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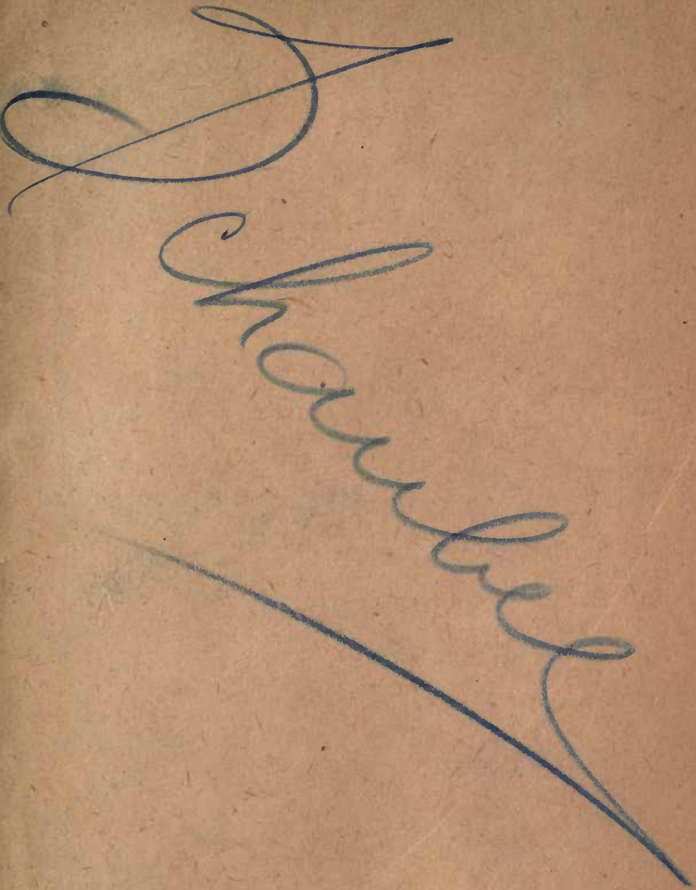

THE

# WORKS' MANAGER'S HANDBOOK

OF

MODERN RULES, TABLES, AND DATA, FOR CIVIL AND MECHANICAL ENGINEERS, ETC.

THE

# WORKS' MANAGER'S HAND-BOOK

OF

## MODERN RULES, TABLES, AND DATA

FOR

*CIVIL AND MECHANICAL ENGINEERS, MILLWRIGHTS, AND BOILER MAKERS;*
*TOOL MAKERS, MACHINISTS, AND METAL WORKERS;*
*IRON AND BRASS FOUNDERS,*
*ETC., ETC.*

**In Six Sections:**

I.—STATIONARY AND LOCOMOTIVE STEAM ENGINES, GAS ENGINES.
II.—HYDRAULIC MEMORANDA: PIPES, PUMPS, WATER-POWER.
III.—MILLWORK: SHAFTING, GEARING, PULLEYS.
IV.—STEAM BOILERS, SAFETY VALVES, FACTORY CHIMNEYS.
V.—HEAT, WARMING AND VENTILATING; MELTING, CUTTING, AND FINISHING METALS; ALLOYS AND CASTING; WHEEL-CUTTING; SCREW-CUTTING.
VI.—STRENGTH AND WEIGHT OF MATERIALS; WORKSHOP DATA, &c.

BY

WALTER S. HUTTON,
CIVIL AND MECHANICAL ENGINEER.

**Third Edition, Carefully Revised, with Additions.**

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# PREFACE.

THE information contained in the following pages was not originally intended for publication, but represents the contents of an Engineer's note book, collected for use in his own Works during many years of practice.

The Author having been in the habit of compiling Rules and Data, relating to his business, for his own use in the practical construction of a great variety of modern engineering work, and having found his notes extremely useful, decided to publish them—after having revised them to date—trusting that a practical work, suited to the daily requirements of modern engineers, would be favourably received by the public.

Among many new and original features of this work will be found the following :—

The weights of those metals usually rolled to gauge are given to the New Imperial Standard Wire-Gauge,—the Birmingham Wire-Gauge being no longer a legal measure.

The weights of sheet-iron, hoop-iron, and corrugated iron are those rolled both to the New Imperial Standard Wire-Gauge, and to the B. G. Gauge, or scale adopted by the South Staffordshire Ironmasters, on March 1st, 1884, as the Trade Standard for sheets and hoop-iron. The weights of iron-wire, steel-wire, copper-wire, and brass-wire are to the New Imperial Standard Wire-Gauge.

The tables of mixtures of metals, for castings of cast-iron, gun-metal, brass, antifriction white-metal, and other alloys, are the most extensive and complete ever published.

Weights are given of a great number of toothed-wheels, and of pulleys for belts and ropes, also of shafting, couplings, plummer-blocks and many other useful materials.

The strengths of materials are based upon the most recent investigations. Particulars are stated of the quantities of work turned out by machine-tools.

A Vocabulary of French and English Engineering Terms, which it is believed will be found a useful feature, is added.

In order to make the very varied and extensive matter given in this work readily comprehensible by all classes of readers, the use of algebraical symbols has been, with one or two exceptions, dispensed with, the rules being expressed in words—many worked-out examples of which are given—and the Author has endeavoured to impart the information as clearly and briefly as possible, and to give nothing but the most recent practical data.

In conclusion the Author takes this opportunity of expressing his indebtedness for some of his information to the columns of "The Engineer," and "Engineering," and to other sources, which are acknowledged where the quotations occur.

## PREFACE TO THE THIRD EDITION.

THE rapid sale of the First and Second Editions of this work, and the favourable manner in which it has been reviewed, may, it is hoped, be taken as indications of the usefulness of the book.

In issuing a Third Edition, the following among other additions have been made, viz.:—Rules for the Proportions of Riveted Joints in Soft Steel Plates, the Results of Experiments by Professor Kennedy, for the Institution of Mechanical Engineers,—Rules for the Proportions of Turbines,—Rules for the Strength of Hollow Shafts of Whitworth's Compressed-Steel, &c.

In conclusion, the Author begs to state that having investigated the strength of Double Helical Toothed-Wheels, and found the additional strength gained by using this form of wheel-tooth to be much less than is popularly supposed, he has briefly embodied the results of these investigations in this Edition.

W. S. HUTTON.

4, SUNDERLAND VILLAS,
FOREST HILL, LONDON,
*June*, 1886.

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# WORKS MANAGER'S HAND-BOOK.

## SECTION I.

## STATIONARY AND LOCOMOTIVE STEAM ENGINES, GAS ENGINES, &c.

### WORK AND HORSE-POWER.

**A Unit of Work** is equivalent to one pound avoirdupois raised vertically one foot. The units of work done in raising a given weight to a given height, are found by multiplying the height in feet by the weight in pounds. The units of work done in raising a weight up an inclined plane, are equal to the work that would be done in raising the weight vertically through the height of the plane.

**The Modulus of a Machine** is the fraction which expresses the relation of the work done to that of the work applied, or the percentage of the power absorbed which a machine will give out in useful work.

### MODULUS OF MACHINES.

| | |
|---|---|
| Centrifugal pump, small | ·25 |
| Undershot water-wheel | ·25 to ·33 |
| Paddle water-wheel | ·25 to ·33 |
| Inclined chain pump | ·38 |
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| Endless chain and buckets—lift 9 feet | ·58 |
| Bucket wheel | ·60 |
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| | |
|---|---|
| Turbine, with sluice half open | ·61 |
| Pumps for mines and deep wells | ·66 |
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| Turbine, with sluice wide open | ·75 |
| Hydraulic ram—lift 4 to 1 of fall | ·75 |
| Hydraulic machines—4 to 1 | ·75 |
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**Horse-power.**—A strong horse can travel $2\frac{1}{2}$ miles per hour and work 8 hours a day, doing the equivalent of pulling a load of 150 lbs. weight up out of a shaft by means of a rope. $2\frac{1}{2}$ miles an hour is 220 feet per minute, and at that speed the load of 150 lbs. is raised vertically the same distance, that is equal to 300 lbs. raised 110 feet high, or 3,000 lbs. raised 11 feet high, or 33,000 lbs. raised one foot high per minute. The unit of power is the mechanical force necessary to lift 33,000 lbs. one foot high in one minute; but, in dealing with steam engines, two terms are used, viz., nominal horse-power, and actual horse-power.

**Nominal Horse-power** is a commercial term used by makers of engines to denote only the size of an engine without regard to the actual power it will exert.

**Nominal Horse-power of Non-Condensing Engines.**—The rule of ordinary practice is to make the sectional area of the cylinder equal to from 9 to 10 square inches for each nominal horse-power. The nominal horse-power of non-condensing engines may be found by the following rule, which accords with the best modern practice. *Rule:* Multiply the square of the diameter of the cylinder in inches by 7, and divide the result by 80.

**Nominal Horse-power of Condensing Engines.**—*Rule:* Multiply the square of the diameter of the cylinder in inches by 7, and divide the product by 200.

**Actual Horse-power of an Engine.**—To find the actual horse-power. *Rule:* Multiply the area of the cylinder in square inches by the average effective pressure in lbs. per square inch, minus 3 lbs. per square inch for friction; and by the speed of the piston in feet per minute. The product will be the number of foot-pounds per minute which the engine will raise. Next, divide the product by 33,000, and the quotient will be the actual horse-power.

**Power and Weight of Men and Animals.**—In working a crane handle, a man can apply a force of 60 lbs. in an emergency with difficulty, or a force of 30 lbs. for a short time with difficulty, or a force of 20 lbs. for a short time easily, or a force of 15 lbs. in continuous work at a velocity of

220 feet per minute; hence the power of a man is $15 \times 220 = 3{,}300$ foot pounds per minute, or one-tenth of a horse-power. A soldier on march travels about 30 inches per step, and occupies a front of 21 inches in the rank; the average weight of men is 150 lbs. each; five men can stand in a space of one square yard; the weight of ordinary crowds of people is 80 lbs. per square foot; the absolute force of a man in pulling horizontally or pushing with his hands is 110 lbs., his lifting power with both hands is 280 lbs., and the greatest load he can support on his shoulders is 336 lbs. A horse will exert a pulling force of 120 lbs. at the rate of $2\frac{1}{2}$ miles an hour during 10 hours. A pony or mule will exert a pulling force of 60 lbs. at the rate of $2\frac{1}{4}$ miles an hour during 10 hours. An ass will exert a pulling force of 30 lbs. at the rate of 2 miles an hour during 10 hours. These animals will each carry a load on its back equal to one-fourth its own weight, at the rate of $2\frac{1}{2}$ miles an hour during 10 hours. A horse will draw a load of one ton at the rate of $2\frac{1}{2}$ miles an hour during 10 hours. A pony or mule will draw a load of 12 cwt. at the rate of $2\frac{1}{4}$ miles an hour during 10 hours. An ass will draw a load of 7 cwt. at the rate of 2 miles an hour during 10 hours. These forces are for a straight pull; when animals work by pulling while walking in a circle, their pulling force is only about 60 per cent. of their force for a straight pull; the diameter of the circular path should not be less than 25 feet, and the velocity should not exceed 2 miles an hour. The average weight of a cart-horse is 13 cwt.; a cob, 7 cwt.; a mule, 6 cwt.

**Resistance of Carts and Waggons to Traction on Level Roads and Rails.**—The resistance to traction in proportion to the whole weight is $\frac{1}{10}$ on fields; $\frac{1}{12}$ on gravel and on broken-stone roads in bad condition; $\frac{1}{25}$ on dry hard turf; $\frac{1}{30}$ on good macadamized roads; $\frac{1}{55}$ on underground tramways with 8-inch diameter wheels; $\frac{1}{60}$ on wood pavement; $\frac{1}{70}$ on good London pavement; $\frac{1}{80}$ on street tramways with grooved rails; $\frac{1}{110}$ on underground tramways with 12-inch wheels on round top rails; $\frac{1}{150}$ on asphalte pavement; $\frac{1}{180}$ on granite tramway; $\frac{1}{280}$ on railways.

The force required to drag a weight on a level firm wood floor without rollers is $\frac{3}{5}$ the whole weight, and with the weight placed on rollers 3 inches diameter, it is $\frac{1}{40}$ of the whole weight.

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## CONDENSATION IN STEAM CYLINDERS.

**Condensation.**—It is found in practice that nearly all steam engines use half as much more steam than is theoretically required, and this loss is mostly caused by condensation of the steam in the cylinder. When steam enters a cold cylinder, it is rapidly condensed during the operation of warming the cylinder and piston, and raising their heat up to the same temperature as the steam, because the piston will not move until both it and the surrounding surfaces are heated to a temperature approaching more or less that of the steam. Re-evaporation takes place during the whole time of exhaust, because the steam, when exhausting after expansion, being lower in pressure and temperature, cools the cylinder and steam passages, and absorbs the heat. The heat thus abstracted must be restored to the metal by the entering steam, a portion of which must be condensed to restore the heat thus lost, because, as already stated, until the metal is considerably raised in temperature, the heat in the entering steam will be expended in heating the surfaces, instead of moving the piston. Condensation also goes on in the cylinder, due to the performance of work during expansion in driving the piston. The steam falls in temperature owing to its change in volume during expansion, and the temperature of the interior surfaces of the cylinder also falls during expansion, nearly with that of the steam, parting with heat to re-evaporate the water formed. Therefore, at the commencement of each stroke, a portion of the entering steam must be condensed to restore the heat lost by condensation and the cooling of the cylinder by re-evaporation during the previous expansion, as well as the heat abstracted by the steam during exhaust.

The extent to which cylinder condensation takes place depends upon the extent of the cooling surfaces opposed, and also upon the quantity of water mixed with the steam and carried with it from the boiler; but part of the water formed from the condensed steam is re-converted into steam during expansion, and the heat necessary for its re-evaporation is supplied from three sources. First, from the heat stored in the metal which was abstracted from the entering steam. Secondly, from the sensible heat given up by the steam as it falls in pressure and temperature during expansion. Thirdly, from the latent heat given up by the steam during condensation. So that the action of condensation and re-evaporation is continually going on in the cylinder. Condensation varies as the size of cylinder, for as the diameter is increased, the condensing surfaces increase directly as the diameter; but the area and consequently the volume of steam increase as the square of the diameter; the condensing surfaces of the piston and cylinder-ends increase as the square of the diameter; but the volume of steam cut off at a given proportion of the stroke increases directly as the length of stroke, so that the loss from condensation diminishes as the diameter of cylinder and the length of stroke are increased. Condensation also varies with the rate of expansion; the weight of steam condensed increases rapidly with each increase in the ratio of expansion.

## CYLINDERS.

**Cylinder Condensation** causes a great loss of both steam and fuel, and forms an obstacle to working expansively; in fact, unless the cylinder is protected in some way, so as to keep up the temperature of the steam during expansion to its initial pressure, little or no gain will be derived from working expansively. If steam could only be maintained at a suitably high temperature during expansion, without condensation, then the reduction of pressure during expansion would be the exact equivalent of the work done in expanding. It is found in practice that even in cylinders jacketed in the best manner the loss from condensation is about from $1\frac{1}{2}$ to 2 lbs. per horse-power per hour, and in unjacketed but well clothed cylinders the loss from condensation is from $4\frac{1}{2}$ to 5 lbs. per horse-power per hour.

**Leaky Pistons** are another source of loss, and the amount of steam which from this cause escapes past the piston increases with the pressure of the steam and also with the age of the engine, so that a quantity of steam is continually passing through the cylinder without performing any work.

**Leaky Valves** also cause loss by admitting the steam after it is supposed to be cut off, and the initial work of such steam is lost, the cause of leakage being either want of stiffness in the valve, which allows it to bend into the ports in passing over them, or the surface is made so small that capillary attraction does not properly take place between the valve and its seat.

**Clearance** between the piston and the cylinder covers and the space occupied by the steam passages cause considerable loss, because these spaces are emptied of steam at each exhaust, and have to be re-filled at the beginning of each stroke, and the steam thus used does no work during admission, although it is not altogether lost, because it acts by expansion during the stroke.

**Compression.**—The loss due to clearance and waste room in the steam passages may be avoided by compressing the steam; this is accomplished by closing the exhaust port a little before the termination of the return stroke, and the advancing piston compresses the confined steam against the cylinder end. This is motion against resistance, and the work lost by the piston is imparted as heat to the steam, the compression of which raises its temperature, and its pressure can thus be raised up to its initial pressure, and heat will be applied to the cylinder covers and piston, which would otherwise be abstracted from the steam from the boiler, and condensation is prevented to that extent.

**Cushioning.**—Another great advantage from compression is that the compressed steam acts as a cushion to the piston and prevents a sudden shock at the end and beginning of each stroke, when the motion of the piston is reversed and the power used in compressing the steam (with the exception of loss from friction) is returned by the re-expansion of the compressed steam on the reversal of the piston. By properly adjusting the *quantity of cushion*, the momentum of the piston is balanced, and the engine is made to run smoothly and noiselessly.

**Back Pressure** causes loss of power, the extent of which depends upon the quantity of water mixed with the exhaust steam and also upon the amount of resistance opposed to the escape of the exhaust steam from the cylinder, in the shape of contracted ports and passages and bent exhaust pipes. Bends and elbows in the exhaust pipe cause great back pressure, but in non-condensing engines the back pressure is never less than the pressure of the atmosphere plus the power required to expel the exhaust steam from the cylinder. In condensing engines, the condenser and air-pump are employed to remove the back pressure or pressure of the atmosphere, but as a perfect vacuum is never obtained and there is always some resistance to the escape of the steam from the cylinder, there is always a back pressure of about 2 lbs. in condensing engines.

**Ratio of Expansion.**—In order to obtain all the available power, the steam should be brought on to the piston at its highest pressure and cut off quickly, so that the pressure does not fall during the closing of the port, as expansion cannot begin properly until the port is closed, and the full expansive force of the steam should be used as nearly as possible to the end of the stroke, and then exhausted freely, therefore the steam must be cut off at such a part of the stroke that it will expand to the lowest practicable point before exhausting. It is found in practice that the best results have been obtained by expanding the steam 6 times in single-cylinder steam-jacketed condensing engines; 4 times in single cylinder condensing engines without steam jackets; 3½ times in single cylinder steam jacketed non-condensing engines; 3 times in single cylinder non-condensing engines without steam jackets, but with well-clothed cylinders; 8 times in compound condensing jacketed engines; 6 times in compound condensing engines without jackets, but with well-clothed cylinders. In all cases the utmost feasible ratio of expansion is the number of times the total back pressure is contained in the total initial pressure.

**Lowest Absolute Terminal Pressure.**—In non-condensing engines, the exhaust port being open to the atmosphere, there is a back pressure of 15 lbs. per square inch, plus the power necessary to drive the engine against its own friction, and to expel the exhaust steam from the cylinder, which is on an average 5 lbs.; so that the lowest terminal absolute pressure to which steam can be economically expanded is 20 lbs. In condensing engines, there is always a pressure in the condenser to be provided against, as well as the resistance to the escape of the steam from the cylinder, and the power necessary to drive the engine against its own friction, so that the lowest terminal absolute pressure to which steam can be economically expanded, is 8 lbs. per square inch. When the steam is expanded to a lower terminal pressure than this, the result will be loss of power.

**Economical Working.**—To secure the utmost economy, it is necessary to work at a good rate of expansion with dry steam, and this can only be obtained by keeping the steam in the cylinder at such a point, that it will be as nearly as possible totally free from condensation; for this purpose the steam jacket was designed.

**Steam Jackets.**—The object of the steam jacket is to prevent condensation in the cylinder, and its effect is to remove the condensation from the inside of the cylinder, where it retards the effective working of the piston, to the outside of the cylinder into the jacket, whence it can easily be drained off and returned to the boiler. To enable the jacket to work properly, means must be provided to keep it clear of both air and water, otherwise they will completely destroy its action. The best form of steam jacket is shewn in Fig. 1, which is a section of a cylinder with both the cylinder and covers jacketed. The jackets of the cylinder and cover should be connected by at least 6 holes, and care must be used in making the joint to prevent these holes from being filled up with red lead, but pieces of tube screwed into the cylinder-cover effectually prevents this taking place. The jacket is filled with steam from the boiler, and condensation in the cylinder during expansion is prevented by the heat passing from the jacket to the expanding steam.

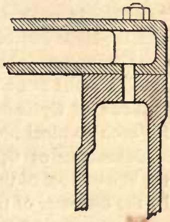
Fig. 1.

**Lead of a Valve.**—It being important to obtain the full pressure of the steam at the commencement of the stroke, the eccentric is fixed a little in advance of the position at right angles to the crank, which causes the port to be slightly open before the piston arrives at the end of the stroke, so that the moment the crank has passed its dead centre the piston begins its stroke with the full pressure of the steam behind it. The amount of lead required depends upon the speed of the piston, the size of the ports and the quantity of steam in the cylinder at the time the valve is opened.

*Insufficient lead* causes the piston to travel a portion of its stroke before it receives the full pressure of the steam, and excessive lead causes an irregular working of the piston, which receives a sudden shock, and the entering steam is compressed, which causes back pressure and loss of power, besides straining the engine.

**Lap of a Valve.**—In order to work expansively, the admission of the steam is cut off and the steam is confined in the cylinder, when the piston has only travelled a portion of its stroke, and this is effected with the common slide valve by making it sufficiently long, when in middle position, to overlap the extreme edges of the steam ports. The overlap is called outside lap.

*Inside lap*, or lap on the exhaust side, when it exists to any extent, is given to the valve to delay the release of the steam, but in engines that work at a good speed no inside lap is given more than is just sufficient to cover the ports on the exhausting side to prevent leakage of steam when the valve is at its half stroke.

## PROPORTIONS OF HIGH PRESSURE NON-CONDENSING STATIONARY ENGINES.

**The speed of piston** in feet per minute is found by multiplying twice the length of stroke in feet by the number of revolutions per minute of the crank shaft; the usual speed is from 300 to 650 per minute. A piston with a given pressure upon it, will exert power in direct proportion to its speed, therefore an engine to work economically should work at as high a speed as is possible without heating and vibration. A high speed enables large measures of expansion to be used, and gives a smooth and uniform motion. A high speed engine requires wide bearings, and the momentum or force stored up in its moving parts should be accurately balanced to enable it to run steadily without tremor; the piston can be balanced by compression, and the large end of the connecting-rod and the crank should be balanced by a counterweight revolving opposite to the crank, so that both may revolve in the same plane of revolution.

**Area of Cylinder.**—9 square inches of cylinder area are usually given for each nominal horse-power.

**Diameter of Cylinder.**—Multiply the nominal horse-power by 9, take the square root of the product and multiply by 1·1283, and the product will be the diameter of the cylinder.

**Thickness of Cylinder.**—There is no rule for thickness of metal that would be applicable to all sizes; the following are the usual proportions, including allowance for reboring.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder, in inches . . | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 22 | 24 |
| Thickness of metal, in inches . . . | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | $\frac{15}{16}$ | 1 | 1 | $1\frac{1}{16}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{5}{16}$ | $1\frac{3}{8}$ |

**Thickness of Cylinder Ribs** = three-quarters the thickness of metal of cylinder.

**Thickness of Cylinder Flanges**=thickness of cylinder × 1·25.

**Thickness of Metal of Steam Passages**=three-quarters the thickness of cylinder.

**Thickness of Cylinder Covers** = thickness of cylinder-flange multiplied by ·83.

**Thickness of Sole Plate of Cylinder** = thickness of cylinder multiplied by 1·25.

**Area of Steam Port** = area of cylinder in square inches divided by 12.

**Length of Steam Port** = diameter of cylinder in inches multiplied by ·88.

**Width of Steam Port** = area of steam port divided by the length of port.

**Width of Exhaust Port** = width of steam port multiplied by 2·25.

**Width of Bridge** = width of steam port divided by 1·37.

**Area of Steam Pipe** = area of cylinder in square inches divided by 16.

**Area of Exhaust Pipe** = area of cylinder in square inches divided by 12.

**Diameter of Piston Rod** = diameter of cylinder divided by 6·2.

**Diameter of Piston Rod Stuffing-Box** = diameter of piston rod multiplied by 1·8.

**Depth of Piston Rod Stuffing-Box** = diameter of piston rod multiplied by 1·6.

**Depth of Bush at bottom of Stuffing-Box** = one-third diameter of piston rod.

**Thickness of Flange of Gland** = one-fourth more than thickness of gland.

**Thickness of Metal round Stuffing-Box** = thickness of gland multiplied by 1·5.

**Diameter of Slide-Valve Spindle** = diameter of cylinder divided by 10.

**Outside Lap of Slide-Valve** = width of steam port multiplied by ·62. See also rule on page 21.

**Inside Lap of Slide-Valve** = $\frac{1}{16}$ inch.

**Stroke of Slide-Valve.**—Add together the width of steam port and the outside lap and multiply by 2.

**Clearance between Piston and Cylinder-Cover at each end of Stroke.**—Divide the diameter of the cylinder by 32.

The cylinder should be cast from tough close-grained cold blast iron, as hard as it can be properly worked, and the ends should be bell-mouthed.

**Length of Stroke** = diameter of cylinder multiplied by 2. Small engines are frequently made with the length of stroke = diameter of cylinder multiplied by 1·5.

**Piston.**—Width of piston = $\frac{1}{4}$ the diameter of cylinder.

Taper of piston rod in the piston = $\frac{1}{4}$ inch per foot.

**Piston-Rings.**—Cast-iron is a good material for piston-rings. An alloy has been successfully used in marine engines, of copper, 15 parts; tin, 5 parts; these rings, it is said, require no lubrication, do not score the cylinder, are very durable, and cause very little wear in the cylinder, which they soon work up to a polished face.

**Diameter of Crank-Shaft.**—This should be proportioned to the strain upon it, by the rule given further on; but in ordinary cases, the diameter of a wrought-iron crank-shaft may be = to the diameter of cylinder multiplied by ·4.

Diameter of neck of crank-shaft, recessed in the crank-shaft = Diameter of crank-shaft multiplied by ·8.

Length of neck of crank-shaft = diameter of crank-shaft multiplied by 1·6 for ordinary cases, and by 2 for high speeds.

**Crank, Cast-Iron.**—Diameter of boss for crank-shaft = diameter of shaft multiplied by 2.

Depth of boss = diameter of shaft.

Crank to be shrunk on and keyed on with a key in width = to $\frac{1}{4}$th the diameter of shaft.

Thickness of key = width of key multiplied by ·42.

Diameter of boss for crank-pin = diameter of crank-pin multiplied by 2·25.

Depth of boss for crank-pin = diameter of crank-pin multiplied by 1·5.

Crank-pin to be shrunk in and riveted at back.

Thickness of web of crank = diameter of crank-pin, and a strong rib in centre should connect the two bosses.

**Crank, Wrought-Iron.**—Diameter of boss for crank-shaft = diameter of shaft multiplied by 1·75.

Depth of boss = diameter of shaft multiplied by ·87.

Diameter of boss for crank-pin = diameter of crank-pin multiplied by 2.

Depth of boss for crank-pin = diameter of crank-pin multiplied by 1·4.

Thickness of web of crank = diameter of crank-pin.

**Crank-Pin.**—Diameter of crank-pin = diameter of cylinder multiplied by ·24.

Length of crank-pin = diameter of crank pin multiplied by 1·5.

**Eccentric.**—Throw of eccentric when it works the valve direct = $\frac{1}{2}$ the travel of the slide-valve.

Width of recess for eccentric-strap = diameter of cylinder multiplied by ·18.

Depth of recess in eccentric, from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch according to size.

Thickness of flange on each side of recess, $\frac{1}{4}$ inch to $\frac{1}{2}$ inch according to size.

Diameter of boss of eccentric = diameter of shafts multiplied by 1·6.

Depth of boss of eccentric = diameter of shafts multiplied by ·7.

**Eccentric-Strap.**—Thickness = to its width multiplied by ·67 for cast iron.

For brass multiply the width by ·53.

When the strap is iron lined with brass, the brass lining should be $\frac{1}{4}$ of the thickness of strap in thickness.

**Eccentric-Rod.**—Diameter at slide-valve spindle-end = diameter of slide-valve spindle.

Diameter at eccentric strap end = diameter of slide valve spindle multiplied by 1·3.

**Feed-Pump.** Diameter = $\frac{1}{8}$ diameter of cylinder when $\frac{1}{2}$ stroke of piston; and $\frac{1}{6}$ diameter of cylinder when $\frac{1}{4}$ stroke of piston.

**Wrought Iron Cross Head**, Fig. 2, for 4-slide bars.

Diameter of recessed part of boss A = diameter of piston-rod multiplied by 1·75.

Length of recessed part of boss A = diameter of piston-rod multiplied by 1·2.

Diameter of collar at end of boss B = diameter of piston-rod multiplied by 2.

Width of collar at end of boss B = diameter of piston-rod multiplied by ·42.

Thickness of fork at the boss C = diameter of piston-rod multiplied by ·6.

Thickness of fork below the boss D = diameter of piston-rod multiplied by ·42.

Diameter of the boss of the fork C = diameter of cross-head pin multiplied by 2.

Diameter of cross-head pin E = diameter of crank-pin multiplied by ·75.

Width of fork F = diameter of cross-head pin multiplied by 1·2.

Length of cotter-hole in boss = diameter of piston-rod multiplied by ·8.

Width of cotter-hole = diameter of piston-rod multiplied by ·22.

Diameter of slideblock-pin = diameter of crosshead-pin multiplied by ·75.

Taper of hole in crosshead for piston-rod = ¼ of an inch per foot.

**Slide Block.**—Width of sliding surface = diameter of piston-rod for

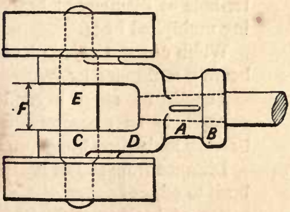


Fig. 2.

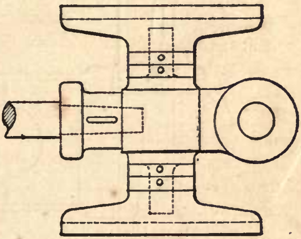

Fig. 3.

wrought-iron slidebars; and diameter of piston-rod multiplied by 1·4 when the slide bars are cast-iron.

Thickness of slideblock = diameter of slideblock-pin multiplied by 1·8.

Length of sliding surface = width of sliding surface multiplied by 3 or 4.

**Wrought-Iron Crosshead**, Fig. 3.—For 2 slidebars, viz. one above and one below the crosshead, the slide-blocks being adjustable by lock-nuts on the slideblock-pin.

Width of slide surface of slideblock = diameter of piston rod multiplied by 2.

Length of sliding surface of slideblock = width of sliding surface multiplied by 4.

From centre of the slideblock-pin to the centre of the crosshead-pin = diameter of crosshead-pin multiplied by 2·5. From centre of the slideblock pin to the outside of the collar on the end of the boss of crosshead = diameter of crosshead-pin multiplied by 2·5. The proportions of the fork and cross-head pin may be found by the same rules as the other crosshead given above.

**Slide Bars**, 4 in number, viz. 2 on each side of crosshead.

Slide bars, width = to diameter of piston-rod when wrought-iron; and when cast-iron, width = to diameter of piston-rod multiplied by 1·4.

Thickness = to width multiplied by ·6 for wrought-iron, and by ·4 for cast-iron when made with a rib in the centre.

Depth of rib = width of bar multiplied by ·7.

Thickness of rib = $\frac{1}{2}$ of the depth of rib.

Diameter of bolts for slide-bar = width of slide-bar multiplied by ·4.

**Slide-bars**, 2 in number, viz. 1 above and 1 below the cross head.

Width = diameter of piston-rod multiplied by 2.

**Connecting-rod with strap-end** like Fig. 4.

Thickness of strap at the end = diameter of bearing multiplied by ·33.

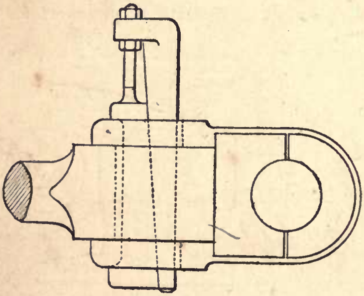

Fig. 4.

Thickness of strap at the side = diameter of bearing multiplied by ·24.

Thickness of strap at cotter-hole = diameter of bearing multiplied by ·4.

Width of strap = length of bearing multiplied by ·7.

Length of strap beyond cotter-hole = diameter of bearing multiplied by ·54.

Distance from end of brass bush to edge of cotter = diameter of bearing multiplied by ·54.

Thickness of brass bush at the end = diameter of bearing multiplied by ·25.

Thickness of brass bush at the side = thickness of brass bush at the end multiplied by ·75.

Width of gib and cotter at the centre = the diameter of the bearing.

Thickness of gib and cotter = diameter of bearing multiplied by ·22.

Taper of cotter, $\frac{1}{2}$ inch per foot.

Depth and width of the clip of the gib, each = the thickness of the gib.

Diameter of the connecting-rod at the small end = the diameter of piston-rod.

Diameter of connecting-rod at the large end = the diameter of piston-rod multiplied by 1·25.

Diameter of connecting-rod at the centre = the diameter of large end plus $\frac{1}{16}$ of an inch per foot of length of rod.

Length of connecting-rod = twice the length of stroke.

**Connecting-rod with cap-end** like Fig. 5.

Cap Bolts.—The sectional area of each bolt to equal one-half the sectional area of the piston-rod.

Thickness of cap = diameter of bearing multiplied by ·5.

Width of cap and rod-end = length of bearing multiplied by ·7.
Thickness of brass bush = diameter of bearing multiplied by ·2.
**Fly-wheel.**—Diameter = length of stroke in feet multiplied by $3\frac{1}{2}$ to 4.
Weight of Fly-wheel in cwts. = nominal horse-power multiplied by 3.
Maximum safe velocity for cast iron = 80 feet per second.
**Engine-bed when made Box-pattern,** like the section of bed, Fig. 6.
Full width across the top = diameter of cylinder multiplied by 2.
Width of each side frame or box = diameter of cylinder multiplied by ·5.
Width inside the two frames = diameter of cylinder.
Thickness of metal = thickness of metal of the cylinder multiplied by ·7.
Depth of bed = diameter of cylinder multiplied by ·5 to ·6.
**Weight of Foundation for an Engine.**—In stone or brick = one ton per nominal horse-power.

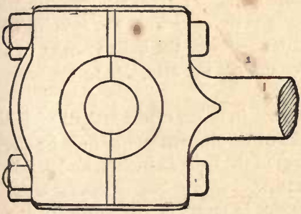

Fig. 5.

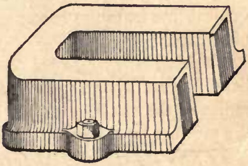

Fig. 6.

**Horizontal High-pressure Condensing Engines.**—The object of the condenser is to remove the pressure of the atmosphere which opposes the advance of the piston in the cylinder, so that all the work performed by the steam may be brought to bear effectually upon the piston, but there is always a back pressure of about 2 lbs. per square inch in the cylinder due to imperfect vacuum. In this class of engine, the condenser, with air-pump and hot-well combined in one casting, is usually fixed on the bed behind the cylinder, the piston-rod of which is continued through the back cylinder-cover to work the air-pump.

Diameter of single-acting air-pump = diameter of cylinder multiplied by ·6.

Diameter of double-acting air-pump = diameter of cylinder multiplied by ·3.

Width of air-pump piston = diameter of air-pump multiplied by ·3.
Diameter of air-pump rod = diameter of air-pump divided by 8.
Area of delivery and suction-valves = diameter of air-pump multiplied by ·7.
Capacity of condensor = the capacity of the air-pump.
Diameter of injection-pipe = diameter of cylinder divided by 8.

Diameter of cold-water pump = diameter of cylinder multiplied by ·3, when its stroke equals ½ the stroke of engine.

Diameter of feed-pump = diameter of cylinder divided by 10 when its stroke equals one-half the stroke of the engine.

Quantity of injection-water required per nominal horse-power in cubic feet per minute, equal temperature of the steam in degrees Fahr. multiplied by ·00304; approximately 5 gallons are required per nominal horse-power per minute, or 2¼ gallons per indicated horse-power per hour.

**Surface-Condensers** require from 2 to 2½ square feet of cooling or tube-surface per indicated horse-power, and from 40 to 50 lbs. of cooling-water for each lb. of steam to be condensed.

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## ENGINE GOVERNORS.

**The Action of a Governor** is controlled by two forces, viz., centrifugal force, or the tendency of the revolving balls to fly away from the spindle or vertical axis, and centripetal force, or the tendency of the balls to hang in a vertical line from the centre of the pin suspending the arm, due to the force of gravity.

*To find the centrifugal force* of a governor in terms of the weight of the balls. Multiply the square of the number of revolutions per minute by the radius of the circle described by the centres of the balls in inches, and divide the product by the constant number 35,226.

*To find the centripetal force* of a governor in terms of the weight of the balls. Divide the horizontal distance of the balls from the centre of the suspending pin, by the vertical height of the same centres.

**Ordinary Governors,** Fig. 7.—The centre of the suspension of the

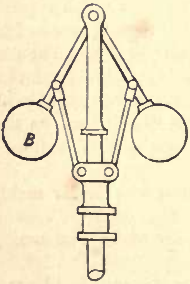


Fig. 7.

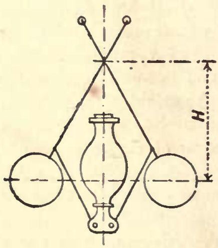


Fig. 8.

arms should invariably be placed in the centre of the spindle, unless it be placed beyond it, as in Fig. 8; because it is essential for a governor to work with the least possible variation in speed, and the placing of the point of suspension away from the centre of the spindle causes considerable variation in velocity. The variation in velocity increases as the distance is increased of the centre of the suspension-pin from the centre of the spindle. Although wrong in principle, the arms are frequently hung away from the centre of the spindle, as in Fig. 9; and in calculating such governors, the vertical height is to be taken from the plane line, P, to the top of the cone, T, instead of the actual centre of suspension.

*To find the power* of a governor, multiply the weight of the balls in lbs. by the vertical height they are lifted.

*To find the vertical height*, H, between the point of suspension and the plane of revolution, P, divide the constant number 187·5 by the number of revolutions of the governor, and square the quotient, which will give the height in inches.

**Diameter of Cast-iron Balls for Ordinary Governors, B.**—The weight of the balls must be sufficient to overcome the resistance of the valve and its connections. In ordinary cases the diameter of each ball may be equal to one half the height of plane line, H, in inches.

**Length of Governor Arms.**—First determine the vertical height from

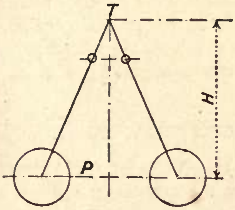

Fig. 9.

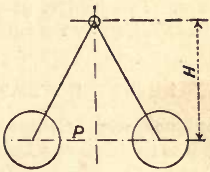

Fig. 10.

the plane of revolutions to point of suspension of arm, H, Fig. 10; then set out the centre lines of the arms at an angle of 60°, as their position at the proper speed of the governor, and where the said centre lines of arms cut the plane line will be the centres of the balls, and the length of arm will be the distance between the centre of suspension and the centre of the ball thus found. The speed required to maintain the balls at that height is obtained by the following rule :—

To find the speed of ordinary governors, divide the constant number, 187·5, by the square root of the vertical height in inches between the plane of revolution and centre of suspension, and the quotient will be the number of revolutions per minute required to maintain the balls at that height.

Governors are driven from the engine crank shaft by means of pulleys or gearing, and the diameter of pulley or number of teeth in the wheel to produce the proper velocity may be found by the following rules :—

*To find the diameter of pulley* (or number of teeth in the wheel) on the driving shaft of the governor. Multiply the number of revolutions of the engine per minute by the diameter of pulley (or number of teeth in the wheel) on the engine crank shaft, and divide by the required number of revolutions per minute of the governor.

*To find the diameter of pulley* (or number of teeth in the wheel) on the engine crank shaft. Multiply the diameter of pulley (or number of teeth in the wheel) on the governor driving shaft by the number of revolutions per minute of the governor, and divide by the number of revolutions per minute of the engine.

**Spring Governor.**—In small engines, the governor is often placed horizontally, the centrifugal force being balanced by a spring placed inside the governor on the spindle. The tension of the spring is regulated by nuts to suit the required speed.

**Cross-armed Governor with Centre Weight**, Fig. 8.—In this class of governor, the centre of suspension must be calculated from the point where the arms cross each other in the centre-line of the spindle, and the vertical height is the distance from that point to the plane of revolution. By crossing the arms in this way the governor becomes very sensitive; when the speed is increased, the point of intersection of the crossed arms rises at the same rate as the plane of revolution, and the governor balls will remain in equilibrium in every angular position at the proper speed of the governor. This kind of governor is run at a high speed; the proportions may be calculated by the following rules for centre-weighted governors.

## ENGINE GOVERNORS WITH CENTRE-WEIGHT.

**Governor with Centre-weight,** Fig. 11.—This form of governor requires to be driven at a high speed, so that the centrifugal force of the

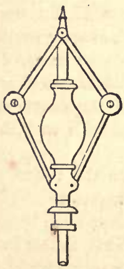

Fig. 11.

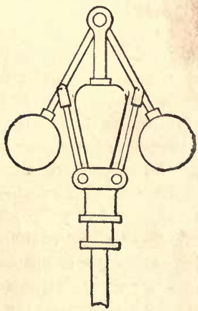

Fig. 12.

balls may overcome the gravity of the centre-weight. Its advantages over the ordinary governor are: its extreme sensitiveness, whereby uniformity of speed is maintained under varying and sudden changes of the load on the engine; and its great power, enabling a much smaller governor to be used.

*To find the vertical height* from the plane of revolution to the point of suspension of a governor with centre-weight. First, fix upon the number of revolutions, divide the constant number 187·5 by the number of revolutions the balls will make when the engine is at its proper speed, and square the quotient, which will give the height in inches for an ordinary governor, H; then add together the weight of the revolving balls and twice the weight of the centre-weight, which sum multiply by the height, H (found as for an ordinary governor), and divide the product by the sum of the weights of the revolving balls, the quotient will be the height of a centre-weighted governor. If the centre-weight is hung by links at a point in the arm above the centre of the balls, like Fig. 12, then use the above rule, but instead of twice the weight of the centre-weight named above, use the product of twice the weight of the centre-weight, multiplied by the result of the length between the centre of suspension of the arm and the point where the link is hung on to the arm, subtracted from the length between the centre of the ball and the centre of suspension of the arm.

*To find the weight of the centre-weight.* Find the vertical height by the above rule, both for a centre-weighted governor and for an ordinary governor, both at the same speed, then multiply the weight of the two revolving balls by the vertical height thus found for the centre-weighted governor, and divide the product by the vertical height thus found for an ordinary governor, which will give twice the weight of the centre-weight plus the two revolving balls, then subtract the weight of the two balls from that result, and divide the remainder by two, which will give the weight of centre-weight required.

*The diameter of the revolving balls* for governors like Fig. 11 should be equal to about $\frac{1}{5}$th of the vertical height from the plane of revolution to the centre of suspension of the arm. The speed of these governors is from 200 to 300 revolutions per minute.

*Example* of the rules for Centre-weighted Governors.—A governor like Fig. 11 revolves at 260 revolutions per minute, the weight of the balls is 3 lbs. each, the weight of the centre weight is 84 lbs, required the vertical height. $\frac{187·5}{260} = ·71$, then $·71 \times ·71 = ·504$, vertical height, then $·5\,(6 + 168) = 87$, then $\frac{87}{6} = 14·5$ inches, vertical height. Taking these particulars to find the centre weight, then $14·5 \times 6 = 87$ and $\frac{87}{·5} = 174$, $174 - 6 = 168$, then $\frac{168}{2} = 84$ lbs., the weight of centre weight.

## STEAM PRESSURE.

**Pressure of Steam.**—The pressure of steam is equal in all directions, therefore each square inch of surface exposed to its action must be equally capable of bearing the given pressure. The pressure is measured from that of the atmosphere, or 14·7 lbs. per square inch.

**Effective Pressure.**—In a non-condensing engine the pressure of the steam is opposed by that of the atmosphere, therefore only pressures above that of the atmosphere are effective for work, and a deduction must also be made for the resistance due to back pressure, caused by the resistance of the exhaust passages, which may be reckoned at 2 lbs. per square inch. In a condensing engine the pressure of the steam is only opposed by a back pressure of about 2 lbs. per square inch, due to imperfect vacuum.

*The initial pressure* of steam is its pressure when admitted to the cylinder.

*The final pressure* of steam is its pressure when discharged from the cylinder.

*The mean pressure* is the average pressure upon the piston through the whole stroke.

*The mean effective pressure* is the mean pressure less the back pressure

*The ratio of expansion* is the proportion which the final volume bears to the initial volume of steam.

*The relative volume* of steam is the volume of steam generated from a given volume of water divided by this volume.

*The absolute pressure* of steam is the pressure of steam given by the steam-gauge plus the pressure of the atmosphere.

*To find the quantity of steam* used by an engine, multiply the area of the cylinder in square feet by the speed of the piston in feet per minute, and divide the result by the nominal ratio of expansion. The result will be the number of cubic feet of boiler pressure steam consumed per minute, to which 10 per cent. must be added for the clearance of the cylinder and capacity of the steam passages.

*To find the pressure* in lbs. per square inch of the steam at any point of the period of expansion, multiply the initial pressure by the distance moved by the piston when the steam is cut off, and divide the product by the distance of the given point from the beginning of the stroke.

*To find the point to cut off* the steam for a given actual ratio of expansion, add the clearance to the length of stroke and divide by the ratio of expansion; from the quotient deduct the clearance, and the remainder will be the point of the stroke at which to cut off the steam.

The temperature, weight, and relative volume of steam for various pressures are given at page 337.

## LAP OF VALVE, ETC.

**Lap of Valve necessary to cut the Steam off at a given part of the Stroke.**—*Rule:* From the length of stroke in inches, deduct the distance in inches moved by the piston when the steam is cut off, divide the remainder by the stroke of the piston in inches, and extract the square root of the quotient, next multiply the result by half the stroke of the valve in inches, and deduct half the lead from the product, the remainder will be the required lap in inches.

**Point of Cut-off of Steam from a given Lap.**—*Rule:* To the lap of the valve on the steam side in inches add one half the lead, then divide by half the travel of the valve in inches, and multiply the square of the quotient by the length of stroke of the piston in inches; deduct the product from the length of stroke of the piston in inches, and the remainder will be the distance in inches the piston moves when the steam is cut off.

Table 1.—Hyperbolic Logarithms.

| Number. | Logarithm. | Number. | Logarithm. | Number. | Logarithm. |
|---|---|---|---|---|---|
| 1¼ | ·2231 | 5½ | 1·7047 | 9¾ | 2·2773 |
| 1½ | ·4054 | 5¾ | 1·7492 | 10 | 2·3026 |
| 1¾ | ·5596 | 6 | 1·7918 | 10¼ | 2·3279 |
| 2 | ·6931 | 6¼ | 1·8325 | 10½ | 2·3513 |
| 2¼ | ·8109 | 6½ | 1·8718 | 10¾ | 2·3749 |
| 2½ | ·9162 | 6¾ | 1·9095 | 11 | 2·3979 |
| 2¾ | 1·0116 | 7 | 1·9459 | 11¼ | 2·4201 |
| 3 | 1·0986 | 7¼ | 1·9810 | 11½ | 2·4430 |
| 3¼ | 1·1787 | 7½ | 2·0149 | 11¾ | 2·4636 |
| 3½ | 1·2528 | 7¾ | 2·0477 | 12 | 2·4849 |
| 3¾ | 1·3217 | 8 | 2·0794 | 12½ | 2·5262 |
| 4 | 1·3862 | 8¼ | 2·1102 | 13 | 2·5649 |
| 4¼ | 1·4469 | 8½ | 2·1401 | 14 | 2·6391 |
| 4½ | 1·5040 | 8¾ | 2·1691 | 15 | 2·7081 |
| 4¾ | 1·5581 | 9 | 2·1972 | 16 | 2·7726 |
| 5 | 1·6094 | 9¼ | 2·2246 | 17 | 2·8332 |
| 5¼ | 1·6582 | 9½ | 2·2513 | 18 | 2·8904 |

## COMPOUND ENGINES.

The steam in a compound engine, after driving the piston in one cylinder is exhausted into a second, and sometimes into a third cylinder, and acts on their pistons before being condensed in a condensing engine, or before being finally exhausted in a non-condensing engine. The saving of fuel effected by compounding is about 25 per cent. To obtain uniformity of rotative pressure upon the cranks they are placed at right angles. In a compound engine, the area of the low pressure cylinder is calculated as if all the power were to be developed in that cylinder, which therefore requires to be of the same area as the cylinder of a simple engine of the same power.

**To find the Area of the Low-pressure Cylinder.**—*Rule:* Multiply the number of horse-power the engine is required to indicate by 33,000, which will give the number of footpounds required per minute, divide this by the speed of the piston in feet per minute, and the result will be the total effective pressure on the piston at that speed to develop the given number of indicated horse-power; divide the quotient by the mean effective pressure per square inch on the piston, and the final quotient is the area in square inches of the low-pressure cylinder,

*The speed of the piston* in compound engines is usually 420 feet per minute.

*The ratio of expansion* is found by dividing the initial absolute pressure of the steam in the high-pressure cylinder by the final pressure in the low-pressure cylinder.

**The mean effective Pressure** on the piston throughout the stroke is found thus.—*Rule:* To the hyperbolic logarithm of the total number of expansions add 1, then divide by the total number of expansions, and multiply the quotient by the initial absolute pressure of the steam (that is the boiler pressure plus 15 lbs.) which will give the average pressure of the steam expanded the given number of times, from which deduct the back pressure, usually 3 lbs., and the result will be the mean effective pressure.

**To find the Area of the High pressure Cylinder.**—*Rule:* Multiply the initial absolute pressure of the steam in the high pressure cylinder by ·042, with which result, divide the area of the low pressure cylinder. In order to provide for the loss due to the fall in pressure of the steam in passing between the two cylinders, their areas found by the above rules should be increased to the extent of from 10 to 20 per cent.

*The steam should be cut off* in the high pressure cylinder when the piston has moved ·45 of its length of stroke, and in the low pressure cylinder at one half the length of stroke. The final pressure in the low pressure cylinder should be from 8 to 9 lbs. in theory, but in practice it is from 2 to 3 lbs. more than that, and the lowest economical final pressure is from 10 to 12 lbs.

As an example of these rules.—Required the area of the cylinders for a compound engine to indicate 100 horse-power: speed of piston 420 feet per minute: boiler pressure 86 lbs. per square inch—then allowing 5 lbs. for loss of pressure between the boiler and the cylinder, the initial pressure in the high pressure cylinder will be 81 lbs., and the initial absolute pressure $81 + 15 = 96$ lbs.—presuming the steam to be worked down to a final pressure of 12 lbs.—it will give

$$\frac{96 \text{ initial absolute pressure in high pressure cylinder}}{12 \text{ final pressure in low pressure cylinder}} = 8, \text{ ratio of expansion.}$$

The hyperbolic logarithm of 8 is $2{\cdot}0794 + 1 = \frac{3{\cdot}0794}{8} = {\cdot}3849 \times 96 =$ $36{\cdot}95$, the average pressure in lbs. per square inch of steam of 96 lbs. pressure expanded eight times, and if 3 lbs. be deducted for back pressure, it leaves 33·95 lbs. mean effective pressure per square inch; then $\frac{100 \text{ indicated horse-power required} \times 33{,}000}{420 \text{ speed of piston in feet per minute}} = 7857{\cdot}14$ gross pressure on the piston at that speed; and $\frac{7857{\cdot}14}{33{\cdot}95 \text{ mean effective pressure}} = 231{\cdot}34$ area in square inches of large cylinder, and $96 \times {\cdot}042 = 4{\cdot}03$, and $\frac{231{\cdot}34}{4{\cdot}03} = 57{\cdot}4$ area of small cylinder, then if 20 per cent. be added to provide against loss by the pressure falling during the passage of the steam between the cylinders, the area of the low pressure cylinder will be $231{\cdot}34 + 46{\cdot}26 = 277{\cdot}6$ square inches, and the area of the high pressure cylinder will be $57{\cdot}4 + 11{\cdot}48 = 68{\cdot}88$ square inches, or $18\frac{3}{4}$ inches diameter for the large, and $9\frac{3}{8}$ inches diameter for the small cylinder, being a cylinder ratio of 4 to 1, which agrees with the best modern practice for that pressure of steam. If the initial absolute pressure had been 75 lbs., the ratio of the areas of the cylinders would have been $75 \times {\cdot}042 = 3{\cdot}15$, and for 60 lbs. it would have been $60 \times {\cdot}042 = 2{\cdot}52$; and for a high absolute pressure of 125 lbs, it would have been $125 \times {\cdot}042 = 5{\cdot}25$.

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## THE INDICATOR.

**The Indicator.**—The action of steam in a cylinder can only be correctly ascertained by means of an indicator; it shews the pressure of the steam at each point of the stroke, the power and performance of the engine, the amount of back pressure or force opposed to the motion of the piston, and enables any imperfections to be detected in the construction of the valve ports and steam passages. The best indicator is that known as Richards' Indicator.*

**Indicator Diagrams.**—Supposing the indicator to be fixed to a cylinder, and that the drum is connected by means of a cord to some part of the engine, which has a motion co-incident with that of the piston, if the barrel be allowed to rotate before the indicator cock is opened, a horizontal line is traced, which is called the atmospheric line, and all portions of the diagram above that line, represent steam pressures and all portions below that line represent vacuum.

If the indicator cock be opened at the beginning of the stroke, when

* Richards' Indicator is made by Messrs. Elliot Brothers, 449, Strand, London, who sell Richards' work on the Indicator, published by Longman & Co., to which the Author is indebted for some of the above information on Indicator Diagrams.

steam enters the engine cylinder, the pencil moves upwards and traces a vertical line, and as the piston moves forward the indicator barrel rotates and a horizontal line is traced until the steam is cut off; then, as the expanding steam increases in volume, it declines in pressure, which causes the pencil to gradually fall and describe a curved line until the exhaust port is opened, when the pencil immediately falls and describes the "toe" of the diagram. On the return stroke the pencil traces the bottom or exhaust line of the diagram until the closing of the exhaust port, when cushioning commences, then the pressure rises and moves the pencil up and completes the diagram.

**Theoretical Indicator Diagram.**—The rules for the expansion of steam are based upon the approximately correct law of gases, viz. that the pressure of gas varies inversely as the volume, or the product of the pressure and volume of a gas is always a constant, other conditions being unaltered; and in order to ascertain the varying pressure and volume of

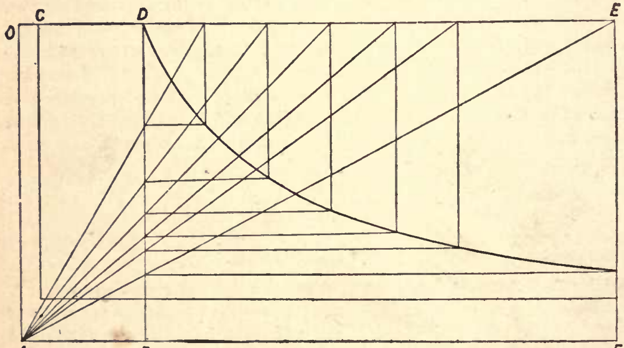

Fig. 13.

steam during expansion, it is necessary to construct a theoretical diagram according to this law, the descending curve of which represents the decreasing force of the steam as it expands in volume. This curve is called a hyperbolic curve, and is the standard by which the character of all expansion curves in indicator diagrams is determined. To draw the theoretical curve upon a diagram as shewn in Fig. 13, draw the line A F, representing the line of perfect vacuum, parallel with the atmospheric line, and at the proper distance below it to represent 14·7 lbs.; and perpendicular to the line A F draw A O, representing the clearance space; draw the line C D, representing the period of admission of the steam; from the point D draw the vertical line D B; draw the line D E; from A to F represents the full length of stroke; divide the distance D E into a number of parts, from which points draw diagonal lines to the point A; from the points where the diagonal lines cut the vertical line D B, draw horizontal lines; and the points where the vertical lines drawn from the points in the line D E meet these horizontal lines, will be the points of the hyperbolic curve, which may be drawn in by hand.

**Indicator Diagrams,** Fig. 14.—The lines forming the outline of a diagram during one revolution of the engine are as follows:—

| | |
|---|---|
| A to B, The admission line. | D to E, The exhaust line. |
| B to C, The steam line. | E to F, The line of back pressure. |
| C to D, The expansion curve. | F to A, The compression line. |

In Fig. 14, A is the point of pre-admission, the steam having been

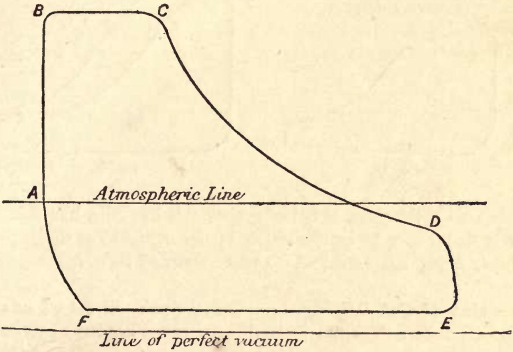


Fig. 14.

admitted a little before the beginning of the steam stroke, due to the lead of the valve, to ensure having the full pressure of steam in the cylinder at the beginning of the stroke.

**Admission Line,** Fig. 14.—A to B is the admission line. This line is formed by the rise of pressure in the cylinder as the port is opened for the admission of steam; the full pressure of the steam should come on to the

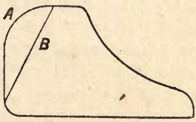


Fig. 15.

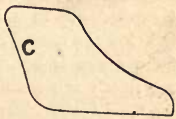


Fig. 16.

piston at the beginning of the stroke, and the admission corner should be sharp. When it is rounded as at A in Fig. 15, or when it slants, as at B, it shows that the steam is admitted too late and the momentum of the piston at the commencement of the stroke is imparted by the engine. To remedy this the valve requires more lead. When the valve has excessive lead, and steam enters too soon, it will produce a slanting line like C, Fig. 16; to remedy this the valve requires less lead.

**Steam Line.**—B to C, Fig. 14, is the steam line or period of admission of the steam. This line is formed by the advance of the piston while the port remains open for the admission of steam; the full pressure of steam should be maintained in the cylinder during the whole period of admission, and the steam line should be straight and horizontal, or parallel with the atmo-

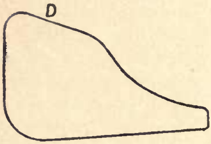


Fig. 17.

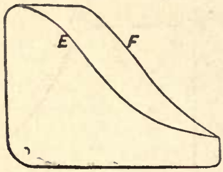


Fig. 18.

spheric line up to the point of cut off; when this line falls, like D in Fig. 17, the fall is due either to condensation in the cylinder, or to the ports and steam pipes being too small, which wiredraws and reduces the pressure of the steam.

**The Point of Cut Off**, Fig. 14.—C is the point of cut off or suppression. As expansion does not properly commence until the port is closed, the action of the valve in cutting off the steam should be sharp and sudden, and the pressure should fall as little as possible during the closing of the port. The point of cut off should be sharp and clear. When this corner is rounded, like E in Fig. 18, it shows that the valve does not close quickly enough, and that the expansion arrangements are defective. When the steam is cut off slowly it causes a fall of pressure in the cylinder before the port is completely closed. When this corner shows a gradually descending line like F in Fig. 18, it shows that some steam has entered the cylinder after it was supposed to have been cut off.

**The Expansion Curve.**—C to D, Fig. 14, is the expansion curve or period of expansion. In a condensing engine this curve is partly above and partly below the atmospheric line, but in a non-condensing engine the whole of the curve is above the atmospheric line. This curve should approach as nearly as possible in form to that of the theoretical diagram, unless it be filled up by leaky valves, or diminished by steam leaking past the piston. When the cylinder is not properly protected, there will be great loss of heat from radiation, and fall of pressure during expansion, which will cause the expansion curve to fall below the theoretical curve. When the curve rises above the theoretical curve, it is generally due to a leaky valve, owing either to the valve being defective in rigidity, which causes it to bend into the ports in passing over them, or to the valve being deficient in wearing surface. When the expansion curve rises above the theoretical curve towards the end of the stroke, it shows that the steam has been condensed at the beginning of the stroke, and evaporated by the walls of the cylinder towards the end of the stroke.

**Point of Pre-release.**—D, Fig. 14, is the point of exhaust or pre-release, the exhaust port being opened before the end of the stroke. The pre-release should allow all the steam in the cylinder to escape before the piston arrives at the end of the stroke, so that during the return stroke the back pressure may be as low as possible.

**Exhaust Line.**—D to E, Fig. 14, is the exhaust line. The full expansive force of the steam during the steam stroke, should be employed as nearly as possible to the end of the stroke, and then the steam should be discharged as rapidly as possible, so as not to hinder the return of the piston. When the exhaust pipe and exhaust passages are cramped, or when the exhaust is too late, all the steam cannot escape properly before the end of the return stroke, which will cause a bad exhaust line, and the expansion curve will be continued to the end of the diagram. The exhaust


Fig. 19.

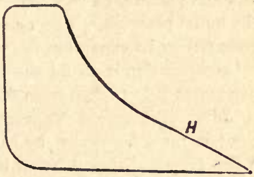


Fig. 20.

line will be shown slanting gradually downwards, as at G, Fig. 19, as the piston advances on its return stroke, instead of being horizontal. When the exhaust is too soon, the exhaust line will slope down, as shown at H, Fig. 20.

**Line of Back Pressure.**—E to F is the line of back pressure, or period of exhaust, during the return stroke. This line extends from the beginning of the return stroke to the point at which the exhaust port is closed. In a condensing engine the steam pressure will fall below the atmospheric line, but in a non-condensing engine the pressure cannot fall to the atmospheric line, because there is always an amount of back pressure, due to the force required to expel the exhaust steam through the exhaust passages and pipe against the resistance of the atmosphere. In a condensing engine, the deeper the line of back pressure measures from, and the more nearly parallel it is to, the atmospheric line, the better. In a non-condensing engine, the nearer and more parallel the line of back pressure is to the atmospheric line the better, as back pressure not only means a loss of force, but it diminishes the efficiency of the engine.

**Point of Compression.**—F, Fig. 14, is the point of compression. This line is formed by the closing of the exhaust port at some point before the end of the return stroke. The advancing piston compresses the confined steam into the clearance space and passages, and provides a cushion which absorbs the momentum of the piston, and enables its motion to be reversed without shock. The rise of pressure is shown by the rising curve at F, and the portion of the stroke between F and A is the period of compression or cushioning. Excessive compression causes the confined steam to rise above its initial pressure before pre-admission commences, as shown by the loop at the admission corner in Fig. 21; consequently, when the port is opened, part of the confined steam flows from the cylinder into the steam chest, and the pressure is reduced and the steam line is lowered, as shown in Fig. 21. In slow running engines only a small amount of cushioning is necessary, but in high-speed engines the cushioning should be so adjusted that the confined steam is compressed up to its initial pressure. The compressed steam acts as an elastic spring, and gives out by its expansion the work expended in compressing it. The effect of compression is to fill the clearance space with compressed steam, and save steam being taken from the boiler for that purpose.

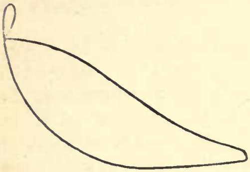

Fig. 21.

**The Line of Perfect Vacuum.**—This line cannot be drawn by the indicator; it must be drawn by hand, parallel with the atmospheric line, and at the proper distance below it to represent, say, 14·7 lbs. per square inch, as the average pressure of the atmosphere, according to the scale of the diagram. In measuring the diagram of a condensing engine, the distance between the vacuum line of the diagram and the line of perfect vacuum, will show the quantity of uncondensed steam in the cylinder or the amount of back pressure due to imperfect vacuum, slightly varying according to the barometric pressure. The temperature of the condensed water is usually about 100° F., or 1 lb. pressure per square inch; but the pressure of air in the condensor prevents the pressure from falling below 2 lbs. per square inch. The usual final pressure is from 4 to 5 lbs. per square inch.

*The initial pressure* of steam in a cylinder is always 4 or 5 lbs. less than the boiler pressure; but when the fall of pressure is much more than this, it is due either to bends in the steam pipes, or to the steam pipes being too small, or to the steam ports being too contracted.

*To find the indicated horse-power* of an engine from an indicator diagram. Divide the diagram at right angles to the atmospheric line into 10 equal parts, take the breadth in the middle between the divisions with the scale of the indicator, add them together, and divide by 10 (the number of divisions)—the result will be the mean or average pressure per square inch on the piston during the stroke; then multiply the area of the cylinder in square inches by the mean pressure, and by the speed of the piston in feet per minute. The product divided by 33,000 gives the indicated horse-power.

*The speed of the piston* in feet per minute is found thus:—Multiply the length of stroke in feet by 2, and by the number of revolutions per minute. A deduction of 2 lbs. per square inch, from the gross diagram must be made for the friction of the engine alone; but if the diagram is taken when the load is on the engine, an additional deduction must be made of 5 per cent. for friction.

*A constant* may be found for any particular engine, which, being multiplied by the mean pressure, will give the horse-power. To find the constant multiplier: multiply the area of the cylinder in square inches, by the speed of the piston in feet per minute, and divide the product by 33,000. The quotient will give the number of horse-power which would be produced by 1 lb. of mean pressure.

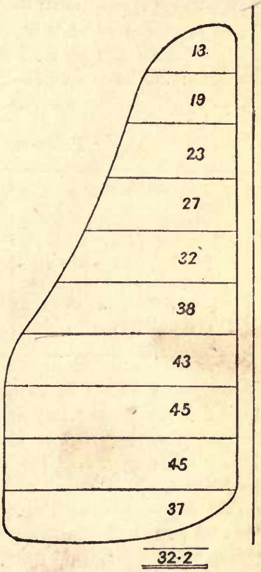


Fig. 22.

*Example.*—Required the power of the engine from which diagram, Fig. 22, was taken. Diameter of cylinder, 12 inches; length of stroke, 2 feet; number of revolutions, 80 per minute. The mean pressure according to the diagram is 32·2 lbs, from which deduct 2 lbs for the friction of the engine, leaving 30·2 lbs. pressure; the area of the cylinder is 113 inches; then $\frac{113 \times 30{\cdot}2 \times 2 \times 2 \times 80}{33{,}000} = 33$, indicated horse power.

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## LOCOMOTIVE ENGINES.

**The Adhesive Power** of a locomotive depends upon the weight on the driving wheels, and is in ordinary weather about $\frac{1}{6}$ of the load on the driving wheels; in goods engines the wheels are coupled, and the adhesive force is due to the weight resting on the coupled wheels.

**Train Resistances.**—Mr. D. K. Clark's rules for the resistance on railways are as follows:—

Resistance of engine, tender, and train . $R = 8 + \frac{V^2}{171}$ | Resistance of train alone $R' = 6 + \frac{V^2}{240}$

$R$ = total resistance of engine, tender and train in lbs. per ton gross; $R'$ = resistance of train alone in lbs. per ton; $V$ = speed in miles per hour. These rules are for a straight line of rails; and one-half more is to be added for the resistance due to curves, imperfections of the road, and wind.

Table 2. Resistance of Trains.

| Speed in Miles per Hour. | 5. | 10. | 15. | 20. | 30. | 40. | 50. | 60. | 70 miles. |
|---|---|---|---|---|---|---|---|---|---|
| Frictional Resistance in lbs. per Ton of Engine, Tender, and Train . . | 12·2 | 13 | 14 | 15·5 | 20 | 26 | 34 | 43·5 | 55 lbs. |
| Frictional Resistance in lbs. per Ton of the Train alone . . . | 9·15 | 9·6 | 10·5 | 11·4 | 14·6 | 19 | 24 | 31·5 | 36·6 lbs. |

It requires a force of about 7 lbs. per ton, to keep wagons moving on a level line of rails, at a very slow speed after they are started.

**The Tractive Power** of a locomotive engine is found thus: *Rule:* Multiply the square of the diameter in inches of one cylinder, by the length of stroke in inches, and divide the product by the diameter in inches of the driving wheel. The quotient will be the tractive force in pounds, for each pound of effective pressure per square inch on the piston; and this quotient multiplied by the effective mean pressure in the cylinder, will give the full tractive force in pounds exerted by the engine.

*The maximum boiler pressure* of locomotives is about 140 lbs. per square inch, but the mean effective pressure is much less, owing to working the steam expansively. The maximum pressure averages three-fourths of the boiler pressure.

*To find the resistance* in lbs. per ton of the train due to gravity, on an incline. *Rule:* Divide 2240 by the rate of the gradient.

*To find the resistance* in lbs. per ton due to the velocity of the engine, tender, and train. *Rule:* Square the speed of the train in miles per hour, and divide the result by 171 and add 8 to the quotient. To the sum, add 50 per cent. for resistance due to curves, imperfections of the road, and wind.

*To find the load* the engine can take, in tons, including the weight of the wagons, but not that of the engine and tender. *Rule:* Add together the resistance due to gravity, and the resistance due to velocity, with which result divide the tractive force, and from the quotient subtract the weight of the engine and tender in tons.

As an example of these rules, required the load which a locomotive engine with cylinders 17 inches diameter and 24 inches length of stroke, with a driving wheel 5 feet diameter, will take on an incline of 1 in 70 at the speed of 20 miles per hour, boiler pressure 140 lbs. per square inch, weight of engine and tender 55 tons. *The tractive force* which the engine is capable of exerting is $\frac{17^2 \times 24}{60} = 115{\cdot}6$ lbs. for each lb. of effective pressure per square inch on the pistons. The boiler pressure of 140 gives $140 \times \frac{3}{4} = 105$ lbs. effective pressure, which multiplied by the tractive force in lbs. $= 105 \times 115{\cdot}6$ gives 12,138 lbs. as the total tractive force exerted by that engine.

*The resistance due to gravity* is $\frac{2240}{70 \text{ gradient}} = 32$ lbs. per ton.

*The resistance due to the velocity* is $\frac{20 \times 20}{171} + 8 = 10{\cdot}34$ lbs., and with 50 per cent. added, gives 15·51 lbs. per ton.

*The load which the engine will take* will be $\frac{12138}{32 + 15{\cdot}51} - 55 = 200$ tons, and taking 8 tons as the average gross weight of each wagon, the train would consist of $\frac{200}{8} = 25$ loaded wagons.

*The total weight of the engine,* tender and train is 255 tons, and the resistances due to velocity and gravity are $32 + 15{\cdot}51 = 47{\cdot}51$ lbs. per ton, or $255 \times 47{\cdot}51 = 12115$ lbs. for the train, the train moves $\frac{20 \text{ m.} \times 1760 \text{ yds.} \times 3 \text{ ft.}}{60 \text{ minutes}} = 1760$ feet in one minute, and $\frac{12115 \times 1760}{33000}$ $= 646$ indicated horse-power.

*The coal burnt per indicated horse-power* would be $2\frac{1}{2}$ lbs. per hour, then $\frac{646 \times 2\frac{1}{2}}{20 \text{ miles}} = 80$ lbs. of coal per mile, or $80 \times 20 = 1600$ lbs. of coal burnt per hour.

*The evaporation* would be 9 lbs. of water per lb. of coal, and it would require $\frac{1600 \times 9 \text{ lbs.}}{10 \text{ lbs. per gallon}} = 1440$ gallons of water per hour.

*The number of revolutions* of the driving wheel would be $\frac{20 \times 1760 \times 3}{60 \times 5 \text{ feet} \times 3{\cdot}1416} = 112$ per minute; for each revolution of the wheel the piston moves twice the length of the stroke, and *the speed of the piston* would be 2 feet stroke $\times$ 2 $\times$ 112 revolutions $= 448$ feet per minute. *The total power* the above locomotive engine is capable of developing at that speed and pressure is,

$$\frac{17 \text{ diam. of cylinder} \times 17 \text{ diam. of cylinder} \times {\cdot}7854 \times 2 \text{ cylinders} \times 105 \text{ lbs. pressure} \times 448 \text{ ft. speed of piston}}{33{,}000}$$

$= 647$ horse-power.

**Locomotive Engine Specifications.**—The specifications given in the following pages are for probably the best engines of their class—both goods and passenger locomotive engines.

## SPECIFICATION FOR GOODS ENGINES, LANCASHIRE AND YORKSHIRE RAILWAY.

*Designed by* MR. W. BARTON WRIGHT, *Locomotive Superintendent of the Line.*

**The Engines** must be made to the dimensions given in the following specification, and exactly to the drawings supplied by the company's locomotive superintendent; any alteration or proposed deviation from the drawings furnished must be first submitted to the locomotive superintendent, and his sanction obtained in writing before it is carried out The materials to be of the make specified in each case, and where no instructions are given, the workmanship and materials must be the very best of their respective kinds. No advantage whatever is to be taken of any omission of details or discrepancies that may occur in the drawings or specification, as the contractor may obtain full information about any part of the work that is not sufficiently explained. The engines must be finished in every respect in the most complete manner, and to the entire satisfaction of the company's locomotive superintendent, who shall be at liberty to inspect, either personally or by deputy, the work during its progress, and to reject any defective or unsuitable materials or workmanship. The contractor is to pay all royalties, and to be liable for all claims in respect of patent rights for any article or part supplied under this contract, or required for its due performance. It must be clearly understood that the prices named in the tender are to include everything required to be done by the conditions of contract and specification, or by any drawings therein referred to, and also all such work as is manifestly necessary to the proper completion of the contract, though special mention thereof may have been omitted in the specification or drawings. The contractor shall pay all costs attendant on any tests which the company's locomotive superintendent or his deputy shall require to be made. In case of any dispute arising, either during the progress of the work or at its termination, the decision of the company's locomotive superintendent is to be taken as final, and binding in every respect. The engines are to be delivered by the builders free of charge to the Lancashire and Yorkshire Railway Company, at Miles Platting, Manchester, fit and ready for work in every respect; and prior to payment each engine will be required to run 3000 miles consecutively, without showing any defects in material or workmanship, and the builders will be held responsible for all such defects that may appear—accidents being excepted, until they have run that distance.

**Drawings and Photographs.**—The contractor is to furnish with the fifth engine two complete sets of detail and general drawings of the engines, exactly as made, on tracing cloth of double elephant size; also twelve large mounted photographs, showing the engines exactly as finished. The cost of these drawings and photographs is to be included in the amount of the tender.

**Quality of Materials.**—Iron: In all cases where "Best Yorkshire iron" is specified, it must be wrought iron of the manufacture of either Lowmoor, Bowling, Farnley Best Iron, Monkbridge, S. T. Cooper and Co., or Taylor and Co., and will be subject to being tested. The brand of the manufacturer must be placed, wherever possible, so as to be seen when finished. Brass: Where "brass" is specified it must be of good tough metal. Gun-metal: Gun-metal must be composed of copper 5 parts, tin 1 part. White metal: White metal must be composed of tin 16 parts, antimony 2 parts, copper 1½ parts. Other materials to be obtained of the manufacture specified under the respective heads, unless the consent of the company's locomotive superintendent be obtained to an alteration.

**Boiler.**—Boiler dome, smoke-box tube plate, and fire-box shell, with all angle irons, rivets, and stays, to be made of Lowmoor iron in sixteen engines; of Bowling iron in sixteen engines; and the remainder of one of the other firms before specified. Barrel to be telescopic as shown, and to be made of three plates. Transverse joints to be single riveted; longitudinal seams to be butt-jointed with inside and outside joint strips, and these seams to be placed on each side of centre line of boiler at the top. Seam joining barrel to fire-box shell to be zigzag riveted. The joint of the middle and dome plate to be welded, and the thickness of this part to be kept full the strength of the plate. A strengthening ring ½ inch thick to be riveted to the inside of the middle barrel, as per detail drawing. Hole for dome to be 19 inches only.

**Smoke-box Tubeplate.**—Smoke-box tubeplate to be secured to boiler barrel by a continuous weldless ring of mild Siemens-Martin angle steel, well annealed, manufactured by Messrs. John Spencer and Sons, of Newcastle-upon-Tyne, or Vicars and Sons, Sheffield. To be faced, bored, and turned to section shown on drawings, and shrunk on to the barrel and double riveted. Two per cent. of these rings to be tested before leaving the steel works by the company's inspector.

**Dome.**—Dome to be in one plate, welded at the seams and flanged top and bottom, and to be fitted with a wrought iron cover. Flanges of dome and cover must be faced, so that a perfectly steam-tight joint can be made.

**Fire-box Shell.**—The side and top to be made in one plate. The front or throat-plate of fire-box shell to be flanged forward and double riveted to boiler. The back plate to be flanged to 6 inch radius outside, and single riveted to sides and top; the upper part to be stayed by a heavy T-girder of best Yorkshire iron, double riveted to the inside of the plate as per detail drawing. A similar stay to be fixed to inside of smoke-box tube-plate, no gussets or longitudinal stays being used. Palm stays to copper box, and other stays were shown on drawing. All iron used in any part of barrel or fire-box shell must be best Yorkshire.

**Manhole.**—A wrought iron manhole, flanged top and bottom, to be double riveted to the centre of the fire-box top; to be fitted with a wrought iron cover-plate $1\frac{3}{8}$ inches thick, on which will be mounted the safety valves. Cover-plate and top flange of manhole to be accurately faced, so that a perfectly steam-tight joint can be made.

**Fire-hole Ring.**—Fire-hole ring of best Yorkshire iron $2\frac{5}{8}$ inches by $2\frac{1}{2}$ inches.

**Foundation Ring.**—Foundation ring to be $4\frac{1}{2}$ inches deep by $2\frac{1}{2}$ inches thick struck to $5\frac{1}{2}$ inches radius outside at the corners, at which parts the side and end plates are continued the full depth to allow of double riveting.

**Wash-out Door and Mud Plugs.**—A heavy cast iron seat and wash-out door to be riveted to underside of boiler barrel, 16 inches in front of fire-box shell. Hole 5 inches diameter, and lid to be made with coned joint as per detail drawing. Thirteen brass taper mud-plugs to be placed for purposes of washing out, viz., three on fire-box front, and three on fire-box back, above bottom ring. Two on fire-box back above copper-box roof, one on each side of fire-box shell, and three on smoke-box tube-plate, as shown on drawings.

**Workmanship.**—All rivets must completely fill the holes, which must be slightly countersunk under the rivet heads, and so punched that when the plates are in a proper position for riveting, the smaller diameters of the holes meet at the centre of the joint. All holes in the plates or angle-irons, &c., must be perfectly fair with each other, and no drifting will be allowed on any consideration whatever. Should any of the holes not come perfectly fair with each other they must be carefully rimered until they become so; care must be taken that, after rimering, the rivets completely fill the holes. All the plates to be brought well together before any rivets are put in. Outside edges of holes to be slightly countersunk, and all burs carefully filed off. Holes in the angle iron must be marked off from the plates and drilled, not punched. Pitch of rivets and lap of plates to be made to detailed drawing. Edges of all the plates to be planed, turned, or shaped to an angle of 1 in 8 before being put together, so as to have a full edge for caulking, which must be done with a broad-faced fuller,so as not to injure the plates.

**Testing.**—The boiler before being lagged is to be tested by the contractor in the presence of the company's locomotive superintendent or his deputy, to a pressure of 200 lbs. per square inch with water, and afterwards to 150 lbs. with steam, and it must be perfectly tight under these pressures. To receive a coat of boiled oil while hot. All fitting and studs must be fixed complete before the boilers are tested with water or steam pressure.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Centre of boiler from rails | 6 | 8 |
| Length of barrel between plates | 10 | 3 |
| Diameter of barrel outside at fire-box end | 4 | 4 |
| Thickness of plates | 0 | 0½ |
| Thickness of smoke-box tube plate | 0 | 0⅞ |
| Length of fire-box shell outside | 6 | 0 |
| Breadth outside at bottom | 4 | 1 |
| Depth from c. line at front | 4 | 11 |
| ,, ,, ,, back | 3 | 3 |
| Thickness of throat plate | 0 | 0⅝ |
| ,, sides, back, and roof | 0 | 0½ |
| Distance apart of copper stays | 0 | 4 |
| Diameter | 0 | 0⅞ |
| Number of threads per inch, 11 | | |

**Inside Fire-box.**—Copper fire-box and stays to be of the very best quality, and obtained from Messrs. Pascoe Grenfell and Co.; Vivian and Co.; Bibby, Son, and Co.; or other approved maker. To bear the test of being doubled cold without showing any signs of cracking. Three brass plugs, with fusible centres, to be inserted in crown of fire-box. The copper stays to be screwed tightly into the fire-box and shell plates, the thread being turned off the portion of the stay between the plates. Great care to be taken in cutting off the ends not to injure the threads. Heads of the stays to be larger on inside of box. Crown and sides of fire-box to be in one plate, and the tube plate to be widened out, forming a pocket on side plates, to allow a wide spacing of tubes. To be riveted together with $\frac{13}{16}$ in. best Yorkshire iron rivets—see drawings. The roof to be stayed with eight girder stays of "best Yorkshire iron," as shown on drawing. Fire bars of cast iron, as shown on drawing.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Length of copper fire-box outside (top) | 5 | 2⅜ |
| Breadth ,, ,, ,, ,, | 3 | 9 |
| ,, ,, ,, ,, (bottom) | 3 | 7 |
| Depth at front end | 5 | 7¾ |
| ,, back ,, | 3 | 11¾ |
| Thickness of sides and top | 0 | 0½ |
| ,, back | 0 | 0⅝ |
| ,, tube plate | 0 | 1 |
| ,, below tubes tapering down to | 0 | 0⅝ |

**Tubes.**—To be lap-welded iron tubes, with 6 inches of solid copper brazed on to the fire-box end, the part passing through the copper tube plate being rolled down to a smaller diameter; manufactured and brazed by the Imperial Tube Company, Smethwick, near Birmingham. To be expanded by a Dudgeon's Tube Expander, beaded over, as shown on drawings, by a Selkirk's or Brisse's tube beader, and fixed with ferrules at fire-box end only. At smoke-box end to stand through plate $\frac{1}{2}$ inch, and be rolled out by a Dudgeon's tube expander.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Number of tubes—194 spaced in vertical rows. | | |
| Length ,, | 10 | $10\frac{1}{2}$ |
| Diameter outside | 0 | $1\frac{3}{4}$ |
| ,, at fire-box end for a length of $1\frac{1}{2}$ inch only | 0 | $1\frac{5}{8}$ |
| Thickness . . . 13 B. W. G. | | |

**Ferrules.**—Ferrules to be made from weldless steel tubing to be obtained from the "Weldless Steel Tube Co.," Birmingham.

**Fire Door and Deflector.**—A casting to be fixed both inside and outside round fire-hole ring, the two to be firmly bolted together. A wrought iron plate to be hinged on the bottom to outside frame and a cast iron deflector hinged to top of inside casting and worked from the outside by a lever, as shown on drawings.

**Brick Arch.**—Fire-box to be fitted with a brick arch, supported by two iron bars $2\frac{1}{2}$ inches by 1 inch thick, to be fastened with studs on side of fire-box.

**Smoke-box.**—The smoke-box front to be made in one plate; all the plates to be specially clean and smooth and well ground over. All rivets countersunk and filed off flush. To be fitted with a spark arrester. The door to be circular and to fit into a recess, bedding on edge of an angle iron ring $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{1}{2}$ inch thick. The cross-bar to be made to lift out. Double handle and gripping screw to be provided, as shown. The tube plate to be flanged forward to smoke-box, and the front plate to extend onwards across ends of leading sand boxes.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Radius of smoke-box outside | 2 | $5\frac{3}{4}$ |
| Thickness of plates | 0 | $0\frac{5}{8}$ |
| ,, door | 0 | $0\frac{3}{8}$ |
| ,, liner plate | 0 | $0\frac{1}{4}$ |
| Size of angle iron | 0 | $2\frac{1}{2}$ |
| Diameter of rivets | 0 | $0\frac{5}{8}$ |
| Pitch of rivets | 0 | 3 |

**Chimney.**—The chimney to be of best Staffordshire iron, $\frac{5}{16}$ inch thick, butt jointed with rivets countersunk on outside. To have a cast iron top neatly finished. Height from rail to top of chimney to be 13 feet.

**Ash-pan.**—Fitted with one movable door worked from the foot-plate, and arranged to contain water supplied by a tap on injector suction pipe worked from foot-plate. Sides and door of ash-pan to be made of $\frac{1}{4}$ inch plate, and bottom of $\frac{3}{8}$ inch plate.

**Safety Valves.**—Two 3-inch Ramsbottom's, placed on seating on centre of fire-box shell. Adjusted to blow off at 140 lbs. per square inch.

**Regulator.**—To be of cast iron; the upper portion being removable and attached to the lower by a flange joint. The main valve to be of brass, and to have an easing slide of brass working on the back, making it equilibrium. The internal steam pipe to be of copper, and the end in regulator to have a copper cone.

**Steam Pipe.**—The smoke-box steam pipe to be also of copper, and the connection at the top of the T-pipe, and at the bottom to the cylinders, to be also made of coned copper; ends brazed on and held in place with wrought iron loose gland flanges and two bolts with brass close-ended nuts as shown.

DIMENSIONS.

| | in. |
|---|---|
| Diameter inside of internal steam pipe . . . . . | $4\frac{1}{4}$ |
| ,, ,, smoke-box steam pipe . . . . . | 4 |
| Thickness of each . . . . . . . . . . | 7 W.G. |

Best brazed pipes.

**Exhaust Pipe.**—Of cast iron, with loose top bored to $4\frac{7}{8}$ inches diameter, and made with separate branch at base to each cylinder; fixed by four studs only, with brass cover-ended nuts.

**Cylinders.**—To be of the best close-grained, tough, cold-blast cast iron, as hard as can be worked, and perfectly free from honey-comb or other defects. They must be accurately bored and bell-mouthed as shown on drawings. All joints and surfaces to be planed or turned, and scraped to a true surface, so that perfectly steam-tight joints can be obtained. Centre line of ports to be raised $1\frac{1}{2}$ inch to give greater area for exhaust, as per drawings. Top of cylinder castings to be protected by fireclay and bricks, and bottom covered with $\frac{1}{8}$ inch plate.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Inside diameter of cylinders . . . . . . . | 1 | $5\frac{1}{2}$ |
| Stroke of piston . . . . . . . . . . | 2 | 2 |
| Steam port, 15 inches by $1\frac{1}{4}$ inch. | | |
| Exhaust port, 15 inches by 3 inches. | | |
| Centre to centre of cylinders . . . . . . . | 2 | 4 |
| ,, ,, valve spindles . . . . . . | 0 | $3\frac{3}{4}$ |

**Glands.**—The piston rod glands must be in halves, notched one into the other, and made removable while rod is in place. The leading end of valve spindle glands to be solid, and the two cast in one piece.

**Lubricators.**—One of Dewrance's patent piston lubricators to be fixed on smoke-box side, delivering into steam pipe, and two of Dewrance's patent window lubricators, viz., one connected to boss on centre of each cylinder, as per drawing.

**Pistons.**—To be of good, tough cast iron, made from cylinder metal, and to be sound and free from all defects. Fitted with two cast iron rings sprung into their places.

**Piston-rods and Crossheads.**—Solid with crosshead, and made of the very best mild crucible cast steel, well annealed, manufactured by Messrs. Vickers, or J. Spencer and Sons, of Newcastle-upon-Tyne. Ends steeply coned, and secured by brass nut and cotter, as shown on drawing. At the crosshead end the gudgeon must be of wrought iron, case hardened, and be forced into place by screw or hydraulic pressure.

DIMENSIONS.

| | in. |
|---|---|
| Width of pistons | 4 |
| Diameter of rod | $2\frac{3}{4}$ |
| „ gudgeon | 3 |
| „ gudgeon ends | $1\frac{5}{8}$ |

**Side-blocks.**—To be of good sound cast iron—chilled—perfectly free from all defects. Surface of slide blocks, 14 in. by $2\frac{3}{4}$ in.

**Slide-bars.**—Of the very best mild crucible cast steel, manufactured by Vickers and Co., or J. Spencer, of Newcastle-upon-Tyne. Section of slide bars $2\frac{3}{4}$ in. by 2 in.

**Slide-valves.**—Slide valves to be of best gun-metal, of form shown on drawings.

DIMENSIONS.

| | in. |
|---|---|
| Lap outside of valve | 1 |
| Lead in full gear | $\frac{3}{32}$ |

**Slide-valve Spindles.**—Slide-valve spindles to be made of best Yorkshire iron, as per drawings.

**Valve-motion and Reversing Gear.**—All motion work of "Best Yorkshire Iron," and all working surfaces to be well case-hardened, and finished in the best manner. Expansion links to be lifted from the top, the weigh shaft being placed below, and worked by a screw reversing gear, fixed on left-hand trailing splasher, and made to drawings. Reversing screw and nut to be of steel; all motion pins to be of "Best Yorkshire Iron," well case-hardened and accurately fitted.

**Valve-spindle Connecting Rods and Guides.**—The valve-spindle connecting rods to be circular on wearing surfaces, and the guides to be of gun-metal, lined with white metal.

**Excentrics.**—Excentric tumblers to be cast, the two halves in one. Excentric straps of "Best Iron" with white metal liners. Ends of excentric rods to be furnished with butt-ends for adjustment, as shown on drawings.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter of excentrics | 1 | 4 |
| Breadth of " | 0 | $2\frac{7}{8}$ |
| Throw of " | 0 | $6\frac{1}{4}$ |
| Radius of expansion links | 4 | 8 |
| Thickness of " | 0 | $2\frac{1}{4}$ |
| Centre to centre of pins of expansion links | 1 | 5 |
| Diameter of pins | 0 | $1\frac{1}{2}$ |
| Diameter of reversing shaft at centre | 0 | $3\frac{1}{2}$ |
| " " " bearings | 0 | 3 |
| Diameter of valve spindle connecting rod guide | 0 | $3\frac{1}{4}$ |
| Length of valve spindle connecting rod guide | 1 | 0 |

**Connecting-rods.**—To be of Best Yorkshire iron, forged without weld. Brasses of gun-metal lined with white metal at the large end, and brasses of gun-metal, adjusted by wedge and screw at the small end, as shown on drawings. Both ends to be supplied with buttons in oil cups.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Length of connecting rod, centre to centre | 6 | 2 |
| Diameter of large end bearing | 0 | $7\frac{1}{2}$ |
| Width " " | 0 | $3\frac{15}{16}$ |
| Diameter of small end bearing | 0 | 3 |
| Width " " | 0 | 3 bare. |
| Section of rod at large end | 0 | $4\frac{1}{2}$ by $1\frac{5}{8}$ |
| " " small end | 0 | $3\frac{1}{4}$ by $1\frac{5}{8}$ |
| Thickness of swelled part at large end | 0 | $2\frac{3}{4}$ |
| " " small end | 0 | 3 bare. |

**Coupling-rods and Crank-pins.**—Coupling rods of Best Yorkshire iron, forged without weld, and centre coupling case-hardened. Crank pins of best mild crucible cast steel, manufactured by Vickers and Sons, or John Spencer and Sons, Newcastle-upon-Tyne. Bushes of solid brass, lined with white metal, as shown on drawings, and forced into rods by hydraulic pressure. Oil cups to be supplied with buttons.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter of leading and trailing crank pins . | 0 | $3\frac{1}{2}$ |
| Width " " " | 0 | $4\frac{3}{8}$ |
| Diameter of driving crank pin . . . . | 0 | 4 |
| Width " " . . . . . | 0 | $4\frac{3}{8}$ |
| Diameter of pin in wheel boss . . . . | 0 | $4\frac{1}{2}$ (taper 1 in 100) |
| Length " " . . . . . | 0 | $6\frac{3}{4}$ (finished) |
| Diameter of joint pin . . . . . . | 0 | $2\frac{1}{2}$ |
| Centre of leading to centre of driving crank pin | 7 | 3 |
| " driving " trailing " | 7 | 9 |

**Axles.**—Straight axles for the first twelve engines to be of the best mild crucible cast steel, manufactured by Vickers and Sons only, and those for the remaining engines of the best Bessemer steel, manufactured by Cammell and Co.; Brown, Bayley, and Dixon; or the Bolton Iron and Steel Co.; all turned accurately to gauges. Two per cent. of the axles to be tested by the company's inspector before leaving the steel works.

STRAIGHT AXLES.

| | ft. | in. |
|---|---|---|
| Diameter in the middle . . . . . . . . | 0 | $6\frac{1}{2}$ |
| " of journals . . . . . . . . | 0 | $7\frac{1}{2}$ |
| Length " . . . . . . . . | 0 | 7 |
| Diameter of wheel-seat (to be made parallel) . . . | 0 | $8\frac{1}{2}$ |
| Length " . . . . . . . | 0 | $7\frac{1}{16}$ |
| Centre to centre of journals . . . . . . | 3 | $11\frac{1}{2}$ |

**Crank Axles.**—The crank axles for the first twelve engines to be of the best mild crucible cast steel, manufactured by Vickers and Sons only; those for the remaining engines of the best Bessemer steel, manufactured by Cammell and Co., or the Bolton Iron and Steel Company, and turned accurately to gauges; the right-hand crank to lead. The axles to be annealed after the sweeps have been slotted out, and to be tested in the presence of the company's inspector before leaving the steel works. For specification of tests apply to the locomotive superintendent.

DIMENSIONS.

CRANK AXLES.

| | ft. | in. |
|---|---|---|
| Diameter in the middle . . . . . . . | 0 | 7 |
| " of crank pin journal . . . . . | 0 | $7\frac{1}{2}$ |
| Width of " " . . . . . | 0 | 4 |
| Diameter of journal . . . . . . . | 0 | $7\frac{1}{2}$ |
| Length of " . . . . . . . | 0 | 7 |

| | ft. | in. |
|---|---|---|
| Diameter of wheel seat (to be made parallel) . . | 0 | $8\frac{1}{2}$ |
| Length of ,, . . . . . . . | 0 | $7\frac{1}{16}$ |
| Centre to centre of cranks . . . . . . | 2 | 4 |
| ,, ,, journals . . . . . | 3 | $11\frac{1}{2}$ |
| Throw of cranks . . . . . . . . | 1 | 1 |
| Section of inside crank arm . . . . . | 0 | 11 × $4\frac{1}{2}$ in. |
| ,, outside ,, . . . . . . | 0 | 11 × $4\frac{1}{4}$ in. |

**Axle-boxes.**—Made of gun-metal, with bearing surfaces of white metal, and fitted with lubricating pad and trough, as shown by drawing.

**Hornblocks.**—Of crucible cast steel, horseshoe form, manufactured by Vickers and Sons, Cammell and Co., or J. Spencer and Sons, of Newcastle-upon-Tyne.

**Wheels.**—The best description of wrought iron solid bossed wheels, with balance weights forged in, as shown in drawings. Heads of spokes to be forged solid. To be pressed on the axles with hydraulic pressure of about 85 tons.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter outside rim of wheel . . . . . | 4 | 0 |
| Width of rim . . . . . . . . . | 0 | $4\frac{1}{2}$ |
| Thickness of rim . . . . . . . | 0 | $1\frac{3}{4}$ |
| Diameter of wheel boss . . . . . . | 1 | $3\frac{1}{2}$ |
| ,, wheel seat (to be made parallel) . . | 0 | $8\frac{1}{2}$ |
| Length of ,, . . . . . . . | 0 | 7 |
| Throw of crank pins . . . . . . | 0 | 10 |
| Diameter of hole for crank pins . . . . . | 0 | $4\frac{1}{2}$(taper 1 in 100) |
| Number of spokes, 13. | | |
| Section of ,, at large end . . . . | 0 | $3\frac{7}{8}$ by $1\frac{1}{2}$ |
| ,, ,, at small end . . . . . | 0 | $3\frac{3}{8}$ by $1\frac{1}{4}$ |

**Tires.**—The tires for the first twelve engines to be of the best crucible cast steel, manufactured by Vickers and Sons only; the remainder to be of the best Bessemer steel, manufactured by Cammell and Co., or Brown, Bayley, and Dixon, and to be stamped with the name of the maker. Two per cent. of the tires to be tested, before leaving the steel works, by the company's inspector. For specification of tests apply to the locomotive superintendent. Tires to be of the section shown on drawings, and fixed to wheels by tire fastening, as shown.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter of tire on tread (when finished) . . . . | 4 | 6 |
| Thickness of ,, ,, ,, . . . . . . | 0 | 3 |
| Width . . . . . . . . . . . . | 0 | $5\frac{1}{2}$ |
| Distance between tires . . . . . . . . | 4 | $5\frac{5}{8}$ |

**Frames.**—To be of good tough fibrous Yorkshire iron, frame plate quality, and to be obtained from Messrs. Cammell and Co., or Sir John Brown and Co., to be planed over entire surface on inside and outside, and finished 1 inch full thick. All frames marked and drilled from one template. All cross-stays and attachments to be planed where they abut on frames. When the frames and cylinders, &c., are bolted together, the accuracy of all work must be tested by diagonal, transverse, and longitudinal measurements.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Between frames | 4 | 2 |
| Total length of frame | 24 | 10 |
| Depth above leading horns | 1 | 4 |
| " driving " | 1 | 5 |
| " trailing " | 1 | $4\frac{1}{8}$ |
| Buffer beam to leading axle | 5 | 7 |
| Leading axle to driving " | 7 | 3 |
| Driving " to trailing " | 7 | 9 |
| Total wheel base | 15 | 0 |

**Motion-plate.**—To be of wrought iron 1 inch in thickness, with angle iron stiffeners as shown on drawings.

**Outside Frames and Buffer-beams.**—A long angle iron frame, $4\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{1}{2}$ inch, to extend on each side of the engine full length of platform, on front curved downwards full depth of buffer beam, and at back welded to plate forming footsteps, as shown on drawings; buffer beams of wrought iron plate, at the leading end stiffened by a heavy angle iron girder in the centre, and plate gussets behind buffers.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Width over angle frames | 7 | 4 |
| " foot plate | 7 | 6 |
| Thickness of " | 0 | $0\frac{3}{8}$ |
| " leading buffer beam | 0 | $1\frac{1}{4}$ |
| " trailing " | 0 | $0\frac{5}{8}$ |

**Buffers.**—To be Turton's patent wrought iron buffer, B3 pattern, manufactured by Messrs. Ibbotson Brothers and Co., as per drawing.

**Springs.**—To be made of the best Swedish spring steel, and to be manufactured by Messrs. John Spencer and Sons, of Newcastle-upon-Tyne. Each spring must be thoroughly tested before being put into its place by being weighted until the camber has been taken off, and on the removal of the weight the spring must resume its original form.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Length of leading springs (loaded) . . . . . | 3 | 1 |
| Camber ,, ,, ,, . . . . . . . | 0 | 3 |
| Breadth ,, ,, ,, . . . . . . . | 0 | $4\frac{1}{2}$ |
| Thickness—twelve plates, $\frac{1}{2}$ inch full thick. | | |
| Length of driving and trailing springs (loaded) . . . . | 3 | 6 |
| Camber ,, ,, ,, . . . . . . | 0 | 3 |
| Breadth ,, ,, ,, . . . . . . | 0 | $4\frac{1}{2}$ |
| Thickness—twelve plates, $\frac{1}{2}$ inch full thick. | | |

**Drawhook.**—Drawhook to be provided with screw shackle, and to be mounted with a Timmis's spring, as shown on drawing.

**Injectors.**—To be two in number, of brass, Sheward and Gresham's patent, class G, No. 8 size, to be placed under foot-plate and delivering into brass clack-boxes on back plate of fire-box casing. The clack-boxes to be provided with screw cone stop-valve, so as to allow for removal of pipes when boiler is in steam—see drawings. The right-hand injector must be provided with an overflow valve, closed by gear from the foot-plate, to allow for warming through to tender. All pipes to be seamless copper.

**Brake.**—The engine to be fitted with a vacuum-brake, consisting of a 30 mm. ejector, Gresham and Craven's patent; one starting valve, fitted with sector and handle to regulate the admission of steam; one asbestos-packed cock, one vacuum gauge, one release valve, two 15 inch Hardy sacks; the whole of which, including all wrought iron piping, elbows, couplings, &c., for the above, are to be obtained by the contractor from the Vacuum Brake Company. All copper piping to be furnished by the contractor. The ejector to be fixed to the inside of cab, and connected by a copper pipe to the starting valve, which is mounted on the asbestos-packed cock, the latter being fixed on the fire-box top. The Hardy sacks to be connected with the ejector by means of a copper pipe. The release valve to be fixed at back of fire-box, and to be connected with the sacks by means of a wrought iron pipe, and with the vacuum gauge by a copper pipe. The Hardy sacks to be bolted to the underside of drag plate, and to be connected by links to the levers of brake shaft. The entire arrangement of brake and details, such as brake shaft, hangers, carriers, blocks, rods, and cross-bars, must be made as per drawings supplied.

**Platform or Drag-plate.**—The platform behind fire-box to consist of a heavy casting, forming drag-plate, and weighing three tons; to be firmly bolted to frames, and have projections for brake shaft carrier, intermediate safety chains, &c., &c.,—see drawings—to be covered with a timber platform $3\frac{1}{2}$ inches thick.

**Cab.**—To be made of $\frac{3}{16}$ inch plates, and stiffened on the edges with beading and angle iron, neatly polished. The front to be provided with two spectacle glasses, fixed in brass frames made to swivel on centre, as shown on drawings.

**Splashers and Sand-boxes.**—To be made of $\frac{1}{8}$ inch plate, the tops curved to form flange for attachment to foot-plate. The leading splasher to be continued forward to face of smoke-box; this portion to be made of cast iron, so as to form the front sand-boxes, which must be worked simultaneously from the foot-plate. Two sand-boxes also to form part of trailing splashers, and to be connected so as to be worked together from the foot-plate.

**Safety-valve Casing.**—To be of wrought iron, painted; thickness, 14 B.W.G.

**Dome Casing.**—Made of iron plates, 14 B.W.G., and brazed up solid.

**Hand-rail.**—Of iron piping, $1\frac{1}{2}$ inch diameter outside, polished, and carried round front of smoke-box, as shown on drawings.

**Lamp-holders.**—To be fixed on smoke-box front, as shown on drawings.

**Mountings.**—Each boiler to be provided with two whistles, two injector steam cocks, one Schaffer and Budenberg's patent steel tube pressure gauge, one scum cock with copper pipe leading under foot-plate, one set of glass gauge cocks, asbestos packed, Dewrance's patent, and two gauge cocks, one blower cock on face of fire-box with copper pipe through boiler—all made on the screw cone principle, as shown on drawings.

