
| discharge in pipes. | 655 |
| elevated, quantity of. | 654 |
| expansion of. | 662 |
| flow of. | 643 |
| freezing-point. | 650 |
| heat of. | 650 |
| loss of head by friction. | 645 |
| pressure of. | 638 |
| of column. | 652 |
| pure. | 650 |
| sea-. | 650 |
| to compute the diameter of pipes. | 655 |
| head of. | 656 |
| inclination of pipes. | 656 |
| velocity. | 656 |
| volume of. | 655 |
| to find pressure. | 652 |
| velocity of. | 640 |
| weight at different temperatures. | 651 |
| of column. | 650 |
| of cubic foot. | 651 |
| of gallon. | 650 |
| of different gallons. | 655 |
| Water-proof wash for cement. | 154 |
| Watt, electrical. | 484 |
| Wedge, to find contents of. | 613 |
| Wedges used to set stone. | 62 |
| Weight of— | |
| aluminum. | 658 |
| beams, I. | 468 |
| block-tin pipe. | 367 |
| brass rods. | 395 |
| sheets. | 393-461 |
| brick. | 75 |
| brick-dust. | 661 |
| bushel. | 582 |
| cast iron. | 423 |
| cement | 659-661 |
| cubic yard | 198 |
| channels. | 472 |
| coins. | 581 |
| concrete. | 183 |
| copper rods. | 395 |
| sheets. | 393-461 |
| crowds. | 681 |
| fire-brick. | 661 |

| Weight of— | PAGE |
|--------------------------------------|---------|
| fire-clay. | 661 |
| flat steel bars. | 450 |
| flue lining. | 371 |
| galvanized sheets. | 391 |
| granite. | 31 |
| grindstone. | 622 |
| I beams. | 468 |
| lead. | 743 |
| lead pipe. | 366 |
| lime. | 661 |
| marble-dust. | 661 |
| mineral wool. | 689 |
| plaster. | 661 |
| roof covering. | 677 |
| round steel bars. | 455 |
| sash-weights, lead. | 682 |
| iron. | 681 |
| sewer-pipe. | 370 |
| sheet brass. | 393 |
| copper. | 393 |
| iron and steel. | 390-461 |
| iron. | 461 |
| steel. | 461 |
| lead. | 368 |
| soil-pipes. | 368 |
| steel wire. | 673 |
| square steel bars. | 455 |
| tin per box. | 392 |
| plates. | 386 |
| various materials. | 658 |
| water. | 661 |
| woods. | 352 |
| wrought iron. | 426-461 |
| weights, various. | 582 |
| Weir-dam measurement. | 635 |
| Whipple truss. | 631 |
| White lead: | |
| adulteration of. | 402 |
| amount required for testing. | 3 |
| tests for. | 402 |
| White oak. | 314 |
| pine. | 313 |
| walnut. | 315 |
| Whitewash. | 296 |
| Whiting. | 684 |
| Wind, force of. | 679 |
| pressure of. | 678 |
| Wine measure. | 579 |
| Wire: | |
| electric, inside. | 503 |
| outside. | 499 |

| | PAGE |
|------------------------------------|------|
| Wire: | |
| electrical capacity of | 494 |
| resistance of copper | 482 |
| ropes for inclined planes | 668 |
| rope, general information on | 669 |
| to measure..... | 672 |
| strength of | 665 |
| sash-cord | 667 |
| trolley | 501 |
| weight, etc., of steel | 673 |
| Wire-glass, use of | 284 |
| Wiring, electrical. | 480 |
| table | 485 |
| formula | 497 |
| Wood: | |
| beams, etc. | 306 |
| blocking for nailing | 303 |
| columns, etc. | 319 |
| fuel value of | 526 |
| hearth bottoms | 86 |
| trim, securing of | 303 |
| Woods: | |
| description of | 313 |
| lasting qualities | 317 |
| strength of | 352 |
| weight of | 352 |
| where found | 350 |
| Wrought iron: | |
| defects in | 426 |
| melting-point | 426 |
| specific gravity | 426 |
| strength, working | 426 |
| tests for | 426 |
| weight of | 426 |
| Yellow ochre. | 404 |
| pine | 313 |
| inspection of | 322 |
| Zinc: | |
| amount required for testing | 3 |
| expansion of | 662 |
| roofing | 384 |
| white | 402 |
| tests of | 402 |
| weight of | 661 |



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