**Lagging.**—The boiler and fire-box shell to be lagged with well seasoned pine, tongued and grooved, and neatly covered with sheet iron, 14 W.G., and secured with hoops. Dome to be covered with "silicate cotton," instead of being lagged with wood. There must be two discharge cocks to each cylinder, and one on steam chest, all to be simultaneously worked from foot-plate.

**Bolts, Nuts, and Threads.**—All bolts, nuts, and threads to be made to Whitworth standard. All brass work up to and including $\frac{7}{8}$ inch diameter to be screwed 14 threads per inch. All brass work above $\frac{7}{8}$ inch diameter to be screwed 12 threads per inch. Copper stays to be screwed 11 threads per inch.

**Tools.**—Each engine must be supplied with a complete set of screw-keys and gland-keys, all case-hardened, and stamped with the company's initials and the number of the engine; also one large and one small monkey-wrench, one heavy and small hammer, one lead and one copper hammer, one large and one small pin punch, two drifts, three chisels, one steel-pointed crowbar, one small steel pinch bar, one gland packing bar, one 10-ton bottle-jack—to drawing—two head lamps to pattern, one hand lamp and one gauge lamp, one oil can, one large and one small oil feeder, and one tallow kettle; also one shovel, one coal-pick, one hand-brush, and a complete set of fire-irons; one tube scraper, and one wire tube brush.

**Painting.**—The boiler to receive two coats of oxalic paint before being lagged with wood; after lagging, the boiler, frames, wheels, splashers, handrail plates, and weather screen, to have one coat of lead colour, two coats of stopping, three coats of filling up properly rubbed down, two coats of lead colour sand-papered, two coats of green—to sample—picked out with black, and fine-lined with white. Rim of tire to be black with white line. The whole to be finished with three coats of varnish. Inside of frames and axles to be finished with one coat of vermilion and one of varnish; outside of frames, rail-guards, &c., to be finished brown, picked out with black, and fine-lined with white. Front buffer beam and buffers to be finished vermilion and varnished. Number of the engine to be placed in gold leaf on engine front and tender hind buffer planks, and a brass number plate to be fixed in centre of handrail plate—see pattern. Smoke-box, chimney, back of fire-box, platforms, steps, &c., to be painted black; two coats inside of cab to be prepared similar to boiler and frame, and finished in brown and lined.

**Tank.**—Of horseshoe form; the sides each made of one plate, and all vertical rows of rivets countersunk. The tank plates to be made of BB Staffordshire or Yorkshire iron. The bottom plate of tank to form foot-plate of tender, and the sides and back of tank to be well stayed to the bottom plate with T-irons, angle irons, and stay plates, as per drawing. The sides and back of tank to be finished with a wrought iron half-round moulding piece, as per drawing.

### Dimensions.

| | ft. | in. |
|---|---|---|
| Length of tank sides | 18 | 4 |
| Width | 6 | 9 |
| Height above frame | 4 | $2\frac{1}{16}$ |
| Thickness of tank sides and end | 0 | $0\frac{1}{4}$ |
| ,, ,, top | 0 | $0\frac{3}{8}$ and $\frac{1}{4}$ inch. |
| ,, ,, bottom | 0 | $0\frac{5}{16}$ |

**Cab.**—The tender is to be fitted at the front end with Sharp's, of Sheffield, patent arrangement of cab, tool-box, and filling-hole combined, as shown on drawings. The feed pipes to be protected by a perforated copper sieve. Feed cocks to be of brass, asbestos packed, Dewrance's patent, as per drawings.

**Axles.**—To be of the best Bessemer steel, manufactured by Cammell and Company; Brown, Bayley, and Dixon; or the Bolton Iron and Steel Company; to be all turned accurately to gauges. Two per cent. of the axles to be tested by the company's inspector before leaving the steel works.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter in the middle . . . . . . . . | 0 | $5\frac{1}{4}$ |
| „ of wheel seat (to be made parallel) . . . | 0 | $6\frac{1}{4}$ |
| Length of „ . . . . . . . . | 0 | 8 |
| Diameter of journal . . . . . . . . | 0 | $4\frac{1}{2}$ |
| Length „ . . . . . . . . | 0 | 9 |
| Centre to centre of journals . . . . . . | 6 | 3 |

**Axle-boxes.**—Made of hard cast iron, with gun-metal bearings, to be fitted with lubricating trough and pad, as per drawings.

**Hornblocks.**—To be made of hard cast iron, planed and fitted, and riveted to frame, as shown on drawings.

**Wheels.**—Wrought iron of the best description; to be made in the same manner as those of engine.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter outside rim of wheel . . . . . . | 3 | $1\frac{3}{4}$ |
| Width of rim . . . . . . . . . . | 0 | $4\frac{1}{2}$ |
| Thickness of rim . . . . . . . . . | 0 | $1\frac{1}{2}$ |
| Diameter of wheel boss . . . . . . . | 1 | $0\frac{3}{4}$ |
| „ wheel seat (to be made parallel) . . . | 0 | $6\frac{1}{4}$ |
| Length „ . . . . . . . . | 0 | 7 |

Number of spokes—10.

Section of spokes at large end—$3\frac{7}{8}$ inches by $1\frac{5}{8}$ inch.

„ „ small end—$3\frac{3}{8}$ inches by $1\frac{1}{8}$ inch.

**Tires.**—To be made of the best mild Bessemer steel of special quality, manufactured by Cammell and Co., or Brown, Bayley, and Dixon, and to be stamped with the name of the maker. Two per cent. of the tires to be tested, in the presence of the company's inspector, by percussion, and to be deflected 2 inches to each foot of external diameter, and to bear a strain of 35 tons per square inch. To be fixed to wheels by tire fastening, as shown on drawings.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter of tires on tread (when finished) . . . | 3 | $7\frac{3}{4}$ |
| Thickness of „ „ „ . . . . . | 0 | 3 |
| Width . . . . . . . . . . . | 0 | $5\frac{1}{2}$ |
| Between tires . . . . . . . . . | 4 | $5\frac{5}{8}$ |

**Frames.**—To be of good tough fibrous Yorkshire iron, of frame-plate quality, and to be obtained from Messrs. Cammell and Co., or Sir John Brown and Co. Each frame to be made of one plate, and all holes marked and drilled from one template. Drawbar arrangement, safety chains, rolling pieces between engine and tender, intermediate buffers and ball-joint connection to be fixed as per drawings. Drawhook to be provided with a screw-shackle the same as for the engine, and to be mounted with a Timmis's spring.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Distance between outside frames . . . . . . | 5 | $8\frac{3}{4}$ |
| Length of „ „ . . . . . . . | 19 | 10 |
| Thickness of „ „ . . . . . . | 0 | $0\frac{7}{8}$ |
| Distance between inside frames . . . . . | 3 | 4 |
| Length of „ „ . . . . . . | 17 | $9\frac{7}{8}$ |
| Thickness of „ „ . . . . . . . | 0 | $0\frac{1}{2}$ |
| Distance from leading axle to front end of frame . . | 4 | 3 |
| „ „ „ „ to centre axle . . . . | 6 | 3 |
| „ „ centre axle to trailing „ . . . | 6 | 3 |
| „ „ trailing axle to hind end of frame . . | 3 | 1 |

**Buffer-beams.**—To be of wrought-iron, frame-plate quality, as per drawing.

**Buffers.**—To be Turton's patent wrought iron buffer, B 3 pattern, manufactured by Messrs. Ibbotson Brothers and Co., as per drawing.

**Springs.**—Of the best Swedish spring steel, and to be manufactured by Messrs. John Spencer and Sons, of Newcastle-upon-Tyne. Each spring to be tested in the same manner as described for the engine springs.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Length of leading and trailing springs (loaded) . . | 2 | 9 |
| Camber „ „ „ „ . . . | 0 | 3 |
| Breadth „ „ „ „ . . | 0 | $3\frac{1}{2}$ |
| Thickness—top plate $\frac{7}{16}$ inch, 14 plates $\frac{3}{8}$ inch. | | |
| Length of centre springs (loaded) . . . . . . | 3 | 3 |
| Camber „ „ „ . . . . . . . | 0 | 3 |
| Breadth „ „ „ . . . . . . . | 0 | $3\frac{1}{2}$ |
| Thickness—top plate, $\frac{7}{16}$ inch, 16 plates $\frac{3}{8}$ inch. | | |

**Brake.**—Tender to be fitted with a vacuum brake, consisting of two 15-inch Hardy sacks, which, together with wrought iron piping, elbows, and couplings, and flexible hose-pipe connection between engine and tender, are to be obtained by the contractor from the Vacuum Brake Company. A solid angle iron ring for carrying the sacks to be fixed to under side of tender at front end between longitudinal stretchers, as shown on drawings. Sacks to be connected by links to the levers of brake shaft, which is to be also provided with a lever for hand brake. The entire brake arrangement and details, such as handle, brake, screw, brake shaft, hangers, blocks, carriers, rods, and cross-bars to be made in accordance with drawings supplied.

**Handrail.**—Handrail of iron piping $1\frac{1}{4}$ inch diameter outside, polished and fastened by two brackets to end of tank. Two handrail pillars to be placed on each side of foot-plate and fixed to tank, as shown on drawings.

**Lamp-holders.**—Two to be fixed on back of tender, as shown on drawings.

**Bolts, Nuts, and Threads.**—To be of Whitworth standard.

**Painting.**—The inside of the tender tank to have two coats of good thick red lead; the outside of the tank, cab, and tool-box to be prepared and finished in the same manner as the engine boiler covering. The inside of the cab to be treated exactly the same as the inside of the engine cab. Inside of frames to have two coats of lead colour. Outside of frames and wheels to be prepared and finished identically the same as those of the engine. Hind buffer beams and buffers to be finished vermilion and varnished. Coke space, foot-plate, bottom of tank, and brake-work under tender to have two coats of black.

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## SPECIFICATION FOR FOUR-COUPLED EXPRESS LOCOMOTIVE, GREAT EASTERN RAILWAY.

*Express Locomotive Engine, designed by* MR. T. W. WORSDELL, *Locomotive Superintendent, Great Eastern Railway Works, Stratford.*

### CYLINDERS.

| | ft. | in. |
|---|---|---|
| Diameter of cylinder | 1 | 6 |
| Stroke | 2 | 0 |
| Length of ports | 0 | $11\frac{3}{4}$ |
| Width of steam ports | 0 | $1\frac{3}{4}$ |
| Width of exhaust ports | 0 | $4\frac{1}{8}$ |
| Distance apart of cylinders, centre to centre | 2 | 0 |
| Distance of centre line of cylinders to valve face | 1 | 1 |
| Distance of centres of valve spindles | 2 | 0 |
| Lap of slide valve | 0 | $1\frac{1}{8}$ |
| Maximum travel of valve | 0 | 5 |
| Lead of slide valve | 0 | $0\frac{3}{16}$ |
| Motion, Joy's patent, to drawing. | | |
| Diameter of piston-rod | 0 | 3 |
| Length of slide blocks | 1 | 3 |
| Length of connecting-rod between centres | 6 | 10 |
| Length of radius rod | 3 | $9\frac{1}{4}$ |

### Wheels and Axles.

| | ft. | in. |
|---|---|---|
| Diameter of driving-wheel | 7 | 0 |
| Diameter of trailing-wheel | 7 | 0 |
| Diameter of leading-wheel | 4 | 0 |
| Distance from centre of leading to driving | 8 | 9 |
| Distance from centre of driving to trailing | 8 | 9 |
| Distance from driving to front of fire-box | 2 | 0 |
| Distance from leading to front buffer-plate | 4 | 6 |
| Distance from trailing to back buffer-plate | 4 | 3 |

### Crank Axles.

| | ft. | in. |
|---|---|---|
| Diameter at wheel seat | 0 | 9 |
| Diameter at bearings | 0 | 7½ |
| Diameter at the centre | 0 | 7 |
| Distance between centres of bearings | 3 | 10 |
| Length of wheel seat | 0 | 8 |
| Length of bearing | 0 | 9 |

### Trailing Axle.

| | ft. | in. |
|---|---|---|
| Diameter at wheel seat | 0 | 9 |
| Diameter at bearings | 0 | 7½ |
| Diameter at centre | 0 | 7 |
| Length of wheel seat | 0 | 8 |
| Length of bearings | 0 | 9 |
| Diameter of outside coupling pins | 0 | 4¼ |
| Length of outside coupling pins | 0 | 4 |
| Throw of outside coupling pins | 1 | 0 |

### Leading Axle.

| | ft. | in. |
|---|---|---|
| Diameter at wheel seat | 0 | 8½ |
| Diameter at bearing | 0 | 7 |
| Diameter at centre | 0 | 6½ |
| Length at wheel seat | 0 | 6¾ |
| Length at bearing | 0 | 11 |
| Centre to centre of bearings | 3 | 8 |
| Thickness of all tires on tread | 0 | 3 |
| Width of all tires on tread | 0 | 5⅜ |

### Frames.

| | ft. | in. |
|---|---|---|
| Distance apart of main frames | 4 | 0 |
| Thickness of frame (steel) | 0 | 1 |
| | | 8 |

### Boiler.

| | ft. | in. |
|---|---|---|
| Centre of boiler from rails | 7 | 6 |
| Length of barrel | 11 | $5\frac{1}{4}$ |
| Diameter of boiler outside | 4 | 2 |
| Thickness of plates (steel) | 0 | $0\frac{7}{16}$ |
| Thickness of smoke-box tube plate | 0 | $0\frac{3}{4}$ |
| Lap of plates | 0 | $2\frac{1}{2}$ |
| Pitch of rivets | 0 | $1\frac{13}{16}$ |
| Diameter of rivets | 0 | $0\frac{13}{16}$ |

### Fire-box shell (steel).

| | ft. | in. |
|---|---|---|
| Length outside | 6 | 0 |
| Breadth outside at bottom | 3 | 11 |
| Depth below centre line of boiler | 5 | 6 |
| Thickness of front plates | 0 | $0\frac{1}{2}$ |
| Thickness of back plates | 0 | $0\frac{1}{2}$ |
| Thickness of side plates | 0 | $0\frac{1}{2}$ |
| Distance of copper stays apart | 0 | 4 |
| Diameter of copper stays | 0 | 1 |

### Inside Fire-box (Copper).

| | ft. | in. |
|---|---|---|
| Length at the bottom inside | 5 | 4 |
| Breadth at the bottom inside | 3 | 3 |
| Top of box to inside of shell | 1 | 4 |
| Depth of box inside | 6 | $2\frac{1}{2}$ |

### Tubes.

Number of tubes . . . . . . 201

| | ft. | in. |
|---|---|---|
| Length of tubes | 11 | $9\frac{1}{4}$ |
| Diameter outside | 0 | $1\frac{3}{4}$ |
| Thickness | No. 11 and No. 13 W. G. | |

| | ft. | in. |
|---|---|---|
| Diameter of exhaust nozzle | 0 | $4\frac{3}{4}$ |
| Height from top of top row of tubes | 0 | 2 |
| Height of chimney from rail | 12 | 11 |

### Heating Surface.

| | sq. ft. |
|---|---|
| Of tubes | 1082·5 |
| Of fire-box | 117·5 |
| Total | 1200·0 |
| Grate area | 17·3 |

WEIGHT OF ENGINE IN WORKING ORDER.

| | tns. | cwt. | qr. |
|---|---|---|---|
| Leading wheels | 12 | 19 | 1 |
| Driving wheels | 15 | 0 | 0 |
| Trailing wheels | 13 | 3 | 3 |
| Total | 41 | 3 | 0 |

WEIGHT OF ENGINE EMPTY.

| | tns. | cwt. | qr. |
|---|---|---|---|
| Leading wheels | 12 | 4 | 2 |
| Driving wheels | 12 | 15 | 1 |
| Trailing wheels | 13 | 1 | 1 |
| Total | 38 | 1 | 0 |

The tender holds 5 tons of coal and 3200 gallons of water.

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## SPECIFICATION FOR EXPRESS ENGINES, LONDON, CHATHAM, AND DOVER RAILWAY.

*These engines were designed by* MR. W. KIRTLEY, *Locomotive Superintendent of the line, for working heavy trains at express speed for Continental traffic.*

The engines described in the following specification are known as class M. The following are their leading dimensions:—Diameter of cylinders, $17\frac{1}{2}$ inches; stroke of cylinders, 26 inches; diameter of bogie wheels, 3 feet 6 inches; diameter of coupled wheels, 6 feet 6 inches; total wheel base of engine, 21 feet $0\frac{1}{2}$ inch; total wheel base of tender, 12 feet; heating surface of tubes, 962 square feet; fire-box, 107 square feet; total heating surface, 1069 square feet; grate surface, 16·3 square feet; capacity of tank, 2550 gallons.

**Quality of Materials.**—Where "brass" is specified it must be good tough metal. Gun-metal must be composed of five parts of copper to one part of tin. White metal.—This must be composed of—Tin, sixteen parts; antimony, two parts; copper, one part and a-half. Other materials to be obtained of the manufacture to be hereinafter specified, unless the consent of the company's locomotive superintendent in writing be first obtained to an alteration.

**Boiler.**—Barrel, dome, fire-box casing, and smoke-box tube plate, and all angle irons, rivets, and stays to be made of Lowmoor, Bowling, Taylor's, or Cooper's (best Yorkshire) iron. Barrel to be made in three plates as shown, transverse joints to be made with a butt strip ring, and to be single riveted, the longitudinal seams to be butt jointed, and to have inside and outside strips, and to be double riveted; seam of middle plate to be welded, and to be strengthened by a liner plate riveted on inside under the dome flange. Tube plate to be attached to barrel by ring of angle iron, bored, faced, and turned on edges, and zig-zag riveted to both. The dome to be in one plate welded at the seam, and flanged at the bottom to fit barrel, to which it is to be double riveted; to have an angle iron ring in the top, and to be fitted with a strong wrought iron cover. The cover and angle iron must be accurately faced so as to make a perfectly steam-tight joint. The foundation ring to be of the form shown, so that the casing plates may be double riveted at the corners, and having lugs to carry the ash-pan and fire-bar brackets. The fire-hole to be circular, and both the fire-box and casing plates must be kept well clear of the inner edge of the ring. A girder stay is to be fixed to the smoke-box tube plate by an angle iron of the section shown, and also to be flanged and riveted to the barrel in the manner shown on drawings. Double gusset stays must be securely riveted to the back and top plates of the fire-box casing. All the plates are to be planed or turned on the edges before being put together. The holes must be drilled or punched slightly countersunk, and rhymed out perfectly fair with each other in all plates and angle irons; drifting will under no circumstances be allowed; care must be taken that the smaller diameters of the holes come together, that all burrs are carefully filed off, and that the plates are brought well together before any rivet is put in. All rivets must completely fill the holes, and the heads must be perfectly true and central. Any caulking that may be required must be done with a broad-faced tool, so that the plates may sustain no injury. Fifteen brass wash-out plugs, and four mud doors of wrought iron are to be placed in the positions shown on drawings; the latter are to be fitted in position before the fire-box is put in. Before being lagged the boiler is to be tested in the presence of the company's locomotive superintendent, or his inspector, to a pressure of 200 lb. per square inch with water, and afterwards to 160 lb. per square inch with steam, and it must be perfectly tight under these pressures.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Length of barrel | 10 | 2 |
| Diameter, outside | 4 | 3 |
| Thickness of plates | 0 | $0\frac{7}{16}$ |
| „ tube plate | 0 | $0\frac{7}{8}$ |
| „ dome plate | 0 | $0\frac{9}{16}$ |
| Diameter of rivets | 0 | $0\frac{13}{16}$ |

FIRE-BOX SHELL.

| | ft. | in. |
|---|---|---|
| Length, outside | 5 | 9 |
| Breadth at bottom, outside | 3 | 11 |

| | ft. | in. |
|---|---|---|
| Bottom of foundation ring below centre line of boiler | 5 | 2 |
| Thickness of side, top, and back-plates | 0 | $0\frac{1}{2}$ |
| „ throat-plate | 0 | $0\frac{5}{8}$ |
| Diameter of rivets | 0 | $0\frac{13}{16}$ |
| „ foundation ring rivets | 0 | $0\frac{7}{8}$ |
| Height of centre line of boiler from rail | 7 | 2 |

**Fire-box.**—The fire-box plates to be of copper of the very best quality, obtained from Messrs. Everitt and Sons, Grenfell and Sons, Vivian and Sons, or other approved makers. The stays and rivets to be made from the very best soft rolled copper bars, by the same makers as the plates. The plates to be annealed both before and after flanging, and to stand a test of being doubled cold without showing any sign of fracture. The sides and crown to be in three plates, the crown plate to be curved as shown and stayed to roof bars by bolts turned taper where they go into the plate; these bars are to be connected to angle irons on the casing plate by sling stays. Great care must be taken to bed the ends of the roof bars accurately on the fire-box plates, also that the sling stays are the correct length. The copper stays are to be tightly screwed into the fire-box and casing plates, and to be neatly riveted over at the ends, the thread being turned off the portion of stay between the plates. Six palm stays to be placed on the barrel of boiler in the positions shown, the outer ends of the copper screws in tube plate to be countersunk and neatly riveted over. A brass plug with fusible lead centre to be inserted in the crown of fire-box. A brick arch to be built in the fire-box, supported on studs in the manner shown on drawings.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Length at top, outside | 5 | $0\frac{1}{2}$ |
| „ bottom „ | 5 | $1\frac{7}{8}$ |
| Breadth | 3 | 4 |
| Depth, inside | 6 | 0 |
| Water space at bottom, all round | 0 | 3 |
| Thickness of plates | 0 | $0\frac{1}{2}$ |
| Thickness of tube plate | 0 and 0 | $0\frac{13}{16}$ and $0\frac{1}{2}$ |
| Diameter of fire-hole | 1 | $3\frac{1}{2}$ |
| Section „ ring—$3\frac{1}{2}$ inches by 3 inches. | | |
| Roof bars—No., 8. | | |
| Depth—Six to be 6 inches, two to be 5 inches. | | |
| Thickness—Two plates each | 0 | $0\frac{3}{4}$ |
| Diameter of roof bar bolts | 0 | $0\frac{7}{8}$ |
| „ copper rivets | 0 | $0\frac{13}{16}$ |
| „ copper stays | 0 | $0\frac{7}{8}$ |
| Distance of copper stays apart, about | 0 | 4 |
| Diameter of copper screws of palm stays | 0 | 1 |

**Tubes.**—To be of copper, solid drawn, of either Everitt's, Green's, Wilkes', Birmingham Battery Company's, Broughton Copper Company's or other approved make, 9 BWG at the fire-box end tapering to 12 BWG at the smoke-box end. To be secured by a roller tube expander—great care being taken that the tubes are not cracked—and fixed with ferrules at the fire-box end. Ferrules to be of ferrule steel, and to go into the tubes a tight driving fit. The tubes are to project through the smoke-box tube plate $\frac{7}{16}$ inch.

DIMENSIONS.

| | ft | in. |
|---|---|---|
| No. 200 | — | — |
| Length between tube plates | 10 | 6 |
| Diameter, outside | 0 | $1\frac{3}{4}$ |
| " " at smoke-box end for a length of 4 inches | 0 | $1\frac{7}{8}$ |
| Thickness at fire-box end—No. 9, BWG. | | |
| " smoke-box end—No. 12, BWG. | | |
| Distance apart of centres, about | 0 | $2\frac{1}{2}$ |

**Smoke-box and Spark-arrester.**—Plates for smoke-box and door to be of BB Staffordshire iron, having a perfectly smooth surface. The rivets are to be countersunk outside and filed smooth. Wrought iron liners are to be placed against the tube plate, and the sides and front of smoke-box. The door to be dished as shown on drawings, and fitted with baffle plates and suitable dart, handles, and hinges, the latter to be finished bright.

A cast iron grate for arresting sparks to be supported in the smoke-box in a horizontal position just below top of blast pipe. Care must be taken that this grate fits accurately round the steam and blast pipes.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Length of smoke-box, inside | 2 | $8\frac{1}{8}$ |
| Width on centre line of boiler, inside | 4 | 11 |
| Thickness of plates | 0 | $0\frac{3}{8}$ |
| Section of angle iron—$2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{1}{2}$ inch. | | |
| " ring round door hole—3 inches by $\frac{3}{4}$ inch. | | |
| Diameter of rivets | 0 | $0\frac{5}{8}$ |
| Pitch of rivets, about | 0 | 3 |

**Chimney.**—To be of BB Staffordshire iron; joint to be made with a butt strip, and the rivets to be countersunk, and filed smooth on the outside. The bottom to be quite free from hammer marks, and to be carefully fitted to smoke-box. The top, of cast iron, to be made to drawing.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Height of top of chimney from rail | 13 | $3\frac{7}{8}$ |
| Diameter inside at top | 1 | 6 |
| " " bottom | 1 | $4\frac{1}{2}$ |
| Thickness of plates | 0 | $0\frac{1}{4}$ |

**Ash-pan.**—To be made to hold water, and fixed to lugs on the foundation ring as shown on drawings; to be fitted with a damper, front and back, each to be worked separately from the foot-plate; the damper rods to be on the right-hand side of foot-plate.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Thickness of plates of ash-pan . . . . . . | 0 | $0\frac{5}{16}$ |
| Depth of ash-pan . . . . . . . . . | 1 | 2 |
| Width " . . . . . . . | 3 | 4 |

**Safety-valves.**—To be of the kind known as "Ramsbottom's duplex" safety valves, to be fixed on the fire-box casing. The columns to be of brass turned bright, fixed on a cast iron manhole cover. The springs (of approved manufacture) and gear to be made accurately to drawing, and set so as to blow off at 150 lb. per square inch. The seating to be of wrought iron, carefully fitted to the fire-box casing. All the joints must be accurately faced, so as to be perfectly steam-tight.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter of valves . . . . . . . . | 0 | $3\frac{1}{2}$ |
| Distance apart of columns . . . . . . | 0 | $10\frac{5}{16}$ |
| Height of brass columns . . . . . . | 1 | $0\frac{1}{2}$ |
| Diameter of spring steel . . . . . . | 0 | $0\frac{13}{16}$ |
| " manhole cover . . . . . . | 1 | 6 |
| Thickness of seat . . . . . . . . | 0 | $1\frac{1}{8}$ |

**Regulator and Steam-pipes.**—Regulator to be of cast iron, the head to be fitted with double valves. The steam pipes to be of copper sheets hard soldered together on the inside. Flanges and cone to be brass. Steam pipe in boiler to be fixed to tube plate by a turned ferrule of best steel and to regulator by means of three claw bolts. Elbow pipe in smoke-box to be of cast iron.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter of steam pipes, inside . . . . . . | 0 | $4\frac{1}{2}$ |
| Thickness—No. 7, BWG. | | |

**Blast-pipe.**—The blast pipe to be of cast iron fitted with an adjustable nozzle to be worked by suitable gear from the right-hand side of foot-plate.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Smallest diameter of nozzle . . . . . . . | 0 | $4\frac{3}{4}$ |
| Height of nozzle above top row of tubes . . . . | 0 | 2 |

**Frames, Inside.**—Inside frames and front buffer plate to be of Yorkshire iron, frame plate quality, made by Taylor Brothers, Cammell and Co., Brown and Co., Parkgate Iron Co., or other approved makers. Each frame plate must be in one length—without weld—and it must have the brand of the manufacturer legibly stamped on its outer side. The plates are to be planed all over on the inner side, and the outer side must be finished with a good smooth surface. All holes to be marked from one template, and drilled and rhymed out to the exact size given. The frames to be set in and thoroughly well stayed together by the buffer plate, and with plates and angle irons at the leading end in the manner shown on drawings, the front foot-plate to be thinned at the edges as shown. A plate is to be placed horizontally under the cylinders to carry the bogie pin, and must be firmly bolted to angle irons on the frames. A transverse stay arranged to carry the back ends of motion bars and the intermediate spindle guides, and a vertical stay in front of the fire-box casing must be placed in the positions shown. Over the trailing axle a horizontal flanged stay is to be securely bolted to the frames, and at the hind end of frames a cast iron foot-plate arranged for the tender couplings, is to be placed. All these stay plates and angle irons to be of BB Staffordshire iron. The casting and the transverse stays must be securely fastened to the frames by turned bolts. The rubbing pieces for tender buffers to be well case-hardened. When finished the frames must be perfectly true and square in all directions. The foot-plate to be of BB Staffordshire iron, and the rivets to be countersunk on the top. Guard bars of the form shown are to be securely bolted to the frames and buffer plates.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Thickness of frames, finished | 0 | $1\frac{1}{16}$ |
| Depth over leading bogie wheels | 1 | 2 |
| „ between cylinders and driving horns | 1 | 6 |
| „ between driving and trailing wheels, open | 1 | 11 |
| Greatest depth of plates | 2 | $11\frac{3}{4}$ |
| Distance from centre of bogie to front end of frame | 5 | 0 |
| „ „ „ to centre of driving axle | 9 | 10 |
| „ „ driving axle to centre of trailing axle | 8 | 4 |
| „ „ trailing axle to hind end of frame | 4 | 0 |
| Extreme length of plates | 27 | 2 |
| Distance from centre of driving axle to front of fire-box casing | 1 | $10\frac{1}{4}$ |
| Distance between frames at leading end | 3 | 9 |
| „ „ from cylinders to trailing end | 4 | 0 |
| Height of top of frame from rail | 4 | $1\frac{1}{2}$ |
| Depth of buffer-plate | 1 | 4 |
| Length „ | 7 | 6 |
| Thickness „ | 0 | $1\frac{1}{2}$ |
| Thickness of foot-plate | 0 | $0\frac{5}{16}$ |
| Extreme width of foot-plate | 7 | 10 |

**Outside.**—To be of BB Staffordshire angle iron—the step plates to be riveted on—and to be stayed to the inside frames as shown on drawings. All the rivets to be countersunk outside. Section of angle iron for frames 6 inches by 2½ inches by ½ inch.

**Buffers and Drawgear.**—Buffers to have wrought iron cases and plungers, with india-rubber springs, No. 2, of George Spencer and Co.'s make, and to be in all respects similar to drawings supplied. Draw-bar to be of best chain cable iron, to be arranged to radiate, and to be fitted with shackle and coupling chain and screw coupling, and to have an india-rubber spring, No. 6, to drawing, of George Spencer & Co.'s make.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Height of centre line of buffers from rail | 3 | 5 |
| Distance of centres of buffers apart | 5 | 8 |
| Diameter of draw-bar | 0 | 2 |

**Cylinders.**—To be made of the best close-grained, hard, and strong cold-blast cast iron, twice cast, as hard as can be worked, and perfectly free from honeycomb or other defects. They must be bored out perfectly true, the ends being bell-mouthed. The cylinders are to be made with loose covers at each end, the back cover having provision for carrying the front ends of slide bars. All joints and faces to be machined and scraped to a true surface, so that a perfect joint can be obtained. The cylinders to be set as shown on drawings, and to be attached to the frames by flanges—the holes in which and in the frames are to be rose-bitted—and secured by turned bolts a driving fit. The front flanges and covers are to project through the frames as shown on drawings. To be provided with waste-water cocks and gear worked from the right-hand side of foot-plate. The top of cylinders to be covered with thin fire-brick or cement; the bottom flanges to be planed perfectly true, so that the bogie pin-plate may bear truly against them.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter | 1 | 5½ |
| Stroke | 2 | 2 |
| Distance of centres | 2 | 4 |
| " valve spindle centres | 0 | 3½ |
| Thickness of metal | 0 | 0⅞ |
| Length of ports | 1 | 2 |
| Width of steam ports | 0 | 1½ |
| " exhaust ports | 0 | 3½ |
| Thickness of bridges | 0 | 1 |
| Length of working face | 0 | 11 |
| Distance from centre of driving axle to centre of exhaust port | 9 | 9½ |

Incline of cylinders—1 in 25.

**Pistons.**—To be of tough cast iron, made from cylinder metal, and to be sound and free from all defects. To be accurately fitted to cones on ends of piston rods, and fixed with nuts as shown on drawings. Piston heads to be turned $\frac{1}{32}$ inch smaller than bore of cylinder. Packing rings to be of cast iron, turned only on the outside and on edges, and made $\frac{1}{2}$ inch larger in diameter than cylinder bore, and then cut and sprung into their places. When finished the whole must be an easy but accurate fit in the cylinder, so that the piston and rod can be moved backwards and forwards by hand.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Width of piston | 0 | $3\frac{1}{4}$ |
| „ rings, two in each piston | 0 | $0\frac{5}{8}$ |
| Thickness of rings | 0 | $0\frac{1}{2}$ |

**Piston-rod.**—To be of the best mild cast steel, manufactured by Taylor Brothers, Vickers, Sons, and Co., Cammell and Co., or other approved makers, with cone and nut for fixing to piston; the cone at crosshead to be enlarged, as shown on drawings.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter of rod | 0 | $2\frac{3}{4}$ |
| Length between cones | 2 | $10\frac{15}{16}$ |

Taper of cone in crosshead—1 in 16.
„ „ piston—1 in 6.
No. of threads per inch piston end—6.

**Crossheads and Gudgeon-pins.**—To be of best Yorkshire iron, and to be finished bright; the gudgeon pins to be keyed in the crossheads and well case-hardened.

**Slide-bars and Slide-blocks.**—Slide bars to be of cast steel from the same makers as piston rods, and to be provided with brass oil syphons to drawings. The slide blocks to be of cylinder metal, sound and free from all defects.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Width of slide bars | 0 | 3 |
| Thickness | 0 | $2\frac{1}{4}$ |
| Length | 4 | 1 |
| „ of slide block | 1 | 2 |
| Distance between slide bars vertically | 0 | $3\frac{3}{8}$ |
| „ „ „ horizontally | 0 | $6\frac{7}{8}$ |

**Connecting-rods.**—To be of best Yorkshire iron, forged solid in one length. The brasses to be of gun metal, those for the big ends to be lined with white metal. The cottars to be of steel, and the bolts of the best Lowmoor iron forged from the solid, the heads must on no account be welded on.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Distance of centres | 5 | 10 |
| Diameter of big end bearings | 0 | $7\frac{3}{4}$ |
| ,, small end bearings | 0 | 3 |

**Slide-valves and Valve-spindles.**—The valves to be of gun-metal, with $\frac{1}{2}$inch holes drilled in the face. The spindle frames and intermediate spindles to be of best Yorkshire iron, of the form shown on drawings, the latter to be well case-hardened.

The intermediate spindle guides to be of cast iron, bushed from either end with gun-metal bushes, and to have oil boxes cast on as shown.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Lap of valve | 0 | 1 |
| Lead, in full gear | 0 | $0\frac{3}{32}$ |
| Centre line of valve above centre line of cylinder | 0 | 1 |
| Diameter of valve spindle | 0 | $1\frac{3}{4}$ |
| ,, intermediate spindle | 0 | $3\frac{1}{2}$ |
| Length of ,, ,, guides | 1 | 0 |

**Valve-motion.**—The valve-motion to be made from the best scrap iron, and the working and rubbing surfaces to be thoroughly case-hardened, and provided with oil syphons and grooves, and finished in the best manner. Expansion link to be supported at the top from the forward excentric rod pin, the reversing shaft being below the motion and behind tbe link. The motion pins to be of best iron, thoroughly case-hardened and accurately fitted. Excentric sheaves to be in two pieces, the smaller piece being of best scrap iron, and the larger piece of cylinder metal. Excentric straps to be of wrought iron, solid with the rod, and to be fitted with white metal liners.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Length of expansion link between centres | 1 | $4\frac{1}{2}$ |
| ,, excentric rods | 4 | 3 |
| ,, lifting links | 1 | $10\frac{1}{2}$ |
| Diameter of motion pins | 0 | $1\frac{3}{4}$ |
| ,, excentric sheaves | 1 | $4\frac{1}{4}$ |
| Throw ,, ,, | 0 | $3\frac{1}{4}$ |

**Reversing-gear.**—Reversing to be performed by means of a screw arrangement, firmly supported on the right hand side of foot-plate.

**Coupling-rods.**—To be of Bessemer steel of approved make with solid ends and syphons, and to be fitted with phosphor-bronze bushes. Each rod to be forged solid in one length, and finished bright.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Distance of centres . . . . . . . | 8 | 4 |
| Section of rod—$4\frac{1}{2}$ by $1\frac{5}{8}$ in. | | |

**Coupling-rod Pins.**—To be of wrought iron case-hardened, accurately turned to gauge, and to be exact duplicates; to be turned to a taper of 1 in 50 and forced into the wheels by hydraulic pressure, the inner end to be afterwards riveted over; the outside end of pin to be fitted with a washer and taper pin as shown on drawings.

**Bogie.**—William Adams' Patent.—To have four wheels, and to be in all respects of the form and dimensions shown on drawings. The frames to be of Yorkshire iron by the same makers as the engine frames, the brand to be on the outer side, raised as shown over the axles, the inner sides to be planed all over, and the outer sides where any attachment is made. The carrying girders to be of best Yorkshire angle iron bent round and securely riveted to the frames, and machined on the outer sides, clearances being made where shown; steel bearing-plates planed and scraped to a good working surface are to be riveted to the angle irons. The ends of the frames are to be stayed by flanged plates of BB Staffordshire iron placed vertically, and bolted to the frames by the horn block bolts. When finished the frames must be perfectly true and square. The sliding block is to bear on the steel plates and work between the angle irons before mentioned, the side play being controlled by suitable india-rubber springs arranged as shown on drawings. The leading end of engine is to be supported on an india-rubber pad, through which and into a corresponding hole in the sliding block passes the bogie pin. A sheet brass dish is to be inserted between the india-rubber pad and the sliding block. The bogie pin to have a projection on it fitting into a corresponding hole in the horizontal plate under cylinders before mentioned, to which it is to be securely bolted, and to have a wrought iron safety pin with washer, nut, and cottar through it. The sliding block to be of tough cylinder metal perfectly free from honeycomb or other defect; the bogie pin to be of cast steel of approved manufacture, thoroughly annealed. These castings are to be machined on all working and bearing parts, and the sliding block is to be scraped to a good working surface on the sliding portions, and to have lubricators fixed and oil grooves cut where shown. The spring cradles are to be made of best Yorkshire iron, with cast iron saddle pieces at each end, shaped to bear on the axle-boxes, and cored out for oil syphons as shown. The main spring pins are to be of best Yorkshire iron forged from the solid, and securely riveted to the frames with turned cold rivets of Lowmoor iron. The india-rubber pad and the check springs to be of George Spencer and Co.'s make.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Bogie wheel base | 5 | 9 |
| Thickness of frames, finished | 0 | 1 |
| Depth at centre | 0 | 10 |
| ,, horns | 1 | 7½ |
| Length of frames | 7 | 6½ |
| Distance between frames | 2 | 7½ |
| Section of angle iron for carrying girders—7 inches by 7 inches by 1 inch. | | |
| Section of steel bearing-plates—7 inches by ¾ inch. | | |
| Length | 2 | 6½ |
| Thickness of end stays | 0 | 0½ |
| Depth ,, | 0 | 10 |
| Total side play of bogie | 0 | 2 |
| Diameter of india-rubber pad unloaded | 2 | 0 |
| Thickness ,, ,, ,, | 0 | 4½ |
| Diameter of hole in india-rubber pad | 0 | 8 |
| ,, cast steel bogie pin | 0 | 6 |
| ,, wrought iron safety pin | 0 | 2½ |
| Section of iron for spring cradles—5 inches by 1 inch. | | |
| Diameter of mainspring pins | 0 | 2½ |
| ,, india-rubber check springs unloaded | 0 | 5¼ |
| Length ,, ,, ,, ,, | 0 | 11¼ |

**Springs and Connections.**—The springs to be of the very best spring steel, manufactured by Messrs. Turton and Sons, or other approved makers. Before being put in position, each spring is to be fully tested until the camber is taken out, and the spring must afterwards resume its original form. The bogie springs are to be inverted, the buckles being connected direct to the pins before mentioned, on the bogie frames; the ends of springs are to be connected to the spring cradles by hooks. The driving and trailing springs are to be under-hung, and the buckles are to be connected to the axle-boxes by T-links. The ends of driving springs are to be connected to wrought iron liners on the frames by adjustable links; the ends of trailing springs are to be connected to wrought iron brackets firmly bolted to the frames by links of the form shown on drawings. All the brackets, links, hooks, buckles, and pins connected with the springs must be of best Yorkshire iron, and the working surfaces must be thoroughly case-hardened.

DIMENSIONS.

BOGIE.

| | ft. | in. |
|---|---|---|
| Length loaded | 4 | 0 |

| | ft. | in. |
|---|---|---|
| Camber | 0 | 3 |
| No. of plates—14. | | |
| Thickness of plates | 0 | 0½ |

DRIVING AND TRAILING.

| | ft. | in. |
|---|---|---|
| Length loaded | 3 | 4 |
| Camber ,, | 0 | 3 |
| Breadth of plates | 0 | 4½ |
| No. of plates—13. | | |
| Thickness of plates | 0 | 0½ |

**Axle-boxes.**—The axle-boxes to be of the very best gun-metal, lined with white metal, and fitted with cast iron keeps and spring lubricating pads, and suitable covers. Every axle-box must be made accurately to dimensions, so as to be interchangeable in any of the engines.

**Horn-blocks and Horn-stays.**—The horn-blocks to be of crucible cast-steel of Vickers', Cammell's, Taylor's, or other approved make; the bogie horn blocks to be fitted with cast iron distance blocks and securing bolts as shown. The driving and trailing horn blocks to be solid, and provided with adjustable wedges and securing bolts. The horn blocks must be accurately bedded to the frames, and secured by turned bolts a driving fit. The horn stays for the driving to be of wrought iron; those for the trailing to be the form shown on drawings, of cast steel, by the same makers as the blocks; care must be taken that these stays fit the horn blocks accurately.

**Axles.**—To be of crucible cast steel of Vickers, Sons, and Co.'s make; the webs of crank axle to be hooped; all corresponding parts to be of an exact size and made to template, so that they may be interchangeable, and each axle must be clearly stamped with the maker's name. The journals are on no account to be swaged down, but in all cases turned from the solid. The wheel seats must be accurately turned to a taper of 1 in 100.

DIMENSIONS.

BOGIE AXLES.

| | ft. | in. |
|---|---|---|
| Diameter in middle | 0 | 5¾ |
| ,, on wheel seats | 0 | 7½ |
| ,, of journals | 0 | 6 |
| Length ,, | 0 | 9 |
| Distance apart of centres of journals | 3 | 7 |

### Crank Axle.

| | ft. | in. |
|---|---|---|
| Diameter in middle | 0 | 7 |
| ,, on wheel seats | 0 | 9 |
| ,, of journals | 0 | 7½ |
| Length ,, | 0 | 7½ |
| Diameter of crank pin journals | 0 | 7¾ |
| Distance apart of centres of cranks | 2 | 4 |
| ,, ,, journals | 4 | 0 |
| Cross sections of crank arms—12 inches by 4¼ inches and 12 inches by 4½ inches. | | |
| Throw of cranks | 1 | 1 |

### Trailing Axle.

| | ft. | in. |
|---|---|---|
| Diameter in middle | 0 | 7 |
| ,, on wheel seats | 0 | 9 |
| ,, of journals | 0 | 7½ |
| Length ,, | 0 | 7½ |
| Distance apart of centres of journals | 4 | 0 |

**Wheels.**—To be of wrought iron, of the best materials and workmanship, with solid rims, spokes, bosses, and balance weights. The spokes must be forged with solid T ends, and welded in the centre. The surfaces of rims and spokes to be shaped so that the wheels are exactly balanced. Each wheel is to be bored taper and put on the axle, before the tires are shrunk on, by hydraulic pressure of not less than 60 tons, and then properly keyed on. Great care must be taken that the keys fit accurately.

### Dimensions.

#### Bogie.

| | ft. | in. |
|---|---|---|
| Diameter on rim | 3 | 0 |
| Width of rim | 0 | 4¾ |
| Thickness of rim | 0 | 1⅝ |
| No. of spokes—10. | | |
| Section of spokes at boss—4 inches by 1⅝ inch. | | |
| ,, ,, rim—3½ inches by 1¼ inch. | | |
| Diameter of boss | 1 | 4 |
| Width of boss | 0 | 7 |
| Diameter of hole in boss | 0 | 7½ |

### Driving and Trailing.

| | ft. | in. |
|---|---|---|
| Diameter on rim . . . . . . . . . . | 6 | 0 |
| Width of rim . . . . . . . . . . . | 0 | $4\frac{7}{8}$ |
| Thickness of rim . . . . . . . . . . | 0 | $1\frac{3}{4}$ |

No. of spokes—22.

Section of spokes at boss—$4\frac{1}{4}$ inches by $1\frac{3}{4}$ inch.

" " rim—$3\frac{1}{2}$ inches by $1\frac{3}{8}$ inch.

| | ft. | in. |
|---|---|---|
| Diameter of boss . . . . . . . . . . | 1 | 7 |
| Width of boss . . . . . . . . . . | 0 | $7\frac{1}{2}$ |
| Diameter of hole in boss . . . . . . . . | 0 | 9 |
| Centre of wheel to centre of coupling pin . . . | 1 | 0 |

### Wheel Centres.

| | ft. | in. |
|---|---|---|
| Trailing to driving . . . . . . . . . . | 8 | 4 |
| Driving to centre of bogie . . . . . . | 9 | 10 |
| Bogie wheel base . . . . . . . . . . | 5 | 9 |
| Total wheel base of engine . . . . . . | 21 | $0\frac{1}{2}$ |

**Tires.**—To be of crucible cast steel, of Vickers, Sons, and Co.'s extra manufacture, and to be of the section shown on drawing; to be shrunk on, and to be fixed to the wheel by lips on the outside, and by screws $\frac{7}{8}$ inch diameter, placed between each spoke. Each tire must be clearly stamped with the maker's name and the brand "Extra."

### Dimensions.

#### Bogie.

| | ft. | in. |
|---|---|---|
| Diameter on tread . . . . . . . . | 3 | 6 |
| Width . . . . . . . . . . . . . | 0 | $5\frac{3}{8}$ |
| Thickness, finished . . . . . . . . | 0 | 3 |
| Distance between tires . . . . . . . | 4 | $5\frac{7}{8}$ |

#### Driving and Trailing.

| | ft. | in. |
|---|---|---|
| Diameter on tread . . . . . . . . . | 6 | 6 |
| Width . . . . . . . . . . . . . | 0 | $5\frac{1}{2}$ |
| Thickness, finished . . . . . . . . | 0 | 3 |
| Distance between tires . . . . . . . | 4 | $5\frac{5}{8}$ |

**Cab and Splashers.**—The cab and splashers for trailing wheels to be made of best Staffordshire plate $\frac{3}{16}$ inch—full—thick, the former to be fitted with two plate-glass windows in brass frames, to be made to open. The splashers for driving and bogie wheels to be made of best Staffordshire plate $\frac{1}{8}$ inch—full—thick. All rivets to be countersunk and filed smooth. A brass number plate, to pattern, is to be placed on each wing plate.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Width of cab | 6 | 6 |
| Height at centre | 7 | 0 |

**Sand Boxes.**—To be of cast iron, four in number, and fitted with valves and substantial gear for working from footplate. The leading boxes to be fixed on to the splashers of driving wheels, and the valves are to be coupled together so as to work simultaneously.

**Lagging.**—The boiler and fire-box shell to be lagged with well seasoned pine, and covered with smooth iron sheets—14 BWG—supported on a light wrought iron frame, and secured by belts in the usual manner.

**Brake.**—A powerful steam brake to drawing to be fitted to the engine, having cast iron balanced brake blocks to the driving and trailing wheels. All pins and working parts of the brake gear to have large bearing surfaces, and to be thoroughly case-hardened. Diameter of brake cylinder, $9\frac{1}{2}$ inches.

**Dome and Manhole Casings, &c.**—To be of the form shown on drawings, of charcoal iron 14 BWG thick, thoroughly well finished. Brass moulding pieces are to be arranged round the back of smoke-box and fire-box casings.

**Hand Rail and Lamp Irons.**—A neat hand rail to be provided round the boiler, supported by polished wrought iron standards. Lamp irons to be fixed on the smoke-box, footplate, and fire-box casing, in the positions shown.

**Injectors.**—Two injectors, Friedman's (brass) No. 9, to pattern, to be suitably fixed on the ash-pan sides.

**Boiler Mountings, &c.**—A brass stand-pipe to be fitted on to fire-box casing, to carry two whistles, two injector steam valves, and one pressure gauge cock. Pressure gauge to be Bourdon's manufacture (Paris), with solid drawn tube (to sample to be supplied), to indicate from 1 to 200 lb. per square inch. A blower to be fixed on right-hand side of smoke-box, and worked from foot-plate. Two glass water-gauges, two ball clack boxes, a Furness lubricator to each cylinder, a displacement lubricator, oil boxes for axle-boxes and glands, lubricators for bogie sliding block, and an ash-pan water cock to be suitably fixed, the whole to be made of brass, in accordance with drawings, and of first-class finish.

DIMENSIONS, &C., OF PIPES.

| | Diameter inside. | Thickness. BWG. |
|---|---|---|
| Main steam pipes in boiler and smoke-box | $4\frac{1}{2}$ in. | 7 |
| Injector suction and delivery pipes | $1\frac{3}{4}$ in. | 10 |
| „ steam pipes | $1\frac{3}{8}$ in. | 10 |

| | Diameter inside. | Thickness. BWG. |
|---|---|---|
| Blower pipe in smoke-box, copper solid drawn | $\frac{5}{8}$ in. | 12 |
| Furness lubricator pipes in smoke-box, copper solid drawn . . . . . . . . | $\frac{3}{8}$ in. | 11 |
| Oil pipes . . . . . . . . . | $\frac{5}{16}$ in. | 15 |
| Pressure gauge pipe, copper solid drawn . . | $\frac{5}{16}$ in. | 15 |

**Bolts and Nuts.**—To be made to drawings and gauges, and all threads to be Whitworth's standard, except where otherwise specified or shown on drawings. Every nut of the same description, to be exactly the same size. Gland nuts to be case-hardened. All nuts in the smoke-box to be of hard brass, and made with a cap. All union nuts to be made exactly to drawings.

No. of Threads per Inch.

| | |
|---|---|
| Brass work of $\frac{1}{2}$ in. diameter and upwards . . . . . | 12 |
| Mud plugs . . . . . . . . . . . . | 12 |
| Copper fire-box stays . . . . . . . . . | 12 |
| Piston rods, piston end . . . . . . . . . | 6 |

Tender.

**Tank.**—Tank to hold about 2550 gallons, to be of the horseshoe form with a well, with angle irons, stays, manhole, and coping as shown on drawings, to be constructed entirely independent of the frames and foot-plate. The whole of the plates, angle irons, and stays to be of BB Staffordshire iron. All the joints to be made with butt strips, and the rivets to be countersunk on the outside and filed smooth; care must be taken that the holes are perfectly fair with each other in all plates and angle irons, and that the rivets completely fill the holes. The manhole to be fitted with a lid and strainer. Two water-tight tool boxes of wrought iron, lined with wood, are to be fixed on the tank. The mouths of feed pipes to be protected by copper rose-boxes. The feed cocks of hard brass are to be provided with suitable sectors and handles worked from the foot-plate. The tank is to be fixed to the framing in the manner shown on drawings.

Dimensions.

| | ft. | in. |
|---|---|---|
| Length of tank, outside . . . . . . . . . | 18 | 2 |
| Width " " . . . . . . . . . | 7 | 1 |
| Height " " . . . . . . . . | 3 | 6 |
| Between arms of horseshoe . . . . . . . | 3 | 6 |
| Length of " " . . . . . . . . | 7 | 0 |
| " well outside . . . . . . . . | 11 | 6 |
| Width " " . . . . . . . . . | 3 | 6½ |
| Depth " " . . . . . . . . . | 1 | 6 |
| Height of coping above tank . . . . . . . | 0 | 10 |

| | ft. | in. |
|---|---|---|
| Thickness of side, back, and coping plates . . . . | 0 | $0\frac{1}{4}$ |
| " inside of horseshoe and top and bottom plates | 0 | $0\frac{5}{16}$ |
| Section of angle iron for tank—$2\frac{1}{4}$ in. by $2\frac{1}{4}$ in. by $\frac{3}{8}$ in. | | |
| " " " stays—$2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by $\frac{1}{2}$ in. | | |
| " stays—6 in. by $\frac{3}{8}$ in. | | |
| Diameter of rivets . . . . . . . . . . | 0 | $0\frac{1}{2}$ |
| Pitch " . . . . . . . . . . | 0 | $1\frac{3}{4}$ |
| Diameter of manhole, inside . . . . . . . | 1 | 6 |
| Height " above tank . . . . . . | 0 | 9 |

**Frames.**—Outside frames and buffer plates to be of Yorkshire iron, frame-plate quality, by the same makers as the engine frames; each frame to be in one length, without weld, and finished with a good smooth surface, angle irons of the sections shown to be securely riveted to the frames. Inside frames, vertical and horizontal transverse stays of BB Staffordshire iron, draw pin washers, and foot-steps, are to be placed as shown on drawings. All holes are to be marked from one template, and drilled and rhymed out to the exact size.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Thickness of outside frame . . . . . . . . | 0 | $0\frac{7}{8}$ |
| Depth " " open . . . . . . | 2 | 11 |
| Distance from front end of frame to leading axle . . | 4 | 0 |
| " leading axle to middle " . . | 6 | 0 |
| " middle " trailing " . . | 6 | 0 |
| " trailing " hind end of frame . . | 3 | 4 |
| Extreme length . . . . . . . . . . | 19 | 4 |
| Distance apart . . . . . . . . . . . | 5 | $8\frac{1}{2}$ |
| Height of top of frame from rail . . . . . . | 4 | $1\frac{1}{2}$ |
| Thickness of inside frame . . . . . . . . | 0 | $0\frac{1}{2}$ |
| Depth " " . . . . . . . | 1 6 and 1 1 | |
| Length " " . . . . . . . . . | 17 | $6\frac{1}{2}$ |
| Distance apart . . . . . . . . . . | 3 | 8 |
| Thickness of vertical and horizontal transverse stays . . | 0 | $0\frac{1}{2}$ |
| Section of angle iron for stays, $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by $\frac{1}{2}$ in. | | |
| Length of buffer plates . . . . . . . . . | 7 | 6 |
| Depth " " . . . . . . . . . . | 1 | 4 |
| Thickness " " leading end . . . . . | 0 | $0\frac{3}{4}$ |
| " " " trailing end . . . . . | 0 | 1 |
| Thickness of foot-plate . . . . . . . . . | 0 | $0\frac{5}{16}$ |
| Extreme width of foot-plate . . . . . . . | 7 | 10 |

**Buffers and Draw-gear.**—Buffers on trailing end of tender to be in respects similar to those on the engine; buffer spindles at leading end to be of wrought iron case-hardened, and to be guided in cast iron sockets. The draw-bars, safety links, and coupling chains to be of best chain cable iron. Trailing draw-bar to be arranged to radiate, and to have an india-rubber spring, No. 6, of George Spencer and Co.'s make, and to be fitted with a shackle and coupling chain, and screw coupling.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Distances of centres of buffer spindles apart . . . | 3 | 3 |
| " " buffers apart . . . . . . | 5 | 8 |
| Height of centre line of buffers from rail . . . . | 3 | 5 |

**Hand-rail, Pillars, Lamp-Irons, &c.**—A hand-rail and pillar to be placed on each side of the foot-plate, as shown, and fixed to the tank and foot-plate. Three lamp-irons, one gong-iron, pulleys for communication cord, and a brass number-plate, to be fixed on the tank in the position shown on drawings.

**Springs.**—Bearing springs to be of the very best spring steel, by the same makers as engine springs, and to be similarly tested. They are to be connected by links to brackets riveted to the frames by turned cold rivets of Lowmoor iron. Brackets, links, buckles, and pins, to be of best Yorkshire iron, and the working surfaces must be well case-hardened. A laminated buffing spring of similar quality to the bearing springs is to be arranged at the leading end of the tender, as shown on drawings.

DIMENSIONS.

BEARING SPRINGS.

| | ft. | in. |
|---|---|---|
| Length, loaded . . . . . . . . . . | 3 | 6 |
| Camber . . . . . . . . . . . . | 0 | 3½ |
| Breadth of plates . . . . . . . . . | 0 | 4 |
| Thickness " . . . . . . . . . . | 0 | 0½ |

No. of plates in leading and middle springs—11.

" " trailing springs—12.

BUFFING SPRING.

| | ft. | in. |
|---|---|---|
| Length screwed up . . . . . . . . . | 3 | 3 |
| Camber " . . . . . . . . . . | 0 | 3½ |
| Breadth of plates . . . . . . . . . | 0 | 3½ |

Thickness—1 plate ½ inch and 16 plates ⅜ inch.

**Axle-boxes.**—Axle-boxes to be of good tough cast iron, and to be carefully fitted with gun-metal bearings lined with white metal, wrought iron covers, and keeps of cast iron arranged for spring lubricating pads.

**Horn-blocks.**—Horn blocks to be of cylinder metal as hard as can be worked, secured to the frames by turned bolts a driving fit; they are to have cast iron distance blocks and securing bolts, as shown on drawings.

**Axles.**—To be of crucible cast steel of Vickers', Cammell's, Taylor's, or other approved manufacture, all corresponding parts to be of the same size, and made to a template, so that they may be interchangeable, and each axle must be clearly stamped with the brand and the maker's name. The journals must on no account be swaged down, but turned from the solid metal.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter in middle | 0 | 6 |
| " on wheel seat | 0 | 6¾ |
| " of journal | 0 | 5¼ |
| Length of journal | 0 | 9½ |
| Distance apart of centre of journals | 6 | 4 |

**Wheels.**—To be of wrought iron, of the best materials and workmanship, with solid rims, spokes, and bosses. The spokes to be made in a similar manner to the engine wheel spokes. The wheels to be put on axles—before the tires are shrunk on—by hydraulic pressure of not less than 60 tons, and then properly keyed.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter on rim | 3 | 3 |
| Width of rim | 0 | 4⅞ |
| Thickness of rim | 0 | 1⅝ |
| Number of spokes—11. | | |
| Section of spokes at boss—4 in. by 1⅝ in. | | |
| " " rim—3½ in. by 1¼ in. | | |
| Diameter of boss | 1 | 2 |
| Width of boss | 0 | 7 |
| Diameter of hole in boss | 0 | 6¾ |

**Tires.**—To be of crucible cast steel of Vickers', Cammell's, Taylor's, Monkbridge, or Bowling Iron Company's manufacture, of the same section as driving and trailing tires, and to be fixed to the wheels in a similar manner.

DIMENSIONS.

| | ft. | in. |
|---|---|---|
| Diameter on tread | 3 | 9 |
| Width | 0 | 5½ |
| Thickness (finished) | 0 | 3 |
| Distances between tires | 4 | 5⅝ |

**Brake.**—A powerful brake to be fitted to the tender, having a brake block to each wheel; to be worked by a screw, as shown. All the brake gear to be of best scrap iron, and the pins and working surfaces to be thoroughly case-hardened. The handle for the brake to be on the left-hand side of tender, and to work in a cast iron column attached to the tank.

**Bolts and Nuts.**—To be similar in all respects to those used on the engine.

**Painting.**—Each engine and tender is to be painted in the following manner:—The boiler, before being lagged, to receive one coat of boiled oil and one coat of thick red-lead; the inside of tender tank to have two coats of thick red-lead. The lagging plates, cab, splashers, outside frames, tank plates, and wheels to have one coat of lead colour, then to be thoroughly stopped and filled up and rubbed down, one coat of lead colour, two coats of olive green, then to be panelled and lined to pattern, and afterwards to have three coats of best engine copal varnish, to be properly rubbed down between each coat. The buffers and buffer plates to be similarly prepared and painted vermilion; inside of frames and axles to be finished with one coat of vermilion and one coat of varnish. The frames, smoke-box, chimney, fire-box casing, ash pan, coal space, foot-plate, bottom of tank, brake work, &c., to have three coats of japan black.

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## SPECIFICATION FOR LONDON AND NORTH WESTERN RAILWAY.—COMPOUND EXPRESS LOCOMOTIVE ENGINE.

*Designed by* Mr. Francis W. Webb, *of Crewe.*

### Three-cylinder Compound Express Passenger Locomotive.

#### Cylinders.

| | | in. |
|---|---|---|
| Two high-pressure outside cylinders | Diameter | 13 |
| | Stroke | 24 |
| One low pressure inside cylinder | Diameter | 26 |
| | Stroke | 24 |

Joy's Valve Motion.

#### Wheels.

| | ft. | in. |
|---|---|---|
| Diameter of leading wheels, with radial axle-box | 3 | 6 |
| Diameter of front driving wheels (low-pressure cylinder) | 6 | 6 |
| Diameter of hind driving wheels (high-pressure cylinders) | 6 | 6 |
| Distance between leading and front driving wheels | 9 | 4 |
| Distance between front driving and hind driving wheels | 8 | 3 |
| Total wheel base | 17 | 7 |

### Boiler.

| | ft. | in. |
|---|---|---|
| Length of barrel | 9 | 10 |
| Mean diameter of barrel, outside | 4 | $1\frac{3}{16}$ |
| Length of fire-box, inside—4 ft. $9\frac{1}{8}$ in. at top, 4 ft. $10\frac{1}{2}$ in. at bottom. | | |
| Width of fire-box, inside | 3 | $5\frac{1}{2}$ |
| Height of fire-box from top of fire-bars to crown | 5 | $5\frac{1}{2}$ |
| Length of tubes between tube plates | 10 | 1 |
| Diameter of tubes, outside | 0 | $1\frac{7}{8}$ |
| Number of tubes—198. | | |

### Heating Surface.

| | square ft. |
|---|---|
| Fire-box | 103·5 |
| Tubes | 980 |
| Total | 1083·5 |
| Area of fire-grate | 17·1 |

Ratio of heating surface to grate area = 63·35 to 1.

### Weight.

| | | |
|---|---|---|
| Weight of engine when empty | | 34·75 tons. |
| Weight of engine when in working order— | | |
| Leading wheels | 10·40 tons. | |
| Front driving wheels | 14·20 tons. | |
| Hind driving wheels | 13·15 tons. | |
| Total | | 37·75 tons. |

The high-pressure slide valves are of the Trick or Allen type, which give double the lead shown at the edge of the port when the piston is at the end of its stroke; they have a travel of $3\frac{1}{8}$ inches in full forward and backward gear. The lap is $\frac{3}{4}$ inch and the lead $1\frac{1}{8}$ inch; the port opens $\frac{3}{4}$ inch for admission, and closes at 70 per cent. of the stroke. The sizes of the ports in the cylinders are, steam, $1\frac{1}{8}$ inch by 9 inches; exhaust, $2\frac{1}{2}$ inches by 9 inches. The low-pressure cylinder: the travel of the valve in full gear is $4\frac{1}{2}$ inches; lap of valve, 1 inch; lead, $\frac{3}{16}$ inch; the port opens 1 inch for admission, and is closed at 75 per cent. of the stroke, and the exhaust closes at 93 per cent. of the stroke. The sizes of the ports are, for steam 2 inches by 16 inches; exhaust, $3\frac{1}{4}$ inches by 16 inches. With regard to the degree of expansion at which the engine is worked, in practice the low-pressure cylinder is kept nearly in full gear, while all the expansion is done in the small high-pressure cylinders, so that no more steam is used than is absolutely necessary to do the work. The two high-pressure cylinders have their steam-chests placed underneath, in order to allow the valves to fall from their faces; so that there is no wear when the steam is shut off. These two cylinders are attached to the outside frame plates immediately under the foot-plate, about midway between the leading and middle wheels, and are connected through their piston-rods and connecting-rods to the trailing wheels. The low-pressure cylinder, which has its steam-chest on the top, is placed directly over the leading axle, and is carried between two cross steel plates, one at either end, securely fixed between the main frames; its connecting-rod lays hold of a single throw crank on the axle of the middle pair of wheels. The steam is supplied through the regulator in the dome to a brass T-pipe on the smoke-box tube-plate, and thence by two 3-inch copper steam pipes, first running parallel to the tube-plate, then through the back-plate that carries the low-pressure cylinder, and between the plates of the inside and outside frames, to the steam-chests of the high-pressure cylinders. The exhaust steam from these cylinders is returned by two 4-inch pipes, running parallel with the high-pressure pipes, through the back-plate that carries the low-pressure cylinder and into the smoke-box; following round the curved sides of the smoke-box nearly to the top, each pipe passes across to the opposite side, and enters the steam-chest of the low-pressure cylinder through passages in the cover. Thus the exhaust steam becomes superheated in these pipes by the waste gases in the smoke-box, while the large capacity of the pipes themselves obviates the necessity for a separate steam receiver. The final exhaust escapes from each side of the steam-chest of the low-pressure cylinder into the blast-pipe, and thence to the chimney in the usual way, the only difference being that there are only half the number of blasts for urging the fire compared with an ordinary engine; yet the compound engine steams very freely, and has a blast pipe of $4\frac{7}{8}$ inch diameter for the final exhaust, compared with $4\frac{1}{2}$ inches in engines of the ordinary type. The steam-chest cover of the large cylinder is provided with a relief valve, so adjusted that the pressure admitted may never exceed 75 lb. per square inch; and a small pipe, which is connected to the low-pressure steam pipe, and carried back to a gauge fixed inside the cab, shows at a glance the actual pressure of steam being used in the large cylinder. Arrangement is also made whereby steam direct from the boiler can be admitted to the low-pressure cylinder, which is useful for warming up before starting. The journals of the leading axle are 10 inches long and 6 inches diameter; while those of the front driving-axle are $13\frac{1}{2}$ inches long and 7 inches diameter, with crank journal $5\frac{1}{2}$ inches long and $7\frac{3}{4}$ inches diameter; and the trailing-axle journals are 9 inches long and 7 inches diameter. The average consumption of coal, per train mile is 26·6 lbs.

## SPECIFICATION FOR EXPRESS LOCOMOTIVE ENGINES—GREAT WESTERN RAILWAY.

*These Engines were made at the Swindon Works of the Great Western Railway Company, from the designs of the late* MR. ARMSTRONG, *Locomotive Superintendent.*

THE PRINCIPAL DIMENSIONS ARE AS FOLLOWS :—

### BOILER.

| | ft. | in. |
|---|---|---|
| Length,—Lowmoor iron | 10 | 6 |
| Diameter, inside | 4 | $1\frac{1}{8}$ |
| Thickness of plates | 0 | $0\frac{7}{16}$ |
| „ of tube plate | 0 | $0\frac{5}{8}$ |
| Angle iron | $4\frac{1}{2} \times 3\frac{1}{2}$ | |
| Diameter of rivets | 0 | $0\frac{3}{4}$ |
| Distance of centres | 0 | $1\frac{7}{8}$ |
| Number of stays, 7; diameter | 0 | 1 |

### OUTSIDE FIRE-BOX.

| | ft. | in. |
|---|---|---|
| Description—Lowmoor iron. | | |
| Length, outside | 6 | 4 |
| Breadth, „ | 4 | 0 |
| Height above boiler—flush. | | |
| Depth below „ | 3 | $3\frac{5}{8}$ |
| Thickness of plates | 0 | $0\frac{1}{2}$ |
| Diameter of rivets | 0 | $0\frac{3}{4}$ |
| Distance of centres | 1 | $1\frac{7}{8}$ |
| Number of stays, 2; gusset. | | |
| Distance of copper stays apart | 0 | $4\frac{1}{8}$ |
| Diameter | 0 | $0\frac{7}{8}$ |

### INSIDE FIRE-BOX.

| | ft. | in. |
|---|---|---|
| Description—copper. | | |
| Length, outside | 5 | $9\frac{1}{4}$ |
| Breadth, „ | 3 | $6\frac{1}{2}$ |
| From top of box to grate | 5 | $9\frac{1}{2}$ |
| From bottom of box to top of grate | 0 | 3 |

Side water spaces }
Front „ „ } 3 in.
Back „ „ }

Thickness of plates—Back plates, $\frac{9}{16}$ in.; lapping do. $\frac{1}{2}$ in.
„ of tube plate—$\frac{3}{4}$ in. at top, $\frac{1}{2}$ in. at bottom.
Fire door . . . . . . 15 inches × 12 inches

| | ft. | in. |
|---|---|---|
| Number of stays, 104; vertical stays, diameter | 0 | $1\frac{1}{8}$ |
| Number of fire bars, 44; distance apart | 0 | $0\frac{5}{8}$ |
| Diameter of rivets | 0 | $0\frac{3}{4}$ |
| Distance of centres | 0 | $1\frac{7}{8}$ |
| Area of fire-grate . . . sq. ft. | 17 | 0 |
| Superficial area of box . . . sq. ft. | 133 | 0 |
| Diameter of steam pipe, inside | 0 | $4\frac{1}{4}$ |

### Tubes.

| | ft. | in. |
|---|---|---|
| Description—iron. | | |
| Length | 10 | $11\frac{1}{2}$ |
| Diameter, outside | 0 | $1\frac{5}{8}$ |
| Distance of centres, $2\frac{1}{4}$ in. vertical, 2 in. horizontal. | | |
| Number, 15 W. G. | | |
| Number, 250. | | |
| Sectional area . . . sq. ft. | 1145 | 6 |
| Superficial area . . . sq. ft. | 1278 | 6 |

### Smoke Box.

| | ft. | in. |
|---|---|---|
| Description—circular. | | |
| Length, outside | 2 | $7\frac{3}{4}$ |
| Breadth, outside | 5 | 0 |
| Depth below boiler | 0 | $4\frac{1}{2}$ |
| Thickness of plate | 0 | $0\frac{1}{4}$ |
| Diameter of rivets | 0 | $0\frac{1}{2}$ |
| Distance of centres | 0 | 3 |

### Chimney.

| | ft. | in. |
|---|---|---|
| Diameter, taper . . . 1 ft. 4 in to | 1 | 6 |
| Height of top from rail | 12 | $10\frac{1}{2}$ |
| Thickness of plate | 0 | $0\frac{1}{8}$ |

### Blast Pipe.

| | ft. | in. |
|---|---|---|
| Description—cast iron. | | |
| Diameter at top, inside | 0 | $5\frac{1}{4}$ |
| Size at bottom | $1{\cdot}5 \times 9\frac{1}{2}$ | |
| Height | 3 | 0 |
| Injectors, two No. 8. | | |

### Safety Valves.

| | ft. | in. |
|---|---|---|
| Description—brass, 1 lever, 1 lock. | | |
| Diameter | 0 | 4 |
| Centres of valves | 0 | $5\frac{1}{2}$ |
| Centres of levers $3\frac{1}{16}$ in., 2 ft. $8\frac{15}{16}$ in. | | |

## CYLINDER.

| | ft. | in. |
|---|---|---|
| Diameter | 1 | 6 |
| Stroke | 2 | 0 |
| Distance of centres | 2 | 6½ |
| Distance below boiler | 1 | 4 |
| Distance of centres of valve spindles | 0 | 5¼ |
| Diameter of „ „ „ | 0 | 1¾ |
| From centre of cylinder to centre of valve spindle | 1 | 0⅝ |
| Number of bolts in front flange, 14; diameter | 0 | 0¾ |
| „ „ back „ 8; diameter | 0 | 0⅞ |
| Thickness of cylinder | 0 | 1 |
| Diameter of piston rod | 0 | 3 |
| Depth of piston | 0 | 4 |
| Description—cast iron. | | |
| Depth of packing ring | 0 | 0¾ |
| Distance between inside of ports | 2 | 2 |
| „ „ „ of covers | 1 | 8 |

## PORTS.

| | ft. | in. |
|---|---|---|
| Size of steam port . 16 inches × | 0 | 1¾ |
| Size of exhaust port . 16 inches × | 0 | 3½ |
| Thickness of bridge | 0 | 1 |

## SLIDES.

| | ft. | in. |
|---|---|---|
| Travel | 0 | 4½ |
| Lead—fore gear, $\frac{7}{32}$ in.; back gear, $\frac{9}{32}$ in. | | |
| Steam overlap | 0 | 1⅛ |
| Eduction overlap—*nil.* | | |
| From face of slide to centre of spindle | 0 | 0⅞ |

## EXCENTRICS.

| | ft. | in. |
|---|---|---|
| Description—cast iron. | | |
| Throw | 0 | $3\frac{1}{16}$ |
| Diameter | 1 | 2⅞ |
| Number, 4. | | |
| Breadth | 0 | 3¼ |
| Diameter of weigh bar for lifting excentric rod | 0 | 3¼ |

## REGULATOR.

| | ft. | in. |
|---|---|---|
| Description—cast iron. | | |
| Steam way—two ports . 1 inch × | 0 | 6½ |

### Motion Bars.

| | ft. | in. |
|---|---|---|
| Length inside | 3 | $8\frac{1}{2}$ |
| Breadth | 0 | 5 |
| Distance apart | 0 | 10 |
| Depth at centre | 0 | $2\frac{1}{4}$ |
| „ at ends | 0 | $1\frac{3}{8}$ |
| Length of block | 1 | 2 |

### Crosshead.

| | ft. | in. |
|---|---|---|
| Diameter of pin for blocks | 0 | $3\frac{1}{2}$ |
| Diameter of boss for piston rod | 0 | $2\frac{3}{4}$ |
| Diameter of socket for connecting-rod | 0 | 3 |
| Length of „ „ „ „ | 0 | $3\frac{1}{8}$ |

### Driving Wheels.

| | ft. | in. |
|---|---|---|
| Diameter | 7 | 0 |
| Breadth of outside tire | 0 | $5\frac{3}{4}$ |
| Thickness of outside tire | 0 | $2\frac{1}{2}$ |
| Height of flange | 0 | $0\frac{15}{16}$ |
| Inside tire—breadth | 0 | $4\frac{3}{8}$ |
| „ „ thickness | 0 | 2 |
| Spokes—flat, $4\frac{1}{2}$ in. at boss; $3\frac{1}{4}$ in. at rim. | | |
| Number of spokes, 24. | | |
| Thickness at top | 0 | $1\frac{1}{8}$ |
| „ at bottom | 0 | $1\frac{3}{8}$ |
| Distance of wheels apart | 4 | $5\frac{1}{2}$ |
| Cone of wheel, 1 in 15. | | |

### Distance of Centres of Wheels.

| | ft. | in. |
|---|---|---|
| Centre wheels from front wheels | 8 | 6 |
| Centre wheels from hind wheels | 9 | 0 |

The Driving Axle is $6\frac{3}{4}$ inches diameter in the middle, and $8\frac{1}{2}$ inches diameter where the wheels are on.—Crank Pin $7\frac{1}{2}$ inches diameter, and 4 inches long, inside bearing 7 inches diameter, and 6 inches long. Outside bearings, 6 inches diameter, and 9 inches long. Frame—extreme length, 25 feet; extreme breadth, 6 feet 9 inches; distance of centres of frame—inside, 4 feet $0\frac{1}{2}$ inch; outside, 6 feet 6 inches; depth, 1 foot 3 inches; thickness, $\frac{7}{8}$ inch inside; $\frac{3}{4}$ inch outside. Front wheels, 4 feet diameter; height of buffers from rail, 3 feet 4 inches: distance of centres of buffers, 5 feet 10 inches.

Weight of engine in working trim, 32 tons 10 cwt.
do. do. empty, 28 tons 10 cwt.

## SPECIFICATION FOR MIDLAND RAILWAY, FOUR-COUPLED BOGIE EXPRESS PASSENGER LOCOMOTIVE ENGINE. NUMBER 1668.

*Designed by* MR. S. W. JOHNSON, *Locomotive Superintendent.*

| | ft. | in. |
|---|---|---|
| ***Cylinders—*** | | |
| Diameter of cylinders | 1 | 7 |
| Stroke | 2 | 2 |
| Length of ports | 1 | 1½ |
| Width of steam ports | 0 | 1⅝ |
| Width of exhaust ports | 0 | 4 |
| Distance apart of cylinders, centre to centre | 2 | 0 |
| Lap of slide valve | 0 | 1⅛ |
| Lead of slide valve | 0 | 0 3/16 |
| ***Motion—Joy's—*** | | |
| Diameter of piston-rod (steel) | 0 | 2¾ |
| Length of slide blocks | 0 | 10 |
| Length of connecting-rod between centres | 6 | 2¾ |
| ***Wheels and Axles—*** | | |
| Diameter of driving wheel on tread | 7 | 0 |
| Diameter of trailing wheel on tread | 7 | 0 |
| Diameter of bogie wheels on tread | 3 | 6 |
| Distance from centre of bogie to driving | 10 | 0 |
| Distance from centre of driving to trailing | 8 | 6 |
| Distance from driving to front of fire-box | 1 | 8½ |
| Distance from centre of bogie to front buffer plate | 5 | 3 |
| Distance from trailing to back buffer plate | 4 | 4 |
| Wheel base of bogie | 6 | 0 |
| ***Crank Axle (Iron)—*** | | |
| Diameter at wheel seat | 0 | 8½ |
| Diameter at bearings | 0 | 7½ |
| Diameter at centre | 0 | 7½ |
| Distance between centres of bearings | 3 | 10 |
| Length of wheel seat | 0 | 6⅝ |
| Length of bearings | 0 | 9 |
| ***Trailing Axle (Steel)—*** | | |
| Diameter at wheel seat | 0 | 8½ |
| Diameter at bearings | 0 | 7½ |
| Diameter at centre | 0 | 7¼ |
| Length of bearings | 0 | 9 |
| Diameter of outside coupling pins | 0 | 3½ |
| Length of ditto | 0 | 3½ |
| Throw of ditto | 1 | 0 |
| ***Bogie Axles (Iron)—*** | | |
| Diameter at wheel seat | 0 | 6½ |
| Diameter at bearings | 0 | 5¾ |
| Diameter at centre | 0 | 5¾ |
| Length at wheel seat | 0 | 6 |
| Length at bearing | 0 | 9 |
| Distance between centres of bearings | 3 | 7 |
| ***Tires—*** | | |
| Thickness of all tires on tread | 0 | 2¾ |
| Width of all tires | 0 | 5½ |
| ***Frames—*** | | |
| Distance apart at leading end | 3 | 11¾ |
| Ditto at trailing end | 4 | 1½ |
| Thickness of frames (iron) | 0 | 1 |
| ***Boiler—*** | | |
| Centre of boiler from rail | 7 | 4 |
| Length of barrel | 10 | 6 |
| Diameter of ring next to fire-box | 4 | 3 |
| Thickness of plates (iron) | 0 | 0½ |
| Thickness of smoke-box tube plate | 0 | 0¾ |
| Lap of plates | 0 | 2½ |
| Pitch of rivets | 0 | 1⅞ |
| Diameter of rivets | 0 | 0 13/16 |
| Thickness of butt strips, outside | 0 | 0½ |
| Thickness of butt strips, inside | 0 | 0 7/16 |
| Width of butt strips | 0 | 7½ |
| ***Fire-box Shell—*** | | |
| Length outside | 5 | 11 |
| Width outside at centre line of boiler | 4 | 4 |
| Ditto at bottom | 4 | 0½ |
| Thickness of front plates | 0 | 0 9/16 |
| Thickness of back plates | 0 | 0½ |
| Thickness of side plates | 0 | 0½ |
| Distance apart of copper stays | 0 | 4 |
| Diameter of copper stays | 0 | 0⅞ |
| ***Inside Fire-box—*** | | |
| Length at bottom, inside | 5 | 3 |
| Width at bottom, inside | 3 | 4½ |
| Top of box to inside of shell | 1 | 3 |
| Depth of box inside, front | 5 | 11½ |
| Depth of box inside, back | 5 | 4½ |
| ***Tubes (Copper)—*** | | |
| 175 diam. | 0 | 1¾ |
| 30 „ | 0 | 1½ |
| Total No. of tubes, 205 | | |
| Thickness, 11 and 13 b.w.g. | | |
| Diameter of exhaust nozzle | 0 | 4⅝ |
| Height from top of top row of tubes | 0 | 0½ |
| Height of chimney from rail | 13 | 1½ |

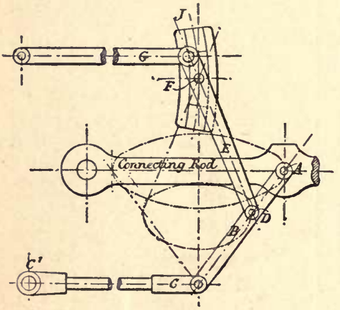
| ***Heating Surface—*** | sq. ft. |
|---|---|
| Tubes | 1011·459 |
| Fire-box | 110·163 |
| Total | 1121·622 |
| Area of grate | 17½ |

| | tons. | cwt. | qrs. |
|---|---|---|---|
| ***Engine Empty—*** | | | |
| Bogie | 13 | 14 | 2 |
| Driving | 13 | 12 | 2 |
| Trailing | 12 | 4 | 1 |
| Total | 39 | 11 | 1 |
| ***Engine in Working Order—*** | | | |
| Bogie | 14 | 16 | 3 |
| Driving | 15 | 0 | 3 |
| Trailing | 12 | 18 | 3 |
| Total | 42 | 16 | 1 |
| ***Tender Empty—*** | | | |
| Leading | 6 | 10 | 0 |
| Middle | 6 | 6 | 2 |
| Trailing | 6 | 0 | 2 |
| Total | 18 | 17 | 0 |
| ***Tender in Working Order—*** | | | |
| Leading | 10 | 17 | 3 |
| Middle | 12 | 5 | 1 |
| Trailing | 12 | 0 | 0 |
| Total | 35 | 3 | 0 |

| | lb. |
|---|---|
| Adhesion | 12,544 |
| Tractive power at 100 lb. mean pressure | 11,173 |

These engines are employed in working the express traffic between London and Nottingham, the average speed being 53·5 miles an hour, with loads of nine to ten coaches. The consumption is only 27 lb. to 29 lb. per mile, of common Derbyshire coal. The valves are placed on the top of the cylinders, as there is no room between them, and are worked by Joy's Valve-Gear.

**Joy's Valve-Gear**, shown in the annexed sketch, dispenses with eccentrics and is less costly than the ordinary link-motion. The main valve-lever E is pinned at D to a link B, one end of which is fastened to the connecting rod at A and the other end maintained by the radius-rod C, which is fixed at the point C¹. The centre or fulcrum F of the lever E, partaking of the vibrating movement of the connecting-rod at the point A, is carried in a curved slide J, the radius of which is equal to the length of the link G, and the centre of which is fixed to be concentric with the fulcrum F of the lever when the piston is at either extreme end of its stroke. From the upper end of the lever E, the motion is carried direct to the valve by the rod G. By one revolution of the crank the lower end of the lever E will have imparted to it two different movements, one along the lower axis of the ellipse, travelled by the point A, and one through its minor axis up and down, these movements differing as to time and corresponding with the part of the movement of the valve required for lap and lead and that part constituting the port opening for admission of steam. The former of these is constant and unalterable, the latter is controllable by the angle at which the curved slide J may be set with the vertical. If the lever E were pinned direct to the connecting rod at the point A, which passes through a practically true ellipse, it would vibrate its fulcrum F, unequally on either side of the centre of the curved slide J, by the amount of the versed line of the arc of the lever E from F D: it is to correct this error that the lever E is pinned at the point D, to a parallel motion formed by the parts B and C, the point D performing a figure which is equal to an ellipse, with the error to be eliminated added, so neutralising its effect on the motion of the fulcrum F. The lap and lead are opened by the action of the valve-lever acting as a lever, and the port opening is given by the incline of the curved slide in which the centre of that lever slides.



## SPECIFICATION FOR EXPRESS PASSENGER LOCOMOTIVE ENGINE, LONDON AND BRIGHTON RAILWAY. NUMBER 214.

*Designed and constructed by* MR. W. STROUDLEY, *Locomotive Superintendent of the London, Brighton, and South Coast Railway, for working fast trains.*

### CYLINDERS (1 IN $11\frac{1}{2}$ INCLINATION).

| | ft. | in. |
|---|---|---|
| Diameter of | 1 | $6\frac{1}{4}$ |
| Stroke | 2 | 2 |
| Length of ports | 1 | 3 |
| Width of steam ports | 0 | $1\frac{3}{8}$ |
| Width of exhaust port | 0 | 2 |
| Distance apart of cylinders from centre to centre | 2 | 1 |

### VALVES (1 IN 15 INCLINATION).

| | ft. | in. |
|---|---|---|
| From centre to centre of valves | 1 | 5 |
| From centre to centre of valve spindles | 1 | $0\frac{1}{4}$ |
| Lap of slide valve | 0 | $0\frac{7}{8}$ |
| Lead | 0 | $0\frac{1}{16}$ |
| Maximum travel of valve | 0 | $3\frac{3}{4}$ |

### MOTION.

| | ft. | in. |
|---|---|---|
| Link, radius | 4 | 7 |
| Link, centres | 1 | 5 |
| Intermediate valve rod, diameter | 0 | $3\frac{1}{2}$ |
| Valve spindle, diameter | 0 | 2 |
| Excentric rods, length | 4 | 7 |
| Excentric pulleys, diameter | 1 | 4 |
| Width of forward excentric | 0 | $2\frac{7}{8}$ |
| Width of backward excentric | 0 | $2\frac{7}{16}$ |
| Throw of excentric | 0 | $5\frac{1}{2}$ |
| Connecting-rod centres | 6 | 6 |
| Diameter of piston rod | 0 | $2\frac{3}{4}$ |
| Slide block, length | 0 | 11 |
| Slide block, width | 0 | 3 |

### FRAMES (STEEL).

| | ft | in. |
|---|---|---|
| Distance apart | 4 | $1\frac{1}{2}$ |
| Thickness of frames | 0 | 1 |
| Distance of foot-plate from rail | 4 | 0 |
| Width of foot-plate | 7 | 6 |
| Thickness of foot-plate | 0 | $0\frac{1}{4}$ |

### Boiler.

| | ft. | in. |
|---|---|---|
| Centre of from rails | 7 | 5 |
| Length of barrel | 10 | 2 |
| Diameter outside | 4 | 6 |
| Thickness of plate, iron | 0 | 0½ |
| Thickness of smoke-box tube plate | 0 | 1 |
| Lap of plates, circular seams | 0 | 2½ |
| Pitch of rivets | 0 | 2 |
| Diameter of rivets | 0 | 0¾ |

### Longitudinal Seams.

| | ft. | in. |
|---|---|---|
| Double butt straps, double riveted, 9¼ in. wide by $\frac{9}{16}$ in. thick. | | |
| Diameter of rivets | 0 | 0⅞ |
| Pitch of rivets | 0 | 3¾ |
| Strength of joint, 82 per cent. of strength of plate. | | |

### Fire-box Shell (Iron).

| | ft. | in. |
|---|---|---|
| Length outside | 6 | 8¼ |
| Breadth outside, bottom | 4 | 1 |
| Depth below centre line of boiler at back | 4 | 3 |
| „ „ „ at front | 5 | 6 |
| Thickness of front plates | 0 | 0⅝ |
| „ back plates | 0 | 0⅝ |
| „ side and top plate | 0 | 0½ |
| Distance of copper stays apart | 0 | 3¾ |
| Diameter of copper stays | 0 | 0⅞ |

### Inside Fire-box (Copper).

| | ft. | in. |
|---|---|---|
| Length inside, bottom | 5 | 11¾ |
| Breadth „ „ | 3 | 4¾ |
| From top of box to inside of shell | 1 | 4 |
| Thickness of plate | 0 | 0⅝ |
| Tube plate, ⅝ in. and 1 in. | | |
| Depth of box inside, front | 5 | 10 |
| „ „ back | 4 | 6¾ |

### Tubes (Steel).

| | ft. | in. |
|---|---|---|
| Number of—331. | | |
| Length over all | 10 | 8¼ |
| Diameter, outside | 0 | 1½ |

| | ft. | in. |
|---|---|---|
| Thickness, No. 14 BWG. | | |
| Diameter of blast pipe | 0 | $4\frac{3}{4}$ |
| Height from top of blast pipe to bottom of chimney | 1 | $6\frac{1}{4}$ |
| Height of top of chimney from rail | 13 | 2 |

### Heating Surface.

| | sq. ft. |
|---|---|
| Of tubes | 1372·92 |
| Of fire-box | 112·48 |
| Total | 1485·40 |
| Grate area | 20·65 |

### Wheels and Axles.

| | ft. | in. |
|---|---|---|
| Diameter of driving wheel | 6 | 6 |
| Diameter of leading wheel | 6 | 6 |
| Diameter of trailing wheel | 4 | 6 |
| Distance from centre of leading to driving wheel | 7 | 7 |
| Distance from centre of driving to trailing wheel | 8 | 0 |
| Distance from driving wheel to front of fire-box | 1 | $10\frac{3}{8}$ |
| Distance from leading wheel to front buffer plate | 5 | 10 |
| Distance from trailing wheel to back buffer plate | 4 | 4 |

### Crank Axle (Steel).

| | ft. | in. |
|---|---|---|
| Diameter of wheel seat | 0 | $8\frac{1}{4}$ |
| Diameter of bearings | 0 | 8 |
| Diameter at centre | 0 | $7\frac{3}{4}$ |
| Diameter of crank journal | 0 | $8\frac{1}{4}$ |
| Distance between centres of bearings | 3 | $11\frac{1}{4}$ |
| Length of wheel seat | 0 | $7\frac{1}{16}$ |
| Length of journal | 0 | $8\frac{1}{8}$ |
| Length of crank journal | 0 | 4 |

### Trailing Axle (Iron).

| | ft. | in. |
|---|---|---|
| Diameter at wheel seat | 0 | $8\frac{1}{4}$ |
| Diameter at bearings | 0 | 8 |
| Diameter at centre | 0 | $6\frac{1}{2}$ |
| Length of wheel seat | 0 | $7\frac{1}{16}$ |
| Length of journals | 0 | $8\frac{3}{4}$ |

### Leading Axle (Iron).

| | ft. | in. |
|---|---|---|
| Diameter of wheel seat | 0 | $8\frac{1}{4}$ |
| Diameter at bearings | 0 | 8 |

| | ft. | in. |
|---|---|---|
| Diameter at centre | 0 | 7 |
| Length at wheel seat | 0 | $7\frac{1}{16}$ |
| Length at bearing | 0 | 8 |
| Centre to centre of bearings | 3 | $11\frac{1}{4}$ |
| Thickness of all tires on tread | 0 | 3 |
| Width of all tires on tread | 0 | $5\frac{1}{4}$ |
| Diameter of outside coupling pin | 0 | 4 |
| Length of outside coupling pin | 0 | $4\frac{1}{2}$ |
| Throw of outside coupling pin | 0 | 9 |

### Weight of Engine in Working Order.

| | tons | cwts. |
|---|---|---|
| Leading wheels | 13 | 16 |
| Driving wheels | 14 | 10 |
| Trailing wheels | 10 | 8 |
| Total | 38 | 14 |

### Tender—Tank.

| | ft. | in. |
|---|---|---|
| Length outside | 20 | 0 |
| Breadth outside | 6 | 0 |
| Depth outside | 3 | 6 |
| Thickness of side plates | 0 | $0\frac{3}{16}$ |
| Thickness of top plates | 0 | $0\frac{3}{16}$ |
| Thickness of bottom plates | 0 | $0\frac{5}{16}$ |

Total capacity in gallons—2250.
Coal bunker capacity—2 tons.

### Frames (Steel).

| | ft. | in. |
|---|---|---|
| Distance apart of | 4 | $1\frac{1}{2}$ |
| Thickness of frames | 0 | $0\frac{7}{8}$ |
| Distance of foot-plate from rail | 4 | 0 |
| Width of foot-plate | 7 | 6 |
| Thickness of foot-plate | 0 | $0\frac{5}{16}$ |

### Wheels and Axles.

| | ft. | in. |
|---|---|---|
| Diameter of centre wheels | 4 | 6 |
| Diameter of leading wheels | 4 | 6 |
| Diameter of trailing wheels | 4 | 6 |
| Distance from centre of leading to centre of centre wheels | 7 | 0 |
| Distance from centre of centre wheels to centre of trailing wheels | 7 | 0 |

### Axles.

| | ft. | in. |
|---|---|---|
| Diameter at wheel seat . . . . . . . . . | 0 | 7½ |
| Diameter at bearings . . . . . . . . . | 0 | 7 |
| Diameter at centre . . . . . . . . . | 0 | 6¼ |
| Distance between centres of bearings . . . . . | 3 | 11¼ |
| Length of wheel seat . . . . . . . . . | 0 | 7 1/16 |
| Length of journal . . . . . . . . . | 0 | 8¾ |

### Weight in Working Order.

| | tons | cwts. | qrs. |
|---|---|---|---|
| Weight on leading wheels . . . . . . . | 9 | 2 | 1⅓ |
| Weight on centre wheels . . . . . . . | 9 | 2 | 1⅓ |
| Weight on trailing wheels . . . . . . . | 9 | 2 | 1⅓ |
| Total Weight . . . . . . | 27 | 7 | 0 |

Table 3.—Dimensions, Weights, and Capacities of Railway Wagons on Different Lines.

| Name of Railway. | Class of Vehicle. | Dimensions of Body. | | | | Capacity. | | Wheels. | Journals. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Length Inside. | Width Inside. | Height at Centre Inside. | Height at Side Inside. | Area of Floor. Square Feet. | Cubical Contents, Cubic Feet. | Number. | Length. | Diameter. | Weight Empty. |
| | | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | | ins. | ins. | tons. cwt. |
| London and North-Western . | Low-sided open . | 15 0 | 7 1½ | 1 8 | 1 8 | 107 0 | ... | 4 | 6 | 3 | 4 0 |
| Ditto . . | Covered . | 12 10 | 6 6 | 6 2 | 5 6 | 83 5 | 486 9 | 4 | 6 | 3 | 5 1 |
| London and South-Western . | Ditto . . | 15 9 | 7 1½ | 6 1 | 5 6 | 112 2 | 654 4 | 4 | 8 | 3½ | 5 6 |
| Ditto . . | High-sided open . | 15 0 | 7 2 | 5 3 | 3 3 | 107 6 | 456 10 | 4 | 7 | 3½ | 5 18 |
| London, Brighton, and South Coast Railway . | Ditto . . | 15 6 | 7 5 | 4 2 | 2 3 | 115 0 | 373 9 | .4 | 8 | 3½ | 5 11 |
| Ditto . . | Covered . | 16 0 | 7 1 | 5 11 | 5 8 | 113 4 | 661 1 | 4 | 8 | 3½ | 6 2 |
| Ditto . . | Low-sided . | 13 6 | 6 11 | 1 9 | 1 9 | 93 4 | ... | 4 | 6 | 3 | 4 0 |
| Midland . | Covered . | 13 0 | 6 7 | 6 2 | 5 5 | 85 7 | 499 4 | 4 | 6 | 3 | 4 18 |
| Ditto . . | High-sided open . | 13 5 | 6 11 | 6 0 | 3 9 | 92 9 | 409 7 | 4 | 6 | 3 | 5 0 |
| Ditto . . | Low-sided open . | 17 6 | 7 2 | 0 11 | 0 11 | 125 5 | ... | 4 | 7 | 3½ | 5 6 |

**Super-elevation of Rails on Railway Curves.**—All moving bodies have a tendency to continue their motion in a straight line; therefore, when a railway train moves in a curve the centrifugal force produced by the velocity urges the carriages towards the outer rail, which it is necessary to elevate above the inner one in order to counteract the centrifugal force. The super-elevation of the outer rail required for trains of different speeds is given in the following table:—

Table 4.—Super-elevation of the Outer Rail on Railway Curves.

| Radius of Curve. | | Maximum Speed in Miles per Hour. | | |
|---|---|---|---|---|
| | | 25 | 40 | 60 |
| Miles. | Chains. | Super-elevation of the outer Rail. | | |
| | | Inches. | Inches. | Inches. |
| $\frac{1}{8}$ | 10 | $3\frac{1}{2}$ | | |
| | 15 | $2\frac{7}{16}$ | | |
| $\frac{1}{4}$ | 20 | $1\frac{7}{8}$ | $4\frac{1}{2}$ | |
| | 25 | $1\frac{1}{2}$ | $3\frac{5}{8}$ | |
| $\frac{3}{8}$ | 30 | $1\frac{1}{4}$ | 3 | |
| | 35 | $1\frac{1}{8}$ | $2\frac{9}{16}$ | |
| $\frac{1}{2}$ | 40 | 1 | $2\frac{3}{16}$ | $5\frac{1}{4}$ |
| | 45 | $\frac{7}{8}$ | 2 | $4\frac{5}{8}$ |
| $\frac{5}{8}$ | 50 | $\frac{3}{4}$ | $1\frac{3}{4}$ | $4\frac{1}{8}$ |
| | 55 | $\frac{3}{4}$ | $1\frac{5}{8}$ | 4 |
| $\frac{3}{4}$ | 60 | $\frac{11}{16}$ | $1\frac{1}{2}$ | $3\frac{1}{2}$ |
| | 65 | $\frac{11}{16}$ | $1\frac{7}{16}$ | $3\frac{3}{8}$ |
| $\frac{7}{8}$ | 70 | $\frac{5}{8}$ | $1\frac{5}{16}$ | 3 |
| 1 | 80 | $\frac{5}{8}$ | $1\frac{1}{8}$ | $2\frac{5}{8}$ |
| | 90 | $\frac{9}{16}$ | 1 | $2\frac{3}{8}$ |
| $1\frac{1}{4}$ | 100 | $\frac{1}{2}$ | $\frac{7}{8}$ | $2\frac{1}{8}$ |

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## GAS ENGINES.*

Until within the last few years a strong prejudice existed amongst engineers against the use of gas engines. This arose from the unsatisfactory working of the early engines of this kind. Since the introduction of the "Otto" gas engine this prejudice has been gradually disappearing. The great success of the "Otto" engine, since its introduction by Messrs. Crossley Bros., of Manchester and London, shows that whilst the steam engine has almost reached its limit of improvement, the gas engine offers a possibility of improvement in efficiency and economy, about double that attainable by the steam engine.

Apart from their superior economy, gas engines possess many advantages over small steam engines. No boiler is required for a gas engine; it can be started at a moment's notice on lighting a gas jet and turning a fly wheel, and stopped by turning the gas off. No extra insurance is charged by the leading insurance companies. Gas engines can be fixed in the upper storeys of a building without danger from fire. They are more regular in speed and more easily managed than a steam boiler and engine.

* The Author is indebted for this information to Mr. Robert Wilson, 24, Poultry, London.

In instituting a comparison of the consumption of fuel in a gas engine and a steam engine, nothing may be more misleading than to take the cubic feet of gas and the pounds of coal respectively, per horse-power when the engines are working up to full power. A steam engine, and a boiler that consumes 5 lb. coal per horse-power when working up to 12 horse-power may consume fully one half that amount when driving the engine itself only. But in the case of a gas engine the quantity of gas required to drive the engine only is but $\frac{1}{6}$ to $\frac{1}{4}$ of that required to drive it with all its work on. In varying and intermittent work, the quantity of fuel consumed varies according to the work done much more nearly in a gas engine than in a steam engine. It is this fact, so often overlooked, which accounts for the unexpected superior economy of the gas engine.

The following explanation of the manner in which a gas engine works may not be altogether out of place. It is known to every one that if a gas tap is left turned on overnight and the gas is allowed to escape into the room, the striking of a match or bringing a lighted candle into the room will probably cause a violent and disastrous explosion. A mixture of from 7 to 12 parts of air to 1 of gas may be ignited at atmospheric pressure. Such a mixture forms an explosive compound which may prove dangerous when filling a room, but may be made a very useful servant when confined in a cylinder with a movable piston.

If ignited under pressure considerably above that of the atmosphere, still weaker mixtures can be employed. This is one reason why compression engines like the "Otto" are more economical than the non-compression engines, which are not, as a rule, made in sizes over 2 horse-power.

The "Otto" may be regarded as the parent or prototype of gas engines over 2 horse-power, and as the makers guarantee an economy of from 25 to 70 per cent. over other engines it may still be considered the best.

In general appearance it resembles a horizontal steam engine, but here the resemblance ceases. It is single-acting, the cylinder being open at the front end. The engine acts alternately as a pump for drawing in and compressing its charge, and as a motor for utilising this charge when fired. The fly-wheel makes two complete revolutions for every charge of gas admitted. The first outstroke draws in the compound charge; by the first instroke the charge drawn in by the previous outstroke is compressed to about one-third its volume; at the end of this first instroke or the beginning of the second outstroke, the compressed charge is ignited, when the expanding gases propel the piston to the end of the stroke; and the second instroke expels the products of combustion and completes the cycle of operations which are continually repeated when the engine is working up to its full power. When the engine is working within its power, the gas is temporarily cut off by the governor, and the engine simply works as a pump for drawing in, compressing and expelling the air.

The "Otto" engine differs also in other respects from all other gas engines previously made. The charge to be ignited is not a uniform mixture of gas and air, but consists of a compound charge of incombustible gas, *i.e.* combustion products or air next the piston combining gradually with a mixture of gas and air that becomes stronger and more readily ignitable as it reaches the point where it is fired. The effect of this so-called stratification is that whilst the charge is as easily ignited as a uniform charge of highly explosive mixture, the presence of a large quantity of diluent, causes the combustion of the complete charge to be effected gradually. The result of this is most important. In the first place it prevents the sudden shock that occurs when a uniform mixture is ignited, and which is a sure indication of waste. In the second place, it ensures the pressure being sustained to the end of the stroke.

The "Otto" is the first gas engine in which the whole length of the stroke has been utilised for propelling the piston.

The initial pressure of the gas in the cylinder when ignited at the beginning of the stroke is about 170 lbs. per square inch. The gases expand to a pressure of about 35 lbs. at the end of the stroke. The average pressure is about 70 lbs. per square inch on the piston.

The consumption of gas varies from 18 cubic feet per indicated horse-power in the largest sizes of engines to 25 cubic feet in the smallest. With gas at 4*s.* per 1000 cubic feet, this corresponds to a working cost of about one penny per indicated horse-power per hour. For engines working up to 20 horse-power, the cost of working is generally greatly in favour of a gas engine with coal and gas at the respective prices prevailing in London. For engines of larger size, in order to compete in economy with steam where coal is comparatively cheap, gas other than that supplied for lighting must be employed, such as the Dowson Economic Gas. This is a so-called water gas, and can be made at a cost of three-pence per 1000 feet. In an "Otto" using this Dowson gas, the consumption is as low as 1¼ lb. of anthracite coal per indicated horse-power per hour,—an economy of working not yet reached by a small steam engine.

Table 5.—The "Otto" Engine is made of the following Sizes:—

| Nominal Horse Power. | Approximate Indicated Horse Power. | Approximate Net Weight of Engine. | | | Size of Pulleys. | | Net Space Occupied by Engine. | | | | Diameter of Gas Pipe. | Size of Gas Meter. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cwts. | qrs. | lbs. | Diameter. Inches. | Width. Inches. | Ft. | In. | Ft. | In. | Inch. | |
| ½ | 1·9 | 12 | 0 | 0 | 10 × | 5 | 6 | 0 × | 3 | 6 | ½ | 5 light |
| 1 | 2·7 | 17 | 0 | 0 | 12 × | 6 | 7 | 6 × | 4 | 0 | ¾ | 10 „ |
| 2 | 3·96 | 26 | 0 | 0 | 17 × | 6 | 8 | 10 × | 4 | 4 | ¾ | 10 „ |
| 3½ | 5·9 | 32 | 2 | 0 | 20 × | 7 | 8 | 10 × | 4 | 6 | 1 | 20 „ |
| 6 | 11·57 | 52 | 0 | 0 | 24 × | 10 | 10 | 8 × | 6 | 6 | 1¼ | 30 „ |
| 8 | 14·7 | 54 | 2 | 0 | 27 × | 12 | 10 | 8 × | 6 | 6 | 1¼ | 30 „ |
| 12 | 24· | 74 | 0 | 0 | 36 × | 12 | 10 | 8 × | 7 | 0 | 1½ | 80 „ |
| 16 | 40· | 131 | 0 | 0 | 54 × | 18 | 12 | 6 × | 8 | 8 | 2½ | 150 „ |

With the exception of the ½ and 1 H.P. sizes, which run at a speed of 180 revolutions per minute, these engines are all speeded to run at 160 revolutions.

**Instructions for Fixing the "Otto" Gas Engine.**—Always leave plenty of room to get at the fly wheel for starting. These engines, with the exception of the larger sizes, are frequently fixed on the upper floors of buildings, where they require no special foundation. When fixed on the ground floor or basement, no special foundation is necessary if the floor is concreted. Where there is only loose earth, stone blocks of from 9 inches to 12 inches thick should be laid at each end, or about 6 inches or 9 inches of concrete for the smaller sizes. For the larger engines, concrete 12 inches to 24 inches thick, or a stone bed about 24 inches thick, is required.

For holding down, Lewis bolts are used with stone. When new concrete beds are laid, it is advisable to place a tube about 2 inches diameter temporarily round the bolt when filling in, to allow it to have a certain amount of play when the tube is withdrawn, so that the bolt can adapt itself to the position of the hole in engine bed when it is let down over the bolts. In cases where the concrete is already laid, bolts of sufficient length may be firmly fixed by arranging them head downwards in a hole made large enough to receive a stout washer, 4 inches to 6 inches square, which rests on the head at the bottom of the hole. This is filled in with cement, which holds the bolt firmly in position.

As gas engines are often placed in dwelling houses, underneath offices, and in other places where no one would dream of fixing a steam engine and boiler, great care is often necessary to prevent the noise that is inseparable from the working of quick-running machinery, being conveyed to portions of the building where it would be objectionable. This can generally be effected by isolating the engine bed completely from the walls of the building, and by insulating any pipes or other material that is likely to convey the sound.

**The Sizes of Gas-Pipes** for the various engines are given in the table of the sizes of gas engines. In fixing gas-pipes, all sharp elbows should be avoided.

**The Pipe for the Slide-Light** should be taken, if possible, from a separate meter, or at some distance from the gas-bag if taken from the same pipe that supplies the engine. This is to provide against the possibility of the slide-lights being sucked out by the working of the engine itself.

**The Exhaust-Pipe** should be carefully kept away from all woodwork, and on no account should the exhaust-box be placed on or close to wood, as the heat is likely to char it. The exhaust-pipe should be laid in such a manner that the water from condensation can easily flow away, and not lodge in the pipes to cause back pressure. The exhaust-pipe should discharge into the open air, not into a chimney, flue, or drain, lest damage arise from an accumulation of gas therein.

**The Water-Pipes** should be arranged with an inclination of about 1 inch per foot from the engine to the water-vessel.

During frosty weather, a gas jet should be kept burning close underneath the cylinder, to prevent the water in the jacket from freezing.

The engine is provided with a governor, which performs two distinct functions; it cuts off the gas both when the proper speed is exceeded, and when the engine stops. The piston is so constructed as to be capable of perfect adjustment, it being of primary importance that the piston should not leak.

**Consumption of Gas.**—Regular working requires a certain proportion of gas to air, when the engine is working full power. The movement of the finger of the gas meter may be watched and the number of explosions counted, thus:—A ½ nominal horse-power engine should make, say, 145 explosions per cubic feet of gas burned, and a 1 horse-power say 95 explosions; a 2 horse-power, say, 55; a 3½ horse-power, say, 40; a 6 horse-power, say, 19; an 8 horse-power, say, 16; a 12 horse-power, say, 11; and a 16 horse-power, say, 6 explosions. One explosion occurs after each lift of the small gas valve. When full gas is used, the engines indicate much beyond their nominal power—a 16 horse indicating up to, say, 40 horse, and others as stated in the above table.

Fine sperm oil is found to be the best lubricant for gas engines.

Table 6.—Showing the efficiency of an "Otto" Gas Engine compared with a Steam Engine, each developing 6 Actual Horse-power.

| Otto Gas Engine, 6 Horse Power, actual. Working one week of 54 hours. | £ | s. | d. | Steam Engine with Tubular Boiler, 6 Horse Power, actual. Working one week of 54 hours. | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| Gas at 25 cubic feet per horse power per hour 8100 cubic feet at 3s. per thousand | 1 | 4 | 4 | Coal at 6 lbs. per horse power per hour = 17 cwt. 1 qr. 12 lb. at 15s. per ton | 0 | 13 | 0 |
| Water for water vessel | 0 | 0 | 6 | Feed water at 5 gallons per horse power per hour = 1620 gallons | 0 | 2 | 0 |
| Lubrication | 0 | 2 | 6 | Lubrication | 0 | 2 | 0 |
| Wages for occasional attendance | 0 | 5 | 0 | Engine man's wages | 1 | 6 | 0 |
| Depreciation at 10 per cent. per annum on cost, £174 | 0 | 6 | 8 | Depreciation at 12½ per cent. per annum on cost, £120 | 0 | 5 | 9 |
| Interest on capital at 5 per cent. per annum on £174 | 0 | 3 | 4 | Interest on capital at 5 per cent. per annum on £120 | 0 | 2 | 3 |
| Weekly expense of gas engine | £2 | 2 | 4 | Weekly expense of steam engine | £2 | 11 | 0 |

# SECTION II.

## HYDRAULIC MEMORANDA: PIPES, PUMPS, WATER POWER, &c.

## SECTION II.

# HYDRAULIC MEMORANDA: PIPES, PUMPS, WATER POWER, &c.

Water is composed of oxygen and hydrogen, in the proportion of one part of hydrogen and eight parts of oxygen, by weight.

### Weight and Capacity of Water.

A cubic inch of water = ·0361 lb.
A cubic foot of water = 62·42 lbs.
A cubic foot of water = ·557 cwt.
A cubic foot of water = ·028 ton.
A cubic foot of water = 6·24 gallons.
1 cwt. of water = 1·8 cubic feet.
1 cwt. of water = 11·2 gallons.
1 ton of water = 35·9 cubic feet.
1 ton of water = 224 gallons.
1 lb. of water = 27·7 cubic inches.
1 lb. of water = 0·16 cubic ft.
1 cylindrical inch of water = ·0284 lb.
1 cylindrical foot of water = 49·10 lbs.
1 gallon of water = 10 lbs.
11·2 gallons of water = 112 lbs.
224 gallons of water = 2240 lbs.
1·8 cubic feet of water = 112 lbs.
35·84 cubic feet of water = 2240 lbs.
277·274 cubic inches = 1 gallon.
353 cylindrical inches = 1 gallon.
Cubic inches multiplied by ·0036 = gallons.
Cubic feet multiplied by 6·24 = gallons.
Cubic inches divided by 277·274 = gallons.
Gallons multiplied by ·16045 = cubic feet.
Cylindrical feet multiplied by 4·895 = gallons.
1 cubic foot of town's sewage = 62·42 lbs.
1 cubic foot of ice at 32° = 58 lbs.
1 lb. of ice at 32° = 30·06 cubic inches.

1 lb. of ice at 32° = ·017 cubic ft.

Water in freezing expands to the extent of $8\frac{1}{2}$ per cent.

The specific heat of ice is one-half the specific heat of water.

Ice 3 inches thick, will bear the passage of infantry; 5 inches thick, of cavalry and light guns.

A cubic foot of fresh snow = 6 lbs.

Snow has twelve times the bulk of water.

A cubic foot of sea water = 64·10 lbs.

Weight of sea water = 1·027 the weight of fresh water.

35 cubic feet of sea water = 1 ton.

1 cubic yard of sea water weighs 15 cwt. 1 qr. 20 lbs.

A column of water 1 inch diameter and 12 inches high = ·341 lb.

A column of water 1 inch square and 12 inches high = ·434 lb.

The capacity of a cylinder 1 inch diameter and 12 inches long = ·034 gallon.

The capacity of a cylinder 12 inches diameter and 12 inches long = 4·895 gallons.

The capacity of a cylinder 1 inch diameter and 1 inch long = ·00283 gallon.

The capacity of a 1-inch cube = ·0036 gallon.

The capacity of a 12-inch cube = 6·24 gallons.

The capacity of a sphere 1 inch diameter = ·00188 gallon.

The capacity of a sphere 12 inches diameter = 3·26 gallons.

The cube of the diameter of a sphere in feet multiplied by 3·26 = gallons.

Or the cube of the diameter of a sphere in inches multiplied by ·00188 = gallons.

A column of water produces approximately a pressure of half a lb. per square inch, for every foot in height.

**Pressure of Water.**—The side of any vessel containing water sustains a pressure = to the area of the side in feet multiplied by half the depth in feet, that product multiplied by 62·5 will give the pressure in lbs. on each side of the vessel.

The pressure in lbs. on the bottom of a vessel is = to the area of the bottom in feet multiplied by the depth of water in feet, that product multiplied by 62·5 will give the pressure in lbs.

**Contents of Cisterns.**—*To find the number of gallons* contained in a cistern. Multiply the length, width, and depth together, all in feet. This will give the contents in cubic feet, which multiply by 6·24, and the product will be the number of gallons. If the dimensions are in inches use ·003607 in place of 6·24.

*Two dimensions of a cistern being given to find the third,* to contain a given number of gallons, multiply the required number of gallons by ·16046 if the dimensions are in feet, or by 277·274 if the dimensions are in inches, and divide the result by the product of the two given dimensions. The quotient will be the third dimension required.

*To find the number of gallons* contained in a cylinder, multiply the square of the diameter in feet by the length in feet of the cylinder, and multiply the product by 4·895; or multiply the square of the diameter in inches by the length in feet, and multiply the product by ·034; or multiply the square of the diameter in inches by the length in inches, and multiply the product by ·00283.

*The diameter of a cylinder* being given, to find the length, multiply the number of gallons by ·2043, and divide the product by the square of the diameter in feet, and the quotient is the length in feet.

*The length of a cylinder* being given, to find the diameter, multiply the number of gallons by ·2043, and divide the product by length in feet, and the square root of the quotient is the diameter in feet. If the dimensions are in inches, use 353 in place of ·2043.

**Reservoirs for Cooling Condensation-Water** for condensing engines should equal in capacity 130 gallons of water per indicated horse-power per hour. The area of the surface of the water should equal 75 square feet per indicated horse-power for an engine working 12 hours per day, or 150 square feet if working 24 hours, or day and night.

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## PUMPS.

**Lifting Pumps.**—When a pump lifts water it withdraws the pressure of the atmosphere from the surface of the water inside the suction-pipe, and the pressure of the atmosphere outside the suction-pipe forces up the water until the pressures inside and outside the suction-pipe become balanced. The distance the water is lifted is equal to the height of a column of water weighing 15 lbs. per square inch of area at its base, which is theoretically 34 feet; but, as it is impossible in practice to make perfect joints and prevent leakage of air, a perfect vacuum is never obtained, and 28 feet is the greatest distance above the level of the water from which a pump will lift water, although at that distance it will be liable to lose its water when the barometer is low. To prevent occasionally having a dry pump, the supply should never be drawn through a greater height than 25 feet; but, as the efficiency of a pump varies with the distance it lifts the water, the suction-pipe should be made as short as possible, and 15 feet is the maximum safe distance above the level of the water for a pump to work well and uniformly and draw its proper quantity of water at each stroke; but if the pump works quickly, better results will be obtained by making the distance 10 feet. The quicker the speed of the pump, the shorter should the suction-pipe be.

**Load on a Hand-worked Pump.**—In a common hand-pump, with lever-handle, the leverage is generally 6 to 1, and the resistance on the handle, exclusive of friction, is found by dividing the weight due to the column of water by 6—the leverage.

**Load on a Hand-Power Lift-Pump, with Crank and Well-Frame.**—The radius of the winch-handle of a well-frame is generally 16 inches, and the leverage is found by dividing the radius of the winch-handle by the throw of the crank (or half-stroke of pump). Thus a pump, with 8-inch stroke, and with 16 inches radius of winch-handle, would have a leverage of 4 to 1, and the weight of the column of water it has to raise, divided by 4, will give the resistance to be overcome, exclusive of friction.

**Load on Hand-Power Geared Well-Frames.**—When gearing is applied to drive the crank of a well-frame, what is gained in power is lost in quantity in a given time. Thus, if a wheel and pinion of 2 to 1 are added to the above frame, only one-half the power will be required, but only one half the quantity of water will be raised at each turn of the handle.

*To find the resistance* in working a geared well-frame, divide the radius of the winch-handle by the throw of the crank (or half-stroke of pump), and multiply the result by the proportion of the wheel and pinion, and with the product divide the weight of the column of water, which will give the resistance to be overcome, exclusive of friction.

*The power exerted by a man* in turning the winch-handle of a pump may be reckoned at 20 lbs. In a single-barrel pump the whole lift comes at one half of the turn of the handle; but in a double-barrel pump it is distributed over the two halves of the turn; and in a treble-barrel pump the work is still more equalised. Therefore, it is easier to work a pump with two barrels than with one barrel, when the united capacity of the two barrels is the same as that of the single barrel.

**Suction and Delivery-Pipes of Pumps.**—The suction-pipe of a pump should always be larger than the delivery-pipe, because the friction has to be overcome in the suction-pipe by the pressure of the atmosphere only; but in the delivery-pipe the friction is overcome by the power of the pump. The suction and delivery pipes should never be less than one-half the diameter of the pump-barrel. A good proportion for the suction-pipe is two-thirds the diameter of barrel. In quick-working pumps it is sometimes necessary to make it as large as the barrel. A long suction-pipe should fall evenly along its length towards the well, as, if any portion of it is higher than the pump-end, a trap will be formed in which air will accumulate, and from which it cannot easily be drawn away. A long suction-pipe should have a retaining or foot-valve placed near the water to prevent it losing its water, and to obviate the charging of the suction-pipe at each stroke.

**Pumps for Hot Water.**—A pump will not lift hot water efficiently, because the steam destroys the vacuum; therefore the pump should be placed at the same level as the supply tank, so that the water may flow into the barrel by its own gravity. The valves of hot-water pumps should be made one-half larger in diameter than the ram, in order to obtain a large escape for the water with a small lift of the valve.

**Force-Pump.**—The barrel of a force-pump should be as close to the ram as possible, otherwise air will accumulate and impair the working of the pump. The diameter of the valves should never be less than three-fourths the diameter of the ram; but it is preferable to make them of the same diameter as the ram, which they should be placed as near to as convenient, and they should only lift sufficiently to deliver their full capacity of water.

**An air-vessel** should be placed on the delivery side of a pump—and also on the suction side of fast-moving pumps the air in which becomes compressed, and its elastic force causes the water to flow uniformly into the barrel, and ensures the barrel being properly and continuously filled at each stroke. The neck of the air-vessel should be long and narrow, to prevent the action of the pump disturbing its water-level. An air-vessel also greatly reduces the percussion and wear and tear of the valves.

**Calculations for Pumps.**—In addition to the weight of the water, allowance must be made for the friction of the pump and the friction of the water in the pipes, and also for the weight of the valves and for the resistance caused by the water passing through the valves, and likewise for the "slip," or water lost by the pump, as all pumps throw considerably less water than their capacity. In the following rules allowance is made for these contingencies.

**Capacity of a Pump.**—The capacity of a pump with piston or bucket is the product of the area of the barrel multiplied by the length of stroke, and the capacity of a pump with a ram is the product of the area of the end of the ram multiplied by the length of stroke.

**Gallons of Water delivered per Stroke.**—Multiply the square of the diameter in inches of the pump-bucket, or ram, by ·034, and by the length of the stroke in feet, and the product will be the number of gallons which the pump will deliver per stroke, provided the barrel gets properly filled with water at each stroke. But as all pumps throw considerably less than their capacity, deduct one-third from the number of gallons thus obtained for leakage, or "slip," and the remainder will be the actual quantity of water delivered per stroke, provided the pump is in first-rate order. But if the pump is of second-rate quality, it will be necessary to deduct one-half instead of one-third for "slip."

**Actual Horse-power of Pumps.**—Find the number of gallons per stroke by the above rule, and multiply it by 10 (the weight of a gallon of water), and by the number of strokes per minute. The product will be the weight of water lifted per minute, which multiply by the height in feet from the water to the point of delivery. The product will be the total work done per minute in foot-lbs. Divide by 21,780, then add $\frac{1}{8}$th for the friction of the engine itself, and the sum will be the actual horse-power of the engine required to drive that pump.

**Nominal Horse-power of a Pump.**—Find the total work done per minute, as in the last rule, and divide it by 32,670, then add $\frac{1}{8}$th for the friction of the engine itself. The product will be the nominal horse-power of the engine required to drive that pump.

In calculating the horse-power of deep-well pumps, the weight of the spears and spear-plates, rods, bucket, &c., must be added to the total work per minute before dividing by the above given divisor.

*The effective work* done by a pump is equal to the product of the weight of the water by the height it is raised, and the efficiency of that pump is the ratio of the effective work to the total work expended in driving it. In ordinary pumps the efficiency is about 66 per cent.

**Diameter of Pump.**—To find the diameter of a pump, multiply ·034 by the length of stroke in feet, then multiply by the number of strokes per minute, and divide the number of gallons to be delivered per minute by the said product. The square root of the quotient will be the diameter of the pump in inches; but as all pumps throw considerably less water than their capacity, add a third to the area of the pump, to allow for leakage or "slip;" this allowance for "slip" only applies to pumps in first-rate order; if the pump is of second-rate quality, it will be necessary to add one-half instead of one-third for slip.

**The length of stroke** of pump, is found thus—Divide 277·27 (the number of cubic inches in one gallon) by the area of the pump-barrel, which will give the length of stroke for each gallon. Multiply this by the number of gallons per stroke, and the product will be the length of stroke in inches of that pump.

The velocity of the water in feet per minute in a pump, is found by multiplying the length of stroke in feet by the number of strokes per minute.

**Centrifugal Pumps** are particularly adapted for irrigation, drainage, and sewage works. The maximum distance they will effectively draw water is 25 feet, but 15 feet will give better results; and the maximum height from surface of the water to the point of delivery to which they will lift water effectively is 70 feet. High lifts require very high velocities and large pumps.

TABLE 7.—HORSE POWER REQUIRED FOR CENTRIFUGAL PUMPS.

| | DIAMETER IN INCHES OF SUCTION AND DELIVERY PIPES. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 16 | 18 |
| Quantity of Water in Gallons delivered per Minute. | 16 | 50 | 100 | 200 | 300 | 500 | 700 | 800 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4200 |
| Horse-power required for each foot in Height which the water is lifted. | ·012 | ·025 | ·056 | ·085 | ·16 | ·25 | ·35 | ·40 | ·50 | ·75 | 1· | 1·2 | 1·3 | 1·6 | 2· |

**Hydraulic Ram.**—This useful self-acting apparatus is used where there is a good flow of water with a moderate fall, to raise a small portion of that flow to a greater height than the fall. About 10 gallons of water must pass through the ram for every gallon raised, and the elevation to which water can be raised by the ram is in proportion to the fall obtainable, generally equal to ten times the fall.

The following are the usual proportions of the supply pipes and delivery pipes to the number of gallons.

| | | | | | |
|---|---|---|---|---|---|
| Number of Gallons to be raised in 24 Hours . . . . . . . | 500 | 1000 | 2500 | 4000 | 6000 |
| Diameter of Fall or Supply Pipe in Inches . . . . . . . . | 1½ | 2 | 2½ | 3 | 4 |
| Diameter of Rising Main or Delivery Pipe in Inches . . . . . | ¾ | 1 | 1½ | 2 | 2 |

The efficiency of hydraulic rams rapidly decreases, as the height to which the water is to be raised increases above the fall, as will be seen from the following table.

TABLE 8.—EFFICIENCY OF HYDRAULIC RAMS.

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of times the height to which the Water is to be raised contains the fall . . | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 25 |
| Efficiency per cent. . | 75 | 72 | 68 | 62 | 57 | 53 | 48 | 43 | 38 | 35 | 32 | 28 | 23 | 17 | 15 | 12 | 0 |

**Speed of Pumps.**—The greatest speed at which water will flow through a suction-pipe, is 500 feet per minute; but, in practice, water should not flow through a suction-pipe at a greater speed than 200 feet per minute to ensure the pump-barrel being properly filled at each stroke, that is 200 feet of the suction-pipe should hold as much water as the pump will deliver per minute, and the pump should work at such a speed that it will deliver per minute the quantity of water contained in 200 feet of its suction-pipe. For pumping engines, the most economical speed is from 4 to 5 strokes per minute, the length of stroke being generally 8 feet for small pumping engines; 10 feet for medium size; and 12 feet for large sizes.

**Proportion of Cocks.**—D = the internal diameter of pipe. Square of plug = D × ·5. Height of square = D × ·5. Length of handle = D × 6. Diameter of plug at the centre = D × 1·25. Length of taper part of plug = D × 2 to 2½ for solid bottom gland cocks, and D × 3 to 3½ for plugs with screw bottom. Height of water-way in plug = D × 1·25. Width of water-way in plug = D × ·7. Taper of plug on each side = 1 inch in 9 inches for small cocks, and 1 inch in 12 inches for large cocks.

TABLE 9.—SHEWING THE WEIGHT OF A COLUMN OF WATER, OR THE LOAD TO BE OVERCOME IN PUMP-BARRELS, EXCLUSIVE OF THE FRICTION IN THE PIPES.

| Perpendicular Height from Bottom. | Diameter of Pump Barrel in Inches. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1½ | 2 | 2½ | 3 | 3½ | 4 | 4½ | 5 | 5½ | 6 | 6½ | 7 | 8 | 9 | 10 | 12 |
| Feet. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | bs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 10 | 8 | 14 | 22 | 32 | 42 | 55 | 69 | 85 | 103 | 123 | 144 | 167 | 218 | 276 | 341 | 492 |
| 20 | 16 | 28 | 43 | 62 | 84 | 109 | 138 | 170 | 206 | 246 | 288 | 333 | 436 | 552 | 680 | 980 |
| 30 | 23 | 42 | 64 | 92 | 125 | 164 | 207 | 255 | 308 | 368 | 432 | 499 | 653 | 826 | 1020 | 1469 |
| 40 | 32 | 55 | 85 | 124 | 167 | 218 | 276 | 340 | 412 | 492 | 575 | 666 | 872 | 1102 | 1360 | 1958 |
| 50 | 39 | 68 | 106 | 153 | 208 | 272 | 345 | 425 | 515 | 614 | 719 | 832 | 1088 | 1377 | 1700 | 2448 |
| 60 | 46 | 82 | 128 | 184 | 250 | 327 | 413 | 510 | 617 | 736 | 862 | 998 | 1306 | 1652 | 2040 | 2937 |
| 70 | 54 | 96 | 149 | 215 | 292 | 382 | 482 | 595 | 720 | 859 | 1006 | 1164 | 1524 | 1928 | 2380 | 3427 |
| 80 | 62 | 109 | 170 | 246 | 333 | 436 | 552 | 680 | 823 | 982 | 1149 | 1332 | 1742 | 2203 | 2720 | 3916 |
| 90 | 69 | 123 | 192 | 276 | 375 | 490 | 620 | 765 | 926 | 1104 | 1293 | 1497 | 1958 | 2478 | 3060 | 4406 |
| 100 | 77 | 136 | 212 | 306 | 416 | 544 | 689 | 850 | 1029 | 1227 | 1436 | 1663 | 2176 | 2754 | 3400 | 4895 |
| 110 | 85 | 150 | 233 | 338 | 458 | 599 | 758 | 935 | 1132 | 1349 | 1580 | 1829 | 2393 | 3029 | 3740 | 5385 |
| 120 | 92 | 164 | 255 | 368 | 500 | 653 | 826 | 1020 | 1234 | 1472 | 1724 | 1996 | 2612 | 3304 | 4079 | 5874 |
| 130 | 99 | 177 | 276 | 398 | 542 | 707 | 895 | 1105 | 1337 | 1595 | 1867 | 2162 | 2829 | 3580 | 4419 | 6364 |
| 140 | 107 | 192 | 297 | 429 | 583 | 762 | 964 | 1190 | 1440 | 1717 | 2012 | 2328 | 3046 | 3855 | 4759 | 6853 |
| 150 | 115 | 204 | 318 | 459 | 624 | 816 | 1033 | 1275 | 1543 | 1840 | 2155 | 2495 | 3264 | 4130 | 5099 | 7343 |
| 160 | 124 | 218 | 340 | 490 | 666 | 870 | 1102 | 1360 | 1646 | 1963 | 2298 | 2662 | 3482 | 4406 | 5439 | 7832 |
| 170 | 130 | 232 | 362 | 520 | 707 | 925 | 1172 | 1445 | 1748 | 2085 | 2442 | 2827 | 3699 | 4681 | 5779 | 8322 |
| 180 | 138 | 245 | 383 | 552 | 749 | 979 | 1239 | 1530 | 1852 | 2208 | 2585 | 2993 | 3916 | 4956 | 6119 | 8812 |
| 190 | 146 | 259 | 404 | 582 | 792 | 1034 | 1308 | 1615 | 1954 | 2331 | 2729 | 3160 | 4134 | 5232 | 6459 | 9301 |
| 200 | 153 | 272 | 426 | 612 | 832 | 1089 | 1378 | 1700 | 2057 | 2453 | 2874 | 3326 | 4352 | 5508 | 6800 | 9792 |

TABLE 10.—SHEWING THE QUANTITY OF WATER DISCHARGED PER MINUTE BY SINGLE-, DOUBLE-, AND TREBLE-BARREL PUMPS AT VARIOUS SPEEDS, EXCLUSIVE OF SLIP.

| Diameter of Pump. | Length of Stroke. | Single Barrel. | | Double Barrel. | | Treble Barrel. | |
|---|---|---|---|---|---|---|---|
| | | 30 Strokes per Minute. | 40 Strokes per Minute. | 30 Strokes per Minute. | 40 Strokes per Minute. | 30 Strokes per Minute. | 40 Strokes per Minute. |
| Inches. | Inches. | Gallons. | Gallons. | Gallons. | Gallons. | Gallons. | Gallons. |
| 1½ | 9 | 1¾ | 2¼ | 3½ | 4½ | 4½ | 6¾ |
| 2 | 9 | 3 | 4 | 6 | 8 | 9 | 12 |
| 2½ | 9 | 4¾ | 6¼ | 9½ | 12 | 14 | 19 |
| 3 | 9 | 6¾ | 9 | 13¾ | 18 | 20 | 27 |
| 3½ | 9 | 9¼ | 12½ | 18¾ | 25 | 28 | 37 |
| 4 | 9 | 12¼ | 16 | 24½ | 32 | 36 | 48 |
| 4½ | 9 | 15½ | 20¾ | 32 | 42 | 46 | 62 |
| 5 | 9 | 19 | 25½ | 38 | 50 | 57 | 76 |
| 5½ | 9 | 23¼ | 32 | 46½ | 62 | 69 | 92 |
| 6 | 9 | 27½ | 37 | 55 | 73 | 82 | 110 |
| 2 | 10 | 3½ | 4½ | 6 | 9 | 10 | 13 |
| 2½ | 10 | 5¼ | 7 | 10 | 14 | 15 | 22 |
| 3 | 10 | 7½ | 10 | 15 | 20 | 22 | 30 |
| 3½ | 10 | 10½ | 13¾ | 20 | 27 | 32 | 42 |
| 4 | 10 | 13½ | 18 | 27 | 36 | 40 | 54 |
| 4½ | 10 | 17 | 23 | 34 | 45 | 52 | 68 |
| 5 | 10 | 22 | 28 | 42 | 56 | 63 | 84 |
| 5½ | 10 | 25½ | 34 | 51 | 68 | 77 | 102 |
| 6 | 10 | 30½ | 40 | 62 | 82 | 92 | 122 |
| 2 | 12 | 4 | 5 | 8 | 10 | 12 | 16 |
| 2½ | 12 | 6¼ | 8 | 12 | 17 | 19 | 25 |
| 3 | 12 | 9 | 12 | 18 | 24 | 27 | 36 |
| 3½ | 12 | 12½ | 16 | 24 | 33 | 37 | 50 |
| 4 | 12 | 16¼ | 22 | 32 | 43 | 49 | 65 |
| 4½ | 12 | 20½ | 27 | 42 | 55 | 62 | 82 |
| 5 | 12 | 25¼ | 33 | 50 | 68 | 76 | 100 |
| 5½ | 12 | 30¾ | 42 | 62 | 82 | 92 | 123 |
| 6 | 12 | 36½ | 49 | 73 | 97 | 110 | 146 |
| 6½ | 12 | 43 | 57 | 86 | 114 | 129 | 172 |
| 7 | 12 | 50 | 66 | 100 | 134 | 149 | 199 |
| 7½ | 12 | 57 | 76 | 114 | 152 | 171 | 229 |
| 8 | 12 | 65 | 87 | 130 | 174 | 195 | 262 |
| 9 | 12 | 82 | 110 | 165 | 220 | 246 | 330 |
| 10 | 12 | 102 | 134 | 202 | 268 | 303 | 404 |
| 12 | 12 | 146 | 195 | 294 | 390 | 440 | 588 |

**Water Supply.**—15 gallons per head per day, for domestic purposes; 10 gallons per head per day, for manufacturing purposes; 5 gallons per actual horse-power per hour, for feeding boilers; 5 gallons per nominal horse-power per minute, for injection water for condensing engines.

TABLE 11.—SHEWING THE QUANTITY OF WATER IN GALLONS DELIVERED AT EACH STROKE OF A PUMP.

| Diameter of Pump. | Length of Stroke of the Pump in Inches. | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 16 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 72 |
| Inches. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. | Gall. |
| 1 | ·008 | ·011 | ·014 | ·017 | ·02 | ·022 | ·025 | ·028 | ·031 | ·034 | ·04 | ·045 | ·05 | ·068 | ·085 | ·102 | | | | | |
| 1¼ | ·013 | ·017 | ·021 | ·026 | ·03 | ·035 | ·04 | ·044 | ·048 | ·053 | ·061 | ·07 | ·08 | ·106 | ·132 | ·160 | | | | | |
| 1½ | ·019 | ·025 | ·031 | ·038 | ·044 | ·05 | ·057 | ·063 | ·07 | ·076 | ·09 | ·101 | ·114 | ·153 | ·191 | ·230 | | | | | |
| 1¾ | ·026 | ·034 | ·042 | ·052 | ·06 | ·07 | ·078 | ·086 | ·095 | ·104 | ·121 | ·138 | ·156 | ·208 | ·260 | ·312 | | | | | |
| 2 | ·034 | ·044 | ·055 | ·067 | ·08 | ·09 | ·10 | ·113 | ·124 | ·135 | ·158 | ·181 | ·20 | ·272 | ·340 | ·407 | | | | | |
| 2¼ | ·043 | ·056 | ·070 | ·086 | ·10 | ·11 | ·13 | ·143 | ·157 | ·172 | ·20 | ·22 | ·25 | ·344 | ·430 | ·51 | | | | | |
| 2½ | ·053 | ·070 | ·086 | ·10 | ·12 | ·14 | ·16 | ·17 | ·19 | ·21 | ·24 | ·28 | ·31 | ·424 | ·531 | ·637 | | | | | |
| 3 | ·076 | ·100 | ·125 | ·15 | ·17 | ·20 | ·22 | ·25 | ·28 | ·30 | ·35 | ·4 | ·45 | ·611 | ·764 | ·917 | 1·06 | 1·22 | 1·37 | 1·52 | 1·83 |
| 3½ | | | | ·20 | ·24 | ·27 | ·31 | ·34 | ·38 | ·41 | ·48 | ·55 | ·62 | ·832 | 1·04 | 1·25 | 1·45 | 1·66 | 1·87 | 2·08 | 2·50 |
| 4 | | | | ·27 | ·31 | ·36 | ·40 | ·45 | ·50 | ·54 | ·63 | ·72 | ·81 | 1·09 | 1·36 | 1·63 | 1·90 | 2·17 | 2·44 | 2·72 | 3·26 |
| 4½ | | | | ·34 | ·4 | ·45 | ·51 | ·57 | ·63 | ·68 | ·8 | ·91 | 1·0 | 1·37 | 1·72 | 2·06 | 2·40 | 2·75 | 3·09 | 3·44 | 4·12 |
| 5 | | | | | ·49 | ·56 | ·63 | ·71 | ·77 | ·85 | ·92 | 1·13 | 1·27 | 1·70 | 2·12 | 2·55 | 2·97 | 3·40 | 3·82 | 4·25 | 5·10 |
| 6 | | | | | | ·81 | ·92 | 1·02 | 1·12 | 1·22 | 1·42 | 1·63 | 1·83 | 2·44 | 3·05 | 3·67 | 4·28 | 4·89 | 5·50 | 6·11 | 7·34 |
| 7 | | | | | | | 1·25 | 1·38 | 1·52 | 1·66 | 1·94 | 2·22 | 2·50 | 3·33 | 4·16 | 5·00 | 5·82 | 6·66 | 7·50 | 8·32 | 9·99 |
| 8 | | | | | | | | 1·81 | 2·0 | 2·17 | 2·53 | 2·90 | 3·26 | 4·35 | 5·43 | 6·52 | 7·61 | 8·70 | 9·78 | 10·87 | 13·05 |
| 9 | | | | | | | | | 2·52 | 2·75 | 3·21 | 3·67 | 4·13 | 5·50 | 6·88 | 8·26 | 9·63 | 11·01 | 12·38 | 13·76 | 16·52 |
| 10 | | | | | | | | | | 3·40 | 3·96 | 4·53 | 5·09 | 6·80 | 8·50 | 10·20 | 11·90 | 13·60 | 15·30 | 17·00 | 20·40 |
| 11 | | | | | | | | | | | 4·80 | 5·48 | 6·17 | 8·22 | 10·27 | 12·33 | 14·38 | 16·45 | 18·50 | 20·55 | 24·67 |
| 12 | | | | | | | | | | | | 6·52 | 7·34 | 9·79 | 12·23 | 14·68 | 17·13 | 19·58 | 22·02 | 24·47 | 29·37 |
| 13 | | | | | | | | | | | | | 8·61 | 11·49 | 14·36 | 17·23 | 20·10 | 22·98 | 25·85 | 28·72 | 34·47 |
| 14 | | | | | | | | | | | | | 10·0 | 13·32 | 16·65 | 19·98 | 23·31 | 26·65 | 29·97 | 33·31 | 39·97 |
| 15 | | | | | | | | | | | | | 11·5 | 15·29 | 19·11 | 22·94 | 26·76 | 30·59 | 34·41 | 38·23 | 45·89 |
| 16 | | | | | | | | | | | | | 13·0 | 17·40 | 21·76 | 26·11 | 30·46 | 34·80 | 39·16 | 43·51 | 52·22 |
| 17 | | | | | | | | | | | | | 14·7 | 19·65 | 24·56 | 29·47 | 34·38 | 39·30 | 44·21 | 49·12 | 58·94 |
| 18 | | | | | | | | | | | | | 16·5 | 22·02 | 27·53 | 33·04 | 38·54 | 44·05 | 49·55 | 55·06 | 66·08 |
| 19 | | | | | | | | | | | | | 18·4 | 24·54 | 30·67 | 36·81 | 42·94 | 49·08 | 55·21 | 61·35 | 73·62 |
| 20 | | | | | | | | | | | | | 20·4 | 27·19 | 33·98 | 40·79 | 47·59 | 54·39 | 61·18 | 67·98 | 81·58 |
| 22 | | | | | | | | | | | | | 24·6 | 32·90 | 41·13 | 49·36 | 57·58 | 65·81 | 74·03 | 82·25 | 98·72 |
| 24 | | | | | | | | | | | | | 29·3 | 39·16 | 48·95 | 58·74 | 68·53 | 78·32 | 88·10 | 97·90 | 117·47 |

**The Strength of Steam-Cylinders, Water-Cylinders**, pipes, and tubes of all kinds subject to internal pressure, may be found by the following rules. In the case of steam cylinders, allowance must be made for wear and for boring and re-boring.

**Thickness of Metal for Pipes.**—*Rule:* Multiply the working pressure inside the pipe in lbs. per square inch, by the internal radius of the pipe in inches, and divide the product by the safe working tension given in the table below for the material of which the pipe is made, to which quotient add the constant number C., and the result will be the thickness of the pipe in inches. The value of C. ranges from ·13 to 1·0, according to circumstances, for cast-iron pipes for water, C. is ·3; and for steam-pipes ·5, the working pressure in each case being taken at 133 lbs. per square inch, to allow for contingencies in making stock sizes of pipes.

Example: required the thickness of a cast-iron pipe 8 inches in diameter, suitable for a working head of 300 feet water-pressure, or 133 lbs. per square inch, then $= \frac{133 \text{ lbs. pressure} \times 4 \text{ (radius of pipe)}}{2500 \text{ safe working tension of cast-iron}} = \cdot 212 + \cdot 3$ $= \cdot 512$ inches thickness.

**Bursting Pressure of Pipes.**—*Rule:* Multiply the bursting tension in lbs. per square inch—given in the table below—of the metal of which the pipe is made, by the thickness of metal in inches, and divide the product by the internal radius of the pipe in inches, the result will be the bursting pressure in lbs. per square inch,

Example, required the bursting pressure of the 8-inch pipe given in the last example, then, $\frac{15000 \text{ bursting tension} \times \cdot 512 \text{ thickness of pipe}}{4 \text{ inches internal radius of pipe}} =$ 1920 lbs. bursting pressure.

TABLE 12.—STRENGTH OF MATERIALS FOR PIPES FOR THE ABOVE RULES.

| Material of which the Pipe, or Tube, or Cylinder is composed. | Bursting Tension in lbs. | Safe Working Tension in lbs. |
|---|---|---|
| Mild Bessemer-Steel | 71680 | 11940 |
| Phosphor-Bronze | 56000 | 9330 |
| Homogeneous Metal | 56000 | 9330 |
| Lowmoor or Best Yorkshire Iron | 53760 | 8960 |
| Solid-Drawn Wrought-Iron Tubes | 49200 | 8200 |
| Good Ordinary Wrought-Iron | 47040 | 7840 |
| Copper, Wrought | 33600 | 5600 |
| Best Bronze | 33600 | 5600 |
| Gun-Metal | 31360 | 5200 |
| Good Brass | 18000 | 3000 |
| Common Brass | 16000 | 2670 |
| Cast-Iron | 15000 | 2500 |
| Zinc | 6720 | 1120 |
| Lead | 2240 | 370 |

## CAST-IRON SOCKET-PIPES FOR WATER.

**Pipes** should be cast from good grey metal, twice run, of such quality that a bar of the same 2 inches deep × 1 inch thick placed upon supports 3 feet apart will not break with a less load than from 28 to 30 cwt. suspended at the centre, which weight will cause a deflection of about $\frac{3}{8}$ inch.

**Strength of Metal.**—The tenacity of the cast-iron of which pipes are usually made, averages 15000 lbs. per square inch, which divided by the factor of safety, 6, gives a working strength of 2500 lbs. per square inch.

**Thickness of Metal of Pipes.**—Besides making the thickness sufficient to bear the water pressure, allowance must be made for hydraulic shocks due to the closing of cocks, &c., as well as for the strain due to weights falling upon, or passing over them after they are laid underground; the following two rules are used by makers of water-pipes, both of which give good and nearly the same results.

*Rule* 1.—Multiply the internal diameter of the pipe in inches by the working head in feet, divide the product by 10,000, and add the constant number, ·30, to the result, which will give the thickness of metal (cast-iron) in inches.

*Rule* 2.—Multiply the working pressure in lbs. per square inch by the internal radius of the pipe in inches, and divide the product by the working strength of the metal 2500, then add the constant number ·30 to the result, which will give the thickness of the metal of the pipe in inches; this constant number is added for the allowance to be made for shocks, &c., mentioned above, and may be varied to suit circumstances.

**The Depth of Socket** is varied a little by different iron founders; a good proportion is to make the inside depth according to the following rule. Multiply the internal diameter of the pipe by ·13, and add the constant number 3 to the result. The space for the lead joint should be $\frac{5}{16}$ inch for small pipes, $\frac{3}{8}$ inch for medium-sized pipes, $\frac{1}{2}$ inch for large pipes, and $\frac{3}{4}$ inch for very large pipes.

**Testing Pipes.**—Pipes should be tested to double their working pressure—but not beyond that—otherwise the metal is liable to be strained and weakened; and, while under pressure, they should be struck moderately hard with a hammer to represent the shocks they will be subject to after being laid underground.

Deviation in thickness and weight.—A deviation in thickness of $\frac{1}{16}$ inch for small, and $\frac{1}{8}$ inch for medium sized, and $\frac{3}{16}$ for large sizes, is sometimes permitted, and a deviation in weight of about 1 lb. per inch in diameter is permitted.

**Weight of Socket-Pipes.**—The weights of ordinary sizes of pipes for water are given in Table 13.

The first two sizes are suitable for a working head of 100 feet water pressure, the $1\frac{1}{4}$ to 9-inch pipes are suitable for 150 feet water-pressure, and the pipes above that size are suitable for a working head of 300 feet water-pressure—the proof strain being double these quantities.

TABLE 13.—WEIGHT OF ORDINARY SIZES OF CAST-IRON SOCKET-PIPES.

| Internal Diameter in Inches. | Length of Pipe, exclusive of Socket. | Thickness of Metal in Inches. | Average Weight of Pipe. | | | Internal Diameter in Inches. | Length of Pipe, exclusive of Socket. | Thickness of Metal in Inches. | Average Weight of Pipe. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feet. | | cwt. | qr. | lb. | | Feet. | | cwt. | qr. | lb. |
| $\frac{3}{4}$ | $4\frac{1}{2}$ | $\frac{7}{32}$ | 0 | 0 | 16 | 10 | 9 | $\frac{9}{16}$ | 5 | 0 | 0 |
| 1 | 6 | $\frac{1}{4}$ | 0 | 0 | 24 | 11 | 9 | $\frac{9}{16}$ | 5 | 2 | 4 |
| $1\frac{1}{4}$ | 6 | $\frac{1}{4}$ | 0 | 1 | 0 | 12 | 9 | $\frac{5}{8}$ | 6 | 2 | 10 |
| $1\frac{1}{2}$ | 6 | $\frac{1}{4}$ | 0 | 1 | 4 | 13 | 9 | $\frac{5}{8}$ | 7 | 0 | 6 |
| $1\frac{3}{4}$ | 6 | $\frac{9}{32}$ | 0 | 1 | 10 | 14 | 9 | $\frac{11}{16}$ | 8 | 1 | 24 |
| 2 | 6 | $\frac{9}{32}$ | 0 | 1 | 15 | 15 | 9 | $\frac{11}{16}$ | 9 | 0 | 22 |
| $2\frac{1}{4}$ | 6 | $\frac{9}{32}$ | 0 | 1 | 21 | 16 | 9 | $\frac{3}{4}$ | 10 | 2 | 0 |
| $2\frac{1}{2}$ | 6 | $\frac{5}{16}$ | 0 | 2 | 1 | 18 | 9 | $\frac{13}{16}$ | 13 | 2 | 21 |
| 3 | 9 | $\frac{5}{16}$ | 0 | 3 | 22 | 20 | 9 | $\frac{7}{8}$ | 15 | 1 | 18 |
| $3\frac{1}{2}$ | 9 | $\frac{5}{16}$ | 1 | 0 | 16 | 21 | 9 | $\frac{7}{8}$ | 16 | 1 | 0 |
| 4 | 9 | $\frac{11}{32}$ | 1 | 1 | 16 | 24 | 9 | 1 | 18 | 2 | 14 |
| $4\frac{1}{4}$ | 9 | $\frac{11}{32}$ | 1 | 1 | 23 | 27 | 9 | $1\frac{1}{16}$ | 25 | 2 | 4 |
| $4\frac{1}{2}$ | 9 | $\frac{11}{32}$ | 1 | 2 | 14 | 30 | 9 | $1\frac{3}{16}$ | 31 | 2 | 16 |
| 5 | 9 | $\frac{3}{8}$ | 1 | 3 | 15 | 33 | 9 | $1\frac{1}{4}$ | 36 | 2 | 20 |
| $5\frac{1}{2}$ | 9 | $\frac{3}{8}$ | 2 | 1 | 0 | 36 | 9 | $1\frac{3}{8}$ | 44 | 0 | 14 |
| 6 | 9 | $\frac{3}{8}$ | 2 | 1 | 15 | 39 | 9 | $1\frac{7}{16}$ | 50 | 1 | 0 |
| 7 | 9 | $\frac{7}{16}$ | 2 | 3 | 15 | 42 | 9 | $1\frac{9}{16}$ | 59 | 0 | 0 |
| 8 | 9 | $\frac{1}{2}$ | 3 | 1 | 15 | 45 | 9 | $1\frac{5}{8}$ | 66 | 0 | 10 |
| 9 | 9 | $\frac{1}{2}$ | 4 | 0 | 0 | 48 | 9 | $1\frac{3}{4}$ | 75 | 2 | 0 |

NOTE.—The Length does not include the Length of the Socket, but the Weight includes that of the Socket.

Table 14.—WEIGHT OF ORDINARY STOCK SIZES OF CAST-IRON FLANGE-PIPES FOR WATER, PROVED TO THE SAME WATER PRESSURE AS THE SOCKET PIPES GIVEN IN TABLE 13.

| Size inside Diameter. | Length of Pipe. | Thickness of Metal. | Diameter of Flange. | Thickness of Flange. | Number of Bolts. | Diameter of Bolts. | Diameter of circle of Centre of Bolts. | Average Weight of Pipe. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Inches. | Feet. | Inches. | Inches. | Inches. | Bolts. | Inches. | Inches. | cwt. | qr. | lb. |
| $1\frac{1}{2}$ | 6 | $\frac{1}{4}$ | $4\frac{3}{4}$ | $\frac{1}{2}$ | 3 | $\frac{3}{8}$ | $3\frac{3}{8}$ | 0 | 1 | 6 |
| $1\frac{3}{4}$ | 6 | $\frac{9}{32}$ | $5\frac{1}{2}$ | $\frac{9}{16}$ | 3 | $\frac{1}{2}$ | 4 | 0 | 1 | 16 |
| 2 | 6 | $\frac{9}{32}$ | $6\frac{1}{2}$ | $\frac{9}{16}$ | 4 | $\frac{1}{2}$ | $4\frac{3}{4}$ | 0 | 1 | 18 |
| $2\frac{1}{2}$ | 6 | $\frac{5}{16}$ | 7 | $\frac{5}{8}$ | 4 | $\frac{1}{2}$ | $5\frac{1}{2}$ | 0 | 2 | 13 |
| 3 | 9 | $\frac{5}{16}$ | $7\frac{1}{2}$ | $\frac{11}{16}$ | 4 | $\frac{5}{8}$ | 6 | 1 | 0 | 0 |
| $3\frac{1}{2}$ | 9 | $\frac{5}{16}$ | $8\frac{1}{2}$ | $\frac{11}{16}$ | 4 | $\frac{5}{8}$ | 7 | 1 | 0 | 22 |
| 4 | 9 | $\frac{11}{32}$ | $9\frac{1}{2}$ | $\frac{3}{4}$ | 4 | $\frac{3}{4}$ | $7\frac{3}{4}$ | 1 | 1 | 20 |
| $4\frac{1}{2}$ | 9 | $\frac{11}{32}$ | 10 | $\frac{3}{4}$ | 4 | $\frac{3}{4}$ | $8\frac{1}{4}$ | 1 | 3 | 0 |
| 5 | 9 | $\frac{3}{8}$ | $10\frac{1}{2}$ | $\frac{7}{8}$ | 4 | $\frac{3}{4}$ | $8\frac{3}{4}$ | 2 | 0 | 15 |
| 6 | 9 | $\frac{3}{8}$ | 12 | $\frac{7}{8}$ | 6 | $\frac{3}{4}$ | 10 | 2 | 3 | 0 |
| 7 | 9 | $\frac{7}{16}$ | 14 | 1 | 6 | $\frac{3}{4}$ | $11\frac{3}{4}$ | 3 | 0 | 23 |
| 8 | 9 | $\frac{1}{2}$ | 15 | 1 | 6 | $\frac{7}{8}$ | $12\frac{3}{4}$ | 3 | 3 | 0 |
| 9 | 9 | $\frac{1}{2}$ | $16\frac{1}{2}$ | $1\frac{1}{16}$ | 6 | $\frac{7}{8}$ | $14\frac{1}{4}$ | 4 | 2 | 20 |
| 10 | 9 | $\frac{9}{16}$ | $17\frac{1}{2}$ | $1\frac{1}{8}$ | 6 | $\frac{7}{8}$ | $15\frac{1}{4}$ | 5 | 3 | 0 |
| 11 | 9 | $\frac{9}{16}$ | 19 | $1\frac{3}{16}$ | 6 | 1 | $16\frac{3}{4}$ | 6 | 0 | 10 |
| 12 | 9 | $\frac{5}{8}$ | 20 | $1\frac{1}{4}$ | 6 | 1 | $17\frac{3}{4}$ | 7 | 1 | 0 |

Table 15.—WEIGHT OF EXTRA STRONG CAST-IRON FLANGE-PIPES.

| Size inside Diameter. | Length of Pipe. | Thickness of Metal. | Diameter of Flange. | Thickness of Flange. | Number of Bolts. | Diameter of Bolts. | Diameter of circle of Centre of Bolts. | Average Weight of Pipe. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Inches. | Feet. | Inches. | Inches. | Inches. | Bolts. | Inches. | Inches. | cwt. | qr. | lb. |
| 2 | 6 | $\frac{3}{8}$ | $6\frac{1}{2}$ | $\frac{9}{16}$ | 4 | $\frac{1}{2}$ | $4\frac{3}{4}$ | 0 | 2 | 3 |
| $2\frac{1}{2}$ | 6 | $\frac{3}{8}$ | 7 | $\frac{5}{8}$ | 4 | $\frac{1}{2}$ | $5\frac{1}{2}$ | 0 | 3 | 4 |
| 3 | 9 | $\frac{3}{8}$ | $7\frac{1}{2}$ | $\frac{11}{16}$ | 4 | $\frac{5}{8}$ | 6 | 1 | 0 | 10 |
| $3\frac{1}{2}$ | 9 | $\frac{7}{16}$ | $8\frac{1}{2}$ | $\frac{11}{16}$ | 4 | $\frac{5}{8}$ | 7 | 1 | 2 | 8 |
| 4 | 9 | $\frac{1}{2}$ | $9\frac{1}{2}$ | $\frac{3}{4}$ | 4 | $\frac{3}{4}$ | $7\frac{3}{4}$ | 1 | 3 | 6 |
| 5 | 9 | $\frac{1}{2}$ | $10\frac{1}{2}$ | $\frac{7}{8}$ | 4 | $\frac{3}{4}$ | $8\frac{3}{4}$ | 2 | 1 | 15 |
| 6 | 9 | $\frac{5}{8}$ | 12 | $\frac{7}{8}$ | 6 | $\frac{3}{4}$ | 10 | 3 | 2 | 5 |
| 7 | 9 | $\frac{5}{8}$ | 14 | 1 | 6 | $\frac{3}{4}$ | $11\frac{3}{4}$ | 4 | 1 | 15 |
| 8 | 9 | $\frac{3}{4}$ | 15 | 1 | 6 | $\frac{7}{8}$ | $12\frac{3}{4}$ | 5 | 2 | 10 |
| 9 | 9 | $\frac{3}{4}$ | $16\frac{1}{2}$ | $1\frac{1}{16}$ | 6 | $\frac{7}{8}$ | $14\frac{1}{4}$ | 6 | 1 | 13 |
| 10 | 9 | $\frac{3}{4}$ | $17\frac{1}{2}$ | $1\frac{1}{8}$ | 6 | $\frac{7}{8}$ | $15\frac{1}{4}$ | 7 | 0 | 0 |
| 11 | 9 | $\frac{7}{8}$ | 19 | $1\frac{3}{16}$ | 6 | 1 | $16\frac{3}{4}$ | 9 | 0 | 0 |
| 12 | 9 | $\frac{7}{8}$ | 20 | $1\frac{1}{4}$ | 6 | 1 | $17\frac{3}{4}$ | 9 | 3 | 8 |
| 13 | 9 | $\frac{7}{8}$ | 21 | $1\frac{1}{4}$ | 6 | 1 | $18\frac{3}{4}$ | 10 | 2 | 0 |
| 14 | 9 | $\frac{7}{8}$ | 22 | $1\frac{1}{4}$ | 8 | $1\frac{1}{8}$ | $19\frac{3}{4}$ | 11 | 1 | 0 |
| 15 | 9 | $\frac{7}{8}$ | 23 | $1\frac{1}{4}$ | 8 | $1\frac{1}{8}$ | $20\frac{3}{4}$ | 12 | 1 | 0 |
| 16 | 9 | $\frac{7}{8}$ | $24\frac{1}{2}$ | $1\frac{5}{16}$ | 8 | $1\frac{1}{8}$ | 22 | 12 | 3 | 10 |

**Weight of Pipes and Cylinders.**—A simple rule to find the weight of pipes and cylinders of cast-iron is:—From the square of the outside diameter subtract the square of the inside diameter in inches, multiply the result by 7 and divide that product by 3, which will give the weight in lbs. approximately of one foot in length of the pipe. To find the exact weight, use 7·4 as a multiplier instead of 7 given above.

To find the weight of pipes and cylinders of other metals, multiply the result found by the above rule by 1·05 for wrought iron; 1·08 for steel; 1·2 for gun metal; 1·15 for brass; 1·21 for copper; 1·004 for tin; 1·56 for lead; and by ·988 for zinc.

**Contents of Pipes.**—To find the number of gallons contained in a circular pipe, multiply the square of the diameter in inches by ·034; the product will be the contents in gallons in a foot length of pipe.

To find the weight of water in lbs. in a circular pipe 1 foot long, square the diameter in inches and multiply the result by ·34.

To find the weight of water in lbs. in a pipe 3 feet long, square the diameter in inches.

**Thickness of Cast-Iron Gas-Pipes.**—The thickness of metal given in Table 13 for water pipes, is also suitable for gas pipes up to 6 inches diameter, but above that size, the thickness is too great for pipes for this purpose, and the correct thickness of metal for cast-iron gas-pipes may be obtained by multiplying the thickness given in that Table,

by ·86 for cast-iron pipes of from 7 to 13 inches diameter.
·76 Do. Do. 14 to 20 Do.
·70 Do. of 21 inches diameter and upwards.

Table 16.—Shewing the Contents in Gallons and Weight in lbs. of Water in Pipes and Wells 1 foot in Depth.

| Diameter in Inches. | Number of Gallons. | Weight in lbs. | Diameter in Feet. | Inches. | Number of Gallons. | Weight in lbs. |
|---|---|---|---|---|---|---|
| 1 | ·034 | ·34 | 1 | 9 | 14·99 | 149·94 |
| 2 | ·13 | 1·36 | 1 | 10 | 16·45 | 164·56 |
| 3 | ·30 | 3·06 | 1 | 11 | 17·88 | 178·86 |
| 4 | ·54 | 5·44 | 2 | 0 | 19·58 | 195·84 |
| 5 | ·85 | 8·50 | 2 | 6 | 30·60 | 306·00 |
| 6 | 1·22 | 12·24 | 3 | 0 | 44·06 | 440·64 |
| 7 | 1·66 | 16·66 | 3 | 6 | 59·97 | 599·76 |
| 8 | 2·17 | 21·76 | 4 | 0 | 78·33 | 783·30 |
| 9 | 2·75 | 27·54 | 4 | 6 | 99·14 | 991·44 |
| 10 | 3·4 | 34·00 | 5 | 0 | 122·40 | 1224·00 |
| 11 | 4·11 | 41·14 | 6 | 0 | 176·25 | 1762·56 |
| 12 | 4·89 | 48·96 | 7 | 0 | 239·90 | 2399·04 |
| 13 | 5·74 | 57·46 | 8 | 0 | 313·34 | 3133·44 |
| 14 | 6·64 | 66·64 | 9 | 0 | 396·57 | 3965·76 |
| 15 | 7·65 | 76·50 | 10 | 0 | 489·60 | 4896·00 |
| 16 | 8·70 | 87·04 | 12 | 0 | 705·02 | 7050·24 |
| 17 | 9·82 | 98·26 | 15 | 0 | 1101·60 | 11016·00 |
| 18 | 11·01 | 110·16 | 18 | 0 | 1586·30 | 15863·04 |
| 19 | 12·27 | 122·74 | 20 | 0 | 1958·40 | 19584·00 |
| 20 | 13·60 | 136·00 | | | | |

To find the pressure in lbs. per square inch of water in pipes, multiply the head of water in feet by ·443.

Table 17.—Shewing the Pressure in Pipes with Various Heads of Water.

| Head of Water in Feet. | Pressure per Square Inch in lbs. | Head of Water in Feet. | Pressure per Square Inch in lbs. | Head of Water in Feet. | Pressure per Square Inch in lbs. | Head of Water in Feet. | Pressure per Square Inch in lbs. |
|---|---|---|---|---|---|---|---|
| 10 | 4·43 | 160 | 70·88 | 310 | 137·33 | 460 | 203·78 |
| 20 | 8·86 | 170 | 75·31 | 320 | 141·76 | 470 | 208·21 |
| 30 | 13·29 | 180 | 79·74 | 330 | 146·19 | 480 | 212·64 |
| 40 | 17·72 | 190 | 84·17 | 340 | 150·62 | 490 | 217·07 |
| 50 | 22·15 | 200 | 88·60 | 350 | 155·05 | 500 | 221·50 |
| 60 | 26·58 | 210 | 93·03 | 360 | 159·48 | 550 | 243·65 |
| 70 | 31·01 | 220 | 97·46 | 370 | 163·91 | 600 | 265·80 |
| 80 | 35·44 | 230 | 101·89 | 380 | 168·34 | 650 | 287·95 |
| 90 | 39·87 | 240 | 106·32 | 390 | 172·77 | 700 | 310·10 |
| 100 | 44·30 | 250 | 110·75 | 400 | 177·20 | 750 | 332·25 |
| 110 | 48·73 | 260 | 115·18 | 410 | 181·63 | 800 | 354·40 |
| 120 | 53·16 | 270 | 119·61 | 420 | 186·06 | 850 | 376·55 |
| 130 | 57·59 | 280 | 124·04 | 430 | 190·49 | 900 | 398·70 |
| 140 | 62·02 | 290 | 128·47 | 440 | 194·92 | 950 | 420·85 |
| 150 | 66·45 | 300 | 132·90 | 450 | 199·35 | 1000 | 443·00 |

**Injectors for Feeding Boilers.**—For the average temperature of feed and height of lift of ordinary injectors, the quantity of water delivered in gallons per hour by an ordinary injector feeding the boiler from whence its steam supply is derived, may be found by Mr. Hey's rule. Multiply the square of the diameter of the injector nozzle in millimetres by the square root of the pressure of the steam in lbs. per square inch, and multiply the product by the constant number 2.

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## WATER WHEELS.

**The Driving Power** of flowing water being gravity, the power exerted by a weight of water falling from a given height is equal to the product of the weight of water in lbs., and the height of the fall in feet. But, in driving a waterwheel, a percentage of the power is absorbed by friction, by overcoming the resistance of the waterwheel, and by the loss due to leakage. The efficicncy or power given out varies from 30 to 75 per cent. of the power of the water, according to the class of waterwheel employed. A horse-power being 33,000 lbs. raised one foot high in a minute, or 550 foot lbs. per second, *the theoretical force in a fall of water* is found thus:—Multiply the weight of a cubic foot of water, 62·4 lbs., by the number of cubic feet falling per second; multiply that product by the height of the fall in feet, and divide the result by 550; the quotient will be the available theoretical horse power of that fall.

**Overshot Water-wheels.**—The water is generally laid on this class of wheel at a little below the top of the wheel from the side at which it approaches. The current of water being reversed in the pentrough, it is called a pitch-back wheel; diameter of wheel from 1 to $1\frac{1}{3}$ the height of fall; speed of the circumference 4 to 5 feet per second; efficiency from 60 to 70 per cent. of the waterpower expended.

**High-Breast Water-wheel.**—The water is laid on to this class of wheel about 27° from the top; diameter of wheel $1\frac{1}{2}$ times the height of the fall; speed of the circumference 5 feet per second; efficiency 75 per cent. of the waterpower expended.

**Breast Water-wheel.**—The water is laid on to this class of wheel a little below the level of its axis; diameter of wheel equal to about twice the height of fall; speed of the circumference from 5 to 6 feet per second; efficiency from 55 to 60 per cent. of the waterpower expended.

**Undershot Water-wheels** with radial floats are used when the fall is under 5 feet; diameter of wheel from 12 to 20 feet; speed of the circumference = ·50 of the velocity of the water; efficiency from 25 to 33 per cent. of the waterpower expended.

**Paddle Water-wheel.**—Wheels of this class are fixed on boats moored in an open current; diameter of wheel from 14 to 20 feet; speed of the circumference = ·50 of the velocity of the water; efficiency from 25 to 33 per cent. of the waterpower expended.

**Poncelet's undershot Water-wheel** with curved floats is suitable for falls under 6 feet; diameter of wheel from 10 to 20 feet; speed of circumference from 8 to 12 feet per second; efficiency 55 per cent. of the water-power expended.

**Diameter of the Journals** or necks of cast-iron main shafts of water-wheels.—*Rule* to find: Multiply three times the width in feet of the water-wheel by its diameter in feet, and the cube root of the product will be the diameter in inches of the neck or journal. Example: required the diameter of the neck of a main shaft for a water-wheel of 15 feet wide and 20 feet in diameter; then $15 \times 3 \times 20 = 900$; and $\sqrt[3]{900} = 9·65$ inches, diameter of neck.

Length of neck or journal = $1\frac{1}{2}$ times the diameter.

**Horse-power of Water-wheels.**—To find the effective power of a water-wheel.—*Rule:* Multiply the quantity of water expended in cubic feet per second by the effective height of the fall in feet, and divide the product by one of the following divisors:—viz., 11·7 for high breast water-wheels; 13 for overshot; 15 for breast; and 22 for undershot water-wheels. Example: required the effective horse-power of a high breast water-wheel requiring 20 cubic feet of water per second, the effective height of fall being 29 feet 3 inches; then, $\frac{20 \times 29·25}{11·7} = 50$ effective horse-power.

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## FLOW OF WATER.

**Flow of Water through Orifices.**—To find the velocity of the discharge in feet per second of water flowing from the side of the cistern. *Rule:* Multiply the square root of the height in feet from the centre of the orifice to the surface of the water by 8. To find the height in feet.—*Rule:* Divide the square of the velocity in feet per second by 64.

*To find the quantity of water in cubic feet per second discharged through an orifice.—Rule:* Multiply the area of the orifice in square feet by the number of seconds, and multiply the product by five times the square root of the height in feet from the centre of the orifice to the surface of the water.

*To find the quantity of water in gallons per second discharged through an orifice.—Rule:* Multiply the area of the orifice in square feet by the number of seconds, and multiply the product by 31·5 times the square root of the height in feet from the centre of the orifice to the surface of the water.

The above rules apply to the discharge from a hole cut in the side of a cistern. If a short pipe be fixed inside the cistern, the discharge will be diminished to the extent of one-fifth; if a short pipe, in length equal to 4 times its diameter, be fixed on the outside of the cistern, the quantity discharged will be increased to the extent of about one-third, the quantity slightly decreasing as the length of the pipe is increased beyond a length equal to 4 times the pipe's diameter until it reaches a length equal to sixty times the diameter, when the discharge equals that of a simple orifice.

**Time required to fill a Cistern** when a known quantity of water per hour is going in and a known quantity going out. Templeton's *Rule* is: Divide the contents in gallons of the cistern by the difference of the quantity going in and the quantity going out, and the quotient is the time in hours and parts that the cistern will take in filling.

**Time required in Seconds for a Cistern to empty itself.**—Mr. Banks' *Rule* is: Multiply the square root of the height in feet of the surface of the water from the orifice, by the area of the falling water surface in square inches, and divide the result by 3·7 times the area of the orifice in square inches.

**Flow of Water over Weirs.**—Eytelwein's *Rule* is: Multiply the square root of the depth in feet from the surface of the water to the bottom of the orifice, or top of dam, by the sectional area of the water passage in square feet and multiply the product by 3·4. The result will be the discharge in cubic feet per second.

**Flow of Water in Open Streams.**—The velocity of water in a stream or river is greatest near the surface at the centre of the stream, and less near the sides and at the bottom. The surface velocity may be ascertained by placing a thin wood float on the centre of the stream and noting the time it requires to pass a measured distance; then the mean velocity will be ·8 of the surface velocity. The available quantity of water in the stream may be found by this *Rule:* multiply the sectional area of the stream in square feet by the surface velocity in feet per second and multiply that product by ·8, the result will be the discharge in cubic feet per second.

**The Hydraulic Mean Depth** is the quotient of the sectional area of a stream or river, divided by its wet perimeter; in circular pipes running full, the hydraulic mean depth is one-fourth of the diameter of the pipe.

**The Velocity and Discharge of Water** through pipes and channels running wholly or partly filled, may be found by Mr. Beardmore's *Rule:* Multiply the hydraulic mean depth in feet, by twice the fall in feet per mile, and multiply the square root of the product by 55: the result is the mean velocity of the stream in feet per minute, which result multiplied by the sectional area in square feet, gives the volume or discharge in cubic feet per minute, and this product multiplied by 6·24 gives the number of gallons discharged per minute.

**Loss of Head due to Friction.**—The loss of head arising from the friction of the water against the sides of the pipe may be found by the following *Rule* (Prony's): Multiply 2·25 times the length of the pipe in miles by the square of the velocity of the water in the pipe in feet per second, and divide the product by the diameter of the pipe in feet: the result will be head of water in feet required to balance the friction. The friction of water increases nearly as the square of its velocity. When calculating the diameter of a pipe for water supply, the quantity of water should be increased to the extent of from 33 to 50 per cent. to provide against the reduction of the flowing section due to encrustation.

**Bends in Pipes.**—The above rules apply to straight pipes only; as bends in a pipe diminish the velocity of a fluid equal to ·0039 times the sum of the sines of the several angles of inflection, sharp turns should be avoided. In the report on the supply of water to the Metropolis, it is stated that the time necessary for the discharge of a given quantity of water through a straight pipe being 1, the time for an equal quantity through a curve of 90° would be 1·11; with a right angle 1·57; two right angles would increase the time to 2·464; and two curved junctions to only 1·23.

Mr. Blackwell's rules for pipes are very convenient, as they make allowance for bends and other irregularities in pipes of considerable length; they are as follows*:—

**To find the Velocity in Feet per Second.**—*Rule:* Multiply the diameter of the pipe in feet by the inclination of the pipe in feet per mile, divide the product by 2·3, and extract the square root of the result.

**To find the Diameter of the Pipe in Feet.**—*Rule:* Multiply the square of the velocity in feet per second by 2·3, and divide the product by the inclination of the pipe in feet per mile.

**To find the Inclination of the Pipe in Feet per Mile,** to be given to overcome friction.—*Rule:* Multiply the square of the velocity in feet per second by 2·3, and divide the product by the diameter of the pipe in feet.

FALL OR INCLINATION OF DRAINS, SEWERS, WATER CHANNELS AND RIVERS.

| | Inch. | | Feet. |
|---|---|---|---|
| Minimum inclination for drains for houses | 1 | in | 12 |
| " " " land | 1 | " | 16 |
| " " submain drains for houses | 1 | " | 40 |
| " " main drains for houses | 1 | " | 100 |
| Fall of mountain torrents | 1 | " | 150 |
| " " rivers with rapid current | 1 | " | 230 |
| " " " strong current | 1 | " | 280 |
| " ordinary rivers with good current | 1 | " | 340 |
| " " winding rivers, subject to inundations with slow current | 1 | " | 440 |
| Fall of water channels, supply pipes to reservoirs and small canals | 1 | " | 480 |
| Fall of large canals | 1 | " | 570 |
| Very slow current, nearly approaching to stagnant water | 1 | " | 1000 |

* See Hughes on Waterworks. Crosby Lockwood & Co.

**Mill Race.**—In order to prevent deposits and the growth of plants, the mean velocity of water in a mill race or water channel, should not be less than from 1 to $1\frac{1}{2}$ feet per second.

**Limits of Velocity.**—To prevent injury to the bed and banks, the velocity of water in feet per minute in a channel should be proportioned to the tenacity of the soil:—in soft alluvial deposits, 25; in clayey beds, 40; in sandy and silty beds, 60; in gravelly beds, 120; in strong gravelly shingle, 180; in shingly beds, 240; in shingly and rocky beds, 300 to 400.

**Velocity of Water.**—The velocity in feet per second at which various substances are carried off:—river mud, ·3; gravel, fine, ·4; clay, ·5; gravel, coarse, ·6; yellow sand··7; river sand, 1·0; gravel, size of beans, 1·2; shingle, small, 2·3; shingle, large, 2·6; angular stones, size of an egg, 3·0; rock, soft, 5·0; rock, seamy, 6·0; rock, hard, 10·0.

**Turbines.**—The following are Mr. Nystrom's formulæ for Jonval's turbines, but the principal formulæ will answer for any kind of turbine.

$$D=\frac{K\sqrt{h}}{n};\ D=\frac{a}{\cdot 436\, r};\ n=\frac{K\sqrt{h}}{D};\ n=\frac{20\,K\,Q}{a\,D};\ r=\frac{a}{\cdot 436\, D};\ r=\frac{46\,K\,Q}{D^2\,n};\ r=\frac{D}{5}\text{ to }\frac{D}{8};\ t=\frac{m}{10}$$

$$a=\frac{20\,Q}{\sqrt{h}};\ a=\frac{20\,K\,Q}{D\,n};\ a=\cdot 436\,D\,r;\ a=m'rs;\ a'=mrs;\ a'=\cdot 98\,a;\ Q=\frac{a\sqrt{h}}{20};\ Q=\frac{a\,D\,u}{20\,K}$$

$$m=5\sqrt{D};\ m'4\cdot 5\sqrt{D};\ b=\frac{625\,D}{\sqrt{m}};\ C=\frac{78\,D}{\sqrt{m'}};\ s=\cdot 86\,S;\ d=D+r+\sqrt[2]{l};\ d'=D+2r;\ W=\frac{D^2\,h}{3}$$

$H=\cdot 1134\,Q\,h$, natural effect of fall. $H=\frac{30\,Q^3}{a^2}$ $H=\frac{ah\sqrt{h}}{267\cdot 5}$ } actual horse-power, 66 per cent. of the natural.

Where $Q$ = cubic feet of water passed through the turbine per second; $h$ = height of fall in feet; $D$ = diameter in inches of circle of effort in the turbine; $a$ = area in square inches of the conduit passage into the turbine wheel; $b$ = depth in inches of turbine buckets; $c$ = depth in inches of leading buckets; $r$ = breadth of turbine buckets in inches; $m$ = number of buckets in the turbine wheel; $m'$ = number of leading buckets; $n$ = number of revolutions of turbine per minute; S and $s$ = height of conduit and discharge in inches; $t$ = thickness of steel-plate buckets in 16ths of an inch: H = actual horse-power of the turbine; $l$ = length in feet, and $d$ the diameter in inches of conduit pipe; $d'$ = the diameter in inches of the discharge pipe; W = hydraulic pressure on the turbine wheel bearing on the end of the shaft; K = 950.

### Memoranda for calculating Flow of Water, &c.

Discharge in 24 hours divided by 1440 = discharge per minute.

Discharge in cubic feet per minute multiplied by 9000 = gallons per day of 24 hours.

Discharge in cubic feet per second multiplied by 2·2 = cubic yards per minute.

Discharge in cubic feet per second multiplied by 6·24 = gallons per second.

Discharge in cubic feet per second multiplied by 133 = cubic yards per hour.

Discharge in cubic feet per second multiplied by 375 = gallons per minute.

Discharge in cubic feet per second multiplied by 2400 = tons per day of 24 hours.

Velocity in feet per second multiplied by ·68 = miles per hour.

Velocity in feet per second multiplied by 60 = feet per minute.

Velocity in feet per second multiplied by 20 = yards per minute.

Pressure of water in lbs. per square foot = head in feet multiplied by 62·32.

Head of water in feet = pressure of water in lbs. per square foot multiplied by ·016.

**Discharge of Sewers.**—The discharge of sewage pipes is less than that of water pipes, the flow being retarded by the rough surface of the pipes caused by deposit. Mr. Blackwell's rules given above will apply to sewage pipes by using a constant of 2·8, instead of 2·3 used for water pipes.

**Hydraulic Press.**—To find the pressure on the ram of the press in tons.—*Rule:* Multiply the area in square inches, of the press ram, by the length of the pump handle, from the fulcrum to the point the force is applied, in feet, and multiply the product by the force in lbs. applied to the handle, and call the result A. Next multiply the area in square inches, of the pump-plunger, by the distance in feet, between the fulcrum and the centre of the pump-plunger, and multiply the product by 2240, and call the result B.; then divide the result A. by the result B., and the quotient will be the pressure in tons on the ram.

**Thickness of Metal for Hydraulic-Press Cylinders.**—Cast-iron cylinders for hydraulic presses are generally made in thickness = to one-half the diameter of the ram for a working permanent strain of 2 tons per square inch. Barlow's *Rule for the bursting pressure of thick cylinders is:* —multiply the cohesive strength of the metal in tons per square inch by the thickness of metal in inches, and divide the result by the sum of the internal radius of the pipe, and the thickness of metal in inches. *For the thickness of metal it is:*—multiply the internal radius of the pipe in inches, by the internal bursting pressure in tons per square inch, and divide the product, by the quotient of the internal pressure, in tons per square inch of section, subtracted from the cohesive strength of the metal, in tons per square inch.

Example: A hydraulic-press cylinder of cast-iron 5 inches thick, with ram 10 inches diameter, cohesive strength of metal 7 tons, would burst with $\frac{7 \text{ tons} \times 5 \text{ inches thickness of metal}}{5 \text{ inch radius} + 5 \text{ inches thickness of metal}} = 3\frac{1}{2}$ tons. The bursting pressure should have by the last rule, a thickness of metal $\frac{5 \text{ inch radius} \times 3\cdot5 \text{ tons bursting pressure}}{3\cdot5 \text{ tons} - 7 \text{ tons cohesive strength of metal}} = 5$ inches. *The rule for finding the cohesive strength required for a given pressure is*—add the internal radius in inches of the pipe to the thickness of the metal in inches; multiply the result by the internal pressure in tons per square inch, and divide the product by the thickness of metal.

Taking the above example, the cohesive strength would be

$$\frac{\text{5 in. rad.} + \text{5 in. thickness of metal} \times \text{3·5 tons internal bursting pressure}}{\text{5 inches thickness of metal}}$$

= 7 tons.

**The Accumulator.**—The accumulator is used for storing the pressure of water, for working hydraulic cranes and machines. It consists of a long cast-iron cylinder, fitted at the top with a stuffing box and gland, through which a solid ram works; at the bottom of the cylinder are two pipes, one of which is connected to a pump, and the other to a hydraulic machine. On the top of the ram a cross head is fixed, which supports an annular cylinder, loaded with scrap-iron. The pump forces water into the cylinder, which raises the ram, and so long as the ram is upheld, the pressure of the water in the cylinder, and pipes connected to it, will be determined by the area of the ram, and the load upon it.

To find the pressure in pounds per square inch on the water in an accumulator: *Rule*, add the weight in pounds of the ram to the weight in pounds of the cross head and weighted cylinder, and divide the sum by the area of the ram in square inches.

The usual working pressure of hydraulic cranes is 700 lbs. per square inch, and of other hydraulic machines from 1500 lbs. to 2000 lbs. per square inch.

**Pipe Coverings.**—The loss of heat and power by radiation of heat from steam pipes is considerable, but it may be reduced to a minimum by clothing the pipes with a good non-conducting material, such as hair felt, which—being light and fibrous—is a good confiner of air. Organic substances are good non-conductors, but they should be protected from charring by encasing the pipes with tin-plate, so as to form a ⅜ inch air space round the pipe, the air in which makes an efficient insulator of heat.

**Steam Saved by Non-Conducting Coverings for Steam Pipes,** relatively to the bare pipes, Each composition being wrapped twice round with paper, with an outside cover of double wrapped canvas painted with two coats of paint. Total thickness of each covering 1½ inches.

| | PER CENT. | | PER CENT. |
|---|---|---|---|
| Hair felt, wood lagged | 96 | Clay, sawdust, paper-pulp, flour | 80 |
| Slag wool, wrapped in felt | 95 | Flax fibre, clay, paper shavings, flour | 79 |
| Paper, hair felt | 93 | Moss, hair, sawdust, flour | 79 |
| Air space, hair felt | 93 | Thin hair felt, straw rope | 78 |
| Chopped straw, silicated | 92 | Chalk, hair, flour | 78 |
| Bran, silicated, thin felt | 91 | Charcoal, sawdust, hair, flour | 76 |
| Air space, bran, hair | 90 | Peat, sawdust, hair, flour | 74 |
| Fossil meal and hair plaster | 89 | Pumice stone, sawdust, clay, flour | 74 |
| Air space, fine wool | 89 | Ashes, hair, cement | 72 |
| Air space, fine cotton | 87 | Asbestos paste, paper | 71 |
| Air space, goat's hair | 86 | Brick dust, sand, flax, cement | 70 |
| Air space, paper-pulp, hair | 84 | Air space, tin-plate case, paper | 69 |
| Clay, hair, flour, flax fibre | 84 | Clay, flax refuse | 69 |
| Larch turnings, hair, flour | 82 | Asbestos paper, brown paper | 68 |

# SECTION III.

## MILLWORK: SHAFTING, GEARING, PULLEYS, ETC.

# SECTION III.

# MILLWORK: SHAFTING, GEARING, PULLEYS, ETC.

## TOOTHED WHEEL GEARING.

**Wheel Gearing.**—Where motion has to be transmitted with precision, toothed wheel gearing must be used. The teeth should be so formed that the wheels will work together with the smallest amount of friction, and work smoothly and uniformly with a constantly equal power and with comparatively little noise, in the same manner as if two plain cylinders were rolling upon each other by the friction of their own pitch circles. As a wheel acts as a lever of a length represented by its radius, the leverage is governed by the diameter; but in making calculations, the number of teeth

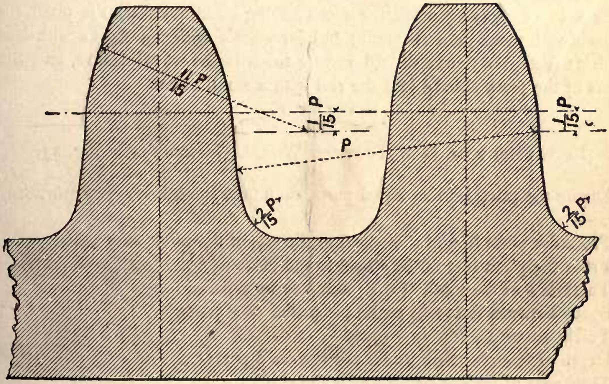


Fig. 23.

is used instead of the diameter. As fine-pitch wheels have a smoother and more uniform action than coarse ones, the pitch should always be made as fine as possible, consistent with the power transmitted. In calculating gearing, the diameter of the pitch-circle is taken as the diameter of the wheel, and when the wheels are properly in gear their pitch-circles meet and roll upon each other.

**Bevel and Mitre Wheels** must be regarded as two cones rolling upon each other, and the teeth are drawn upon the same principle as those of spur wheels, the maximum pitch diameter being always taken as the diameter of bevel and mitre wheels.

**Form of Teeth of Wheels.**—The following simple method of forming the teeth of wheels gives good results. Teeth thus formed and wheels made to the following proportions work accurately and smoothly together, wear uniformly, maintain their shape, and make very little noise in working. The utmost strength being given to the roots of the teeth, the liability to breakage and wear and tear is reduced to a minimum, and all wheels of the same pitch work properly together.

When the flank—or side of the tooth below the pitch line—is curved, the radius of the flank equals the pitch of the tooth, and the point from which this radius is struck is $\frac{1}{15}$ part of the pitch in depth below the pitch line, as shown at Fig. 23.

The radius of the point or face of the tooth,—or that portion of the tooth above the pitch circle,—equals $\frac{9}{15}$ the pitch for wheels with less than 21 teeth, and $\frac{11}{15}$ the pitch for wheels with upwards of 20 teeth. The point from which each radius is struck, is $\frac{1}{15}$ part of the pitch in depth, below the pitch line; the radius of the curve at the root of the tooth is $\frac{2}{15}$ the pitch. The flank of the tooth may also be made flat or parallel, and joined to the rim with a curve at the root of the tooth having a radius of $\frac{2}{15}$ the pitch, for wheels with more than 20 teeth; but for wheels with flat flanks with less than 21 teeth, the flanks should radiate towards the wheel centre, and the roots of the teeth should join the rim with a small curve.

Proportions of Iron Toothed Wheel Gearing. *See* Fig. 23.

Divide the pitch into 15 equal parts, then take the following proportions, viz.:—

From the pitch line of the wheel to the top of the tooth = 5 parts.
From the pitch line of the wheel to the bottom of the tooth = 6 parts.
Thickness of the tooth at the pitch line = 7 parts.
Space between the teeth at the pitch line = 8 parts.
Thickness of the rim = 7 parts.
Depth of feather or rib under the rim = 8 parts.
Thickness of feather or rib under the rim = 7 parts.
Thickness of the arm = 7 parts.
Thickness of the feather or rib on the arm = 4 parts.
Depth of the feather or rib on the arm = 3 parts.
Diameter of the boss = twice the diameter of the shaft.
Depth of the boss = $1\frac{1}{4}$ times the width of face of the wheel.
Depth of the feather or rib round the boss = 8 parts.
Thickness of the feather or rib round the boss = 7 parts.

Radius of curve at the root of the tooth = 2 parts. *See* Fig. 23.

Radius of the point or face of the tooth of wheels with upwards of 20 teeth = 11 parts.

Radius of the point or face of the tooth of wheels with less than 21 teeth = 9 parts.

Point below the pitch line of the wheel, from which the radius of the point or face of the tooth is struck = 1 part.

Breadth of the arm at the rim = $1\frac{3}{4}$ the pitch of the teeth, when the wheel face does not exceed $2\frac{1}{4}$ times the pitch in width; and = 2 times the pitch for widths of face from $2\frac{1}{2}$ to 3 times the pitch; and = 3 times the pitch for widths of face equal to 4 times the pitch.

Breadth of the arm at the boss, should be increased by tapering the arm down from the rim to the boss, at the rate of $\frac{1}{4}$ inch per foot, on each side of the arm. The tendency of the strain being to twist the arm, the power acts with the greatest effect near the boss.

Fig. 24 shows a form of tooth used for crab wheels, called knuckle gear.

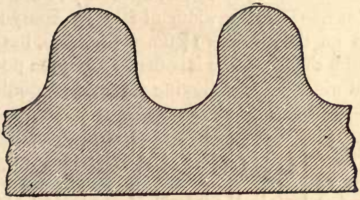

Fig. 24.

Fig. 25 shows the way to project a pair of bevel wheels, with their shafts at right angles,

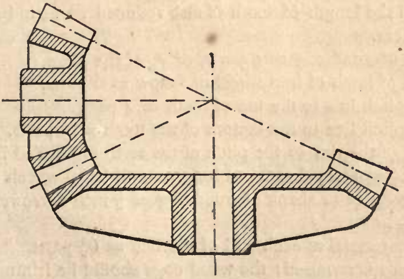

Fig. 25.

Fig. 26 shows the way to project a pair of angle wheels, or bevel wheels, with their shafts at an angle of 65°.

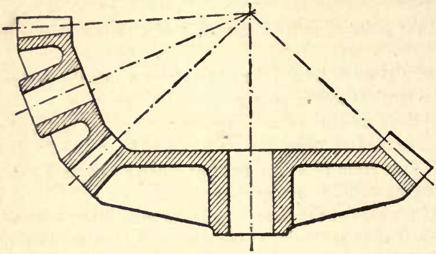

Fig. 26.

**Number of Arms.**—Wheels under 2 feet diameter should have 4 arms; wheels from 2 to 7 feet 6 inches diameter, 6 arms; wheels from 8 to 12 feet, 8 arms; and wheels from 13 to 16 feet diameter, 10 arms.

**Width of Face.**—The least width of face necessary to resist the full transverse strain on the tooth is $1\frac{1}{2}$ times the pitch, but for the sake of durability the width should not be less than 2 times the pitch; $2\frac{1}{2}$ times the pitch is the usual width. The following are good proportions:—

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pitch of wheel, in inches . . | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{7}{8}$ | 2 | $2\frac{1}{4}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ | 3 | $3\frac{1}{4}$ | $3\frac{1}{2}$ | 4 |
| Width of face of wheel, in inches | 2 | $2\frac{1}{4}$ | $2\frac{1}{2}$ | 3 | $3\frac{1}{2}$ | $3\frac{3}{4}$ | 4 | $4\frac{1}{2}$ | 5 | $5\frac{1}{2}$ | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 15 |

**Mortice Wheels.**—The wood teeth of a mortice wheel are made thicker than the teeth of its iron fellow, to compensate for the difference in strength of the material; consequently the thickness of the iron tooth has to be reduced, and the length of tooth is also reduced so as to be in proportion to the thickness.

Thickness of wood cog = 9 parts, or $\frac{9}{15}$ of the pitch.

Thickness of tooth of iron wheel or fellow = 6 parts.

From the pitch line to the top of tooth = 4 parts.

From the pitch line to the bottom of the tooth = 5 parts.

Thickness of the rim = the pitch of the teeth multiplied by 1·2.

Width of face of wheel same as for spur and bevel wheels given above.

Width of mortice or shank of wood cog = $\frac{1}{2}$ inch narrower than the face of the tooth.

Thickness of metal at each end of mortice = $6\frac{1}{2}$ parts.

No clearance is required; the wood cogs should be trimmed to fit accurately between the iron teeth.

When a pair of wheels of large diameter and quick speed work together, the larger one should have wood teeth, and the smaller one iron teeth. Wood teeth wear out sooner, but are not more liable to break than iron teeth. Hornbeam and crab-tree are the best woods for making the cogs, and when working they should be smeared with a mixture of soft soap and plumbago.

**Worm-Wheels.**—When the shafts are at right angles, the action of a worm and worm wheel is similar to that of a rack and pinion, and the formation of the teeth at the section at the centre of a worm wheel, should be the same as those of a spur wheel of the same diameter, and the section of the thread of the worm should be the same as the teeth of a rack of the same pitch of tooth. Each revolution of the worm, turns the worm-wheel, to the extent of one tooth with a single thread worm, and 2 teeth with a double thread worm. The teeth of worm-wheels are made shorter than spur wheels. The amount the teeth are angled or skewed is equal to the pitch of the teeth.

Thickness of tooth = 7 parts, or $\frac{7}{15}$ of the pitch.
Space between the teeth = 8 parts.
From the pitch line to the top of the tooth = $4\frac{1}{2}$ parts.
From the pitch line to the bottom of the tooth = $5\frac{1}{2}$ parts.
Radius of the point or face of the tooth = 9 parts.
Flank of tooth, straight and flat.
Width of face of tooth = $1\frac{1}{2}$ times the pitch.

**Pitch of Small Wheels.**—The pitch of change wheels and other small wheels, is reckoned on the diameter of the pitch circle, of the wheel instead of the circumference, and it is called the pitch per inch—thus 8 per inch, 10 per inch, and so on.

To find the number of teeth, in a wheel of a given diameter and pitch per inch:—

Multiply the diameter of the pitch circle in inches, by the given pitch per inch.

To find the diameter of the pitch circle, to contain a given number of teeth of a given pitch per inch:—

Divide the number of teeth by the required pitch per inch.

TABLE 18.—PITCH PER INCH IN DIAMETER AND CIRCULAR PITCH COMPARED.

| Pitch per Inch in Diameter. | Nearest Circular Pitch in Inches. | Pitch per Inch in Diameter. | Nearest Circular Pitch in Inches. |
|---|---|---|---|
| 3 | $1\frac{1}{32}$ | 9 | $\frac{1}{4}$ and $\frac{3}{32}$ |
| 4 | $\frac{3}{4}$ and $\frac{1}{32}$ | 10 | $\frac{5}{16}$ |
| 5 | $\frac{5}{8}$ | 12 | $\frac{1}{4}$ |
| 6 | $\frac{1}{2}$ | 14 | $\frac{1}{8}$ and $\frac{3}{32}$ |
| 7 | $\frac{7}{16}$ | 16 | $\frac{3}{16}$ |
| 8 | $\frac{3}{8}$ | 20 | $\frac{1}{8}$ and $\frac{1}{32}$ |

**The pitch per inch** in diameter (Table 18), bears the same ratio to the circular pitch, as the diameter to the circumference, a diametral pitch of 1 inch, corresponds with a circular pitch of 3·1416 inches; hence to find the circular pitch divide 3·1416 by the given diametral pitch, and to find the diametral pitch divide 3·1416 by the given circular pitch. The outside diameter of a wheel—over the top of the teeth—is found by adding two parts of the diametral pitch to the pitch diameter, for instance a wheel of 48 teeth, 8 per inch pitch, is $6 + \frac{2}{8}$ths $= 6\frac{1}{4}$ inches diameter outside. *The depth of tooth* of these small wheels is usually $= \frac{3}{4}$ths the pitch.

**Angular and Circumferential Velocity of Wheels.**—The angular velocity of a revolving body, is the velocity of a point at a unit's distance from the centre of motion, or the angle swept through in a second by a line perpendicular to the axis of motion, the angle being expressed in circular measure. Every point of a revolving wheel has a different velocity in proportion to its distance from the centre of motion, for instance in a revolving pulley, the boss will make the same number of revolutions as the rim, but the angular velocity of the rim will be greater than that of the boss.

*To find the circumferential velocity of a wheel:*—Multiply the circumference in feet by the number of revolutions per minute, the product will give the space passed through by any point of the circumference in feet per minute, which divided by 60 will give the velocity in feet per second.

*To find the angular velocity of a wheel,* or the number of revolutions made in a given time:—Divide the circumferential velocity per second, (found by the last rule) by the circumference in feet, the result will give the angular velocity, which multiplied by 60 will give the number of revolutions per minute.

**The Centre of Gyration** is a point in a revolving body in which the momentum, or energy of the moving mass, is supposed to be concentrated.

The radius of gyration of a fly-wheel (including arms and rim) and of gearing may be assumed in practice as the radius of the inside of the rim. To find the amount of force, to apply at the radius of a wheel, to cause it to make a certain number of revolutions, in a given number of seconds, *Rule:* multiply the number of revolutions by the weight of the wheel in lbs., and multiply the product by the square of the distance in feet from the centre of motion to the centre of gyration, and call the result A. Then multiply the constant number 153·5 by the number of seconds during which the force is applied, and multiply the product by the radius in feet on which the force acts, and call the result B.; lastly, divide the result A. by the result B., which will give the required force in lbs.

**The Radius of Gyration** of a solid wheel of uniform thickness, or of a circular plate, or of a solid cylinder of any length, revolving on its axis, is = to the radius of the object multiplied by ·7071.

## SPEED OF GEARING.

The ratio of the numbers of teeth in a pair of wheels, must be the same as that of their diameters.

**To find the speed of the driving wheel:**—Multiply the number of teeth in the driven wheel, by the number of revolutions it makes per minute, and divide the product by the number of teeth in the driving wheel.

**To find the speed of the driven wheel.**—Multiply the number of teeth in the driving wheel, by the number of revolutions it makes per minute, and divide the product by the number of teeth in the driven wheel.

**To find the final speed of a train of wheels.**—Multiply the number of revolutions per minute of the first driving wheel, by the product of the number of teeth in the driving wheels, and divide the result by the product of the number of teeth in the driven wheels.

**To find the number of teeth in the driving wheel.**—Multiply the number of teeth in the driven wheel, by the number of revolutions it makes per minute, and divide the product by the number of revolutions of the driving wheel.

**To find the number of teeth in the driven wheel.**—Multiply the number of teeth in the driving wheel, by the number of revolutions it makes per minute, and divide the product by the number of revolutions of the driven wheel.

**To find the relative numbers of teeth in a pair of wheels,** when the speeds of the driving and driven shafts are given. Divide the speed of the driven shaft, by the speed of the driving shafts; the quotient is the ratio of their speeds; and the numbers of teeth in the wheels must be in the same ratio.

**To find the diameters of a pair of wheels,** the distance between the centres, and also the speed of each shaft being given. Multiply the speed of one shaft by the distance between the centres in inches, and divide the product by the sum of the speeds of the two shafts, the result will give the radius of one wheel, which doubled, will give its pitch diameter in inches. The radius of this wheel subtracted from the distance between the centres, will give the radius of the other wheel.

**To find the pitch of a wheel.**—Divide the diameter of the wheel at the pitch circle, by the number of teeth, and multiply the quotient by 3·1416.

**To find the number of teeth in a wheel.**—Divide 3·1416 by the pitch, and multiply the quotient, by the diameter of the pitch circle in inches.

**To find the diameter of a wheel at the pitch circle.**—Divide the pitch by 3·1416, and multiply the quotient by the number of teeth.

**Wheels and Pinions.**—A wheel should not have more teeth than 6 for 1 of its pinion. Large pinions are desirable, because when a large wheel drives a small pinion rapidly, the teeth of the pinion moving in a small circle, abruptly meet the teeth of the wheel, and cause an uneven jolting motion. When wheels drive pinions, no pinion should have less than 20 teeth, and in millwork not less than from 35 to 45 teeth, to enable them to work properly, and have a sufficient number of teeth in gear at the same time. When pinions drive wheels no pinion should have a less number than 13 teeth; rather 16 or 18. When quick speed is required instead of using a large wheel and very small pinion, it is better to get up the speed by using an intermediate shaft with wheel and pinion, and the friction will not be materially increased thereby.

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## POWER OF WHEEL GEARING.

**Power of Wheel Gearing.**—The pressure on the teeth of wheels varies inversely as the number of revolutions and directly as the power transmitted. Thus, if the same power be transmitted by two wheels at different velocities, say one at 30 and the other at 120 revolutions, the strain on the former will be four times that of the latter; or if one wheel transmits 10 horse-power and another 20 horse-power at the same velocity, the strain on the latter will be double that of the former. Again, the power transmitted by a wheel depends upon the number of teeth in gear at one time and also upon its velocity.

**Power of Spur Wheels.**—The horse-power of the ordinary spur wheels used in machinery and millwork is given in table 19, which has been deduced from cases in practice. In cases where wheels are subject to unusually great strains they are made of other materials than cast iron.

**Good Malleable Cast-Iron Wheels** have double the strength of cast-iron wheels.

**Good tough Gun-metal Wheels,** have double the strength of cast-iron wheels.

**Wrought-Iron Wheels,** are three times as strong as cast-iron wheels, when made of best iron, with the grain of the iron in the direction of the circumference of the wheel.

**Good Cast-Steel Wheels,** are four times as strong as cast-iron wheels.

**Shrouded Wheels,** or wheels with two flanges, are from one-third to one-half stronger, according to the form of tooth, than plain wheels.

**The Power of Bevel and Mitre Wheels** may be taken from table 19, but instead of the maximum, the mean diameter and pitch must be taken; for instance, a bevel wheel 36 inches maximum diameter, with 6 inches face, has a minimum diameter of 30 inches, the mean diameter is therefore 33 inches, the pitch is 3 inches, but the minimum pitch is in proportion to the diameter; thus $\frac{3 \times 30}{36} = 2{\cdot}5$ minimum pitch, and the mean pitch will therefore be $\frac{3 + 2{\cdot}5}{2} = 2{\cdot}75$ mean pitch, and in looking for the horse-power in the table, it must be called 33 inches diameter × $2\frac{3}{4}$ inches pitch.

**Power of Mortice-Wheels.**—When running at a good speed, mortice-wheels are quite as strong as iron toothed wheels, but at a low speed they are weaker than iron wheels.

**Power of Crane Gearing.**—When wheels work at very low velocities lifting heavy weights, as in cranes, the safe working load should not exceed $\frac{1}{10}$ of the breaking weight, and the strength of the teeth should be calculated accordingly. A bar of good cast-iron 1 inch long, and 1 inch square, loaded at the end, will break with 6000 lbs., and the tooth of a wheel is similar to a beam loaded at one end and fixed at the other, hence the following rule:—

**To find the Breaking Strain of each Tooth in a Wheel.**—Multiply the square of the thickness of one tooth by its width, then by 6000, and divide the result by the length of tooth, the product will be the breaking weight in lbs. of each tooth.

*Example:* A crane to lift 4 tons, has a wheel 4 feet diameter, with a barrel 12 inches diameter, measuring to the centre of the chain. The pressure at the pitch-line of the wheel will be the weight to be lifted in lbs., multiplied by the diameter of the barrel in feet, and divided by the diameter of the wheel in feet: then $\frac{8960 \times 1}{4} = 2240$ lbs. actual strain, and suppose the teeth to be $\frac{3}{4}$ thick × $1\frac{1}{8}$ long × 4 inches wide, then $\frac{{\cdot}75^2 \times 4 \times 6000}{1{\cdot}125}$ = 11,786 lbs. the breaking weight of one tooth, and if two teeth are in gear at the same time, the breaking strain of two teeth will be 11,786 × 2 = 23,572 lbs., the ratio of which to the actual strain is $\frac{23572}{2240} = 10\frac{1}{2}$ to 1, which is ample for safety. Machinery subject to shocks from sudden change of speed and irregular strains, must have an excess of power in the gearing to provide against accidents. This rule for obtaining the actual strength of teeth applies to wheels working slowly and lifting heavy weights—the following rule is used for ordinary gearing.

**Horse-Power of Gearing.**—*To find the horse-power of ordinary iron-toothed spur wheels*, used in machinery and millwork. *Rule:* Multiply the square of the pitch of the teeth in inches, by the width of face of the teeth in inches, multiply the product by the diameter of the wheel in feet at the pitch circle, and multiply that product by the number of revolutions per minute, and divide the result by the constant number 240, the result will be the actual or indicated horse-power which that wheel will properly transmit.

## CRANE GEARING.

To find the strains at the pitch-lines of a train of wheels, such as the crane gearing shown at Fig. 27. The power exerted by a man at the handle of a crane, working continuously, is 15 lbs. at a velocity of 220 feet per minute; the strain at the handles worked by 4 men will be 15 × 4 = 60 lbs., and assuming the gearing to be as follows:—

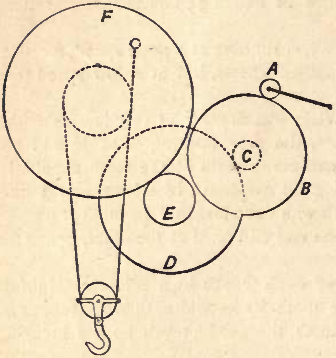



Fig. 27.

1st pinion A, 6 inches diameter.
1st wheel B, 36 ,, ,,
2nd pinion C, 10 ,, ,,
2nd wheel D, 60 ,, ,,
3rd pinion E, 20 ,, ,,
3rd wheel F, 80 ,, ,,

Diameter of the barrel at the centre of the chain = 20 inches.

Radius of the handles = 16 inches,

then $\frac{\text{60 lbs. strain at the handles} \times \text{16 radius of the handle}}{\text{3 inches radius of first pinion A}} = 320$ lbs. strain at the pitch lines of wheels A and B.

$\frac{\text{320 lbs.} \times \text{18 inches radius of first wheel B}}{\text{5 inches radius of second pinion C}} = 1152$ lbs. strain at the pitch lines of wheels C and D.

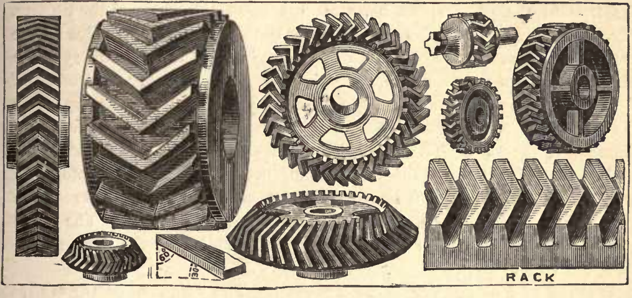
$\frac{\text{1152 lbs.} \times \text{30 inches radius of second wheel D}}{\text{10 inches radius of third pinion E}} = 3456$ lbs. strain at the pitch lines of wheels E and F.

$\frac{\text{3456 lbs.} \times \text{40 radius of third wheel F}}{\text{10 inches radius of barrel at the centre of the chain}} = 13824$ lbs. strain on the chain,

or $\frac{13824}{2240} = 6{\cdot}126$ tons, and as the snatch block, or running pulley, will double the power, about $12\frac{1}{4}$ tons would be lifted by the 4 men.

**Double Helical Toothed-Wheels**, shown in the engraving on the next page, possess a strong and durable form of tooth; they work smoothly and almost noiselessly, without vibration, and the teeth always keep in the right plane of revolution. As angular teeth of this form approach to, and recede from each other more gradually than ordinary straight teeth, a more perfect rolling motion is obtained. A good angle for the teeth is 30°, from the straight line or 60° from the side of the wheel, but the angle may be varied.

**The Strength of Double Helical Toothed-Wheels** with teeth at an angle of 30°, is 20 per cent. greater than the strength of ordinary toothed-wheels of the same pitch and width.




**The Horse-power of Double Helical Toothed-Wheels**, having teeth at the above angle, may be found by this Rule. Multiply together the square of the pitch in inches, the width of face in inches, the diameter of the wheel at the pitch circle in feet, the number of revolutions per minute, and divide the product by the constant number 200, the quotient will be the actual or indicated horse-power which that wheel will properly transmit.

**Frictional Gearing.**—The pitch of frictional gearing varies from $\frac{1}{4}$ inch to 1 inch; the driving power is one-sixth of the interpressure between the wheels. Fig. 28 is a full size section of teeth 1 inch pitch—which is the pitch generally used for hoists—and represents the exact form of tooth found to answer best in practice for this purpose. Thickness of tooth = $\frac{3}{8}$ths the pitch: width of space between the teeth = $\frac{2}{5}$ths the pitch: depth of tooth = $\frac{4}{5}$ths the pitch: angle of point of tooth = 70°.

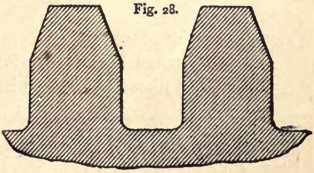


Fig. 28.

**Rope-Gearing.** — Rope driving-gear is used for transmitting power from the fly-wheel of engines, &c.; it is best adapted for driving shafts which run at high and uniform speeds, such as the main shafts of factories. For such purposes its cost is about one-third that of belt-gearing. The ropes are generally made of hemp of $4\frac{3}{4}$ inches circumference for small powers, and

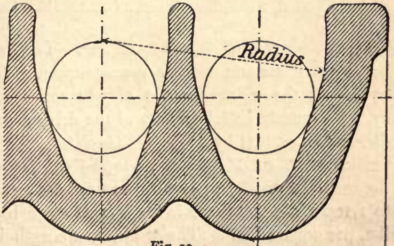


Fig. 29

$5\frac{1}{4}$ and $6\frac{1}{2}$ inches circumference for large powers. The slack or return side of the rope should be at the top, and the tight or driving side at the bottom of the pulleys. The ropes are never tightened to run straight over the tops of the pulleys, but hang with a good sag between the pulleys. Fig. 29 shows the form of pulley used for rope gearing. The sides of the grooves below the centre of the rope are inclined at an angle of 45°; the distance between the centres of the grooves is equal to from ·45 to one-half the circumference of the rope; the distance of the centre of the rope from the top of the pulley, and also from the bottom of the groove is $\frac{7}{8}$ths of the diameter of the rope. The circumference of the smallest pulley should not be less than thirty times the diameter of the rope. The circumferential velocity of the flywheel may be from 3000 to 5000 feet per minute—but a speed of 4500 feet gives, probably, the best results in practice. The shafts should be from 30 feet to 80 feet apart. The splice of the rope should be about 10 feet long.

**Weight of Pulleys for Rope-Gearing.**—The weight of cast-iron rope pulleys—turned and finished—made to the above proportions, may be calculated approximately by the following rule: Multiply the square of the pitch of the grooves in inches by the number of grooves, and by the diameter of the pulley in feet, and divide the last product by one of the following constant numbers, viz., by 13 if the pulley is cast whole; or by 10 if it is split—that is, in halves and bolted together;—and the quotient will be the weight in cwts.

Weight of Cast-Iron Rope-Pulleys—Turned and Finished—for Ropes 2 Inches Diameter.—Pitch of grooves, $2\frac{7}{8}$ inches; the sizes above 8 feet diameter being in halves and bolted together.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter, in feet . . . | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Bore of pulley, in inches . | 5 | 6 | $6\frac{1}{2}$ | 7 | 8 | $8\frac{1}{2}$ | 9 | 10 | 11 | 12 | 13 |
| Number of ropes . . . | 5 | 7 | 8 | 8 | 9 | 9 | 10 | 10 | 10 | 12 | 14 |
| Weight, in cwts. . . | 15 | 26 | 35 | 40 | 66 | 74 | 90 | 99 | 107 | 139 | 173 |

**Horse-power of Rope-Gearing.**—To find the number of indicated horse-power transmitted by rope-gearing. *Rule:* Multiply 8 times the square of the circumference of one rope by the number of ropes, and by the circumferential velocity of the driving pulley in feet per minute; and divide the product by 33,000.

**Strength of Ropes for Rope-Gearing.**—The breaking strength of the untarred or white hemp-ropes used for rope-belts, varies from 6,400 lbs. to 1,100 lbs. per square inch; the average breaking strength being 8,700 lbs. per square inch. The working strength is one-sixth of the breaking strength or 1,450 lbs. per square inch.

**Weight of Rope-Belts.**—Rope-belts, $1\frac{3}{4}$ inches diameter, weigh about 3 lbs. per yard, and rope-belts, 2 inches diameter, weigh about 4 lbs. per yard, the weight of the rope in lbs. per yard being approximately equal to the square of the diameter of the rope in inches.

**Friction of Rope-Belts.**—The friction of a rope working in a taper groove on a cast-iron pulley is three times greater than that of a rope working on a cast-iron pulley without a groove. The co-efficient of friction for a rope on a cast-iron pulley without a groove being ·28; that of a rope working in a taper groove on a cast-iron pulley is $\cdot 28 \times 3 = \cdot 84$, when the groove is not greased. If the groove be greased the co-efficient of friction is reduced to the extent of one-half.

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## WEIGHT AND HORSE-POWER OF TOOTHED WHEEL GEARING.

**The weight of cast-iron toothed-wheel gearing** may be found approximately by the following rule. Multiply the number of teeth by the square of the pitch in inches, and by the width of the face in inches; and divide the product by one of the following constant numbers, which will give the weight of the wheel in lbs.

2·2 for spur mortice wheels complete with wood teeth.

2·4 for iron toothed spur wheels.

2·6 for bevel and mitre wheels complete with wood teeth.

2·9 for bevel and mitre iron toothed wheels.

*The weight of cast-iron spur wheels,* cast from a good set of patterns, is given in table 19; the weight of cast iron bevel and mitre wheels, is one-sixth less than the weight of cast iron spur wheels. The weight of spur and bevel mortice wheels complete with wood teeth, is one-tenth more than similar wheels of cast iron.

*The horse-power of an ordinary spur wheel* may be found by multiplying the horse-power given in Table 19 by the number of revolutions the wheel will make per minute.

**The weight of small spur wheels,** commonly called change wheels, is given at page 299.

**Machine-Moulded Wheels** vary much in weight, and are usually made unnecessarily heavy,—wheels being sold by weight, many ironfounders make them as heavy as they can—their weight being generally from 25 to 50 per cent. heavier than pattern-moulded wheels. The weight of machine-moulded toothed-wheels may be found approximately by adding 30 per cent. to the weight of the pattern-moulded wheels given in Table 19, this percentage being the average overweight of a large number of machine-moulded wheels.

**The Weight of Cast-Steel Wheel-Castings** may be found by adding 1 lb. for every 12 lbs. weight of similar wheels of cast-iron. The Breaking strain per square inch of section of good ordinary mild-steel castings varies from 28 to 34 tons, with from 10 to 15 per cent. elongation.

TABLE 19.—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | Pitch 1⅛ In. Face, 3 In. Wide. | | | | | | Pitch 1¼ In. Face, 3½ In. Wide. | | | | | | Pitch 1⅜ In. Face, 3¾ In. Wide. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 13 | 0 | 4¾ | 0 | 0 | 18 | ·0050 | 0 | 5¼ | 0 | 0 | 26 | ·0090 | 0 | 5¾ | 0 | 1 | 6 | ·013 |
| 14 | 0 | 5 | 0 | 0 | 19 | ·0055 | 0 | 5⅝ | 0 | 0 | 27 | ·0100 | 0 | 6¼ | 0 | 1 | 9 | ·014 |
| 15 | 0 | 5⅜ | 0 | 0 | 20 | ·0060 | 0 | 6 | 0 | 1 | 1 | ·0110 | 0 | 6⅝ | 0 | 1 | 11 | ·015 |
| 16 | 0 | 5¾ | 0 | 0 | 21 | ·0070 | 0 | 6⅜ | 0 | 1 | 3 | ·0116 | 0 | 7 | 0 | 1 | 13 | ·016 |
| 17 | 0 | 6⅛ | 0 | 0 | 22 | ·0076 | 0 | 6¾ | 0 | 1 | 5 | ·0123 | 0 | 7½ | 0 | 1 | 15 | ·018 |
| 18 | 0 | 6½ | 0 | 0 | 23 | ·0081 | 0 | 7⅛ | 0 | 1 | 7 | ·0129 | 0 | 8 | 0 | 1 | 17 | ·019 |
| 19 | 0 | 6⅞ | 0 | 0 | 24 | ·0085 | 0 | 7½ | 0 | 1 | 9 | ·0136 | 0 | 8⅜ | 0 | 1 | 19 | ·020 |
| 20 | 0 | 7⅛ | 0 | 0 | 25 | ·0088 | 0 | 8 | 0 | 1 | 11 | ·0145 | 0 | 8⅞ | 0 | 1 | 21 | ·021 |
| 21 | 0 | 7½ | 0 | 0 | 27 | ·0093 | 0 | 8⅜ | 0 | 1 | 13 | ·0151 | 0 | 9¼ | 0 | 1 | 24 | ·022 |
| 22 | 0 | 7⅞ | 0 | 1 | 0 | ·0097 | 0 | 8¾ | 0 | 1 | 15 | ·0159 | 0 | 9⅝ | 0 | 1 | 27 | ·023 |
| 23 | 0 | 8¼ | 0 | 1 | 1 | ·0102 | 0 | 9⅛ | 0 | 1 | 17 | ·0167 | 0 | 10 | 0 | 2 | 3 | ·024 |
| 24 | 0 | 8⅝ | 0 | 1 | 2 | ·0107 | 0 | 9½ | 0 | 1 | 19 | ·0173 | 0 | 10½ | 0 | 2 | 6 | ·025 |
| 25 | 0 | 9 | 0 | 1 | 3 | ·0112 | 0 | 10 | 0 | 1 | 21 | ·0182 | 0 | 11 | 0 | 2 | 8 | ·026 |
| 26 | 0 | 9¼ | 0 | 1 | 4 | ·0116 | 0 | 10⅜ | 0 | 1 | 23 | ·0189 | 0 | 11½ | 0 | 2 | 10 | ·027 |
| 27 | 0 | 9⅝ | 0 | 1 | 5 | ·0120 | 0 | 10¾ | 0 | 1 | 25 | ·0195 | 0 | 11⅞ | 0 | 2 | 12 | ·028 |
| 28 | 0 | 10 | 0 | 1 | 8 | ·0125 | 0 | 11¼ | 0 | 1 | 27 | ·0204 | 1 | 0¼ | 0 | 2 | 14 | ·029 |
| 29 | 0 | 10⅜ | 0 | 1 | 10 | ·0129 | 0 | 11⅝ | 0 | 2 | 2 | ·0211 | 1 | 0¾ | 0 | 2 | 16 | ·030 |
| 30 | 0 | 10¾ | 0 | 1 | 12 | ·0134 | 1 | 0 | 0 | 2 | 4 | ·0227 | 1 | 1⅛ | 0 | 2 | 18 | ·031 |
| 31 | 0 | 11⅛ | 0 | 1 | 13 | ·0138 | 1 | 0⅜ | 0 | 2 | 6 | ·0233 | 1 | 1⅝ | 0 | 2 | 21 | ·032 |
| 32 | 0 | 11½ | 0 | 1 | 14 | ·0143 | 1 | 0¾ | 0 | 2 | 8 | ·0240 | 1 | 2 | 0 | 2 | 24 | ·033 |
| 33 | 0 | 11⅞ | 0 | 1 | 15 | ·0147 | 1 | 1⅛ | 0 | 2 | 10 | ·0247 | 1 | 2½ | 0 | 3 | 0 | ·034 |
| 34 | 1 | 0⅛ | 0 | 1 | 17 | ·0152 | 1 | 1⅝ | 0 | 2 | 12 | ·0248 | 1 | 3 | 0 | 3 | 4 | ·035 |
| 35 | 1 | 0⅝ | 0 | 1 | 18 | ·0157 | 1 | 2 | 0 | 2 | 15 | ·0255 | 1 | 3⅜ | 0 | 3 | 8 | ·036 |
| 36 | 1 | 1 | 0 | 1 | 19 | ·0161 | 1 | 2⅜ | 0 | 2 | 18 | ·0261 | 1 | 3¾ | 0 | 3 | 12 | ·037 |
| 37 | 1 | 1¼ | 0 | 1 | 20 | ·0165 | 1 | 2¾ | 0 | 2 | 20 | ·0268 | 1 | 4¼ | 0 | 3 | 16 | ·038 |
| 38 | 1 | 1⅝ | 0 | 1 | 22 | ·0170 | 1 | 3¼ | 0 | 2 | 23 | ·0279 | 1 | 4⅝ | 0 | 3 | 20 | ·039 |
| 39 | 1 | 2 | 0 | 1 | 23 | ·0174 | 1 | 3½ | 0 | 2 | 25 | ·0283 | 1 | 5 | 0 | 3 | 22 | ·040 |
| 40 | 1 | 2⅜ | 0 | 1 | 24 | ·0179 | 1 | 4 | 0 | 2 | 27 | ·0292 | 1 | 5½ | 0 | 3 | 25 | ·041 |
| 41 | 1 | 2¾ | 0 | 1 | 25 | ·0183 | 1 | 4⅜ | 0 | 3 | 2 | ·0299 | 1 | 6 | 1 | 0 | 1 | ·042 |
| 42 | 1 | 3 | 0 | 1 | 27 | ·0188 | 1 | 4¾ | 0 | 3 | 6 | ·0305 | 1 | 6⅜ | 1 | 0 | 4 | ·043 |
| 43 | 1 | 3½ | 0 | 2 | 0 | ·0193 | 1 | 5⅛ | 0 | 3 | 9 | ·0312 | 1 | 6⅞ | 1 | 0 | 7 | ·044 |
| 44 | 1 | 3¾ | 0 | 2 | 3 | ·0197 | 1 | 5⅝ | 0 | 3 | 11 | ·0321 | 1 | 7¼ | 1 | 0 | 10 | ·045 |
| 45 | 1 | 4⅛ | 0 | 2 | 6 | ·0201 | 1 | 6 | 0 | 3 | 13 | ·0330 | 1 | 7¾ | 1 | 0 | 13 | ·046 |
| 46 | 1 | 4½ | 0 | 2 | 8 | ·0205 | 1 | 6⅜ | 0 | 3 | 16 | ·0336 | 1 | 8⅛ | 1 | 0 | 16 | ·047 |
| 47 | 1 | 4⅞ | 0 | 2 | 10 | ·0210 | 1 | 6¾ | 0 | 3 | 19 | ·0343 | 1 | 8⅝ | 1 | 0 | 19 | ·048 |
| 48 | 1 | 5¼ | 0 | 2 | 13 | ·0215 | 1 | 7⅛ | 0 | 3 | 21 | ·0349 | 1 | 9 | 1 | 0 | 22 | ·049 |
| 49 | 1 | 5⅝ | 0 | 2 | 15 | ·0220 | 1 | 7½ | 0 | 3 | 23 | ·0356 | 1 | 9½ | 1 | 0 | 25 | ·050 |
| 50 | 1 | 6 | 0 | 2 | 17 | ·0225 | 1 | 8 | 0 | 3 | 25 | ·0365 | 1 | 9⅞ | 1 | 1 | 0 | ·051 |
| 51 | 1 | 6¼ | 0 | 2 | 18 | ·0228 | 1 | 8⅜ | 1 | 0 | 0 | ·0371 | 1 | 10⅜ | 1 | 1 | 2 | ·052 |
| 52 | 1 | 6⅝ | 0 | 2 | 19 | ·0232 | 1 | 8¾ | 1 | 0 | 3 | ·0378 | 1 | 10¾ | 1 | 1 | 5 | ·053 |
| 53 | 1 | 6⅞ | 0 | 2 | 20 | ·0235 | 1 | 9⅛ | 1 | 0 | 6 | ·0387 | 1 | 11¼ | 1 | 1 | 8 | ·054 |
| 54 | 1 | 7⅜ | 0 | 2 | 21 | ·0240 | 1 | 9½ | 1 | 0 | 8 | ·0393 | 1 | 11⅝ | 1 | 1 | 11 | ·055 |
| 55 | 1 | 7¾ | 0 | 2 | 22 | ·0245 | 1 | 9⅞ | 1 | 0 | 10 | ·0400 | 2 | 0 | 1 | 1 | 15 | ·056 |
| 56 | 1 | 8⅛ | 0 | 2 | 24 | ·0250 | 1 | 10¼ | 1 | 0 | 13 | ·0407 | 2 | 0½ | 1 | 1 | 18 | ·057 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | PITCH 1⅛ IN. FACE, 3 IN. WIDE. | | | | | | PITCH 1¼ IN. FACE, 3½ IN. WIDE. | | | | | | PITCH 1⅜ IN FACE, 3¾ IN. WIDE. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 57 | 1 | 8½ | 0 | 2 | 26 | ·0255 | 1 | 10⅝ | 1 | 0 | 15 | ·0413 | 2 | 0⅞ | 1 | 1 | 21 | ·059 |
| 58 | 1 | 8¾ | 0 | 3 | 0 | ·0260 | 1 | 11 | 1 | 0 | 18 | ·0420 | 2 | 1⅜ | 1 | 1 | 24 | ·060 |
| 59 | 1 | 9⅛ | 0 | 3 | 2 | ·0264 | 1 | 11½ | 1 | 0 | 20 | ·0429 | 2 | 1⅞ | 1 | 1 | 27 | ·061 |
| 60 | 1 | 9⅜ | 0 | 3 | 4 | ·0268 | 1 | 11⅞ | 1 | 0 | 23 | ·0435 | 2 | 2¼ | 1 | 2 | 2 | ·062 |
| 61 | 1 | 9⅞ | 0 | 3 | 5 | ·0272 | 2 | 0¼ | 1 | 0 | 25 | ·0460 | 2 | 2¾ | 1 | 2 | 6 | ·063 |
| 62 | 1 | 10¼ | 0 | 3 | 7 | ·0276 | 2 | 0⅝ | 1 | 1 | 0 | ·0466 | 2 | 3⅛ | 1 | 2 | 9 | ·064 |
| 63 | 1 | 10½ | 0 | 3 | 9 | ·0280 | 2 | 1 | 1 | 1 | 3 | ·0474 | 2 | 3½ | 1 | 2 | 12 | ·065 |
| 64 | 1 | 10⅞ | 0 | 3 | 11 | ·0285 | 2 | 1½ | 1 | 1 | 5 | ·0480 | 2 | 4 | 1 | 2 | 15 | ·066 |
| 65 | 1 | 11¼ | 0 | 3 | 13 | ·0290 | 2 | 1⅞ | 1 | 1 | 8 | ·0485 | 2 | 4½ | 1 | 2 | 17 | ·067 |
| 66 | 1 | 11⅝ | 0 | 3 | 15 | ·0294 | 2 | 2¼ | 1 | 1 | 10 | ·0490 | 2 | 4⅞ | 1 | 2 | 20 | ·068 |
| 67 | 2 | 0 | 0 | 3 | 17 | ·0300 | 2 | 2⅝ | 1 | 1 | 12 | ·0495 | 2 | 5¼ | 1 | 2 | 23 | ·069 |
| 68 | 2 | 0⅜ | 0 | 3 | 19 | ·0304 | 2 | 3 | 1 | 1 | 15 | ·0497 | 2 | 5¾ | 1 | 2 | 26 | ·070 |
| 69 | 2 | 0¾ | 0 | 3 | 20 | ·0308 | 2 | 3½ | 1 | 1 | 17 | ·0503 | 2 | 6¼ | 1 | 3 | 0 | ·071 |
| 70 | 2 | 1 | 0 | 3 | 21 | ·0310 | 2 | 3⅞ | 1 | 1 | 20 | ·0511 | 2 | 6⅝ | 1 | 3 | 3 | ·072 |
| 71 | 2 | 1½ | 0 | 3 | 22 | ·0316 | 2 | 4¼ | 1 | 1 | 22 | ·0517 | 2 | 7 | 1 | 3 | 6 | ·073 |
| 72 | 2 | 1¾ | 0 | 3 | 24 | ·0320 | 2 | 4⅝ | 1 | 1 | 25 | ·0522 | 2 | 7½ | 1 | 3 | 9 | ·074 |
| 73 | 2 | 2⅛ | 0 | 3 | 25 | ·0325 | 2 | 5 | 1 | 2 | 0 | ·0530 | 2 | 8 | 1 | 3 | 12 | ·075 |
| 74 | 2 | 2½ | 0 | 3 | 26 | ·0330 | 2 | 5½ | 1 | 2 | 3 | ·0536 | 2 | 8⅜ | 1 | 3 | 15 | ·076 |
| 75 | 2 | 2⅞ | 0 | 3 | 27 | ·0335 | 2 | 5⅞ | 1 | 2 | 5 | ·0545 | 2 | 8⅞ | 1 | 3 | 18 | ·077 |
| 76 | 2 | 3¼ | 1 | 0 | 0 | ·0340 | 2 | 6¼ | 1 | 2 | 8 | ·0558 | 2 | 9¼ | 1 | 3 | 21 | ·078 |
| 77 | 2 | 3½ | 1 | 0 | 2 | ·0344 | 2 | 6⅝ | 1 | 2 | 11 | ·0561 | 2 | 9¾ | 1 | 3 | 24 | ·079 |
| 78 | 2 | 3⅞ | 1 | 0 | 4 | ·0348 | 2 | 7 | 1 | 2 | 13 | ·0566 | 2 | 10⅛ | 1 | 3 | 27 | ·080 |
| 79 | 2 | 4⅛ | 1 | 0 | 6 | ·0353 | 2 | 7⅜ | 1 | 2 | 16 | ·0580 | 2 | 10½ | 2 | 0 | 3 | ·081 |
| 80 | 2 | 4⅝ | 1 | 0 | 8 | ·0358 | 2 | 7¾ | 1 | 2 | 18 | ·0584 | 2 | 11 | 2 | 0 | 6 | ·082 |
| 81 | 2 | 5 | 1 | 0 | 10 | ·0363 | 2 | 8¼ | 1 | 2 | 21 | ·0589 | 2 | 11½ | 2 | 0 | 11 | ·083 |
| 82 | 2 | 5⅜ | 1 | 0 | 12 | ·0366 | 2 | 8⅝ | 1 | 2 | 23 | ·0598 | 2 | 11⅞ | 2 | 0 | 14 | ·084 |
| 83 | 2 | 5¾ | 1 | 0 | 14 | ·0370 | 2 | 9 | 1 | 2 | 25 | ·0605 | 3 | 0⅜ | 2 | 0 | 17 | ·085 |
| 84 | 2 | 6 | 1 | 0 | 16 | ·0375 | 2 | 9⅜ | 1 | 2 | 27 | ·0610 | 3 | 0¾ | 2 | 0 | 20 | ·086 |
| 85 | 2 | 6⅜ | 1 | 0 | 18 | ·0380 | 2 | 9¾ | 1 | 3 | 2 | ·0618 | 3 | 1¼ | 2 | 0 | 23 | ·087 |
| 86 | 2 | 6¾ | 1 | 0 | 20 | ·0386 | 2 | 10¼ | 1 | 3 | 4 | ·0624 | 3 | 1⅝ | 2 | 0 | 24 | ·088 |
| 87 | 2 | 7⅛ | 1 | 0 | 22 | ·0390 | 2 | 10⅝ | 1 | 3 | 7 | ·0633 | 3 | 2 | 2 | 0 | 27 | ·089 |
| 88 | 2 | 7½ | 1 | 0 | 24 | ·0394 | 2 | 11 | 1 | 3 | 10 | ·0642 | 3 | 2½ | 2 | 1 | 3 | ·090 |
| 89 | 2 | 7⅞ | 1 | 0 | 26 | ·0398 | 2 | 11⅜ | 1 | 3 | 12 | ·0646 | 3 | 2⅞ | 2 | 1 | 7 | ·091 |
| 90 | 2 | 8¼ | 1 | 1 | 0 | ·0402 | 2 | 11¾ | 1 | 3 | 15 | ·0660 | 3 | 3¼ | 2 | 1 | 10 | ·092 |
| 91 | 2 | 8½ | 1 | 1 | 2 | ·0404 | 3 | 0¼ | 1 | 3 | 18 | ·0664 | 3 | 3⅞ | 2 | 1 | 13 | ·093 |
| 92 | 2 | 8⅞ | 1 | 1 | 4 | ·0410 | 3 | 0⅝ | 1 | 3 | 20 | ·0672 | 3 | 4¼ | 2 | 1 | 15 | ·094 |
| 93 | 2 | 9¼ | 1 | 1 | 6 | ·0415 | 3 | 1 | 1 | 3 | 22 | ·0680 | 3 | 4¾ | 2 | 1 | 18 | ·095 |
| 94 | 2 | 9⅝ | 1 | 1 | 8 | ·0420 | 3 | 1⅜ | 1 | 3 | 25 | ·0686 | 3 | 5⅛ | 2 | 1 | 21 | ·096 |
| 95 | 2 | 10 | 1 | 1 | 10 | ·0425 | 3 | 1¾ | 2 | 0 | 0 | ·0690 | 3 | 5½ | 2 | 1 | 24 | ·097 |
| 96 | 2 | 10⅜ | 1 | 1 | 12 | ·0430 | 3 | 2⅛ | 2 | 0 | 3 | ·0698 | 3 | 6 | 2 | 2 | 0 | ·098 |
| 97 | 2 | 10¾ | 1 | 1 | 14 | ·0435 | 3 | 2⅝ | 2 | 0 | 6 | ·0706 | 3 | 6½ | 2 | 2 | 4 | ·099 |
| 98 | 2 | 11 | 1 | 1 | 16 | ·0440 | 3 | 3 | 2 | 0 | 9 | ·0712 | 3 | 6⅞ | 2 | 2 | 8 | ·100 |
| 99 | 2 | 11⅜ | 1 | 1 | 18 | ·0445 | 3 | 3⅜ | 2 | 0 | 12 | ·0721 | 3 | 7⅜ | 2 | 2 | 11 | ·101 |
| 100 | 2 | 11⅞ | 1 | 1 | 20 | ·0450 | 3 | 3¾ | 2 | 0 | 14 | ·0730 | 3 | 7¾ | 2 | 2 | 14 | ·102 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | Pitch 1½ In., Face 4 In. Wide. | | | | | | Pitch 1⅝ In., Face 4½ In. Wide. | | | | | | Pitch 1¾ In., Face 5 In. Wide. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 13 | 0 | 6¼ | 0 | 1 | 14 | ·019 | 0 | 6¾ | 0 | 1 | 26 | ·026 | 0 | 7¼ | 0 | 2 | 15 | ·037 |
| 14 | 0 | 6¾ | 0 | 1 | 17 | ·020 | 0 | 7¼ | 0 | 2 | 3 | ·028 | 0 | 7¾ | 0 | 2 | 22 | ·039 |
| 15 | 0 | 7⅛ | 0 | 1 | 19 | ·021 | 0 | 7¾ | 0 | 2 | 7 | ·030 | 0 | 8⅜ | 0 | 3 | 0 | ·042 |
| 16 | 0 | 7⅝ | 0 | 1 | 23 | ·023 | 0 | 8¼ | 0 | 2 | 11 | ·032 | 0 | 9 | 0 | 3 | 4 | ·046 |
| 17 | 0 | 8⅛ | 0 | 1 | 26 | ·024 | 0 | 8⅞ | 0 | 2 | 15 | ·035 | 0 | 9½ | 0 | 3 | 8 | ·048 |
| 18 | 0 | 8⅝ | 0 | 2 | 0 | ·026 | 0 | 9⅜ | 0 | 2 | 20 | ·037 | 0 | 10 | 0 | 3 | 13 | ·051 |
| 19 | 0 | 9⅛ | 0 | 2 | 4 | ·028 | 0 | 9⅞ | 0 | 2 | 24 | ·039 | 0 | 10⅝ | 0 | 3 | 16 | ·054 |
| 20 | 0 | 9⅝ | 0 | 2 | 8 | ·029 | 0 | 10⅜ | 0 | 3 | 0 | ·041 | 0 | 11¼ | 0 | 3 | 22 | ·057 |
| 21 | 0 | 10 | 0 | 2 | 11 | ·030 | 0 | 11 | 0 | 3 | 4 | ·043 | 0 | 11¾ | 1 | 0 | 0 | ·060 |
| 22 | 0 | 10½ | 0 | 2 | 14 | ·031 | 0 | 11½ | 0 | 3 | 8 | ·045 | 1 | 0⅜ | 1 | 0 | 7 | ·063 |
| 23 | 0 | 11 | 0 | 2 | 16 | ·033 | 1 | 0 | 0 | 3 | 12 | ·048 | 1 | 0⅞ | 1 | 0 | 14 | ·066 |
| 24 | 0 | 11½ | 0 | 2 | 18 | ·035 | 1 | 0½ | 0 | 3 | 16 | ·049 | 1 | 1½ | 1 | 0 | 21 | ·069 |
| 25 | 1 | 0 | 0 | 2 | 25 | ·037 | 1 | 1 | 0 | 3 | 22 | ·051 | 1 | 2 | 1 | 1 | 0 | ·072 |
| 26 | 1 | 0½ | 0 | 3 | 0 | ·038 | 1 | 1½ | 0 | 3 | 27 | ·053 | 1 | 2½ | 1 | 1 | 7 | ·074 |
| 27 | 1 | 1 | 0 | 3 | 3 | ·040 | 1 | 2 | 1 | 0 | 5 | ·055 | 1 | 3 | 1 | 1 | 14 | ·077 |
| 28 | 1 | 1⅜ | 0 | 3 | 6 | ·041 | 1 | 2½ | 1 | 0 | 12 | ·056 | 1 | 3⅝ | 1 | 1 | 21 | ·080 |
| 29 | 1 | 1⅞ | 0 | 3 | 9 | ·042 | 1 | 3 | 1 | 0 | 17 | ·058 | 1 | 4⅛ | 1 | 2 | 0 | ·082 |
| 30 | 1 | 2⅜ | 0 | 3 | 12 | ·043 | 1 | 3½ | 1 | 0 | 23 | ·060 | 1 | 4⅝ | 1 | 2 | 7 | ·085 |
| 31 | 1 | 2⅞ | 0 | 3 | 15 | ·044 | 1 | 4 | 1 | 1 | 0 | ·063 | 1 | 5¼ | 1 | 2 | 14 | ·088 |
| 32 | 1 | 3⅜ | 0 | 3 | 20 | ·046 | 1 | 4⅝ | 1 | 1 | 6 | ·065 | 1 | 5⅞ | 1 | 2 | 21 | ·091 |
| 33 | 1 | 3¾ | 0 | 3 | 25 | ·047 | 1 | 5⅛ | 1 | 1 | 12 | ·068 | 1 | 6½ | 1 | 3 | 0 | ·095 |
| 34 | 1 | 4¼ | 1 | 0 | 2 | ·048 | 1 | 5⅝ | 1 | 1 | 19 | ·070 | 1 | 7 | 1 | 3 | 7 | ·098 |
| 35 | 1 | 4¾ | 1 | 0 | 7 | ·050 | 1 | 6⅛ | 1 | 1 | 25 | ·072 | 1 | 7½ | 1 | 3 | 14 | ·100 |
| 36 | 1 | 5¼ | 1 | 0 | 12 | ·052 | 1 | 6⅝ | 1 | 2 | 4 | ·074 | 1 | 8 | 1 | 3 | 21 | ·102 |
| 37 | 1 | 5⅝ | 1 | 0 | 16 | ·053 | 1 | 7⅛ | 1 | 2 | 9 | ·076 | 1 | 8⅝ | 2 | 0 | 0 | ·106 |
| 38 | 1 | 6¼ | 1 | 0 | 20 | ·056 | 1 | 7⅝ | 1 | 2 | 14 | ·078 | 1 | 9¼ | 2 | 0 | 7 | ·109 |
| 39 | 1 | 6⅝ | 1 | 0 | 24 | ·057 | 1 | 8¼ | 1 | 2 | 20 | ·080 | 1 | 9¾ | 2 | 0 | 14 | ·112 |
| 40 | 1 | 7 | 1 | 1 | 0 | ·058 | 1 | 8¾ | 1 | 2 | 25 | ·082 | 1 | 10⅜ | 2 | 0 | 21 | ·115 |
| 41 | 1 | 7⅝ | 1 | 1 | 4 | ·059 | 1 | 9¼ | 1 | 3 | 2 | ·084 | 1 | 10⅞ | 2 | 1 | 0 | ·118 |
| 42 | 1 | 8 | 1 | 1 | 8 | ·060 | 1 | 9¾ | 1 | 3 | 8 | ·086 | 1 | 11½ | 2 | 1 | 7 | ·121 |
| 43 | 1 | 8⅝ | 1 | 1 | 12 | ·062 | 1 | 10¼ | 1 | 3 | 14 | ·088 | 2 | 0 | 2 | 1 | 14 | ·124 |
| 44 | 1 | 9 | 1 | 1 | 16 | ·063 | 1 | 10¾ | 1 | 3 | 20 | ·090 | 2 | 0½ | 2 | 1 | 21 | ·126 |
| 45 | 1 | 9½ | 1 | 1 | 20 | ·065 | 1 | 11⅜ | 1 | 3 | 22 | ·093 | 2 | 1 | 2 | 2 | 0 | ·129 |
| 46 | 1 | 10 | 1 | 1 | 24 | ·066 | 1 | 11⅞ | 2 | 0 | 0 | ·096 | 2 | 1⅝ | 2 | 2 | 7 | ·132 |
| 47 | 1 | 10½ | 1 | 2 | 0 | ·068 | 2 | 0⅜ | 2 | 0 | 5 | ·097 | 2 | 2⅛ | 2 | 2 | 14 | ·135 |
| 48 | 1 | 11 | 1 | 2 | 4 | ·070 | 2 | 0⅞ | 2 | 0 | 10 | ·099 | 2 | 2¾ | 2 | 2 | 21 | ·137 |
| 49 | 1 | 11½ | 1 | 2 | 8 | ·072 | 2 | 1⅜ | 2 | 0 | 16 | ·101 | 2 | 3⅜ | 2 | 3 | 0 | ·140 |
| 50 | 2 | 0 | 1 | 2 | 12 | ·074 | 2 | 1⅞ | 2 | 0 | 22 | ·102 | 2 | 3⅞ | 2 | 3 | 7 | ·143 |
| 51 | 2 | 0⅜ | 1 | 2 | 16 | ·075 | 2 | 2⅜ | 2 | 1 | 0 | ·105 | 2 | 4½ | 2 | 3 | 14 | ·146 |
| 52 | 2 | 0⅞ | 1 | 2 | 20 | ·076 | 2 | 2⅞ | 2 | 1 | 5 | ·107 | 2 | 4⅞ | 2 | 3 | 21 | ·148 |
| 53 | 2 | 1¼ | 1 | 2 | 24 | ·078 | 2 | 3⅜ | 2 | 1 | 10 | ·110 | 2 | 5½ | 3 | 0 | 0 | ·152 |
| 54 | 2 | 1¾ | 1 | 3 | 0 | ·080 | 2 | 3⅞ | 2 | 1 | 15 | ·111 | 2 | 6 | 3 | 0 | 7 | ·155 |
| 55 | 2 | 2¼ | 1 | 3 | 4 | ·081 | 2 | 4½ | 2 | 1 | 21 | ·113 | 2 | 6⅝ | 3 | 0 | 14 | ·158 |
| 56 | 2 | 2¾ | 1 | 3 | 8 | ·083 | 2 | 4⅞ | 2 | 1 | 26 | ·115 | 2 | 7⅛ | 3 | 0 | 21 | ·160 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | Pitch 1½ In., Face 4 In. Wide. | | | | | | Pitch 1⅝ In., Face 4½ In. Wide. | | | | | | Pitch 1¾ In., Face 5 In. Wide. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 57 | 2 | 3¼ | 1 | 3 | 12 | ·084 | 2 | 5¼ | 2 | 2 | 3 | ·116 | 2 | 7¾ | 3 | 1 | 0 | ·163 |
| 58 | 2 | 3⅝ | 1 | 3 | 16 | ·085 | 2 | 6 | 2 | 2 | 8 | ·120 | 2 | 8¼ | 3 | 1 | 7 | ·166 |
| 59 | 2 | 4⅛ | 1 | 3 | 20 | ·086 | 2 | 6½ | 2 | 2 | 14 | ·121 | 2 | 8⅞ | 3 | 1 | 14 | ·169 |
| 60 | 2 | 4⅝ | 1 | 3 | 24 | ·087 | 2 | 7 | 2 | 2 | 19 | ·123 | 2 | 9⅜ | 3 | 1 | 21 | ·172 |
| 61 | 2 | 5¼ | 2 | 0 | 0 | ·088 | 2 | 7½ | 2 | 2 | 25 | ·125 | 2 | 10 | 3 | 2 | 0 | ·175 |
| 62 | 2 | 5⅝ | 2 | 0 | 4 | ·089 | 2 | 8 | 2 | 3 | 4 | ·127 | 2 | 10½ | 3 | 2 | 7 | ·178 |
| 63 | 2 | 6 | 2 | 0 | 8 | ·091 | 2 | 8⅝ | 2 | 3 | 10 | ·130 | 2 | 11 | 3 | 2 | 14 | ·180 |
| 64 | 2 | 6½ | 2 | 0 | 12 | ·092 | 2 | 9⅛ | 2 | 3 | 17 | ·132 | 2 | 11⅝ | 3 | 2 | 21 | ·183 |
| 65 | 2 | 7 | 2 | 0 | 16 | ·094 | 2 | 9⅝ | 2 | 3 | 23 | ·134 | 3 | 0¼ | 3 | 3 | 0 | ·187 |
| 66 | 2 | 7½ | 2 | 0 | 20 | ·095 | 2 | 10⅛ | 3 | 0 | 3 | ·136 | 3 | 0¾ | 3 | 3 | 10 | ·190 |
| 67 | 2 | 8 | 2 | 0 | 24 | ·096 | 2 | 10⅝ | 3 | 0 | 10 | ·138 | 3 | 1⅜ | 3 | 3 | 18 | ·193 |
| 68 | 2 | 8½ | 2 | 1 | 0 | ·097 | 2 | 11⅛ | 3 | 0 | 16 | ·140 | 3 | 1⅞ | 3 | 3 | 24 | ·195 |
| 69 | 2 | 8⅞ | 2 | 1 | 4 | ·100 | 2 | 11¾ | 3 | 0 | 21 | ·142 | 3 | 2⅜ | 4 | 0 | 4 | ·198 |
| 70 | 2 | 9⅜ | 2 | 1 | 8 | ·102 | 3 | 0¼ | 3 | 1 | 0 | ·144 | 3 | 3 | 4 | 0 | 10 | ·201 |
| 71 | 2 | 9⅞ | 2 | 1 | 12 | ·103 | 3 | 0¾ | 3 | 1 | 6 | ·146 | 3 | 3½ | 4 | 0 | 17 | ·204 |
| 72 | 2 | 10⅜ | 2 | 1 | 16 | ·104 | 3 | 1¼ | 3 | 1 | 13 | ·148 | 3 | 4⅛ | 4 | 0 | 22 | ·207 |
| 73 | 2 | 10⅞ | 2 | 1 | 20 | ·105 | 3 | 1¾ | 3 | 1 | 19 | ·150 | 3 | 4⅝ | 4 | 1 | 0 | ·210 |
| 74 | 2 | 11⅜ | 2 | 1 | 24 | ·106 | 3 | 2¼ | 3 | 1 | 24 | ·152 | 3 | 5¼ | 4 | 1 | 6 | ·212 |
| 75 | 2 | 11⅞ | 2 | 2 | 0 | ·109 | 3 | 2¾ | 3 | 2 | 0 | ·154 | 3 | 5¾ | 4 | 1 | 11 | ·215 |
| 76 | 3 | 0¼ | 2 | 2 | 4 | ·111 | 3 | 3¼ | 3 | 2 | 5 | ·156 | 3 | 6⅜ | 4 | 1 | 16 | ·218 |
| 77 | 3 | 0¾ | 2 | 2 | 8 | ·112 | 3 | 3⅞ | 3 | 2 | 10 | ·158 | 3 | 6⅞ | 4 | 1 | 20 | ·221 |
| 78 | 3 | 1¼ | 2 | 2 | 12 | ·113 | 3 | 4⅜ | 3 | 2 | 15 | ·160 | 3 | 7½ | 4 | 1 | 24 | ·224 |
| 79 | 3 | 1¾ | 2 | 2 | 16 | ·114 | 3 | 4⅞ | 3 | 2 | 20 | ·162 | 3 | 8 | 4 | 2 | 0 | ·227 |
| 80 | 3 | 2¼ | 2 | 2 | 20 | ·116 | 3 | 5⅜ | 3 | 2 | 26 | ·165 | 3 | 8½ | 4 | 2 | 6 | ·230 |
| 81 | 3 | 2⅝ | 2 | 2 | 24 | ·118 | 3 | 5⅞ | 3 | 3 | 6 | ·168 | 3 | 9⅛ | 4 | 2 | 11 | ·233 |
| 82 | 3 | 3⅛ | 2 | 3 | 0 | ·120 | 3 | 6⅜ | 3 | 3 | 13 | ·170 | 3 | 9⅝ | 4 | 2 | 16 | ·236 |
| 83 | 3 | 3⅝ | 2 | 3 | 4 | ·121 | 3 | 6⅞ | 3 | 3 | 20 | ·172 | 3 | 10¼ | 4 | 2 | 20 | ·238 |
| 84 | 3 | 4 | 2 | 3 | 8 | ·123 | 3 | 7½ | 4 | 0 | 0 | ·174 | 3 | 10¾ | 4 | 2 | 24 | ·240 |
| 85 | 3 | 4½ | 2 | 3 | 12 | ·124 | 3 | 7⅞ | 4 | 0 | 7 | ·176 | 3 | 11¼ | 4 | 3 | 4 | ·243 |
| 86 | 3 | 5 | 2 | 3 | 16 | ·125 | 3 | 8½ | 4 | 0 | 14 | ·178 | 3 | 11⅞ | 4 | 3 | 8 | ·246 |
| 87 | 3 | 5½ | 2 | 3 | 20 | ·126 | 3 | 9 | 4 | 0 | 20 | ·180 | 4 | 0½ | 4 | 3 | 13 | ·250 |
| 88 | 3 | 6 | 2 | 3 | 24 | ·128 | 3 | 9½ | 4 | 0 | 26 | ·182 | 4 | 1 | 4 | 3 | 18 | ·252 |
| 89 | 3 | 6½ | 3 | 0 | 0 | ·129 | 3 | 10 | 4 | 1 | 3 | ·184 | 4 | 1½ | 4 | 3 | 24 | ·255 |
| 90 | 3 | 7 | 3 | 0 | 4 | ·131 | 3 | 10½ | 4 | 1 | 8 | ·186 | 4 | 2⅛ | 5 | 0 | 2 | ·258 |
| 91 | 3 | 7½ | 3 | 0 | 8 | ·133 | 3 | 11 | 4 | 1 | 13 | ·188 | 4 | 2¾ | 5 | 1 | 7 | ·261 |
| 92 | 3 | 7⅞ | 3 | 0 | 12 | ·134 | 3 | 11⅝ | 4 | 1 | 18 | ·190 | 4 | 3¼ | 5 | 1 | 14 | ·264 |
| 93 | 3 | 8⅜ | 3 | 0 | 16 | ·135 | 4 | 0⅛ | 4 | 1 | 23 | ·192 | 4 | 3⅞ | 5 | 1 | 21 | ·267 |
| 94 | 3 | 8⅞ | 3 | 0 | 20 | ·137 | 4 | 0⅝ | 4 | 1 | 26 | ·194 | 4 | 4⅜ | 5 | 2 | 0 | ·269 |
| 95 | 3 | 9⅜ | 3 | 0 | 24 | ·138 | 4 | 1⅛ | 4 | 2 | 3 | ·196 | 4 | 4⅞ | 5 | 2 | 7 | ·272 |
| 96 | 3 | 9¾ | 3 | 1 | 0 | ·140 | 4 | 1⅝ | 4 | 2 | 8 | ·198 | 4 | 5½ | 5 | 2 | 14 | ·275 |
| 97 | 3 | 10¼ | 3 | 1 | 4 | ·142 | 4 | 2⅛ | 4 | 2 | 13 | ·200 | 4 | 6 | 5 | 2 | 21 | ·279 |
| 98 | 3 | 10¾ | 3 | 1 | 8 | ·144 | 4 | 2⅝ | 4 | 2 | 18 | ·202 | 4 | 6½ | 5 | 3 | 0 | ·281 |
| 99 | 3 | 11¼ | 3 | 1 | 12 | ·146 | 4 | 3¼ | 4 | 2 | 23 | ·204 | 4 | 7⅛ | 5 | 3 | 7 | ·284 |
| 100 | 3 | 11¾ | 3 | 1 | 16 | ·148 | 4 | 3¾ | 4 | 3 | 0 | ·206 | 4 | 7¾ | 5 | 3 | 14 | ·287 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | Pitch 1¾ In., Face 5¼ In. Wide. | | | | | | Pitch 2 In., Face 6 In. Wide. | | | | | | Pitch 2¼ In., Face 7 In. Wide. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 13 | 0 | 7⅞ | 0 | 3 | 13 | ·052 | 0 | 8⅜ | 1 | 0 | 0 | ·069 | 0 | 9⅜ | 1 | 2 | 0 | ·082 |
| 14 | 0 | 8½ | 0 | 3 | 16 | ·056 | 0 | 9 | 1 | 0 | 7 | ·075 | 0 | 10 | 1 | 2 | 14 | ·087 |
| 15 | 0 | 9 | 0 | 3 | 20 | ·060 | 0 | 9⅝ | 1 | 0 | 14 | ·080 | 0 | 10¾ | 1 | 2 | 24 | ·094 |
| 16 | 0 | 9⅝ | 0 | 3 | 24 | ·064 | 0 | 10¼ | 1 | 0 | 21 | ·085 | 0 | 11½ | 1 | 3 | 8 | ·100 |
| 17 | 0 | 10¼ | 1 | 0 | 0 | ·070 | 0 | 10⅞ | 1 | 1 | 3 | ·090 | 1 | 0¼ | 1 | 3 | 18 | ·108 |
| 18 | 0 | 10¾ | 1 | 0 | 5 | ·073 | 0 | 11½ | 1 | 1 | 13 | ·095 | 1 | 0⅞ | 2 | 0 | 6 | ·113 |
| 19 | 0 | 11⅜ | 1 | 0 | 10 | ·075 | 1 | 0⅛ | 1 | 1 | 24 | ·101 | 1 | 1⅝ | 2 | 0 | 22 | ·117 |
| 20 | 1 | 0 | 1 | 0 | 15 | ·080 | 1 | 0¾ | 1 | 2 | 8 | ·106 | 1 | 2⅜ | 2 | 1 | 10 | ·126 |
| 21 | 1 | 0½ | 1 | 0 | 20 | ·083 | 1 | 1½ | 1 | 2 | 20 | ·112 | 1 | 3 | 2 | 2 | 0 | ·132 |
| 22 | 1 | 1⅛ | 1 | 0 | 26 | ·087 | 1 | 2 | 1 | 3 | 4 | ·116 | 1 | 3¾ | 2 | 2 | 16 | ·138 |
| 23 | 1 | 1¾ | 1 | 1 | 5 | ·092 | 1 | 2⅝ | 1 | 3 | 16 | ·121 | 1 | 4½ | 2 | 3 | 6 | ·145 |
| 24 | 1 | 2⅜ | 1 | 1 | 13 | ·095 | 1 | 3⅜ | 2 | 0 | 0 | ·128 | 1 | 5¼ | 2 | 3 | 20 | ·154 |
| 25 | 1 | 2⅞ | 1 | 1 | 20 | ·098 | 1 | 3⅞ | 2 | 0 | 12 | ·132 | 1 | 6 | 3 | 0 | 10 | ·159 |
| 26 | 1 | 3½ | 1 | 2 | 0 | ·103 | 1 | 4½ | 2 | 0 | 24 | ·137 | 1 | 6⅝ | 3 | 1 | 0 | ·160 |
| 27 | 1 | 4⅛ | 1 | 2 | 8 | ·107 | 1 | 5¼ | 2 | 1 | 8 | ·143 | 1 | 7⅜ | 3 | 1 | 16 | ·164 |
| 28 | 1 | 4⅝ | 1 | 2 | 16 | ·110 | 1 | 5¾ | 2 | 1 | 18 | ·147 | 1 | 8 | 3 | 2 | 0 | ·175 |
| 29 | 1 | 5⅜ | 1 | 2 | 24 | ·115 | 1 | 6½ | 2 | 2 | 0 | ·154 | 1 | 8¾ | 3 | 2 | 15 | ·182 |
| 30 | 1 | 6 | 1 | 3 | 4 | ·119 | 1 | 7⅛ | 2 | 2 | 10 | ·159 | 1 | 9½ | 3 | 3 | 0 | ·189 |
| 31 | 1 | 6½ | 1 | 3 | 12 | ·123 | 1 | 7¾ | 2 | 2 | 20 | ·164 | 1 | 10¼ | 3 | 3 | 14 | ·196 |
| 32 | 1 | 7⅛ | 1 | 3 | 20 | ·127 | 1 | 8⅜ | 2 | 3 | 0 | ·169 | 1 | 11 | 4 | 0 | 0 | ·201 |
| 33 | 1 | 7¾ | 2 | 0 | 0 | ·131 | 1 | 9 | 2 | 3 | 10 | ·175 | 1 | 11⅝ | 4 | 0 | 14 | ·207 |
| 34 | 1 | 8⅜ | 2 | 0 | 8 | ·136 | 1 | 9⅝ | 2 | 3 | 20 | ·180 | 2 | 0⅜ | 4 | 1 | 3 | ·214 |
| 35 | 1 | 9 | 2 | 0 | 16 | ·140 | 1 | 10⅛ | 3 | 0 | 0 | ·184 | 2 | 1 | 4 | 1 | 20 | ·220 |
| 36 | 1 | 9½ | 2 | 0 | 24 | ·143 | 1 | 10⅞ | 3 | 0 | 10 | ·190 | 2 | 2 | 4 | 2 | 6 | ·227 |
| 37 | 1 | 10 | 2 | 1 | 4 | ·148 | 1 | 11½ | 3 | 0 | 20 | ·195 | 2 | 2½ | 4 | 2 | 20 | ·233 |
| 38 | 1 | 10¾ | 2 | 1 | 12 | ·152 | 2 | 0¼ | 3 | 1 | 3 | ·202 | 2 | 3¼ | 4 | 3 | 6 | ·240 |
| 39 | 1 | 11⅜ | 2 | 1 | 20 | ·155 | 2 | 0⅞ | 3 | 1 | 13 | ·207 | 2 | 4 | 4 | 3 | 20 | ·246 |
| 40 | 1 | 11⅞ | 2 | 2 | 0 | ·158 | 2 | 1½ | 3 | 1 | 23 | ·212 | 2 | 4⅝ | 5 | 0 | 5 | ·252 |
| 41 | 2 | 0½ | 2 | 2 | 8 | ·162 | 2 | 2⅛ | 3 | 2 | 5 | ·217 | 2 | 5⅜ | 5 | 0 | 21 | ·258 |
| 42 | 2 | 1 | 2 | 2 | 16 | ·166 | 2 | 2¾ | 3 | 2 | 14 | ·221 | 2 | 6 | 5 | 1 | 9 | ·265 |
| 43 | 2 | 1⅝ | 2 | 2 | 24 | ·170 | 2 | 3⅜ | 3 | 2 | 24 | ·228 | 2 | 6¾ | 5 | 1 | 24 | ·271 |
| 44 | 2 | 2¼ | 2 | 3 | 4 | ·174 | 2 | 4 | 3 | 3 | 8 | ·233 | 2 | 7½ | 5 | 2 | 10 | ·278 |
| 45 | 2 | 2⅞ | 2 | 3 | 13 | ·179 | 2 | 4⅝ | 3 | 3 | 18 | ·238 | 2 | 8¼ | 5 | 2 | 24 | ·284 |
| 46 | 2 | 3½ | 2 | 3 | 22 | ·183 | 2 | 5¼ | 4 | 0 | 0 | ·243 | 2 | 9 | 5 | 3 | 10 | ·290 |
| 47 | 2 | 4 | 3 | 0 | 3 | ·187 | 2 | 6 | 4 | 0 | 10 | ·250 | 2 | 9⅝ | 5 | 3 | 24 | ·296 |
| 48 | 2 | 4⅝ | 3 | 0 | 12 | ·190 | 2 | 6½ | 4 | 0 | 20 | ·254 | 2 | 10⅜ | 6 | 0 | 10 | ·308 |
| 49 | 2 | 5¼ | 3 | 0 | 22 | ·194 | 2 | 7¼ | 4 | 1 | 0 | ·260 | 2 | 11 | 6 | 0 | 26 | ·311 |
| 50 | 2 | 5⅞ | 3 | 1 | 5 | ·198 | 2 | 7⅞ | 4 | 1 | 10 | ·265 | 2 | 11¾ | 6 | 1 | 14 | ·316 |
| 51 | 2 | 6½ | 3 | 1 | 14 | ·203 | 2 | 8½ | 4 | 1 | 21 | ·270 | 3 | 0½ | 6 | 2 | 1 | ·322 |
| 52 | 2 | 7⅛ | 3 | 1 | 24 | ·207 | 2 | 9⅛ | 4 | 2 | 4 | ·276 | 3 | 1¼ | 6 | 2 | 15 | ·328 |
| 53 | 2 | 7⅝ | 3 | 2 | 6 | ·210 | 2 | 9¾ | 4 | 2 | 14 | ·281 | 3 | 2 | 6 | 3 | 2 | ·334 |
| 54 | 2 | 8¼ | 3 | 2 | 15 | ·212 | 2 | 10⅜ | 4 | 2 | 24 | ·286 | 3 | 2⅝ | 6 | 3 | 16 | ·341 |
| 55 | 2 | 8⅞ | 3 | 2 | 24 | ·217 | 2 | 11 | 4 | 3 | 7 | ·291 | 3 | 3½ | 7 | 0 | 4 | ·348 |
| 56 | 2 | 9⅜ | 3 | 3 | 8 | ·222 | 2 | 11⅝ | 4 | 3 | 18 | ·296 | 3 | 4⅛ | 7 | 0 | 18 | ·354 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | Pitch 1¾ In., Face 5½ In. Wide. | | | | | | Pitch 2 In., Face 6 In. Wide. | | | | | | Pitch 2¼ In., Face 7 In. Wide. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 57 | 2 | 10 | 3 | 3 | 20 | ·226 | 3 | 0¼ | 5 | 0 | 0 | ·302 | 3 | 4⅞ | 7 | 1 | 4 | ·360 |
| 58 | 2 | 10⅝ | 4 | 0 | 4 | ·230 | 3 | 0⅞ | 5 | 0 | 10 | ·307 | 3 | 5½ | 7 | 1 | 18 | ·367 |
| 59 | 2 | 11¼ | 4 | 0 | 16 | ·234 | 3 | 1½ | 5 | 0 | 20 | ·312 | 3 | 6¼ | 7 | 2 | 4 | ·373 |
| 60 | 2 | 11¾ | 4 | 1 | 0 | ·237 | 3 | 2¼ | 5 | 1 | 2 | ·318 | 3 | 7 | 7 | 2 | 18 | ·379 |
| 61 | 3 | 0⅜ | 4 | 1 | 12 | ·242 | 3 | 2⅞ | 5 | 1 | 12 | ·323 | 3 | 7¾ | 7 | 3 | 4 | ·385 |
| 62 | 3 | 1 | 4 | 1 | 24 | ·246 | 3 | 3½ | 5 | 1 | 22 | ·329 | 3 | 8½ | 7 | 3 | 19 | ·392 |
| 63 | 3 | 1⅝ | 4 | 2 | 8 | ·250 | 3 | 4⅛ | 5 | 2 | 6 | ·334 | 3 | 9⅛ | 8 | 0 | 4 | ·399 |
| 64 | 3 | 2¼ | 4 | 2 | 16 | ·254 | 3 | 4¾ | 5 | 2 | 16 | ·339 | 3 | 9⅞ | 8 | 0 | 18 | ·404 |
| 65 | 3 | 2⅞ | 4 | 2 | 24 | ·258 | 3 | 5⅜ | 5 | 2 | 26 | ·344 | 3 | 10½ | 8 | 1 | 5 | ·408 |
| 66 | 3 | 3⅜ | 4 | 3 | 4 | ·262 | 3 | 6 | 5 | 3 | 10 | ·350 | 3 | 11¼ | 8 | 1 | 19 | ·416 |
| 67 | 3 | 4 | 4 | 3 | 12 | ·266 | 3 | 6½ | 5 | 3 | 19 | ·354 | 4 | 0 | 8 | 2 | 6 | ·423 |
| 68 | 3 | 4⅝ | 4 | 3 | 20 | ·270 | 3 | 7¼ | 6 | 0 | 5 | ·360 | 4 | 0¾ | 8 | 2 | 20 | ·430 |
| 69 | 3 | 5⅛ | 5 | 0 | 0 | ·274 | 3 | 7⅞ | 6 | 0 | 16 | ·365 | 4 | 1½ | 8 | 3 | 8 | ·436 |
| 70 | 3 | 5¾ | 5 | 0 | 8 | ·277 | 3 | 8½ | 6 | 0 | 26 | ·370 | 4 | 2⅛ | 8 | 3 | 24 | ·442 |
| 71 | 3 | 6⅜ | 5 | 0 | 16 | ·281 | 3 | 9¼ | 6 | 1 | 8 | ·376 | 4 | 2⅞ | 9 | 0 | 12 | ·448 |
| 72 | 3 | 6¾ | 5 | 0 | 24 | ·284 | 3 | 9⅞ | 6 | 1 | 18 | ·382 | 4 | 3½ | 9 | 1 | 0 | ·454 |
| 73 | 3 | 7½ | 5 | 1 | 4 | ·288 | 3 | 10½ | 6 | 2 | 0 | ·387 | 4 | 4¼ | 9 | 1 | 15 | ·460 |
| 74 | 3 | 7⅞ | 5 | 1 | 12 | ·292 | 3 | 11⅛ | 6 | 2 | 10 | ·392 | 4 | 5 | 9 | 2 | 5 | ·467 |
| 75 | 3 | 8¾ | 5 | 1 | 20 | ·297 | 3 | 11¾ | 6 | 2 | 20 | ·397 | 4 | 5¾ | 9 | 2 | 20 | ·474 |
| 76 | 3 | 9⅜ | 5 | 2 | 0 | ·302 | 4 | 0⅜ | 6 | 3 | 2 | ·403 | 4 | 6½ | 9 | 3 | 6 | ·481 |
| 77 | 3 | 9⅞ | 5 | 2 | 8 | ·306 | 4 | 1 | 6 | 3 | 12 | ·408 | 4 | 7⅛ | 9 | 3 | 22 | ·487 |
| 78 | 3 | 10½ | 5 | 2 | 16 | ·309 | 4 | 1⅝ | 6 | 3 | 22 | ·413 | 4 | 7⅞ | 10 | 0 | 12 | ·492 |
| 79 | 3 | 11⅛ | 5 | 2 | 24 | ·313 | 4 | 2¼ | 7 | 0 | 4 | ·418 | 4 | 8½ | 10 | 1 | 0 | ·498 |
| 80 | 3 | 11¾ | 5 | 3 | 4 | ·317 | 4 | 3 | 7 | 0 | 15 | ·425 | 4 | 9¼ | 10 | 1 | 15 | ·505 |
| 81 | 4 | 0⅜ | 5 | 3 | 12 | ·321 | 4 | 3½ | 7 | 1 | 0 | ·429 | 4 | 10 | 10 | 2 | 4 | ·511 |
| 82 | 4 | 0⅞ | 5 | 3 | 20 | ·325 | 4 | 4¼ | 7 | 1 | 10 | ·435 | 4 | 10¾ | 10 | 2 | 20 | ·518 |
| 83 | 4 | 1½ | 6 | 0 | 0 | ·331 | 4 | 4⅞ | 7 | 1 | 21 | ·440 | 4 | 11½ | 10 | 3 | 9 | ·524 |
| 84 | 4 | 2⅛ | 6 | 0 | 8 | ·336 | 4 | 5½ | 7 | 2 | 4 | ·445 | 5 | 0⅛ | 10 | 3 | 25 | ·531 |
| 85 | 4 | 2¾ | 6 | 0 | 12 | ·338 | 4 | 6⅛ | 7 | 2 | 14 | ·451 | 5 | 0⅞ | 11 | 0 | 10 | ·537 |
| 86 | 4 | 3¼ | 6 | 0 | 20 | ·341 | 4 | 6¾ | 7 | 2 | 25 | ·457 | 5 | 1⅝ | 11 | 0 | 26 | ·543 |
| 87 | 4 | 3⅞ | 6 | 1 | 0 | ·345 | 4 | 7⅜ | 7 | 3 | 8 | ·461 | 5 | 2¼ | 11 | 1 | 14 | ·549 |
| 88 | 4 | 4½ | 6 | 1 | 9 | ·349 | 4 | 8 | 7 | 3 | 18 | ·466 | 5 | 3 | 11 | 2 | 4 | ·556 |
| 89 | 4 | 5⅛ | 6 | 1 | 18 | ·353 | 4 | 8⅝ | 8 | 0 | 0 | ·471 | 5 | 3¼ | 11 | 2 | 21 | ·562 |
| 90 | 4 | 5¾ | 6 | 2 | 0 | ·357 | 4 | 9¼ | 8 | 0 | 11 | ·477 | 5 | 4¼ | 11 | 3 | 10 | ·567 |
| 91 | 4 | 6¼ | 6 | 2 | 9 | ·362 | 4 | 9⅞ | 8 | 0 | 22 | ·482 | 5 | 5⅛ | 12 | 0 | 0 | ·573 |
| 92 | 4 | 7 | 6 | 2 | 19 | ·366 | 4 | 10½ | 8 | 1 | 7 | ·487 | 5 | 5⅞ | 12 | 0 | 18 | ·580 |
| 93 | 4 | 7½ | 6 | 3 | 0 | ·370 | 4 | 11¼ | 8 | 1 | 18 | ·493 | 5 | 6⅝ | 12 | 1 | 8 | ·587 |
| 94 | 4 | 8⅛ | 6 | 3 | 10 | ·373 | 4 | 11¾ | 8 | 2 | 4 | ·499 | 5 | 7⅜ | 12 | 2 | 0 | ·594 |
| 95 | 4 | 8¾ | 6 | 3 | 20 | ·378 | 5 | 0½ | 8 | 2 | 15 | ·504 | 5 | 8 | 12 | 2 | 20 | ·600 |
| 96 | 4 | 9⅜ | 7 | 0 | 4 | ·382 | 5 | 1⅛ | 8 | 3 | 0 | ·509 | 5 | 8¾ | 12 | 3 | 16 | ·606 |
| 97 | 4 | 10 | 7 | 0 | 14 | ·386 | 5 | 1¾ | 8 | 3 | 12 | ·515 | 5 | 9½ | 13 | 0 | 10 | ·613 |
| 98 | 4 | 10½ | 7 | 1 | 25 | ·389 | 5 | 2⅜ | 9 | 0 | 0 | ·519 | 5 | 10⅛ | 13 | 1 | 14 | ·619 |
| 99 | 4 | 11 | 7 | 2 | 12 | ·393 | 5 | 3 | 9 | 0 | 14 | ·525 | 5 | 11 | 13 | 2 | 16 | ·625 |
| 100 | 4 | 11⅝ | 7 | 3 | 0 | ·396 | 5 | 3⅝ | 9 | 1 | 0 | ·530 | 5 | 11⅝ | 14 | 0 | 0 | ·631 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | Pitch 2½ In., Face 8 In. Wide. | | | | | | Pitch 2¾ In., Face 9 In. Wide. | | | | | | Pitch 3 In., Face 10 In. Wide. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 13 | 0 | 10⅜ | 2 | 0 | 7 | ·17 | 0 | 11½ | 2 | 3 | 20 | ·26 | 1 | 0½ | 3 | 2 | 0 | ·37 |
| 14 | 0 | 11¼ | 2 | 1 | 0 | ·18 | 1 | 0⅜ | 3 | 0 | 8 | ·28 | 1 | 1½ | 3 | 3 | 14 | ·42 |
| 15 | 1 | 0 | 2 | 1 | 20 | ·20 | 1 | 1¼ | 3 | 1 | 5 | ·30 | 1 | 2⅜ | 4 | 1 | 10 | ·44 |
| 16 | 1 | 0¾ | 2 | 2 | 7 | ·21 | 1 | 2 | 3 | 2 | 16 | ·32 | 1 | 3⅜ | 4 | 2 | 0 | ·46 |
| 17 | 1 | 1½ | 2 | 3 | 0 | ·22 | 1 | 2⅞ | 3 | 3 | 18 | ·34 | 1 | 4¼ | 4 | 3 | 18 | ·50 |
| 18 | 1 | 2⅜ | 2 | 3 | 8 | ·24 | 1 | 3¾ | 4 | 1 | 0 | ·36 | 1 | 5¼ | 5 | 0 | 20 | ·53 |
| 19 | 1 | 3⅛ | 3 | 0 | 10 | ·25 | 1 | 4⅝ | 4 | 2 | 6 | ·38 | 1 | 6¼ | 5 | 2 | 15 | ·56 |
| 20 | 1 | 4 | 3 | 1 | 8 | ·26 | 1 | 5½ | 4 | 3 | 4 | ·40 | 1 | 7⅛ | 6 | 0 | 0 | ·59 |
| 21 | 1 | 4¾ | 3 | 2 | 0 | ·27 | 1 | 6⅜ | 5 | 0 | 8 | ·42 | 1 | 8⅛ | 6 | 2 | 16 | ·62 |
| 22 | 1 | 5½ | 3 | 2 | 20 | ·28 | 1 | 7¼ | 5 | 1 | 6 | ·44 | 1 | 9 | 7 | 0 | 0 | ·65 |
| 23 | 1 | 6⅜ | 3 | 3 | 12 | ·29 | 1 | 8 | 5 | 2 | 8 | ·46 | 1 | 10 | 7 | 1 | 0 | ·68 |
| 24 | 1 | 7⅛ | 4 | 0 | 0 | ·31 | 1 | 9 | 5 | 3 | 0 | ·49 | 1 | 10⅞ | 7 | 2 | 16 | ·71 |
| 25 | 1 | 8 | 4 | 0 | 20 | ·33 | 1 | 9⅞ | 6 | 0 | 7 | ·51 | 1 | 11⅞ | 8 | 0 | 0 | ·73 |
| 26 | 1 | 8¾ | 4 | 1 | 12 | ·34 | 1 | 10¾ | 6 | 1 | 2 | ·53 | 2 | 0⅞ | 8 | 1 | 16 | ·75 |
| 27 | 1 | 9½ | 4 | 2 | 4 | ·35 | 1 | 11⅝ | 6 | 2 | 5 | ·55 | 2 | 1¾ | 8 | 3 | 0 | ·78 |
| 28 | 1 | 10¼ | 4 | 2 | 24 | ·37 | 2 | 0½ | 6 | 3 | 9 | ·57 | 2 | 2¾ | 9 | 0 | 0 | ·82 |
| 29 | 1 | 11⅛ | 4 | 3 | 18 | ·38 | 2 | 1⅜ | 7 | 0 | 5 | ·59 | 2 | 3¾ | 9 | 1 | 8 | ·84 |
| 30 | 2 | 0 | 5 | 0 | 20 | ·40 | 2 | 2¼ | 7 | 1 | 9 | ·61 | 2 | 4⅝ | 9 | 2 | 14 | ·86 |
| 31 | 2 | 0¾ | 5 | 1 | 14 | ·41 | 2 | 3⅛ | 7 | 2 | 8 | ·63 | 2 | 5⅝ | 10 | 0 | 0 | ·89 |
| 32 | 2 | 1½ | 5 | 2 | 8 | ·42 | 2 | 4 | 7 | 3 | 14 | ·65 | 2 | 6½ | 10 | 2 | 0 | ·94 |
| 33 | 2 | 2¼ | 5 | 3 | 10 | ·43 | 2 | 4⅞ | 8 | 0 | 16 | ·67 | 2 | 7½ | 10 | 3 | 0 | ·96 |
| 34 | 2 | 3 | 6 | 0 | 10 | ·45 | 2 | 5¾ | 8 | 1 | 20 | ·69 | 2 | 8½ | 11 | 0 | 0 | 1·00 |
| 35 | 2 | 3⅞ | 6 | 1 | 8 | ·46 | 2 | 6⅝ | 8 | 2 | 22 | ·71 | 2 | 9½ | 11 | 1 | 0 | 1·04 |
| 36 | 2 | 4⅝ | 6 | 2 | 0 | ·47 | 2 | 7½ | 8 | 3 | 20 | ·73 | 2 | 10⅜ | 11 | 2 | 0 | 1·06 |
| 37 | 2 | 5½ | 6 | 2 | 15 | ·48 | 2 | 8⅜ | 9 | 0 | 18 | ·75 | 2 | 11⅜ | 11 | 3 | 4 | 1·10 |
| 38 | 2 | 6¼ | 6 | 3 | 2 | ·50 | 2 | 9¼ | 9 | 1 | 20 | ·77 | 3 | 0¼ | 12 | 0 | 0 | 1·12 |
| 39 | 2 | 7 | 6 | 3 | 16 | ·51 | 2 | 10⅛ | 9 | 2 | 21 | ·79 | 3 | 1¼ | 12 | 2 | 0 | 1·13 |
| 40 | 2 | 7⅞ | 7 | 0 | 20 | ·52 | 2 | 11 | 9 | 3 | 24 | ·81 | 3 | 2¼ | 12 | 3 | 10 | 1·18 |
| 41 | 2 | 8⅝ | 7 | 1 | 13 | ·53 | 2 | 11⅞ | 10 | 1 | 0 | ·83 | 3 | 3⅛ | 13 | 0 | 8 | 1·20 |
| 42 | 2 | 9⅜ | 7 | 2 | 8 | ·54 | 3 | 0¾ | 10 | 2 | 0 | ·85 | 3 | 4⅛ | 13 | 1 | 16 | 1·24 |
| 43 | 2 | 10¼ | 7 | 3 | 0 | ·55 | 3 | 1⅝ | 10 | 3 | 6 | ·87 | 3 | 5 | 13 | 3 | 10 | 1·26 |
| 44 | 2 | 11 | 7 | 3 | 22 | ·56 | 3 | 2½ | 11 | 0 | 0 | ·89 | 3 | 6 | 14 | 0 | 0 | 1·30 |
| 45 | 2 | 11¾ | 8 | 0 | 20 | ·58 | 3 | 3⅜ | 11 | 1 | 4 | ·91 | 3 | 7 | 14 | 2 | 0 | 1·34 |
| 46 | 3 | 0⅝ | 8 | 1 | 16 | ·60 | 3 | 4¼ | 11 | 2 | 0 | ·93 | 3 | 7⅞ | 14 | 3 | 10 | 1·36 |
| 47 | 3 | 1½ | 8 | 2 | 4 | ·61 | 3 | 5⅛ | 11 | 3 | 6 | ·95 | 3 | 8⅞ | 15 | 0 | 18 | 1·40 |
| 48 | 3 | 2¼ | 8 | 2 | 20 | ·63 | 3 | 6 | 12 | 0 | 0 | ·97 | 3 | 9⅞ | 15 | 3 | 0 | 1·42 |
| 49 | 3 | 3 | 8 | 3 | 6 | ·64 | 3 | 6⅞ | 12 | 1 | 5 | ·99 | 3 | 10⅞ | 16 | 0 | 0 | 1·44 |
| 50 | 3 | 3¾ | 9 | 0 | 25 | ·65 | 3 | 7¾ | 12 | 2 | 0 | 1·01 | 3 | 11¾ | 16 | 2 | 0 | 1·47 |
| 51 | 3 | 4½ | 9 | 1 | 15 | ·66 | 3 | 8⅝ | 12 | 3 | 6 | 1·03 | 4 | 0¾ | 16 | 3 | 0 | 1·50 |
| 52 | 3 | 5⅜ | 9 | 2 | 10 | ·68 | 3 | 9½ | 13 | 0 | 0 | 1·05 | 4 | 1⅝ | 17 | 0 | 14 | 1·52 |
| 53 | 3 | 6¼ | 9 | 3 | 10 | ·69 | 3 | 10½ | 13 | 1 | 0 | 1·07 | 4 | 2⅝ | 17 | 3 | 0 | 1·55 |
| 54 | 3 | 7 | 10 | 0 | 0 | ·70 | 3 | 11 | 13 | 2 | 5 | 1·09 | 4 | 3½ | 18 | 1 | 4 | 1·60 |
| 55 | 3 | 7¾ | 10 | 0 | 20 | ·72 | 4 | 0⅛ | 13 | 3 | 8 | 1·11 | 4 | 4½ | 18 | 2 | 14 | 1·63 |
| 56 | 3 | 8½ | 10 | 1 | 16 | ·73 | 4 | 1 | 14 | 0 | 0 | 1·13 | 4 | 5½ | 19 | 0 | 0 | 1·66 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | Pitch 2½ In., Face 8 In. Wide. | | | | | | Pitch 2¾ In., Face 9 In. Wide. | | | | | | Pitch 3 In., Face 10 In. Wide. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 57 | 3 | 9⅜ | 10 | 2 | 4 | ·74 | 4 | 1⅞ | 14 | 1 | 0 | 1·16 | 4 | 6⅜ | 19 | 1 | 0 | 1·69 |
| 58 | 3 | 10⅛ | 10 | 3 | 0 | ·75 | 4 | 2¾ | 14 | 2 | 8 | 1·18 | 4 | 7⅜ | 19 | 2 | 18 | 1·72 |
| 59 | 3 | 11⅛ | 10 | 3 | 18 | ·77 | 4 | 3⅝ | 14 | 3 | 10 | 1·20 | 4 | 8⅜ | 20 | 0 | 0 | 1·75 |
| 60 | 3 | 11¾ | 11 | 0 | 10 | ·78 | 4 | 4½ | 15 | 0 | 7 | 1·22 | 4 | 9¼ | 20 | 1 | 0 | 1·77 |
| 61 | 4 | 0½ | 11 | 1 | 20 | ·79 | 4 | 5⅜ | 15 | 1 | 8 | 1·24 | 4 | 10¼ | 20 | 2 | 14 | 1·81 |
| 62 | 4 | 1⅜ | 11 | 2 | 18 | ·81 | 4 | 6¼ | 15 | 2 | 9 | 1·26 | 4 | 11¼ | 21 | 0 | 0 | 1·84 |
| 63 | 4 | 2⅛ | 11 | 3 | 10 | ·83 | 4 | 7⅛ | 15 | 3 | 10 | 1·28 | 5 | 0⅛ | 21 | 1 | 8 | 1·87 |
| 64 | 4 | 3 | 12 | 0 | 16 | ·84 | 4 | 8 | 16 | 0 | 10 | 1·30 | 5 | 1⅛ | 21 | 2 | 16 | 1·90 |
| 65 | 4 | 3¾ | 12 | 1 | 20 | ·85 | 4 | 8⅞ | 16 | 1 | 0 | 1·32 | 5 | 2 | 22 | 0 | 0 | 1·93 |
| 66 | 4 | 4½ | 12 | 2 | 12 | ·86 | 4 | 9¾ | 16 | 2 | 4 | 1·35 | 5 | 3 | 22 | 1 | 8 | 1·96 |
| 67 | 4 | 5⅜ | 12 | 3 | 0 | ·87 | 4 | 10⅝ | 16 | 3 | 12 | 1·37 | 5 | 4 | 22 | 2 | 6 | 1·99 |
| 68 | 4 | 6⅛ | 12 | 3 | 15 | ·89 | 4 | 11½ | 17 | 0 | 10 | 1·39 | 5 | 5 | 23 | 0 | 0 | 2·02 |
| 69 | 4 | 7 | 13 | 0 | 5 | ·90 | 5 | 0⅜ | 17 | 1 | 5 | 1·40 | 5 | 6 | 23 | 1 | 0 | 2·06 |
| 70 | 4 | 7¾ | 13 | 1 | 6 | ·92 | 5 | 1¼ | 17 | 2 | 8 | 1·42 | 5 | 6⅞ | 23 | 2 | 0 | 2·09 |
| 71 | 4 | 8½ | 13 | 2 | 10 | ·93 | 5 | 2⅛ | 17 | 3 | 10 | 1·45 | 5 | 7¾ | 23 | 3 | 0 | 2·11 |
| 72 | 4 | 9¼ | 13 | 3 | 14 | ·94 | 5 | 3 | 18 | 0 | 20 | 1·47 | 5 | 8¾ | 24 | 0 | 0 | 2·14 |
| 73 | 4 | 10 | 14 | 0 | 0 | ·95 | 5 | 3⅞ | 18 | 1 | 20 | 1·49 | 5 | 9¾ | 24 | 1 | 0 | 2·17 |
| 74 | 4 | 10⅞ | 14 | 0 | 18 | ·96 | 5 | 4¾ | 18 | 2 | 22 | 1·51 | 5 | 10⅝ | 24 | 2 | 0 | 2·20 |
| 75 | 4 | 11¾ | 14 | 1 | 14 | ·97 | 5 | 5⅝ | 18 | 3 | 24 | 1·52 | 5 | 11⅝ | 25 | 0 | 0 | 2·23 |
| 76 | 5 | 0½ | 14 | 2 | 10 | ·98 | 5 | 6½ | 19 | 1 | 10 | 1·55 | 6 | 0½ | 25 | 2 | 0 | 2·25 |
| 77 | 5 | 1¼ | 14 | 3 | 8 | ·99 | 5 | 7⅜ | 19 | 2 | 20 | 1·57 | 6 | 1½ | 26 | 0 | 0 | 2·29 |
| 78 | 5 | 2 | 15 | 0 | 6 | 1·03 | 5 | 8¼ | 20 | 0 | 21 | 1·59 | 6 | 2½ | 26 | 2 | 0 | 2·32 |
| 79 | 5 | 2⅞ | 15 | 1 | 0 | 1·04 | 5 | 9⅛ | 20 | 2 | 24 | 1·61 | 6 | 3½ | 27 | 0 | 0 | 2·35 |
| 80 | 5 | 3⅝ | 15 | 3 | 4 | 1·06 | 5 | 10 | 21 | 1 | 4 | 1·63 | 6 | 4⅜ | 27 | 2 | 0 | 2·38 |
| 81 | 5 | 4½ | 16 | 0 | 0 | 1·07 | 5 | 10⅞ | 21 | 2 | 0 | 1·65 | 6 | 5⅜ | 28 | 0 | 0 | 2·41 |
| 82 | 5 | 5¼ | 16 | 0 | 14 | 1·09 | 5 | 11¾ | 21 | 3 | 10 | 1·67 | 6 | 6⅜ | 28 | 2 | 0 | 2·44 |
| 83 | 5 | 6 | 16 | 1 | 0 | 1·10 | 6 | 0⅝ | 22 | 0 | 8 | 1·69 | 6 | 7¼ | 29 | 0 | 0 | 2·47 |
| 84 | 5 | 6⅞ | 16 | 1 | 16 | 1·11 | 6 | 1½ | 22 | 1 | 20 | 1·71 | 6 | 8⅛ | 29 | 2 | 0 | 2·50 |
| 85 | 5 | 7⅝ | 16 | 3 | 8 | 1·12 | 6 | 2⅜ | 22 | 3 | 5 | 1·73 | 6 | 9⅛ | 30 | 0 | 0 | 2·54 |
| 86 | 5 | 8½ | 17 | 0 | 6 | 1·14 | 6 | 3¼ | 23 | 0 | 10 | 1·75 | 6 | 10½ | 30 | 2 | 0 | 2·57 |
| 87 | 5 | 9¼ | 17 | 0 | 20 | 1·15 | 6 | 4⅛ | 23 | 1 | 20 | 1·77 | 6 | 11 | 31 | 0 | 0 | 2·60 |
| 88 | 5 | 10 | 17 | 1 | 10 | 1·16 | 6 | 5 | 23 | 2 | 20 | 1·79 | 7 | 0 | 31 | 2 | 0 | 2·62 |
| 89 | 5 | 10¾ | 17 | 2 | 16 | 1·17 | 6 | 5⅞ | 24 | 0 | 16 | 1·81 | 7 | 1 | 32 | 0 | 0 | 2·65 |
| 90 | 5 | 11⅝ | 17 | 3 | 20 | 1·18 | 6 | 6¾ | 24 | 1 | 20 | 1·82 | 7 | 2 | 32 | 2 | 0 | 2·68 |
| 91 | 6 | 0⅜ | 18 | 1 | 3 | 1·20 | 6 | 7⅝ | 24 | 2 | 21 | 1·85 | 7 | 2⅞ | 33 | 0 | 0 | 2·71 |
| 92 | 6 | 1 | 18 | 2 | 0 | 1·21 | 6 | 8½ | 25 | 0 | 10 | 1·87 | 7 | 3⅞ | 33 | 2 | 0 | 2·73 |
| 93 | 6 | 2 | 18 | 2 | 23 | 1·22 | 6 | 9⅜ | 25 | 1 | 10 | 1·89 | 7 | 4⅞ | 34 | 0 | 0 | 2·76 |
| 94 | 6 | 2¾ | 18 | 3 | 13 | 1·23 | 6 | 10¼ | 25 | 2 | 20 | 1·91 | 7 | 5¾ | 34 | 2 | 0 | 2·79 |
| 95 | 6 | 3½ | 19 | 0 | 0 | 1·25 | 6 | 11⅛ | 26 | 0 | 24 | 1·93 | 7 | 6¾ | 35 | 0 | 0 | 2·83 |
| 96 | 6 | 4⅜ | 19 | 0 | 18 | 1·27 | 7 | 0 | 26 | 2 | 20 | 1·95 | 7 | 7⅝ | 35 | 2 | 0 | 2·86 |
| 97 | 6 | 5¼ | 19 | 1 | 10 | 1·28 | 7 | 0⅞ | 27 | 0 | 0 | 1·97 | 7 | 8⅝ | 36 | 0 | 0 | 2·89 |
| 98 | 6 | 6 | 19 | 2 | 4 | 1·29 | 7 | 1¾ | 27 | 1 | 20 | 1·99 | 7 | 9½ | 36 | 2 | 0 | 2·92 |
| 99 | 6 | 6¾ | 19 | 3 | 10 | 1·30 | 7 | 2⅝ | 27 | 3 | 10 | 2·01 | 7 | 10½ | 37 | 0 | 0 | 2·96 |
| 100 | 6 | 7½ | 20 | 0 | 0 | 1·32 | 7 | 3½ | 28 | 2 | 12 | 2·04 | 7 | 11½ | 37 | 2 | 0 | 3·00 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | PITCH 3¼ IN., FACE 11 IN. WIDE. | | | | | | PITCH 3½ IN., FACE 12 IN. WIDE. | | | | | | PITCH 4 IN., FACE 14 IN. WIDE. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. | Diameter of Pitch Circle. | | Weight of Spur Wheel Casting. | | | Horse Power at one Revolution per Minute. |
| | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | | ft. | in. | cwt. | qr. | lb. | |
| 13 | 1 | 1½ | 4 | 3 | 20 | ·53 | 1 | 2½ | 5 | 3 | 0 | ·73 | 1 | 4½ | 9 | 1 | 20 | 1·26 |
| 14 | 1 | 2½ | 5 | 1 | 12 | ·57 | 1 | 3½ | 6 | 2 | 10 | ·78 | 1 | 5¾ | 10 | 0 | 16 | 1·36 |
| 15 | 1 | 3½ | 5 | 2 | 16 | ·61 | 1 | 4¾ | 7 | 2 | 20 | ·85 | 1 | 7 | 11 | 0 | 0 | 1·46 |
| 16 | 1 | 4½ | 6 | 1 | 0 | ·65 | 1 | 5¾ | 8 | 0 | 10 | ·89 | 1 | 8⅜ | 12 | 0 | 14 | 1·56 |
| 17 | 1 | 5½ | 6 | 3 | 0 | ·69 | 1 | 6⅞ | 8 | 3 | 0 | ·95 | 1 | 9⅝ | 13 | 0 | 0 | 1·66 |
| 18 | 1 | 6⅝ | 7 | 1 | 6 | ·73 | 1 | 8 | 9 | 0 | 8 | 1·01 | 1 | 10⅞ | 14 | 0 | 8 | 1·76 |
| 19 | 1 | 7⅝ | 7 | 3 | 0 | ·77 | 1 | 9⅛ | 9 | 2 | 10 | 1·06 | 2 | 0⅛ | 15 | 0 | 9 | 1·86 |
| 20 | 1 | 8⅝ | 8 | 1 | 8 | ·82 | 1 | 10¼ | 10 | 0 | 0 | 1·14 | 2 | 1½ | 16 | 0 | 0 | 1.96 |
| 21 | 1 | 9¾ | 8 | 2 | 20 | ·86 | 1 | 11⅜ | 10 | 2 | 7 | 1·19 | 2 | 2¾ | 16 | 2 | 0 | 2·06 |
| 22 | 1 | 10¾ | 9 | 0 | 0 | ·90 | 2 | 0½ | 11 | 0 | 0 | 1·24 | 2 | 4 | 17 | 0 | 9 | 2·16 |
| 23 | 1 | 11¾ | 9 | 1 | 0 | ·94 | 2 | 1⅝ | 11 | 2 | 0 | 1·30 | 2 | 5¼ | 17 | 3 | 0 | 2·26 |
| 24 | 2 | 0¾ | 9 | 3 | 0 | ·98 | 2 | 2¾ | 12 | 0 | 0 | 1·35 | 2 | 6½ | 18 | 0 | 20 | 2·35 |
| 25 | 2 | 1⅞ | 10 | 1 | 7 | 1·02 | 2 | 3⅞ | 12 | 2 | 8 | 1·41 | 2 | 7¾ | 19 | 0 | 0 | 2·45 |
| 26 | 2 | 2⅞ | 10 | 2 | 0 | 1·07 | 2 | 5 | 13 | 0 | 0 | 1·47 | 2 | 9 | 20 | 0 | 0 | 2·55 |
| 27 | 2 | 3⅞ | 10 | 3 | 5 | 1·10 | 2 | 6 | 13 | 2 | 0 | 1·52 | 2 | 10⅜ | 21 | 0 | 10 | 2·65 |
| 28 | 2 | 5 | 11 | 1 | 16 | 1·15 | 2 | 7⅛ | 14 | 0 | 0 | 1·57 | 2 | 11⅝ | 22 | 0 | 14 | 2·75 |
| 29 | 2 | 6 | 11 | 3 | 4 | 1·20 | 2 | 8¼ | 14 | 2 | 9 | 1·64 | 3 | 0⅞ | 23 | 0 | 0 | 2·85 |
| 30 | 2 | 7 | 12 | 0 | 0 | 1·24 | 2 | 9⅜ | 15 | 0 | 14 | 1·71 | 3 | 2⅛ | 24 | 0 | 0 | 2·95 |
| 31 | 2 | 8 | 12 | 1 | 0 | 1·28 | 2 | 10½ | 15 | 2 | 20 | 1·78 | 3 | 3½ | 25 | 0 | 10 | 3·05 |
| 32 | 2 | 9 | 12 | 2 | 14 | 1·32 | 2 | 11⅝ | 16 | 2 | 0 | 1·84 | 3 | 4¾ | 26 | 0 | 8 | 3·15 |
| 33 | 2 | 10⅛ | 13 | 1 | 8 | 1·36 | 3 | 0¾ | 17 | 0 | 10 | 1·89 | 3 | 6 | 27 | 0 | 0 | 3·25 |
| 34 | 2 | 11⅛ | 13 | 2 | 21 | 1·40 | 3 | 1⅞ | 17 | 3 | 10 | 1·94 | 3 | 7¼ | 28 | 0 | 19 | 3·35 |
| 35 | 3 | 0⅛ | 14 | 0 | 16 | 1·44 | 3 | 3 | 18 | 3 | 20 | 1·98 | 3 | 8½ | 29 | 0 | 7 | 3·45 |
| 36 | 3 | 1¼ | 14 | 2 | 18 | 1·48 | 3 | 4 | 19 | 2 | 0 | 2·03 | 3 | 9¾ | 30 | 0 | 20 | 3·55 |
| 37 | 3 | 2¼ | 15 | 1 | 0 | 1·52 | 3 | 5¼ | 20 | 0 | 0 | 2·08 | 3 | 11 | 30 | 3 | 0 | 3·65 |
| 38 | 3 | 3¼ | 15 | 3 | 4 | 1·56 | 3 | 6¼ | 20 | 2 | 0 | 2·14 | 4 | 0⅜ | 31 | 2 | 0 | 3·75 |
| 39 | 3 | 4⅜ | 16 | 1 | 0 | 1·61 | 3 | 7⅜ | 21 | 0 | 0 | 2·20 | 4 | 1⅝ | 32 | 0 | 0 | 3·85 |
| 40 | 3 | 5⅜ | 16 | 3 | 7 | 1·65 | 3 | 8½ | 21 | 2 | 8 | 2·25 | 4 | 10⅞ | 33 | 0 | 0 | 3·95 |
| 41 | 3 | 6⅜ | 17 | 1 | 3 | 1·69 | 3 | 9⅝ | 22 | 0 | 0 | 2·31 | 4 | 4⅛ | 34 | 0 | 10 | 4·05 |
| 42 | 3 | 7⅜ | 17 | 3 | 4 | 1·73 | 3 | 10¾ | 22 | 2 | 0 | 2·37 | 4 | 5½ | 35 | 0 | 21 | 4·15 |
| 43 | 3 | 8½ | 18 | 1 | 0 | 1·76 | 3 | 11⅞ | 23 | 0 | 6 | 2·42 | 4 | 6¾ | 36 | 0 | 0 | 4·25 |
| 44 | 3 | 9½ | 18 | 3 | 7 | 1·81 | 4 | 1 | 23 | 2 | 0 | 2·48 | 4 | 8 | 37 | 0 | 0 | 4·35 |
| 45 | 3 | 10½ | 19 | 1 | 6 | 1·84 | 4 | 2⅛ | 24 | 0 | 8 | 2·54 | 4 | 9¼ | 38 | 0 | 15 | 4·45 |
| 46 | 3 | 11½ | 19 | 3 | 4 | 1·88 | 4 | 3¼ | 24 | 2 | 0 | 2·59 | 4 | 10½ | 39 | 0 | 0 | 4·55 |
| 47 | 4 | 0⅝ | 20 | 1 | 7 | 1·93 | 4 | 4⅜ | 25 | 0 | 0 | 2·65 | 4 | 11¾ | 40 | 0 | 0 | 4·65 |
| 48 | 4 | 1⅝ | 20 | 3 | 0 | 1·96 | 4 | 5½ | 25 | 2 | 0 | 2·71 | 5 | 1 | 41 | 0 | 17 | 4·72 |
| 49 | 4 | 2⅝ | 21 | 1 | 8 | 2·00 | 4 | 6½ | 26 | 0 | 0 | 2·76 | 5 | 2⅜ | 42 | 0 | 0 | 4·82 |
| 50 | 4 | 3¾ | 21 | 3 | 15 | 2·04 | 4 | 7⅝ | 26 | 2 | 7 | 2·82 | 5 | 3⅝ | 43 | 0 | 0 | 4·92 |
| 51 | 4 | 4¾ | 22 | 1 | 0 | 2·08 | 4 | 8¾ | 27 | 0 | 0 | 2·89 | 5 | 4⅞ | 44 | 0 | 0 | 5·02 |
| 52 | 4 | 5¾ | 22 | 3 | 9 | 2·13 | 4 | 9⅞ | 27 | 2 | 16 | 2·95 | 5 | 6 | 45 | 0 | 16 | 5·10 |
| 53 | 4 | 6¾ | 23 | 1 | 7 | 2·17 | 4 | 11 | 28 | 1 | 8 | 3·00 | 5 | 7½ | 46 | 0 | 0 | 5·20 |
| 54 | 4 | 7⅞ | 23 | 3 | 8 | 2·20 | 5 | 0⅛ | 28 | 3 | 20 | 3·05 | 5 | 8¾ | 47 | 0 | 0 | 5·30 |
| 55 | 4 | 8⅞ | 24 | 1 | 0 | 2·25 | 5 | 1¼ | 29 | 3 | 24 | 3·11 | 5 | 10 | 48 | 0 | 17 | 5·40 |
| 56 | 4 | 9⅞ | 24 | 3 | 9 | 2·29 | 5 | 2⅜ | 30 | 2 | 18 | 3·17 | 5 | 11⅛ | 49 | 0 | 0 | 5·50 |

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

| Number of Teeth. | Pitch 3½ In., Face 11 In. Wide. Diameter of Pitch Circle. ft. | in. | Weight of Spur Wheel Casting. cwt. | qr. | lb. | Horse Power at one Revolution per Minute. | Pitch 3½ In., Face 12 In. Wide. Diameter of Pitch Circle. ft. | in. | Weight of Spur Wheel Casting. cwt. | qr. | lb. | Horse Power at one Revolution per Minute. | Pitch 4 In., Face 14 In. Wide. Diameter of Pitch Circle. ft. | in. | Weight of Spur Wheel Casting. cwt. | qr. | lb. | Horse Power at one Revolution per Minute. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 | 4 | 11 | 25 | 1 | 7 | 2·35 | 5 | 3½ | 31 | 0 | 10 | 3·25 | 6 | 0½ | 50 | 0 | 0 | 5·60 |
| 58 | 5 | 0 | 25 | 3 | 4 | 2·40 | 5 | 4½ | 31 | 3 | 10 | 3·31 | 6 | 1¾ | 51 | 0 | 0 | 5·70 |
| 59 | 5 | 1 | 26 | 1 | 0 | 2·44 | 5 | 5¾ | 32 | 2 | 14 | 3·35 | 6 | 3 | 52 | 0 | 12 | 5·80 |
| 60 | 5 | 2 | 26 | 3 | 0 | 2·48 | 5 | 6¾ | 33 | 3 | 0 | 3·40 | 6 | 4⅜ | 53 | 0 | 0 | 5·90 |
| 61 | 5 | 3 | 27 | 1 | 4 | 2·52 | 5 | 7⅞ | 34 | 1 | 0 | 3·45 | 6 | 5⅝ | 54 | 0 | 0 | 6·00 |
| 62 | 5 | 4⅛ | 27 | 3 | 5 | 2·56 | 5 | 9 | 34 | 3 | 19 | 3·50 | 6 | 6⅞ | 55 | 0 | 0 | 6·10 |
| 63 | 5 | 5⅛ | 28 | 1 | 0 | 2·60 | 5 | 10⅛ | 35 | 2 | 20 | 3·55 | 6 | 8 | 56 | 0 | 10 | 6·20 |
| 64 | 5 | 6⅛ | 28 | 3 | 0 | 2·64 | 5 | 11¼ | 36 | 1 | 0 | 3·63 | 6 | 9½ | 57 | 0 | 0 | 6·30 |
| 65 | 5 | 7¼ | 29 | 0 | 0 | 2·68 | 6 | 0⅜ | 36 | 2 | 24 | 3·68 | 6 | 10¾ | 58 | 0 | 0 | 6·40 |
| 66 | 5 | 8¼ | 29 | 3 | 7 | 2·72 | 6 | 1½ | 37 | 3 | 0 | 3·73 | 7 | 0 | 59 | 0 | 0 | 6·50 |
| 67 | 5 | 9¼ | 30 | 1 | 0 | 2·76 | 6 | 2⅝ | 38 | 1 | 0 | 3·78 | 7 | 1⅛ | 60 | 0 | 0 | 6·60 |
| 68 | 5 | 10¼ | 30 | 3 | 5 | 2·80 | 6 | 3¾ | 38 | 3 | 22 | 3·84 | 7 | 2½ | 61 | 0 | 0 | 6·70 |
| 69 | 5 | 11⅜ | 31 | 1 | 0 | 2·84 | 6 | 4⅞ | 39 | 3 | 4 | 3·90 | 7 | 3¾ | 62 | 0 | 15 | 6·80 |
| 70 | 6 | 0⅜ | 31 | 3 | 6 | 2·88 | 6 | 6 | 40 | 0 | 10 | 3·96 | 7 | 5⅛ | 63 | 0 | 0 | 6·90 |
| 71 | 6 | 1½ | 32 | 1 | 8 | 2·92 | 6 | 7 | 40 | 3 | 20 | 4·01 | 7 | 6⅜ | 64 | 0 | 0 | 7·00 |
| 72 | 6 | 2½ | 32 | 3 | 0 | 2·96 | 6 | 8¼ | 41 | 3 | 0 | 4·06 | 7 | 7⅝ | 65 | 0 | 16 | 7·10 |
| 73 | 6 | 3½ | 33 | 1 | 10 | 3·00 | 6 | 9¼ | 42 | 0 | 0 | 4·11 | 7 | 8⅞ | 66 | 0 | 0 | 7·20 |
| 74 | 6 | 4½ | 33 | 2 | 17 | 3·04 | 6 | 10⅜ | 42 | 2 | 20 | 4·17 | 7 | 10 | 67 | 0 | 11 | 7·30 |
| 75 | 6 | 5½ | 34 | 0 | 12 | 3·08 | 6 | 11½ | 43 | 3 | 8 | 4·24 | 7 | 11½ | 68 | 0 | 0 | 7·40 |
| 76 | 6 | 6⅝ | 34 | 2 | 8 | 3·12 | 7 | 0⅝ | 44 | 0 | 10 | 4·30 | 8 | 0¾ | 69 | 0 | 20 | 7·50 |
| 77 | 6 | 7⅝ | 35 | 0 | 0 | 3·16 | 7 | 1¾ | 45 | 3 | 0 | 4·35 | 8 | 2 | 70 | 0 | 20 | 7·60 |
| 78 | 6 | 8⅝ | 35 | 2 | 21 | 3·20 | 7 | 2⅞ | 46 | 2 | 0 | 4·41 | 8 | 3⅛ | [illegible] | 0 | 0 | 7·70 |
| 79 | 6 | 9¾ | 36 | 1 | 0 | 3·24 | 7 | 4 | 47 | 0 | 0 | 4·46 | 8 | 4½ | 72 | 0 | 17 | 7·80 |
| 80 | 6 | 10¾ | 36 | 3 | 24 | 3·28 | 7 | 5⅛ | 47 | 3 | 0 | 4·52 | 8 | 5¾ | 73 | 0 | 0 | 7·90 |
| 81 | 6 | 11¾ | 37 | 3 | 0 | 3·32 | 7 | 6¼ | 48 | 0 | 0 | 4·58 | 8 | 7⅛ | 74 | 0 | 0 | 8·00 |
| 82 | 7 | 0¾ | 38 | 2 | 22 | 3·36 | 7 | 7⅜ | 48 | 2 | 10 | 4·64 | 8 | 8⅜ | 75 | 0 | 10 | 8·10 |
| 83 | 7 | 1¾ | 39 | 1 | 6 | 3·40 | 7 | 8⅜ | 49 | 0 | 12 | 4·70 | 8 | 9⅝ | 76 | 1 | 0 | 8·20 |
| 84 | 7 | 2⅞ | 39 | 2 | 10 | 3·45 | 7 | 9½ | 49 | 3 | 4 | 4·75 | 8 | 10⅞ | 77 | 0 | 18 | 8·30 |
| 85 | 7 | 4 | 40 | 0 | 10 | 3·51 | 7 | 10⅝ | 50 | 1 | 6 | 4·80 | 9 | 0 | 78 | 0 | 16 | 8·37 |
| 86 | 7 | 5 | 40 | 2 | 17 | 3·56 | 7 | 11¾ | 50 | 3 | 18 | 4·86 | 9 | 1½ | 79 | 0 | 0 | 8·47 |
| 87 | 7 | 6 | 41 | 0 | 0 | 3·60 | 8 | 0⅞ | 51 | 0 | 20 | 4·91 | 9 | 2¾ | 80 | 1 | 0 | 8·57 |
| 88 | 7 | 7 | 41 | 2 | 12 | 3·64 | 8 | 2 | 51 | 3 | 20 | 4·97 | 9 | 3 | 81 | 0 | 0 | 8·67 |
| 89 | 7 | 8 | 42 | 0 | 0 | 3·68 | 8 | 3⅛ | 52 | 3 | 0 | 5·03 | 9 | 4¼ | 82 | 0 | 0 | 8·77 |
| 90 | 7 | 9 | 42 | 2 | 15 | 3·72 | 8 | 4¼ | 53 | 0 | 0 | 5·09 | 9 | 6½ | 83 | 1 | 0 | 8·87 |
| 91 | 7 | 10⅛ | 43 | 1 | 17 | 3·76 | 8 | 5⅜ | 53 | 2 | 14 | 5·14 | 9 | 7⅞ | 84 | 0 | 0 | 8·97 |
| 92 | 7 | 11⅛ | 43 | 3 | 25 | 3·80 | 8 | 6½ | 54 | 1 | 10 | 5·20 | 9 | 9⅛ | 85 | 2 | 20 | 9·07 |
| 93 | 8 | 0⅛ | 44 | 2 | 20 | 3·84 | 8 | 7½ | 55 | 0 | 10 | 5·25 | 9 | 10⅜ | 86 | 3 | 0 | 9·17 |
| 94 | 8 | 1¼ | 45 | 1 | 10 | 3·88 | 8 | 8½ | 55 | 3 | 12 | 5·30 | 9 | 11⅝ | 87 | 3 | 20 | 9·27 |
| 95 | 8 | 2¼ | 45 | 2 | 14 | 3·92 | 8 | 9½ | 56 | 3 | 24 | 5·36 | 10 | 0⅞ | 89 | 0 | 0 | 9·36 |
| 96 | 8 | 3¼ | 46 | 1 | 7 | 3·96 | 8 | 10⅞ | 57 | 3 | 0 | 5·42 | 10 | 2¼ | 91 | 2 | 20 | 9·46 |
| 97 | 8 | 4¼ | 46 | 3 | 18 | 4·00 | 9 | 0 | 58 | 0 | 0 | 5·48 | 10 | 3½ | 92 | 3 | 10 | 9·56 |
| 98 | 8 | 5⅜ | 47 | 2 | 24 | 4·04 | 9 | 1⅛ | 58 | 2 | 10 | 5·54 | 10 | 4¾ | 94 | 2 | 0 | 9·66 |
| 99 | 8 | 6⅜ | 48 | 2 | 20 | 4·08 | 9 | 2¼ | 59 | 1 | 0 | 5·60 | 10 | 6 | 95 | 3 | 20 | 9·76 |
| 100 | 8 | 7½ | 50 | 0 | 0 | 4·15 | 9 | 3⅜ | 60 | 0 | 20 | 5·66 | 10 | 7⅜ | 97 | 0 | 0 | 9·86 |

## FRICTION OF SHAFTS.

**Friction of Shafts.**—Friction is governed by pressure, and is independent of surface, and the friction of a revolving body is nearly independent of its velocity. Shafting should be made as light as possible consistent with strength and stiffness, because the friction of shafts on their bearings is directly proportional to their weight. The friction of any two surfaces when no lubricant is interposed, is directly proportional to the force with which they are pressed together, and is entirely independent of the extent of surfaces in contact; so that the power absorbed by friction does not increase with the length of bearing. But when the surfaces in contact are lubricated, then the amount of friction depends upon the adhesive nature of the lubricant, and the effect will be in proportion to the extent of the surfaces between which it is interposed. Therefore, to diminish the power absorbed by friction as much as possible, and to secure easy working, it is important to use the best quality of oil.

**Machinery Oils.**—The best lubricant for high-speed machinery under light pressure is sperm oil; for heavy machinery at low speeds, rape oil; for general machinery, olive oil; for general light machinery, equal parts of sperm oil and good mineral oil; for heated machinery and pistons, neatsfoot oil mixed with tallow and plumbago.

**Resistance due to Friction.**—The amount of friction between two surfaces, is found by multiplying the weight or force in lbs. with which they are pressed together by the co-efficient of friction in the following table. The co-efficient of friction, means the resistance from friction, between two surfaces, due to a pressure of 1 lb.

**The power absorbed by Friction,** is found by multiplying the resistance due to friction, found by the above rule, by the space in feet passed through by one surface upon the other.

The power absorbed by friction in footpounds, on round shafts in one revolution, is found thus: Multiply the diameter of the shaft in inches by ·26, and by the product of the weight of the shaft by the co-efficient of friction; which will give the power absorbed for one revolution in foot-lbs.

The weight of pulleys and the load due to the pull of belts must be added to the weight of the shafting in calculating the power absorbed by friction. Shafting $2\frac{1}{2}$ inches diameter, making 100 revolutions per minute with the ordinary proportional number of pulleys upon it, but without belts on, requires about 1 horse-power to drive it alone, for every 120 feet in length.

**Horse-power absorbed by Friction** on a revolving shaft with parallel necks is found thus: Multiply the power absorbed in one revolution, found by the last rule, by the number of revolutions per minute, and divide the product by 33,000.

**The co-efficients of Friction** for ordinary shafts and shafting, under ordinary conditions, deduced from the experiments on friction, by the Institution of Mechanical Engineers, are given in the following Table.

Table 20.—FRICTION OF SHAFTING AND SHAFTS IN MOTION UPON WELL-FITTED AND EFFICIENTLY LUBRICATED BEARINGS.

| Surfaces in Contact. | Revolutions per Minute. | | |
|---|---|---|---|
| | 150 | 300 | 400 |
| | Coefficients of Friction. | | |
| Wrought Iron on Gun Metal Bearings. Wrought Iron on Cast Iron Bearings. Cast Iron on Cast Iron Bearings. Cast Iron on Gun Metal Bearings. | ·002 | ·003 | ·004 |
| Gun Metal on Gun Metal Bearings | ·003 | ·004 | ·006 |

These data apply to Horizontal Shafting with Parallel Necks. The Friction of Upright Shafting is 20 per cent. less.

The above co-efficients × the Nominal Load = Nominal Friction Resistance per square inch of Bearing. The Nominal Load per square inch, is the total load on the Bearing divided by the product of the diameter in inches, and the length in inches of the Bearing.

## SHAFTING.

**Strain on Shafting.**—Shafting is subject to two forces—twisting and bending. The twisting force is due to the power transmitted, and increases in proportion to the power; but decreases in proportion to the velocity. The bending force is due to the weight of the shaft, also to the strain of belts upon it, and the weights of pulleys and gearing. When the weight is distributed along the length of a shaft, it only causes one-half the quantity of deflection that it would if placed on the middle of the shaft.

**Torsional Strength of Shafts.**—The strength of round shafts to resist being twisted asunder is in proportion to the cubes of their diameters, and is independent of the length. A bar of wrought-iron of average quality, 1 inch diameter, is twisted asunder by a weight of 800 lbs. at the end of a lever 12 inches long, or at the pitch-line of a wheel 24 inches diameter; and a cast-iron shaft is twisted asunder by a weight of 450 lbs. applied in the same way. From these data, any other diameter can be calculated, the strength increasing as the cube of the diameter. But the power of a bar to resist a load is in inverse proportion to the length of lever; thus a lever 24 inches long, only requires one-half the weight to break a bar, that would be required with a lever 12 inches long.

**Safe Torsional Strength of Shafts.**—To find the safe working strain in lbs. that may be put on to the circumference of wheels and pulleys fixed to shafts, Mr. Fairbairn's rule is: multiply the cube of the diameter of the shaft in inches, by 1765 for wrought iron, or by 980 for cast iron, and divide the product by the radius of the wheel or pulley in inches. If a lever or crank is employed, use the length of the lever or crank as a divisor in the above rule. For steel shafts, use a multiplier of 2500.

**Hollow Shafts.**—To find the relative value for transmitting power of a hollow shaft, from the cube of the outside diameter deduct the cube of the inside diameter; the result will be the relative value of that shaft.

**The Diameter of Hollow-Shafting of Whitworth's Compressed-Steel** may be found by this rule.—Multiply the indicated horse-power the shaft is required to transmit by 90, divide the product by the number of revolutions per minute, and the cube root of the quotient will be the *external* diameter of the shaft in inches; the *internal* diameter of the shaft to be = the external diameter of the shaft multiplied by ·56.

**Torsional Stiffness of Shafting.**—Stiffness in shafting is more important than strength; when the length of a line of shafting does not exceed 100 feet, the tendency is greater to bend than to twist; but a long line of shafting of from 140 to 200 feet long is very elastic, and when driving machinery at the extreme end, it has a great tendency to twist, so much so, that the driving end may make nearly a revolution before the extreme end begins to turn. A shaft that bends or yields to the strain, will take more power to keep it in motion, than would be required by a heavier shaft, stiff enough to resist the same strain. Consequently, when long lines of shafting are employed, sufficient stiffness should be given to them to withstand the torsion at the extreme end, by making the lengths of shafting increase in diameter towards the driving end, each length being made stiff in proportion to the anticipated stress. A shaft may be strong enough to resist the twisting strain, but may not be stiff enough to drive steadily without vibration. The torsional stiffness of shafting varies as the fourth power of the diameter divided by the length. Shafting of 5 inches diameter and upwards, which is strong enough to resist the torsional strain, will be stiff enough to work properly; but, below that size, a larger shaft should be used than is necessary to resist the torsional strain, in order to ensure proper stiffness and steady driving power.

RELATIVE STRENGTH OF METALS TO RESIST TORSION, THAT OF WROUGHT-IRON BEING 1.

| | | | |
|---|---|---|---|
| Wrought Iron | 1·00 | Brass | ·27 |
| Cast Iron | ·90 | Copper | ·25 |
| Cast Steel | 1·95 | Tin | ·13 |
| Gun Metal | ·35 | Lead | ·10 |

## POWER OF SHAFTS.

**Size of Crankshafts.**—The size of a crankshaft should be determined by the maximum strain it has to resist, which may be found as follows:—

1. *Find the maximum of pressure on the crank* exclusive of friction, thus: multiply the area of the piston in square inches, by the pressure of steam in lbs. per square inch.

2. *Find the breaking strength in lbs.* by multiplying the pressure on the crank, found by the last rule, by the number of times the breaking strength is to exceed the working strength—say 6.

3. *Find the strain in lbs. due to the leverage of the crank,* thus: divide the constant number 800 for a wrought-iron crankshaft, or 450 for cast-iron, or 1100 for steel, by the length of the crank in feet.

4. Divide the breaking strength by the strain due to the leverage of the crank found by the above rules, and the cube root of the quotient will be the diameter in inches of the shaft required.

**The Nominal Horse-power** of shafts may be found by a modification of *Murray's Rule,* thus: multiply the cube of the diameter of the shaft in inches by the number of revolutions per minute, and divide the product by 170 for wrought-iron, or by 260 for cast-iron, or by 85 for steel.

*To find the diameter of a shaft suitable for a given nominal horse-power,* multiply the horse-power by 170 for wrought-iron, or by 260 for cast-iron, or by 85 for steel, and divide the product by the number of revolutions per minute; the cube root of the quotient will be the diameter of the shaft in inches.

*To find the speed necessary for a given nominal horse-power,* with a given size of shaft, multiply the horse-power by 170 for wrought-iron, or by 260 for cast-iron, or by 85 for steel, and divide the product by the cube of the diameter of the shaft in inches: the quotient will be the number of revolutions per minute. These rules for nominal horse-power apply to shafts above $4\frac{1}{2}$ inches diameter; below that size something must be added to the result given by the above rules, if a long shaft is employed, in order to obtain sufficient stiffness, which is of more importance than strength in a long shaft, and the proper size of shaft may be found from Table 21, which has been deduced from cases in practice.

**The Nominal Horse-power of Crankshafts** may be found thus:—Multiply the nominal horse-power of ordinary shafts found by the above rules, by 1·57 for a single engine, or by 1·11 for a pair of engines coupled at right angles.

**Power of Crane Shafts of Wrought-Iron.**—When shafts work at very slow speeds and lift heavy weights, such as crane shafts, the safe working load should not exceed $\frac{1}{10}$th of the breaking weight, and the diameter of the shaft must be proportioned to the strain, according to the following rule. A bar of wrought-iron, 1 inch diameter, is twisted asunder by a weight of 800 lbs. applied at the end of a lever 12 inches long, from the centre of the shaft, therefore—

1. Divide the constant number 800 by the length of lever, or radius of the wheel in feet, and the quotient will be the breaking strain in lbs.

2. Multiply the weight or strain on the shaft in lbs. by 10 (the factor of safety), and divide the product by the breaking strain, and the cube root of the quotient will be the proper diameter in inches of the shaft of wrought-iron.

TABLE 21.—NOMINAL HORSE-POWER OF WROUGHT-IRON, CAST-IRON, AND STEEL SHAFTS.

| Diameter of the Shaft in Inches. | Wrought-Iron Shaft. | Cast-Iron Shaft. | Steel Shaft. | Diameter of the Shaft in Inches. | Wrought-Iron Shaft. | Cast-Iron Shaft. | Steel Shaft. |
|---|---|---|---|---|---|---|---|
| | Nominal Horse Power at one Revolution per Minute. | Nominal Horse Power at one Revolution per Minute. | Nominal Horse Power at one Revolution per Minute. | | Nominal Horse Power at one Revolution per Minute. | Nominal Horse Power at one Revolution per Minute. | Nominal Horse Power at one Revolution per Minute. |
| 1 | ·001 | ·0006 | ·002 | 4 | ·34 | ·21 | ·51 |
| 1⅛ | ·002 | ·001 | ·003 | 4¼ | ·44 | ·29 | ·66 |
| 1¼ | ·003 | ·002 | ·005 | 4½ | ·56 | ·36 | ·84 |
| 1⅜ | ·004 | ·003 | ·006 | 4¾ | ·64 | ·41 | ·96 |
| 1½ | ·006 | ·004 | ·009 | 5 | ·73 | ·47 | 1·09 |
| 1⅝ | ·009 | ·006 | ·013 | 5¼ | ·85 | ·54 | 1·27 |
| 1¾ | ·013 | ·008 | ·019 | 5½ | ·97 | ·62 | 1·45 |
| 1⅞ | ·016 | ·010 | ·024 | 6 | 1·27 | ·81 | 1·91 |
| 2 | ·021 | ·013 | ·031 | 6½ | 1·61 | 1·03 | 2·41 |
| 2⅛ | ·027 | ·017 | ·041 | 7 | 2·0 | 1·28 | 3·01 |
| 2¼ | ·035 | ·024 | ·052 | 7½ | 2·43 | 1·56 | 3·64 |
| 2⅜ | ·046 | ·029 | ·069 | 8 | 3·0 | 1·92 | 4·51 |
| 2½ | ·053 | ·034 | ·079 | 9 | 4·22 | 2·71 | 6·33 |
| 2⅝ | ·066 | ·042 | ·099 | 10 | 5·88 | 3·85 | 8·82 |
| 2¾ | ·077 | ·049 | ·115 | 11 | 7·83 | 5·03 | 11·74 |
| 2⅞ | ·095 | ·061 | ·142 | 12 | 10·16 | 6·53 | 15·24 |
| 3 | ·11 | ·07 | ·160 | 13 | 12·91 | 8·28 | 19·36 |
| 3⅛ | ·14 | ·09 | ·21 | 14 | 16·14 | 10·37 | 24·61 |
| 3¼ | ·16 | ·1 | ·24 | 15 | 19·85 | 12·76 | 29·77 |
| 3⅜ | ·19 | ·12 | ·28 | 16 | 24·09 | 15·48 | 36·13 |
| 3½ | ·22 | ·13 | ·32 | 17 | 28·9 | 18·57 | 42·13 |
| 3¾ | ·28 | ·17 | ·41 | 18 | 34·3 | 22·05 | 51·42 |

**To find the nominal horse-power of a shaft,** multiply the horse-power given in this table by the nnmber of revolutions per minute at which the required shaft is to work. This table applies to all shafting and shafts, except crane shafts and crank shafts.

**Actual or Indicated Horse-power of Shafts.**—The actual or indicated horse-power, which a shaft is capable of properly transmitting, may in a general way, be taken at from 60 to 100 per cent. more than the nominal horse-power found from the above Table.

**Distance between the Bearings of Shafting.**—The distance between the bearings, should be arranged to suit the load to be carried, but in a general way, the distance between the bearings of shafting carrying its own weight only, and also of shafting carrying the usual proportion of pulleys or gearing, may be according to the table No. 22. Couplings and gearing to be fixed close to bearings.

**Pressure on the Necks, or Journals of Shafts.**—The pressure on the necks of shafts, should not exceed 350 lbs. per square inch, measured on the surface or circumference, for necks of ordinary length; for extra long necks, it may in unavoidable cases be from 500 to 600 lbs. per square inch. Should the pressure exceed the latter amount, the surfaces of the neck and bushes will be brought into such close contact, that the surfaces cannot properly retain oil, and the bearings will be liable to heat and cut.

**Corners of Shaft-Necks.**—The corners of necks of shafts should always be rounded, because square corners reduce the strength of the neck to resist strains, to the extent of one-fifth.

**Actual Horse-power of Shafts.**—To find the actual horse-power of a shaft, multiply the load by the distance in feet, through which it travels in one minute, and divide the product by 33,000.

*To find the load,* multiply the constant number 800 for wrought-iron, or 450 for cast-iron, or 1100 for steel, by the cube of the diameter of the shaft, in inches, and the product will be the breaking weight in lbs., which divide by 6 (the factor of safety): the result gives the safe working load in lbs.

*To find the distance through which the load travels,* multiply the circumference of the pitch circle of a wheel, or the circumference of a pulley, or circle described by a lever or crank, in feet, by the number of revolutions per minute.

**Crank Shafts of Engines.**—A crank shaft has to resist a varying strain, and its strength must be in proportion to the maximum strain upon it.

*The average pressure upon a crank,* is found thus: multiply the pressure upon the piston, by the distance through which it travels in making a double stroke, and divide the product by the distance through which the crankpin travels in the same time. The distance the piston travels equals twice the diameter of the circle described by the crankpin; the distance the crank travels is 3·1416 times the diameter of the circle described by the crankpin; therefore, the mean strain on the piston $= \frac{3 \cdot 1416}{2} = 1 \cdot 57$ times the driving pressure upon the crankpin. The power exerted by the piston, varies with every change of position of the crank, but the varying strain on the crankshaft is equalised by the fly-wheel. But, that part of the crankshaft between the crank and the fly-wheel, has a greater strain upon it in the ratio of 1·57 to 1 than the part of the shaft behind the flywheel.

**The Speed of Shafting** for driving machine-tools and general machinery is usually from 90 to 100 revolutions per minute, and for driving wood-working machinery it is generally 240 revolutions per minute.

**Hire of Steam Power.**—The price charged for the hire of steam power and use of shafting is usually £12, per indicated horse power per annum.—The price charged for the hire of a portable engine is usually £18, per nominal horse power per annum.

TABLE 22.—DISTANCE BETWEEN THE BEARINGS OF SHAFTING.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of the shafting, in inches | 1¼ | 1½ | 1¾ | 2 | 2¼ | 2½ | 3 | 3½ | 4 | 4½ | 5 | 6 | 7 | 8 | 9 | 10 |
| Distance between the bearings, for shafting carrying its own weight only, in feet . . . . . | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 14 | 15 | 16 | 17 | 20 | 22 | 24 | 26 | 28 |
| Distance between the bearings, for shafting carrying the ordinary proportion of pulleys, &c., in feet | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 10½ | 11 | 12 | 13 | 15 | 16 | 18 | 19 | 20 |

TABLE 23.—WEIGHT OF SHAFTING PER FOOT IN LENGTH, AND THE AVERAGE WEIGHT OF COLLARS, COUPLINGS AND PLUMMER BLOCKS IN LBS.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of shafting, in inches . | 1¼ | 1½ | 1¾ | 2 | 2¼ | 2½ | 2¾ | 3 | 3½ | 4 | 4½ | 5 | 6 | 7 | 8 | 9 | 10 |
| Weight of plain wrought-iron shafting, per foot in length, in lbs. . | 4·09 | 5·89 | 8·02 | 10·5 | 13·3 | 16·5 | 19·8 | 23·6 | 32·2 | 42 | 53·2 | 66 | 95 | 130 | 168 | 213 | 264 |
| Weight of collars welded on, for necks, per *pair*, in lbs. . . | ½ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 12 | 16 | 21 | 28 | 35 | 42 | 50 | 60 |
| Weight of loose collars with set screws, per *pair*, in lbs. . . | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 20 | 28 | 35 | 47 | 53 | 64 | 80 |
| Weight of cast-iron flange coupling, complete with bolts, in lbs. . | 17 | 23 | 38 | 54 | 74 | 96 | 109 | 125 | 165 | 234 | 289 | 322 | 406 | 466 | | | |
| Weight of cast-iron muff coupling, for shafting, without swelled ends, in lbs. . . . . . | 14 | 17 | 21 | 31 | 41 | 62 | 70 | 94 | 106 | 178 | 202 | 241 | 396 | 476 | | | |
| Weight of plummer block, complete with brasses and bolts, in lbs. . . . . . | 10 | 15 | 19 | 24 | 33 | 40 | 48 | 56 | 76 | 99 | 124 | 156 | 224 | 324 | 420 | 518 | 636 |

The dimensions and weight of couplings for shafting, are given at pp. 145 to 147, and of plummer blocks, at p. 149.

## CAST-IRON COUPLINGS FOR SHAFTS.

**Cast-Iron Flange-Couplings,** Fig. 30.—In order to keep the shafts in line with each other, the end of one shaft projects from one half-coupling to a length equal to $\frac{1}{4}$ the thickness of one flange, and enters the other half-

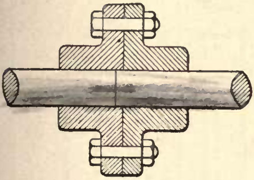

Fig. 30.

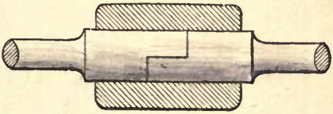

Fig. 31.

coupling. Each half-coupling is keyed on with a sunk key, and afterwards turned true in its place. The bolt-heads and nuts are sometimes counter-sunk, in which cases the flanges must be made proportionally thicker.

Table 24.—PROPORTIONS OF CAST-IRON FLANGE-COUPLINGS.

| Diameter of Shaft. | Diameter of Flange. | Thickness of each Flange. | Diameter of Boss. | Length of Boss beyond the Flange. | Diameter of Circle of the Centres of Bolts. | Diameter of Bolts. | Number of Bolts. | Keyway. | | Weight of Coupling complete with Bolts. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Wide. | Deep. | | | |
| Inches. | Inches. | Inches. | Inch. | Inches. | Inches. | Inch. | | Inch. | Inch. | cwt. | qr. | lb. |
| $1\frac{1}{2}$ | 7 | $\frac{7}{8}$ | 3 | $1\frac{7}{8}$ | $5\frac{1}{8}$ | $\frac{3}{4}$ | 3 | $\frac{7}{16}$ | $\frac{3}{16}$ | 0 | 0 | 23 |
| $1\frac{3}{4}$ | $7\frac{3}{4}$ | 1 | $3\frac{1}{2}$ | 2 | $5\frac{3}{4}$ | $\frac{3}{4}$ | 3 | $\frac{1}{2}$ | $\frac{3}{16}$ | 0 | 1 | 10 |
| 2 | $8\frac{1}{4}$ | $1\frac{1}{8}$ | 4 | $2\frac{1}{8}$ | $6\frac{1}{4}$ | $\frac{7}{8}$ | 4 | $\frac{5}{8}$ | $\frac{1}{4}$ | 0 | 1 | 26 |
| $2\frac{1}{4}$ | $9\frac{1}{4}$ | $1\frac{3}{16}$ | $4\frac{1}{2}$ | $2\frac{1}{4}$ | 7 | $\frac{7}{8}$ | 4 | $\frac{5}{8}$ | $\frac{1}{4}$ | 0 | 2 | 18 |
| $2\frac{1}{2}$ | 10 | $1\frac{1}{4}$ | 5 | $2\frac{1}{2}$ | $7\frac{1}{2}$ | $\frac{7}{8}$ | 4 | $\frac{3}{4}$ | $\frac{5}{16}$ | 0 | 3 | 12 |
| $2\frac{3}{4}$ | $10\frac{1}{2}$ | $1\frac{3}{8}$ | $5\frac{1}{2}$ | $2\frac{5}{8}$ | 8 | 1 | 4 | $\frac{3}{4}$ | $\frac{5}{16}$ | 0 | 3 | 25 |
| 3 | $11\frac{1}{4}$ | $1\frac{1}{2}$ | 6 | 3 | $8\frac{3}{4}$ | 1 | 4 | $\frac{7}{8}$ | $\frac{5}{16}$ | 1 | 0 | 13 |
| $3\frac{1}{2}$ | 13 | $1\frac{5}{8}$ | 7 | $3\frac{3}{8}$ | 10 | 1 | 4 | 1 | $\frac{3}{8}$ | 1 | 1 | 25 |
| 4 | $14\frac{1}{2}$ | $1\frac{3}{4}$ | 8 | $3\frac{3}{4}$ | $11\frac{1}{2}$ | 1 | 6 | $1\frac{1}{8}$ | $\frac{3}{8}$ | 2 | 0 | 10 |
| $4\frac{1}{2}$ | 16 | $1\frac{7}{8}$ | 9 | $4\frac{1}{8}$ | 13 | $1\frac{1}{8}$ | 6 | $1\frac{1}{4}$ | $\frac{3}{8}$ | 2 | 2 | 9 |
| 5 | $17\frac{3}{4}$ | 2 | 10 | $4\frac{1}{2}$ | 14 | $1\frac{1}{4}$ | 6 | $1\frac{3}{8}$ | $\frac{1}{2}$ | 2 | 3 | 14 |
| 6 | $20\frac{1}{2}$ | $2\frac{1}{4}$ | 12 | $5\frac{1}{4}$ | $16\frac{1}{4}$ | $1\frac{3}{8}$ | 6 | $1\frac{5}{8}$ | $\frac{5}{8}$ | 3 | 2 | 14 |
| 7 | 23 | $2\frac{3}{8}$ | 14 | $6\frac{1}{8}$ | 18 | $1\frac{1}{2}$ | 6 | $1\frac{7}{8}$ | $\frac{5}{8}$ | 4 | 0 | 18 |

**Muff or Solid Cast-Iron Couplings,** Fig. 31.—For best work, the ends of the shafts should be swelled and joined together with a half-lap joint, which takes the driving strain. Taper of joint, 1 inch per foot. A hollow key, is used to key on the coupling.

Table 25.—Proportions of Muff-Couplings, for Shafts with Half-Lap Joint.

| Diameter of the Shaft. | Diameter of the Swell. | Length of the Swell. | Length of Lap. | Diameter of Coupling. | Length of Coupling. | Keyway. | | Weight of Coupling. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Width. | Depth. | | | |
| Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | cwt. | qr. | lb. |
| 1½ | 2½ | 3⅞ | 1⅜ | 5 | 7 | ¾ | 5/16 | 0 | 0 | 25 |
| 1¾ | 3 | 4½ | 1½ | 5½ | 8 | ⅞ | 5/16 | 0 | 1 | 5 |
| 2 | 3¼ | 4¾ | 1¾ | 6 | 8½ | ⅞ | 5/16 | 0 | 1 | 14 |
| 2¼ | 3½ | 5⅛ | 2 | 6½ | 9 | 1 | ⅜ | 0 | 1 | 25 |
| 2½ | 4 | 5⅝ | 2¼ | 7½ | 10 | 1⅛ | ⅜ | 0 | 2 | 22 |
| 2¾ | 4½ | 6⅛ | 2⅜ | 8 | 11 | 1¼ | ⅜ | 0 | 3 | 12 |
| 3 | 4¾ | 6¾ | 2½ | 9 | 12 | 1⅜ | ½ | 1 | 1 | 0 |
| 3½ | 5¼ | 7¼ | 3 | 10 | 13 | 1½ | ½ | 1 | 2 | 20 |
| 4 | 6 | 8 | 3½ | 11 | 14 | 1⅝ | ⅝ | 2 | 0 | 4 |
| 4½ | 6½ | 8½ | 4 | 12 | 15 | 1¾ | ⅝ | 2 | 2 | 0 |
| 5 | 7¼ | 9 | 4¼ | 13 | 16 | 1⅞ | ⅝ | 3 | 1 | 10 |
| 6 | 9 | 10½ | 5 | 16 | 18 | 2⅜ | ¾ | 5 | 2 | 18 |
| 7 | 10½ | 12 | 6 | 18 | 21 | 2¾ | ⅞ | 7 | 3 | 18 |

**Muff-Couplings for Shafts with Butt-Ends,** Fig. 32.—Where price is an object, muff-couplings are used with shafts without swells, and the ends of the shafts butt together, instead of being half-lapped.

Table 26.—Muff-Couplings for Shafts with Butt-Ends.

| Diameter of the Shaft. | Diameter of Coupling. | Length of Coupling. | Keyway. | | Weight of Coupling. | | |
|---|---|---|---|---|---|---|---|
| | | | Width. | Depth. | | | |
| Inches. | Inches. | Inches. | Inches. | Inches. | cwt. | qr. | lb. |
| 1½ | 4½ | 6¾ | 7/16 | 3/16 | 0 | 0 | 17 |
| 1¾ | 5 | 7½ | ½ | 3/16 | 0 | 0 | 21 |
| 2 | 5¼ | 7⅞ | ⅝ | ¼ | 0 | 1 | 3 |
| 2¼ | 5½ | 8¼ | ⅝ | ¼ | 0 | 1 | 13 |
| 2½ | 6¼ | 9⅜ | ¾ | 5/16 | 0 | 2 | 6 |
| 2¾ | 6½ | 9¾ | ¾ | 5/16 | 0 | 2 | 14 |
| 3 | 7¼ | 10⅞ | ⅞ | 5/16 | 0 | 3 | 10 |
| 3½ | 8 | 12 | 1 | ⅜ | 0 | 3 | 22 |
| 4 | 9 | 13½ | 1⅛ | ⅜ | 1 | 2 | 10 |
| 4½ | 9½ | 14¼ | 1¼ | ⅜ | 1 | 3 | 6 |
| 5 | 10¼ | 15⅜ | 1⅜ | ½ | 2 | 0 | 17 |
| 6 | 12 | 18 | 1⅝ | ⅝ | 3 | 2 | 4 |
| 7 | 13 | 19½ | 1⅞ | 11/16 | 4 | 1 | 0 |

**Cast-Iron Claw-Coupling,** Fig. 33.—This is a very strong coupling,

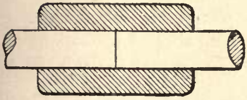

Fig. 32.

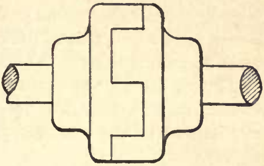

Fig 33.

and is suitable for heavy work; it can also be constructed as a disengaging coupling.

Table 27.—Proportions of Cast-Iron Claw-Couplings.

| Diameter of Shaft where Coupling is fitted. | Outside Diameter of Claw. | Length of Claw. | Thickness of Flange at back of Recess. | Diameter of the Boss. | Length of Boss beyond the Flange. | Extra Length to be added to one-half of the Coupling when it is required for a Disengaging Coupling. | | Size of Keyway. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Width of Groove. | Thickness of end Collar. | Width. | Depth. |
| Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| 3 | 7½ | 1⅞ | 1 | 5¾ | 2 | 1¾ | ⅞ | ⅞ | 5/16 |
| 4 | 10 | 2½ | 1¼ | 7¼ | 2½ | 1⅞ | 1 | 1⅛ | ⅜ |
| 5 | 12½ | 3⅛ | 1⅝ | 9½ | 3 | 2 | 1⅛ | 1⅜ | ½ |
| 6 | 15 | 3¾ | 2 | 11½ | 3½ | 2⅛ | 1¼ | 1⅝ | ⅝ |
| 7 | 17½ | 4⅜ | 2⅜ | 13¼ | 4 | 2¼ | 1⅜ | 1⅞ | ⅝ |
| 8 | 20 | 4¾ | 2¾ | 14¾ | 4½ | 2⅜ | 1½ | 2⅛ | ¾ |
| 9 | 22½ | 5⅝ | 3 | 16½ | 5 | 2½ | 1⅝ | 2⅜ | ¾ |
| 10 | 25 | 6¼ | 3½ | 18½ | 5½ | 2⅝ | 1¾ | 2⅝ | ¾ |
| 11 | 27½ | 6⅞ | 3¾ | 20½ | 6 | 2¾ | 1⅞ | 2¾ | ⅞ |
| 12 | 30 | 7½ | 4 | 21 | 6½ | 3 | 2 | 3 | 1 |
| 13 | 32½ | 8⅛ | 4¼ | 23 | 7 | 3⅛ | 2⅛ | 3¼ | 1 |
| 14 | 35 | 8¾ | 4½ | 25 | 7½ | 3¼ | 2¼ | 3½ | 1⅛ |
| 15 | 37½ | 9⅜ | 5 | 27 | 8 | 3½ | 2½ | 3¾ | 1¼ |

**The Dynamometer** or Friction Brake is used for testing the power of an engine, and consists of a horizontal lever having at one end, a strap of iron lined with wood,—which embraces a pulley keyed on the engine shaft—and at the other end a suspended scale for weights. If the reputed power of the engine is known, a weight corresponding to that power is placed in the scale, and after the engine is started, the strap is gradually tightened, and the wood is drawn tightly against the surface of the pulley,—

which is kept cool by a stream of water. When the engine is running at its proper speed, with the correct pressure of steam, the lever will be raised slightly above its horizontal position; if the lever be raised considerably, the power will be in excess of the calculated power, and the weight in the scale must be increased so as to obtain the maximum power.

*To find the Dynamometrical horse power. Rule:* Multiply the circumference in feet described by the lever, by the number of revolutions per minute and by the weight suspended, in lbs., and divide the product by 33,000.

*To find what weight must be used to test an Engine. Rule:* Multiply the horse power by 33,000, and divide by the product of the circumference in feet described by the lever, multiplied by the number of revolutions. The weight of the lever must either be balanced, or provided for in the calculation.

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Table 28.—PROPORTIONS OF KEYS FOR WHEELS, ETC.

| Diameter of Shaft. | Size of Key. | | Depth sunk in Shaft. | Depth sunk in Wheel. | Diameter of Shaft. | Size of Key. | | Depth sunk in Shaft. | Depth sunk in Wheel. |
|---|---|---|---|---|---|---|---|---|---|
| | Breadth. | Thickness. | | | | Breadth. | Thickness. | | |
| Inches. | Inch. | Inch. | Inch. | Inch. | Inches. | Inches. | Inches. | Inch. | Inches. |
| $\frac{5}{8}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{1}{16}$ | $\frac{1}{16}$ | $3\frac{1}{4}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{5}{16}$ |
| $\frac{3}{4}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{1}{16}$ | $\frac{1}{8}$ | $3\frac{1}{2}$ | 1 | $\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{3}{8}$ |
| $\frac{7}{8}$ | $\frac{1}{4}$ | $\frac{3}{16}$ | $\frac{1}{16}$ | $\frac{1}{8}$ | $3\frac{3}{4}$ | 1 | $\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{3}{8}$ |
| 1 | $\frac{5}{16}$ | $\frac{1}{4}$ | $\frac{1}{16}$ | $\frac{3}{16}$ | 4 | $1\frac{1}{8}$ | $\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{3}{8}$ |
| $1\frac{1}{8}$ | $\frac{5}{16}$ | $\frac{1}{4}$ | $\frac{1}{16}$ | $\frac{3}{16}$ | $4\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{3}{8}$ |
| $1\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{5}{16}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | 5 | $1\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{1}{4}$ | $\frac{1}{2}$ |
| $1\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{5}{16}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $5\frac{1}{2}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{4}$ | $\frac{1}{2}$ |
| $1\frac{1}{2}$ | $\frac{7}{16}$ | $\frac{5}{16}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | 6 | $1\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{1}{4}$ | $\frac{5}{8}$ |
| $1\frac{5}{8}$ | $\frac{7}{16}$ | $\frac{5}{16}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $6\frac{1}{2}$ | $1\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{4}$ | $\frac{5}{8}$ |
| $1\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{5}{16}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | 7 | $1\frac{7}{8}$ | 1 | $\frac{3}{8}$ | $\frac{5}{8}$ |
| $1\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{5}{16}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $7\frac{1}{2}$ | 2 | 1 | $\frac{3}{8}$ | $\frac{5}{8}$ |
| 2 | $\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{1}{8}$ | $\frac{1}{4}$ | 8 | $2\frac{1}{8}$ | $1\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{3}{4}$ |
| $2\frac{1}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{1}{8}$ | $\frac{1}{4}$ | $8\frac{1}{2}$ | $2\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{3}{4}$ |
| $2\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{1}{8}$ | $\frac{1}{4}$ | 9 | $2\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ | $\frac{3}{4}$ |
| $2\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{1}{8}$ | $\frac{1}{4}$ | $9\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ | $\frac{3}{4}$ |
| $2\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | 10 | $2\frac{5}{8}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ | $\frac{3}{4}$ |
| $2\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | $10\frac{1}{2}$ | $2\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ |
| $2\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | 11 | 3 | $1\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ |
| $2\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | $11\frac{1}{2}$ | $3\frac{1}{8}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ | 1 |
| 3 | $\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | 12 | $3\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ | 1 |

NOTE.—The depth sunk in the shaft or wheel is measured at the side of the key. When keys are made with gib-heads, the depth and length of the gib-head should each be equal to the thickness of the key. Taper of keys, $\frac{3}{16}$ inch per foot in length.

## PLUMMER-BLOCKS.

### TABLE 29.—PROPORTIONS OF PLUMMER-BLOCKS.

| Diameter of Neck. | Length of Neck. | Height to Centre. | Dimensions of Base. | | | | | Dimensions of Bushes. | | | Centres of Cap Bolts. | Diameter of Cap Bolts. | Weight of Plummer-Block Complete, with Gun Metal Bushes. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length of Base. | Breadth of Base. | Thickness of Base at End. | Centres of Holding down Bolts in Base. | Size of Bolt Holes in Base. | Thickness of Bush at Side. | Thickness of Bush at Bottom. | Thickness of Flange of Bush. | | | | | |
| Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | cwt. | qr. | lb. |
| 1 | 1½ | 1⅜ | 7 | 1 | ¾ | 5 | ½ × 1 | 3/16 | ¼ | ¼ | 2 | ⅜ | 0 | 0 | 6 |
| 1¼ | 2 | 1¾ | 8 | 1½ | ⅞ | 6 | ⅝ × 1⅛ | 3/16 | 5/16 | ¼ | 2½ | ½ | 0 | 0 | 10 |
| 1½ | 2½ | 2 | 9 | 1¾ | 1 | 7 | ⅝ × 1¼ | ¼ | ⅜ | ⅜ | 3 | ⅝ | 0 | 0 | 15 |
| 1¾ | 3 | 2¼ | 9½ | 2¼ | 1⅛ | 7¼ | ¾ × 1⅜ | ¼ | ⅜ | ⅜ | 3½ | ⅝ | 0 | 0 | 19 |
| 2 | 3½ | 2½ | 10 | 2½ | 1¼ | 7½ | ⅞ × 1½ | 5/16 | 7/16 | ½ | 4 | ¾ | 0 | 0 | 24 |
| 2¼ | 3¾ | 2¾ | 11 | 2¾ | 1¼ | 8½ | ⅞ × 1½ | 5/16 | 7/16 | ½ | 4½ | ¾ | 0 | 1 | 5 |
| 2½ | 4 | 3 | 12 | 3 | 1⅜ | 9¼ | 1 × 1⅝ | ⅜ | ½ | ½ | 5 | ⅞ | 0 | 1 | 12 |
| 2¾ | 4¼ | 3¼ | 13 | 3¼ | 1½ | 10 | 1 × 1⅝ | ⅜ | ½ | ½ | 5⅜ | ⅞ | 0 | 1 | 20 |
| 3 | 5 | 3½ | 14 | 3¾ | 1⅝ | 11 | 1⅛ × 1¾ | ⅜ | 9/16 | ⅝ | 5¾ | 1 | 0 | 2 | 0 |
| 3¼ | 5¼ | 3⅝ | 14½ | 4 | 1⅝ | 11¼ | 1⅛ × 1¾ | ⅜ | 9/16 | ⅝ | 6⅛ | 1 | 0 | 2 | 10 |
| 3½ | 5½ | 3¾ | 15 | 4¼ | 1¾ | 11¾ | 1⅛ × 2 | ⅜ | 9/16 | ⅝ | 6½ | 1 | 0 | 2 | 20 |
| 3¾ | 5¾ | 4 | 15½ | 4½ | 1¾ | 12 | 1¼ × 2 | ⅜ | 9/16 | ⅝ | 7 | 1⅛ | 0 | 3 | 6 |
| 4 | 6 | 4¼ | 16 | 4½ | 1⅞ | 12½ | 1¼ × 2¼ | 7/16 | ⅝ | ¾ | 7½ | 1⅛ | 0 | 3 | 15 |
| 4¼ | 6¼ | 4½ | 17 | 4¾ | 1⅞ | 13½ | 1¼ × 2¼ | 7/16 | ⅝ | ¾ | 8 | 1⅛ | 0 | 3 | 24 |
| 4½ | 6½ | 4¾ | 18 | 5 | 2 | 14 | 1¼ × 2¼ | ½ | 11/16 | ¾ | 8½ | 1⅛ | 1 | 0 | 12 |
| 4¾ | 6¾ | 5 | 19 | 5¼ | 2⅛ | 14½ | 1⅜ × 2¼ | ½ | 11/16 | ¾ | 9 | 1¼ | 1 | 1 | 0 |
| 5 | 7 | 5¼ | 20 | 5¼ | 2¼ | 15½ | 1⅜ × 2½ | ½ | ¾ | ⅞ | 9¼ | 1¼ | 1 | 1 | 16 |
| 5¼ | 7¼ | 5½ | 21 | 5½ | 2⅜ | 16½ | 1½ × 2½ | ½ | ¾ | ⅞ | 9½ | 1¼ | 1 | 2 | 8 |
| 5½ | 7½ | 6 | 22 | 5¾ | 2½ | 17 | 1½ × 2½ | ½ | 13/16 | ⅞ | 10¼ | 1¼ | 1 | 3 | 0 |
| 6 | 8 | 6½ | 23 | 6¼ | 2¾ | 18 | 1⅝ × 2¾ | ⅝ | ⅞ | ⅞ | 11 | 1⅜ | 2 | 0 | 0 |
| 6½ | 9 | 7 | 24 | 7 | 3 | 19 | 1⅝ × 3 | ⅝ | ⅞ | 1 | 12 | 1½ | 2 | 1 | 24 |
| | | | | | | | Four | | | | | Four | | | |
| 7 | 10 | 7½ | 25 | 8 | 3⅛ | 20 | 1⅝ × 3 | ¾ | 1 | 1 | 13 | 1¼ | 2 | 3 | 16 |
| 8 | 11 | 8½ | 29 | 9 | 3¼ | 23 | 1⅝ × 3 | ¾ | 1 1/16 | 1 | 14¾ | 1½ | 3 | 3 | 0 |
| 9 | 12 | 9½ | 30 | 10 | 3½ | 24 | 1¾ × 3¼ | ¾ | 1⅛ | 1 | 16¾ | 1⅝ | 4 | 2 | 14 |
| 10 | 14 | 10½ | 33 | 11¾ | 3¾ | 26 | 1⅞ × 3¼ | ⅞ | 1 3/16 | 1⅛ | 18½ | 1¾ | 5 | 2 | 20 |
| 11 | 15 | 11 | 34 | 12½ | 4 | 27 | 2 × 3½ | ⅞ | 1¼ | 1¼ | 20 | 1⅞ | 6 | 3 | 0 |
| 12 | 16 | 12 | 36 | 13½ | 4¼ | 28 | 2¼ × 3¾ | ⅞ | 1¼ | 1¼ | 22 | 2⅛ | 8 | 0 | 16 |
| 13 | 17 | 13 | 40 | 14¼ | 4½ | 32 | 2¼ × 4 | 1 | 1⅜ | 1⅜ | 24 | 2⅛ | 9 | 2 | 10 |
| 14 | 18 | 14 | 48 | 15 | 5 | 39 | 2⅜ × 4½ | 1 | 1½ | 1½ | 26 | 2¼ | 11 | 1 | 0 |

Thickness of Cap of Plummer-Block = the Diameter of the Neck Multipled by ·43. Plummer-Blocks of 7 Inches Neck and upwards have 4 Bolts in the Cap and in the Base.

**Wall-Plates for Plummer-Blocks** should equal, in length, 7 times the diameter of the neck; in thickness = diameter of neck multiplied by ·4; in width = twice the diameter of neck, and the centres of the holding down bolts in same should = $5\frac{1}{2}$ times the diameter of the neck. Depth of boss for bolt-holes, and also the depth of the joggles for holding the wedge, should = three-fourths of the thickness of base of plummer-block.

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## DIAMETER AND SPEED OF PULLEYS FOR BELTS.

**To find the speed of the driving pulley,** multiply the diameter in inches of the driven pulley, by the number of revolutions it makes per minute, and divide the product by the diameter in inches of the driving pulley.

**To find the speed of the driven pulley,** multiply the diameter in inches of the driving pulley, by the number of revolutions it makes per minute, and divide the product by the diameter in inches of the driven pulley.

**To find the final speed of a train of pulleys,** multiply the number of revolutions per minute of the first driving pulley, by the product of the diameters of the driving pulleys, and divide the result by the product of the diameters of the driven pulleys.

**To find the diameter of the driving pulley,** multiply the diameter in inches of the driven pulley, by the number of revolutions it makes per minute, and divide the product by the number of revolutions of the driving pulley.

**To find the diameter of the driven pulley,** multiply the diameter in inches of the driving pulley by the number of revolutions it makes per minute, and divide the product by the number of revolutions of the driven pulley.

**To find the diameters of two pulleys,** when the speeds of the driving and driven shafts are given: divide the speed of the driven shaft by the speed of the driving shaft, which will give the ratio of their speeds, and the diameters of the pulleys must be in the same ratio.

**Friction-Cone Keys,** for fixing pulleys on shafting, are used for pulleys not made in halves, which require to be passed over swells on shafting. They are also fitted to split pulleys in cases where they have to fit different sizes of shafts. A cast-iron cone is turned to a taper of $\frac{3}{8}$ inch in diameter per foot in length, and the pulley is bored to suit it. The cone is split after being turned, into three pieces. The minimum thickness of metal at the small end of the cone, should be $\frac{5}{8}$ inch.

**Strain on Bearings due to Pulleys and Pull of Belts.**—The gross weight of shafting per foot in length, including the weight of the pulleys, and the load due to the pull of the belts, is equal to about two and one-half times the weight per foot in length, of the shafting.

---

## PULLEYS FOR BELTS.

**Proportions of Pulleys.**—The arms of pulleys are mostly made straight, and when made according to the proportions in the following table, they will not break from contraction in casting; the diameter of boss varies with the diameter of the pulley as well as with the diameter of shaft; the proper size is given in the following table.

**Number and Shape of Arms.**—Pulleys up to 17 inches diameter should have 4 arms; and from 18 inches to 8 feet, 6 arms; and above that size, 8 arms. The section of the arm should be of oval shape, struck from a radius equal to $\frac{3}{4}$ the width of arm, and the edges should be rounded off instead of left sharp.

**Round Face of Pulleys.**—When a belt is to work constantly in one position on the face of a pulley, the face should be rounded to the extent of $\frac{3}{8}$ inch per foot of the width of the rim. But when the belt is to be shifted along the face of the pulley to drive fast and loose pulleys, the face should be turned flat.

**The Width of Face** of a pulley should be about one-fourth more than the width of the belt it has to carry.

**Pulleys with Curved Arms.**—Fig. 34 shows the way to project the curved arm of a pulley. Draw the horizontal centre-line, A B, and from it,

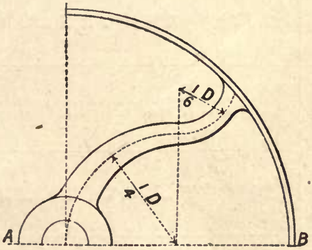


Fig. 34.

with a radius of $\frac{1}{4}$th the diameter of the pulley, draw the centre-line of the arm for the bottom curve. From the point where the said radius is struck, draw a vertical line, and on that line, with a radius of $\frac{1}{6}$th the diameter of the pulley, draw the centre-line of the arm for the top curve. The dimensions of the arm can be taken from Table 29.

Table 30.—Proportion of the Arms and Boss of Pulleys for Belts.

| Diameter of Pulley, in Inches. | Dimensions of Arms. | | | | Depth of Rib round Boss. | Diameter of Shaft, 1½ to 2 Inches. | Diameter of Shaft, 2⅛ to 3 Inches. | Diameter of Shaft, 3⅛ to 4 Inches. | Diameter of Shaft. 4⅛ to 5 Inches. | Diameter of Shaft, 5⅛ to 6 Inches. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Width at Boss. | Thickness at Boss. | Width at Rim. | Thickness at Rim. | | Thickness of Metal round Shaft. | Thickness of Metal round Shaft. | Thickness of Metal round Shaft. | Thickness of Metal round Shaft. | Thickness of Metal round Shaft. |
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| 12 | 1¾ | ¾ | 1¼ | ⅝ | ⅞ | 1 | 1⅛ | 1¼ | 1⅜ | 1½ |
| 15 | 1⅞ | ¾ | 1⅜ | ⅝ | 1 | 1 | 1⅛ | 1¼ | 1⅜ | 1½ |
| 18 | 2 | ¾ | 1½ | ⅝ | 1 | 1 | 1⅛ | 1¼ | 1⅜ | 1½ |
| 21 | 2⅛ | ⅞ | 1⅝ | ¾ | 1⅛ | 1⅛ | 1¼ | 1⅜ | 1½ | 1⅝ |
| 24 | 2¼ | ⅞ | 1¾ | ¾ | 1⅛ | 1⅛ | 1¼ | 1⅜ | 1½ | 1⅝ |
| 27 | 2½ | 1 | 2 | ⅞ | 1¼ | 1⅛ | 1¼ | 1⅜ | 1⅝ | 1¾ |
| 30 | 2¾ | 1 | 2⅛ | ⅞ | 1¼ | 1⅛ | 1¼ | 1⅜ | 1⅝ | 1¾ |
| 33 | 2⅞ | 1 | 2¼ | ⅞ | 1⅜ | 1¼ | 1⅜ | 1½ | 1⅝ | 1¾ |
| 36 | 3 | 1⅛ | 2⅜ | 1 | 1½ | 1¼ | 1⅜ | 1½ | 1¾ | 1⅞ |
| 39 | 3⅛ | 1⅛ | 2⅜ | 1 | 1½ | 1¼ | 1⅜ | 1½ | 1¾ | 1⅞ |
| 42 | 3¼ | 1⅛ | 2½ | 1 | 1⅝ | 1⅜ | 1½ | 1⅝ | 1¾ | 2 |
| 45 | 3⅜ | 1⅛ | 2⅝ | 1 | 1¾ | 1⅜ | 1½ | 1⅝ | 1¾ | 2 |
| 48 | 3½ | 1¼ | 2¾ | 1⅛ | 1¾ | 1½ | 1⅝ | 1¾ | 1⅞ | 2⅛ |
| 54 | 3⅝ | 1¼ | 2⅞ | 1⅛ | 1¾ | 1½ | 1⅝ | 1¾ | 1⅞ | 2⅛ |
| 60 | 3¾ | 1¼ | 3 | 1⅛ | 1⅞ | 1⅝ | 1¾ | 1⅞ | 2 | 2¼ |
| 66 | 4 | 1⅜ | 3⅛ | 1⅛ | 2 | | 1¾ | 1⅞ | 2 | 2⅜ |
| 72 | 4¼ | 1⅜ | 3¼ | 1⅛ | 2¼ | | 1⅞ | 2 | 2¼ | 2½ |
| 84 | 4½ | 1½ | 3½ | 1¼ | 2¼ | | 2 | 2¼ | 2½ | 2¾ |
| 96 | 5 | 1⅝ | 3¾ | 1¼ | 2½ | | 2¼ | 2½ | 2¾ | 3 |

Table 31.—Weight of Cast-Iron Pulley Castings, both Whole, and Split, that is in Halves, bolted together.

| Diameter of Pulley. | Width of Face. | Weight. | | | | | | Diameter of Pulley. | Width of Face. | Weight. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Whole. | | | Split. | | | | | Whole. | | | Split. | | |
| Inches. | Inches. | cwt. | qr. | lb. | cwt. | qr. | lb. | Inches. | Inches. | cwt. | qr. | lb. | cwt. | qr. | lb. |
| 6 | 3 | 0 | 0 | 10 | 0 | 0 | 14 | 33 | 8 | 1 | 2 | 24 | 2 | 0 | 18 |
| 8 | 3 | 0 | 0 | 12 | 0 | 0 | 16 | 33 | 12 | 2 | 0 | 20 | 2 | 2 | 14 |
| 9 | 3 | 0 | 0 | 14 | 0 | 0 | 18 | 34 | 8 | 1 | 3 | 15 | 2 | 1 | 9 |
| 10 | 3 | 0 | 0 | 17 | 0 | 0 | 22 | 34 | 12 | 2 | 1 | 10 | 2 | 3 | 4 |
| 10 | 6 | 0 | 1 | 0 | 0 | 1 | 8 | 35 | 8 | 2 | 0 | 4 | 2 | 2 | 0 |
| 11 | 3 | 0 | 0 | 18 | 0 | 0 | 27 | 35 | 12 | 2 | 1 | 15 | 2 | 3 | 10 |
| 11 | 6 | 0 | 1 | 7 | 0 | 1 | 17 | 36 | 6 | 1 | 1 | 10 | 1 | 3 | 5 |
| 12 | 3 | 0 | 0 | 20 | 0 | 1 | 2 | 36 | 8 | 1 | 2 | 8 | 2 | 0 | 14 |
| 12 | 6 | 0 | 1 | 10 | 0 | 1 | 20 | 36 | 12 | 2 | 2 | 0 | 2 | 3 | 24 |
| 13 | 3 | 0 | 0 | 22 | 0 | 1 | 4 | 37 | 6 | 1 | 1 | 22 | 1 | 3 | 20 |
| 13 | 6 | 0 | 1 | 12 | 0 | 1 | 23 | 37 | 8 | 1 | 3 | 0 | 2 | 2 | 18 |
| 14 | 3 | 0 | 0 | 25 | 0 | 1 | 8 | 37 | 12 | 2 | 3 | 6 | 3 | 1 | 7 |
| 14 | 6 | 0 | 1 | 20 | 0 | 2 | 3 | 38 | 6 | 1 | 2 | 4 | 2 | 0 | 3 |
| 15 | 3 | 0 | 1 | 0 | 0 | 1 | 12 | 38 | 8 | 2 | 0 | 0 | 2 | 2 | 0 |
| 15 | 6 | 0 | 1 | 24 | 0 | 2 | 9 | 38 | 12 | 3 | 0 | 0 | 3 | 2 | 0 |
| 16 | 3 | 0 | 0 | 27 | 0 | 1 | 12 | 40 | 6 | 1 | 2 | 16 | 2 | 0 | 21 |
| 16 | 6 | 0 | 2 | 0 | 0 | 2 | 14 | 40 | 8 | 2 | 0 | 20 | 2 | 3 | 13 |
| 17 | 3 | 0 | 1 | 3 | 0 | 1 | 18 | 40 | 12 | 3 | 0 | 20 | 3 | 2 | 25 |
| 17 | 6 | 0 | 2 | 3 | 0 | 2 | 18 | 42 | 6 | 1 | 3 | 0 | 2 | 1 | 8 |
| 18 | 3 | 0 | 1 | 6 | 0 | 1 | 22 | 42 | 9 | 2 | 2 | 5 | 3 | 0 | 14 |
| 18 | 6 | 0 | 2 | 6 | 0 | 2 | 22 | 42 | 12 | 3 | 1 | 12 | 3 | 3 | 12 |
| 19 | 3 | 0 | 1 | 8 | 0 | 2 | 0 | 45 | 6 | 2 | 0 | 0 | 2 | 2 | 16 |
| 19 | 6 | 0 | 2 | 10 | 0 | 3 | 2 | 45 | 9 | 2 | 1 | 5 | 2 | 3 | 21 |
| 20 | 3 | 0 | 1 | 12 | 0 | 2 | 12 | 45 | 12 | 3 | 2 | 4 | 4 | 1 | 20 |
| 20 | 6 | 0 | 2 | 14 | 0 | 3 | 12 | 48 | 6 | 2 | 1 | 4 | 2 | 3 | 23 |
| 21 | 4 | 0 | 1 | 22 | 0 | 2 | 21 | 48 | 9 | 2 | 3 | 14 | 3 | 2 | 6 |
| 21 | 6 | 0 | 2 | 14 | 0 | 3 | 13 | 48 | 12 | 3 | 2 | 8 | 4 | 0 | 0 |
| 22 | 4 | 0 | 1 | 25 | 0 | 2 | 27 | 54 | 6 | 2 | 2 | 16 | 3 | 1 | 16 |
| 22 | 8 | 0 | 3 | 14 | 1 | 0 | 10 | 54 | 9 | 3 | 0 | 4 | 3 | 3 | 4 |
| 24 | 4 | 0 | 2 | 0 | 0 | 2 | 26 | 54 | 12 | 4 | 3 | 10 | 5 | 2 | 10 |
| 24 | 8 | 1 | 0 | 0 | 1 | 0 | 26 | 57 | 6 | 2 | 3 | 0 | 3 | 1 | 26 |
| 24 | 12 | 1 | 1 | 18 | 1 | 2 | 16 | 57 | 9 | 4 | 0 | 21 | 4 | 3 | 19 |
| 25 | 4 | 0 | 2 | 3 | 0 | 3 | 0 | 57 | 12 | 5 | 1 | 13 | 6 | 1 | 10 |
| 25 | 10 | 1 | 0 | 12 | 1 | 1 | 10 | 60 | 7 | 3 | 0 | 18 | 3 | 3 | 20 |
| 26 | 6 | 0 | 2 | 24 | 0 | 3 | 23 | 60 | 9 | 4 | 2 | 5 | 5 | 1 | 2 |
| 26 | 12 | 1 | 2 | 3 | 1 | 3 | 2 | 60 | 12 | 5 | 3 | 18 | 6 | 2 | 14 |
| 27 | 4 | 0 | 2 | 10 | 0 | 3 | 8 | 66 | 8 | 4 | 1 | 12 | 5 | 0 | 13 |
| 27 | 8 | 1 | 0 | 10 | 1 | 1 | 8 | 66 | 12 | 6 | 2 | 5 | 7 | 1 | 4 |
| 27 | 12 | 1 | 2 | 9 | 1 | 3 | 8 | 66 | 14 | 7 | 2 | 13 | 8 | 1 | 15 |
| 28 | 4 | 0 | 2 | 16 | 0 | 3 | 15 | 72 | 8 | 5 | 0 | 0 | 5 | 3 | 2 |
| 28 | 8 | 1 | 1 | 4 | 1 | 2 | 26 | 72 | 12 | 7 | 1 | 16 | 8 | 0 | 18 |
| 28 | 12 | 1 | 3 | 0 | 2 | 0 | 0 | 72 | 14 | 8 | 2 | 12 | 9 | 1 | 14 |
| 29 | 6 | 0 | 3 | 22 | 1 | 0 | 24 | 75 | 8 | 5 | 2 | 23 | 6 | 2 | 0 |
| 29 | 8 | 1 | 1 | 24 | 1 | 2 | 26 | 75 | 12 | 8 | 0 | 0 | 8 | 3 | 6 |
| 29 | 12 | 1 | 3 | 10 | 2 | 0 | 12 | 75 | 14 | 9 | 1 | 0 | 10 | 0 | 4 |
| 30 | 6 | 1 | 0 | 0 | 1 | 1 | 4 | 78 | 9 | 6 | 2 | 10 | 7 | 2 | 0 |
| 30 | 8 | 1 | 2 | 3 | 1 | 3 | 7 | 78 | 12 | 8 | 3 | 0 | 9 | 2 | 14 |
| 30 | 12 | 1 | 3 | 20 | 2 | 0 | 25 | 78 | 14 | 10 | 0 | 0 | 11 | 0 | 8 |
| 31 | 6 | 1 | 0 | 10 | 1 | 1 | 20 | 84 | 9 | 8 | 0 | 3 | 9 | 0 | 10 |
| 31 | 8 | 1 | 2 | 14 | 1 | 3 | 26 | 84 | 12 | 10 | 2 | 17 | 11 | 3 | 0 |
| 31 | 12 | 2 | 0 | 4 | 2 | 1 | 14 | 84 | 14 | 12 | 2 | 0 | 13 | 2 | 8 |
| 32 | 6 | 1 | 0 | 16 | 1 | 2 | 0 | 90 | 10 | 10 | 0 | 6 | 11 | 1 | 0 |
| 32 | 8 | 1 | 2 | 16 | 2 | 0 | 0 | 90 | 14 | 14 | 0 | 0 | 15 | 0 | 18 |
| 32 | 12 | 2 | 0 | 10 | 2 | 1 | 21 | 96 | 12 | 13 | 1 | 0 | 14 | 2 | 10 |
| 33 | 6 | 1 | 0 | 23 | 1 | 2 | 16 | 96 | 15 | 16 | 2 | 0 | 17 | 3 | 20 |

**Belt-Pulleys or Riggers.**—The preceding table gives the weight of pulley castings, cast from a good set of patterns. The rims of main driving

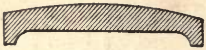

Fig. 35.

pulleys, may be strengthened without materially increasing the weight, by casting a rib about $\frac{5}{8}$ inch square, round the edge of the inside of the rim, like Fig. 35.

*The weight of turned pulleys*, may be found by deducting 12 lbs. for every cwt. in weight of the casting, which is the average reduction in weight due to turning and boring the same.

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## POWER OF BELTS.

The motion transmitted by a belt, is maintained solely by the frictional adhesion of the belt to the surface of the pulleys. Belts will not communicate motion with precision, on account of their liability to slip on the pulleys. When one pulley is larger than the other, an open belt will slip on the smallest one first, because the arc of contact is smaller; but if the belt be crossed, the arc of contact will be the same, whatever the diameter of the pulleys may be. A belt will always climb to the highest point of a pulley, and the position it takes upon a driven pulley, is determined by the side of the belt which moves towards the pulley.

A long horizontal belt increases the tension and arc of contact, by its own weight forming a curve between the pulleys, therefore it should drive from the under side, then the slack side is on the top and drops between the pulleys. A belt running on a pulley on a vertical shaft requires to be stretched very tightly over the pulleys, because its weight lessens its contact, and it should therefore be made broader than a horizontal belt.

**The working tension of leather belts** should not exceed 330 lbs. per square inch of the section of the belt. The adhesive grip of a belt, is the same on cast-iron pulleys whether they are turned or not, but it is greater on a wooden than on a cast-iron pulley.

**The strain in lbs. upon the driving side of a belt,** due to the power transmitted, independent of the initial tension producing adhesion between the pulley and the belt, is found thus: Multiply the number of the horse-power by 33,000, and divide the product by the velocity of the pulley in feet per minute. The velocity is found by multiplying the circumference of the pulley in feet by the number of revolutions per minute.

**The Actual Horse-power of a Belt** is found thus.—Multiply the force in lbs. transmitted to the surface of the pulley, by its velocity in feet per minute, and divide the result by 33,000.

**The Nominal Horse-power of Single Leather Belts** is found thus:—Multiply the diameter of the pulley in inches, by the width of belt in inches, and multiply the product by the number of revolutions per minute, then divide by the constant number due to the arc of contact of the belt, which is given in the following table.

**To find the Width of a Single Leather Belt.**—Multiply the nominal horse-power, by the constant number due to the arc of contact of the belt, and divide by the product of the number of revolutions per minute, and the diameter of the pulley in inches.

Table 32.—MULTIPLIERS FOR THE ABOVE RULES FOR THE HORSE-POWER OF SINGLE LEATHER BELTS.

| | | | | | |
|---|---|---|---|---|---|
| Portion of the circumference of the pulley in contact with the belt . . . . . . | $\frac{1}{4}$ | $\frac{1}{3}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ |
| Constant multiplier or divisor for the above rules . . . . . | 5715 | 4737 | 4000 | 3590 | 3297 |

The arc of contact, of the smaller of two pulleys, must be taken in calculating belts, when an open one is employed, but when a cross belt is employed, the arc of contact will be the same for both pulleys, and the arc of contact, of either of them may be taken.

**Double Belts.**—A double leather belt will drive double the power of a single one, and consequently it only requires to be one-half the width of a single belt, to drive the same power.

Table 33.—WEIGHT IN LBS. OF 100 FEET IN LENGTH OF SINGLE AND DOUBLE LEATHER BELTING.

| Width of Belt, Inches. . | 1½ | 2 | 2½ | 3 | 3½ | 4 | 4½ | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Single Belt, Strong, lbs. . | 14 | 19 | 25 | 31 | 38 | 43 | 50 | 54 | 67 | 78 | 100 | 110 | 130 | 140 | 160 | 200 | — |
| Single Belt, Medium, lbs. | 12 | 17 | 23 | 29 | 35 | 40 | 47 | 51 | 64 | 74 | 94 | 100 | 120 | 130 | 150 | 180 | — |
| Double Belt, Strong, lbs. . | 30 | 35 | 46 | 59 | 70 | 80 | 90 | 100 | 110 | 150 | 175 | 200 | 230 | 260 | 280 | 340 | 380 |
| Double Belt, Medium, lbs. | 24 | 30 | 40 | 53 | 64 | 74 | 84 | 93 | 103 | 142 | 165 | 190 | 220 | 250 | 270 | 325 | 360 |

**The safe working tension of Leather Belting** is 20 lbs. per inch in width, for each one-sixteenth of an inch in thickness of the belt, or 40 lbs. per inch in width, for each one-eighth of an inch in thickness.

**The Breaking Strain** per square inch of section, of best quality leather belting is . . . . . . . . 3,360 lbs.

The breaking strain, per square inch of section, of best quality stout stitched cotton belting is . . . . . . . 6,800 lbs.

The breaking strain, per square inch of section, of best quality stout solid-woven cotton belting is . . . . . 10,420 lbs.

**The belts for use in wet or damp places** are :— lbs.
Waterproof Linen Belting—4 ply—Breaking strength per square in. 12,000
India-rubber Belting—4 ply, $\frac{5}{16}$ inch thick, with canvas layers—
Breaking Strain per square inch . . . . . . . . 1,020

The strengths of belting only refer to new belts of best quality.

**The Co-efficients of Friction for Belts and Ropes,** from the experiments of M. Morin are as follows :—

For new belts on wooden pulleys . . . . . . . . ·50
For leather belts in ordinary condition on wooden pulleys . . . ·47
For belts in ordinary condition on cast-iron pulleys, either turned or not . . . . . . . . . . . . . ·28
For wet belts on cast-iron pulleys . . . . . . . . ·38
For hemp-ropes on wooden pulleys . . . . . . . . ·50

**A rope when wound round a Barrel** with a rough surface, offers very great frictional resistance to sliding, the resistance being the following number of times greater than the pull at the slack end : viz.—

24 when the rope is wound once round the barrel.
111 when the rope is wound $1\frac{1}{2}$ times round the barrel.
535 " " 2 " "
2575 " " $2\frac{1}{2}$ " "

**Transmission of Power to Long Distances.**—Power may be efficiently transmitted to long distances by M. Hirn's system of flexible wire-rope gearing. The wire-ropes are from $\frac{3}{8}$ to 1 inch diameter, and consist of a number of strands of iron wire, wound round a core of hemp, each strand consisting of 6 or more fine wires wound round a core of hemp. The wire rope runs at a speed of about 60 feet per second, on grooved pulleys of from 12 to 15 feet diameter; the bottom of the groove is round in shape and is composed of willow wood, sunk into the casting of the pulley. The distance between the pulleys should not be less than 70 yards,—because short wire ropes do not run steadily in working—and it may be any reasonably greater distance, guide pulleys—spaced about 70 yards apart—being used to support the rope in long distances. The rope rests upon the bottom of the groove, clear of the sides; the following are good proportions for the groove, viz. : Depth of groove from where the rope rests to the top of the rim of the pulley = $2\frac{1}{2}$ times the diameter of the rope : Width of groove at the top = 4 times the diameter of the rope : Radius of the bottom of the groove on which the rope rests = the diameter of the rope : Thickness of wood at the bottom of the groove = the diameter of the rope : Weight of the rope in lbs. per yard, in length = four times the square of the diameter of the wire-rope, in inches.

**Horse-power of Wire-rope Gearing.**—To find the number of indicated horse-power transmitted by wire-rope gearing. *Rule :* Multiply the strain in lbs. at the circumference of the pulley, by the velocity of the rope in feet per second, and divide the product by 550. The strain in lbs. at the circumference of the pulley is equal to 550 times the horse power divided by the velocity of the rope, in feet, per second.

Speed = 54½ ft per second. Magn Foundry C. Schaubel -

# SECTION IV.

## STEAM BOILERS, SAFETY VALVES, FACTORY CHIMNEYS, &c.

# SECTION IV.

## STEAM BOILERS, SAFETY VALVES, FACTORY CHIMNEYS, &c.

### STEAM BOILERS.

**Effect of Heat upon Water.**—When heat is first applied under a boiler, the material of the boiler absorbs and transfers the heat to the water, which causes the water to circulate. The water at the bottom becomes heated first and expands, and being lighter than the rest, is forced upwards by the greater density of the colder water above it, and a current of colder water descends and takes its place, and in turn becomes heated; afterwards the particles of water expand, and form themselves into bubbles of steam (that is, the heat becomes enclosed in films of water), and gradually ascend until they are robbed of their heat by the colder water, which they come in contact with in their ascent; then they condense and disappear. When the water becomes uniformly heated, the bubbles increase in size and number, and ascend higher as the heat increases, until the temperature of the whole reaches 212° Fahr., when the water will boil, and all subsequent additions of heat, will be carried off by the water in the form of steam. This is called convection, and is the only way water can be heated, as, being a bad conductor of heat, water cannot be heated by conduction.

**Fresh water boils** under atmospheric pressure at 212° F., and one cubic inch produces about one cubic foot of steam, equal in pressure to that of the atmosphere, or 14·7 lbs. per square inch, and until this point is reached steam will not rush into the atmosphere; therefore, unless the pressure of the atmosphere is removed, only pressures above 15 lbs. are available for performing work. The boiling point is always constant for the same liquid under the same conditions; but foreign substances, held in solution with it, considerably affect it. The boiling point rises in a closed vessel, as the pressure of the steam increases, because the tension of the vapour has to overcome a greater pressure, before it can escape from the water; but the temperature of steam is always the same as the water, which produced and is in contact with it, and there is a fixed temperature and density, to each pressure of steam when in contact with water.

**The Expansive Force of Steam** is nearly inversely as the volume; thus, if steam at 15 lbs. pressure occupies one cubic foot, the same quantity at 30 lbs. pressure would only occupy about half a cubic foot. Steam contains about $5\frac{1}{2}$ times as much heat as water; at atmospheric pressure, steam is 1,700 times the volume of the water which produced it.

**The Elastic or Mechanical Force of Steam** increases in a much greater ratio than its temperature; thus, at 212° its force is, in round numbers, 15 lbs. per square inch, but if its temperature be raised to 283° the force is 52 lbs. As small additions of heat produce a rapid increase of force, so small abstractions of heat rapidly reduce the elastic force.

**Saturated Steam.**—When steam is in contact with the water from which it was generated, it is called saturated steam.

**Superheated Steam.**—When steam is isolated from the water which produced it, and further heat is applied to it, it is called superheated or gaseous steam, because its temperature is raised above that of saturation. The extra heat thus applied to the steam is sensible heat, and it increases the volume of the steam in proportion to the increase of the absolute temperature. The object of superheating is to dry the steam, to prevent partial condensation in the cylinder; but only sufficient extra heat should be imparted to it, to barely dry the steam, because a little moisture is necessary in the steam to lubricate and reduce the friction of the surfaces, and to prevent the packing becoming charred. Superheated steam is usually produced by means of a superheater, composed of tubes, placed between the boiler and the chimney, and heated by the waste products of combustion; the steam passes through the superheater before entering the cylinder.

**Combustion of Coal and the Evaporative Power of Fuels.**—The total heat per lb. of coal may be expressed in units of evaporation, a unit of evaporation being the quantity of heat required to convert 1 lb. of water of 212° into steam at the same temperature; or in units of heat, a unit of heat being the quantity required to raise the temperature of 1 lb. of water 1°. Coal is composed of carbon,—1 lb. of which yields 14,500 units of heat, and of hydrogen,—1 lb. of which yields 62,032 units of heat, and of sulphur,—1 lb. of which yields 4,032 units of heat. From the results of Government experiments on 98 samples of coal, the average composition was deduced by Mr. D. K. Clark, as follows:—

| | | | | |
|---|---|---|---|---|
| Carbon . | ·80 | or 80 per cent. | Sulphur . | ·0125 or $1\frac{1}{4}$ per cent. |
| Hydrogen . | ·05 | or 5 „ | Oxygen . | ·08 or 8 „ |
| Nitrogen . | ·012 | or $1\frac{1}{5}$ „ | Ash . . | ·04 or 4 „ |

From this we find that the total heat of combustion of coal is:—

| | Units of heat. |
|---|---|
| Carbon, 14,500, multiplied by ·80 = . . . . . | 11,600 |
| Hydrogen, 62,032, multiplied by $\left(\cdot 05 - \frac{\cdot 08}{8}\right)^*$ = . . | 2,481 |
| Sulphur, 4,032, multiplied by ·0125 = . . . . . | 50 |
| Total . . . . . . . . . . | 14,131 |

* A portion of the hydrogen combines with the oxygen and forms water, and a deduction from the hydrogen of a quantity equal to $\frac{1}{8}$ of the oxygen must be made to provide for this condition.

By dividing this quantity by the units of heat required to convert 1 lb. of water of 212° into steam of the same temperature (14,131÷966), we have 14·63 units of evaporation, or 14·63 lbs. evaporated from and at 212°.

**Coke** contains ·86 carbon, but no hydrogen or oxygen, and yields (14,500 multiplied by ·86)=12,470 units of heat.

**Wood,** when dry, contains ·50 carbon, and the hydrogen and oxygen combine without yielding heat; and yields (14,500 multiplied by ·50) = 7,250 units of heat per lb.

**Peat** contains about one-third more units of heat than wood. These are the maximum heating powers of the above combustibles, for which at least 10 per cent. must be deducted for imperfect combustion. In practice it is impossible to utilize all the available heat, and it is distributed as follows:—

Heat lost by radiation—10 per cent.

Heat lost by ashes falling unburnt through the fire bars—10 per cent.

Heat lost by gases escaping at a high temperature to the chimney—20 per cent.

Heat used in producing steam in internally fired boilers—60 per cent.

In externally fired boilers the loss is 10 per cent. greater.

**The average evaporative power,** of different kinds of fuels, is as follows:—

| | | |
|---|---|---|
| 1 lb. good coal will evaporate 9 lbs. water which | has been | raised to 212°. |
| ¾ lb. of petroleum—Ditto. | ditto. | ditto. |
| 2 lb. of dry peat—Ditto. | ditto. | ditto. |
| 2½ lbs. of dry wood—Ditto. | ditto. | ditto. |
| 3¼ lbs. of cotton stalks—Ditto. | ditto. | ditto. |
| 3½ lbs. of brushwood—Ditto. | ditto. | ditto. |
| 3¾ lbs. of wheat or barley straw—Ditto. | ditto. | ditto. |
| 4 lbs. of megass or sugar cane refuse—Ditto. | ditto. | ditto. |

**The consumption of coal** per indicated horse-power per hour, in first-class compound condensing engines, is from 1¾ to 2 lbs.; in single cylinder condensing engines, 2½ to 3 lbs.; in locomotives, 2½ lbs.; and in high pressure non-condensing engines, 3 to 4 lbs.

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## CYLINDRICAL STEAM BOILERS.*

**Boiler-Shells.**—The resistance of a boiler-shell to internal pressure, varies inversely as the diameter. A shell 2 feet diameter, will bear double the internal pressure of one 4 feet diameter, the thickness being the same in

* The Author is indebted for some information on steam boilers to Mr. Robert Wilson's excellent work on Steam Boilers, and to the Reports of the Manchester Steam Users' Association, by Mr. Lavington E. Fletcher.

both cases. The resistance of the plates varies as their thickness. A shell of $\frac{1}{2}$ inch thickness, will bear double the pressure of one $\frac{1}{4}$ inch thickness, the diameter of the shell being the same in both cases. The thickness of the plates should be in proportion to the diameter of shell. A shell of 6 feet diameter, will require plates double the thickness of one 3 feet diameter, to resist the same pressure. The pressure of steam being equal in all directions, the pressure inside the shell of a boiler, acts uniformly all round its circumference, and tends to maintain its form perfectly circular, and also to restore any departure of its shape from a true circle. The shell cannot, however, be made perfectly circular, owing to the plates overlapping each other at the longitudinal seams, but the amount of deviation caused thereby, is so small that it need not be taken into consideration. The circumferential strain, being the greatest from the pressure inside the shell, the plates should be placed lengthways round the circumference, that is, the fibre of the iron should run round the circumference, because the plates are strongest in the direction in which they were rolled. The longitudinal seams should not be in line from end to end, but they should break joint, thereby considerably increasing the strength of the shell, and the longitudinal seams should be placed away from the centre line, along the top and bottom of the boiler. The transverse joints, requiring only half the strength of the longitudinal seams, only require to be single-riveted; but the longitudinal seams should be double-riveted.

**Longitudinal Strain on Boiler-Shells.**—The strain inside a boiler-shell, tending to rupture it longitudinaily in lines parallel to its axis, is found by multiplying the diameter in inches by the length in inches, and then by the pressure of steam per square inch.

**Transverse Strain on Boiler-Shells.**—The strain inside a boiler-shell, tending to rupture it transversely in lines at right angles to its axis, is the amount of pressure against each end of the shell, and it is found by multiplying the area of the end of the shell in square inches, by the pressure per square inch.

**Length of Boilers.**—The strength of a boiler is not affected by its length as regards internal pressure, but the liability to strain increases with the length; short boilers do more work in proportion than long ones. The minimum length of Cornish and Lancashire boilers, for confined positions, should be $2\frac{1}{2}$ times the diameter, and the maximum, and best working length, should be 4 times the diameter.

**Cornish and Lancashire Boilers** are more used than any other form of boiler, and cannot be surpassed for accessibility, simplicity, durability and economy: they are steady and good steam producers, they will burn the commonest qualities of fuel, and with a good draught they will burn any kind of refuse fuel. They should always be made with Galloway tubes, which strengthen the flues, increase the heating surface and circulation, and keep an equal temperature throughout the boiler, and thus prevent unequal expansion and contraction.

**Cornish Boilers.**—Cornish or single flue-tube boilers, are made from 3 to 5 feet in diameter. The flue-tube is generally made one-half the diameter of the shell, and is fixed so as to leave a depth of 6 inches, between the bottom of the flue-tube, and the bottom of the shell, which is ample space for the proper circulation of the water, and leaves sufficient depth of end plate, to allow it to yield to the expansion and contraction of the flue-tube. When less depth of water-space than this is allowed, the bottom part of the end plate is liable to crack, for want of sufficient flexibility, to allow for its springing during unequal expansion, owing to the top portion of the flue-tube becoming much hotter, and expanding more than the bottom portion, which causes the end plates to be forced out at an angle; to provide for this unequal expansion, the end plates should be made as flexible as possible.

**Lancashire Boilers.**—Lancashire, or double flue-tube boilers, are generally made from 5 feet 6 inches to 7 feet 6 inches diameter; the space between the two furnace-tubes should not be less than 5 inches, and that between the furnace-tube and the side of the shell should not be less than 4 inches.

**End Plates of Cornish and Lancashire Boilers.**—The back end plate may be attached to the shell by an inside angle-iron, but in order to increase the flexibility of the front end plate, it should be attached to the shell by an outside angle-iron. The end plate should be made out of one piece of iron, and the openings for flues should be cut out in a lathe.

**Gusset-Stays.**—The end plates of Lancashire and Cornish boilers should be stayed to the shell by gusset-stays, of single plates and double angle-iron. The number of stays will depend upon the size of boiler; large boilers should have 5 at each end above the flue tubes: 2 at the front end, and one at the back end below the flues; two of the gusset stays should be secured to the second belt of plates of the shell, and the bottom of the gusset-stays, should not go nearer to the flue than 8 inches, from the bottom rivet in the stay, to the rivets of angle-iron connecting the flue-tube to the shell, so as not to injure the flexibility of the end plate.

**Longitudinal Stay-Bolts.**—The end plate of Lancashire and Cornish boilers, should be stayed with two longitudinal stay-bolts, one on each side of the centre gusset-stay, at a good height above the flue, so as not to injure the flexibility of the end plates. The screwed part of the stay-ends, should be larger in diameter, than the body of the stay, so that the diameter at the bottom of the thread, may not be less than the plain part of the stay. The stay should be secured to the end plates, by nuts and washers both inside and outside.

**Internal Flue-Tube.**—As the pressure acts all round the circumference of a flue-tube, in order to make the pressure uniform the flue should be a true circle; any deviation therefrom, seriously weakens it, and the external pressure tends to increase the amount of deviation from the true circle, and to collapse the flue. When the plates overlap each other in the longitudinal seams, the flue cannot be made perfectly circular, and the amount of deviation caused thereby, reduces its strength to resist external pressure, to the extent of 30 per cent.

**Longitudinal Seams of Internal Flue-Tubes.**—When the workmanship can be relied upon, the longitudinal seams should be welded, otherwise they should be made with butt joints double riveted, with the strip on the outside of the flue.

**Diameter of Flue-Tube.**—The resistance of internal flues to collapse, varies inversely as the diameter, a tube 12 inches diameter, being double the strength of one 24 inches diameter, and as wrought-iron will sustain double the force to tear it asunder, that it will to crush it, the diameter of the internal flue should never exceed one-half the diameter of the boiler.

**Length of Flue-Tube.**—The resistance of wrought-iron flues to collapse, varies inversely as the length, a tube 5 feet long being double the strength of one 10 feet long; but as flues are constructed with several belts of plates, the ring seams add considerable strength to the flues, and by strengthening the ring seams the length is practically reduced to the distance between each ring seam; the best mode of strengthening the ring seams is the Adamson flanged seam, or the Bowling expansion hoop.

**Longitudinal Expansion of Flue-Tube.**—The flue expands more longitudinally than the shell, and unless provision is made for this expansion, the tube in expanding will become arched, and likewise will cause the end plates to spring out. This can be prevented by making the ring seams of the flue with Adamson's flanged joint, shewn at Fig. 43, which will allow the flue to expand sufficiently, and the strain on the end plates will be reduced; by using these flanged joints, besides strengthening the flues, the edges of the plates, and the rivet heads, are placed out of reach of the fire.

**Strengthening Flue-Tube over the Fire.**—In order to assist the flue-tube to retain its shape, in case of over-heating, and also to increase its resistance against collapsing pressure, strengthening rings, 3 feet apart, should be placed round the flue at the furnace end; they should be made of light angle iron of best quality, and riveted to the flue tube with rivets at not more than 6 inches centres, passed through ferrules $1\frac{1}{4}$ inches deep, so as to leave a water space of that depth.

**Man-hole.**—The man-hole of Cornish and Lancashire boilers should be guarded with a strong wrought iron raised mouth-piece, welded into one piece, flanged at the bottom, and riveted to the boiler with a double row of rivets,—the diameter inside should be 16 inches, the height 8 inches, the thickness of the body should be equal to double the thickness of the shell of the boiler, and the flanges should be one-fourth thicker than the body. Cast-iron should never be used for this purpose, because it elongates much less with the same stress than wrought-iron, and as they both must stretch together, the cast-iron will give way long before the breaking strain comes on the wrought-iron. When a raised mouth-piece is not used, a wrought-iron ring equal in thickness to not less than $1\frac{3}{4}$ the thickness of the shell, and in width to 12 times the thickness of the shell, should be riveted on with rivets, at centres equal to 4 times the diameter of the rivets.

**Mud-holes.**—The mud-hole at the front of the boiler, beneath the furnace-tubes of Lancashire boilers, should be guarded with a strong wrought-iron mouth-piece, and the small mud-holes of vertical and other boilers, should be guarded with a strong mouth-piece, raised sufficiently to form a flat face for the cover to bed against.

**Boiler Fittings for Cornish and Lancashire Boilers.**—Every boiler should have two safety-valves, and two water-gauges: the one acts as a check on the other. The water-gauges should be fixed, so that the lowest visible point of the glass, is 5 inches above the highest point of the internal flue; the average working height of water above flues is from 9 to 10 inches. Height of deadplate above floor 2 feet 8 inches. Inclination of boiler towards blow-off cock, $\frac{1}{2}$ inch in 10 feet. Inclination of fire-bars towards back of boiler, 1 inch in 12 inches. The height of the bridge at the back of the fire-grate, should be made such, as to leave a passage over it, equal to one-sixth of the area of fire-grate. The mouth-piece of the furnace should be made of two wrought-iron plates, with an air-space between, the door of which should have a sliding grid on the outside and a perforated box baffleplate on the inside, for admitting air above the fire. The size of the perforations should not exceed $\frac{3}{8}$ inch in diameter, and the sum of their areas should not be less than 3 inches per square foot of fire-grate surface.

**Boiler Setting.**—Cornish and Lancashire boilers, should rest upon fire-brick blocks, set on side walls, the width of bearing surface for the boiler, on each side, should be $\frac{3}{4}$ of an inch, for each foot in diameter of the boiler, each side flue should be 6 inches wide, carried up to the level of the furnace crown, and down to the level of the bottom of the boiler, the width of the bottom flue under the boiler, should be equal to one-half the diameter of the boiler, and the depth of the flue should be about 2 feet. When thus set, the flame after leaving the furnace-tube, passes under the bottom of the boiler, and returns to the chimney along the side flues. The face of the brickwork, at the front of the boiler, should be set back 6 inches, so as to leave the angle-iron and its rivets open. Fire-clay, instead of lime, should be used throughout, in setting the boiler.

**Staying Flat Surfaces.**—In a flat surface, such as the side of a loco-motive firebox, each stay sustains the pressure on the square area of plate which surrounds it, whose side is equal to the distance between the centres of the stays; and the strain on the flat surface between the stays, is found, by multiplying the area in square inches between the adjacent stay-rods by the pressure.

**The diameter of staybolts,** for flat surfaces, should not be less than twice the thickness of the plate, and should never exceed three times the thickness of plate.

**The working steam pressure of staybolts,** per square inch of section at the threads, should not exceed 4,300 lbs., to provide against wasting from corrosion.

**The distance of centres of staybolts** is found thus: Multiply the constant number, 4,300, by the area of the staybolt, and divide the product by the working pressure; then take the square root of the quotient, and the answer will be the proper centres. The usual pitch for locomotive fire-box stays is 4 inches centres, irrespective of the thickness of plate.

**The dished end** of a cylindrical shell, such as the top of a dome, should be dished to a radius equal to the diameter of the cylinder, in order to make it equal in strength to the cylinder, a hollow sphere being twice as strong as a cylindrical shell, of the same radius and thickness.

**Position of Feed Delivery in Boilers.**—In Cornish and Lancashire boilers, the feed should be introduced on one side of the front end plate, about 4 inches above the furnace crown, through an internal dispersing pipe, carried inside the boiler to at least one-third of its length, and perforated for the last half of the pipe's length; and in vertical boilers, the feed should be introduced through a short perforated pipe, so as to deliver just below the water-level, but clear of the fire-box and tubes. When the feed is introduced below the furnace crown, if anything gets into the back-pressure valve to prevent its closing, the pressure in the boiler will force the water back through the feedpipe, and the furnace crown will become bare and overheated.

**Heating Feedwater.**—In order to prevent unequal expansion and contraction, by keeping an even temperature in the boiler, and also to save fuel, the feedwater should always be heated. In heating by exhaust steam, the feedwater should not be allowed to come in direct contact with the exhaust steam, but the steam should pass through pipes around which the feedwater should be made to pass. One great advantage of a feedwater heater, is, that it arrests the substances held in suspension by the water, and scale, &c., is deposited in the heater, which would otherwise form in the boiler. The exhaust steam from a non-condensing engine, will heat the feedwater to within a few degrees of the boiling point (212°), and a saving of about 13 per cent. will be effected over cold water.

In condensing engines the feedwater is generally taken from the hot well, at about 100°, effecting a saving of about 4½ per cent. over cold water.

**Nominal Horse-power of Boilers.**—The nominal horse-power of a boiler is estimated by its size, and may be found by the following rules deduced from practice:—

**Nominal horse-power of plain, cylindrical, or egg-ended boilers:** Multiply the diameter in feet by the length in feet and divide by 6.

**Nominal horse-power of Cornish boilers:** Add the diameter of the shell, and the diameter of the flue together, in feet, and multiply the sum by the length in feet, and divide the product by 8.

**Nominal horse-power of Lancashire boilers:** Add the diameters of both flues, and the diameter of the shell together, in feet, multiply the sum by the length in feet, and divide the product by 8.

**Nominal horse-power of vertical cross tube boilers:** Add together the diameter of the shell, the diameter of the fire box, the diameters of all the tubes, and the diameter of the uptake tube, all in feet; multiply the sum by the length in feet, and divide by 10.

**Nominal horse-power of vertical tubular boilers,** with vertical tubes: Add together the diameter of the shell, the diameter of the fire box, the diameters of all the tubes, all in feet; multiply the sum by the length in feet and divide by 12.

**The actual horse-power of a boiler** is estimated by the number of cubic feet of water, evaporated into steam per hour. The simplest way of ascertaining the actual evaporation of any boiler is as follows. When the boiler is working satisfactorily, feed the boiler up to the top of the water-gauge glass, then shut off the feed, weigh all the coal used after this time, and observe the time occupied in reducing the water, from the top to the bottom of the glass, fire carefully, and see that the same quantity of fire, is left at the end, as at the beginning of the test. Then the evaporative power may be ascertained, from the data obtained in the above test, by the following rules:—

**To find the number of cubic feet of water evaporated per hour** Multiply the number of square feet of water-surface, by the evaporation in inches of gauge-glass, multiply the product by 5, and divide the result by the number of minutes occupied in evaporation.

**To find the quantity of water in lbs. evaporated per lb. of coal:** Multiply the number of cubic feet of water, evaporated per hour, by 62·5, and divide the product by the quantity of coal in lbs. consumed per hour.

**Heating Surface.**—The evaporative power of a boiler depends upon the efficiency of its heating surface, the values of which are as follows:—

| | |
|---|---|
| All horizontal surface above the flame . | Being taken as effective heating surface. |
| $\frac{1}{2}$ vertical surface . . . . . . | |
| $1\frac{1}{4}$ the diameter of tubes or round flues . | |
| $1\frac{1}{6}$ convex surfaces above the flame . . | |

Horizontal surfaces beneath the flame, are of no value as heating surfaces.

**The Dome** should be equal to one-half the diameter of the boiler in diameter, and in height, and the hole through the plate should not be larger than a manhole; the edge of the hole should be strengthened by riveting a strong ring to it; but as a steam-dome weakens the boiler shell, and is apt to leak at the base, it is better to dispense with it, and take the steam through an internal perforated pipe, about 6 feet long, fixed close to the top of the shell.

**Cornish and Lancashire Boilers** of 5 feet in diameter and upwards, should have the longitudinal seams double-riveted. The plates over the fire in the flue, should be of Lowmoor iron, to a length of double the length of the firegrate; the shell should be Staffordshire Best plates, and the ends Staffordshire Best Best plates, or of equal quality.

In fixing Galloway tubes, the welded part should face the back end of the boiler.

**The Galloway Boiler** in its present improved form is an excellent and economical steam producer—an 8 hours test of one with 70 lbs. pressure of steam, was conducted as follows:—steam being raised to 70 lbs., the height of water in the boiler was noted, and the fires drawn: the fires were then re-lighted, all the fuel used was weighed, allowance being made for unconsumed fuel in the fires at the end of the test. Calorimeter observations were taken, a certain weight of steam being condensed in a given quantity of water, the dampness of the steam being determined by the increase of weight and temperature in the water, the feed-water was measured and also weighed. The boiler evaporated 11·72 lbs. of water at 212° F. per lb. of coal, or 2603 lbs. of water per hour, with a heating surface of 973 square feet: the boiler power being 41·64 horse power, at 1 cubic foot of water evaporated per hour, percentage of water in steam ·5: coal burnt per hour 283 lbs., or 7·269 lbs. per square foot of grate per hour: temperature of gases leaving the boiler 324°: cubic feet of water space per horse-power, 14 10: cubic feet of steam space per horse-power, 4·04.

**To find the Number of Gallons of Water a Boiler will hold.**—If a plain cylinder without tubes, multiply the square of the diameter in feet by the length in feet, and by 4·89; the answer will be in gallons. Or, multiply the square of the diameter in inches by the length in feet, and by ·034. Or multiply the square of the diameter in inches, by the length in inches, and by ·00283.

**To find the Number of Gallons in a Cornish or Lancashire Boiler.**—Multiply the sectional area of the boiler shell in inches, by the length of the shell in inches; multiply the combined sectional area of the flues in inches by their length in inches; subtract this product from the first, and divide the remainder by ·1728; this will give the number of cubic feet of water the boiler will contain, which multiplied by 6·24 will give the contents in gallons.

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## VERTICAL BOILERS.

**The Firebox** should be of Lowmoor iron, the crowns, cross tubes and uptake should be Staffordshire Best Best plates, and the shell should be Best Staffordshire plates, or equal quality; there should be one mudhole opposite the large end of each cross tube, and mudholes should be placed round the bottom of the boiler. The diameter of firebox given in the table is at the bottom; the top should be less in diameter; the taper should be about 1 inch per foot in height.

**The Cross-Tubes** should be lower at the small end than at the other, and their seams should be placed away from the fire.

Table 34.—PROPORTIONS OF CORNISH AND LANCASHIRE BOILERS.

| Nominal Horse Power. | Cornish Boilers (One Flue). 4. | 6. | 8. | 10. | 12. | 14. | 16. | 18. | 20. | Lancashire Boilers (Two Flues). 25. | 30. | 40. | 50. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. |
| Diameter of shell . . | 3 0 | 3 6 | 4 0 | 4 4 | 4 6 | 4 9 | 4 9 | 5 0 | 5 0 | 5 6 | 6 0 | 7 0 | 7 6 |
| Length of shell . . | 8 0 | 10 0 | 11 0 | 13 0 | 15 0 | 16 0 | 19 0 | 20 0 | 22 0 | 21 0 | 24 0 | 27 0 | 30 0 |
| Thickness of shell . | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ |
| Diameter of flue . | 1 6 | 1 9 | 2 0 | 2 2 | 2 3 | 2 4 | 2 5 | 2 6 | 2 6 | Two. 2 0 | Two. 2 3 | Two. 2 9 | Two. 3 0 |
| Thickness of flue . . | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{7}{16}$ |
| Thickness of ends . | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{5}{8}$ |
| Length of fire-grate . | 2 9 | 3 3 | 3 6 | 3 9 | 4 0 | 4 6 | 4 9 | 5 0 | 5 6 | 6 0 | 6 0 | 6 0 | 6 0 |
| Number of Galloway tubes . . . | | | | | 2 | 2 | 4 | 4 | 4 | 8 | 8 | 10 | 12 |
| Approximate weight, in cwts. . . | 22 | 32 | 42 | 54 | 65 | 75 | 85 | 110 | 120 | 147 | 190 | 260 | 300 |

Table 35.—Proportions of Vertical Cross Tube Boilers.

| Nominal Horse Power. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 14. | 15. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. |
| Diameter of shell . | 2 6 | 2 7 | 2 9 | 3 0 | 3 3 | 3 6 | 3 6 | 3 9 | 4 0 | 4 6 | 4 6 | 5 0 | 5 0 |
| Height of shell . . | 5 0 | 5 6 | 6 0 | 7 0 | 7 6 | 8 6 | 9 0 | 9 0 | 9 0 | 9 0 | 10 0 | 10 0 | 11 0 |
| Thickness of shell . | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ |
| Diameter of fire-box . | 2 0 | 2 0 | 2 3 | 2 6 | 2 9 | 3 0 | 3 1 | 3 3 | 3 6 | 4 0 | 4 0 | 4 6 | 4 6 |
| Height of fire-box . | 3 3 | 3 6 | 3 9 | 4 0 | 4 6 | 5 0 | 5 3 | 5 6 | 5 9 | 6 0 | 6 3 | 6 6 | 7 0 |
| Thickness of fire-box | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ |
| Number of cross tubes | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 |
| Diameter of cross tubes . . . | 6 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 |
| Thickness of cross tubes . . . | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ |
| Diameter of uptake . | 6 | 7 | 8 | 8 | 8 | 9 | 9 | 10 | 10 | 1 0 | 1 0 | 1 0 | 1 0 |
| Thickness of uptake . | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ |
| Thickness of crowns . | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ |
| Approximate weight, in cwts. . . | 12 | 14 | 17 | 21 | 25 | 30 | 32 | 35 | 37 | 42 | 48 | 54 | 63 |

Table 36.—Proportions of Vertical Tubular Boilers with Vertical Tubes.

| Nominal Horse Power. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 14. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. |
| Diameter of shell | 2 6 | 2 7 | 2 9 | 3 0 | 3 3 | 3 6 | 3 6 | 3 9 | 4 0 | 4 6 | 4 6 | 5 0 |
| Height of shell | 5 0 | 5 6 | 6 0 | 7 0 | 7 6 | 8 6 | 9 0 | 9 0 | 9 0 | 9 0 | 10 0 | 10 0 |
| Thickness of shell | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ |
| Diameter of fire-box | 2 0 | 2 0 | 2 3 | 2 6 | 2 9 | 3 0 | 3 0 | 3 3 | 3 6 | 4 0 | 4 0 | 4 6 |
| Height of fire-box | 2 6 | 3 0 | 3 2 | 3 4 | 3 6 | 3 9 | 4 0 | 4 0 | 4 0 | 4 0 | 4 6 | 4 6 |
| Thickness of fire-box | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ |
| Number of tubes | 10 | 12 | 14 | 16 | 18 | 22 | 24 | 26 | 30 | 30 | 30 | 34 |
| Diameter of tubes | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ |
| Thickness of tube plate | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{3}{4}$ |
| Thickness of crown | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{3}{4}$ |
| Approximate weight in cwts. | 12 | 15 | 19 | 22 | 26 | 31 | 33 | 37 | 40 | 45 | 50 | 57 |

**Chimneys for Vertical Steam Boilers.**—The height of chimney from the ground, for a vertical steam boiler, should not be less than 50 times the internal diameter of the chimney, in order to obtain sufficient draught for the proper and steady combustion of fuel, as well as to discharge the noxious products of combustion at such a height, that they will not cause a nuisance.

Table 37.—Proportions of Boilers for Portable Engines.

| Nominal Horse Power. | 2. | 4. | 6. | 8. | 10. | 12. | 15. | 20. | 25. | 30. |
|---|---|---|---|---|---|---|---|---|---|---|
| | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. |
| Size across front | 2 3 | 2 7 | 2 11 | 3 1 | 3 3 | 3 7 | 3 9 | 4 0 | 4 3 | 4 6 |
| Width of casing | 1 9 | 1 11 | 2 0 | 2 4 | 2 6 | 2 10 | 3 0 | 3 6 | 4 0 | 4 3 |
| Height of casing | 3 0 | 3 7 | 4 0 | 4 3 | 4 6 | 4 8 | 5 0 | 5 6 | 6 0 | 6 6 |
| Diameter of barrel | 1 9 | 2 2 | 2 6 | 2 8 | 2 9 | 3 0 | 3 3 | 3 7 | 3 9 | 4 0 |
| Length of barrel | 3 9 | 4 6 | 5 8 | 6 0 | 6 6 | 6 9 | 7 0 | 7 6 | 8 0 | 8 6 |
| Thickness of barrel | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{7}{16}$ |
| Thickness of fire-box | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ |
| Thickness of fire-box tube plate | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{11}{16}$ | $\frac{11}{16}$ |
| Thickness of back tube plate | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ |
| Thickness of shaped plate | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ |
| Thickness of arch plate | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ |
| Number of tubes | 12 | 18 | 24 | 28 | 32 | 34 | 40 | 46 | 52 | 60 |
| Diameter of tubes | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ |
| Approximate weight in cwts. | 16 | 25 | 30 | 35 | 45 | 54 | 63 | 74 | 88 | 94 |

Table 38.—Proportions of Return-Tube Boilers, for small Steam Boats, Tugs, &c.

| Nominal Horse Power. | 5. | 6. | 7. | 8. | 10. | 12. | 14. | 15. | 16. |
|---|---|---|---|---|---|---|---|---|---|
| | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. | ft. in. |
| Diameter of shell | 4 0 | 4 3 | 4 6 | 4 9 | 5 0 | 5 3 | 5 6 | 5 6 | 5 6 |
| Length of shell | 5 6 | 6 0 | 6 0 | 6 6 | 6 0 | 7 0 | 7 0 | 7 6 | 8 0 |
| Thickness of shell | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ |
| Diameter of flue | 2 0 | 2 0 | 2 3 | 2 3 | 2 6 | 2 6 | 2 9 | 2 9 | 2 9 |
| Length of flue | 4 0 | 4 3 | 4 3 | 4 9 | 4 3 | 5 0 | 5 0 | 5 6 | 6 0 |
| Thickness of flue | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ |
| Number of tubes | 26 | 30 | 34 | 36 | 44 | 46 | 50 | 50 | 50 |
| Diameter of tubes | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ |
| Thickness of ends | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{9}{16}$ |
| Thickness of tube-plate of combustion-chamber | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ |
| Thickness of tube-plate, back of combustion-chamber | $\frac{7}{16}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{9}{16}$ |
| Thickness of smoke-box | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{1}{4}$ |
| Depth of combustion-chamber | 1 2 | 1 5 | 1 5 | 1 5 | 1 5 | 1 6 | 1 6 | 1 6 | 1 6 |
| Diameter of dome | 1 9 | 2 0 | 2 0 | 2 3 | 2 3 | 2 6 | 2 6 | 2 6 | 2 6 |
| Height of dome | 1 9 | 2 0 | 2 0 | 2 3 | 2 3 | 2 6 | 2 6 | 2 6 | 2 6 |
| Diameter of funnel | 9 | 9 | 10 | 10 | 10 | 1 0 | 1 2 | 1 2 | 1 2 |
| Height of funnel | 6 0 | 6 0 | 8 0 | 8 0 | 10 0 | 10 0 | 10 0 | 10 0 | 10 0 |
| Approximate weight, in cwts. | 30 | 33 | 45 | 54 | 63 | 70 | 76 | 81 | 86 |

Table 39.—Weight of one Foot in Length of Wrought-Iron Boiler-Tubes.

| Outside Diameter. | Thickness by Number of the New Imperial Standard Wire-Gauge. | Weight in Lbs. | Outside Diameter. | Thickness by Number of the New Imperial Standard Wire-Gauge. | Weight in Lbs. |
|---|---|---|---|---|---|
| Inches. | | | Inches. | | |
| $1\frac{1}{4}$ | 14 | 1·00 | $5\frac{1}{4}$ | 8 | 8·81 |
| $1\frac{3}{8}$ | 13 | 1·25 | $5\frac{1}{2}$ | 7 | 10·52 |
| $1\frac{1}{2}$ | 13 | 1·30 | $5\frac{3}{4}$ | 7 | 11·25 |
| $1\frac{5}{8}$ | 13 | 1·46 | 6 | 7 | 12·16 |
| $1\frac{3}{4}$ | 12 | 1·95 | $6\frac{1}{4}$ | 6 | 13·25 |
| $1\frac{7}{8}$ | 12 | 2·17 | $6\frac{1}{2}$ | 6 | 14·00 |
| 2 | 12 | 2·32 | $6\frac{3}{4}$ | 5 | 15·10 |
| $2\frac{1}{8}$ | 12 | 2·40 | 7 | 5 | 16·00 |
| $2\frac{1}{4}$ | 11 | 2·78 | $7\frac{1}{4}$ | 4 | 17·47 |
| $2\frac{1}{2}$ | 11 | 3·06 | $7\frac{1}{2}$ | 4 | 18·42 |
| $2\frac{3}{4}$ | 11 | 3·32 | | Inch. | |
| 3 | 11 | 3·61 | $7\frac{3}{4}$ | $\frac{1}{4}$ | 19·50 |
| $3\frac{1}{4}$ | 10 | 4·50 | 8 | $\frac{1}{4}$ | 20·54 |
| $3\frac{1}{2}$ | 10 | 4·91 | $8\frac{1}{2}$ | $\frac{9}{32}$ | 23·75 |
| $3\frac{3}{4}$ | 10 | 5·16 | 9 | $\frac{9}{32}$ | 26·25 |
| 4 | 9 | 6·19 | $9\frac{1}{2}$ | $\frac{5}{16}$ | 30·28 |
| $4\frac{1}{4}$ | 9 | 6·70 | 10 | $\frac{5}{16}$ | 32·57 |
| $4\frac{1}{2}$ | 9 | 7·31 | $10\frac{1}{2}$ | $\frac{11}{32}$ | 36·58 |
| $4\frac{3}{4}$ | 8 | 7·95 | 11 | $\frac{11}{32}$ | 39·06 |
| 5 | 8 | 8·25 | $11\frac{1}{2}$ | $\frac{3}{8}$ | 44·10 |
| | | | 12 | $\frac{3}{8}$ | 46·64 |

**Weight of Boilers.**—The weights of boilers of different kinds, are given in tables 34 to 38; the weight of other sizes may be calculated from the weight of boiler-shells, table 40, and a rough approximation of the weight may be obtained by the following rules.

**Approximate Weight of Boilers in Cwts.**

| | | | | | | |
|---|---|---|---|---|---|---|
| Vertical Cross-tube Boilers | = | Diameter in feet | | | × | Length in feet. |
| Egg-ended Boilers . . | = | ditto | × | ·50 | × | ditto |
| Cornish Boilers . . . | = | ditto | × | ·95 | × | ditto |
| Vertical Tubular Boilers . | = | ditto | × | 1·10 | × | ditto |
| Lancashire Boilers . . | = | ditto | × | 1·34 | × | ditto |
| Return-tube Boilers . . | = | ditto | × | 2·00 | × | ditto |
| Portable Engine Boilers, under 10 horse power . | = | ditto | × | 2·20 | × | Length in feet of the barrel. |
| Portable Engine Boilers, 10 horse power and upwards | = | ditto | × | 2·70 | × | ditto |

Table 40.—Approximate Weight of one Foot in Length of Wrought-Iron Cylindrical Lap-Jointed Boiler-Shells, Lap and Rivets included.

| Internal Diameter. | | Thickness ¼ Inch. | | Thickness 5/16 Inch. | | Thickness ⅜ Inch. | | Thickness 7/16 Inch. | | Thickness ½ Inch. | | Thickness 9/16 Inch. | | Thickness ⅝ Inch. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. |
| feet. | inches. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 1 | 0 | 37 | 38 | 46 | 47 | 56 | 57½ | 67 | 68¾ | 74 | 76 | 85 | 87½ | 94 | 97 |
| 1 | 3 | 46¼ | 47½ | 57½ | 58¾ | 70 | 71¼ | 83¾ | 85¾ | 92½ | 95 | 106¼ | 108¾ | 117½ | 121¼ |
| 1 | 6 | 55½ | 57 | 69 | 70½ | 84 | 86 | 100½ | 103 | 111 | 114 | 127½ | 130½ | 141 | 145½ |
| 1 | 9 | 64¾ | 66½ | 80½ | 82¼ | 98 | 100½ | 117¼ | 120¼ | 129½ | 133 | 148¾ | 152¼ | 164½ | 169¾ |
| 2 | 0 | 74 | 76 | 92 | 94 | 112 | 115 | 134 | 138 | 148 | 152 | 170 | 174 | 188 | 194 |
| 2 | 3 | 83¼ | 85½ | 103½ | 105¾ | 126 | 129¼ | 150¾ | 155¼ | 166½ | 171 | 191¼ | 195¾ | 211½ | 218¼ |
| 2 | 6 | 92½ | 95 | 115 | 117½ | 140 | 144 | 167½ | 172¼ | 185 | 190 | 212½ | 217½ | 235 | 242½ |
| 2 | 9 | 101¾ | 104½ | 126½ | 129¼ | 154 | 158¼ | 184¼ | 189 | 203½ | 209 | 233¾ | 239¼ | 258½ | 266¾ |
| 3 | 0 | 111 | 114 | 138 | 141 | 168 | 172½ | 201 | 206¼ | 222 | 228 | 255 | 261 | 282 | 291 |
| 3 | 3 | 120¼ | 123½ | 149½ | 152¾ | 182 | 186¾ | 217¾ | 224 | 240½ | 247 | 276¼ | 282¾ | 305½ | 315¼ |
| 3 | 6 | 129½ | 133 | 161 | 164½ | 196 | 201½ | 234½ | 240½ | 259 | 266 | 297½ | 304½ | 329 | 339½ |
| 3 | 9 | 138¾ | 142½ | 172½ | 176¼ | 210 | 215¾ | 251¼ | 258 | 277½ | 285 | 318¾ | 326¼ | 352½ | 363¾ |
| 4 | 0 | 148 | 152 | 184 | 188 | 224 | 230 | 268 | 275 | 296 | 304 | 340 | 348 | 376 | 388 |
| 4 | 3 | 157¼ | 161½ | 195½ | 199¾ | 238 | 244¼ | 284¾ | 292 | 314½ | 323 | 361¼ | 369¾ | 399½ | 412¼ |
| 4 | 6 | 166½ | 171 | 207 | 211½ | 252 | 258½ | 301½ | 309¼ | 333 | 342 | 382½ | 391½ | 423 | 436½ |
| 4 | 9 | 175¾ | 180½ | 218½ | 223¼ | 266 | 272¾ | 318¼ | 326½ | 351½ | 361 | 403¾ | 413¼ | 446½ | 460¾ |
| 5 | 0 | 185 | 190 | 230 | 235 | 280 | 287 | 335 | 343¾ | 370 | 380 | 425 | 435 | 470 | 485 |
| 5 | 3 | 194¼ | 199½ | 241½ | 246½ | 294 | 301½ | 351¾ | 361 | 388½ | 399 | 446 | 456¾ | 493½ | 509¼ |
| 5 | 6 | 203½ | 209 | 253 | 258½ | 308 | 315¾ | 368½ | 378 | 407 | 418 | 467½ | 478½ | 517 | 533½ |
| 5 | 9 | 212¾ | 218½ | 264½ | 270¼ | 322 | 330½ | 385¼ | 395¼ | 425½ | 437 | 488¾ | 500¼ | 540½ | 557¾ |
| 6 | 0 | 222 | 228 | 276 | 282 | 336 | 345 | 402 | 412½ | 444 | 456 | 510 | 522 | 564 | 582 |
| 6 | 3 | 231¼ | 237½ | 287½ | 293¾ | 350 | 359¼ | 418¾ | 429½ | 462½ | 475 | 531¼ | 543¾ | 587½ | 606¼ |
| 6 | 6 | 240½ | 247 | 299 | 305½ | 364 | 373½ | 435½ | 447 | 481 | 494 | 552½ | 565½ | 611 | 630½ |
| 6 | 9 | 249¾ | 256½ | 310½ | 317¼ | 378 | 387¾ | 452¼ | 464 | 499½ | 513 | 573¾ | 587¼ | 634½ | 654¾ |
| 7 | 0 | 259 | 266 | 322 | 329 | 392 | 402½ | 469 | 481¼ | 518 | 532 | 595 | 609 | 658 | 679 |
| 7 | 6 | 277½ | 285 | 345 | 352½ | 420 | 431 | 502½ | 516 | 555 | 570 | 637½ | 652½ | 705 | 727½ |
| 8 | 0 | 296 | 304 | 368 | 376 | 448 | 460 | 536 | 550 | 592 | 608 | 680 | 696 | 752 | 776 |

Table 41.—Approximate Weight of one Foot in Length of Wrought-Iron Lap-Welded Tubes.

| Internal Diameter. | Thickness ¼ Inch. | Thickness 5/16 Inch. | Thickness ⅜ Inch. | Thickness 7/16 Inch. | Thickness ½ Inch. | Thickness 9/16 Inch. | Thickness ⅝ Inch. |
|---|---|---|---|---|---|---|---|
| inches. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 6 | 17 | 21 | 25 | 30 | 35 | 39 | 44 |
| 8 | 22½ | 28 | 33¼ | 40 | 46½ | 52 | 58½ |
| 10 | 28½ | 35 | 41½ | 50 | 58 | 65 | 73½ |
| 12 | 34 | 42 | 50 | 60 | 70 | 78 | 88 |
| 14 | 39¾ | 49 | 58¼ | 70 | 81½ | 91 | 102½ |
| 16 | 45 | 56 | 66½ | 80 | 93 | 104 | 117 |
| 18 | 51 | 63 | 75 | 90 | 104½ | 117 | 131½ |
| 20 | 57 | 70 | 83¼ | 100 | 116 | 130 | 146 |
| 22 | 62¼ | 77 | 91½ | 110 | 127½ | 143 | 161 |
| 24 | 68 | 84 | 100 | 120 | 140 | 156 | 176 |
| 26 | 73¼ | 91 | 108¼ | 130 | 151½ | 169 | 191 |
| 28 | 79½ | 98 | 116½ | 140 | 163 | 182 | 205½ |
| 30 | 85 | 105 | 124¾ | 150 | 174½ | 195 | 220 |
| 32 | 90 | 112 | 133 | 160 | 186 | 208 | 234½ |
| 34 | 96¼ | 119 | 141¼ | 170 | 197½ | 221 | 249 |
| 36 | 102 | 126 | 150 | 180 | 210 | 234 | 264 |
| 38 | 107½ | 133 | 158¼ | 190 | 221½ | 247 | 279 |
| 40 | 114 | 140 | 166½ | 200 | 232½ | 260 | 293½ |
| 42 | 119 | 147 | 174¾ | 210 | 244 | 273 | 308 |
| 44 | 125½ | 154 | 183 | 220 | 255½ | 286 | 322 |
| 46 | 130¼ | 161 | 191¼ | 230 | 267½ | 299 | 337½ |
| 48 | 136 | 168 | 200 | 240 | 280 | 312 | 352 |
| 54 | 153 | 189 | 225 | 270 | 315 | 351 | 395½ |
| 60 | 170 | 210 | 250 | 300 | 350 | 390 | 440 |
| 66 | 187 | 231 | 275 | 330 | 385 | 429 | 484 |
| 72 | 204 | 252 | 300 | 360 | 420 | 468 | 528 |

**The Tensile Strength of Good Boiler Plates** when the strain is applied in the direction in which they are rolled, or along the grain, is 21 tons per square inch of section; when the strain is applied across the grain it is only 18 tons. The tensile strength of Lowmoor and Best Yorkshire plates is 24 tons per square inch of section lengthways of the grain, and 22 tons across the grain.

**Riveted Joints** are liable to fracture in 4 different ways: (1.) *The rivets may be shorn off*—the force required to shear a rivet being the shearing strength of the iron multiplied by the area of the rivet. The strength of rivet-iron to resist shearing is about that of the plate to resist tearing, or 21 tons per square inch of section. The strength of the rivets in a joint, may be found by multiplying the area in square inches of one rivet by the number of rivets, and multiplying the product by 47,000 for ordinary rivets, and by 53,760 for Lowmoor Iron rivets.

(2.) *The plate may tear along the line of rivet-holes* as shown at A B, Fig. 36, that is, between the rivet-holes. The strength of the plate between the rivet-holes is impaired by punching to the extent of 20 per cent; and the strength to resist fracture between the rivet-holes is found thus:—first find the area of plate between two rivet-holes, which is found by subtracting the diameter of the rivet from the pitch of the rivets in inches, and multiply the remainder by the thickness of the plate in inches, giving the area in square inches between two rivet-holes. Multiply this by 38,700 when the rivet-holes are punched and by 44,000 when the rivet-holes are drilled. The answer will be the strength of metal left between two rivet-holes.

(3.) *The plate may crush in front of the rivet* as shown at Fig. 37. The

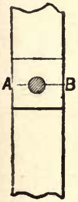


Fig 36.

Fig. 37.

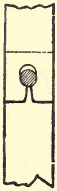

Fig. 38.

resistance offered by a plate to the crushing strain of a rivet, is one and three-quarter times the amount of the tensile strength of that plate, or say 37 tons. The area which resists the crushing strain, is found by multiplying the diameter of the rivet by the thickness of plate in inches; and the strength of the plate between the rivet-hole and the edge of the plate is found thus:—multiply the diameter of the rivet by the thickness of plate in inches, and multiply the product by 82,800.

(4.) *The plate may break across in front of the rivet* as shown at Fig. 38, and the strength opposed to resist this transverse fracture may be found thus: Multiply the square of the distance between the rivet-hole, and the edge of the plate, by the thickness of the plate, then divide the product by the diameter of rivet, and multiply the quotient by 48. The answer will be in tons, which multiplied by 2240 gives the strength in lbs.

Example of the above rules.—Required the strength of the riveted joint of two plates, each $41\frac{1}{2}$ inches wide $\times$ $\frac{7}{16}$ inch thick, fastened with 20 rivets $\frac{3}{4}$ inch diameter $\times$ 2 inch pitch; in punched holes $\frac{3}{4}$ inch from edge of plate.

| | | |
|---|---|---|
| (1.) $\cdot4417 \times 20 \times 47{,}000$ . | Rivets shearing off . . | 415,198 lbs. |
| (2.) $2 - \cdot75 = 1\cdot25 \times \cdot437 \times 38{,}700 \times 20$ . . | Tearing between rivet holes | 422,600 „ |

| | | |
|---|---|---|
| (3.) $\frac{\cdot 437 \times \cdot 75 \times 82{,}800 \times}{20}$ . . . . . | Crushing in front of rivet holes . . . . | 541,500 lbs. |
| (4.) $\frac{\frac{\cdot 75^2 \times \cdot 437}{\cdot 75} = \cdot 3274 \times}{48 \times 2240 \times 20}$ . | Breaking across in front of rivet holes . . . | 703,800 „ |
| The strength of the solid plate will equal its sectional area × 47,000, or $41\frac{1}{2}$ inches wide × ·437 thick × 47,000 lbs. tensile strength . . . . . . | | 852,340 „ |

*The Weakest Part of the above Seam* is the resistance offered to the rivets shearing off. The strength to resist tearing between the rivet-holes,

Fig. 39.

Fig. 40.

Fig. 41.

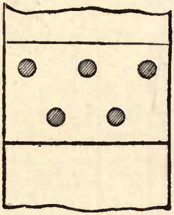

Fig. 42.

is also very small compared with the strength of the solid plate, the strength of the joint with punched holes and single riveted, being only equal to one-half of the solid plate. The efficiency of the joint is the ratio of its strength to that of the solid plate, which Mr. Fairbairn found to be for single-riveting 56 per cent., and for double-riveting 70 per cent. of the strength of solid plate.

Fig. 39 shows a single-riveted lap-joint; Fig. 40 a butt joint with single

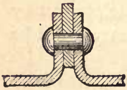

Fig. 43.

Fig. 44.

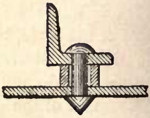

Fig. 45.

covering strip; Fig. 41, butt joint with double covering strip; Fig. 42, a double riveted lap joint with zigzag rivets; Fig. 43, Adamson's flanged seam for furnace-tubes: Fig. 44, Expansion hoop for furnace-tubes; Fig. 45, Angle iron hoop, or strengthening ring for furnace-tubes.

**The Pitch of Rivets** for boilers, varies considerably in practice. The proportions of riveted joints given in Table 103, page 280, give good results.

**Bursting Pressure of Cylindrical Steam Boilers.**—To find the strength to resist—in a line parallel to its axis—the internal bursting pressure of a cylindrical boiler shell. *Rule:* Multiply twice the thickness of the plate in inches, by one of the following constant numbers, and divide the product by the diameter of the boiler shell in inches, and the quotient will be the bursting pressure in lbs. per square inch.

| | | | |
|---|---|---|---|
| 26,000 | constant number | for | single-riveted joint of wrought-iron. |
| 32,500 | „ | „ | double-riveted joint of wrought-iron. |
| 40,500 | „ | „ | single-riveted joint of steel. |
| 50,625 | „ | „ | double-riveted joint of steel. |

Table 42 has been calculated by these rules. It gives the bursting pressure in pounds per square inch of lap-jointed wrought-iron cylindrical boiler shells, of from 2 feet to 9 feet diameter, of various thickness of plates, both single and double-riveted.

**Bursting pressure of Spherical Shells.**—To find the bursting pressure in lbs. per square inch, of a wrought-iron spherical shell, take double the bursting pressure of a cylindrical shell, of the same radius and thickness.

**To find the Collapsing Pressure in lbs. per Square Inch** of boiler tubes, or flues of wrought-iron, of perfectly circular shape, or not more than the thickness of plate from the true circle. *Rule:* Multiply the square of the thickness of the plate in 32nd parts of an inch, by the constant number 800, and divide that product, by the product of the length in feet, multiplied by the diameter of the tube in inches. In calculating elliptical tubes, the diameter of a circle, equal to the largest circle of curvature of the tube, should be used in the above rule, for finding the collapsing pressure.

Table 43 has been calculated by this rule. It gives the collapsing pressure in pounds per square inch of wrought-iron cylindrical boiler flue tubes, of from 12 inches to 42 inches diameter, of various thickness and length.

**Factor of Safety** for New Cylindrical Steam Boilers, which have been tested by hydraulic pressure to twice the working pressure. When the quality of the materials and workmanship is known to be first-class, a factor of safety of 6 may be used, but when this condition is not complied with, the following additions should be made to the factor of safety 6, viz., ·25 if the holes are not good and fair in the circumferential seams; ·5 if the seams are not properly crossed; ·5 if the holes are not good and fair in the longitudinal seams; 1·0 if the longitudinal seams are single-riveted; and 2·0 when the quality of the materials and workmanship is doubtful.

Table 42.—Bursting Pressure in lbs. per Square Inch of Lap Jointed Wrought-Iron Cylindrical Boiler-Shells.

| Diameter of Boiler-Shell. | | Bursting Pressure, 5/16 Plates. | | Bursting Pressure, 3/8 Plates. | | Bursting Pressure, 7/16 Plates. | | Bursting Pressure, 1/2 Plates. | | Bursting Pressure, 9/16 Plates. | | Bursting Pressure, 5/8 Plates. | | Bursting Pressure, 11/16 Plates. | | Bursting Pressure, 3/4 Plates. | | Bursting Pressure, 7/8 Plates. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. | Single Riveted. | Double Riveted. |
| ft. | in. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 2 | 0 | 677 | 846 | 812 | 1015 | 948 | 1184 | 1083 | 1354 | 1218 | 1523 | 1354 | 1692 | 1490 | 1862 | 1624 | 2030 | 1896 | 2368 |
| 2 | 3 | 602 | 752 | 722 | 902 | 842 | 1052 | 963 | 1203 | 1083 | 1353 | 1204 | 1504 | 1324 | 1655 | 1444 | 1804 | 1684 | 2104 |
| 2 | 6 | 542 | 677 | 650 | 812 | 758 | 948 | 866 | 1083 | 975 | 1218 | 1084 | 1354 | 1191 | 1489 | 1300 | 1624 | 1516 | 1896 |
| 2 | 9 | 492 | 615 | 590 | 738 | 689 | 861 | 788 | 984 | 886 | 1107 | 984 | 1230 | 1083 | 1354 | 1180 | 1476 | 1378 | 1722 |
| 3 | 0 | 451 | 564 | 541 | 677 | 631 | 789 | 722 | 902 | 812 | 1015 | 902 | 1128 | 993 | 1241 | 1082 | 1354 | 1262 | 1578 |
| 3 | 3 | 416 | 520 | 500 | 625 | 583 | 729 | 666 | 833 | 750 | 937 | 832 | 1040 | 916 | 1145 | 1000 | 1250 | 1166 | 1458 |
| 3 | 6 | 386 | 483 | 464 | 580 | 541 | 677 | 619 | 773 | 696 | 870 | 772 | 966 | 851 | 1064 | 928 | 1160 | 1082 | 1354 |
| 3 | 9 | 361 | 451 | 433 | 541 | 504 | 631 | 577 | 724 | 650 | 812 | 722 | 902 | 794 | 993 | 866 | 1082 | 1008 | 1262 |
| 4 | 0 | 338 | 423 | 406 | 507 | 474 | 592 | 541 | 677 | 609 | 761 | 677 | 846 | 745 | 931 | 812 | 1015 | 948 | 1184 |
| 4 | 3 | 318 | 398 | 382 | 478 | 446 | 557 | 510 | 637 | 573 | 716 | 636 | 796 | 701 | 876 | 764 | 956 | 892 | 1114 |
| 4 | 6 | 301 | 376 | 361 | 451 | 421 | 526 | 481 | 601 | 541 | 676 | 602 | 752 | 662 | 827 | 722 | 902 | 842 | 1052 |
| 4 | 9 | 285 | 356 | 342 | 427 | 399 | 499 | 456 | 570 | 513 | 641 | 570 | 712 | 627 | 784 | 684 | 854 | 798 | 998 |
| 5 | 0 | 271 | 338 | 325 | 406 | 379 | 474 | 433 | 541 | 487 | 609 | 542 | 677 | 595 | 744 | 650 | 812 | 758 | 948 |
| 5 | 3 | 258 | 322 | 309 | 387 | 361 | 451 | 412 | 515 | 464 | 580 | 515 | 644 | 567 | 709 | 618 | 774 | 722 | 902 |
| 5 | 6 | 246 | 307 | 295 | 369 | 344 | 430 | 394 | 492 | 443 | 553 | 492 | 615 | 541 | 677 | 590 | 738 | 689 | 861 |
| 5 | 9 | 235 | 294 | 282 | 353 | 329 | 412 | 376 | 471 | 423 | 530 | 471 | 588 | 518 | 647 | 564 | 706 | 658 | 824 |
| 6 | 0 | 226 | 282 | 270 | 338 | 315 | 394 | 361 | 451 | 406 | 507 | 451 | 564 | 496 | 620 | 541 | 677 | 631 | 789 |
| 6 | 6 | 208 | 260 | 250 | 312 | 291 | 364 | 333 | 416 | 375 | 468 | 416 | 520 | 458 | 572 | 500 | 625 | 583 | 729 |
| 7 | 0 | 193 | 241 | 232 | 290 | 270 | 338 | 309 | 386 | 348 | 435 | 386 | 483 | 425 | 532 | 464 | 580 | 541 | 677 |
| 7 | 6 | 180 | 225 | 216 | 270 | 252 | 315 | 288 | 362 | 325 | 406 | 361 | 451 | 397 | 496 | 433 | 541 | 504 | 631 |
| 8 | 0 | 169 | 211 | 203 | 253 | 237 | 296 | 270 | 338 | 304 | 380 | 338 | 423 | 372 | 465 | 406 | 507 | 474 | 592 |
| 8 | 6 | 159 | 199 | 191 | 239 | 223 | 278 | 255 | 318 | 286 | 358 | 318 | 398 | 350 | 438 | 382 | 478 | 446 | 557 |
| 9 | 0 | 150 | 188 | 180 | 225 | 210 | 263 | 240 | 300 | 270 | 338 | 301 | 376 | 331 | 413 | 361 | 451 | 421 | 526 |

Note.—Factor of Safety.—The Working pressure should never exceed one-sixth of the Bursting pressure.

TABLE 43.—COLLAPSING PRESSURE OF WROUGHT-IRON CYLINDRICAL TUBES IN LBS. PER SQUARE INCH, WHEN NOT MORE THAN THE THICKNESS OF THE PLATE FROM BEING A TRUE CIRCLE.

| Length of Tube and Thickness of Plate. | | | Diameter of Tube, in Inches. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length. | | Thickness | 12. | 15. | 18. | 21. | 24. | 27. | 30. | 33. | 36. | 39. | 42. |
| feet. | | inches. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 6 | × | $\frac{1}{4}$ | 711 | 568 | 474 | 406 | 350 | 316 | 284 | 258 | 237 | 218 | 203 |
| 6 | × | $\frac{5}{16}$ | 1111 | 888 | 740 | 634 | 555 | 493 | 444 | 404 | 370 | 341 | 317 |
| 6 | × | $\frac{3}{8}$ | 1600 | 1280 | 1066 | 914 | 800 | 711 | 640 | 581 | 533 | 492 | 457 |
| 6 | × | $\frac{7}{16}$ | 2177 | 1742 | 1451 | 1244 | 1088 | 967 | 871 | 791 | 725 | 670 | 622 |
| 6 | × | $\frac{1}{2}$ | 2844 | 2275 | 1896 | 1625 | 1422 | 1264 | 1137 | 1034 | 948 | 875 | 812 |
| 6 | × | $\frac{9}{16}$ | 3600 | 2880 | 2400 | 2057 | 1800 | 1600 | 1440 | 1309 | 1200 | 1107 | 1028 |
| 6 | × | $\frac{5}{8}$ | 4444 | 3555 | 2962 | 2539 | 2200 | 1975 | 1777 | 1616 | 1481 | 1367 | 1269 |
| 8 | × | $\frac{5}{16}$ | 833 | 666 | 555 | 476 | 416 | 370 | 333 | 303 | 278 | 256 | 238 |
| 8 | × | $\frac{3}{8}$ | 1200 | 960 | 800 | 686 | 600 | 533 | 480 | 436 | 400 | 369 | 343 |
| 8 | × | $\frac{7}{16}$ | 1633 | 1300 | 1088 | 933 | 817 | 725 | 650 | 593 | 544 | 502 | 467 |
| 8 | × | $\frac{1}{2}$ | 2133 | 1706 | 1422 | 1219 | 1067 | 948 | 853 | 770 | 711 | 656 | 609 |
| 8 | × | $\frac{9}{16}$ | 2700 | 2160 | 1800 | 1542 | 1350 | 1200 | 1080 | 981 | 900 | 830 | 771 |
| 8 | × | $\frac{5}{8}$ | 3333 | 2666 | 2222 | 1910 | 1667 | 1481 | 1333 | 1212 | 1111 | 1025 | 955 |
| 10 | × | $\frac{5}{16}$ | 666 | 533 | 444 | 380 | 333 | 296 | 267 | 242 | 222 | 205 | 190 |
| 10 | × | $\frac{3}{8}$ | 960 | 768 | 640 | 548 | 480 | 426 | 384 | 349 | 320 | 295 | 274 |
| 10 | × | $\frac{7}{16}$ | 1306 | 1045 | 871 | 746 | 653 | 580 | 523 | 475 | 436 | 402 | 373 |
| 10 | × | $\frac{1}{2}$ | 1706 | 1365 | 1137 | 975 | 853 | 758 | 683 | 620 | 569 | 526 | 488 |
| 10 | × | $\frac{9}{16}$ | 2160 | 1728 | 1440 | 1234 | 1080 | 960 | 864 | 785 | 720 | 664 | 617 |
| 10 | × | $\frac{5}{8}$ | 2666 | 2133 | 1777 | 1523 | 1333 | 1185 | 1067 | 969 | 889 | 820 | 762 |
| 12 | × | $\frac{3}{8}$ | 800 | 640 | 533 | 457 | 400 | 356 | 320 | 290 | 267 | 246 | 229 |
| 12 | × | $\frac{7}{16}$ | 1089 | 871 | 726 | 622 | 544 | 489 | 436 | 396 | 363 | 335 | 311 |
| 12 | × | $\frac{1}{2}$ | 1422 | 1138 | 948 | 813 | 711 | 632 | 569 | 517 | 474 | 438 | 406 |
| 12 | × | $\frac{9}{16}$ | 1800 | 1440 | 1200 | 1029 | 900 | 800 | 720 | 655 | 600 | 554 | 514 |
| 12 | × | $\frac{5}{8}$ | 2222 | 1778 | 1481 | 1269 | 1100 | 988 | 889 | 808 | 742 | 684 | 635 |
| 14 | × | $\frac{3}{8}$ | 685 | 548 | 457 | 391 | 343 | 304 | 274 | 248 | 229 | 210 | 196 |
| 14 | × | $\frac{7}{16}$ | 933 | 746 | 622 | 530 | 467 | 414 | 373 | 339 | 311 | 287 | 265 |
| 14 | × | $\frac{1}{2}$ | 1213 | 975 | 812 | 696 | 607 | 541 | 488 | 443 | 406 | 375 | 348 |
| 14 | × | $\frac{9}{16}$ | 1542 | 1234 | 1028 | 881 | 771 | 680 | 617 | 561 | 514 | 475 | 440 |
| 14 | × | $\frac{5}{8}$ | 1904 | 1523 | 1269 | 1088 | 952 | 846 | 761 | 696 | 635 | 586 | 544 |
| 16 | × | $\frac{3}{8}$ | 600 | 480 | 400 | 343 | 300 | 267 | 240 | 219 | 200 | 185 | 172 |
| 16 | × | $\frac{7}{16}$ | 817 | 650 | 544 | 467 | 409 | 363 | 325 | 297 | 272 | 251 | 234 |
| 16 | × | $\frac{1}{2}$ | 1067 | 853 | 711 | 609 | 534 | 474 | 426 | 385 | 356 | 328 | 305 |
| 16 | × | $\frac{9}{16}$ | 1350 | 1080 | 900 | 771 | 675 | 600 | 540 | 491 | 450 | 415 | 386 |
| 16 | × | $\frac{5}{8}$ | 1667 | 1333 | 1111 | 955 | 834 | 741 | 667 | 606 | 556 | 513 | 478 |
| 18 | × | $\frac{3}{8}$ | 533 | 427 | 356 | 305 | 267 | 237 | 214 | 194 | 178 | 164 | 153 |
| 18 | × | $\frac{7}{16}$ | 726 | 581 | 484 | 415 | 363 | 322 | 290 | 264 | 242 | 223 | 207 |
| 18 | × | $\frac{1}{2}$ | 948 | 758 | 632 | 542 | 474 | 421 | 374 | 345 | 316 | 292 | 271 |
| 18 | × | $\frac{9}{16}$ | 1200 | 960 | 800 | 686 | 600 | 534 | 480 | 436 | 400 | 369 | 343 |
| 18 | × | $\frac{5}{8}$ | 1481 | 1185 | 988 | 846 | 740 | 658 | 593 | 539 | 494 | 456 | 423 |
| 20 | × | $\frac{3}{8}$ | 480 | 384 | 320 | 274 | 240 | 213 | 192 | 175 | 160 | 148 | 137 |
| 20 | × | $\frac{7}{16}$ | 653 | 523 | 436 | 373 | 327 | 290 | 262 | 238 | 218 | 201 | 187 |

Table 43 *continued*.—Collapsing Pressure of Wrought-Iron Tubes.

| Length of Tube and Thickness of Plate. | | Diameter of Tube, in Inches. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length. | Thickness | 12. | 15. | 18. | 21. | 24. | 27. | 30. | 33. | 36. | 39. | 42. |
| feet. | inches. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 20 × | $\frac{1}{2}$ | 853 | 683 | 568 | 488 | 427 | 379 | 342 | 310 | 285 | 263 | 244 |
| 20 × | $\frac{9}{16}$ | 1080 | 864 | 720 | 617 | 540 | 480 | 432 | 393 | 360 | 332 | 309 |
| 20 × | $\frac{5}{8}$ | 1333 | 1067 | 889 | 762 | 667 | 593 | 534 | 485 | 445 | 410 | 381 |
| 22 × | $\frac{3}{8}$ | 432 | 346 | 295 | 247 | 216 | 192 | 173 | 158 | 216 | 134 | 124 |
| 22 × | $\frac{7}{16}$ | 588 | 471 | 393 | 336 | 294 | 262 | 236 | 215 | 197 | 181 | 168 |
| 22 × | $\frac{1}{2}$ | 768 | 615 | 512 | 440 | 384 | 342 | 308 | 279 | 256 | 237 | 220 |
| 22 × | $\frac{9}{16}$ | 972 | 778 | 648 | 556 | 486 | 432 | 389 | 354 | 324 | 299 | 278 |
| 22 × | $\frac{5}{8}$ | 1200 | 961 | 801 | 686 | 600 | 535 | 481 | 437 | 400 | 369 | 343 |
| 24 × | $\frac{3}{8}$ | 400 | 320 | 267 | 229 | 200 | 178 | 160 | 145 | 134 | 123 | 115 |
| 24 × | $\frac{7}{16}$ | 545 | 436 | 363 | 311 | 272 | 245 | 218 | 193 | 182 | 168 | 155 |
| 24 × | $\frac{1}{2}$ | 711 | 569 | 474 | 407 | 356 | 316 | 285 | 259 | 237 | 219 | 203 |
| 24 × | $\frac{9}{16}$ | 900 | 720 | 600 | 515 | 450 | 400 | 360 | 328 | 300 | 277 | 257 |
| 24 × | $\frac{5}{8}$ | 1111 | 889 | 741 | 635 | 550 | 494 | 445 | 404 | 371 | 342 | 318 |
| 26 × | $\frac{3}{8}$ | 369 | 295 | 246 | 210 | 185 | 164 | 148 | 134 | 123 | 114 | 105 |
| 26 × | $\frac{7}{16}$ | 500 | 402 | 335 | 287 | 250 | 223 | 201 | 183 | 168 | 154 | 144 |
| 26 × | $\frac{1}{2}$ | 656 | 525 | 437 | 374 | 328 | 291 | 263 | 238 | 219 | 201 | 187 |
| 26 × | $\frac{9}{16}$ | 830 | 664 | 553 | 474 | 415 | 369 | 332 | 302 | 277 | 255 | 237 |
| 26 × | $\frac{5}{8}$ | 1025 | 820 | 683 | 586 | 512 | 455 | 410 | 372 | 342 | 315 | 293 |
| 28 × | $\frac{3}{8}$ | 343 | 274 | 229 | 196 | 172 | 152 | 137 | 124 | 114 | 105 | 98 |
| 28 × | $\frac{7}{16}$ | 467 | 373 | 311 | 265 | 234 | 207 | 187 | 169 | 156 | 144 | 133 |
| 28 × | $\frac{1}{2}$ | 607 | 488 | 406 | 348 | 304 | 270 | 244 | 222 | 203 | 188 | 174 |
| 28 × | $\frac{9}{16}$ | 771 | 617 | 514 | 440 | 386 | 340 | 309 | 280 | 257 | 238 | 220 |
| 28 × | $\frac{5}{8}$ | 952 | 762 | 635 | 544 | 476 | 423 | 380 | 348 | 318 | 293 | 272 |

Note.—Factor of Safety. The working pressure should never exceed one-sixth of the collapsing pressure.

This Table shows how weak long cylindrical tubes are, to resist external or collapsing pressure, and the necessity of strengthening the flue-tubes, of Lancashire and Cornish boilers, with strengthening rings of angle-iron, and also by using Adamson's flanged seams at the joint of each belt, or at least of alternate belts of plate, whereby the length of tube is practically reduced to the length between the strengthening rings.

**The Strength of Corrugated Furnaces** with corrugations $1\frac{1}{2}$ inches deep, may be found by the following formula, given by Mr. Parker, of Lloyd's. Where T=thickness of plates in sixteenths of an inch, D=greatest diameter of furnace in inches, $\frac{1000 \times (T-2)}{D} = \left\{ \begin{array}{l} \text{Working pressure in lbs.} \\ \text{per square inch.} \end{array} \right.$

## SAFETY-VALVES.

**A Safety-Valve** should be capable of discharging considerably more steam than the boiler can generate, by the combustion of all the coal that can be burnt upon its fire-grate, to prevent the blowing-off pressure being materially exceeded, and the area should be proportional both to the fire-grate surface and to the pressure of steam. The lower the pressure the larger must the safety-valve be. When steam flows through an orifice with a square edge such as a safety-valve, its flow is considerably reduced, and the weight in lbs. of steam discharged per minute, per square inch of opening, corresponds nearly with three-fourths of the absolute pressure in the boiler, when that pressure is not less than 25 lbs., or 10 lbs. above the atmosphere. The area of opening requisite for the discharge of any given constant weight of steam, is in inverse ratio of the pressure; that is to say, it requires an orifice of three times larger area, to discharge steam of 30 lbs. pressure, than is required to discharge the same weight of steam per minute at 90 lbs. pressure.

The opening for the escape of steam, through a conical valve with cone of 45°, is about one-third less than the lift.

**To find the proper area of a Safety-Valve,** multiply the area in square feet of fire-grate surface, by one of the following multipliers, corresponding with the pressure at which the safety-valve is to blow off, and the product will give the area in square inches of that safety-valve; to which must be added the area of the wings of the valve, when the valve is constructed with wings.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pressure as shown by the steam gauge | | | | 10 lbs., | constant multiplier | | 1·4 |
| " | " | " | " | 15 " | " | " | 1·2 |
| " | " | " | " | 20 " | " | " | 1·04 |
| " | " | " | " | 25 " | " | " | ·9 |
| " | " | " | " | 30 " | " | " | ·8 |
| " | " | " | " | 35 " | " | " | ·72 |
| " | " | " | " | 40 " | " | " | ·66 |
| " | " | " | " | 45 " | " | " | ·6 |
| " | " | " | " | 50 " | " | " | ·56 |
| " | " | " | " | 55 " | " | " | ·54 |
| " | " | " | " | 60 " | " | " | ·52 |
| " | " | " | " | 70 to 80 " | " | " | ·5 |
| " | " | " | " | 80 to 100 " | " | " | ·48 |

**Direct Load upon the Valve.**—When the valve is loaded by a weight or spring, placed direct upon the valve, without the intervention of a lever.

*To find the necessary weight* in lbs. to attach, or the amount of tension to put upon the spring, to prevent the valve blowing off before the blowing-off pressure is reached, multiply the area of the valve in square inches by the pressure of steam in lbs. per square inch, and to the product add the weight of the valve.

*To find the pressure* in lbs. per square inch, divide the load in lbs. upon the valve, by the area of the valve in square inches.

**Safety Valve with Lever.**—The centre of gravity of the lever, is the point at which it will balance, when placed upon a knife-edge. In Fig. 46, F is the fulcrum, or joint where the lever is fixed, V is the centre of the valve, W is the weight.

*The best angle* for the seat of the valve is 45°; the width of mitre should not exceed $\frac{1}{16}$ inch; the lift of the valve should not exceed $\frac{1}{10}$ inch; the distance between the fulcrum and the centre of the valve, should equal the diameter of the valve; the pivot should bear upon the valve considerably below the level of the valve-seat. When a weight is used the total length of lever should equal one-third the diameter of the boiler; when the lever is held down by a spring-balance, the distance between the fulcrum and the

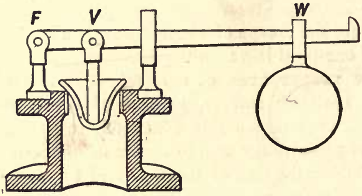


Fig. 46.

centre of the valve should equal the diameter of the valve, and the distance between the fulcrum and the spring-balance, should equal as many times the diameter of the valve, as there are square inches in its area.

**Safety-Valve Loaded by a Lever and Weight.**—When a lever and weight are employed to load a valve, it is necessary to find the resistance due to the weight of the lever and the valve. This may be ascertained by securing the valve to the lever with a piece of wire, and attaching a spring balance directly over the centre of the valve, which will give the load due to the weight of the valve and the action of the lever. This result divided by the area of the valve in square inches, will give the pressure in lbs. per square inch, at which the steam will raise that valve.

**To calculate the action of the lever** when the above method cannot be employed, *Approximate Rule:* Multiply the weight in lbs. of the lever, by the distance between the fulcrum and the centre of gravity, and divide the product, by the distance between the fulcrum and the centre of the valve; which will give the approximate resistance in lbs. due to the action of the lever, to which result add the weight of the valve and pivot.

**To find the pressure** in lbs. per square inch, at which the valve will begin to blow off:—

1. Multiply the weight in lbs. of the ball, by the distance in inches it is placed from the fulcrum.

2. Multiply the weight in lbs. of the lever, by the distance in inches between the centre of gravity and the fulcrum.

3. Multiply the weight in lbs. of the valve, by the distance in inches between the centre of the valve and the fulcrum.

4. Multiply the area of the valve in square inches, by the distance in inches between the centre of the valve and the fulcrum, then add together the first 3 products, and divide the sum by the 4th product.

**To find the position of the weight on the lever,** so that the safety-valve will blow off at a given pressure:—

1. Multiply the weight in lbs. of the lever, by the distance in inches between the centre of gravity and the fulcrum.

2. Multiply the weight in lbs. of the valve, by the distance in inches between the centre of the valve and the fulcrum.

3. Multiply the area of the valve in square inches, by the pressure of the steam in lbs. per square inch, and multiply the product by the distance in inches between the centre of the valve and the fulcrum; then add together the first two products, and subtract the sum from the 3rd product, and divide the remainder by the weight of the ball in lbs.

**To find the weight to place on the lever,** so that the valve will blow off at a given pressure:—Multiply the area of the valve in square inches, by the required pressure of steam in lbs. per square inch, from which result deduct the weight of the valve and action of the lever in lbs.; then multiply by the distance from the fulcrum to the centre of the valve in inches, and divide the product by the distance in inches, between the fulcrum and the point of the lever at which the weight is placed.

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## PROPORTIONS OF STEEL SPRINGS.

**Spiral Springs.**—The proportions of spiral springs for safety valves loaded with direct springs, may be determined by the following rules:—

*The internal diameter of the coil,* should equal 4 times the thickness of the steel of which the spring is composed.

*The lift of safety valves* for all sizes, may be taken at one-tenth part of an inch.

*The compression or extension of the spring,* to produce the initial load, should be forty times the lift of the valve, or 4 inches for all sizes of valves with the above lift.

**To find the diameter of round steel,** or side of square of square steel, for springs:—*

* The Author is indebted for the above rules for safety-valve springs, and for some of the information on safety-valves to a report on safety-valves in the Transactions of the Institution of Engineers and Shipbuilders of Scotland.

Find the load, by multiplying the area of the safety-valve in square inches, by the pressure of the steam in lbs. per square inch; then multiply the load by the diameter of the coil, from centre to centre of the steel; divide the quotient by the constant number 3 for round steel, or by the constant number 4·29 for square steel, and the cube root of the quotient will give the size of steel in sixteenths of an inch, that is, the diameter when round, and the side of the square when square.

**To find the compression or extension of one coil in inches:**—Cube the diameter in inches of the coil (from centre to centre of the steel), then multiply by the load in lbs., and divide the product by the product of the fourth power of the diameter (or side of square if square) of the steel in sixteenths of an inch, multiplied by the constant number 22 for round steel, and 30 for square steel.

**To find the pitch of a spiral spring:**—The distance between neighbouring coils should be equal to twice the compression (or extension as the case may be), found by the last rule, and the pitch will be twice the compression added to the diameter of the steel when round, or the side of the square when square.

**To find the number of coils:**—Divide the initial compression of spring (or 4 inches for all sizes) by the amount of compression, or extension of one coil (found by the above rule), which will give the effective number of coils.

**To find the length of spring,** multiply the number of coils found by last rule by the pitch of spiral, and add two more coils, to allow for the two end coils serving as bases for the spring.

The above rules are for valves loaded with direct springs, but the same rules apply to springs acting at the end of levers, in which case the lift of the end of the lever where the spring is attached, must be taken instead of the lift of the valve.

**Laminated Springs for Locomotive Engines,** railway carriages and waggons, and conveyances.—The thickness of steel plate for springs under $3\frac{1}{2}$ to 4 feet span, should not exceed $\frac{1}{4}$ inch in the smaller, and from $\frac{5}{16}$ to $\frac{3}{8}$ inch in the larger sizes; for larger spans the thickness is generally $\frac{1}{2}$ inch, with the two top plates $\frac{5}{8}$ inch thick. The deflection per ton of load, is about $\frac{1}{2}$ inch for railway waggons, $\frac{3}{4}$ to 1 inch for locomotive engines, $1\frac{1}{2}$ inch for horse boxes, and from $1\frac{3}{4}$ to $2\frac{1}{4}$ inches for railway carriages. The following are Mr. D. K. Clark's rules for laminated or plate springs.

Let D = the deflection in sixteenths of an inch per ton load.
S = the span of the spring in inches when loaded.
$b$ = the breadth of the spring plate in inches, considered uniform.
$t$ = the thickness of plates in sixteenths of an inch.
$n$ = the number of plates.
W = the working strength of spring in tons, or safe load.

Then

$$W = \frac{n\,b\,t^2}{11{\cdot}3\,S}$$

$$D = \frac{1{\cdot}66\,S^3}{n\,b\,t^3}$$

$$n = \frac{11{\cdot}3\,S\,W}{b\,t^2}$$

and $n$ necessary to a given elastic flexure, span, and size of plates =

$$n = \frac{1{\cdot}66\,S^3}{D\,b\,t^3}$$

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## CHIMNEYS FOR FACTORY STEAM BOILERS.

**The source of power for the draught of a chimney,** is the difference in weight of a vertical column of cool air outside the chimney, compared with that of a vertical column of the heated gases inside the chimney. These two columns of air being of unequal weight, motion ensues. The best draught takes place, when the temperature of the gases inside the chimney is at 552°, which weighs only one-half the weight of the air outside the chimney when at 62°. A quantity of heat is absorbed in producing draught, but only about one-fourth the quantity of the heat is required to raise 1 lb. of air one degree, which is required to raise 1 lb. of water one degree, and the heat carried off by the gases may be found thus: Multiply the weight of air per lb. of coal, by the difference in temperature between the gases in the chimney and the external air, and multiply the product by ·238. The quantity of air required is 24 lbs. for each lb. of fuel. The usual rate of combustion is 12 lbs. of coal per square foot of grate-area per hour in Cornish and Lancashire boilers.

**Proportions of Brick Chimneys.**—For an ordinary factory chimney, say, one for a good-sized cotton factory, the thickness of brickwork is 9 inches at the top; 14 inches at a distance of one-fourth the height from the top; 18 inches at one-half the height; 23 inches at a distance of three-fourths the height from the top; and 28 inches at the base.

**To find the area in square feet at the top of a chimney** for a given boiler: *Rule*, multiply the area of the fire-grate surface in square feet by ·80, and divide the product by the square root of the height of the chimney in feet.

**To find the maximum horse-power of a chimney,** when the inside area at the top, and the height, are given, divide the area in square inches by 70, and multiply the result by the square root of the height in feet. This will give the maximum horse-power, but a chimney should always be made about one-third larger than necessary, to allow for contingencies.

**Flues.**—The horse-power of a chimney reduces with the length of flue. The power with longer flues than 50 feet, may be found by multiplying the horse-power in the following table by ·8 for flues 100 feet, by ·7 for flues of 200 feet, and by ·6 for flues of 500 feet in length, from the furnace to the chimney bottom.

Table 44.—MAXIMUM HORSE-POWER OF FACTORY CHIMNEYS, WITH FLUES 50 FEET LONG IN CIRCUIT FROM THE FURNACE TO THE BOTTOM OF THE CHIMNEY.

| Size at the Top, Inside. | | HEIGHT, 40 FEET. | | HEIGHT, 50 FEET. | | HEIGHT, 60 FEET. | | HEIGHT, 70 FEET. | | HEIGHT, 80 FEET. | | HEIGHT, 90 FEET. | | HEIGHT, 100 FEET. | | HEIGHT, 120 FEET. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Round. | Square. | Round. | Square. | Round. | Square. | Round. | Square. | Round. | Square. | Round. | Square. | Round. | Square. | Round. | Square. |
| ft. | in. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. | h. p. |
| 1 | 3 | 15 | 19 | 17 | 21 | | | | | | | | | | | | |
| 1 | 6 | 22 | 28 | 25 | 32 | 27 | 34 | | | | | | | | | | |
| 1 | 9 | 30 | 38 | 34 | 43 | 37 | 47 | 40 | 50 | 43 | 55 | | | | | | |
| 2 | 0 | 40 | 50 | 44 | 56 | 49 | 62 | 53 | 67 | 57 | 73 | 60 | 76 | | | | |
| 2 | 3 | 50 | 64 | 56 | 71 | 62 | 79 | 67 | 85 | 72 | 92 | 76 | 97 | | | | |
| 2 | 6 | 63 | 80 | 70 | 80 | 77 | 98 | 83 | 106 | 89 | 114 | 94 | 120 | 100 | 128 | | |
| 2 | 9 | | | 85 | 108 | 94 | 120 | 101 | 126 | 108 | 138 | 114 | 146 | 122 | 156 | | |
| 3 | 0 | | | 101 | 126 | 111 | 142 | 120 | 153 | 129 | 165 | 136 | 174 | 145 | 185 | 158 | 200 |
| 3 | 6 | | | | | | | 163 | 208 | 175 | 224 | 185 | 237 | 197 | 252 | 214 | 274 |
| 4 | 0 | | | | | | | | | 229 | 293 | 242 | 310 | 258 | 330 | 281 | 360 |
| 4 | 6 | | | | | | | | | 291 | 373 | 307 | 393 | 327 | 419 | 356 | 456 |
| 5 | 0 | | | | | | | | | | | 378 | 484 | 403 | 516 | 439 | 562 |
| 5 | 6 | | | | | | | | | | | 458 | 587 | 488 | 625 | 531 | 680 |
| 6 | 0 | | | | | | | | | | | 546 | 700 | 581 | 744 | 633 | 810 |

**The Height** of Factory Chimneys in towns and populous districts should not be less than 90 feet.

**A Lightning Conductor** consisting of a $\frac{5}{8}$ inch copper wire-rope should be fixed, with fastenings spaced 6 feet apart, on the outside of every Factory Chimney. Insulators should not be used. Height of point above the Chimney Top = to the inside Diameter of the Chimney. Earth connection, not less than 7 yards; the wire-strands should be unwound and spread out so as to expose as much surface to the soil as possible, which should be permanently damp; or the wire-rope may terminate in a water pipe or well.

## THE PREVENTION OF SCALE IN STEAM BOILERS.

**Hardness of Water** is caused by the water coming in contact with various mineral substances, as it passes over or through the ground, and which it partially dissolves and holds in solution. These substances are chiefly sulphate of lime, bicarbonate of lime, and carbonate of magnesia. These, as well as various other impurities, are contained more or less in all river, lake, and well water. The action of heat in a boiler makes these substances insoluble, and causes their deposit on the boiler-plates in the form of scale, which, being a non-conducting material, retards the transmission of heat from the iron to the water, and also renders the plates liable to be burnt, by preventing the water from coming in contact with the plates. The loss of fuel caused by incrustation has been observed to be about 15 per cent. for every $\frac{1}{16}$ inch of thickness of scale. For softening water and preventing incrustation, pure caustic soda has been found to be the most effective; its strength should be 98 per cent., that is, containing only 2 per cent. impurities. Some caustic soda has only 60 per cent. strength, and contains common salts and sulphur salts, which injure the boiler plates. The pure caustic soda in powder should be dissolved in water, and introduced continually with the feedwater, by connecting the suction-pipe of the pump with the vessel containing the composition. The proper amount is, for very hard water, 1 oz. to every 5 gallons of water, and for water of medium hardness 1 oz. for every 10 gallons, and for fairly good water 1 oz. for every 15 gallons. In using caustic soda, the boiler should be frequently blown off.

Soda-ash is sometimes used, but it is not nearly so effective as pure caustic soda; besides, soda-ash often contains impurities which injure the plates.

**Proportions of Fire-Bars.**—Fire-bars should be as short as convenient; thin bars keep cooler, stand the fire better, and do not twist so much as thick ones. The dimensions for all lengths of bars (except in the middle, which is given below) are :—

Thickness at the top = $\frac{3}{4}$ inch; thickness at the bottom = $\frac{3}{8}$ inch; the sides to be parallel at the top to a depth of about $\frac{5}{8}$ inch, and then to be tapered downwards; ends and centre rib $1\frac{1}{4}$ inches thick, so as to leave an air space of $\frac{1}{2}$ inch; ends $1\frac{1}{2}$ inches deep × $1\frac{3}{8}$ inches long.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length of fire-bar, in inches . . . | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 |
| Depth at the centre, in inches . . . | 2 | $2\frac{1}{4}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ | 3 | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $3\frac{3}{4}$ | 4 | $4\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | 5 |
| Weight of the bar, in lbs. | 5 | 7 | 8 | 10 | 12 | 15 | 17 | 19 | 22 | 26 | 29 | 32 | 36 |

## THE CARE OF STEAM BOILERS.

*The following is a copy of a sheet of instructions to boiler attendants, issued to their clients by the* MANCHESTER STEAM USERS' ASSOCIATION.

### INSTRUCTIONS TO BOILER ATTENDANTS.

**Getting up Steam.**—Warm the boiler gradually. Do not get up steam from cold water in less than six hours. If possible, light the fires overnight.

Nothing turns a new boiler into an old one sooner than getting up steam too quickly. It hogs the furnace tubes, leads to grooving, strains the end plates, and sometimes rips the ring-seams of rivets at the bottom of the shell.

**Firing,**—Fire regularly. After firing, open the ventilating grid in the door for a minute or so. Keep the bars covered right up to the bridge. Keep as thick a fire as the quality of coal will allow. Do not rouse the fires with a rake. Should the coal cake together, run a slicer in on the top of the bars and gently break up the burning mass.

It has been found by repeated trials, that, under ordinarily fair conditions, no smoke need be made with careful hand-firing.

**Cleaning Fires and Slacking Ashes.**—Clean the fires as often as the clinker renders it necessary. Do not slack the clinkers and ashes on the flooring plates in front of the boiler, but draw them directly into an iron barrow and wheel them away.

Slacking ashes on the flooring plates corrodes the front of the boiler at the flat end plate, and also at the bottom of the shell where resting on the front cross wall.

**Feed-Water Supply.**—Set the feed-valve so as to give a constant supply, and keep the water up to the height indicated by the water-level pointer.

There is no economy in keeping a great depth of water over the furnace crowns, whilst, at the same time, the steam-space is reduced thereby, and the boiler is rendered more liable to prime. Nor is there any economy in keeping a very little water over the furnace-crowns, whilst the furnaces are thereby rendered more liable to be laid bare.

**Glass Water-Gauges and Floats.**—Blow through the test-tap at the bottom of the gauge hourly, as well as through the tap in the bottom neck, and the tap in the top neck twice daily. These taps should be blown through more frequently when the water is sedimentary, and whenever the movement of the water in the glass is at all sluggish. Should either of the thoroughfares become choked, clean them out with a wire. Work the floats up and down by hand three or four times a day to see that they are quite free. Always test the glass water-gauges and the floats thoroughly the first thing in the morning before firing up.

It does not follow that there is plenty of water in the boiler because there is plenty of water in the gauge-glass. The passages may be choked. Also, empty gauge-glasses are sometimes mistaken for full ones, and explosions have resulted therefrom. Hence the importance of blowing through the test-taps frequently.

**Blow-out Taps and Scum Taps.**—Open the blow-out tap in the morning defore the engine is started, and at dinner time when the engine is at rest. Open the scum tap when the engine is running, before breakfast, before dinner, and after dinner. If the water be sedimentary, run down half an inch of water at each blowing. If not sedimentary, merely turn the taps round. See that the water is at the height indicated by the water-level pointer at the time of opening the scum tap. Do not neglect blowing out for a single day, even though anti-incrustation compositions are put into boiler.

Water should be blown from the bottom of the boiler when steam is not being drawn off, so that the water may be at rest and the sediment have an opportunity of settling. Water should be blown from the surface when steam is being drawn off, so that the water may be in ebullition and the scum floating on the top. If the water be below the pointer, the scum tap will blow steam; if above the pointer, the scummer will miss the scum.

**Safety-Valves.**—Lift each safety-valve by hand in the morning before setting to work, to see that it is free. If there is a low-water safety valve, test it occasionally by lowering the water level to see that the valve begins to blow at the right point. When the boiler is laid off, examine the float and lever and see that they are free, and that they give the valve the full rise.

If safety-valves are allowed to go to sleep, they may get set fast.

**Shortness of Water.**—In case the boiler should be found to be short of water, draw the fires, if practicable, and draw them quickly, beginning at the front. In some cases it may be more convenient to smother the fires with ashes or with anything else ready to hand. If the fires are not drawn, leave the furnace doors open, turn on the feed, lower the dampers, shut down the stop-valve if the boiler be one of a series, and relieve the weight on the safety-valve so as to blow off the steam. Warn passers-by from the front of the boiler.

Drawing the fires must be done with discretion, and ought not to be attempted if the furnace crowns have begun to bulge out of shape. At Clay Cross, near Chesterfield, on Thursday, January 14, 1869, as the attendant was in the act of drawing the fire from a furnace overheated from shortness of water, the crown rent, when the torrent of steam and hot water that ensued blew him backwards to a distance of 25 yards, rake in hand, and killed him on the spot.

**Use of Anti-Incrustation Compositions.**—Do not use any of these without the consent of the Manchester Steam Users' Association. If used, never introduce them in heavy charges at the manhole or safety-valve, but in small daily quantities along with the feed-water.

Many furnace-crowns have been overheated and bulged out of shape through the use of anti-incrustation compositions, and in some cases explosions have resulted.

**Emptying the Boiler.**—Do not empty the boiler under steam pressure, but cool it down with the water in; then open the blow-out tap and let the water pour out. To quicken the cooling the damper may be left open, and the steam blown off through the safety-valves. Do not on any account dash cold water on to the hot plates. But, in cases of emergency, pour cold water in before the hot water is let out, and mix the two together so as to cool the boiler down gradually and generally, and not suddenly and locally.

If a boiler is blown off under steam pressure, the plates and brickwork are left hot. The hot plates harden the scale, and the hot brickwork hurts the boiler. Cold water dashed on to hot plates will cause severe straining by local contraction, sometimes sufficient to fracture the seams.

**Cleaning Out the Boiler.**—Clean out the boiler at least every two months, and oftener if the water be sedimentary. Remove all the scale and sediment as well as the flue dust and soot. Show the scale and sediment to the manager. Pass through the flues, and see not only that all the soot and flue dust have been removed, but that the plates have been well brushed. Also see whether the flues are damp or dry, and, if damp, find out the cause. Further, see that the thoroughfares in the glass water-gauges and in the blow-out elbow pipe, as well as the thoroughfares and the perforations in the internal feed dispersion pipe and the scum pipe, are free. Take the feed pipe and scum troughs out of the boiler if necessary to clean them thoroughly. Take the taps and the feed valve to pieces, examine, clean, and grease them, and if necessary grind them in with a little fine sand. Examine the fusible plugs. Do not put any blocks under the pipes in the hearth pit.

Putting blocks under the pipes in the hearth pit robs them of their spring, strains them, and sometimes breaks them.

**Preparation for Entire Examination.**—Have the boiler cooled and carefully cleaned out as explained above. Show both scale and sediment to the inspector, as well as the old cap of the fusible plug, and tell him of any defects that may have manifested themselves in working, and of any repairs or alterations that may have been made since the last examination.

Unless a boiler be suitably prepared, a satisfactory entire examination cannot be made. Inspectors are sent at considerable expense to make entire examinations, and it is a great disappointment when their visits are wasted from want of preparation. The Association is always happy to afford information to boiler attendants by means of its printed monthly reports, and to help them in the discharge of their duties, and expects them in return to do all they can to promote a thoroughly sound inspection of the boilers under their charge.

**Fusible Plugs.**—Keep these free from soot on the fire side, and from incrustation on the water side. Change the fusible metal once every year, at the time of preparing for the Manchester Steam Users' Association annual entire examination.

If fusible plugs are allowed to become incrusted, or if the metal be worked too long, they become useless, and many furnace crowns have rent from shortness of water, even though fitted with fusible plugs.

**General Keeping of Boiler.**—Polish up the brass and other bright work in the fittings. Sweep up the flooring plate frequently. Keep ashes and water out of the hearth-pit below the flooring plates. Keep the space on the top of the boiler free, and brush it down once or twice a week. Take a pleasure in keeping the boiler and the boiler-house clean and bright, and in preventing smoke.

**Remarks.**—Shortness of water generally arises from neglect of the boiler attendant, and ought not to occur. It is by no means easy to give precise instructions as to what should be done to put things right when shortness of water has occurred, so as to meet every case. Drawing the fires when the water is out of sight must always be a matter of more or less risk, as there is a difficulty in determining how far and for how long a time the furnace crowns have been laid bare. If it is known that the water has only just passed out of sight, say from the sticking fast of the blow-out tap when attempting to shut it, the fires may be drawn with safety. But if an empty gauge glass has been mistaken for a full one, and the boiler has been worked on in this state for some time, the case will be different. Again, there would be more risk in drawing the fires from a plain furnace tube, or from one made of ordinary plates, than from one strengthened with encircling rings and made of ductile steel, or of iron equal to Lowmoor or Bowling. In the Manchester Steam Users' Association Museum there is a photograph of a pair of steel furnaces, strengthened with flanged seams, which have bulged down to the firebars through overheating from shortness of water, without rending. Also there is a pair of furnaces made of Lowmoor iron and strengthened with flanged seams, which, though seriously overheated through shortness of water, have rent for a limited extent only in the neighbourhood of the flanged joint, the opening formed measuring about 7 inches in length by 1 inch at the widest part. On the other hand, there are in the museum two furnaces from different boilers, neither of which is strengthened with encircling hoops, nor made of ductile steel or of Lowmoor or Bowling iron, both of which have rent right across, forming an opening 12 inches wide in one case and $6\frac{1}{2}$ inches in the other. Thus it will be seen it is difficult to give precise instructions to suit all circumstances. A fire may be safely drawn in one case and not in another. Discretion must be exercised.

It should be borne in mind that the rupture of a furnace crown is not only dangerous to the fireman, but in many cases to those outside the works, as the torrent of steam and hot water that ensues frequently carries away the furnace mountings along with any brickwork lying in its course, and scattering the debris like so much grape shot, severely injures, and sometimes kills persons on their own premises. Thus boiler attendants must remember that shortness of water endangers other persons' lives as well as their own.

The best advice the Manchester Steam Users' Association can give to boiler attendants with regard to shortness of water is—Do not let it occur. Keep a sharp look-out on the water-gauge.

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**Wood Fuel** for steam boilers requires one-third more grate-surface, and two-thirds more cubical space in the furnace, than is required for coal, for equal generation of steam. Two cords of wood will evaporate about the same quantity of water as one ton of coal. A cord of dry pine-wood, 4 feet × 4 feet × 8 feet = 128 cubic feet, weighs 17 cwt.

**Expansion of Water by Heat.**—Water attains its maximum density at 39°·1 Fahr.—or say 40° Fahr.—from which point, any rise or fall of temperature is accompanied by expansion.

| Temperature. | Volume. | Temperature. | Volume. |
|---|---|---|---|
| 12° Fahr. | 1·0024 | 110° Fahr. | 1·0100 |
| 22° | 1·0001 | 120° | 1·0120 |
| 32° Freezing point | 1·0003 | 130° | 1·0146 |
| 40° | 1·0000 | 140° | 1·0177 |
| 50° | 1·0004 | 150° | 1·0206 |
| 62° Mean temperature | 1·0012 | 160° | 1·0240 |
| 70° | 1·0023 | 180° | 1·0297 |
| 80° | 1·0038 | 212° Boiling point | 1·0460 |
| 90° | 1·0053 | 250° | 1·0592 |
| 100° | 1·0074 | 300° | 1·0863 |

**Sea Water** requires more heat to boil it, than is required to boil fresh water. No salt passes away with the steam. Its average boiling point is 213·2° F. The proportion of salt held in solution is $\frac{1}{33}$ part of its weight, or about 4 ounces of salt per gallon of sea water. The point of saturation is $\frac{12}{33}$, when the water is full of salt, and will hold no more. Salt water varies in density, and in the nature of its ingredients in different seas. The composition of average sea water is—water, 96·6 parts: chloride of sodium 2·6; chloride of magnesia, ·4; sulphate of soda, ·37; carbonate of lime, ·02; sulphate of lime, ·01. The ice of sea water contains no salt.

## SECTION V.

## HEAT, WARMING, AND VENTILATING; MELTING, CUTTING, AND FINISHING METALS; ALLOYS AND CASTING; WHEEL-CUTTING; SCREW-CUTTING, &c.

# SECTION V.

## HEAT, WARMING, AND VENTILATING; MELTING, CUTTING, AND FINISHING METALS; ALLOYS AND CASTING; WHEEL-CUTTING; SCREW-CUTTING, &c.

### HEAT.

**Unit of Heat.**—The amount of heat necessary to raise the temperature of one pound of water at 32° one degree Fahrenheit (that is from 32° to 33°) is called the standard unit of heat.

Table 45.—Specific Heat of Solid and Liquid Bodies, being the fraction of a Unit of Heat necessary to heat one pound of the Body one degree Fahrenheit. From the Experiments of Regnault and Dulong.

| | | | |
|---|---|---|---|
| Water at 32° | 1·000 | Marble | ·215 |
| Ether | ·660 | Chalk | ·214 |
| Pine wood | ·650 | Sulphur | ·202 |
| Alcohol | ·620 | Graphite, natural | ·201 |
| Oak | ·570 | Coke | ·200 |
| Oil | ·520 | Brickwork and masonry | ·191 |
| Ice | ·504 | Glass | ·190 |
| Birch wood | ·480 | Phosphorus | ·182 |
| Steam, gaseous | ·475 | Burnt clay | ·180 |
| Oil of turpentine | ·472 | Carbonate of iron | ·180 |
| Beeswax | ·450 | Cast-iron | ·129 |
| Petroleum | ·434 | Cast-steel | ·118 |
| Nitric acid | ·426 | Wrought-iron | ·113 |
| Sulphuric acid | ·333 | Nickel | ·108 |
| Spermaceti | ·320 | Cobalt | ·106 |
| Steam, saturated | ·305 | Zinc | ·095 |
| Nitrate of soda | ·278 | Copper | ·095 |
| Coal | ·277 | Brass | ·093 |
| Charcoal | ·263 | Silver | ·057 |
| Carbonic oxide | ·247 | Tin | ·056 |
| Nitrogen | ·244 | Cadmium | ·056 |
| Carbon | ·241 | Antimony | ·050 |
| Air | ·237 | Mercury | ·033 |
| Salt | ·225 | Gold | ·032 |
| Oxygen | ·218 | Platinum | ·032 |
| Carbonic acid | ·216 | Lead | ·031 |
| Quicklime | ·216 | Bismuth | ·030 |

**The Specific Heat** of a body is its power of storing up heat, and the number of units of heat necessary to heat one pound of the body 1° Fahr. is its specific heat, water being used as the standard of comparison. Thus, to heat 100 lbs. of water 80° requires $100 \times 80 = 8000$ units of heat, and to heat the same weight of wrought-iron requires $100 \times 80 \times \cdot 113 = 904$, or only about $\frac{1}{9}$th of the heat necessary for the same weight of water.

Table 46.—Expansion of Liquids and Gases in volume by the addition of Heat from 32° to 212° F.

| | |
|---|---|
| 1000 parts of mercury become . . . . | 1018 |
| 1000 parts of water become . . . . | 1046 |
| 1000 parts of salt water become . . . | 1050 |
| 1000 parts of oil become . . . . | 1080 |
| 1000 parts of alcohol become . . . | 1110 |
| 1000 parts of air become . . . . | 1366 |
| 1000 parts of hydrogen become . . . | 1366 |
| 1000 parts of nitrogen become . . . | 1366 |
| 1000 parts of carbonic acid become . . | 1368 |
| 1000 parts of sulphurous acid become . . | 1384 |

Table 47.—Heat-conducting Power of Metals, &c.—Latent Heat.

| (Wiedemann.) | | | | Latent Heat of Liquefaction or units of Heat absorbed by one lb. of the substance in Melting from Solid to Liquid. (Person & Clement.) | |
|---|---|---|---|---|---|
| Silver | 100 | Platinum | 8·4 | | |
| Copper | 73·6 | German Silver | 6·3 | | |
| Gold | 53·2 | Bismuth | 1·8 | Lead | 9·7 |
| Brass | 23·6 | Marble | 2·4 | Bismuth | 22·7 |
| Tin | 14·5 | Porcelain | 1·2 | Tin | 25·6 |
| Iron | 11·9 | Fire Clay | 1·1 | Zinc | 50·6 |
| Steel | 11·6 | Terra Cotta | 1·1 | Silver | 38·0 |
| Lead | 8·5 | Water | ·9 | Cast-iron | 233·0 |

Table 48.—Expansion in Length of Metals, &c., by Heat per degree Fahrenheit from 32°.

| | | | |
|---|---|---|---|
| Fire bricks | ·00000235 | Roman cement | ·0000080 |
| Stock bricks | ·00000306 | Copper | ·0000101 |
| Granite | ·00000439 | Bronze and gun metal | ·0000104 |
| Glass | ·00000460 | Brass | ·0000106 |
| Platinum | ·00000484 | Gold | ·0000108 |
| Antimony | ·00000617 | Silver | ·0000112 |
| Cast-iron | ·00000650 | Tin | ·0000132 |
| Steel | ·00000668 | White solder | ·0000143 |
| Wrought-iron | ·00000681 | Lead | ·0000159 |
| Iron wire | ·00000745 | Zinc | ·0000173 |
| Bismuth | ·00000762 | Ice, from −17° to +30° | ·0000286 |

Table 49.—Radiation, Absorption and Reflection of Heat. From the Experiments of Provostage and Desains.

| | Radiating and Absorbing Power. | Reflecting Power. |
|---|---|---|
| Smoke-blackened surface | 100 | 0 |
| Carbonate of lead | 100 | 0 |
| Writing paper; ivory; jet; marble | 98 | 2 |
| Glass | 90 | 10 |
| China ink; ice | 85 | 15 |
| Gum lac | 72 | 28 |
| Silver-foil, on glass | 27 | 73 |
| Cast-iron, polished brightly | 25 | 75 |
| Mercury | 23 | 77 |
| Wrought-iron, polished | 23 | 77 |
| Zinc, polished | 19 | 81 |
| Platinum, polished; also steel | 17 | 83 |
| Tin | 14 | 86 |
| Metallic mirrors, slightly tarnished | 17 | 83 |
| Brass, cast, imperfectly polished | 11 | 89 |
| Brass, hammered, dead polished | 9 | 91 |
| Brass, highly polished | 7 | 93 |
| Brass, cast | 7 | 93 |
| Copper, coated on iron | 7 | 83 |
| Copper, varnished | 14 | 86 |
| Copper, hammered or cast | 7 | 93 |
| Gold plating | 5 | 95 |
| Gold, deposited on polished steel | 3 | 97 |
| Silver, hammered and well polished | 3 | 97 |
| Silver, cast and well polished | 3 | 97 |

**Superficial expansion** or expansion in two directions, is twice the linear expansion; and cubical expansion, or expansion in three directions, is three times the linear expansion.

**The Quantity of Heat** given in Table 50 for each material named, is deduced from experiments on the transmission of heat through plates of metal, which were heated on one side by hot water, and cooled on the other side by water at a low temperature. The quantity of heat in units, transmitted through one square foot of plate, per hour, may be found thus: subtract the temperature of the cooler side, from that of the hotter side of the plate, then multiply the result by the number in Table 50 corresponding to the material used, and divide the product by the thickness of plate. Thus an iron plate 2 inches thick, having a temperature of 60° on one side and 80° on the other, will transmit $80-60 = \frac{20 \times 230}{2} = 2300$ units of heat, per square foot per hour.

Table 50.—QUANTITY OF HEAT IN UNITS TRANSMITTED PER SQUARE FOOT PER HOUR, THROUGH A PLATE 1 INCH THICK, THE DIFFERENCE OF TEMPERATURE BETWEEN THE TWO FACES BEING 1° F.—FROM THE EXPERIMENTS OF PECLET.

| Materials. | Quantity of Heat in Units. | Materials. | Quantity of Heat in Units. |
|---|---|---|---|
| Gold | 625 | Gutta percha | 1·37 |
| Platinum | 600 | India rubber | 1·36 |
| Silver | 595 | Brick dust, sifted | 1·33 |
| Copper | 520 | Coke, powdered | 1·29 |
| Iron | 230 | Iron filings | 1·26 |
| Zinc | 225 | Cork | 1·15 |
| Tin | 178 | Chalk, powdered | ·86 |
| Lead | 113 | Wood charcoal, powdered | ·63 |
| Marble | 24 | Straw, chopped | ·56 |
| Stone | 14 | Coal, small sifted | ·54 |
| Glass | 6·6 | Wood ashes | ·53 |
| Terra cotta | 4·8 | Mahogany dust | ·52 |
| Brickwork | 4·8 | Canvas hemp, new | ·41 |
| Plaster | 3·8 | Calico, new | ·40 |
| Sand | 2·17 | White writing paper | ·34 |
| Oak, across fibre | 1·7 | Cotton wool & sheep's wool | ·32 |
| Walnut, along fibre | 1·4 | Eiderdown | ·31 |
| Fir, along fibre | 1·37 | Gray blotting paper | ·26 |

## HEATING ROOMS BY HOT WATER.

**A Hot Water Boiler** with its flow and return pipe, resembles an inverted syphon; the motive power in the circulation of hot water, is the difference in weight between the columns of water, ascending from the boiler through its top outlet, or flow pipe, and returning to the boiler through its bottom inlet, or return pipe. As the water in the boiler is heated it expands, becomes lighter and ascends to the top of the boiler in the direction of the flow pipe, and is replaced by colder and consequently heavier water from the bottom or return pipe; this in turn gets heated, ascends, and is replaced by more cold water from the return pipe, and this circulation continues so long as the fire is kept up, the hot water continually ascending, and the cold water descending. Mr. Hood, who is an authority on this subject, gives the following tables for heating rooms by hot water.

Table 51.—Difference in Weight of two Columns of Water, each 1 foot high at various Temperatures; assumed actual Temperatures from 170° to 190° F.

| Difference in Temperature of the two Columns. | Diameter of the Pipe. | | | | Difference in Weight of the Columns per Square Inch. |
|---|---|---|---|---|---|
| | 1 Inch. | 2 Inch. | 3 Inch. | 4 Inch. | |
| Fahrenheit. | Grains. | Grains. | Grains. | Grains. | |
| 2° ......... | 1·5 | 6·3 | 14·3 | 25·4 | 2·028 |
| 4° ......... | 3·1 | 12·7 | 28·8 | 51·1 | 4·068 |
| 6° ......... | 4·7 | 19·1 | 43·3 | 76·7 | 6·108 |
| 8° ......... | 6·4 | 25·6 | 57·9 | 102·5 | 8·160 |
| 10° ......... | 8·0 | 32·0 | 72·3 | 128·1 | 10·200 |
| 12° ......... | 9·6 | 38·5 | 87·0 | 154·1 | 12·264 |
| 14° ......... | 11·2 | 45·0 | 101·7 | 180·0 | 14·328 |
| 16° ......... | 12·8 | 51·4 | 116·3 | 205·9 | 16·392 |
| 18° ......... | 14·4 | 57·9 | 131·0 | 231·9 | 18·456 |
| 20° ......... | 16·1 | 64·5 | 145·7 | 258·0 | 20·532 |

Table 52.—Length of 4-inch Pipe to Heat 1000 Cubic Feet of Air per Minute; Temperature of the Pipe 200° F.

| Temperature of External Air. | Temperature at which the Room is required to be kept. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fahrenheit. | 45° | 50° | 55° | 60° | 65° | 70° | 75° | 80° | 85° | 90° |
| | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. | Feet. |
| 10° ...... | 126 | 150 | 174 | 200 | 229 | 259 | 292 | 328 | 367 | 409 |
| 12° ...... | 119 | 142 | 166 | 192 | 220 | 251 | 283 | 318 | 357 | 399 |
| 14° ...... | 112 | 135 | 159 | 184 | 212 | 242 | 274 | 309 | 347 | 388 |
| 16° ...... | 105 | 127 | 151 | 176 | 204 | 233 | 265 | 300 | 337 | 378 |
| 18° ...... | 98 | 120 | 143 | 168 | 195 | 225 | 256 | 290 | 328 | 368 |
| 20° ...... | 91 | 112 | 135 | 160 | 187 | 216 | 247 | 281 | 318 | 358 |
| 22° ...... | 83 | 105 | 128 | 152 | 179 | 207 | 238 | 271 | 308 | 347 |
| 24° ...... | 76 | 97 | 120 | 144 | 170 | 199 | 229 | 262 | 298 | 337 |
| 26° ...... | 69 | 90 | 112 | 136 | 162 | 190 | 220 | 253 | 288 | 327 |
| 28° ...... | 61 | 82 | 104 | 128 | 154 | 181 | 211 | 243 | 279 | 317 |
| 30° ...... | 54 | 75 | 97 | 120 | 145 | 173 | 202 | 234 | 269 | 307 |
| *32° ...... | 47 | 67 | 89 | 112 | 137 | 164 | 193 | 225 | 259 | 296 |
| 34° ...... | 40 | 60 | 81 | 104 | 129 | 155 | 184 | 215 | 249 | 286 |
| 36° ...... | 32 | 52 | 73 | 96 | 120 | 147 | 175 | 206 | 239 | 276 |
| 38° ...... | 25 | 45 | 66 | 88 | 112 | 138 | 166 | 196 | 230 | 266 |
| 40° ...... | 18 | 37 | 58 | 80 | 104 | 129 | 157 | 187 | 220 | 255 |
| 42° ...... | 10 | 30 | 50 | 72 | 95 | 121 | 148 | 178 | 210 | 245 |
| 44° ...... | 3 | 22 | 42 | 64 | 87 | 112 | 139 | 168 | 200 | 235 |
| 46° ...... | ... | 15 | 34 | 56 | 79 | 103 | 130 | 159 | 190 | 225 |
| 48° ...... | ... | 7 | 27 | 48 | 70 | 95 | 121 | 150 | 181 | 214 |
| 50° ...... | ... | ... | 19 | 40 | 62 | 86 | 112 | 140 | 171 | 204 |
| 52° ...... | ... | ... | 11 | 32 | 54 | 77 | 103 | 131 | 161 | 194 |

* Freezing point.

**To find the length in feet of iron pipe** required for heating the air in a building. *Rule:* Multiply the volume of air in cubic feet, to be warmed per minute, by the difference in temperature in the room, and the external temperature, and multiply by 1·12 for 2-inch pipes, by ·75 for 3-inch pipes, by ·56 for 4-inch pipes, and divide the product by the difference of the internal temperature and that of the pipes.

Table 53.—LENGTH OF 4-INCH PIPE REQUIRED TO WARM VARIOUS BUILDINGS.

(Divide the cubic contents of the room in feet, by one of the following divisors.)

| Description of Building. | Divisor for cubic contents of Room. | Temperature Maintained. |
|---|---|---|
| | Feet. | Fahrenheit. |
| Churches and large public rooms | 200 | 55° |
| Schools and lecture rooms | 170 | 60° |
| Dwelling rooms | 150 | 60° |
| Work rooms and manufactories | 125 | 60° |
| Halls, waiting rooms, and shops | 100 | 60° |
| Leather, &c., drying rooms | 40 | 100° |
| Greenhouses and conservatories | 30 | 60° |
| Horticultural forcing houses | 20 | 75° |
| Ditto ditto | 18 | 80° |
| Laundry drying rooms | 8 | 110° |

3-inch pipes require to be one-third longer than 4-inch pipes, to heat the same number of cubic feet; and 2-inch pipes require to be double the length of 4-inch pipes, to heat the same number of cubic feet.

Table 54.—COOLING OF IRON PIPES.

Temperature of room, 67°; maximum temperature of thermometer, 152°.

| THERMOMETER COOLED. | | RUSTY SURFACE. | | BLACK VARNISHED SURFACE. | | WHITE SURFACE. | |
|---|---|---|---|---|---|---|---|
| From. | To. | Observed Time. | Calculated Time. | Observed Time. | Calculated Time. | Observed Time. | Calculated Time. |
| 152° | 150° | 2′ 30″ | 2′ 21″ | 2′ 16″ | 2′ 16″ | 2′ 19″ | 2′ 24″ |
| 152° | 148° | 5′ 0″ | 4′ 40″ | 4′ 38″ | 4′ 36″ | 4′ 53″ | 4′ 51″ |
| 152° | 146° | 7′ 45″ | 7′ 12″ | 7′ 28″ | 7′ 3″ | 7′ 28″ | 7′ 22″ |
| 152° | 144° | 10′ 15″ | 9′ 44″ | 9′ 45″ | 9′ 27″ | 10′ 13″ | 9′ 57″ |
| 152° | 142° | 12′ 45″ | 12′ 15″ | 12′ 2″ | 11′ 54″ | 12′ 57″ | 12′ 36″ |
| 152° | 140° | 15′ 0″ | 15′ 0″ | 14′ 32″ | 14′ 32″ | 15′ 22″ | 15′ 22″ |

Table 55.—RATE OF COOLING BY RADIATION FOR THE SAME BODY, AT DIFFERENT TEMPERATURES.

| Excess of Temperature. | Velocity of Cooling when the Surrounding Medium is at the Undermentioned Temperatures. | | | |
|---|---|---|---|---|
| | 0° | 20° | 40° | 60° |
| 220° | 8·81 | 10·41 | 11·98 | — |
| 200° | 7·40 | 8·58 | 10·01 | 11·64 |
| 180° | 6·10 | 7·04 | 8·20 | 9·55 |
| 160° | 4·89 | 5·67 | 6·61 | 7·68 |
| 140° | 3·88 | 4·57 | 5·32 | 6·14 |
| 120° | 3·02 | 3·56 | 4·15 | 4·84 |
| 100° | 2·30 | 2·74 | 3·16 | 3·68 |

Table 56.—SHOWING THE QUANTITY OF COAL USED PER HOUR, TO HEAT 100 FEET IN LENGTH OF PIPE OF DIFFERENT SIZES.

| Diameter of Pipe in Inches. | Difference between the Temperature of the Pipe and the Room in Degrees of Fahrenheit. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 150 | 145 | 140 | 135 | 130 | 125 | 120 | 115 | 110 | 105 | 100 | 95 | 90 | 85 | 80 |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 4 | 4·7 | 4·5 | 4·4 | 4·2 | 4·1 | 3·9 | 3·7 | 3·6 | 3·4 | 3·2 | 3·1 | 2·9 | 2·8 | 2·6 | 2·5 |
| 3 | 3·8 | 3·4 | 3·3 | 3·1 | 3·0 | 2·9 | 2·8 | 2·7 | 2·5 | 2·4 | 2·3 | 2·2 | 2·1 | 2·0 | 1·8 |
| 2 | 2·3 | 2·2 | 2·2 | 2·1 | 2·0 | 1·9 | 1·8 | 1·8 | 1·7 | 1·6 | 1·5 | 1·4 | 1·4 | 1·3 | 1·2 |
| 1 | 1·1 | 1·1 | 1·1 | 1·0 | 1·0 | ·9 | ·9 | ·9 | ·8 | ·8 | ·7 | ·7 | ·7 | ·6 | ·6 |

When pipes are laid in trenches covered with grating the loss of heat amounts to about 10 per cent., which passes into the ground.

**Boiler Power.**—For heating purposes by hot water, the saddle boiler gives good results. One square foot of boiler surface exposed to the direct action of the fire, or three square feet of flue surface, will heat 40 feet of 4-inch pipe.

**The Quantity of Air to be Warmed per Minute** is from 4 to 5 cubic feet for each person, with the addition of $1\frac{1}{4}$ cubic feet for each square foot of glass in habitable rooms; for conservatories and hot-houses the quantity of air to be warmed is $1\frac{1}{4}$ cubic feet per square foot of glass per minute; as iron frames and sashes radiate as much heat as glass, their surfaces are to be measured with the glass. For wood frames deduct $\frac{1}{8}$ from the gross area of surface.

**Heating Rooms by Steam at 212° F.**—A 1-horse-power boiler is sufficient for 48,000 cubic feet of space. To heat a room to 60° F. the length of steam-pipe may be found by the following rule. To find the length in feet of steam-pipe: Multiply the volume of air in cubic feet, to be warmed per minute, by the difference of temperature in the room and the external temperature, and divide the product by 304 for 4-inch pipe, or by 228 for 3-inch pipe, by 152 for 2-inch pipes, and by 76 for 1-inch pipe.

**Expansion of Steam and Hot-water Pipes.**—An expansion-joint should be added to long lengths of steam-pipes, to allow for their increase of length from expansion. The quantity of expansion can be found thus: Multiply the coefficient of expansion given in Table 48 by the difference in temperature of the outside and inside of the pipe, which result multiply by the length of pipe. Thus with a cast-iron steam-pipe 160 feet long, with the temperature of the air at 60° and the steam at 324° F., the difference of temperature will be 324—60 = 264°, and the increase in length due to expansion will be ·0000065 rate of expansion × 264° temperature × 160 feet × 12 inches = 3·294 inches.

## VENTILATION, &c.

**The Amount of Air required** for the proper ventilation of apartments is from 4 to 5 cubic feet of air per head per minute in winter, and from 6 to 10 cubic feet in summer. A man makes about 17 respirations per minute each of 40 cubic inches, or $\frac{17 \times 40 \times 60}{1728} = 23·6$ cubic feet per hour; for respiration and transpiration a man requires 215 cubic feet of air per hour. A man generates about 290 units of heat per hour, 100 units of which go in the formation of vapour, and the remaining 190 units are dissipated by radiation to the surrounding objects and contact with cold air. An ordinary gas burner consumes about 5 feet of gas per hour, and requires for combustion 12 cubic feet of air per cubic foot of gas, or 60 cubic feet per hour for each gas burner; each cubic foot of gas burned emits about 690 units of heat; each pound of candles or oil burnt requires 160 cubic feet of air for combustion, and emits 16,000 units of heat.

**The Quantity of Air required** for the proper ventilation of various buildings is given below:—

| | Cubic feet per head per hour. |
|---|---|
| For apartments with healthy occupants | 300 |
| For apartments with sick occupants | 1200 |
| For prisons and workhouses | 350 |
| For churches and assembly rooms | 550 |
| Hospitals, ordinary, and barracks | 2200 |
| Hospitals for infectious diseases | 4500 |

**The Space provided for each Bed** in the wards of ordinary hospitals, should not be less than 1800 cubit feet, and in hospitals for infectious diseases not less than 2500 cubic feet. The space provided in dwelling houses, should not be less than 300 cubic feet for each person in a room, whether children or adults, as children require as much space as adults.

**Ventilation of Mines.**—The quantity of air required for the health of each person underground is 100 cubic feet per minute; in addition to this, in fiery mines air is required in the proportion of 30 cubic feet for each cubic foot per minute of firedamp given off.

**Space Required for Animals.**—A pig requires 10 square feet of floor space; a sheep, 15; a bullock, 70; a cow, 100; and a horse, 120 square feet of floor space. The cubical space should equal 13 times the given floor space for a horse, and 10 times the given floor space for each of the other animals above mentioned.

**Furnace-ventilation.**—The power obtained is measured by the difference between the weights of air in the downcast and upcast shafts. The length of column in the downcast shaft, which would be equal in weight to the difference of the weight of air in the two shafts, is called the motive column. To find the motive column.—*Rule:* From the temperature of the upcast shaft, subtract the temperature of the downcast shaft, and divide the remainder by the product of the temperature of the upcast multiplied by 459; multiply this quotient by the depth in feet of the downcast shaft.

To find the weight in lbs. of a cubic foot of air.—Divide the number 519 by the product of 459 multiplied by the temperature, and multiply the quotient by ·0765546. By multiplying the weight of one cubic foot of the air in the shaft by the cubic area of the shaft, the total weight of the air in the shaft is obtained.

**Weight of one cubic foot of pure Air** under a pressure of one atmosphere.

| | | | lbs. | | | | lbs. |
|---|---|---|---|---|---|---|---|
| At 0° | Fahr. | = | ·0866 | At 300° | Fahr. | = | ·0525 |
| „ 12° | „ | = | ·0845 | „ 400° | „ | = | ·0465 |
| „ 22° | „ | = | ·0826 | „ 500° | „ | = | ·0415 |
| „ 32° | „ | = | ·0808 | „ 800° | „ | = | ·0318 |
| „ 62° | „ | = | ·0762 | „ 1200° | „ | = | ·0242 |
| „ 102° | „ | = | ·0709 | „ 2000° | „ | = | ·0165 |
| „ 162° | „ | = | ·0640 | „ 2500° | „ | = | ·0136 |
| „ 212° | „ | = | ·0592 | “ 3000° | „ | = | ·0116 |

**Atmospheric Air is increased in volume** by elevation of temperature, as follows.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| At 32° | Fahr., | volume | = | 1·000 | At 180° | Fahr., | volume | = | 1·310 |
| „ 42° | „ | „ | = | 1·021 | „ 212° | „ | „ | = | 1·370 |
| „ 50° | „ | „ | = | 1·040 | „ 300° | „ | „ | = | 1·550 |
| „ 60° | „ | „ | = | 1·060 | „ 400° | „ | „ | = | 1·756 |
| „ 70° | „ | „ | = | 1·080 | „ 500° | „ | „ | = | 1·960 |
| „ 80° | „ | „ | = | 1·100 | „ 800° | „ | „ | = | 2·570 |
| „ 90° | „ | „ | = | 1·120 | „ 1200° | „ | „ | = | 3·386 |
| „ 100° | „ | „ | = | 1·140 | „ 1600° | „ | „ | = | 4·200 |
| „ 120° | „ | „ | = | 1·180 | „ 2000° | „ | „ | = | 5·020 |
| „ 150° | „ | „ | = | 1·242 | „ 3000° | „ | „ | = | 7·058 |

## WIND PRESSURE ON RAILWAY STRUCTURES.

The following is an extract from the report of the committee appointed to consider the question of wind pressure on railway structures in 1881 :—

In the case of high winds, with which alone we have to deal, it was found that the greatest pressure recorded in an hour was tolerably well proportional to the square of the mean velocity during the hour, and that the empirical formula $\frac{V^2}{100} = P$, where V = maximum run in miles of the wind in any one hour and P = maximum pressure in pounds on the square foot at any time during the storm to which V refers, represented very fairly the greatest pressure as deduced from the mean velocity for an hour. We have accordingly given a table calculated from the above formula for deducing maximum pressures from observed velocities.

Table 57.—Wind Velocities and Pressures.

| Maximum hourly run of the wind in miles. | Maximum pressure in lbs. on the sq. foot. | Maximum hourly run of the wind in miles. | Maximum pressure in lbs. on the sq. foot. | Maximum hourly run of the wind in miles. | Maximum pressure in lbs. on the sq. foot. |
|---|---|---|---|---|---|
| 40 | 16·0 | 61 | 37·2 | 81 | 65·6 |
| 41 | 16·8 | 62 | 38·4 | 82 | 67·2 |
| 42 | 17·6 | 63 | 39·7 | 83 | 68·9 |
| 43 | 18·5 | 64 | 41·0 | 84 | 70·6 |
| 44 | 19·4 | 65 | 42·2 | 85 | 72·2 |
| 45 | 20·2 | 66 | 43·6 | 86 | 74·0 |
| 46 | 21·2 | 67 | 44·9 | 87 | 75·7 |
| 47 | 22·1 | 68 | 46·2 | 88 | 77·4 |
| 48 | 23·0 | 69 | 47·6 | 89 | 79·2 |
| 49 | 24·0 | 70 | 49·0 | 90 | 81·0 |
| 50 | 25·0 | 71 | 50·4 | 91 | 82·8 |
| 51 | 26·0 | 72 | 51·8 | 92 | 84·6 |
| 52 | 27·0 | 73 | 53·3 | 93 | 86·5 |
| 53 | 28·1 | 74 | 54·8 | 94 | 88·4 |
| 54 | 29·2 | 75 | 56·2 | 95 | 90·3 |
| 55 | 30·2 | 76 | 57·8 | 96 | 92·2 |
| 56 | 31·4 | 77 | 59·3 | 97 | 94·1 |
| 57 | 32·5 | 78 | 60·8 | 98 | 96·0 |
| 58 | 33·6 | 79 | 62·4 | 99 | 98·0 |
| 59 | 34·8 | 80 | 64·0 | 100 | 100·0 |
| 60 | 36·0 | | | | |

From the consideration we have given to the subject, we are of opinion that the following rules will sufficiently meet the cases referred to us :—

(1) That for railway bridges and viaducts a maximum wind pressure of 56 lbs. per square foot should be assumed for the purpose of calculation.

(2) That where the bridge or viaduct is formed of close girders, and the tops of such girders are as high or higher than the top of a train passing over the bridge, the total wind pressure upon such bridge

or viaduct should be ascertained by applying the full pressure of 56 lbs. per square foot to the entire vertical surface of one main girder only. But if the top of a train passing over the bridge is higher than the tops of the main girders, the total wind pressure upon such bridge or viaduct should be ascertained by applying the full pressure of 56 lbs. per square foot to the entire vertical surface from the bottom of the main girders to the top of the train passing over the bridge.

(3) That where the bridge or viaduct is of the lattice form or of open construction, the wind pressure upon the outer or windward girder should be ascertained by applying the full pressure of 56 lbs. per square foot, as if the girder were a close girder, from the level of the rails to the top of a train passing over such bridge or viaduct, and by applying in addition the full pressure of 56 lbs. per square foot to the ascertained vertical area of surface of the ironwork of the same girder situated below the level of the rails or above the top of a train passing over such bridge or viaduct. The wind pressure upon the inner or leeward girder or girders should be ascertained by applying a pressure per square foot to the ascertained vertical area of surface of the ironwork of one girder only situated below the level of the rails or above the top of a train passing over the said bridge or viaduct, to this scale, viz. :—

(*a*) If the surface area of the open spaces does not exceed two-thirds of the whole area included within the outline of the girder, the pressure should be taken at 28lbs. per sq. foot.

(*b*) If the surface area of the open spaces lie between two-thirds and three-fourths of the whole area included within the outline of the girder, the pressure should be taken at 42lbs. per square foot.

(*c*) If the surface area of the open spaces be greater than three-fourths of the whole area included within the outline of the girder, the pressure should be taken at the full pressure of 56lbs. per square foot.

(4) That the pressure upon arches and the piers of bridges and viaducts should be ascertained as nearly as possible by the above rules.

(5) That in order to ensure a proper margin of safety for bridges and viaducts in respect of the strains caused by wind pressure, they should be made of sufficient strength to withstand a strain of four times the amount due to the pressure calculated by the foregoing rules. And that, for cases where the tendency of the wind to overturn structures is counteracted by gravity alone, a factor of safety of 2 will be sufficient.

**The Pressure of Wind on Roofs** of buildings seldom exceeds 40lbs. per square foot in this country, except in great storms, when it may be 50lbs. per square foot. In countries subject to hurricanes the wind pressure is sometimes from 60 to 70lbs. per square foot.

**Pressure, Power and Discharge of Gas.**—The total heat of coal gas is 690 units per cubic foot, its evaporative power is 1 lb. of water from 62° per cubic foot of gas. The pressure of gas is measured in inches of water; the pressure at the gas works is from 2 to $2\frac{1}{2}$ inches of water, or a pressure of under 2 oz. per square inch. Gas weighs about 240 grains per cubic foot, or less than half the weight of air, which weighs about 560 grains per cubic foot. Gas has an ascending power equal to one inch of water for every 100 feet in height; it increases $\frac{1}{10}$ inch in pressure for every rise of 10 feet in height and decreases at the same rate in pressure for a descent. Each gas-burner consumes 5 cubic feet per hour, and the quantity of gas that can be supplied by various sizes of pipes at various distances from the supply pipe is given in the following table, which is useful for fixing gas stoves, &c.

Table 58.—Number of Cubic Feet of Gas discharged per Hour by Pipes of various Sizes and Lengths at a Pressure of $\frac{4}{10}$.

| Length from the Supply Pipe. | Internal Diameter. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\frac{5}{16}$ In. | $\frac{3}{8}$ In. | $\frac{7}{16}$ In. | $\frac{1}{2}$ In. | $\frac{5}{8}$ In. | $\frac{3}{4}$ In. | 1 In. | $1\frac{1}{4}$ In. | $1\frac{1}{2}$ In. | $1\frac{3}{4}$ In. | 2 In. |
| 10 feet. | 40 | 63 | 93 | 130 | 228 | 360 | 738 | 1291 | 2037 | 2995 | 4185 |
| 20 " | 28 | 45 | 66 | 92 | 161 | 254 | 522 | 913 | 1440 | 2118 | 2952 |
| 30 " | 23 | 37 | 54 | 75 | 131 | 208 | 426 | 745 | 1176 | 1729 | 2415 |
| 40 " | 20 | 32 | 46 | 68 | 114 | 180 | 369 | 645 | 1018 | 1497 | 2090 |
| 50 " | 18 | 28 | 41 | 58 | 102 | 160 | 330 | 577 | 911 | 1339 | 1871 |
| 60 " | 16 | 26 | 38 | 53 | 93 | 147 | 302 | 527 | 832 | 1223 | 1707 |
| 70 " | 15 | 24 | 35 | 49 | 86 | 136 | 279 | 488 | 768 | 1132 | 1583 |
| 80 " | 14 | 22 | 33 | 46 | 80 | 127 | 261 | 456 | 720 | 1059 | 1478 |
| 90 " | 13 | 21 | 31 | 43 | 76 | 120 | 246 | 430 | 679 | 998 | 1396 |
| 100 " | 12 | 20 | 29 | 41 | 72 | 114 | 233 | 408 | 644 | 947 | 1322 |
| 125 " | 11 | 18 | 26 | 37 | 64 | 101 | 209 | 365 | 576 | 847 | 1184 |
| 150 " | 10 | 16 | 24 | 33 | 58 | 93 | 190 | 334 | 528 | 773 | 1080 |
| 175 " | 9 | 15 | 22 | 31 | 54 | 86 | 176 | 308 | 487 | 716 | 1000 |
| 200 " | 9 | 14 | 20 | 29 | 51 | 80 | 165 | 288 | 455 | 669 | 935 |
| 225 " | ... | 13 | 19 | 27 | 48 | 76 | 156 | 274 | 430 | 630 | 880 |
| 250 " | ... | 12 | 18 | 26 | 46 | 72 | 147 | 258 | 407 | 599 | 836 |
| 300 " | ... | ... | 17 | 24 | 41 | 65 | 137 | 236 | 376 | 547 | 764 |

**Lifting Power of Gas.**—About 30 cubic feet of coal gas, or about $13\frac{1}{2}$ cubic feet of hydrogen gas, will lift 1 lb. weight.

**Cupola.**—One lb. of carbon burning to carbonic acid develops 12,906 units of heat, and the quantity of coke required to melt cast iron may be found thus:—2190, melting point,—50, temperature of the iron, × ·13 specific heat, = 278·2 units of heat to raise 1 lb. of metal to the melting point, and 278·2 + 233, latent heat of liquefaction of cast iron, = 511·2, total amount of heat required to melt 1 lb. Therefore, one ton of cast iron will require $\frac{2240 \times 511\cdot 2\text{, total heat per lb.}}{12906 \times \cdot 82 \text{ per cent. of carbon in the coke}} =$ 108·2 lbs. of coke, or nearly 1 cwt. of coke per ton of metal melted

## CUTTING METALS.

**The most advantageous speed** in lineal feet per minute, for planing, shaping, slotting, and turning metals, is, for copper 120 feet, brass 50 feet, wrought-iron 20 feet, cast-iron 18 feet, steel 12 feet. By dividing these numbers by the circumference in feet of the work to be turned, the number of revolutions of the lathe-spindle is obtained. For boring work in a lathe, the speed is limited by the overhanging of the tool, to from 6 to 10 feet per minute; for screwing bolts and tapping nuts the surface-speed is from 4 to 8 feet per minute. The speed of cutters for wheel-cutting and milling machines should not exceed 18 feet per minute at the largest cutting diameter.

Table 59.—Cutting Speeds for Lathe Work.

| Diameter of the Work in Inches. | Wrought Iron. | Cast Iron. | Steel. | Brass. | Copper. |
|---|---|---|---|---|---|
| | Number of Revolutions per Minute of the Lathe Spindle. | Number of Revolutions per Minute of the Lathe Spindle. | Number of Revolutions per Minute of the Lathe Spindle. | Number of Revolutions per Minute of the Lathe Spindle. | Number of Revolutions per Minute of the Lathe Spindle. |
| 1 | 76 | 68 | 45 | 190 | 456 |
| 1½ | 50 | 45 | 30 | 127 | 300 |
| 2 | 38 | 34 | 22 | 95 | 228 |
| 2½ | 30 | 27 | 18 | 75 | 180 |
| 3 | 25 | 22 | 15 | 63 | 150 |
| 3½ | 22 | 19 | 13 | 55 | 132 |
| 4 | 19 | 17 | 11 | 47 | 114 |
| 5 | 15 | 13 | 9 | 38 | 90 |
| 6 | 12 | 11 | 7·6 | 30 | 72 |
| 7 | 10 | 9 | 6·5 | 25 | 60 |
| 8 | 9 | 8·6 | 5·7 | 23 | 54 |
| 10 | 7·7 | 6·8 | 4·58 | 19 | 46 |
| 12 | 6·3 | 5·7 | 3·83 | 16 | 37 |
| 15 | 5·0 | 4·5 | 3·05 | | |
| 18 | 4·24 | 3·8 | 2·54 | | |
| 21 | 3·63 | 3·27 | 2·18 | | |
| 24 | 3·18 | 2·85 | 1·91 | | |
| 30 | 2·54 | 2·29 | 1·52 | | |
| 36 | 2·12 | 1·91 | 1·27 | | |
| 42 | 1·81 | 1·66 | 1·10 | | |
| 48 | 1·59 | 1·44 | ·96 | | |
| 54 | 1·41 | 1·27 | ·85 | | |
| 60 | 1·27 | 1·14 | ·76 | | |
| 72 | 1·06 | ·95 | ·63 | | |
| 84 | ·90 | ·82 | ·54 | | |
| 96 | ·79 | ·71 | ·47 | | |
| 108 | ·70 | ·63 | ·44 | | |

**The feed or advance of tool** suitable for the speeds given in the table of cutting speeds for lathe work, is given in the following table for roughing cuts. The finishing cut should be as light as possible, with a broad advance or feed of cut.

Table 60.—Feed or Advance of Cut for Roughing Cuts in Lathe Work.

| Diameter of Work, in Inches. | Advance or Travel of the Tool to one Revolution of the Lathe Spindle. | | | | |
|---|---|---|---|---|---|
| | Wrought-Iron. | Cast-Iron. | Steel. | Brass. | Copper. |
| | Inch. | Inch. | Inch. | Inch. | Inch. |
| Under $1\frac{1}{4}$ inches . | $\frac{1}{32}$ | $\frac{1}{24}$ | $\frac{1}{40}$ | $\frac{1}{24}$ | $\frac{1}{24}$ |
| $1\frac{1}{4}$ to 2 " . | $\frac{1}{24}$ | $\frac{1}{20}$ | $\frac{1}{32}$ | $\frac{1}{24}$ | $\frac{1}{24}$ |
| $2\frac{1}{8}$ to $2\frac{7}{8}$ " . | $\frac{1}{20}$ | $\frac{1}{18}$ | $\frac{1}{24}$ | $\frac{1}{24}$ | $\frac{1}{24}$ |
| 3 to $5\frac{7}{8}$ " . | $\frac{1}{16}$ | $\frac{1}{14}$ | $\frac{1}{20}$ | $\frac{1}{24}$ | $\frac{1}{24}$ |
| 6 to 12 " . | $\frac{1}{10}$ | $\frac{1}{8}$ | $\frac{1}{18}$ | $\frac{1}{24}$ | $\frac{1}{24}$ |
| 13 and upwards . | $\frac{1}{8}$ | $\frac{1}{7}$ | $\frac{1}{16}$ | $\frac{1}{24}$ | $\frac{1}{24}$ |

As each revolution of the lathe moves the tool forward the portion of an inch given in this table, a 3-inch shaft making 25 revolutions per minute would be turned with a rough cut at the rate of $\frac{25 \text{ revolutions}}{16 \text{ advance}} = 1\frac{9}{16}$ inch in length per minute.

The feed or advance of the tool of a planing machine should be 14 or 12 cuts per inch for roughing cuts, and the finishing cuts should be done with a broad tool having an advance for each cut of from $\frac{1}{4}$ to $\frac{3}{8}$ inch.

Speed of circular saws for cutting metal, for brass 350 lineal feet per minute, for cast-iron 190 feet per minute, for wrought-iron 150 lineal feet per minute.

**The speed per square foot of surface at which metals can be cut,** depends greatly upon the efficiency and rigidity of the machine tools, as well as upon the softness and quality of the metal; some iron is very scaly and dirty, and soon blunts the tool. In the following table is given the time required to finish work, including one roughing cut and one finishing cut, the average of a great quantity of work done by ordinary good tools: the finishing cut being light with a broad advance.

**Lathe Centres.**—The usual angle for lathe centres is 60°; but for heavy work a more durable angle is 75°. For heavy work the centre should have a small hole bored up its centre, and another hole drilled at right angles to meet it, by which means the bearing surfaces can be properly oiled without stopping the lathe.

**Cutting Angle of Lathe Tools.**—The cutting angle best adapted for turning tools for soft wood is 30°, for hard wood 40°, for wrought-iron and steel 60°, for cast-iron 70°, for brass 80°, for very hard metals 84°, for gun metal 85°, for hard brass and hard gun metal 90°, and for chilled rolls 90°.

The angle of clearance of these tools is 3°.

Table 61.—WORK DONE BY PLANING, SHAPING, SLOTTING, DRILLING, AND BORING MACHINES AND LATHES.

| Description of Work. | ft. | in. | | Time required for 2 Cuts, viz., 1 Roughing and 1 Finishing Cut, to Finish 1 Square Foot. Hrs. | Min. | Description of Work. | Time required for 2 Cuts, viz., 1 Roughing and 1 Finishing Cut. Hrs. | Min. |
|---|---|---|---|---|---|---|---|---|
| Planing cast iron work | 1 | 6 | long | 1 | 0 | Boring 6 inch diameter holes in cast iron, per square foot | 1 | 0 |
| Ditto ditto | 2 | 6 | ,, | 0 | 40 | Turning 1 ft. length of wrought iron shaft, 1 in. diameter | 0 | 13 |
| Ditto ditto | 4 | 0 | ,, | 0 | 35 | Ditto ditto ditto 1½ ,, | 0 | 14 |
| Ditto ditto | 5 | 0 | ,, | 0 | 30 | Ditto ditto ditto 2 ,, | 0 | 17 |
| Ditto ditto | 8 | 0 | ,, | 0 | 25 | Ditto ditto ditto 2½ ,, | 0 | 18 |
| Ditto ditto | 16 | 0 | ,, | 0 | 20 | Ditto ditto ditto 3 ,, | 0 | 20 |
| Shaping cast iron work | 0 | 3 | ,, | 3 | 0 | Ditto ditto ditto 3½ ,, | 0 | 22 |
| Ditto ditto | 0 | 4 | ,, | 2 | 30 | Ditto ditto ditto 4 ,, | 0 | 25 |
| Ditto ditto | 0 | 6 | ,, | 2 | 0 | Ditto ditto ditto 5 ,, | 0 | 28 |
| Ditto ditto | 0 | 9 | ,, | 1 | 50 | Ditto ditto ditto 6 ,, | 0 | 30 |
| Ditto ditto | 1 | 0 | ,, | 1 | 40 | Ditto ditto ditto 7 ,, | 0 | 32 |
| Ditto ditto | 1 | 3 | ,, | 1 | 25 | Ditto ditto ditto 8 ,, | 0 | 35 |
| Ditto ditto | 1 | 8 | ,, | 1 | 10 | Ditto ditto ditto 9 ,, | 0 | 40 |
| Slotting cast iron work | 0 | 3 | deep | 3 | 30 | Ditto ditto ditto 10 ,, | 0 | 45 |
| Ditto ditto | 0 | 4 | ,, | 3 | 0 | Ditto ditto ditto 11 ,, | 0 | 52 |
| Ditto ditto | 0 | 6 | ,, | 2 | 30 | Ditto ditto ditto 12 ,, | 1 | 0 |
| Ditto ditto | 0 | 9 | ,, | 2 | 15 | Turning 1 foot in length of round steel, 2 inch diameter | 0 | 25 |
| Ditto ditto | 1 | 0 | ,, | 2 | 0 | Turning 1 foot in length of round brass, 2 inch diameter | 0 | 10 |
| Ditto ditto | 1 | 3 | ,, | 1 | 50 | Surfacing a flat cast-iron plate, per square foot | 0 | 16 |
| Ditto ditto | 1 | 6 | ,, | 1 | 40 | Surfacing a flat wrought-iron plate, per square foot | 0 | 12 |
| Slot drilling keyway, 6 inches long × ¾ × ⅜ inch | | | | 0 | 40 | Surfacing a flat steel plate, per square foot | 0 | 20 |
| Ditto ditto 9 ditto × 1 × 1½ inch | | | | 1 | 0 | Surfacing a flat brass plate, per square foot | 0 | 10 |
| Planing keyway, 4 feet long × ¾ inch wide × ⅜ inch deep | | | | 2 | 0 | Turning pulleys from 2 to 4 feet diameter, per square foot | 0 | 25 |
| Screwing machine, screwing ½ inch iron, 1 foot long | | | | 0 | 3 | Turning pulleys from 5 to 8 feet diameter, per square foot | 0 | 20 |
| Screwing 1 inch iron, 1 foot long | | | | 0 | 4 | Turning small fly-wheels from 3 to 6 feet diameter, per square foot | 0 | 15 |
| Tapping 1 gross ½ inch nuts | | | | 0 | 30 | Turning fly-wheels from 7 to 12 ft. diameter, per square foot | 0 | 12 |
| Tapping 1 gross 1 inch nnts | | | | 1 | 0 | Turning hard cast iron rolls, per square foot | 1 | 0 |
| Dilling 1 inch diameter holes in cast-iron, per square foot | | | | 1 | 30 | | | |

NOTE.—The time given includes the time occupied in setting the work.

## SPEED FOR WOOD-WORKING MACHINERY, &c.

Table 62.—Speed for Circular Saws.

| Diameter of Saw. | Number of Revolutions per Minute. | Diameter of Saw. | Number of Revolutions per Minute. | Diameter of Saw. | Number of Revolutions per Minute. | Diameter of Saw. | Number of Revolutions per Minute. |
|---|---|---|---|---|---|---|---|
| Inches. | | Inches. | | Inches. | | Inches. | |
| 10 | 3500 | 24 | 1500 | 38 | 920 | 54 | 600 |
| 12 | 3000 | 26 | 1300 | 40 | 870 | 56 | 580 |
| 14 | 2500 | 28 | 1200 | 42 | 830 | 58 | 560 |
| 16 | 2200 | 30 | 1150 | 44 | 800 | 60 | 540 |
| 18 | 2000 | 32 | 1100 | 48 | 700 | 62 | 520 |
| 20 | 1800 | 34 | 1050 | 50 | 670 | 64 | 500 |
| 22 | 1600 | 36 | 1000 | 52 | 640 | 66 | 480 |

Table 63.—Speed and Horse-Power required to drive Wood-working Machinery.

| Description of Machinery. | Number of Revolutions per Minute. | Horse Power required to drive it. |
|---|---|---|
| Circular saw bench. Size of saw, 14 in. diameter | 2500 | 1 |
| Ditto ditto 24 " | 1500 | 2 |
| Ditto ditto 30 " | 1150 | 3 |
| Ditto ditto 36 " | 1000 | 4 |
| Ditto ditto 42 " | 830 | 5 |
| Ditto ditto 48 " | 700 | 6 |
| Band saws. Diameter of saw pulleys, 24 inches . | 500 | $\frac{1}{2}$ |
| Ditto ditto 30 " | 450 | $\frac{3}{4}$ |
| Ditto ditto 36 " | 400 | 1 |
| Ditto ditto 42 " | 350 | $1\frac{1}{2}$ |
| Vertical timber frame to saw 12 in. logs. Speed of crank shaft | 180 | 3 |
| Ditto ditto 18 ditto " | 160 | 4 |
| Ditto ditto 24 ditto " | 140 | 5 |
| Ditto ditto 30 ditto " | 130 | 7 |
| Double deal frame for deals 11 × 3 in. " | 400 | 4 |
| Ditto ditto 14 × 4 " " | 350 | 5 |
| Ditto ditto 18 × 4 " " | 300 | 7 |
| Single deal frame for deals 11 × 3 " " | 400 | 2 |
| Ditto ditto 14 × 4 " " | 350 | 3 |
| General joiner . . . . . . . . | 1500 | 3 |
| Boring, chamfering, and shaping machine. Speed | 4000 | $\frac{1}{2}$ |
| Planing and moulding machine . . . . . | 5000 | |
| Rate of feed for planing and moulding machine, 20 to 30 feet per minute. | | |
| Angle of plane and moulding irons, 25° for soft wood; 35° for hard wood. | | |
| Breaking strain of band saws = 176 lbs. for each $\frac{1}{16}$ inch width of blade. | | |

Table 64.—Speed of Grindstones for Grinding Tools, &c.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of the grindstone, in inches . . . . . | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 |
| Number of revolutions of the stone per minute . . . | 130 | 106 | 88 | 75 | 66 | 58 | 52 | 48 | 44 | 40 | 37 | 35 | 33 |

## SPEED AND PROPORTIONS OF FANS.

Speed of fan for smithy fires 185, and for a cupola 270 feet per second of circumference.

Fan blades = $\frac{1}{4}$ diameter of fan each way.

Inlet = $\frac{1}{2}$ diameter of fan.

Outlet = area of blades.

Length of neck of spindle = $4\frac{1}{2}$ times the diameter of the spindle.

To find the horse-power required for a fan.—*Rule:* Divide the square of the velocity of the tips of fan in feet per second by 1000, and multiply the result by the density of the blast in ounces per inch, which product multiply by the area of discharge at the tuyeres in square inches, and divide the result by 963.

To find the density of fan blast in ounces per inch.—*Rule:* Divide the velocity in feet per second of the circumference by 4, square the result, and next divide by the product of the diameter of fan in feet by 120.

## WHEEL CUTTING.

**The Dividing Wheel** on the mandrel of a wheel-cutting machine, is a worm-wheel, having usually 180 teeth; the change-wheel on the end of the worm-shaft is called the tangent-wheel, which is geared with an intermediate wheel or wheels, to the wheel on the end of the division-plate shaft. When convenient, the tangent-wheel should have the same number of teeth as that of the wheel to be cut, and the wheel on the division-plate shaft should have half the number of that of the dividing wheel, then two turns of the handle if the worm has a single thread, and one turn if it has a double thread, will give the required number of teeth to be cut. When this arrangement is not convenient, the change wheels may be found thus. Find the ratio between the number of teeth in the wheel to be cut, and that of the dividing wheel, which may be divided by any suitable number, when the numerator will represent the driver or division-plate wheel, and the denominator the driven or tangent-wheel. Thus, to cut a wheel with 90 teeth $\frac{180 \text{ dividing wheel } \div 2}{90 \text{ wheel to be cut } \div 2} = \frac{90}{45}$ the wheels required, with one turn of the handle if a single-thread worm, or with half a turn if the worm has a double-thread.

Table 65.—Table of Change Wheels for a Wheel-Cutting Machine having a Dividing Wheel with 180 teeth.

| Number of Teeth to be Cut. | Number of Turns of the Handle. | Wheel on Division Plate Shaft. | Tangent Wheel on Worm Shaft. | Number of Teeth to be Cut. | Number of Turns of the Handle. | Wheel on Division Plate Shaft. | Tangent Wheel on Worm Shaft. | Number of Teeth to be Cut. | Number of Turns of the Handle. | Wheel on Division Plate Shaft. | Tangent Wheel on Worm Shaft. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 4 | 90 | 20 | 53 | 2 | 90 | 53 | 96 | 1 | 90 | 48 |
| 11 | 4 | 90 | 22 | 54 | 2 | 90 | 54 | 97 | 2 | 90 | 97 |
| 12 | 4 | 75 | 20 | 55 | 2 | 90 | 55 | 98 | 1 | 90 | 49 |
| 13 | 4 | 90 | 26 | 56 | 2 | 90 | 56 | 99 | 2 | 90 | 99 |
| 14 | 4 | 90 | 28 | 57 | 2 | 90 | 57 | 100 | 1 | 90 | 50 |
| 15 | 4 | 60 | 20 | 58 | 2 | 90 | 58 | 101 | 2 | 90 | 101 |
| 16 | 4 | 90 | 32 | 59 | 2 | 90 | 59 | 102 | 1 | 60 | 34 |
| 17 | 4 | 90 | 34 | 60 | 2 | 90 | 60 | 103 | 2 | 90 | 103 |
| 18 | 4 | 50 | 20 | 61 | 2 | 90 | 61 | 104 | 1 | 45 | 46 |
| 19 | 4 | 90 | 38 | 62 | 2 | 90 | 62 | 105 | 1 | 60 | 35 |
| 20 | 4 | 45 | 20 | 63 | 2 | 90 | 63 | 106 | 1 | 90 | 53 |
| 21 | 4 | 90 | 42 | 64 | 2 | 90 | 64 | 107 | 2 | 90 | 107 |
| 22 | 4 | 90 | 44 | 65 | 2 | 90 | 65 | 108 | 1 | 60 | 36 |
| 23 | 4 | 90 | 46 | 66 | 2 | 90 | 66 | 109 | 2 | 90 | 109 |
| 24 | 4 | 30 | 16 | 67 | 2 | 90 | 67 | 110 | 1 | 90 | 55 |
| 25 | 4 | 45 | 25 | 68 | 2 | 90 | 68 | 111 | 1 | 60 | 37 |
| 26 | 4 | 90 | 52 | 69 | 2 | 90 | 69 | 112 | 1 | 90 | 56 |
| 27 | 4 | 40 | 24 | 70 | 2 | 90 | 70 | 113 | 2 | 90 | 113 |
| 28 | 4 | 45 | 28 | 71 | 2 | 90 | 71 | 114 | 1 | 90 | 57 |
| 29 | 4 | 90 | 58 | 72 | 2 | 90 | 72 | 115 | 2 | 90 | 115 |
| 30 | 4 | 60 | 40 | 73 | 2 | 90 | 73 | 116 | 1 | 90 | 58 |
| 31 | 4 | 90 | 62 | 74 | 2 | 90 | 74 | 117 | 1 | 60 | 39 |
| 32 | 4 | 90 | 64 | 75 | 2 | 90 | 75 | 118 | 1 | 90 | 59 |
| 33 | 2 | 90 | 33 | 76 | 2 | 90 | 76 | 119 | 2 | 90 | 119 |
| 34 | 2 | 90 | 34 | 77 | 2 | 90 | 77 | 120 | 1 | 90 | 60 |
| 35 | 2 | 90 | 35 | 78 | 2 | 90 | 78 | 121 | 2 | 90 | 121 |
| 36 | 2 | 90 | 36 | 79 | 2 | 90 | 79 | 122 | 1 | 90 | 61 |
| 37 | 2 | 90 | 37 | 80 | 2 | 90 | 80 | 123 | 1 | 120 | 82 |
| 38 | 2 | 90 | 38 | 81 | 2 | 90 | 81 | 124 | 1 | 45 | 31 |
| 39 | 2 | 90 | 39 | 82 | 2 | 90 | 82 | 125 | 1 | 72 | 50 |
| 40 | 2 | 90 | 40 | 83 | 2 | 90 | 83 | 126 | 1 | 60 | 42 |
| 41 | 2 | 90 | 41 | 84 | 2 | 90 | 84 | 127 | 2 | 90 | 127 |
| 42 | 2 | 90 | 42 | 85 | 2 | 90 | 85 | 128 | 1 | 45 | 32 |
| 43 | 2 | 90 | 43 | 86 | 2 | 90 | 86 | 129 | 1 | 60 | 43 |
| 44 | 2 | 90 | 44 | 87 | 2 | 90 | 87 | 130 | 1 | 90 | 65 |
| 45 | 2 | 90 | 45 | 88 | 2 | 90 | 88 | 131 | 2 | 90 | 131 |
| 46 | 2 | 90 | 46 | 89 | 2 | 90 | 89 | 132 | 1 | 45 | 33 |
| 47 | 2 | 90 | 47 | 90 | 1 | 90 | 45 | 133 | 2 | 90 | 133 |
| 48 | 2 | 90 | 48 | 91 | 2 | 90 | 91 | 134 | 1 | 90 | 67 |
| 49 | 2 | 90 | 49 | 92 | 2 | 90 | 92 | 135 | 1 | 60 | 45 |
| 50 | 2 | 90 | 50 | 93 | 2 | 90 | 93 | 136 | 1 | 45 | 34 |
| 51 | 2 | 90 | 51 | 94 | 1 | 90 | 47 | 137 | 2 | 90 | 137 |
| 52 | 2 | 90 | 52 | 95 | 1 | 72 | 38 | 138 | 1 | 60 | 46 |

Table 65 *continued*.—TABLE OF CHANGE WHEELS.

| Number of Teeth to be Cut. | Number of Turns of the Handle. | Wheel on Division Plate Shaft. | Tangent Wheel on Worm Shaft. | Number of Teeth to be Cut. | Number of Turns of the Handle. | Wheel on Division Plate Shaft. | Tangent Wheel on Worm Shaft. | Number of Teeth to be Cut. | Number of Turns of the Handle. | Wheel on Division Plate Shaft. | Tangent Wheel on Worm Shaft. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 139 | 2 | 90 | 139 | 164 | 1 | 45 | 41 | 189 | 1 | 60 | 63 |
| 140 | 1 | 45 | 35 | 165 | 1 | 60 | 55 | 190 | 1 | 90 | 95 |
| 141 | 2 | 90 | 141 | 166 | 1 | 90 | 83 | 191 | 2 | 90 | 191 |
| 142 | 1 | 90 | 71 | 167 | 2 | 90 | 167 | 192 | 1 | 30 | 32 |
| 143 | 2 | 90 | 143 | 168 | 1 | 45 | 42 | 193 | 2 | 90 | 193 |
| 144 | 1 | 45 | 36 | 169 | 2 | 90 | 169 | 194 | 1 | 90 | 97 |
| 145 | 1 | 72 | 58 | 170 | 1 | 90 | 85 | 195 | 1 | 60 | 65 |
| 146 | 1 | 90 | 73 | 171 | 1 | 60 | 57 | 196 | 1 | 90 | 98 |
| 147 | 1 | 60 | 49 | 172 | 1 | 45 | 43 | 197 | 2 | 90 | 197 |
| 148 | 1 | 45 | 37 | 173 | 2 | 90 | 173 | 198 | 1 | 90 | 99 |
| 149 | 2 | 90 | 149 | 174 | 1 | 60 | 58 | 199 | 2 | 90 | 199 |
| 150 | 1 | 60 | 50 | 175 | 1 | 36 | 35 | 200 | 1 | 45 | 50 |
| 151 | 2 | 90 | 151 | 176 | 1 | 90 | 88 | 201 | 1 | 60 | 67 |
| 152 | 1 | 45 | 38 | 177 | 1 | 60 | 59 | 202 | 1 | 90 | 101 |
| 153 | 1 | 60 | 51 | 178 | 1 | 90 | 89 | 204 | 1 | 60 | 68 |
| 154 | 1 | 90 | 77 | 179 | 2 | 90 | 179 | 205 | 1 | 36 | 41 |
| 155 | 1 | 36 | 31 | 180 | 1 | 90 | 90 | 206 | 1 | 90 | 103 |
| 156 | 1 | 45 | 39 | 181 | 2 | 90 | 181 | 207 | 1 | 60 | 69 |
| 157 | 2 | 90 | 157 | 182 | 1 | 90 | 91 | 210 | 1 | 60 | 70 |
| 158 | 1 | 90 | 79 | 183 | 1 | 60 | 61 | 212 | 1 | 45 | 53 |
| 159 | 1 | 60 | 53 | 184 | 1 | 45 | 46 | 213 | 1 | 60 | 71 |
| 160 | 1 | 90 | 80 | 185 | 1 | 36 | 37 | 214 | 1 | 90 | 107 |
| 161 | 2 | 90 | 161 | 186 | 1 | 90 | 93 | 215 | 1 | 36 | 43 |
| 162 | 1 | 90 | 81 | 187 | 2 | 90 | 187 | 218 | 1 | 90 | 109 |
| 163 | 2 | 90 | 163 | 188 | 1 | 45 | 47 | 220 | 1 | 36 | 44 |

*Rule* to prove the correctness of change wheels for the above wheel-cutting machine:—

Divide the number of teeth in the wheel on the division-plate shaft, by the number of teeth in the wheel on the worm-shaft; multiply the quotient by the number of turns of the handle, and the product will be equal to the quotient of the number of teeth in the dividing wheel divided by the number of teeth in the wheel to be cut.

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## SCREW-CUTTING.

**A Single Train** of change wheels for screw-cutting consists of 3 wheels:—viz., 1 wheel on the lathe-spindle, called the driver; 1 wheel on the lathe's leading screw called the driven wheel, and one intermediate wheel to connect these two wheels, called the stud-wheel. In a double train, 4 wheels are used: a stud-pinion gearing into the leading screw-wheel, being keyed on the same socket as the stud-wheel. The wheel on the lathe-spindle is the first driver, the stud-pinion is the second driver, the stud-wheel is the first driven wheel, and the leading screw-wheel is the second driven wheel.

**The Number of Teeth** in the change-wheels must have the same proportion as the number of threads per inch of the leading screw has to the number of threads per inch of the screw to be cut. Thus, to cut a screw of 8 threads per inch with a leading screw of 2 threads, wheels are required in the ratio of 4 to 1; say a wheel with 20 teeth on the lathe spindle, and a wheel with 80 teeth on the leading screw, connected with an intermediate wheel. When the number of threads to be cut does not exceed 12 per inch, a single train of wheels can be used. To cut a screw of a finer pitch than the leading screw, the following rules will give the required wheels:—

*Rule* 1. Place the number of threads per inch of the leading screw for a numerator, and the number of threads per inch of the screw to be cut for a denominator, then add a cipher to each, which will give the required change wheels. Thus, to cut a screw of 8 threads per inch, with a leading screw of 2 threads per inch:—$\frac{\text{2 threads in leading screw}}{\text{8 threads in screw to be cut}}$; adding a cipher = $\frac{\text{20 driver}}{\text{80 driven}}$.

The wheel representing the numerator is placed on the lathe-spindle, and the wheel representing the denominator on the leading screw.

*Rule* 2. When the number of threads to be cut is uneven: say $2\frac{3}{4}$ threads per inch, multiply the whole number by the denominator of the fraction; and multiply also the number of threads per inch of the leading screw by the same multiplier: $\frac{\text{2 threads per inch in leading screw} \times 4}{2\frac{3}{4}\text{ threads per inch in screw to be cut} \times 4}$ $= \frac{8}{11}$. Add a cipher $= \frac{\text{80 driver}}{\text{110 driven}}$.

When the numbers of teeth of wheels as found by this rule are too large, they may be reduced by dividing them by any suitable common divisor; and, if too small, they may be increased by multiplying them by any suitable common multiplier.

**When a double train**, or 4 change-wheels, are used, fix upon any 3 wheels for the lathe-spindle and stud-wheels, and the fourth or leading screw wheel may be found by the following rule.

*Rule* 3. Multiply the number of teeth in the wheel on the lathe-spindle by the ratio of the screw to be cut and the leading screw; and by the number of teeth in the second driver or stud-pinion; and divide the product by the number of teeth in the first driven wheel. Thus, to cut a screw of 16 threads per inch with a leading screw of 2 per inch, the ratio is 8 to 1. Lathe-spindle wheel 20 teeth, stud-pinion or second driver 50 teeth, stud-wheel or first driven wheel 80 teeth; required the number of teeth in the leading-screw wheel. $\frac{20 \times 8 \times 50}{80} = 100$ teeth. The above arrangement will cut a right-hand thread.

**To cut a left-hand thread,** place another wheel between a driver and a driven wheel to reverse the motion of the saddle.

*Rule* 4. The wheels may also be found by assuming a pair of wheels in conjunction with Rule 1, say $\frac{100}{100}$, and by dividing one of the drivers and one of the driven wheels by any suitable number. Thus, to take the screws in the last example $\frac{2}{16}$, add a cypher, $\frac{20 \text{ driver}}{160 \text{ driven}}$. Assume a pair of wheels, $\frac{100 \text{ driver}}{100 \text{ driven}}$, then by dividing the first driven wheel and the second driver by two, the required wheels are: $\frac{20 \quad 50 \text{ driver}}{80 \quad 100 \text{ driven}}$.

*Rule* 5. To prove the correctness of the change-wheels when the screw to be cut is of finer pitch than the leading screw, multiply the driving wheels together, and multiply the driven wheels together; and divide the greater product by the less. The quotient multiplied by the number of threads per inch of the leading screw, will give the number of threads per inch of the screw to be cut. To prove the wheels in the last example, $\frac{80 \times 100}{20 \times 50} = 8 \times 2 = 16$ threads per inch in the screw to be cut.

**To Cut Coarse-Pitch Screws.**—To find the change-wheels to cut a screw of coarser pitch than the leading screw, it is necessary to assume as many pairs of wheels as will sufficiently reduce the size of the first driver, the ratio of the wheels being the numerator (instead of the denominator as used for pitches finer than the leading screw in the above rules) in coarse pitches. *Rule,* multiply the pitch in inches of the screw to be cut, by the number of threads per inch of the leading screw, which will give the number of threads of the leading screw, in a length equal to the pitch to be cut, and therefore the ratio of the wheels required to cut the pitch. Thus, to cut a screw of 20-inch pitch with a leading screw of 2 threads per inch, $20 \times 2 = \frac{40}{1}$ the ratio required, the denominator must be increased by multiplying it by some suitable number to obtain a wheel of proper size, and the numerator must be increased in the same proportion, say 20, then, $\frac{40 \times 20}{1 \times 20} = \frac{800 \text{ first driver}}{20 \text{ first driven}}$. If two pairs of wheels are assumed, it will stand thus: $\frac{800 \text{ first driver},}{20 \text{ first driven},} \frac{100 \text{ second driver},}{100 \text{ second driven},} \frac{100 \text{ third driver}}{100 \text{ third driven}}$; to reduce the size of the first driver, divide the first driver and second driven by four, which will give wheels $\frac{200}{20}$, $\frac{100}{25}$, $\frac{100}{100}$; and to still further reduce the size of the first driver, divide the first driver and last driven by four, which will give $\frac{50}{20}, \frac{100}{25}, \frac{100 \text{ drivers}}{25 \text{ driven}}$, the wheels required.

*Rule,* to prove the correctness of the change-wheels for coarse-pitch screws, the screw to be cut being coarser in pitch than the leading screw. Multiply the driving wheels together, then multiply the driven wheels together, and multiply the product of the driven wheels by the number of threads per inch of the screw, with which product divide the product of the driving wheels. Thus, to prove the wheels in the last example:—

$\frac{50 \times 100 = 100}{20 \times 25 \times 25 \times 2} = \frac{500000}{25000} = 20$ inches pitch.

**To Cut French Millimetre Pitches of Screws.**—One millimetre pitch is the $\frac{1}{1000}$ part of a metre. One metre is approximately $39\frac{3}{8}$ inches, and a leading screw of $\frac{1}{2}$-inch pitch, or two threads per inch, has $39\frac{3}{8} \times 2 = 78{\cdot}75$ threads in one metre of its length; hence the proportion is $\frac{78{\cdot}75}{1000}$, which, if reduced by, say, multiplying by ·8, gives $\frac{78{\cdot}75 \times {\cdot}8}{1000 \times {\cdot}8} = \frac{63}{800}$, and the numerator 63 is a constant number, by which the number of millimetres, in the pitch of the screw to be cut, is to be multiplied.

Example:—To find the change wheels to cut a pitch of 8 millimetres, with the above leading screw: $8 \times 63 = 504$, then $\frac{504}{800}$ resolved into fractions becomes $\frac{63 \times 8}{80 \times 10}$ and by adding a cypher to the number 8 and another to the number 10, the required wheels to cut 8 millimetres pitch, are $\frac{63 \times 80 \text{ drivers}}{100 \times 80 \text{ driven}}$.

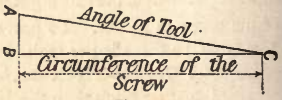

Fig. 47.

**To find the angle to be given to a tool** in order to cut a square-thread screw without injury to the sides of the threads. In Fig. 47, draw the line AB, equal to the pitch of the screw; draw the perpendicular line BC, equal to the circumference of the screw, then draw the line AC, which gives the angle of the screw-cutting tool.

**Price of Machined-Work, &c.**—The price charged per hour for the use of machine-tools,—workmen's wages and trade expenses being covered by the charge—is usually as follows, viz.:—

Grindstones, 1*s*. 3*d*. per hour.—Emery Wheels, 1*s*. 6*d*.—Glaziers, 2*s*. 0*d*.—Lathes, 6 to 8 inch Centre, 1*s*. 6*d*.: 9 to 12 inch, 2*s*. 0*d*.: 13 to 16 inch, 2*s*. 6*d*.: 17 to 22 inch, 3*s*.: 24 to 30 inch, 4*s*.—Surfacing Lathe, medium sized, 4*s*.: large, 5*s*.—Planing Machines, $1\frac{1}{2}$ to $2\frac{1}{2}$ feet wide, 2*s*.: 3 to 4 feet wide, 3*s*.: $4\frac{1}{2}$ to $5\frac{1}{2}$ feet wide, 4*s*.: 6 to 8 feet wide, 5*s*.—Shaping and Slotting Machines, 4 to 6 inch Stroke, 1*s*. 6*d*.: 8 to 12 inch Stroke, 2*s*.: 13 to 15 inch Stroke, 2*s*. 6*d*.: 16 to 18 inch Stroke, 3*s*.: 20 to 24 inch Stroke, 4*s*.—Vertical Drilling Machine, small, 1*s*. 6*d*.: medium sized, 2*s*.: large, 3*s*. 6*d*.—Radial Drilling Machine, small, 2*s*.: large, 3*s*. 6*d*.—Cylinder Boring Machine, small, 2*s*. 6*d*.: medium size, 4*s*.—Slot Drilling Machines, 2*s*.—Screwing Machine, up to $1\frac{1}{2}$ inches, 2*s*.: up to 2 inches, 2*s*. 6*d*.—Milling Machine, 2*s*. 6*d*.—Wheel-Cutting Machine, 3*s*.—The price of Fitters' Best Work per day is equal to double the wages for ordinary work; $2\frac{1}{2}$ times for special or intricate work; and 3 times the wages for very exact work. Planing work per square foot, for large flat work, 4*s*.: for small ditto, 6*s*.: 5*s*. for angles; and 6*s*. for undercut work. Turning work per square foot for large plain turning and surfacing work = the same prices as for planing.

Table 66.—Change Wheels for Screw-cutting. Leading Screw, 2 Threads per Inch.

| Number of Threads in One Inch to be cut. | Drivers. | | Driven. | | Number of Threads in One Inch to be cut. | Drivers. | | Driven. | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 40 | ... | 20 | ... | 4¾ | 40 | ... | 95 | ... |
| | 80 | ... | 40 | ... | | 20 | 100 | 50 | 95 |
| | 50 | 90 | 30 | 75 | | 30 | 100 | 75 | 95 |
| 1¼ | 40 | ... | 25 | ... | 5 | 20 | ... | 50 | ... |
| | 80 | ... | 50 | ... | | 30 | ... | 75 | ... |
| | 40 | 80 | 20 | 100 | | 50 | 60 | 75 | 100 |
| 1½ | 60 | ... | 45 | ... | 5¼ | 40 | ... | 105 | ... |
| | 80 | ... | 60 | ... | | 20 | 80 | 60 | 70 |
| | 40 | 60 | 20 | 90 | | 40 | 60 | 70 | 90 |
| 1¾ | 40 | ... | 35 | ... | 5½ | 20 | ... | 55 | ... |
| | 80 | ... | 70 | ... | | 40 | ... | 110 | ... |
| | 60 | 40 | 30 | 70 | | 20 | 60 | 30 | 110 |
| 2 | 20 | ... | 20 | ... | 5¾ | 40 | ... | 115 | ... |
| | 90 | ... | 90 | ... | | 20 | 40 | 20 | 115 |
| | 30 | 80 | 40 | 60 | | 20 | 60 | 30 | 115 |
| 2¼ | 40 | ... | 45 | ... | 6 | 20 | ... | 60 | ... |
| | 80 | ... | 90 | ... | | 30 | ... | 90 | ... |
| | 40 | 100 | 50 | 90 | | 30 | 50 | 60 | 75 |
| 2½ | 40 | ... | 50 | ... | 6¼ | 40 | ... | 125 | ... |
| | 60 | ... | 75 | ... | | 20 | 60 | 50 | 75 |
| | 30 | 80 | 50 | 60 | | 40 | 60 | 75 | 100 |
| 2¾ | 40 | ... | 55 | ... | 6½ | 20 | ... | 65 | ... |
| | 80 | ... | 110 | ... | | 40 | ... | 130 | ... |
| | 40 | 100 | 50 | 110 | | 40 | 60 | 65 | 120 |
| 3 | 30 | ... | 45 | ... | 6¾ | 40 | ... | 135 | ... |
| | 40 | ... | 60 | ... | | 20 | 40 | 30 | 90 |
| | 30 | 80 | 40 | 90 | | 40 | 80 | 90 | 120 |
| 3¼ | 40 | ... | 65 | ... | 7 | 20 | ... | 70 | ... |
| | 80 | ... | 130 | ... | | 30 | 40 | 60 | 70 |
| | 60 | 80 | 65 | 120 | | 40 | 45 | 70 | 90 |
| 3½ | 40 | ... | 70 | ... | 7¼ | 40 | ... | 145 | ... |
| | 60 | ... | 105 | ... | | 20 | 80 | 40 | 145 |
| | 50 | 60 | 70 | 75 | | 30 | 60 | 45 | 145 |
| 3¾ | 40 | ... | 75 | ... | 7½ | 20 | ... | 75 | ... |
| | 60 | 80 | 90 | 100 | | 30 | 60 | 75 | 90 |
| | 40 | 60 | 45 | 100 | | 30 | 80 | 90 | 100 |
| 4 | 20 | ... | 40 | ... | 7¾ | 40 | ... | 155 | ... |
| | 40 | ... | 80 | ... | | 50 | 60 | 75 | 155 |
| | 30 | 80 | 40 | 120 | | 30 | 60 | 45 | 155 |
| 4¼ | 40 | ... | 85 | ... | 8 | 20 | ... | 80 | ... |
| | 20 | 80 | 40 | 85 | | 25 | ... | 100 | ... |
| | 30 | 80 | 60 | 85 | | 20 | 60 | 40 | 120 |
| 4½ | 20 | ... | 45 | ... | 8¼ | 20 | 80 | 60 | 110 |
| | 40 | ... | 90 | ... | | 20 | 40 | 30 | 110 |
| | 30 | 60 | 45 | 90 | | 20 | 60 | 55 | 90 |

TABLE 66 *continued.*—CHANGE WHEELS FOR SCREW-CUTTING. LEADING SCREW, 2 THREADS PER INCH.

| Number of Threads in One Inch to be cut. | Drivers. | | Driven. | | Number of Threads in One Inch to be cut. | Drivers. | | Driven. | |
|---|---|---|---|---|---|---|---|---|---|
| 8½ | 20 | ... | 85 | ... | 17 | 20 | 25 | 50 | 85 |
| | 30 | 50 | 75 | 85 | | 20 | 50 | 85 | 100 |
| | 40 | 50 | 85 | 100 | | 20 | 45 | 85 | 90 |
| 9 | 20 | ... | 90 | ... | 18 | 20 | 30 | 60 | 90 |
| | 20 | 80 | 60 | 120 | | 25 | 30 | 75 | 90 |
| | 30 | 80 | 90 | 120 | | 30 | 40 | 90 | 120 |
| 9½ | 20 | ... | 95 | ... | 19 | 20 | 30 | 60 | 95 |
| | 30 | 40 | 60 | 95 | | 25 | 30 | 75 | 95 |
| | 40 | 45 | 90 | 95 | | 30 | 40 | 95 | 120 |
| 10 | 20 | ... | 100 | ... | 20 | 20 | 25 | 50 | 100 |
| | 25 | ... | 125 | ... | | 20 | 30 | 60 | 100 |
| | 30 | 40 | 75 | 80 | | 20 | 60 | 100 | 120 |
| 10½ | 20 | ... | 105 | ... | 21 | 20 | 30 | 70 | 90 |
| | 20 | 40 | 60 | 70 | | 20 | 40 | 70 | 120 |
| | 30 | 40 | 70 | 90 | | 20 | 25 | 70 | 75 |
| 11 | 20 | ... | 110 | ... | 22 | 20 | 30 | 60 | 110 |
| | 20 | 30 | 55 | 60 | | 25 | 30 | 75 | 110 |
| | 20 | 45 | 55 | 90 | | 30 | 40 | 110 | 120 |
| 11½ | 20 | ... | 115 | ... | 23 | 20 | 25 | 50 | 115 |
| | 40 | 50 | 100 | 115 | | 25 | 30 | 75 | 115 |
| | 25 | 40 | 50 | 115 | | 20 | 30 | 60 | 115 |
| 12 | 20 | ... | 120 | ... | 24 | 20 | 25 | 75 | 80 |
| | 30 | 40 | 80 | 90 | | 20 | 30 | 80 | 90 |
| | 30 | 50 | 90 | 100 | | 20 | 40 | 80 | 120 |
| 12½ | 20 | ... | 125 | ... | 25 | 20 | 25 | 50 | 125 |
| | 20 | 60 | 75 | 100 | | 20 | 30 | 75 | 100 |
| | 20 | 40 | 50 | 100 | | 25 | 40 | 100 | 125 |
| 13 | 20 | 30 | 60 | 65 | 26 | 20 | 45 | 90 | 130 |
| | 20 | 45 | 65 | 90 | | 20 | 30 | 60 | 130 |
| | 25 | 40 | 65 | 100 | | 20 | 40 | 80 | 130 |
| 13½ | 20 | 40 | 60 | 90 | 27 | 20 | 40 | 90 | 120 |
| | 20 | 40 | 45 | 120 | | 20 | 25 | 75 | 90 |
| | 20 | 80 | 90 | 120 | | 25 | 30 | 75 | 135 |
| 14 | 20 | 25 | 50 | 70 | 28 | 20 | 30 | 70 | 120 |
| | 20 | 45 | 70 | 90 | | 20 | 25 | 70 | 100 |
| | 20 | 40 | 70 | 80 | | 25 | 30 | 100 | 105 |
| 14½ | 20 | ... | 145 | ... | 29 | 20 | 20 | 40 | 145 |
| | 20 | 30 | 30 | 145 | | 20 | 40 | 80 | 145 |
| | 30 | 40 | 60 | 145 | | 20 | 45 | 90 | 145 |
| 15 | 20 | ... | 150 | ... | 30 | 20 | 40 | 100 | 120 |
| | 20 | 40 | 50 | 120 | | 20 | 20 | 75 | 80 |
| | 30 | 40 | 75 | 120 | | 20 | 25 | 75 | 100 |
| 16 | 25 | 30 | 75 | 80 | 32 | 20 | 25 | 80 | 100 |
| | 20 | 50 | 80 | 100 | | 20 | 30 | 80 | 120 |
| | 20 | 75 | 120 | 100 | | 25 | 30 | 100 | 120 |

Table 67.—Change Wheels for Screw-cutting. Leading Screw, 3 Threads to the Inch.

| Number of Threads per Inch to be Cut. | Wheel on Mandrel. | Wheel on Leading Screw. | Number of Threads per Inch to be Cut. | Wheel on Mandrel. | Stud Wheel. | Pinion. | Wheel on Leading Screw. |
|---|---|---|---|---|---|---|---|
| 1 | 60 | 20 | 10½ | 20 | ... | ... | 70 |
| 1¼ | 60 | 25 | 11 | 30 | ... | ... | 110 |
| 1½ | 60 | 30 | 11½ | 30 | ... | ... | 115 |
| 1¾ | 60 | 35 | 12 | 20 | ... | ... | 80 |
| 2 | 60 | 40 | 12½ | 30 | ... | ... | 125 |
| 2¼ | 60 | 45 | 13 | 30 | ... | ... | 130 |
| 2½ | 60 | 50 | 13½ | 30 | ... | ... | 135 |
| 2¾ | 60 | 55 | 14 | 30 | 50 | 70 | 100 |
| 3 | 60 | 60 | 15 | 20 | ... | ... | 100 |
| 3¼ | 60 | 65 | 16 | 20 | 40 | 30 | 80 |
| 3½ | 60 | 70 | 17 | 20 | 40 | 30 | 85 |
| 3¾ | 60 | 75 | 18 | 20 | 40 | 20 | 60 |
| 4 | 30 | 40 | 19 | 20 | 40 | 30 | 95 |
| 4¼ | 60 | 85 | 20 | 20 | 50 | 30 | 80 |
| 4½ | 30 | 45 | 21 | 20 | 60 | 30 | 70 |
| 4¾ | 60 | 95 | 22 | 20 | 40 | 30 | 110 |
| 5 | 30 | 50 | 23 | 30 | 40 | 20 | 115 |
| 5¼ | 60 | 105 | 24 | 20 | 40 | 30 | 120 |
| 5½ | 30 | 55 | 25 | 20 | 50 | 30 | 100 |
| 5¾ | 60 | 115 | 26 | 20 | 65 | 30 | 80 |
| 6 | 30 | 60 | 27 | 20 | 60 | 30 | 90 |
| 6¼ | 60 | 125 | 28 | 20 | 70 | 30 | 80 |
| 6½ | 30 | 65 | 29 | 20 | 40 | 30 | 145 |
| 7 | 30 | 70 | 30 | 20 | 60 | 30 | 100 |
| 7½ | 30 | 75 | 32 | 25 | 80 | 30 | 100 |
| 8 | 30 | 80 | 34 | 30 | 60 | 15 | 85 |
| 8½ | 30 | 85 | 36 | 30 | 60 | 15 | 90 |
| 9 | 30 | 90 | 38 | 30 | 60 | 15 | 95 |
| 9½ | 30 | 95 | 40 | 30 | 60 | 15 | 100 |
| 10 | 30 | 100 | 48 | 20 | 80 | 25 | 100 |

**Whitworth's Standard Screw-Threads for Engineers' Taps.**—The change wheels for cutting these threads are given in Table 83, page 251; and the proportions of screws and bolts in Table 89, page 255.

**Whitworth's Standard Gas Screw-Threads,** for gas piping.—The change wheels for cutting these threads are given in Table 86, page 253.

**Whitworth's Standard Screw-Threads for Hydraulic Pipes,** and gas and water pipes—and the correct thickness of metal for these pipes—are given in Table 88, page 254.

**Whitworth's Standard Screw-Threads for Watch and Instrument Makers** are given in Table 90, page 256.

**Whitworth's Standard Sizes for Nuts and Bolt Heads** are given in Table 108, page 285.

Table 68.—Change Wheels for Screw-cutting. Leading Screw, 4 Threads to the Inch.

| Threads per Inch. | Wheel on Mandrel. | Wheel on Leading Screw. | Threads per Inch. | Wheel on Mandrel. | Wheel on Stud. | Pinion. | Leading Screw. | Threads per Inch. | Wheel on Mandrel. | Wheel on Stud. | Pinion. | Leading Screw. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 80 | 20 | 9 | 80 | 30 | 15 | 90 | 34 | 30 | 45 | 15 | 85 |
| $1\frac{1}{4}$ | 80 | 25 | 10 | 60 | 25 | 15 | 90 | 36 | 40 | 60 | 15 | 90 |
| $1\frac{1}{2}$ | 80 | 30 | 11 | 80 | 30 | 15 | 110 | 38 | 30 | 45 | 15 | 95 |
| $1\frac{3}{4}$ | 80 | 35 | 12 | 100 | 60 | 15 | 75 | 40 | 30 | 50 | 15 | 90 |
| 2 | 90 | 45 | 13 | 80 | 60 | 15 | 65 | 44 | 30 | 55 | 15 | 90 |
| $2\frac{1}{4}$ | 80 | 45 | 14 | 60 | 35 | 15 | 90 | 48 | 20 | 40 | 15 | 90 |
| $2\frac{1}{2}$ | 80 | 50 | 15 | 80 | 45 | 15 | 100 | 50 | 20 | 50 | 15 | 75 |
| $2\frac{3}{4}$ | 80 | 55 | 16 | 60 | 45 | 15 | 80 | 54 | 20 | 45 | 15 | 90 |
| 3 | 100 | 75 | 17 | 60 | 45 | 15 | 85 | 57 | 20 | 45 | 15 | 95 |
| $3\frac{1}{4}$ | 80 | 65 | 18 | 80 | 60 | 15 | 90 | 60 | 20 | 50 | 15 | 90 |
| $3\frac{1}{2}$ | 80 | 70 | 19 | 80 | 60 | 15 | 95 | 66 | 20 | 55 | 15 | 90 |
| $3\frac{3}{4}$ | 80 | 75 | 20 | 60 | 45 | 15 | 100 | 70 | 20 | 70 | 15 | 75 |
| 4 | 90 | 90 | 21 | 40 | 45 | 15 | 70 | 76 | 30 | 90 | 15 | 95 |
| $4\frac{1}{4}$ | 80 | 85 | 22 | 60 | 45 | 15 | 110 | 80 | 30 | 90 | 15 | 100 |
| $4\frac{1}{2}$ | 80 | 90 | 24 | 40 | 45 | 15 | 75 | 96 | 20 | 80 | 15 | 90 |
| 5 | 80 | 100 | 26 | 60 | 65 | 15 | 90 | 100 | 20 | 75 | 15 | 100 |
| $5\frac{1}{2}$ | 80 | 110 | 28 | 60 | 70 | 15 | 90 | 110 | 20 | 75 | 15 | 110 |
| 6 | 60 | 90 | 30 | 60 | 75 | 15 | 90 | 114 | 20 | 90 | 15 | 95 |
| 7 | 40 | 70 | 32 | 30 | 40 | 15 | 90 | 120 | 20 | 90 | 15 | 100 |
| 8 | 40 | 80 | 33 | 40 | 55 | 15 | 90 | 132 | 20 | 90 | 15 | 110 |

The above table will suit a lathe with a leading screw of $\frac{1}{2}$ inch pitch by dividing the mandrel wheel by 2.

**Cutting Right-hand and Left-hand Screws.**—In cutting a right-hand thread, the tool in a lathe travels from right-hand to left-hand, and in cutting a left-hand thread, the tool travels from left-hand to right-hand.

**Double and Treble Threads.**—The distance between the centres of the threads of a screw is only one-half the actual pitch in a double-thread screw, and one-third the pitch in a treble-thread screw. To cut double or treble threads, find the wheels to cut a screw of the required pitch with a single thread, and multiply the number of teeth in the lathe spindle-wheel by the number of threads to be cut—that is, by 2 for a double-thread, or by 3 for a treble-thread—the product will be the number of teeth in the lathe spindle-wheel; the other wheels to complete the set will be the same as for a single thread. In cutting a double-thread screw, a single thread is first cut, a mark is then placed on a tooth of the lathe spindle-wheel and on the space it occupies in the first driven wheel, the change wheels are thrown out of gear and the lathe spindle is turned round, and the wheels are re-placed in gear at one-half the number of teeth of the wheel beyond the marked tooth; the lathe is then ready for cutting the second thread. The wheels for cutting three or more threads can be found in a similar way.

Table 69.—CHANGE WHEELS FOR SCREW-CUTTING. LEADING SCREW, $\frac{3}{8}$ INCH PITCH.

| Number of Threads in One Inch. | Drivers. | | Driven. | | Number of Threads in One Inch. | Drivers. | | Driven. | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 80 | ... | 30 | ... | 12 | 30 | 40 | 60 | 90 |
| $1\frac{1}{4}$ | 80 | 100 | 50 | 75 | $12\frac{1}{2}$ | 20 | 40 | 50 | 75 |
| $1\frac{1}{2}$ | 80 | 100 | 50 | 90 | 13 | 20 | 40 | 60 | 65 |
| $1\frac{3}{4}$ | 40 | 80 | 30 | 70 | $13\frac{1}{2}$ | 20 | 80 | 90 | 90 |
| 2 | 80 | ... | 60 | ... | 14 | 20 | 40 | 60 | 70 |
| $2\frac{1}{4}$ | 60 | 80 | 90 | 45 | $14\frac{1}{2}$ | 20 | 40 | 75 | 58 |
| $2\frac{1}{2}$ | 80 | ... | 75 | ... | 15 | 20 | 40 | 50 | 90 |
| $2\frac{3}{4}$ | 40 | 80 | 30 | 110 | $15\frac{1}{2}$ | 20 | 40 | 62 | 75 |
| 3 | 80 | ... | 90 | ... | 16 | 20 | 40 | 60 | 80 |
| $3\frac{1}{4}$ | 50 | 80 | 65 | 75 | $16\frac{1}{2}$ | 20 | 40 | 55 | 90 |
| $3\frac{1}{2}$ | 30 | 80 | 45 | 70 | 17 | 20 | 40 | 60 | 85 |
| $3\frac{3}{4}$ | 40 | 80 | 60 | 95 | 18 | 20 | 40 | 60 | 90 |
| 4 | 40 | ... | 60 | ... | 19 | 20 | 40 | 60 | 95 |
| $4\frac{1}{4}$ | 40 | 80 | 60 | 85 | 20 | 20 | 30 | 50 | 90 |
| $4\frac{1}{2}$ | 20 | 80 | 30 | 90 | 21 | 20 | 40 | 70 | 90 |
| $4\frac{3}{4}$ | 40 | 80 | 60 | 95 | 22 | 20 | 40 | 60 | 110 |
| 5 | 40 | ... | 75 | ... | 23 | 20 | 40 | 60 | 115 |
| $5\frac{1}{4}$ | 20 | 80 | 45 | 70 | 24 | 20 | 40 | 80 | 90 |
| $5\frac{1}{2}$ | 30 | 80 | 45 | 110 | 25 | 20 | 40 | 75 | 100 |
| $5\frac{3}{4}$ | 40 | 80 | 60 | 115 | 26 | 20 | 40 | 65 | 120 |
| 6 | 30 | 80 | 60 | 90 | 27 | 20 | 40 | 90 | 90 |
| $6\frac{1}{2}$ | 40 | 60 | 65 | 90 | 28 | 20 | 30 | 70 | 90 |
| 7 | 40 | 60 | 70 | 90 | 30 | 20 | 40 | 90 | 100 |
| $7\frac{1}{2}$ | 30 | 80 | 75 | 90 | 32 | 20 | 25 | 75 | 80 |
| 8 | 30 | ... | 90 | ... | 34 | 20 | 20 | 60 | 85 |
| $8\frac{1}{2}$ | 30 | 40 | 45 | 85 | 36 | 20 | 20 | 60 | 90 |
| 9 | 20 | 80 | 60 | 90 | 38 | 20 | 20 | 60 | 95 |
| $9\frac{1}{2}$ | 20 | 40 | 30 | 95 | 40 | 20 | 20 | 75 | 80 |
| 10 | 20 | 80 | 60 | 100 | 42 | 20 | 30 | 70 | 90 |
| $10\frac{1}{2}$ | 20 | 80 | 70 | 90 | 44 | 20 | 30 | 90 | 110 |
| 11 | 20 | 80 | 60 | 110 | 48 | 20 | 30 | 90 | 120 |
| $11\frac{1}{2}$ | 20 | 40 | 30 | 115 | 50 | 20 | 30 | 75 | 150 |

The above Table will suit a lathe with a leading screw of $\frac{3}{4}$ inch pitch by dividing the first driving-wheel by 2.

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**Weight of Screws.**—The weight of a screw with a single thread is approximately equal to that of a solid bar, whose diameter is equal to the diameter of the screw minus the depth of thread. Thus, the weight of a single-thread screw, of 3 inches diameter, with a thread $\frac{1}{2}$ inch deep, would equal that of a solid bar—of the same material—of $2\frac{1}{2}$ inches diameter.

**The Strength of Screws and Bolts** is given at pages 283 and 284. The proportion of V and square threads are given at page 256.

Table 70.—Change Wheels for Cutting Whitworth's Screw Threads for Gas, Water, and Hydraulic Iron Piping. Leading Screw, 2 Threads per Inch.

| Internal Diameter of Pipe. | Number of Threads per Inch. | Wheel on Lathe Spindle. | Wheel on Leading Screw. | Intermediate Wheel. | Stud Pinion. |
|---|---|---|---|---|---|
| Inch. | | | | | |
| $\frac{1}{8}$ | 28 | 20 | 120 | 70 | 30 |
| $\frac{1}{4}$ | 19 | 20 | 95 | 60 | 30 |
| $\frac{3}{8}$ | 19 | 20 | 95 | 60 | 30 |
| $\frac{1}{2}$ | 14 | 20 | 80 | 70 | 40 |
| $\frac{5}{8}$ | 14 | 20 | 80 | 70 | 40 |
| $\frac{3}{4}$ | 14 | 20 | 80 | 70 | 40 |
| $\frac{7}{8}$ | 14 | 20 | 80 | 70 | 40 |
| 1 | 11 | 20 | 110 | ... | ... |

Note.—All larger sizes of piping have 11 threads per inch.

Table 71.—Change Wheels for Cutting Screws from $\frac{1}{4}$ Inch to 4 Inch Pitch. Leading Screws, $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ Inch Pitch.

| Pitch of Thread to be Cut. | Leading Screw $\frac{1}{4}$ In. Pitch. | | | | Leading Screw $\frac{3}{8}$ In. Pitch. | | | | Leading Screw $\frac{1}{2}$ In. Pitch. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Drivers. | | Driven. | | Drivers. | | Driven. | | Drivers. | | Driven. | |
| Inches. | | | | | | | | | | | | |
| $\frac{1}{4}$ | 50 | | 50 | | 50 | | 75 | | 50 | | 100 | |
| $\frac{5}{16}$ | 50 | | 40 | | 40 | | 48 | | 50 | | 80 | |
| $\frac{3}{8}$ | 60 | | 40 | | 50 | | 50 | | 45 | | 60 | |
| $\frac{7}{16}$ | 70 | | 40 | | 70 | | 60 | | 35 | | 40 | |
| $\frac{1}{2}$ | 50 | | 25 | | 40 | | 30 | | 50 | | 50 | |
| $\frac{9}{16}$ | 45 | | 20 | | 45 | | 30 | | 45 | | 40 | |
| $\frac{5}{8}$ | 50 | | 20 | | 50 | | 30 | | 50 | | 40 | |
| $\frac{11}{16}$ | 55 | | 20 | | 55 | | 30 | | 55 | | 40 | |
| $\frac{3}{4}$ | 60 | | 20 | | 60 | | 30 | | 60 | | 40 | |
| $\frac{13}{16}$ | 65 | | 20 | | 65 | | 30 | | 65 | | 40 | |
| $\frac{7}{8}$ | 70 | | 20 | | 70 | | 30 | | 70 | | 40 | |
| $\frac{15}{16}$ | 75 | | 20 | | 75 | | 30 | | 75 | | 40 | |
| 1 | 40 | 50 | 20 | 25 | 40 | 50 | 30 | 25 | 80 | 50 | 80 | 25 |
| $1\frac{1}{8}$ | 90 | 60 | 60 | 20 | 90 | 60 | 60 | 30 | 90 | 60 | 60 | 40 |
| $1\frac{1}{4}$ | 50 | 80 | 40 | 20 | 50 | 80 | 40 | 30 | 50 | 80 | 40 | 40 |
| $1\frac{3}{8}$ | 40 | 110 | 40 | 20 | 40 | 110 | 40 | 30 | 40 | 110 | 80 | 20 |
| $1\frac{1}{2}$ | 50 | 60 | 25 | 20 | 40 | 60 | 30 | 20 | 50 | 60 | 40 | 25 |
| $1\frac{5}{8}$ | 70 | 65 | 20 | 35 | 65 | 70 | 30 | 35 | 65 | 70 | 35 | 40 |
| $1\frac{3}{4}$ | 70 | 80 | 40 | 20 | 70 | 80 | 40 | 30 | 70 | 80 | 80 | 20 |
| 2 | 120 | 80 | 30 | 40 | 120 | 80 | 40 | 45 | 120 | 80 | 40 | 60 |
| $2\frac{1}{4}$ | 120 | 90 | 30 | 40 | 120 | 90 | 40 | 45 | 120 | 90 | 40 | 60 |
| $2\frac{1}{2}$ | 120 | 100 | 30 | 40 | 120 | 100 | 40 | 45 | 120 | 100 | 40 | 60 |
| $2\frac{3}{4}$ | 120 | 110 | 30 | 40 | 120 | 110 | 40 | 45 | 120 | 110 | 40 | 60 |
| 3 | 120 | 100 | 20 | 50 | 120 | 90 | 30 | 45 | 120 | 90 | 30 | 60 |
| 4 | 120 | 100 | 25 | 30 | 120 | 80 | 20 | 45 | 120 | 80 | 20 | 60 |

Table 72.—Change Wheels for Cutting Pitches in Millimetres, for Lathes with Leading Screws of $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$ Inch Pitch.

| Pitch of Screw to be Cut. | Leading Screw ¼ Inch Pitch. | | | | Leading Screw ⅜ Inch Pitch. | | | | Leading Screw ½ Inch Pitch. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Drivers. | | Driven. | | Drivers. | | Driven. | | Drivers. | | Driven. | |
| Millimètres. | | | | | | | | | | | | |
| 1 | 36 | 35 | 80 | 100 | 36 | 35 | 100 | 120 | 36 | 35 | 160 | 80 |
| 2 | 35 | 45 | 50 | 100 | 35 | 45 | 75 | 100 | 63 | 20 | 100 | 80 |
| 3 | 63 | 30 | 50 | 80 | 63 | 30 | 75 | 80 | 63 | 30 | 100 | 80 |
| 4 | 63 | 40 | 50 | 80 | 63 | 40 | 75 | 80 | 63 | 40 | 100 | 80 |
| 5 | 63 | 50 | 50 | 80 | 63 | 50 | 75 | 80 | 63 | 50 | 100 | 80 |
| 6 | 63 | 60 | 50 | 80 | 63 | 60 | 75 | 80 | 63 | 60 | 100 | 80 |
| 7 | 63 | 70 | 50 | 80 | 63 | 70 | 75 | 80 | 63 | 70 | 100 | 80 |
| 8 | 63 | 80 | 50 | 80 | 63 | 80 | 75 | 80 | 63 | 80 | 100 | 80 |
| 9 | 63 | 90 | 50 | 80 | 63 | 90 | 75 | 80 | 63 | 90 | 100 | 80 |
| 10 | 63 | 100 | 50 | 80 | 63 | 100 | 75 | 80 | 63 | 100 | 100 | 80 |
| 11 | 63 | 110 | 50 | 80 | 63 | 110 | 75 | 80 | 63 | 110 | 100 | 80 |
| 12 | 63 | 60 | 50 | 40 | 63 | 60 | 50 | 60 | 63 | 60 | 100 | 40 |
| 13 | 63 | 65 | 50 | 40 | 63 | 65 | 75 | 40 | 63 | 65 | 80 | 50 |
| 14 | 63 | 70 | 40 | 50 | 63 | 70 | 75 | 40 | 63 | 70 | 80 | 50 |
| 15 | 63 | 75 | 40 | 50 | 63 | 75 | 75 | 40 | 63 | 75 | 80 | 50 |
| 16 | 63 | 80 | 40 | 50 | 63 | 80 | 60 | 50 | 70 | 45 | 50 | 50 |
| 17 | 63 | 85 | 40 | 50 | 63 | 85 | 75 | 40 | 63 | 85 | 80 | 50 |
| 18 | 63 | 90 | 40 | 50 | 63 | 90 | 60 | 50 | 63 | 90 | 80 | 50 |
| 19 | 63 | 95 | 40 | 50 | 63 | 95 | 60 | 50 | 63 | 95 | 80 | 50 |
| 20 | 63 | 100 | 40 | 50 | 63 | 100 | 60 | 50 | 63 | 100 | 80 | 50 |
| 21 | 63 | 105 | 40 | 50 | 63 | 105 | 60 | 50 | 63 | 105 | 80 | 50 |
| 22 | 63 | 110 | 40 | 50 | 63 | 110 | 60 | 50 | 63 | 110 | 80 | 50 |
| 24 | 63 | 60 | 20 | 50 | 63 | 60 | 30 | 50 | 63 | 60 | 50 | 40 |
| 25 | 70 | 90 | 40 | 40 | 70 | 90 | 40 | 60 | 70 | 90 | 80 | 40 |
| 26 | 63 | 65 | 25 | 40 | 63 | 65 | 25 | 60 | 63 | 65 | 50 | 40 |
| 28 | 63 | 70 | 20 | 50 | 63 | 70 | 30 | 50 | 63 | 70 | 50 | 40 |
| 30 | 63 | 90 | 40 | 30 | 63 | 90 | 40 | 45 | 63 | 90 | 80 | 30 |
| 32 | 63 | 60 | 30 | 25 | 63 | 60 | 45 | 25 | 63 | 60 | 50 | 30 |
| 34 | 63 | 85 | 40 | 25 | 63 | 85 | 60 | 25 | 63 | 85 | 80 | 25 |
| 35 | 63 | 70 | 40 | 20 | 63 | 70 | 60 | 20 | 63 | 70 | 80 | 20 |
| 36 | 63 | 90 | 50 | 30 | 63 | 90 | 50 | 30 | 63 | 90 | 50 | 40 |
| 38 | 63 | 95 | 40 | 25 | 63 | 95 | 60 | 25 | 63 | 95 | 50 | 40 |
| 40 | 63 | 80 | 40 | 20 | 63 | 80 | 40 | 30 | 63 | 80 | 40 | 40 |
| 42 | 63 | 105 | 40 | 25 | 63 | 105 | 60 | 25 | 63 | 105 | 40 | 50 |
| 44 | 63 | 110 | 40 | 25 | 63 | 110 | 60 | 25 | 63 | 110 | 40 | 50 |
| 45 | 63 | 90 | 40 | 20 | 63 | 90 | 60 | 20 | 63 | 90 | 80 | 20 |
| 46 | 63 | 115 | 40 | 25 | 63 | 115 | 60 | 25 | 63 | 115 | 80 | 25 |
| 48 | 63 | 90 | 30 | 25 | 63 | 90 | 45 | 25 | 63 | 60 | 40 | 25 |
| 50 | 63 | 75 | 30 | 20 | 63 | 75 | 45 | 20 | 63 | 75 | 40 | 60 |

**Millimetre pitches** are the best for small screws. Where very great accuracy is required, a wheel with 127 teeth should be substituted for the 63 wheel in the above table, and the remainder of the set of wheels altered accordingly.

## CAST-IRON AND IRON CASTINGS.

**The Brands of Iron** used in foundries for ordinary castings are Nos. 1, 2, 3, and 4, which are grey cast-irons. The quality of the iron can be judged by inspecting the fracture. When the colour of the fracture is a uniform dark grey with high metallic lustre, the iron is tough; but when the colour is dark grey, mottled, and without lustre, it is very weak. When the colour is lightish grey, with high metallic lustre, the iron is tough and hard; but when the colour is light grey, without metallic lustre, it is hard and brittle. When the colour is dull white, the iron is harder and more brittle than the last named one. When the colour is greyish white, with small radiating crystals, the iron is extremely hard and brittle. No. 1 has a dark grey fracture, with high metallic lustre; it is more fusible and more fluid than the others; but being deficient in hardness and strength, it is only suitable for very light castings. Nos. 2 and 3 are used for ordinary castings, the colour being a lighter grey, with a less degree of lustre than No. 1.

**The Brands** used for the manufacture of wrought-iron are Nos. 4, 5, 6—grey forge-iron; No. 7 is a mottled iron; and No. 8 is a white cast-iron.

**Strength of Cast-iron.**—The average strength of cast-iron to resist a crushing or breaking strain of compression is 42 tons per square inch of section, and its safe working strength in compression free from flexure is:—for cast-iron pillars, girders, and similar castings carrying dead weights, $\frac{1}{6}$th the breaking strain, or 7 tons: for pillars and machinery subject to vibration, $\frac{1}{8}$th, or $5\frac{1}{4}$ tons; and for cast-iron arches, $\frac{1}{14}$th of the breaking strain, or 3 tons per square inch of section. The average tensile strength of cast-iron, is 6 tons per square inch of section, and its safe working strength in tension, is $\frac{1}{4}$th the breaking strain, or $1\frac{1}{2}$ tons per square inch of section.

**Testing Cast-iron.**—A bar of good cast-iron, 1 inch square × 3 feet 6 inches long, placed upon supports 3 feet apart, should bear a gradually applied weight of 7 cwt. In contracts for castings, it is usual to specify the weight which a test-bar, cast from the same metal as the castings, shall carry, the usual stipulation being that a test-bar of cast-iron, 3 feet 6 inches long × 2 inches deep × 1 inch thick, placed upon supports 3 feet apart, shall bear in the middle a gradually applied weight of from 27 to 30 cwt., which will cause a deflection of about $\frac{3}{8}$ inch. The permanent set, caused by the deflection, is not taken notice of. These test-bars generally break, when a weight of from $31\frac{1}{2}$ to 32 cwt. is applied in the middle. The average breaking strain is usually taken of several test-bars, to guard against the effect of flaws in the castings. Cast-iron should be twice run, of fine grain, uniform, and of even grey colour, easily filed, and soft enough to be slightly indented when struck with a hammer.

**Castings.**—The mixtures of cast-iron, found in practice to be most suitable for different kinds of work, are given in the following table.

Table 73.—MIXTURES OF METAL FOR VARIOUS CAST-IRON CASTINGS.

| | | |
|---|---|---|
| Very tough and hard cast-iron, for anvils, for steam hammers, and similar work | Hematite, No. 3<br>Pontypool, No. 4<br>Clyde, No. 4<br>Monkland, No. 8 | 1 part.<br>1 „<br>1 „<br>1 „ |
| Chilled cast-iron rolls, a mixture which chills about ¾ inches deep | Hematite, No. 5<br>Lilleshall, C. B.<br>Cleator white | 5 parts.<br>5 „<br>4 „ |
| Chilled cast-iron rolls, a mixture which chills about 1¼ inches deep | Hematite, No. 5<br>Lilleshall, C. B.<br>Cleator white<br>Brymbo<br>Pontypool white | 10 parts.<br>8 „<br>4 „<br>2½ „<br>4 „ |
| Chilled cast-iron rolls, a mixture which chills about 2¼ inches deep | Hematite, mottled<br>Hematite, No. 5<br>Blaenavon or Pontypool, C. B. | 1 part.<br>1 „<br>1 „ |
| Chilled cast-iron rolls, a mixture which chills from 2½ to 3 inches deep | Cleator white<br>Brymbo<br>Lilleshall, C. B.<br>Hematite, No. 3<br>Pontypool, No. 3 | 4 parts.<br>4 „<br>8 „<br>6 „<br>2 „ |
| Tough and durable cast-iron, for wheel gearing | Barrow hematite, No. 2<br>Glengarnock, No. 2<br>Good clean scrap | 8 cwt.<br>4 „<br>8 „ |
| Tough and durable cast-iron, for cylinders up to 1 inch thick | Pontypool, C. B. No. 4 10 cwt.<br>Clyde, No. 4 10 „ | Melted and cast into pigs in order to mix properly. |
| Tough and durable cast-iron, for cylinders above 1 inch thick | Pontypool, C. B. No. 4 7 cwt.<br>Clyde, No. 4 7 „<br>Gartsherrie, No. 3 6 „ | Melted and cast into pigs in order to mix properly. |
| Good mixture of cast-iron, for ordinary castings | Scotch mixed brands<br>Weardale<br>Good clean scrap | 5 cwt.<br>6 „<br>9 „ |
| Good mixture of cast-iron for light castings | Scotch mixed brands<br>Glengarnock, No. 1<br>Good clean scrap | 5 cwt.<br>6 „<br>9 „ |

The strength of cast-iron is increased by remelting, up to 10 meltings.

## GUN-METAL AND BRASS CASTINGS.

**Brass Furnace.**—A simple and effective brass furnace is shown in Fig. 48. It is 15 inches square × 28 inches deep inside. Hole for flue, 7 inches × 10 inches. Chimney, 10 inches square inside by not less than 15 feet high; the furnace to be built of brick, lined with firebrick; the front fire-bar bearer is moveable, and slides forward to let the fire-bars drop down, when required. This furnace will melt about 80 lb. of metal quickly and easily. A. shows the tongs for pouring the metal, and B. the tongs for lifting the crucible off the fire.

**Brass Melting.**—The process of melting may be briefly described thus. After the fire is lighted, the crucible is placed over it, upside

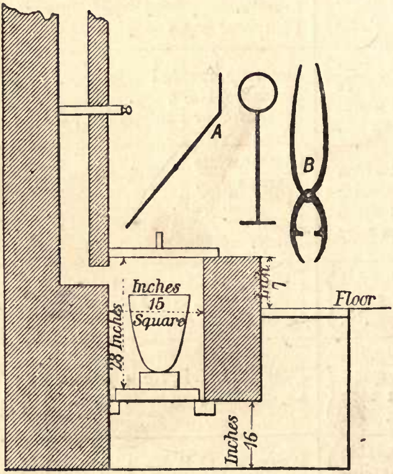


Fig. 48.

down, until properly heated, when it is put in its place with its bottom resting on a firebrick, to keep it off the bars. Coke is then filled round to steady it. Copper cut into small pieces is then placed in the crucible and melted. Afterwards tin is added, melted and mixed. When the metal comes to a proper heat for casting, if a piece of zinc be dropped into the crucible, it will immediately flare up; if it does not flare up, the metal is not at its proper casting heat. When ready, the rubbish is skimmed off the top, and the metal is poured into the moulds. The moulding-boxes are opened as soon as the metal is poured, and the castings are sprinkled with water and cooled as quickly as possible, which makes the metal softer and more uniform than if left to cool slowly. The metals have also a tendency to separate, and the heaviest metal to sink to the bottom of the casting when the cooling takes place slowly. When old brass is melted down, no tin is necessary: but a small quantity of zinc is added. When a mixture of part old brass and part copper is melted, tin is added in proportion to the new copper, and zinc in proportion to the old brass. The tenacity of gun-metal varies considerably, because it depends greatly upon the manipulation of the metal both in the crucible and in the casting.

**Copper** loses its colour and softness when alloyed with other metals. Copper and tin mix well in all proportions. The addition of tin increases hardness, and, in order to be malleable, copper must be mixed with less than 10 per cent. of tin. A mixture containing one-third of tin is very brittle. Lead has the tendency to separate from copper, and cannot be used in larger proportions than ½ lb. to 1 lb. of copper. The tenacity of wrought-copper is 30,000 lbs. per square inch. In making castings of pure copper, to prevent blown castings, use a flux of ¾ lb. zinc for 50 lbs. copper.

**Bronze or Gun-metal** is the best alloy for bearings and general castings where toughness and durability are required. A good mixture is: copper, 9 parts; tin, 1 part. Its tenacity per square inch averages 28,000 lbs. The weight of one square foot 1 inch thick is 45 lbs., and of a piece 12 inches long × 1 inch square, is 3¾ lbs, approximately.

**Good Brass,** for light bearings and castings, consists of: copper, 7 parts; tin, 1 part; zinc, 1 part. Its tenacity per square inch averages 22,000 lbs. The weight of 1 square foot 1 inch thick is 44 lbs., and of a piece 12 inches long × 1 inch square 3·66 lbs. approximately.

**Common Brass** consists of: copper, 4 parts; tin, 1; and zinc, ½ part. Its tenacity per square inch averages 20,000 lbs. The weight of one square foot 1 inch thick is 43 lbs., and of a piece 12 inches long × 1 inch square, 3·55 lbs. approximately.

**Yellow Brass,** of best quality, consists of: copper, 2 parts; zinc, 1 part. Its tenacity per square inch averages 18,000 lbs. The weight of one square foot, 1 inch thick, is 42 lbs., and of a piece 12 inches long × 1 inch square, 3½ lbs. approximately.

**Statuary-Bronze,** or metal for statues, consists of: copper, 91·4 parts; tin, 1·7; zinc, 5·53; and lead, 1·37 parts. Another statuary bronze consists of: copper, 83 parts; tin, 4; zinc, 10; lead, 3 parts.

**Aluminium-Bronze** consists of: copper, 90 parts; aluminium, 10 parts. Its tenacity per square inch is about 70,000 lbs., or more than double that of gun-metal; but it costs about four times as much as gun-metal, and is used chiefly by instrument makers. It is not liable to rust, and may be forged either hot or cold.

**Sterro-Metal** is a special metal for making heavy guns. Its tenacity per square inch is about 60,000 lbs., and consists of various proportions, one of which is: copper, 60 parts; zinc, 35 parts; tin, 2 parts; wrought-iron, 3 parts.

**Muntz Metal** consists of: copper, 3 parts: zinc, 2 parts. It is used for sheathing ships. Tenacity, 49,000 lbs. per square inch.

**Malleable Brass** can be forged either hot or cold. Consists of: copper, 56 parts; zinc, 42; wrought-iron, 2 parts.

**Phosphor-bronze** is a superior metal for bearings, wheels, and other castings, where great strength, toughness, and durability are required. The tenacity per square inch of the toughest quality is about 56,000 lbs.: great care is required in the production of castings from this alloy. Unlike ordinary bronze, it can be remelted without injuring its quality. A steel journal well fitted into phosphor-bronze bearings is much less liable to heat than any other known materials that can be used for such a purpose for heavy work.

**A Non-corrosive Bronze** is manufactured by the Phosphor Bronze Company, in sheets, rods, and tubes, and also in wire for overhead telegraph and telephone-wires and springs. Its tenacity when rolled and drawn into wire is from 100,000 to 150,000 lbs. per square inch.

**Silicium-Bronze** is a new special alloy, manufactured by the Phosphor Bronze Co. for electric conducting wire. It can be made to possess the strength of best iron wire with the conductivity of pure copper, or the strength of steel wire with twice its conductivity.

**Compressed Bronze.**—The compression of the metal while in a fluid state, by closing the blow-holes, caused by the formation of gas, increases the density and tenacity of the metal. The tenacity of compressed bronze is about 65,000 lbs. per square inch.

**Ormolu** is a metal used for ornaments of stoves and artistic metal work. It can be got up by finishing to a brilliant gold-like surface. It consists of from 2½ to 3 parts of copper, according to the depth of colour required, to 1 part of zinc. The castings after being polished are dipped in acid, and then brightened by means of a wire scratch-brush, and finally lacquered to prevent tarnishing.

**Rolled and Wire-Drawn Brass** is stronger than cast brass. The metal during these processes becomes dense and hard, and requires to be frequently annealed, which is effected by heating the metal and allowing it to cool slowly. The tenacity of the best quality of brass wire is 80,000 lbs. per square inch.

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## BRASS WORK.

**Brass Work.**—The proportions of a variety of the alloys, found in practice to be most suitable for different kinds of work, is given in the following table, containing 100 different alloys.

Table 74.—MIXTURES OF METAL FOR BRONZE, GUN METAL, BRASS, AND OTHER CASTINGS.

| Description of Work the Alloy is suitable for. | Number of Parts of | | | |
|---|---|---|---|---|
| | Copper. | Tin. | Zinc. | Lead. |
| Hard bronze | $82\frac{1}{2}$ | $17\frac{1}{2}$ | ... | ... |
| Ordnance metal | $91\frac{2}{3}$ | $8\frac{1}{3}$ | ... | ... |
| Metal for piston rings, requires no lubrication | 15 | 5 | ... | ... |
| Good locomotive brass boiler tubes; 1 fine spelter | 2 | ... | ... | ... |
| Brass tubes for condensers and heaters; 30 spelter | 70 | ... | ... | ... |
| Admiralty gun metal for bearings, &c.; very tough | 88 | 10 | 2 | ... |
| Indian-railway gun metal for bearings | 88 | 12 | ... | ... |
| Bearings for locomotive engines | 64 | 7 | 1 | ... |
| Gun metal for locomotive engine bearings, and for valves and glands | 84 | 16 | ... | ... |
| Gun metal for railway carriage and wagon bearings | 85 | 15 | ... | ... |
| Gun metal for bearings and details of locomotives | 5 | 1 | ... | ... |
| Gun metal for cocks and valves for steam | 9 | 1 | ... | ... |
| Gun metal bushes for lathes and engines, and for all kinds of heavy bearings | 9 | 1 | ... | ... |
| Gun metal for general castings for best work | 9 | 1 | ... | ... |
| Gun metal bushes for plummer blocks and machinery bearings | 8 | 1 | ... | ... |
| Metal for glands, spindles, and eccentric straps | 8 | 1 | 1 | ... |
| Gun metal for railway carriage, engine, and machinery bearings | 7 | 1 | ... | ... |
| Metal for slide valves | 22 | 4 | 1 | ... |
| Metal for pumps and other hydraulic purposes | 36 | 4 | 1 | ... |
| Metal for lining pumps for acid liquids | 97 | 3 | ... | ... |
| Metal for covering iron rods, such as pump rods, &c. | 16 | 2 | 1 | 1 |
| Gun metal for foot-steps of vertical shafts | 20 | 5 | ... | ... |
| Metal for piston rings . . . 93 brass | 7 | ... | ... | ... |
| Metal for cocks, valves, and taps for water | 14 | 1 | 1 | ... |
| Metal for embossing press | 87 | 11 | 2 | ... |
| Metal for rolls | 86 | 12 | 2 | ... |
| Hard metal for bearings | 12 | $1\frac{1}{2}$ | $\frac{1}{2}$ | ... |
| Hard gun metal | 16 | $2\frac{1}{2}$ | ... | ... |
| Soft gun metal | 16 | 1 | ... | ... |
| Hard brass castings | 25 | $4\frac{1}{2}$ | 2 | ... |
| Tough brass for bolts and nuts, and wheels | 16 | $1\frac{1}{2}$ | $\frac{1}{2}$ | ... |
| Good brass for railway carriage and for engine and machinery bearings | 7 | 1 | $\frac{1}{2}$ | ... |
| Good brass for all ordinary castings for engines and machinery | 7 | 1 | 1 | ... |
| Good brass for pump buckets, plungers, valves, and seats of pumps | 44 | 3 | 3 | ... |
| Common brass for light castings | 4 | 1 | $\frac{1}{2}$ | ... |
| Metal for axle boxes of carriages and carts | 86 | 14 | ... | ... |
| Metal for ornamental brass castings | 2 | ... | 1 | ... |

Table 74 *continued.*—MIXTURES OF METAL FOR BRONZE, GUN METAL, BRASS, AND OTHER CASTINGS.

| Description of Work the Alloy is suitable for. | Number of Parts of | | | |
|---|---|---|---|---|
| | Copper. | Tin. | Zinc. | Lead. |
| Copper flanges for pipes | 36 | 1 | 4 | ... |
| Anti-corrosive metal to stand acids 7 antimony | 63 | ... | ... | 30 |
| Anti-rust metal (Baily's metal) for instruments, &c. | 16 | $2\frac{1}{2}$ | 1 | ... |
| Naval brass, very tenacious, used by the Admiralty for bolts, &c. 37 spelter | 62 | 1 | ... | ... |
| Metal for bearings exposed to heat | 18 | 1 | 1 | ... |
| Metal for toothed wheels | 92 | 8 | ... | ... |
| Metal for statues | 88 | 3 | 7 | 2 |
| Spelter | 1 | ... | 1 | ... |
| Pot metal for commonest water taps | 8 | ... | ... | 3 |
| Brass for gas fittings | 40 | ... | 20 | 1 |
| Yellow brass | 2 | ... | 1 | ... |
| Sheet brass | 3 | ... | 1 | ... |
| White brass | 10 | 10 | 80 | ... |
| Red brass | 16 | ... | 2 | ... |
| Brass wire | 67 | ... | 33 | ... |
| Bristol sheet brass; solders well | 16 | ... | 6 | ... |
| Brass which solders well | 16 | 1 | ... | $\frac{1}{2}$ |
| Brass for mathematical instruments | 12 | 1 | ... | ... |
| Brass for watch-makers, malleable | 4 | ... | 1 | ... |
| Brass for watch-makers, not malleable | 1 | ... | 2 | ... |
| Turner's brass 98 brass | ... | ... | ... | 2 |
| Button-maker's brass 8 brass | ... | ... | 5 | ... |
| Brass for making brass pans; very hard | 48 | 11 | ... | ... |
| Brass for cymbals and Chinese gongs | 4 | 1 | ... | ... |
| Metal for cymbals; worked hot | $80\frac{1}{2}$ | $19\frac{1}{2}$ | ... | ... |
| Malleable brass; can be forged hot | 33 | ... | 25 | ... |
| Jeweller's metal 10 brass | 30 | 7 | ... | ... |
| Metal for punches for jewellery and instruments | $83\frac{1}{2}$ | $16\frac{1}{2}$ | ... | ... |
| Metal for screw propellers | 83 | 10 | 7 | ... |
| Gilding metal | 16 | ... | $1\frac{1}{4}$ | ... |
| Lap alloy | 1 | ... | 8 | ... |
| Metal for brass rivets | 16 | 2 | $1\frac{1}{4}$ | ... |
| Metal for copper rivets | 60 | 1 | ... | ... |
| Dipping brass | 16 | ... | 14 | ... |
| Dipping brass, another 6 spelter | 19 | ... | ... | ... |
| Mosaic gold metal | 1 | ... | 1 | ... |
| Manheim gold metal | 3 | ... | 1 | ... |
| Pinchbeck | 5 | ... | 1 | ... |
| Mirror metal | $68\frac{1}{4}$ | $31\frac{3}{4}$ | ... | ... |
| Speculum metal | 43 | 20 | ... | ... |
| Bronze medals | 97 | 3 | ... | ... |
| Bronze medals, another | 96 | 4 | ... | ... |
| Bronze medals, another | 89 | 8 | 3 | ... |

Table 74 *continued.*—MIXTURES OF METAL FOR BRONZE, GUN METAL, BRASS, AND OTHER CASTINGS.

| Description of Work the Alloy is suitable for. | Number of Parts of | | | |
|---|---|---|---|---|
| | Copper. | Tin. | Zinc. | Lead. |
| Bronze medals, another . . . . 3 nickel | 8 | ... | $3\frac{1}{2}$ | ... |
| Dutch metal . . . . . . . . . | $5\frac{1}{2}$ | ... | 1 | ... |
| Bath metal . . . . . . . . 35 brass | ... | ... | 9 | ... |
| Princes metal . . . . . . . . | 1 | ... | 1 | ... |
| Blanched copper . . . . . ½ arsenic | 8 | ... | ... | ... |
| Bronze coins, English and French . . . . | 95 | 4 | 1 | ... |
| Gold coins, French . . . . . 90 gold | 10 | ... | ... | ... |
| Silver coins, French . . . . 90 silver | 10 | ... | ... | ... |
| Shot metal . . . . . . . . 2 arsenic | ... | ... | ... | 98 |
| Bullet metal . . . . . . . 1 antimony | ... | ... | ... | 5 |
| Metal for nails for ship's sheathing . . . . | $86\frac{1}{2}$ | 9 | $4\frac{1}{2}$ | ... |
| Bell metal for musical bells . . . . . . | 25 | $4\frac{1}{2}$ | ... | ... |
| Bell metal for small clock bells . . . . . | 25 | 5 | ... | ... |
| Bell metal for gongs . . . . . . . . | 25 | $5\frac{1}{2}$ | ... | ... |
| Bell metal for house bells . . . . . . . | 25 | 6 | ... | ... |
| Bell metal for larger bells for factories, &c. . . | 25 | $6\frac{1}{2}$ | ... | ... |
| Bell metal for small church bells . . . . . | 25 | 7 | ... | ... |
| Bell metal for the largest church bells . . . | 25 | $7\frac{1}{2}$ | ... | ... |
| Metal for barometer dials . . . 30 arsenic | 70 | ... | ... | ... |
| Imitation gold . . . . . . . 7 platina | 16 | ... | 1 | ... |
| Ring gold . . . . . 5 gold : 3 silver | 6 | ... | ... | ... |
| Standard gold . . . . . 11 pure gold | 1 | ... | ... | ... |

Table 75.—WEIGHT OF BELLS.

| Diameter of bell, in inches | 6 | 7 | 8 | 10 | 12 | 14 | 16 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 | 70 | 80 | $91\frac{1}{2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight, in lbs. | $4\frac{1}{2}$ | $6\frac{1}{2}$ | 11 | 16 | 22 | 45 | 68 | 197 | 393 | 645 | 900 | 1345 | 1795 | 2580 | 2920 | 7952 | 11256 | 18228 |

**Thickness of Bells.**—To obtain variety of tone, the thickness of house bells should range from $\frac{1}{12}$th to $\frac{1}{24}$th of their diameter. Clock bells and dinner bells should be not less than $\frac{1}{14}$th of their diameter in thickness. Large church bells and peals of bells range from $\frac{1}{10}$th to $\frac{1}{14}$th the diameter in thickness at the sound bow. The clapper of small bells should be about $\frac{1}{30}$, and for large church bells from $\frac{1}{40}$ to $\frac{1}{50}$ the weight of bell.

The largest bells in England are:—Great Paul, of St. Paul's Cathedral, which is composed of 13 lbs. of copper to 4 lbs. of tin, and weighs 37,383 lbs.; Great bell of Westminster, weighs 30,352 lbs.; Manchester, 18,256 lbs.; Tom of Oxford, 17,360 lbs.; Tom of Exeter, 13,440 lbs.; Tom of Lincoln, 12,096 lbs.; and Tom of St. Paul's, weighs 11,474 lbs.

## WHITE METAL.

**White Metal** being one of the best alloys for reducing friction, is commonly called antifriction metal. It is cheaper than gun-metal, but it is much softer and is liable to crush and spread out, unless cased in an iron box. Babbit's original receipt was: 4 lbs. copper; 8 lbs. antimony; 24 lbs. tin = 36 lbs. This was called hardening. For every lb. of the above he added 2 lbs. more tin, making altogether 108 lbs.

A great number of other mixtures are now used by brassfounders, and a collection of those most generally used is given in the following table, containing 72 different alloys.

Table 76.—Antifriction White Metal and other Alloys.

| Description of Work the Alloy is suitable for. | Number of Parts of | | | |
|---|---|---|---|---|
| | Tin. | Copper. | Antimony. | Lead. |
| White metal for filling perforations in slide valves | 82 | 6 | 12 | ... |
| Antifriction white metal for bearings of engines, millwork, machine tools, and general machinery | 96 | 4 | 8 | ... |
| Antifriction white metal do. do. | 90 | 2 | 8 | ... |
| Antifriction white metal do. do. | 85 | 5 | 10 | ... |
| Antifriction white metal do. do. | 84 | 6 | 10 | ... |
| Antifriction white metal do. do. | 78 | 10 | 12 | ... |
| Antifriction white metal do. do. | 60 | 3 | 6 | ... |
| Antifriction white metal do. do. | 60 | $7\frac{1}{2}$ | 9 | ... |
| Antifriction white metal do. do. | 56 | 3 | 4 | ... |
| Antifriction white metal do. do. | 50 | 1 | 5 | ... |
| Antifriction white metal do. do. | 50 | $1\frac{1}{2}$ | 5 | ... |
| Antifriction white metal do. do. | 50 | 3 | 5 | ... |
| Antifriction white metal do. 1 bismuth | 42 | 2 | 5 | ... |
| Antifriction white metal for bearings of engines, shafting, tools, millwork, and machinery . . | 40 | 5 | 10 | ... |
| Antifriction white metal do. do. | 36 | $1\frac{1}{2}$ | 3 | ... |
| Antifriction white metal for bearings . . . | 28 | 2 | 3 | ... |
| Antifriction white metal do. . . . . . | 22 | 1 | 2 | ... |
| Antifriction white metal, used for lining locomotive axle boxes, and bearings of machine tools . | 16 | $1\frac{1}{2}$ | 2 | ... |
| Antifriction white metal for bearings of shafting, implements, &c., and general machinery . . | 10 | 1 | 3 | 6 |
| Antifriction white metal do. do. | 20 | ... | 20 | 60 |
| Antifriction white metal do. do. | ... | ... | 15 | 85 |
| Antifriction white metal do. do. | 32 | 5 | 10 | 18 |
| Antifriction white metal do. do. | 2 | ... | 2 | 24 |
| Antifriction white metal do. do. | 2 | ... | 2 | 20 |
| Antifriction white metal do. do. | 8 | 2 | 20 | 20 |
| Antifriction white metal do. 12 bismuth | ... | ... | 1 | 20 |
| Antifriction white metal for bearings of machinery | 16 | 2 | 3 | 4 |

TABLE 76 *continued.*—ANTIFRICTION WHITE METAL AND OTHER ALLOYS.

| Description of Work the Alloy is suitable for. | | Number of Parts of | | | |
|---|---|---|---|---|---|
| | | Tin. | Copper. | Antimony. | Lead. |
| Antifriction white metal for light machinery bearings | | 1½ | ... | 1 | 1½ |
| Antifriction white metal for machinery bearings | | 8 | 1 | 2 | 9 |
| White metal for models and instruments | 1 brass | 2 | ... | 4 | ... |
| Hard white metal | 20 brass; 3 spelter | 1 | ... | ... | ... |
| Hard white metal, another | 16 brass; ½ zinc | 1 | ... | ... | 1 |
| Hard white metal, another | 13 zinc | 2¼ | 35 | ... | ... |
| White metal | 13 zinc | 6 | 1 | ... | ... |
| White metal | 13 zinc | 3 | 1 | ... | ... |
| White metal for sockets | 5 zinc | 8 | 5 | ... | 8 |
| White metal for rolling | | 90 | 3 | 7 | ... |
| White metal for spinning | | 94 | 1 | 5 | ... |
| Metal for vice clams | | ... | ... | 1 | 10 |
| German silver for castings | 20 nickel; 20 zinc | ... | 60 | ... | 3 |
| Imitation silver | 1 metallic arsenic | ... | 9 | ... | ... |
| Imitation silver, another | ¾ oz. tin; 1 lb. copper | ... | ... | | ... |
| Imitation silver | 1 zinc | 5 | 4 | ... | 1 |
| Pewter | | 100 | ... | 2 | ... |
| Metal for organ pipes | | 50 | ... | ... | 50 |
| Pewter, common | | 79 | ... | 1 | 20 |
| Pewter, fine | 1 bismuth | 50 | 1 | 4 | ... |
| Metal for ornaments and lamps | | 76 | 1 | 4 | ... |
| Metal for ornaments and small statues | 20 zinc | 64 | ... | ... | 16 |
| Nickel alloy for candlesticks, &c. | 1 zinc; 1 nickel | ... | 2 | ... | 2½ |
| Nickel alloy for spoons and forks | 1 zinc; 1 nickel | ... | 2 | ... | ... |
| Nickel alloy for knife handles | 2 zinc; 2 nickel | ... | 4½ | ... | ... |
| Nickel alloy in sheets | 2 zinc; 2 nickel | ... | 5½ | ... | ... |
| Nickel alloy for models, &c. | 5 zinc; 3 nickel | 1 | 10 | ... | 5 |
| White metal for buckles and buttons | 16 brass; 2 zinc | 1 | ... | ... | ... |
| Electric amalgam | 4 mercury; 2 zinc | 1 | ... | ... | ... |
| Electrum | 7½ zinc; 8½ nickel | ... | 17 | ... | ... |
| Queen's metal | 1 bismuth | 9 | ... | 1 | 1 |
| Britannia metal | | 10 | ... | 1 | ... |
| Type metal | | ... | ... | 2 | 11 |
| Stereotype metal | 2 bismuth | ... | ... | 4 | 18 |
| Imitation platinum | 8 pale brass; 5 spelter | ... | ... | ... | ... |
| Tutenag | 1 bismuth | 2 | ... | ... | ... |
| Metal for medals | | 6 | ... | 1 | ... |
| Alloy for fusible plugs, softens at 366°, melts at 372°F. | | 2 | ... | ... | 2 |
| Alloy for fusible plugs, " 373° " 383° | | 2 | ... | ... | 6 |
| Alloy for fusible plugs, " 378° " 388° | | 2 | ... | ... | 7 |
| Alloy for fusible plugs, " 396° " 408° | | 2 | ... | ... | 8 |
| Alloy that expands in cooling | 1 bismuth | ... | ... | 2 | 9 |
| Alloy that melts at boiling water heat, 212° F., used for taking impressions | 8 bismuth | 3 | ... | ... | 5 |
| Alloy that melts in hot water | 1 zinc; 1 bismuth | ... | ... | ... | 1 |
| Standard silver | 92½ pure silver | ... | 7½ | ... | ... |

TABLE 77.—MELTING POINTS OF ALLOYS AND METALS, &c., FROM THE EXPERIMENTS OF POUILLET, CLAUDEL, &c., AND FREEZING POINTS OF LIQUIDS, &c.

| Tin. | Lead. | Bismuth. | Melts at. | Tin. | Lead. | Melts at. |
|---|---|---|---|---|---|---|
| | | | Fahr. | | | Fahr. |
| 2 | 3 | 5 | 199° | 22 | 4 | 380° |
| 1 | 1 | 4 | 201° | 4 | 5 | 390° |
| 3 | 5 | 8 | 212° | 8 | 11 | 400° |
| 3 | 7 | 8 | 220° | 16 | 25 | 410° |
| 3½ | 8 | 8 | 230° | 4 | 7 | 420° |
| 5 | 8 | 8 | 240° | 8 | 15 | 430° |
| 7 | 8 | 8 | 250° | 4 | 8 | 440° |
| 8 | 9 | 8 | 260° | 8 | 17 | 450° |
| 8 | 12 | 8 | 270° | 4 | 9 | 460° |
| 8 | 13 | 8 | 290° | 4 | 10 | 470° |
| 14 | 14 | 8 | 300° | 8 | 23 | 480° |
| 8 | 16 | 8 | 310° | 4 | 14 | 490° |
| 24 | 20 | 8 | 320° | 8 | 33 | 500° |
| 24 | 26 | 8 | 330° | 4 | 19 | 510° |
| 8 | 4 | ... | 340° | 4 | 25 | 520° |
| 10½ | 4 | ... | 350° | 4 | 30 | 530° |
| 13 | 4 | ... | 360° | 5 | 38 | 540° |
| 17 | 4 | ... | 370° | 4 | 48 | 550° |

| | |
|---|---|
| Acetic acid congeals at . . | 50° Fahr. |
| Olive oil ,, . . . | 36° ,, |
| Water freezes at . . . | 32° ,, |
| Milk ,, . . . . | 30° ,, |
| Vinegar ,, . . . . | 28° ,, |
| Sea water ,, . . . . | 28° ,, |
| Strong wine freezes at . . | 20° ,, |
| Mercury congeals at . . | —39° ,, |
| Greatest artificial cold . . | —91° ,, |
| Phosphorous burns . . . | —43° ,, |

| Metals, &c. | Melts at. |
|---|---|
| | Fahr. |
| Platinum . . . | 3080° |
| Wrought iron . | 2912° |
| Nickel . . . | 2810° |
| Steel, maximum . | 2552° |
| Steel, minimum . | 2372° |
| Pure gold . . | 2282° |
| Cast iron . . | 2190° |
| Gold coin . . | 2156° |
| Copper. . . | 2050° |
| Pure silver . . | 1830° |
| Bronze . . . | 1690° |
| Brass . . . | 1650° |
| Aluminium . . | 1300° |
| Antimony. . . | 810° |
| Zinc . . . | 773° |
| Lead . . . | 620° |
| Bismuth . . | 507° |
| Tin . . . . | 446° |
| Cadmium . . | 442° |
| Sulphur . . . | 239° |
| Beeswax, white . | 154° |
| Beeswax, yellow . | 142° |
| Stearine . 109° to | 120° |
| Phosphorus . . | 109° |
| Tallow . . . | 92° |
| Oil of turpentine . | 14° |
| Ice of strong brandy | 7° |
| 1 snow and 1 salt . | 0° |
| Mercury . . | —39° |
| Mercury boils . | 662° |

**Temperature of Furnaces, &c.**—When the fire is at red heat = 1,300; at cherry red heat = 1,700; at orange colour = 2,000; at bright white heat = 2,500; and at a dazzling white heat = 2,800 degrees Fahrenheit. Temperature of the hot blast for melting iron, from 900 to 1,200° F. Welding heat of iron, 2,700° F. Iron is bright red in the dark at 752° F. Iron is red in daylight at 885° F. Metals are red in daylight at 1,077° F. Wrought iron boils at 5000° F.: cast iron at 3,350° F.; sulphur at 570° F.; and phosphorus at 556° F. Temperature of Bessemer furnace, 4,000° F.; puddling furnace, 3,500° F; cupola, 3,000° F.; common fire, 790° F.; of ignition, 637° F.; of common oven, 460° F.; disinfecting chamber for clothing, 240° F.; laundry drying rooms, 110° to 150° F.; of the human body, 98½° F.; and of a comfortable room, 70° F.

**Metals when hot** are weaker than when cold. Iron loses strength by every increment of heat above 550° F. Copper loses strength by every increment of heat above 32° F., the loss of strength being 5 per cent. at 212°; 20 per cent. at 450°; 30 per cent. at 600°; 50 per cent. at 800°; 75 per cent. at 1100°; and at 1335° it loses all tenacity and becomes a soft, viscid mass, although it does not melt until it reaches 2050° F.

Table 78.—Shewing in Successive Order the Properties of Metals, viz.:—Malleability, being beat into thin plates; Ductility, being drawn into wire; Tenacity, resistance to pulling asunder.

| Malleability. | Ductility. | Tenacity. |
|---|---|---|
| Gold. | Gold. | Wrought iron. |
| Silver. | Silver. | Wrought copper. |
| Copper. | Platinum. | Platinum. |
| Tin. | Wrought iron. | Silver. |
| Cadmium. | Copper. | Gold. |
| Platinum. | Zinc. | Yellow brass. |
| Lead. | Tin. | Cast iron. |
| Zinc. | Lead. | Zinc. |
| Wrought iron. | Nickel. | Tin. |
| Nickel. | Palladium. | Bismuth. |
| Palladium. | Cadmium. | Lead. |

## SOLDERS.

Table 79.—Solders for Soldering and Brazing.

| Soft Solders. | Parts of Tin. | Parts of Lead. | Parts of Bismuth. | Melts at |
|---|---|---|---|---|
| | | | | Fahr. |
| Bismuth solder . . . . . . | 3 | 5 | 3 | 202° |
| Bismuth solder . . . . . . | 2 | 2 | 1 | 229° |
| Bismuth solder . . . . . . | 2 | 1 | 2 | 236° |
| Bismuth solder . . . . . . | 1 | 1 | 1 | 254° |
| Bismuth solder . . . . . . | 3 | 3 | 1 | 310° |
| Bismuth solder . . . . . . | 4 | 4 | 1 | 320° |
| Tinman's coarse solder . . . | 3 | 2 | ... | 334° |
| Tinman's fine solder . . . . | 2 | 1 | ... | 340° |
| Plumber's fine solder . . . . | 1 | 2 | ... | 441° |
| Plumber's coarse solder . . . . | 1 | 3 | ... | 482° |
| Solder for soldering lead . . . | 1 | $1\frac{1}{2}$ | ... | ... |
| Solder for soldering tin . . . . | 1 | 2 | ... | ... |
| Solder for soldering pewter . . . | 2 | 1 | ... | ... |
| Soft solder for soldering pewter . . | 3 | 4 | 2 | ... |
| Hard solder for soldering pewter . . | 2 | 1 | 1 | ... |

**Bismuth** expands considerably during solidification.

Table 80.—BRAZING SOLDERS FOR BRAZING COPPER, GUN METAL, BRASS, IRON, STEEL, SILVER, AND GOLD.

| | Parts of Gold. | Parts of Silver. | Parts of Brass. | Parts of Copper. | Parts of Tin. | Parts of Zinc. | Parts of Antimony. |
|---|---|---|---|---|---|---|---|
| Soft solder for brazing copper and brass | ... | ... | ... | ... | 2 | ... | 1 |
| Soft solder for brazing copper and brass | ... | ... | ... | 4 | 1 | 3 | ... |
| Hard solder for brazing copper, gun metal, and brass | ... | ... | ... | 1 | ... | 1 | ... |
| Harder solder for brazing iron, copper, gun metal, and brass | ... | ... | ... | 2 | ... | 1 | ... |
| Hardest solder for brazing iron, copper, bronze or gun metal, and brass | ... | ... | ... | 3 | ... | 1 | ... |
| Another hard solder for brazing copper, gun metal, brass, &c. | ... | ... | 5 | ... | ... | 1 | ... |
| Silver solder for fine bronze or gun metal and brass work | ... | 1 | ... | 8 | ... | 8 | ... |
| Silver solder for fine bronze or gun metal and brass work | ... | 1 | 1 | ... | ... | ... | ... |
| Silver solder for German silver and for fine bronze or gun metal | ... | 5 | 5 | ... | ... | 5 | ... |
| Silver solder for steel and for jeweller's and fine work | ... | 19 | 1 | 1 | ... | ... | ... |
| Silver solder for jeweller's and fine work | ... | 19 | 10 | 1 | ... | ... | ... |
| Silver solder for jeweller's, instrument-makers, &c.; very tough and fluid | ... | 11 | ... | 13 | ... | ... | ... |
| Silver solder for plating | ... | 2 | 1 | ... | ... | ... | ... |
| Soft silver solder | ... | 2 | 1 | ... | ... | ... | ... |
| Hard silver solder | ... | 4 | ... | 1 | ... | ... | ... |
| Gold solder for jeweller's ordinary repairs | 3 | 2 | ... | $1\frac{1}{2}$ | ... | $\frac{1}{2}$ | ... |
| Gold solder; fine | 12 | 2 | ... | 4 | ... | ... | ... |
| Gold solder; finer | 24 | 2 | ... | 1 | ... | ... | ... |
| Aluminium solder . . . 6 aluminium | ... | ... | ... | $4\frac{1}{2}$ | ... | $89\frac{1}{2}$ | ... |
| Aluminium solder . . . 6 aluminium | ... | 3 | ... | 3 | 18 | 9 | ... |
| Aluminium solder; soft . . . 6 bismuth | ... | ... | ... | ... | 94 | ... | ... |

In preparing solders, to prevent oxidation, soft solders should be melted under tallow, and hard solders under a thick layer of powdered charcoal.

**Fluxes for soldering.**—For iron or steel, borax or sal-ammoniac ; for tinned iron, resin or chloride of zinc. For zinc, spirits of salts : for lead, tallow, or resin : for lead and tin pipes, and for pewter, resin and sweet oil : for copper, gun-metal, brass, silver, &c., borax or chloride of zinc. : for aluminium, paraffin.

**Finishing and Burnishing Gun Metal and other Metals.**—It is frequently requisite to give a very high finish to metals : for instance, to prepare them for receiving a coating of silver or nickel-plating. This is accomplished by burnishing the articles on buffs revolving at a high speed, for which purpose the following buffs and burnishing compositions are the best.

**Burnishing Bronze, Gun-Metal, Brass, Copper, and White Metal.**—The articles, after being well polished with a fine powder, made from old burnt plumbago crucibles, are finely polished by buffing on a leather buff, with rottenstone and oil, or crocus powder and oil, and are then burnished, by buffing with finely-powdered unslacked lime, or dry crocus powder, on a calico buff.

**Burnishing Iron and Steel Articles.**—The article, after being highly polished with fine emery, is burnished by buffing on a leather buff, first with glass-cutters' sand and afterwards with Trent or finer sand.

**Buffs.**—Calico buffs are made by cutting a great number of pieces of coarse calico into discs ; they are then firmly pressed together, and screwed up on a mandrel, with a nut at each end, between two thick leather discs, with a brass washer at the end of the leather.

Leather buffs are made of a number of discs of walrus hide glued together to the required thickness, and firmly clamped until the glue is set, when they are turned up true, on a mandrel having a nut and washer at each end.

**Finishing Brass Work by Acids.**—Intricate brass work, which cannot be finished in the ordinary way, is finished in the following manner by acids,—viz., the work is first cleansed by heating and dipping in washing soda and water, and afterwards well rinsed in clean water ; it is next plunged for not more than 10 seconds into a solution of water, 1 part, nitric acid, 2 parts ; then taken out and plunged, first into clean cold water, and then into hot soap and water, and dried in hot sawdust. Boxwood sawdust is the best, as it does not contain resin.

**Clouding Brass.**—A solution of charcoal and water is poured on to the surface of highly polished brass, so as to produce circular marks ; slate pencil may be used to fill in part of the cloud. The work when dry, is lacquered.

**The Weights to the New Imperial Standard Wire-Gauge** of sheet-copper, brass, gun-metal, white metal, zinc, and lead are given at pages 290, 291, and the weights of bars of copper, brass, lead, and zinc, at page 301.

## BLUEING, COLOURING, TINNING, BRONZING, LACQUERING, SILVERING AND JAPANNING PROCESSES.

**Blueing Iron and Steel Articles.**—Fill an iron pan with either clean brass filings, sand, powdered charcoal, or mahogany sawdust; heat the same to a dull red heat, and pass the article through it, in and out, until the required colour is obtained. The article to be well polished, free from grease, and not to be touched with the fingers before inserting. The higher the polish the better will the colour be. For very light articles, such as spectacle frames, hot sawdust is preferable. To take away all traces of grease, the articles should be rubbed with powdered quicklime before blueing.

**Blueing Iron and Steel by Boiling.**—Place the articles in the following solution, kept at boiling heat. Dissolve 4 oz. hyposulphite of soda in 1½ pints of water, and then add a solution of 1 oz. acetate of lead in 1 oz. of water.

**Brown Tint for Iron and Steel.**—Dissolve in 4 parts of water, 2 parts of crystallised chloride of iron, 2 parts of chloride of antimony, and 1 part of gallic acid. Apply the solution with a sponge and dry in the air. Repeat the process according to the depth of colour required.

**Browning Gun Barrels.**—The barrels to be well polished and free from grease, and not to be touched with the hands during the process. First rub with powdered quicklime to remove all trace of grease, then apply with a sponge one of the following solutions:—

*Solution No.* 1.—Mix in 1 pint of rain water, ⅛ oz. blue-stone; ½ oz. muriate tincture of steel; ½ oz. spirits of wine; ⅛ oz. strong nitric acid; ¼ oz. muriate of mercury.

*Solution No.* 2.—Sulphate of copper, 1 oz.; sweet spirits of nitre, 1 oz.; rain water, 1 pint.

*Solution No.* 3.—Aqua fortis, ½ oz.; sweet spirits of nitre, ½ oz.; tincture of muriate of iron, 1 oz.; spirits of wine, 1 oz.; sulphate of copper, 2 oz.; water, 30 oz.

*Solution No.* 4.—Tincture of muriate of iron, ½ oz.; spirits of nitric ether, ½ oz.; sulphate of copper, 2 scruples; rain water, ½ pint.

When dry, polish off the rust with a wire scratch brush, and repeat the process until the required depth of colour is obtained. After the last application pour boiling water over the barrels, dry, and while still warm polish with a little beeswax and spirits. *Varnish for gun barrels* after browning: shellac, ½ oz.; dragons' blood, ⅛ oz.; rectified spirits, 1 pint. Warm the barrels before applying.

**Browning Iron and Steel Articles.**—Immerse in a solution of tincture of iodine, with one half its bulk of water.

**Japanning Metal.**—A coat of thick coloured varnish, called japan, is laid on to the metal, and dried by baking in a suitable oven, heated to about 300° F. The high temperature evaporates the solvents of the japan, and causes the residue to adhere firmly to the metal. This process is repeated several times until the required depth of colour, and hardness and finish of the surface is obtained. *The varnish* used consists of, methylated spirit, 1 quart; shellac, 4 oz.; resin, 4 oz., dissolved, and coloured with one of the following mixtures: *for black colour*, with ivory black, or with black made of asphaltum, 1 lb.; balsam of copaiba, 1 lb.; melt and thin with hot oil of turpentine. Another black consists of: asphaltum, 3 oz.; boiled linseed oil, 1 gallon; burnt umber, 8 oz.; melt, mix, and thin with hot oil of turpentine. Another black consists of: amber, 12 oz.; asphaltum, 2 oz.; resin, 1 oz.; boiled linseed oil, ½ pint; melt and mix, and when cooling add 1 pint oil of turpentine. *Yellow colour*, king's yellow *White colour*, white lead, ground up with a sixth of its weight of starch; thin with copal varnish,

**Iron Lacquer.**—Amber, 12 parts; turpentine, 12; resin, 2; asphaltum, 2; drying oil, 6. Another iron lacquer.—Asphaltum, 3 lbs.; shellac, ½ lb.; turpentine, 1 gallon.

**Black Finish for Small Articles of Iron and Steel.**—Boil 1 part of sulphur in 10 parts of oil of turpentine, paint the article with it thinly, and heat over a spirit lamp until the required depth of colour is obtained.

**Tinning Small Articles of Iron, Brass, or Copper by the Boiling Process.**—First clean well and pickle in a bath of dilute muriatic acid, and rinse well in fresh clean water; then immerse for a short time, and stir with a zinc rod, in one of the following solutions, which must be boiling hot:—

*Solution No.* 1.—Ammonia alum, 17¼ oz.; soft water, 12½ lbs.; protochloride of tin, 1 oz.

*Solution No.* 2.—Bitartrate of potassa, 14 oz.; soft water, 24 oz.; protochloride of tin, 1 oz.; and clean zinc in strips, ½ lb.

*Solution No.* 3.—Soft water, 1 gallon; grain tin, 2 lbs.; cream of tartar, 1½ lbs.

**Tinning Zinc.**—Dip in a solution of distilled water, 1 gallon; pyrophosphate of soda, 3¼ oz. fused protochloride of tin, ½ oz.

**Galvanizing Iron.**—Pickle the articles for 8 hours in water containing 1 per cent. of sulphuric acid, held in a wooden vessel; then scour well, rinse in clean water, and immerse them in a bath of melted zinc, kept covered with a layer of melted sal ammoniac to prevent oxidation of the zinc.

**Black Finish for Brass.**—Dissolve copper wire in nitric acid, add 3 parts of water to one of the acid, make the article hot and dip it in the solution; then heat the article over a spirit lamp until the desired depth of colour is obtained, and give one coat only of lacquer.

**Black Finish for Brass.**—Reduce nitrate of copper to the oxide, warm the metal slightly and apply with a brush, and then heat the article until the required depth of colour is obtained.

**Black Finish for Brass.**—Make a strong solution of nitrate of silver in one dish, and of nitrate of copper in another; mix the two together, and plunge the brass into it; remove and heat the brass evenly, until the required depth of colour is obtained.

**Black Finish for Brass.**—Another way is to immerse the brass until it turns black in a mixture of:—white arsenic, $\frac{1}{2}$ lb.; sulphate of iron, $\frac{1}{2}$ lb.; hydrochloric acid, 6 lbs.; when the required depth of colour is obtained, rinse well in water, dry in sawdust, polish with black lead, and lacquer. In some cases brass is simply blackened by laying on a mixture of vegetable black and french polish.

Another way to blacken brass is, first to polish it with tripoli, then wash it with a mixture of 1 part of nitrate of tin and 2 parts of chloride of gold; allow this wash to remain for nearly a quarter of an hour, and wipe off with a linen cloth.

**Bronzing Brass, Copper, and other Metals.**—Copper bronze:—fuchsin, 10 parts; aniline purple, 5 parts; methylated spirit, 100 parts; heat, and, when solution takes place, add benzoic acid, 5 parts; next boil the whole for 10 minutes, or until the colour of the mixture changes to bronze colour.

**Antique Bronze** can be imitated by using the following mixture:—muriate of ammonia, or sal ammoniac, $\frac{3}{4}$ oz.; salts of tartar, or carbonate of potash, $1\frac{1}{2}$ drachms; vinegar, 1 quart. Apply with a sponge and repeat several times until the proper tint is obtained. Brown, and every shade to black: use a mixture of 5 drachms nitrate of iron in 1 pint of water. Chocolate colour is obtained by steeping iron wire in aqua fortis for a quarter of an hour before dipping; then dip the brass in the same.

**Chinese Bronze.**—Powder and make into thin paste with vinegar, vermilion, 2 oz.; verdigris, 2 oz.; alum, 7 oz.; sal ammoniac, 5 oz.; after using, gently warm the article; afterwards wash and dry, and repeat the process until the required tint is obtained. By adding a little blue vitriol to this mixture a chestnut brown is obtained, and a little borax gives a yellow tint.

**Lacquering.**—This process is varnishing metals to protect their colour. The work is first thoroughly cleaned, and then pickled for two hours in a pickling solution of 3 parts water and 1 part nitric acid, contained in an earthenware vessel, and afterwards scoured with fine sand and water, applied with a brush.

**Dipping Brass.**—After pickling, the work is dipped for 3 seconds in pure nitric acid, and afterwards instantly plunged into a solution of whiting and water, or of water and common washing soda, which removes the acid, and the work comes out a fine gold colour; next dry and lacquer. The work should be held with tongs made of brass, when dipping. The lacquer to be warmed and applied with a camel's hair brush to the work, which should be previously heated to 212°.

**Dissolving Metals.**—Copper, bismuth, nickel and zinc, dissolve in nitric acid. Lead and antimony, dissolve in a solution of nitric acid, 1 part; hot water, 2 parts. Tin dissolves in hydrochloric acid.

Table 81.—Composition of Lacquers.

| | | Strong Simple. | Pale Simple. | Fine Pale. | Pale Gold. | Bright Gold. | Deep Gold. | Pale Yellow. | Red. | Tin Lacquer. | Green for Bronze. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shellac . . . . | ounce | 4 | 1 | 1 | 2 | 8 | 3 | 2 | — | 15 | — |
| Mastic . . . . . | drachm | — | — | — | — | — | — | — | — | 30 | — |
| Canada balsam . . | drachm | — | — | — | — | — | — | — | — | 30 | — |
| Spirits of wine . . | pint | 1 | 1 | 1 | 2 | 4 | 1 | 1 | — | 6 | — |
| Simple pale lacquer . | pint | — | — | — | — | — | — | — | 1 | — | 1 |
| Dragon's blood . . | drachm | — | — | — | 1 | — | 4 | — | 8 | 20 | — |
| Annatto . . . . . | drachm | — | — | — | 8 | 1 | — | — | 32 | — | — |
| Turmeric . . . . | drachm | — | — | 1 | 32 | 4 | 16 | — | — | 60 | 4 |
| Gamboge . . . . | drachm | — | — | 1 | — | — | — | 2 | — | — | 1 |
| Saffron . . . . | drachm | — | — | 2 | — | 1 | — | — | — | 10 | — |
| Cape aloes . . . . | drachm | — | — | — | — | — | — | 4 | — | — | — |
| Sandarac . . . . | drachm | — | — | — | 8 | — | — | — | — | — | — |

**To remove lacquer** from brass, boil for 20 minutes in a solution of water, 1 gallon; potash, $\frac{1}{2}$ lb.; withdraw and plunge into cold water.

**Silvering Brass, Iron, and other Metals.**—First clean and pickle the articles in the same way as for tinning, as given above, then immerse them for a few seconds in a solution of cyanide of silver. Another process is: heat 1 oz. nitric acid until it boils, then add a few pieces of silver; as soon as they are dissolved add a handful of common salt to kill the acid, then make it into a paste with whiting, and apply with water and wash leather. Another process is: mix 1 part of dry chloride of silver, finely powdered, with 3 parts of pearl ash, 1 part of chalk, and $1\frac{1}{2}$ parts common salt; rub on with water and wash leather.

**Gilding Brass, Bronze, and Other Metals.**—Apply the following mixture at boiling heat:—cyanide of potass, $2\frac{1}{2}$ lb.; carbonate of potass, 5 oz.; cyanate of potass, 2 oz.; the whole diluted in 5 pints of water, containing in solution $\frac{1}{4}$ oz. chloride of gold; and afterwards varnish the gilt surface.

**To Whiten Silver.**—Boil in a solution of:—1 part cream of tartar; 2 parts common salt, and 50 parts water.

**To Dead-Whiten Silver.**—Boil in a solution of alum and water until the desired tint is obtained, and wash well with a brush in hot water with soap and carbonate of soda.

**Silver Paint.**—Gum lac is dissolved in 4 times its volume of alcohol, and to this thick solution, silver powder is added, in the proportion of 1 part powder to 3 of the solution. The surface to be coated, is covered with spanish white, the metallic mixture is applied with a brush, and when dry, is burnished with a steel or stone burnisher. Bronze gold, or any other metal powder, may be used in the same way.

**Whitening Brass.**—Make a mixture of 2 lbs. grain tin, $1\frac{1}{2}$ lb. cream of tartar, and 1 gallon of water; boil and immerse the brass for a few minutes at a boiling temperature.

**Frosting Silver.**—Apply with a brush, a solution of water half a pint; cyanide of potassium, 1 ounce.

**Lacquer Varnish for Colouring Metals.**—Mix turmeric and annatto, with lac varnish, to the required depth of colour.

**Zinking, or Coating Small Articles with Zinc.**—First clean and pickle, next dip the articles in a mixture of zinc dissolved in hydrochloric acid, to which a little sal ammoniac is added; then dry and dip in melted zinc and shake off the superfluous metal.

**Coppering or Bronzing Iron and Steel Articles.**—Clean and immerse in a solution of sulphate of copper, $3\frac{1}{2}$ oz.; sulphuric acid, $3\frac{1}{2}$ oz.; water, 1 gallon.

**Tinning Iron and Steel.**—Clean and immerse in hot oil or tallow, and then immediately dip into melted tin.

**Moire Metal.**—Clean and heat the tin over a clear fire, until water will fizz on its surface; then dip it quickly into a mixture of—water, 4 parts; muriatic acid, 1 part; nitric acid, 1 part; rinse in water, dry quickly in hot sawdust, and varnish while hot.

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## HARDENING, SOFTENING, AND TEMPERING PROCESSES.

**Case-hardening Wrought-Iron.**—Pack the articles to be hardened, in a box, filled to the top with small pieces of bone and wood charcoal, and a few pieces of burnt leather, the heaviest articles to be placed at the bottom of the box. Make the lid of the box tight, with a lute of equal parts of clay and sand. Subject for 10 hours to a red heat in a furnace, and quench the articles in water.

NOTE.—Articles to be case-hardened before placing in the box, should have the threads of screws and nuts, and other parts which require to be left soft, plugged with clay.

**Hardening Wrought-Iron with Potash.**—This process only hardens to a very slight depth. Heat the article to a bright red, rub the surface well over with powdered prussiate of potash, or with a mixture of 3 of prussiate of potash, to 1 of sal ammoniac reduced to powder, and allow it to cool to a dull red, then quench in water. By repeating the process, a slightly deeper hardening will be obtained, but it is much inferior to case-hardening.

**To harden Malleable Cast-Iron.**—Heat the article to a bright red, rub the surface well over with a mixture of equal parts of potash, saltpetre, and sulphate of zinc, allow it to cool to a dull red, and quench in water.

**To harden Cast-Iron.**—Heat the article to a bright red, and quench in a mixture of 3 gallons of water, $\frac{1}{2}$ pint oil of vitriol, and 2 oz. saltpetre.

Another mixture for quenching consists of salt water 10 gallons, salt 1 peck, oil of vitriol $\frac{1}{2}$ pint, saltpetre $\frac{1}{2}$ lb., prussiate of potash $\frac{1}{4}$ lb., cyanide of potash $\frac{1}{2}$ lb.; by repeating the process cast-iron may be made harder.

**To harden Cast-Iron.**—Another process is to heat to bright red, and rub the surfaces with a mixture of equal parts powdered prussiate of potash, saltpetre and sal ammoniac. Allow the article to cool to red heat and quench in a mixture—4 oz. sal-ammoniac and 2 oz. prussiate of potash per gallon of water.

**To anneal or soften Finished Iron or Steel Work.**—Lute an iron box with clay, and place the articles in the box, full of turnings or borings, of the same metal as the articles are made of. Make the lid of the box tight with a lute of clay. Heat slowly to a red heat in a furnace, and let the fire die out.

**To soften Steel Forgings, &c.**—Heat to a low red heat, and cool in lime or whiting.

**To soften Steel Forgings, or Hard Steel or Iron.**—Another process is to pack the articles in a box full of whiting or iron borings, make the lid of the box tight with a lute of clay, heat to a low red heat in a furnace for 4 hours and let the fire die out.

**To drill Hard Steel.**—Heat the drill in a charcoal fire, and quench in mercury. Moisten the work when drilling with a mixture of turpentine and camphor.

**To soften Chilled Cast-Iron.**—Heat the article to nearly white heat, and cover it with a good depth of small coal, and let it remain until cold.

**To soften small Castings of hard Cast-Iron.**—Pack them in a box of fine coke screenings, put a thin layer of fine sand on the top well damped, heat in a furnace to a low red heat and let the fire die out; or they may be softened to a slight depth by steeping for 24 hours in 1 part aqua fortis to 4 parts of water.

**Malleable Cast-Iron.**—The articles are first cast in cast iron, and malleableised,—by burning off the carbon combined with the iron from which the castings were made,—by a process of annealing. The iron used is a white hematite metal, No. 5 brand, which contains little carbon. The castings are first cleaned, and then packed into iron boxes, with alternate layers of either fine iron scales from rolling mills, or powdered hematite ore. The boxes are closed at the top with a mixture of sand and clay, and are next placed in an annealing oven, where they are kept under an equable red heat for from 7 to 14 days if the castings are light, and for about 21 days if they are heavy.

**Welding Cast-Steel.**—Mix borax 10 parts, sal ammoniac 1. Simmer over fire for 1 hour, or until clear, pour out, cool, and reduce to powder. Heat the steel in a coke fire, to bright yellow heat.

**Welding Cast-Steel.**—Another mixture is, powdered limestone 6 parts, sulphur 1 part; and another mixture is, borax 10 parts, sal-ammoniac 2, sulphur 1 part.

**Restoring slightly burnt Cast-Steel.**—Borax, $1\frac{1}{2}$ lb.; sal-ammoniac, $\frac{1}{2}$ lb.; prussiate of potash, $\frac{1}{4}$ lb.; resin, 1 oz.; powder and mix with 1 gill each of water and alcohol. Boil for a short time to a paste, dip the hot steel in the mixture, and slightly hammer.

**To distinguish Steel from Iron.**—Nitric acid does not affect iron, but produces a black spot on steel. The darker the spot the harder the steel.

**To harden Hammers and other Tools.**—Bone dust, 2 parts; common salt, 3; burnt leather shreds, 1; prussiate of potash, 1 part. Heat to a cherry red and plunge into this compound.

**To harden a Drill to drill Glass.**—Heat to cherry red, and quench in mercury: when drilling moisten with turpentine and a little camphor.

**To soften Copper and Brass, Gold and Silver.**—Heat to a low red heat, and quench in a solution of salt and water.

**Hardening Steel Tools.**—To obtain the best results, the steel should be heated in a charcoal fire. Heat to a cherry red, and dip about an inch deep in tepid water, rub the hardened portion with a piece of sandstone, the heat in the uncooled portion will be quickly transferred to the point just cooled, and by watching the colour any degree of temper may be obtained. *Chisels* for chipping iron, should be tempered, or lowered to a dark straw colour; *turning tools* for wrought iron, to a pale straw colour; *turning tools* for cast iron, should be made as hard as water will make them; *shear blades and punches* should be lowered to light purple colour; *turning tools* for brass, to a straw colour; *turning tools* for wood, to a dark straw colour; *taps and dies, rhymers and circular cutters for milling and wheel cutting machines*, each to a light brown colour.

**To harden Trowels, Saws and various Steel Articles.**—Quench in one of the following mixtures:—

*Mixture No.* 1.—Sperm oil, 1 gallon; beef suet, 1 lb.; neats' foot oil, ½ pint; pitch, 1 oz.; black resin, 3 oz.; melted, mixed and cooled.

*Mixture No.* 2.—Sperm oil, 1 gallon; tallow, 2 lb.; wax, ¼ lb. This mixture is only suitable for very small steel articles.

*Mixture No.* 3.—Sperm oil, 1 gallon; tallow, 2 lb.; wax, ¼ lb.; resin, 1 lb.

*Mixture No.* 4.—Sperm oil, 20 gallons; tallow, 20 lb.; ox foot oil, 10 gallons; pitch, 1 lb.; resin, 3 lb.

Melt the pitch and resin before adding the other ingredients. Mix and heat the whole in an iron pot; when sufficiently heated it will catch fire when a light is held near it. The flame is put out by placing a lid on the pot. These mixtures make the steel very hard and brittle; and to temper the same, wipe a portion only of the composition off when the article is withdrawn from the bath, then hold it over a coke fire till the grease ignites, and blaze off a small portion only if the article is required to be hard, and a larger amount if required to be softer.

**Hardening Tools and Cutters.**—Tools when heated to a cherry red and quenched in one of the following solutions are less liable to crack, and give better results, than when quenched in water.

*Hardening Solution No.* 1.—Soft warm water, 1 gallon; salt, ½ pint.

*Hardening Solution No.* 2.—Make a solution of water, salt, and nitrate of iron. Keep at 60 degrees temperature.

*Hardening Solution No.* 3.—To 1 bucketful of water, add 1 gill vitriol.

*Hardening Solution No.* 4.—To 1 bucketful of water, add a handful of slaked lime.

*Hardening Solution No.* 5.—To 3 gallons rain water, add 3 oz. spirits of nitre, 3 oz. hartshorn, 3 oz. white vitriol, 3 oz. sal-ammoniac, 3 oz. alum, 6 oz. salt, 2 handfuls of shreds of leather partly burnt; this solution is used for hardening chisels, for dressing French burr stones.

**To harden Chisels for cutting Granite and Marble.**—Heat to a cherry red and quench in a mixture of whale oil, 1 gallon; resin, 2 lb.; beeswax, 1 lb.; melted and mixed.

**To harden Gravers and Drills for cutting very hard materials.**—Heat to cherry red, and quench in one of the following:—1st. Mercury; 2nd. Plunge into sealing wax, withdraw quickly, plunge in a fresh place and repeat the process until the drill is cold; 3rd. Plunge repeatedly into either yellow soap, or beeswax, until the drill is cold; 4th. Drive repeatedly into lead, until the drill is cold.

**Hardening Steel Spiral Springs.**—Spiral springs may be heated in a melted alloy, composed of 12 parts lead and 1 tin, until they are of the same temperature as the alloy (which should be just fluid), or they may be placed inside a gas pipe and heated in a fire, the pipe should be turned round frequently in the fire until they are uniformly heated to a cherry red; long springs should be placed on a mandrel before heating, otherwise they are liable to bend and become irregular in the coils; slight springs should be quenched in oil; medium thick springs in hot water about 60 degrees temperature, with a film of oil on the top of the water; and thick springs in water only, heated to 70°. Always plunge the spring endways, and do not take out until quite cold.

**To temper Springs.**—Smear them over with a composition of sperm oil, 1 gallon; rendered beef suet, 1 lb.; neatsfoot oil, 1 gill; resin, $\frac{1}{4}$ lb.; heat uniformly by holding them inside a hot pipe until the grease burns uniformly upon all parts and the grease burns off with a blaze; if the grease on the ends takes fire sooner than that on the middle, cool the same with grease and blaze again. Thick springs require to be repeatedly dipped in the grease and blazed, and unless the blazing is uniform the temper will not be uniform. When the blazing is finished and a uniform blue colour is obtained, finally quench in oil.

**Tempering Steel Tools.**—When steel is hardened to the hardest degree, as at the first quenching, it is comparatively weak and brittle, and to strengthen the steel it is necessary to lower the degree of hardness by re-heating, during which process as the temperature rises, the polished surface assumes various shades of colour, which indicate various degrees of temper, and the colours change successively according to the following table; when the desired colour is reached the tool is then quenched.

Table 82.—TEMPERATURE FOR TEMPERING STEEL TOOLS.

| Temper Colour. | Description of Tools. | Temperature. Fahr. | Alloy whose Fusing Point is of the same Temperature. Tin. | Lead. |
|---|---|---|---|---|
| Very faint yellow | Lancets and instruments | 420° | 4 | 7 |
| Pale straw yellow | Turning tools for metal | 430° | 8 | 15 |
| Straw yellow | Razors | 450° | 8 | 17 |
| Dark straw yellow or orange | Penknives and chipping chisels for hard cast iron | 470° | 4 | 10 |
| Light brown | Taps and dies; rhymers; shears and scissors | 490° | 4 | 14 |
| Brown yellow | Hatchets; chipping chisels; and other percussive tools | 500° | 8 | 33 |
| Red | Carpenter's tools in general | 510° | 4 | 19 |
| Light purple | Saws; shear blades and punches | 520° | 4 | 25 |
| Dark purple | Fine watch springs and table knives | 530° | 4 | 30 |
| Bright blue | Swords and lock springs | 550° | 4 | 48 |
| Full blue | Daggers; fine saws; and needles | 560° | | |
| Darker Blue | Springs and augers | 570° | | |
| Dark blue | Soft, for common saws | 600° | | |

**Tempering by the Thermometer.**—Put the articles to be tempered into a vessel containing sufficient oil, or tallow, or sand to cover them (or use one of the alloys given in the above table), then heat the whole uniformly to the required degree of heat (shown by a suitable thermometer) corresponding to the hardness required, then withdraw and quench. If no thermometer is available, and oil or tallow is used, these begin to smoke at 430°—or pale straw yellow—and go out when the light is withdrawn at 570° or darker blue of the above table.

**The degree of Temper** which a tool will take depends upon the proportion of carbon contained by the steel. The following is the usual percentage of carbon in steel:—

| Description of Steel. | Carbon per cent. | Description of Steel. | Carbon per cent. |
|---|---|---|---|
| Surgical instruments | 1·48 | Carpenter's tools; cutters | 1·10 |
| Razors | 1·45 | Chisels and hatchets | 1·00 |
| Tool steel for chilled rolls | 1·40 | Shears; setts and springs | ·80 |
| Saw files; gravers, &c. | 1·35 | Forgings for shafts, &c. | ·50 |
| Tools for cutting very hard metals | 1·30 | Steel rails | ·40 |
| | | Forgings for shafts; tyres | ·33 |
| Tools for cutting metals | 1·25 | Boiler plates | ·25 |
| Shears; cutlery, files | 1·20 | Ship plates and boiler plates | ·20 |
| Smiths' tools; dies, &c. | 1·15 | | |

## HARDENING AND TEMPERING TAPS, RHYMERS AND CUTTERS.

**The quality of Steel** being much improved by hammering, taps, rhymers, and cutters should be forged to the proper size, to allow for turning. Steel of medium grain should be used, and they should not be softened with their skin on, otherwise they will warp when hardened, owing to the tension caused by forging; to remove the tension, they should be roughly turned all over, before softening them. The process of softening equalises the grain of the metal, and is best performed, by enclosing the taps and rhymers in a piece of wrought-iron gas-tubing, filled with wrought-iron turnings, the ends of the tube being plugged up with clay; the tube is then made red hot, and is allowed to cool slowly, by leaving it covered up with hot ashes for 12 hours.

**To harden Taps.**—First slightly warm and rub them all over, with a mixture of Castile soap and lamp black, which preserves the edges from being burnt, then place them in a wrought iron pipe, say $\frac{3}{4}$ inch thick, filled with charcoal dust, plug the ends of the tube with clay, and heat it uniformly by turning it round occasionally in the furnace, until it comes to a cherry red heat, then carefully withdraw it from the furnace, knock the plug out of one end of the tube, and drop the contents vertically, into a solution heated to 60°, of 1 gallon rain water; 1 lb. salt; and allow them to remain therein, until they become quite cold: if they are taken out of the water during cooling they are liable to crack. Care should be taken to keep the taps perpendicular when in the water, as if allowed to fall sideways they will warp.

**To temper Taps.**—After hardening, polish and then temper as follows:—A wrought iron hoop—of a diameter inside, equal to double the diameter of the tap—and in thickness, not less than the diameter of the tap,—and in depth, about one-half the length of tap,—should be uniformly heated to a cherry red heat, then warm the jaws of a pair of tongs, and hold the square of the tap in the tongs, and pass the tap right through the hoop, leaving only the square part of the tap inside the hoop. The tap should then be turned slowly round, until that end becomes slightly heated; the shank and the screw part should then be moved slowly backwards and forwards through the hoop, and at the same time turned slowly round, until evenly coloured, and when it reaches a light brown colour, the tap should be quenched perpendicularly in oil. The square end of the tap, should be lowered to a deeper colour than the screw part.

**To harden and temper Rhymers.**—Proceed the same way as for taps; or they may be heated in molten lead and quenched in the same solution as the taps; the advantage of heating them in molten lead, is, that the outside can be properly heated, before the metal at the centre is red hot, and the metal at the centre will be sufficiently soft, to allow of the rhymer being straightened after hardening; should it have warped during hardening, to straighten it, lay it on a block of lead with the arched side upwards, place a copper drift in the uppermost flute, and strike the same with a hammer.

**To harden Circular Cutters** for milling machines and wheel-cutting machines, and similar cutters, having a hole through the centre. It is necessary when quenching, to prevent the water from getting to the centre of the hole too soon, otherwise it will cool more rapidly than the body of the cutter, and will crack; to prevent this, protect the hole with a bolt and two turned washers; the bolt should be less than the diameter of the hole, and the washers should be moderately tightened. In cases where it is not convenient to use a bolt and washers, the hole should be plugged with a mixture of clay and finely sifted iron borings. Then warm the cutter slightly and rub the cutting edges over, with a mixture of Castile soap and lamp black, and heat it in a charcoal fire, to a uniform cherry red heat, and quench it edgeways in a solution of 1 gallon of rain water and 1 lb. of salt. To temper these cutters hold them over a piece of hot iron, until they arrive at a light brown colour, and quench in oil. In preparing these and all kinds of cutters, they should be turned before annealing, and they should neither be straightened nor bent after annealing.

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## PRODUCTION AND CONVERSION OF STEEL.

**Steel** is a compound of iron with from 0·5 to 1·5 per cent. of its weight of carbon, the more carbon it contains the harder the steel is. The quality of steel depends upon the purity of the materials, the quality of the workmanship, and the care taken in its production.

**Bessemer Steel** is made from pig iron, by passing a strong blast of air through the molten metal, which removes the carbon and purifies the metal, the residue being malleable iron in a melted state; a small quantity of spiegel-eisen is afterwards run into the vessel. The steel thus produced is run into ingots, which are hammered and rolled like blooms of wrought-iron.

**Blister-Steel** is made by a similar process to case-hardening, called cementation. A number of bars of best wrought-iron are embedded in layers of charcoal—contained in a trough—and are subjected to a temperature of about 2000° F. in a suitable furnace for 4 days for spring steel, 8 days for shear steel, and 12 days for chisel steel. Each bar absorbs carbon, and is converted into steel at the surface, and into steely iron at the interior of the bar.

**Cast Steel** is the strongest steel. Small pieces of blister-steel are melted in a crucible, with the proper quantity of carbon and manganese.

**Shear Steel.** Short bars of blister-steel are tied in bundles to form a fagot, which is heated and welded with a quick speed tilt-hammer, and afterwards re-heated and hammered into a bar. To make double shear steel, the bar is broken in two and the pieces are welded together.

**Homogeneous Metal** is made by melting small pieces of best wrought-iron in a crucible with the proper quantity of carbon, some spiegel-eisen being added when the operation of melting is nearly completed.

Table 83.—PROPORTIONS OF ENGINEERS' HAND-WORKING TAPS, WHITWORTH'S THREAD.

| Diameter of Tap in Inches. | Full Length of Tap from End to End in Inches. | Length of Screw Part in Inches. | Diameter at Bottom of Thread in Inches. | Diameter of Shank in Inches. | Size of Square in Inches. | Length of Square in Inches. | Pitch in Parts of an Inch. | Number of Threads per Inch. | Change Wheels to be Used for Cutting the Screw of Tap, with a Lathe having a Leading Screw of ½ Inch Pitch. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Lathe Spindle. | Leading Screw. | Intermediate Stud Wheel. | Stud Pinion. |
| 1/16 | 1 1/2 | 5/8 | | | | 3/16 | 1/60 | 60 | 10 | 90 | 50 | 15 |
| 3/32 | 1 5/8 | 3/4 | | | | 3/16 | 1/48 | 48 | 10 | 90 | 40 | 15 |
| 1/8 | 1 3/4 | 7/8 | | | | 1/4 | 1/40 | 40 | 20 | 125 | 80 | 25 |
| 5/32 | 1 7/8 | 7/8 | | | | 1/4 | 1/32 | 32 | 20 | 100 | 80 | 25 |
| 3/16 | 2 | 1 | | | | 5/16 | 1/24 | 24 | 20 | 90 | 80 | 30 |
| 7/32 | 2 1/8 | 1 1/16 | | | | 5/16 | 1/24 | 24 | 20 | 90 | 80 | 30 |
| 1/4 | 2 1/4 | 1 1/8 | 3/16 | 3/16 | | 3/8 | 1/20 | 20 | 40 | 100 | 80 | 20 |
| 5/16 | 2 1/2 | 1 3/8 | 1/4 | 1/4 | 5/32 | 7/16 | 1/18 | 18 | 40 | 90 | 80 | 20 |
| 3/8 | 2 3/4 | 1 1/2 | 9/32 | 9/32 | 7/32 | 1/2 | 1/16 | 16 | 45 | 90 | 80 | 20 |
| 7/16 | 3 1/4 | 1 3/4 | 11/32 | 11/32 | 9/32 | 1/2 | 1/14 | 14 | 20 | 140 | | |
| 1/2 | 3 1/2 | 2 | 13/32 | 13/32 | 5/16 | 9/16 | 1/12 | 12 | 20 | 120 | | |
| 9/16 | 3 3/4 | 2 1/8 | 15/32 | 15/32 | 5/16 | 9/16 | 1/12 | 12 | 20 | 120 | | |
| 5/8 | 4 | 2 1/4 | 17/32 | 17/32 | 3/8 | 5/8 | 1/11 | 11 | 20 | 110 | | |
| 11/16 | 4 1/4 | 2 3/8 | 9/16 | 9/16 | 3/8 | 11/16 | 1/11 | 11 | 20 | 110 | | |
| 3/4 | 4 1/2 | 2 1/2 | 5/8 | 5/8 | 7/16 | 3/4 | 1/10 | 10 | 20 | 100 | | |
| 13/16 | 4 3/4 | 2 5/8 | 11/16 | 11/16 | 7/16 | 3/4 | 1/10 | 10 | 20 | 100 | | |
| 7/8 | 5 | 2 7/8 | 23/32 | 23/32 | 1/2 | 13/16 | 1/9 | 9 | 20 | 90 | | |
| 15/16 | 5 1/4 | 3 | 25/32 | 25/32 | 1/2 | 15/16 | 1/9 | 9 | 20 | 90 | | |
| 1 | 5 1/2 | 3 1/4 | 27/32 | 27/32 | 5/8 | 7/8 | 1/8 | 8 | 20 | 80 | | |
| 1 1/8 | 6 | 3 1/2 | 15/16 | 15/16 | 11/16 | 1 | 1/7 | 7 | 20 | 70 | | |
| 1 1/4 | 6 1/2 | 3 3/4 | 1 1/16 | 1 1/16 | 13/16 | 1 1/8 | 1/7 | 7 | 20 | 70 | | |
| 1 3/8 | 7 1/2 | 4 1/4 | 1 5/32 | 1 5/32 | 13/16 | 1 1/8 | 1/6 | 6 | 20 | 60 | | |
| 1 1/2 | 8 | 4 3/4 | 1 9/32 | 1 9/32 | 1 | 1 1/4 | 1/6 | 6 | 20 | 60 | | |

NOTE.—Hand-working master taps are made larger in diameter than ordinary taps, to the extent of twice the depth of the thread, the bottom

Table 83 *continued*.—PROPORTIONS OF ENGINEERS' HAND-WORKING TAPS, WHITWORTH THREAD.

| Diameter of Tap in Inches. | Full Length of Tap from End to End in Inches. | Length of Screw Part in Inches. | Diameter at Bottom of Thread in Inches. | Diameter of Shank in Inches. | Size of Square in Inches. | Length of Square in Inches. | Pitch in Parts of an Inch. | Number of Threads per Inch. | Change Wheels to be Used for Cutting the Screw of Tap, with a Lathe having a Leading Screw of ½ Inch Pitch. Lathe Spindle. | Leading Screw. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $1\frac{5}{8}$ | $8\frac{1}{2}$ | $5\frac{1}{4}$ | $1\frac{11}{32}$ | $1\frac{11}{32}$ | 1 | $1\frac{1}{4}$ | $\frac{1}{5}$ | 5 | 20 | 50 | |
| $1\frac{3}{4}$ | 9 | $5\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $\frac{1}{5}$ | 5 | 20 | 50 | of the thread of |
| $1\frac{7}{8}$ | $9\frac{1}{2}$ | $5\frac{3}{4}$ | $1\frac{19}{32}$ | $1\frac{19}{32}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $\frac{2}{9}$ | $4\frac{1}{2}$ | 40 | 90 | master taps being |
| 2 | 10 | 6 | $1\frac{23}{32}$ | $1\frac{23}{32}$ | $1\frac{5}{16}$ | $1\frac{1}{2}$ | $\frac{2}{9}$ | $4\frac{1}{2}$ | 40 | 90 | the same diameter |
| $2\frac{1}{8}$ | $10\frac{1}{2}$ | $6\frac{1}{4}$ | $1\frac{27}{32}$ | $1\frac{27}{32}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $\frac{2}{9}$ | $4\frac{1}{2}$ | 40 | 90 | as that of the top |
| $2\frac{1}{4}$ | 11 | $6\frac{3}{4}$ | $1\frac{15}{16}$ | $1\frac{15}{16}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $\frac{1}{4}$ | 4 | 40 | 80 | of the thread of |
| $2\frac{3}{8}$ | $11\frac{1}{2}$ | $7\frac{1}{4}$ | $2\frac{1}{32}$ | $2\frac{1}{32}$ | $1\frac{5}{8}$ | $1\frac{5}{8}$ | $\frac{1}{4}$ | 4 | 40 | 80 | ordinary taps. |
| $2\frac{1}{2}$ | 12 | $7\frac{3}{4}$ | $2\frac{3}{16}$ | $2\frac{3}{16}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ | $\frac{1}{4}$ | 4 | 40 | 80 | |
| $2\frac{5}{8}$ | $12\frac{1}{2}$ | $8\frac{1}{4}$ | $2\frac{5}{16}$ | $2\frac{5}{16}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $\frac{1}{4}$ | 4 | 40 | 80 | |
| $2\frac{3}{4}$ | 13 | $8\frac{3}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{7}{8}$ | $\frac{2}{7}$ | $3\frac{1}{2}$ | 40 | 70 | |
| $2\frac{7}{8}$ | $13\frac{1}{2}$ | $9\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{7}{8}$ | $1\frac{7}{8}$ | $\frac{2}{7}$ | $3\frac{1}{2}$ | 40 | 70 | |
| 3 | 14 | $10\frac{3}{4}$ | $2\frac{5}{8}$ | $2\frac{5}{8}$ | 2 | 2 | $\frac{2}{7}$ | $3\frac{1}{2}$ | 40 | 70 | |

Table 84.—WHITWORTH'S THREAD FOR LARGE TAPS.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Size of Tap, in inches . . | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $3\frac{3}{4}$ | 4 | $4\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | 5 | $5\frac{1}{4}$ | $5\frac{1}{2}$ | $5\frac{3}{4}$ | 6 |
| Number of threads per inch . | $3\frac{1}{4}$ | $3\frac{1}{4}$ | 3 | 3 | $2\frac{7}{8}$ | $2\frac{7}{8}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{5}{8}$ | $2\frac{5}{8}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ |

Table 85.—MACHINE WORKING TAPS FOR TAPPING NUTS, WHITWORTH'S THREAD.

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of tap, in inches . . . . . . . | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{7}{8}$ | 2 | $2\frac{1}{8}$ | $2\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{1}{2}$ | $2\frac{5}{8}$ | $2\frac{3}{4}$ | $2\frac{7}{8}$ | 3 |
| Full length of tap, from end to end, in inches . . | $5\frac{1}{2}$ | 6 | $6\frac{1}{2}$ | 7 | 8 | 9 | $9\frac{1}{2}$ | 10 | 11 | 12 | 13 | $13\frac{1}{2}$ | 14 | 15 | 16 | $16\frac{1}{2}$ | 17 | 18 | 19 | $19\frac{1}{2}$ | 20 | 21 |
| Length of screw part, in inches . . . . . | $2\frac{1}{2}$ | 3 | $3\frac{1}{4}$ | $3\frac{3}{4}$ | $4\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | 5 | $5\frac{1}{2}$ | 6 | $6\frac{1}{2}$ | $6\frac{3}{4}$ | 7 | $7\frac{1}{4}$ | $7\frac{1}{2}$ | 8 | $8\frac{1}{2}$ | 9 | $9\frac{1}{2}$ | 10 | 11 | 12 |

NOTE.—The other proportions are the same as for hand-working taps.

Table 86.—PROPORTIONS OF GAS TAPS (WHITWORTH'S GAS SCREW-THREAD).

| Internal Diameter of Pipe. | Diameter of Tap. Also the External Diameter of the Pipe. | Diameter at the Bottom of Thread. | Number of Threads per Inch. | Change Wheels to be Used for Cutting the Screw of Tap, with a Lathe having a Leading Screw of ½ Inch Pitch. | | | | Internal Diameter of Pipe. | Diameter of Tap. Also the External Diameter of the Pipe. | Diameter at the Bottom of Thread. | Number of Threads per Inch. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Lathe Spindle. | Leading Screw. | Intermediate Wheel. | Stud Pinion. | | | | |
| Inches. | Inches. | Inches. | | | | | | Inches. | Inches. | Inches. | Inches. |
| 1/8 | ·3825 | ·3367 | 28 | 20 | 120 | 70 | 30 | 1 5/8 | 2·021 | 1·9045 | 11 |
| 1/4 | ·518 | ·4506 | 19 | 50 | 100 | 95 | 20 | 1 3/4 | 2·047 | 1·9305 | 11 |
| 3/8 | ·6563 | ·5889 | 19 | 50 | 100 | 95 | 20 | 1 7/8 | 2·245 | 2·1285 | 11 |
| 1/2 | ·8257 | ·7342 | 14 | 20 | 140 | | | 2 | 2·347 | 2·2305 | 11 |
| 5/8 | ·9022 | ·8107 | 14 | 20 | 140 | | | 2 1/4 | 2·5875 | 2·471 | 11 |
| 3/4 | 1·041 | ·9495 | 14 | 20 | 140 | | | 2 1/2 | 3·0013 | 2·8848 | 11 |
| 7/8 | 1·189 | 1·0975 | 14 | 20 | 140 | | | 2 3/4 | 3·247 | 3·1305 | 11 |
| 1 | 1·309 | 1·1925 | 11 | 20 | 110 | | | 3 | 3·485 | 3·3685 | 11 |
| 1 1/8 | 1·492 | 1·3755 | 11 | 20 | 110 | | | 3 1/4 | 3·6985 | 3·582 | 11 |
| 1 1/4 | 1·65 | 1·5335 | 11 | 20 | 110 | | | 3 1/2 | 3·912 | 3·7955 | 11 |
| 1 3/8 | 1·745 | 1·6285 | 11 | 20 | 110 | | | 3 3/4 | 4·1255 | 4·009 | 11 |
| 1 1/2 | 1·8825 | 1·766 | 11 | 20 | 110 | | | 4 | 4·339 | 4·2225 | 11 |

Table 87.—PROPORTIONS OF RHYMERS.

| | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of rhymer . . . . | 1/4 | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 11/16 | 3/4 | 13/16 | 7/8 | 1 | 1 1/8 | 1 1/4 | 1 3/8 | 1 1/2 |
| Full length of rhymer, end to end . | 5 | 5 1/2 | 6 | 6 1/2 | 7 | 7 1/2 | 8 | 8 1/2 | 9 | 9 1/2 | 10 | 10 1/2 | 11 | 11 1/2 | 12 | 13 |
| Length of cutting part . . . | 3 3/8 | 3 5/8 | 4 | 4 3/8 | 4 3/4 | 5 | 5 1/2 | 5 3/4 | 6 | 6 1/2 | 6 3/4 | 7 | 7 1/2 | 7 3/4 | 8 | 8 3/4 |
| Diameter of shank . . . . | 3/32 | 3/16 | 1/4 | 9/32 | 5/16 | 3/8 | 13/32 | 7/16 | 1/2 | 9/16 | 9/16 | 5/8 | 11/16 | 3/4 | 7/8 | 1 |
| Size of square . . . . . | | | 5/32 | 1/4 | 1/4 | 9/32 | 5/16 | 15/32 | 3/8 | 3/8 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 3/4 |
| Length of square . . . . | | | 7/16 | 3/8 | 3/8 | 1/2 | 1/2 | 5/8 | 5/8 | 5/8 | 5/8 | 3/4 | 3/4 | 3/4 | 7/8 | 1 |
| Length of taper part from cutting end | 1/2 | 5/8 | 3/4 | 7/8 | 1 | 1 1/8 | 1 1/4 | 1 3/8 | 1 1/2 | 1 5/8 | 1 3/4 | 1 7/8 | 2 | 2 1/4 | 2 3/8 | 2 1/2 |
| Diameter of cutting end . . . | 7/32 | 9/32 | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 11/16 | 3/4 | 13/16 | 15/16 | 1 1/16 | 1 3/16 | 1 9/32 | 1 13/32 |

AND EXTERNAL DIAMETERS OF PIPES, BEING THOSE ADOPTED BY MESSRS. JAMES RUSSELL & SONS, IN PIPES OF THEIR MANUFACTURE.

**GAS AND WATER PIPING.**

| Internal Diameter of Pipe. | External Diameter of Pipe. | Number of Threads per Inch. |
|---|---|---|
| Inches. | Inches. | |
| 1/8 | ·385 | 28 |
| 1/4 | ·520 | 19 |
| 3/8 | ·665 | 19 |
| 1/2 | ·822 | 14 |
| 3/4 | 1·034 | 14 |
| 1 | 1·302 | 11 |
| 1 1/8 | 1·492 | 11 |
| 1 1/4 | 1·650 | 11 |
| 1 3/8 | 1·745 | 11 |
| 1 1/2 | 1·882 | 11 |
| 1 5/8 | 2·021 | 11 |
| 1 3/4 | 2·047 | 11 |
| 1 7/8 | 2·245 | 11 |
| 2 | 2·347 | 11 |
| 2 1/8 | 2·467 | 11 |
| 2 1/4 | 2·587 | 11 |
| 2 3/8 | 2·794 | 11 |
| 2 1/2 | 3·001 | 11 |
| 2 5/8 | 3·124 | 11 |
| 2 3/4 | 3·247 | 11 |
| 2 7/8 | 3·367 | 11 |
| 3 | 3·485 | 11 |
| 3 1/4 | 3·698 | 11 |
| 3 1/2 | 3·912 | 11 |
| 3 3/4 | 4·125 | 11 |
| 4 | 4·339 | 11 |

**HYDRAULIC PIPING.**

| Internal Diameter of Pipe. | External Diameter of Pipe. | Pressure in lbs. per Square Inch. | Number of Threads per Inch. |
|---|---|---|---|
| Inches. | Inches. | | |
| 1/4 | 5/8 | 4000 | 14 |
| 1/4 | 3/4 | 6000 | 14 |
| 1/4 | 7/8 | 8000 | 14 |
| 1/4 | 1 | 10000 | 14 |
| 3/8 | 3/4 | 4000 | 14 |
| 3/8 | 7/8 | 6000 | 14 |
| 3/8 | 1 | 8000 | 14 |
| 3/8 | 1 1/8 | 10000 | 14 |
| 1/2 | 1 | 4000 | 14 |
| 1/2 | 1 1/8 | 6000 | 14 |
| 1/2 | 1 1/4 | 8000 | 11 |
| 1/2 | 1 3/8 | 10000 | 11 |
| 5/8 | 1 1/8 | 4000 | 14 |
| 5/8 | 1 1/4 | 6000 | 11 |
| 5/8 | 1 3/8 | 8000 | 11 |
| 5/8 | 1 1/2 | 10000 | 11 |
| 3/4 | 1 1/4 | 4000 | 11 |
| 3/4 | 1 3/8 | 6000 | 11 |
| 3/4 | 1 1/2 | 8000 | 11 |
| 3/4 | 1 5/8 | 10000 | 11 |
| 7/8 | 1 3/8 | 4000 | 11 |
| 7/8 | 1 1/2 | 6000 | 11 |

| Internal Diameter of Pipe. | External Diameter of Pipe. | Pressure in lbs. per Square Inch. | Number of Threads per Inch |
|---|---|---|---|
| Inches. | Inches. | | |
| 7/8 | 1 5/8 | 8000 | 11 |
| 7/8 | 1 3/4 | 10000 | 11 |
| 1 | 1 1/2 | 4000 | 11 |
| 1 | 1 5/8 | 6000 | 11 |
| 1 | 1 3/4 | 8000 | 11 |
| 1 | 1 7/8 | 10000 | 11 |
| 1 1/8 | 1 5/8 | 4000 | 11 |
| 1 1/8 | 1 3/4 | 6000 | 11 |
| 1 1/8 | 1 7/8 | 8000 | 11 |
| 1 1/8 | 2 | 10000 | 11 |
| 1 1/4 | 1 3/4 | 4000 | 11 |
| 1 1/4 | 1 7/8 | 6000 | 11 |
| 1 1/4 | 2 | 8000 | 11 |
| 1 1/4 | 2 1/8 | 10000 | 11 |
| 1 3/8 | 1 7/8 | 4000 | 11 |
| 1 3/8 | 2 | 6000 | 11 |
| 1 3/8 | 2 1/8 | 8000 | 11 |
| 1 3/8 | 2 1/4 | 10000 | 11 |
| 1 1/2 | 2 | 4000 | 11 |
| 1 1/2 | 2 1/8 | 6000 | 11 |
| 1 1/2 | 2 1/4 | 8000 | 11 |

| Internal Diameter of Pipe. | External Diameter of Pipe. | Pressure in lbs. per Square Inch. | Number of Threads per Inch. |
|---|---|---|---|
| Inches. | Inches. | | |
| 1 1/2 | 2 3/8 | 10000 | 11 |
| 1 1/2 | 2 1/2 | 10000 | 11 |
| 1 5/8 | 2 1/8 | 4000 | 11 |
| 1 5/8 | 2 1/4 | 6000 | 11 |
| 1 5/8 | 2 3/8 | 8000 | 11 |
| 1 5/8 | 2 1/2 | 10000 | 11 |
| 1 3/4 | 2 1/4 | 3000 | 11 |
| 1 3/4 | 2 3/8 | 4000 | 11 |
| 1 3/4 | 2 1/2 | 6000 | 11 |
| 1 3/4 | 2 5/8 | 8000 | 11 |
| 1 3/4 | 2 3/4 | 10000 | 11 |
| 1 7/8 | 2 3/8 | 3000 | 11 |
| 1 7/8 | 2 1/2 | 4000 | 11 |
| 1 7/8 | 2 5/8 | 6000 | 11 |
| 1 7/8 | 2 3/4 | 8000 | 11 |
| 1 7/8 | 2 7/8 | 10000 | 11 |
| 2 | 2 1/2 | 3000 | 11 |
| 2 | 2 5/8 | 4000 | 11 |
| 2 | 2 3/4 | 6000 | 11 |
| 2 | 2 7/8 | 8000 | 11 |
| 2 | 3 | 10000 | 11 |

Table 89.—WHITWORTH'S STANDARD SCREWS AND BOLTS.

| Diameter of Screw. | Number of Threads per Inch. | Diameter at the bottom of Thread. | Thickness of Head. Exact Thickness, in Decimals. | Thickness of Head. Nearest Thickness. | Diameter of Screw. | Number of Threads per Inch. | Diameter at the bottom of Thread. | Thickness of Head. Exact Thickness, in Decimals. | Thickness of Head. Nearest Thickness. |
|---|---|---|---|---|---|---|---|---|---|
| Inches. | | Inches. | Inches. | Inches. | Inches. | | Inches. | Inches. | Inches. |
| $\frac{1}{16}$ | 60 | | | | $1\frac{3}{4}$ | 5 | 1·494 | 1·531 | $1\frac{1}{2}$ and $\frac{1}{32}$ |
| $\frac{3}{32}$ | 48 | | | | $1\frac{7}{8}$ | $4\frac{1}{2}$ | 1·590 | 1·6406 | $1\frac{5}{8}$ and $\frac{1}{32}$ |
| $\frac{1}{8}$ | 40 | ·093 | ·109 | $\frac{3}{32}$ | 2 | $4\frac{1}{2}$ | 1·715 | 1·750 | $1\frac{3}{4}$ |
| $\frac{5}{32}$ | 32 | | | | $2\frac{1}{8}$ | $4\frac{1}{2}$ | 1·840 | 1·852 | $1\frac{7}{8}$ |
| $\frac{3}{16}$ | 24 | ·134 | ·164 | $\frac{1}{8}$ and $\frac{1}{32}$ | $2\frac{1}{4}$ | 4 | 1·930 | 1·968 | $1\frac{15}{16}$ and $\frac{1}{32}$ |
| $\frac{7}{32}$ | 24 | | | | $2\frac{3}{8}$ | 4 | 2·055 | 2·078 | $2\frac{1}{16}$ and $\frac{1}{32}$ |
| $\frac{1}{4}$ | 20 | ·186 | ·219 | $\frac{5}{16}$ and $\frac{1}{32}$ | $2\frac{1}{2}$ | 4 | 2·180 | 2·187 | $2\frac{3}{16}$ |
| $\frac{5}{16}$ | 18 | ·241 | ·273 | $\frac{1}{4}$ and $\frac{1}{32}$ | $2\frac{5}{8}$ | 4 | 2·305 | 2·297 | $2\frac{1}{4}$ and $\frac{1}{32}$ |
| $\frac{3}{8}$ | 16 | ·295 | ·328 | $\frac{5}{16}$ | $2\frac{3}{4}$ | $3\frac{1}{2}$ | 2·384 | 2·406 | $2\frac{3}{8}$ and $\frac{1}{32}$ |
| $\frac{7}{16}$ | 14 | ·346 | ·383 | $\frac{3}{8}$ and $\frac{1}{32}$ | $2\frac{7}{8}$ | $3\frac{1}{2}$ | 2·509 | 2·516 | $2\frac{1}{2}$ and $\frac{1}{32}$ |
| $\frac{1}{2}$ | 12 | ·393 | ·437 | $\frac{7}{16}$ | 3 | $3\frac{1}{2}$ | 2·634 | 2·625 | $2\frac{5}{8}$ |
| $\frac{9}{16}$ | 12 | ·456 | ·492 | $\frac{7}{16}$ and $\frac{1}{32}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | 2·884 | 2·843 | $2\frac{13}{16}$ and $\frac{1}{32}$ |
| $\frac{5}{8}$ | 11 | ·508 | ·547 | $\frac{1}{2}$ and $\frac{1}{32}$ | $3\frac{1}{2}$ | $3\frac{1}{4}$ | 3·106 | 3·062 | $3\frac{1}{16}$ |
| $\frac{11}{16}$ | 11 | ·571 | ·601 | $\frac{5}{8}$ | $3\frac{3}{4}$ | 3 | 3·356 | 3·281 | $3\frac{1}{4}$ and $\frac{1}{32}$ |
| $\frac{3}{4}$ | 10 | ·622 | ·656 | $\frac{5}{8}$ and $\frac{1}{32}$ | 4 | 3 | 3·574 | 3·500 | $3\frac{1}{2}$ |
| $\frac{13}{16}$ | 10 | ·684 | ·711 | $\frac{9}{16}$ and $\frac{1}{32}$ | $4\frac{1}{4}$ | $2\frac{7}{8}$ | 3·824 | 3·718 | $3\frac{11}{16}$ and $\frac{1}{32}$ |
| $\frac{7}{8}$ | 9 | ·733 | ·766 | $\frac{3}{4}$ and $\frac{1}{32}$ | $4\frac{1}{2}$ | $2\frac{7}{8}$ | 4·055 | 3·937 | $3\frac{15}{16}$ |
| $\frac{15}{16}$ | 9 | ·795 | ·820 | $\frac{3}{4}$ and $\frac{1}{32}$ | $4\frac{3}{4}$ | $2\frac{3}{4}$ | 4·305 | 4·156 | $4\frac{1}{8}$ and $\frac{1}{32}$ |
| 1 | 8 | ·840 | ·875 | $\frac{7}{8}$ | 5 | $2\frac{3}{4}$ | 4·534 | 4·375 | $4\frac{3}{8}$ |
| $1\frac{1}{8}$ | 7 | ·942 | ·984 | 1 | $5\frac{1}{4}$ | $2\frac{5}{8}$ | 4·764 | 4·593 | $4\frac{9}{16}$ and $\frac{1}{32}$ |
| $1\frac{1}{4}$ | 7 | 1·067 | 1·094 | $1\frac{1}{16}$ and $\frac{1}{32}$ | $5\frac{1}{2}$ | $2\frac{5}{8}$ | 5·014 | 4·812 | $4\frac{13}{16}$ |
| $1\frac{3}{8}$ | 6 | 1·161 | 1·203 | $1\frac{3}{16}$ and $\frac{1}{32}$ | $5\frac{3}{4}$ | $2\frac{1}{2}$ | 5·238 | 5·031 | $5\frac{1}{32}$ |
| $1\frac{1}{2}$ | 6 | 1·286 | 1·312 | $1\frac{5}{16}$ | 6 | $2\frac{1}{2}$ | 5·488 | 5·250 | $5\frac{1}{4}$ |
| $1\frac{5}{8}$ | 5 | 1·369 | 1·412 | $1\frac{3}{8}$ and $\frac{1}{32}$ | | | | | |

NOTE.—Thickness of nut is equal to the diameter of bolt.

**Bolts and Screws.**—The width across the flats of the bolt-head, is the same as for nuts given in table 108, page 285. The width across the flats is approximately equal to $1\frac{1}{2}$ times the diameter of the bolt added to $\frac{3}{32}$. The angle of the *triangular thread* is 55°, the height of the triangle of thread is reduced one-third by rounding one-sixth off the top, and one-sixth off the bottom of thread. Depth of thread = the pitch multiplied by ·64. To find the diameter at the bottom of the thread, multiply the pitch by 1·28, and subtract the product from the outside diameter.

**For screws with square threads,** the number of threads per inch is one-half of the number for triangular threads, and the depth of thread is $\frac{19}{40}$ of the pitch, or equal to the space between the threads.

Table 90.—Whitworth's Standard Gauges for Watch and Instrument Makers, with Screw-Threads for the Various Sizes, 1881.

| Number of each size in thousandths of an Inch. | Size in decimals of an Inch. | Number of Threads per Inch. | Number of each size in thousandths of an Inch. | Size in decimals of an Inch. | Number of Threads per Inch. |
|---|---|---|---|---|---|
| 10 | ·010 | 400 | 34 | ·034 | 150 |
| 11 | ·011 | 400 | 36 | ·036 | 150 |
| 12 | ·012 | 350 | 38 | ·038 | 120 |
| 13 | ·013 | 350 | 40 | ·040 | 120 |
| 14 | ·014 | 300 | 45 | ·045 | 120 |
| 15 | ·015 | 300 | 50 | ·050 | 100 |
| 16 | ·016 | 300 | 55 | ·055 | 100 |
| 17 | ·017 | 250 | 60 | ·060 | 100 |
| 18 | ·018 | 250 | 65 | ·065 | 80 |
| 19 | ·019 | 250 | 70 | ·070 | 80 |
| 20 | ·020 | 210 | 75 | ·075 | 80 |
| 22 | ·022 | 210 | 80 | ·080 | 60 |
| 24 | ·024 | 210 | 85 | ·085 | 60 |
| 26 | ·026 | 180 | 90 | ·090 | 60 |
| 28 | ·028 | 180 | 95 | ·095 | 60 |
| 30 | ·030 | 180 | 100 | ·100 | 50 |
| 32 | ·032 | 150 | | | |

**Conducting Power of Metals for Electricity** at 32° Fahr. :—

| | | | |
|---|---|---|---|
| Silver | 100 | Tin | 14 |
| Copper | 92 | Iron | 13 |
| Gold | 65 | Lead | 8·3 |
| Zinc | 29 | Platinum | 8 |
| Bronze | 22 | German silver | 5·9 |
| Brass | 18 | Bismuth | 1·9 |

The conductivity diminishes as the temperature increases above 32° F.

## SECTION VI.

## STRENGTH AND WEIGHT OF MATERIALS; WORKSHOP DATA, &c.

# SECTION VI.

## STRENGTH AND WEIGHT OF MATERIALS; WORKSHOP DATA, &c.

**Strength of Wrought-Iron.**—The tensile strength of wrought-iron is about four times as great as that of cast-iron; good wrought-iron should be capable of standing the following tensile strains before breaking, in tons per square inch of section.

| | Tons. | |
|---|---|---|
| Lowmoor or "Best Yorkshire" bar iron . . . . | 26 | The safe working tensile strength is $\frac{1}{4}$ of these amounts for general purposes. |
| Ordinary good merchant bar iron . . . . . . | 25 | |
| Lowmoor or "Best Yorkshire iron" plates along the fibre | 24 | |
| Lowmoor or "Best Yorkshire iron" plates across the fibre | 22 | |
| Ordinary good angle iron . . . . . . . | 22 | |
| Ordinary good boiler-plates along the fibre . . . | 21 | |
| Ordinary good boiler-plates across the fibre . . . | 18 | |
| Ordinary good ship-plates along the fibre . . . . | 20 | |
| Ordinary good ship-plates across the fibre . . . | 17 | |

The strength of wrought-iron to resist a crushing or compressive strain is about half that of its tensile resistance, or say 12 tons, and its working strength in compression free from flexure is one-quarter that amount, or 3 tons per square inch of section.

**Testing Wrought-Iron.**—Good wrought-iron has a fine close-grained fracture of silvery grey colour; inferior quality has a coarse granular fracture similar to that of cast-iron. The elongation under tensile strain is a test of the toughness of wrought iron; the ultimate elongation after fracture of Lowmoor iron plates is about 13 per cent., and of ordinary good iron boiler-plates 7 per cent., and of ordinary good ship-plates 5 per cent., of their original length when torn along the fibre. Lowmoor or best Yorkshire iron plates under $\frac{1}{2}$ inch thick, should bend double when cold without fracture; and from $\frac{1}{2}$ inch to 1 inch thick, should bend double when hot, both lengthways and across the fibre without fracture. The tests for ordinary wrought-iron boiler and ship-plates are the same as those used by the Admiralty, which are given below.

**Admiralty Tests for Wrought-Iron Boiler-Plates.**—All boiler-plates (with the exception of Lowmoor and Bowling iron, which are not tested) must be capable of standing the following test:—

Tensile strain per square inch lengthways, 21 tons: crossways, 18 tons.

**Forge-Test, Hot.**—Plates to admit of being bent hot, without fracture, to the following angles.

Lengthways of the grain, 125°; across, 100°.

**Forge-Test, Cold.**—Plates to admit of being bent cold, without fracture, to the following angles.

| Thickness of Plate, in Inches | $\frac{3}{16}$ and under | $\frac{1}{4}$ and $\frac{5}{16}$ | $\frac{3}{8}$ and $\frac{7}{16}$ | $\frac{1}{2}$. $\frac{9}{16}$, $\frac{5}{8}$ | $\frac{11}{16}$ and $\frac{3}{4}$ | $\frac{13}{16}$ and $\frac{7}{8}$ | $\frac{15}{16}$ and 1 Inch. |
|---|---|---|---|---|---|---|---|
| Lengthways of the Grain . . | 90° | 70° | 50° | 35° | 25° | 20° | 15° angle. |
| Across the Grain . . . | 40° | 30° | 20° | 15° | 10° | 5° | 5° angle. |

**Admiralty Test for Ship-Plates.**—Plate iron, first-class BB.; tensile strain per square inch, lengthways, 22 tons; crossways, 18 tons.

**Forge-Test, Hot.**—All plates of the first-class, 1 inch thick and under should be of such ductility as to admit of bending hot, without fracture, to the following angles. Lengthways of the grain, 125°; across, 90°.

**Forge-Test, Cold.**—All plates of the first-class, should admit of bending cold, without fracture, to the angles given in the above table.

**Plate-Iron Second-class B.**, tensile strain per square inch lengthways, 20 tons; crossways, 17 tons.

**Forge-Test, Hot.**—All plates of the second class, 1 inch thick and under, should be of such ductility as to admit of bending hot, without fracture, to the following angles. Lengthways of the grain, 90°; across, 60°.

**Forge-Test, Cold.**—All plates of the second class should admit of bending cold, without fracture, to the following angles.

| Thickness of Plate, in Inches | $\frac{3}{16}$ and under | $\frac{1}{4}$ and $\frac{5}{16}$ | $\frac{3}{8}$ and $\frac{7}{16}$ | $\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$ | $\frac{11}{16}$ and $\frac{3}{4}$ | $\frac{13}{16}$ and $\frac{7}{8}$ | $\frac{15}{16}$ and 1 Inch. |
|---|---|---|---|---|---|---|---|
| Lengthways of the Grain . . | 75° | 55° | 45° | 30° | 20° | 15° | 10° angle. |
| Across the Grain . . . | 30° | 20° | 15° | 10° | 5° | — | — angle. |

**Steel Boiler-Plates** are generally made of the mildest quality of Bessemer steel, their tensile strength is about one-third greater than that of Lowmoor iron, and they should stand the following test before breaking. Tensile strain per square inch both lengthways and crossways, 32 tons; all steel plates 1 inch thick and under, to admit of being bent double when hot, without fracture, and to admit of bending cold, without fracture, to the angles given in the table below. The safe working tensile strength, is one-fourth the breaking strain, or 8 tons per square inch of section.

| Thickness of Steel Plate, in Inches | $\frac{1}{4}$ and under | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ and $\frac{9}{16}$ | $\frac{5}{8}$ and $\frac{11}{16}$ | $\frac{3}{4}$ and $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ and 1 Inch. |
|---|---|---|---|---|---|---|---|---|---|
| Lengthways of Grain, Angle . | 120° | 120° | 110° | 90° | 80° | 70° | 60° | 50° | 45° angle. |
| Across the Grain, Angle . . | 100° | 90° | 80° | 70° | 60° | 50° | 40° | 30° | 25° angle. |

**Steel Plates** are generally double-riveted, with the best quality of iron rivets, slightly smaller in diameter, and closer in pitch, than for wrought-iron plates; steel rivets not being always used on account of the liability of the heads to fly off from jars, &c. Plates both hot and cold, are tested on a true surface-plate, the radius of the corner over which they are bent being ½ inch, the distance from the edge of the plate to the part bent, is from 3 to 6 inches. When plates are tested hot, they are heated to an orange colour; the plates are bent down to the required angle by hammering.

**Test for Rivets.**—They should be made of the toughest quality of iron, and admit of being bent double, without fracture, when cold; the heads should admit of being hammered down to ⅛ inch in thickness without fracturing the edges, when hot.

**Test for Wrought-Iron Bridge-Plates.**—A piece of plate is cut 2 inches wide and ½ inch thick, of sufficient length to have 7 inches under tension, the plates being rejected if the extension of the test-piece is greater than ⅛ inch under a test of 18 tons, ¼ inch under 21 tons, ½ inch under 23 tons, ¾ inch under 24 tons. All bar iron to stand a tensile strain of 25 tons, per square inch of section, before fracture.

**Diminution of Tenacity of Iron Boiler-plates** at high temperatures, the mean maximum tenacity being at 550° F.=65,000 lbs. per square inch. From the experiments of the Franklin Institute.

| Temperature. | Diminution of Tenacity. | Temperature. | Diminution of Tenacity. |
|---|---|---|---|
| 520° | ·0738 | 824° | ·2010 |
| 570° | ·0870 | 932° | ·3324 |
| 596° | ·0900 | 947° | ·3593 |
| 600° | ·0964 | 1030° | ·4478 |
| 630° | ·1047 | 1111° | ·5514 |
| 662° | ·1155 | 1155° | ·6000 |
| 722° | ·1436 | 1159° | ·6011 |
| 732° | ·1491 | 1187° | ·6352 |
| 754° | ·1535 | 1237° | ·6622 |
| 766° | ·1589 | 1245° | ·6715 |
| 770° | ·1628 | 1317° | ·7000 |

**Effects of Re-heating and Rolling Iron,** from the experiments of Mr. Clay.

| | |
|---|---|
| Puddled Bar. Tenacity in lbs. per square inch | 43,904 |
| The same iron, 5 times piled, re-heated, and rolled. Tenacity in lbs. per square inch | 61,824 |
| The same iron, 11 times piled, re-heated, and rolled. Tenacity in lbs. per square inch | 43,904 |

**Steel Plates and Bars** used in place of wrought iron, to be of equal strength, may in a general way be made 20 per cent. thinner than wrought iron plates and bars.

## ROPES AND CHAINS.

**The Breaking Strain** of hemp-ropes, is 1 ton, for each lb. weight per fathom.

The breaking strain of iron-wire ropes is 2 tons, for each lb. weight per fathom.

The breaking strain of steel-wire ropes is 3 tons, for each lb. weight per fathom.

Table 91.—Size, Weight and Strength of Steel- and Iron-Wire Ropes and Hemp-Ropes.

| Steel-Wire Ropes. | | Iron-Wire Ropes. | | Hemp-Ropes of Equivalent Strength. | | | |
|---|---|---|---|---|---|---|---|
| Circumference in Inches. | Weight per Fathom in lbs. | Circumference in Inches. | Weight per Fathom in lbs. | Circumference in Inches. | Weight per Fathom in lbs. | Safe Working Load in Cwts. | Breaking Strain in Tons. |
| 3½ | 11 | 4⅝ | 18 | 12 | 32 | 108 | 34 |
| 3⅜ | 9½ | 4¼ | 16 | 11 | 30 | 96 | 29 |
| 3⅛ | 8¼ | 4 | 14 | 10 | 28 | 84 | 25 |
| 3 | 7½ | 3¾ | 13 | 9½ | 25 | 78 | 23 |
| 2⅞ | 7 | 3⅝ | 11¾ | 9 | 22 | 70 | 21 |
| 2¾ | 6 | 3½ | 11 | 8½ | 20 | 66 | 19 |
| 2⅝ | 5¾ | 3⅜ | 9½ | 8 | 16 | 57 | 17 |
| 2½ | 4¾ | 3⅛ | 8¼ | 7½ | 14 | 50 | 15 |
| 2⅜ | 4½ | 3 | 7½ | 7 | 12 | 45 | 14 |
| 2¼ | 4 | 2⅞ | 7 | 6½ | 10 | 42 | 13 |
| 2⅛ | 3¾ | 2¾ | 6 | 6 | 9 | 36 | 11 |
| 2 | 3¼ | 2⅝ | 5¾ | 5½ | 8 | 34 | 10 |
| 1⅞ | 3 | 2½ | 4¾ | 5 | 7 | 28 | 9 |
| ... | ... | 2⅜ | 4½ | 4¾ | 6½ | 27 | 8 |
| 1¾ | 2½ | 2¼ | 4 | 4½ | 6 | 24 | 7 |
| ... | ... | 2⅛ | 3¾ | 4 | 5 | 22 | 6½ |
| ... | ... | 2 | 3¼ | 3¾ | 4½ | 20 | 6 |
| 1½ | 1¾ | 1⅞ | 3 | 3½ | 4 | 18 | 5 |
| 1⅜ | 1½ | 1¾ | 2½ | 3 | 3½ | 15 | 4 |
| 1¼ | 1¼ | 1½ | 1¾ | 2¾ | 3 | 10 | 3 |
| 1⅛ | 1 | 1⅜ | 1½ | 2½ | 2½ | 8 | 2½ |
| ⅞ | ¾ | 1¼ | 1¼ | 2¼ | 2 | 6 | 2 |
| ¾ | ½ | 1⅛ | 1 | 2 | 1½ | 4 | 1½ |
| ... | ... | ⅞ | ¾ | 1¾ | 1 | 3 | 1 |
| ... | ... | ¾ | ½ | 1½ | ¾ | 1½ | ¾ |

**Hemp-Ropes.**—Tarred ropes are weaker than white ropes, hot-spun tarred ropes are stronger than cold-spun, but are not so pliable.

**Wet-Ropes.**—When a rope is wet, it expands in diameter, and contracts in length, owing to the fibres being drawn in by this increase of diameter.

**Hemp-Fibres** are about a yard in length, the tensile strength of hemp-fibres is 6,400 lbs. per square inch of sectional area.

Table 92.—SIZE, WEIGHT, AND STRENGTH OF STEEL, IRON AND HEMP FLAT ROPES.

| STEEL-WIRE ROPES. | | IRON-WIRE ROPES. | | HEMP-ROPES OF EQUIVALENT STRENGTH. | | | |
|---|---|---|---|---|---|---|---|
| Size in Inches. | Weight per Fathom in lbs. | Size in Inches. | Weight per Fathom in lbs. | Size in Inches. | Weight per Fathom in lbs. | Safe Working Load in cwts. | Breaking Strain in Tons. |
| $3\frac{1}{4} \times \frac{5}{8}$ | 18 | $4\frac{1}{2} \times \frac{7}{8}$ | 30 | $8\frac{1}{2} \times 2\frac{1}{4}$ | 45 | 120 | 45 |
| $3 \times \frac{5}{8}$ | 16 | $4\frac{1}{4} \times \frac{13}{16}$ | 27 | $7\frac{1}{2} \times 2\frac{1}{8}$ | 40 | 108 | 40 |
| $2\frac{7}{8} \times \frac{9}{16}$ | 14 | $4 \times \frac{3}{4}$ | 24 | $7 \times 1\frac{7}{8}$ | 36 | 96 | 36 |
| ... | ... | $3\frac{3}{4} \times \frac{3}{4}$ | 22 | $6\frac{1}{2} \times 1\frac{5}{8}$ | 32 | 88 | 32 |
| $2\frac{3}{4} \times \frac{1}{2}$ | $12\frac{1}{2}$ | $3\frac{1}{2} \times \frac{11}{16}$ | 20 | $6 \times 1\frac{1}{2}$ | 28 | 80 | 28 |
| ... | ... | $3\frac{1}{4} \times \frac{5}{8}$ | 18 | $5\frac{3}{4} \times 1\frac{1}{2}$ | 27 | 72 | 27 |
| $2 \times \frac{5}{8}$ | 10 | $3 \times \frac{5}{8}$ | 16 | $5\frac{1}{2} \times 1\frac{3}{8}$ | 26 | 64 | 26 |
| $1\frac{1}{8} \times \frac{1}{2}$ | 8 | $2\frac{7}{8} \times \frac{9}{16}$ | 14 | $5\frac{1}{4} \times 1\frac{1}{4}$ | 24 | 56 | 24 |
| ... | ... | $2\frac{3}{4} \times \frac{1}{2}$ | 12 | $5 \times 1\frac{1}{4}$ | 22 | 48 | 22 |
| ... | ... | $2 \times \frac{5}{8}$ | 10 | $4 \times 1\frac{1}{8}$ | 20 | 40 | 20 |
| ... | ... | $1\frac{7}{8} \times \frac{1}{2}$ | 8 | $3 \times 1$ | 16 | 32 | 16 |

Table 93.—WEIGHT, WORKING LOAD, PROOF STRAIN AND BREAKING STRAIN OF CHAINS AND CABLES.

| SHORT-LINK OR CRANE-CHAIN. | | | | | STUD-LINK CHAIN-CABLE. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Diameter of Iron in the Chain in Inches. | Weight per Fathom in lbs. | Safe Working Load in Tons. | Proof Strain in Tons. | Breaking Strain in Tons. | Diameter of Iron in the Chain in Inches. | Weight per Fathom in lbs. | Safe Working Load in Tons. | Proof Strain in Tons. | Breaking Strain in Tons. |
| $\frac{5}{16}$ | $5\frac{1}{2}$ | $\frac{9}{16}$ | $1\frac{1}{8}$ | $2\frac{1}{4}$ | $\frac{1}{2}$ | $13\frac{1}{2}$ | $2\frac{1}{4}$ | $4\frac{1}{2}$ | 7 |
| $\frac{3}{8}$ | 8 | $\frac{13}{16}$ | $1\frac{5}{8}$ | $3\frac{1}{4}$ | $\frac{5}{8}$ | 21 | $3\frac{1}{2}$ | 7 | 11 |
| $\frac{7}{16}$ | $10\frac{1}{2}$ | $1\frac{1}{8}$ | $2\frac{1}{4}$ | $4\frac{1}{2}$ | $\frac{3}{4}$ | 30 | 5 | $10\frac{1}{8}$ | 16 |
| $\frac{1}{2}$ | $13\frac{3}{4}$ | $1\frac{1}{2}$ | 3 | 6 | $\frac{7}{8}$ | 42 | $6\frac{3}{4}$ | $13\frac{3}{4}$ | 22 |
| $\frac{9}{16}$ | 17 | $1\frac{7}{8}$ | $3\frac{3}{4}$ | $7\frac{1}{2}$ | 1 | 54 | 9 | 18 | 28 |
| $\frac{5}{8}$ | 22 | $2\frac{5}{16}$ | $4\frac{5}{8}$ | $9\frac{1}{4}$ | $1\frac{1}{8}$ | 69 | $11\frac{3}{8}$ | $22\frac{3}{4}$ | 36 |
| $\frac{11}{16}$ | 26 | $2\frac{13}{16}$ | $5\frac{5}{8}$ | $11\frac{1}{4}$ | $1\frac{1}{4}$ | 84 | 14 | $28\frac{1}{8}$ | 44 |
| $\frac{3}{4}$ | 30 | $3\frac{3}{8}$ | $6\frac{3}{4}$ | $13\frac{1}{2}$ | $1\frac{3}{8}$ | 102 | 17 | 34 | 54 |
| $\frac{13}{16}$ | 36 | $3\frac{15}{16}$ | $7\frac{7}{8}$ | $15\frac{3}{4}$ | $1\frac{1}{2}$ | 121 | $20\frac{1}{4}$ | $40\frac{1}{2}$ | 64 |
| $\frac{7}{8}$ | 42 | $4\frac{1}{16}$ | $9\frac{1}{8}$ | $18\frac{1}{4}$ | $1\frac{5}{8}$ | 142 | $23\frac{3}{4}$ | $47\frac{1}{2}$ | 74 |
| $\frac{15}{16}$ | 49 | $5\frac{1}{4}$ | $10\frac{1}{2}$ | 21 | $1\frac{3}{4}$ | 165 | $27\frac{9}{16}$ | $55\frac{1}{8}$ | 86 |
| 1 | 55 | 6 | 12 | 24 | $1\frac{7}{8}$ | 189 | $31\frac{1}{2}$ | $63\frac{1}{4}$ | 99 |
| $1\frac{1}{16}$ | 60 | 7 | 14 | 28 | 2 | 215 | 36 | 72 | 113 |
| $1\frac{1}{8}$ | 68 | $7\frac{5}{8}$ | $15\frac{1}{4}$ | $30\frac{1}{2}$ | $2\frac{1}{8}$ | 243 | $40\frac{1}{2}$ | $81\frac{1}{4}$ | 128 |
| $1\frac{3}{16}$ | 76 | $8\frac{1}{4}$ | $16\frac{3}{4}$ | $33\frac{1}{2}$ | $2\frac{1}{4}$ | 277 | $45\frac{1}{2}$ | $91\frac{1}{8}$ | 143 |
| $1\frac{1}{4}$ | 84 | $9\frac{3}{8}$ | $18\frac{3}{4}$ | $37\frac{1}{2}$ | $2\frac{3}{8}$ | 304 | $50\frac{3}{4}$ | $101\frac{1}{2}$ | 159 |
| $1\frac{3}{8}$ | 102 | $11\frac{5}{16}$ | $22\frac{5}{8}$ | $45\frac{1}{4}$ | $2\frac{1}{2}$ | 336 | $56\frac{1}{4}$ | $112\frac{1}{2}$ | 176 |
| $1\frac{1}{2}$ | 120 | $13\frac{1}{2}$ | 27 | 54 | $2\frac{3}{4}$ | 407 | 68 | $136\frac{1}{8}$ | 213 |

**Standard Proportions of** the links of chains in terms of the diameter of the iron from which they are made:—

*Stud-link* = 6 diameters extreme length, and 3·6 diameters extreme width.

*Close-link* = 5 diameters extreme length, and 3·5 diameters extreme width.

*Open-link* = 6 diameters extreme length, and 3·5 diameters extreme width.

*Middle-link* = 5·5 diameters extreme length, and 3·5 diameters extreme width.

*End-link* of each, 15 fathom length of chain, 6·5 diameters extreme length, and 4·1 diameters extreme width.

**Strength of Chains and Ropes.**—To find the breaking strain in tons of short-link chains, square the number of eighths of an inch in the diameter of the iron from which the link is made, and multiply by ·375.

To find the breaking strain in tons of stud-link chains, square the number of eighths of an inch in the diameter of the iron from which the link is made, and multiply by ·44.

To find the breaking strain in tons of ropes of hemp, and of iron and steel wire:—

*For hemp ropes,* square the circumference in inches and multiply by ·25.

*For iron-wire ropes,* square the circumference in inches and multiply by 1·5.

*For steel-wire ropes,* square the circumference in inches and multiply by 2·5.

**The working or safe load for ropes** is from one-sixth to one-seventh of the breaking strain, for round hemp ropes, and for round iron-wire ropes: one-eighth for flat hemp and for flat iron-wire ropes: one-sixth for round steel wire: and one-seventh for flat steel-wire ropes.

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## GIRDERS.

**Girders and Beams.**—To find the breaking weight in tons, of solid beams of wood or iron, square or rectangular, with both ends supported, and loaded in the middle:—*Rule:* Multiply the square of the depth in inches by the breadth in inches, and divide the product by the length in feet between the supports; the result will be the breaking weight in tons of a cast-iron beam. For wrought-iron, multiply the said result by 1·5; for oak, multiply by ·25; and for pine or fir, multiply by ·2.

**Wood Girders** with wrought-iron flitch-plates.—To find the breaking weights in cwts., when loaded in the middle, with both ends supported.—*Rule* for fir: Multiply five times the square of the depth in inches, by the breadth in inches, including the iron flitch plate, and divide the product by the length in feet. For oak, use 6 as a multiplier instead of 5. The thickness of the iron flitch-plate should be one-tenth that of the wood, for which thickness the above rule applies.

**Solid-rolled wrought-iron joists and girders**, Fig. 49. To find the breaking weight in tons when loaded in the middle, with both ends supported. *Rule :* Add one-fourth the area of the web in inches, calculated on the full depth of joist, to the area of the bottom flange in inches;

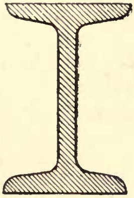

Fig. 49.

multiply that sum by the depth in inches; multiply the product by 6·6, and divide the result by the length in feet between the supports.

**Box-girders** are about 10 per cent. less in strength than solid rolled joists or girders, of equal depth and weight.

**Single-web girders** are about 20 per cent. less in strength than solid rolled joists or girders, of equal depth and weight.

**T girders** are about 40 per cent. less in strength than solid rolled joists or girders, of equal depth and weight.

**Riveted joists** are about 50 per cent. less in strength than solid rolled joists or girders, of equal depth and weight.

**The Deflection** of solid-rolled joists is about 50 per cent. less than that of riveted joists, of equal depth and weight.

A girder fixed at one end only, and loaded at the other end, will support only one-fourth the load that a girder of the same length will bear, when supported at both ends and loaded in the middle.

A girder will support only one-half the load at the middle, that it will if distributed over its length.

**Factor of safety for girders.** The safe dead load for wrought-iron girders is generally $\frac{1}{4}$ the breaking weight, and for cast-iron girders $\frac{1}{6}$ the breaking weight; for moving loads the factor of safety is 50 per cent. more than for dead loads.

**Solid Round Beams** and girders. To find the breaking weight, in tons, of a solid round beam, with both ends supported, and loaded in the middle:—Cube the diameter in inches, and divide by the length in feet between the supports; the result will be the breaking weight in tons of a wrought iron round beam; for cast-iron multiply the said result by ·66; for oak multiply by ·17; for fir or pine multiply by ·13.

Table 94.—Proportions and Safe Dead Distributed Load, for Rolled Wrought-Iron Girders and Joists, Fig. 49.

| Sectional Dimensions. | | | Weight per Foot. | Clear Span in Feet, or Distance between the Supports. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Girder and Breadth of Flanges. | Thickness of Web. | Thickness of Flanges. | | Feet. 6 | Feet. 8 | Feet. 10 | Feet. 12 | Feet. 14 | Feet. 16 | Feet. 18 | Feet. 20 | Feet. 22 | Feet. 24 | Feet. 26 | Feet. 28 | Feet. 30 |
| Inches. | Inches. | Inches. | lbs. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. | Tons. |
| 16 × 6 × 6 | 9/16 | 13/16 | 63 | 58 | 46 | 37 | 30 | 26 | 23 | 20 | 18 | 17 | 14 | 13 | 12 | 10 |
| 14 × 6 × 6 | 9/16 | 13/16 | 60 | 53 | 40 | 31 | 26 | 22 | 19 | 18 | 15 | 13 | 11 | 10 | 9 | 8 |
| 12 × 6 × 6 | 9/16 | 15/16 | 56 | 47 | 37 | 28 | 23 | 20 | 17 | 15 | 13 | 11 | 10 | 9 | 8 | 7 |
| 12 × 5 × 5 | 7/16 | 13/16 | 42 | 32 | 23 | 19 | 15 | 13 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 |
| 10 × 5 × 5 | 7/16 | 13/16 | 36 | 27 | 21 | 15 | 13 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 |
| 9½ × 4½ × 4½ | ⅜ | 11/16 | 30 | 22 | 16 | 11 | 10 | 8 | 7 | 6 | 5 | 4 | 3 | | | |
| 9¼ × 3¾ × 3¾ | 7/16 | ½ | 24 | 13 | 10 | 8 | 6 | 5 | 4 | 3½ | 3 | 2½ | | | | |
| 8 × 5 × 5 | ⅜ | 9/16 | 29 | 14 | 10 | 8 | 7 | 6 | 5 | 4 | 3½ | 3 | | | | |
| 8 × 4 × 4 | ⅜ | ½ | 22 | 12 | 9 | 7 | 6 | 5 | 4 | 3½ | 3 | 2½ | | | | |
| 8 × 2⅝ × 2⅝ | ⅜ | ⅜ | 15 | 7 | 5½ | 4½ | 3½ | 3 | 2½ | 2 | 1¾ | 1½ | | | | |
| 7 × 3⅝ × 3⅝ | 5/16 | ½ | 20 | 6 | 5 | 3½ | 3 | 2½ | 2 | 1¾ | 1½ | 1¼ | | | | |
| 7 × 2¼ × 2¼ | 5/16 | 7/16 | 14 | 4½ | 3½ | 2½ | 2 | 1¾ | 1½ | 1 | | | | | | |
| 6 × 5 × 5 | 7/16 | 9/16 | 28 | 8½ | 6 | 5 | 4 | 3 | 2½ | 2 | 1½ | | | | | |
| 6 × 3 × 3 | 5/16 | 7/16 | 16 | 5½ | 3½ | 2¾ | 2½ | 2 | 1½ | 1¼ | 1 | | | | | |
| 6¼ × 2 × 2 | 5/16 | 7/16 | 11 | 3½ | 2½ | 1¾ | 1½ | 1¼ | 1 | | | | | | | |
| 5 × 4½ × 4½ | ⅜ | ½ | 23 | 5½ | 4½ | 3½ | 2½ | 2¼ | 2 | 1½ | 1¼ | 1 | | | | |
| 5 × 3 × 3 | 5/16 | 7/16 | 13 | 4½ | 3 | 2¼ | 2 | 1½ | 1¼ | 1 | | | | | | |
| 4¾ × 2 × 2 | ¼ | 5/16 | 8 | 1½ | 1¼ | 1 | ¾ | ½ | | | | | | | | |
| 4 × 3 × 3 | ¼ | ⅜ | 12 | 2 | 1½ | 1¼ | 1 | ¾ | ½ | | | | | | | |
| 4 × 2 × 2 | ¼ | 5/16 | 7 | 1¼ | 1 | ¾ | ½ | | | | | | | | | |
| 3 × 3 × 3 | ¼ | 5/16 | 10 | 1¼ | 1 | ¾ | ½ | | | | | | | | | |
| 3 × 1½ × 1½ | 3/16 | 7/32 | 5 | ¾ | ½ | | | | | | | | | | | |

**Hollow Round Beams**. To find the breaking weight in tons of a hollow round beam, subtract the cube of the inside diameter in inches from the cube of the outside diameter in inches, and divide by the length in feet between the supports, the result will be the breaking weight in tons of a hollow round wrought-iron beam; for cast-iron multiply the said result by ·66; for oak multiply by ·17; for fir or pine multiply by ·13.

**Angle-Iron Beams**.—The strength of equal-legged angle or Tee iron, acting as a beam, is 50 per cent. greater than that of a bar of the same height and thickness; in sections of unequal legs, the height only is to be considered.

**Cast-Iron Girders**, Fig. 50.—The depth of girder should be from $\frac{1}{12}$ to $\frac{1}{15}$ of the span; width of bottom flange $\frac{2}{3}$ to $\frac{3}{4}$ of the depth of girder at the centre; width of top flange one-third to one-half of the bottom flange;

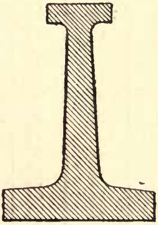

Fig. 50.

maximum span 25 feet; for greater spans wrought-iron is safer. In order to obtain uniformity in cooling and sound castings, there should not be any sudden variation of metal, and the web should be proportioned and tapered, so as to meet each flange with a thickness corresponding to that of the flange. When the depth of girder is limited, the bottom flange is made wider in proportion. When strengthening ribs are cast on girders, they should be curved, as they are less liable to crack, than when made straight.

In the strongest form of a cast-iron girder, the sectional area of the bottom flange, is six times as great as the area of the top flange, and these proportions should be followed, as closely as the proper distribution of the metal will allow, as regards freedom from undue straining, in the cooling of the casting.

**The Compressive Strength of Cast-Iron** of average quality is about 42 tons per square inch of section, but the tensile strength is only about 6 tons per square inch; therefore the bottom flange of cast-iron girders requires to be many times greater than the top flange. The compressive strength of ordinary wrought-iron plates, is about 12 tons per square inch of section, and the tensile strength about 20 tons per square inch; therefore, in wrought-iron girders, the top flange requires to be the greatest.

*To find the breaking weight,* in tons, of a cast-iron girder when loaded in the middle, and with both ends supported.—*Rule:* Multiply twice the depth in inches, by the sectional area of the bottom flange in inches, and divide the result by the length in feet between the supports.

*To find the breaking weight* of a uniformly-distributed load, multiply the result found by this rule by 2.

Table 95.—PROPORTIONS OF CAST-IRON GIRDERS, Fig. 50.

| Safe dead distributed Load in Tons. | Clear Span in Feet. | Depth of Girder in Inches. | BOTTOM FLANGE. | | | TOP FLANGE. | | | WEB. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Breadth in Inches. | Thickness at the Centre in Inches. | Thickness at the Edge in Inches. | Breadth in Inches. | Thickness at the Centre in Inches. | Thickness at the Edge in Inches. | Thickness at the Bottom in Inches. | Thickness at the Top in Inches. |
| 4 | 10 | 9 | 5 | $1\frac{1}{4}$ | $\frac{7}{8}$ | $1\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{3}{4}$ |
| 6 | 10 | 9 | 6 | $1\frac{3}{8}$ | 1 | $1\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | 1 | $\frac{7}{8}$ |
| 12 | 14 | 12 | 8 | $2\frac{1}{4}$ | $1\frac{3}{4}$ | $2\frac{7}{8}$ | 1 | $\frac{7}{8}$ | $1\frac{1}{8}$ | 1 |
| 18 | 15 | 12 | 12 | $2\frac{3}{8}$ | $1\frac{3}{4}$ | $4\frac{1}{8}$ | $1\frac{1}{8}$ | 1 | $1\frac{3}{8}$ | $1\frac{1}{8}$ |
| 25 | 20 | 12 | 18 | $2\frac{7}{8}$ | $2\frac{1}{4}$ | 6 | $1\frac{5}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ |
| 30 | 20 | 12 | 20 | 3 | $2\frac{1}{2}$ | 7 | $1\frac{3}{4}$ | $1\frac{3}{8}$ | 2 | $1\frac{5}{8}$ |
| 9 | 12 | 15 | 7 | $1\frac{3}{8}$ | 1 | $1\frac{7}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | 1 | $\frac{7}{8}$ |
| 18 | 16 | 15 | 10 | $2\frac{3}{8}$ | $1\frac{3}{4}$ | $3\frac{3}{8}$ | $1\frac{1}{8}$ | 1 | $1\frac{3}{8}$ | $1\frac{1}{8}$ |
| 25 | 20 | 15 | 17 | $2\frac{3}{8}$ | $1\frac{3}{4}$ | $5\frac{5}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{5}{8}$ | $1\frac{3}{8}$ |
| 30 | 20 | 15 | 18 | $2\frac{7}{8}$ | $2\frac{3}{8}$ | $6\frac{5}{8}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ |
| 16 | 18 | 18 | 12 | $1\frac{3}{4}$ | $1\frac{1}{8}$ | $3\frac{1}{8}$ | 1 | $\frac{7}{8}$ | $1\frac{1}{8}$ | 1 |
| 25 | 20 | 18 | 16 | $2\frac{1}{8}$ | $1\frac{1}{2}$ | $4\frac{5}{8}$ | $1\frac{1}{8}$ | 1 | $1\frac{1}{2}$ | $1\frac{1}{4}$ |
| 40 | 18 | 18 | 16 | $3\frac{3}{8}$ | $2\frac{1}{2}$ | $5\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{4}$ | 2 | $1\frac{1}{4}$ |
| 15 | 20 | 24 | 13 | $1\frac{3}{8}$ | $1\frac{1}{8}$ | $2\frac{7}{8}$ | $1\frac{1}{8}$ | $\frac{7}{8}$ | 1 | $\frac{7}{8}$ |
| 25 | 20 | 24 | 15 | $1\frac{3}{4}$ | $1\frac{3}{8}$ | $4\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | 1 |
| 40 | 20 | 24 | 16 | $2\frac{5}{8}$ | $1\frac{7}{8}$ | $5\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{1}{8}$ | $1\frac{7}{8}$ | $1\frac{1}{4}$ |
| 60 | 20 | 24 | 17 | $4\frac{1}{2}$ | $3\frac{1}{2}$ | 6 | $2\frac{3}{8}$ | $1\frac{3}{4}$ | $2\frac{7}{8}$ | $1\frac{3}{4}$ |
| 85 | 25 | 24 | 25 | $4\frac{5}{8}$ | $3\frac{5}{8}$ | 8 | $2\frac{1}{2}$ | $1\frac{7}{8}$ | 3 | $1\frac{7}{8}$ |
| 40 | 20 | 30 | 15 | $2\frac{3}{8}$ | $1\frac{5}{8}$ | 5 | $1\frac{3}{8}$ | $1\frac{1}{8}$ | $1\frac{5}{8}$ | $1\frac{1}{8}$ |
| 60 | 25 | 30 | 18 | $3\frac{5}{8}$ | $2\frac{7}{8}$ | $5\frac{1}{4}$ | $2\frac{1}{4}$ | $1\frac{5}{8}$ | 2 | $1\frac{3}{8}$ |
| 90 | 25 | 30 | 25 | $4\frac{1}{2}$ | $3\frac{1}{2}$ | 8 | $2\frac{3}{8}$ | $1\frac{3}{4}$ | $2\frac{7}{8}$ | $1\frac{3}{4}$ |
| 130 | 25 | 30 | 26 | $5\frac{1}{8}$ | 4 | 9 | $2\frac{7}{8}$ | 2 | $3\frac{3}{8}$ | $2\frac{1}{8}$ |
| 70 | 25 | 36 | 19 | $3\frac{3}{4}$ | $2\frac{5}{8}$ | 6 | $2\frac{1}{4}$ | $1\frac{3}{4}$ | $2\frac{1}{8}$ | $1\frac{5}{8}$ |
| 100 | 25 | 36 | 25 | $4\frac{1}{4}$ | $3\frac{1}{8}$ | 8 | $2\frac{1}{4}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $1\frac{3}{4}$ |
| 130 | 25 | 36 | 26 | $4\frac{3}{4}$ | $3\frac{3}{4}$ | 9 | $2\frac{1}{2}$ | $1\frac{7}{8}$ | $3\frac{1}{4}$ | 2 |

*To find the area of the bottom flange* in inches.—*Rule:* Multiply the length in feet by the permanent distributed load in tons, and divide the product by the depth in inches of the girder.

*To find the permanent distributed load.*—*Rule:* Multiply the depth in inches by the sectional area of bottom flange in inches, and divide by the length in feet of the girder.

*To find the weight in lbs. of a brick wall* carried by a girder, multiply the height in feet by the length in feet of brickwork, and then multiply by the number of bricks the wall is thick (that is by 2, if the wall is 2 bricks thick, and so on) and multiply by 75, which result divided by 2240 will give the weight of the wall in tons, or load distributed over the whole length of girder.

**Riveted Wrought-Iron Girders**, Fig. 51. To find the breaking weight in tons, of a girder with a single plate or web united by angle-irons to top and bottom flanges, when loaded in the middle and with both ends supported.—*Rule:* Multiply 5·7 times the depth of girder in inches by the area of the bottom flange in inches, and divide by the length in feet between

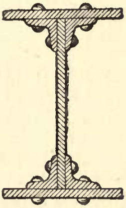

Fig. 51.

the supports (the area of the bottom flange to include the angle-iron). To calculate the area of the bottom flange, multiply the width of flange-plate in inches, by its thickness in inches, to which result add the area of the 2 angle irons, which may be found by the following rule.

*To find the sectional area in square inches of an angle-iron,* add together the width of its two sides, from which sum subtract the thickness of metal, all in inches, and multiply the remainder by the thickness of metal in inches; thus a 3 inch angle iron $\frac{1}{2}$ inch thick has a sectional area of $(3 + 3 - {\cdot}5) \times {\cdot}5 = 2{\cdot}75$ square inches, and as there are 2 angle irons, double the area thus found must be added to the area of the flange-plate.

*To find the sectional area in square inches of the bottom flange* of wrought-iron riveted girders. *Rule:* Multiply the breaking weight in tons, by the span or length between the supports in feet, and divide the product by 5·7 times the depth of girder in inches.

Depth of wrought-iron riveted girders. The depth should be $\frac{1}{12}$ of the span.

**Box-Girders** are 10 per cent. stronger than single-plate girders, of equal depth and weight.

**Pitch of Rivets** for riveted girders. For the compression member, 3 inch pitch for small, and 4 inch pitch for large girders; for the tension member, 6 inch pitch for both large and small girders.

Table 96.—Breaking-Strength of Materials in Tons per Square Inch.

| Description of Materials. | Breaking Strain in Tension per Square Inch, in Tons. | Breaking Strain in Compression per Square Inch, in Tons. |
|---|---|---|
| Cast-steel bars, rolled and forged | 52 | |
| Shear-steel bars ditto | 50 | |
| Bessemer-steel bars ditto | 48 | |
| Blistered-steel bars ditto | 45 | |
| Spring-steel bars ditto | 32 | |
| Steel boiler plates ditto | 32 | 18 |
| Lowmoor or best Yorkshire bar iron | 26 | 12 |
| Ordinary good merchant bar-iron | 25 | 12 |
| Hoop-iron, best quality, average | 25 | |
| Lowmoor or best Yorkshire iron plates along the fibre | 24 | |
| ditto ditto ditto across the fibre | 22 | |
| Ordinary good angle and tee-iron | 22 | |
| Ordinary good boiler-plates along the fibre | 21 | |
| ditto ditto across the fibre | 18 | |
| Ordinary good ship-plates along the fibre | 20 | |
| ditto ditto across the fibre | 17 | |
| Cast-iron, best quality | 7 | 48 |
| ditto ordinary average quality | 6 | 42 |
| Malleable cast-iron, best quality | 20 | |
| Phosphor-bronze wire, not annealed | 55 | |
| Steel wire, not annealed, best quality | 53 | |
| Brass wire ditto , best quality | 36 | |
| Iron wire, best quality | 28 | |
| Copper wire | 28 | |
| Homogeneous metal bars, best | 40 | |
| Muntz metal . . . . . 3 copper; 2 zinc | 22 | |
| Sterro metal | 27 | |
| Brass tubes . . . . 70 copper; 30 zinc | 35 | |
| Railway rails, iron flange | 20 | |
| ditto iron double-headed | 24 | |
| ditto steel flange | 34 | |
| ditto ditto double headed | 44 | |
| Railway-wheel steel tires | 42 | |
| Aluminium-bronze | 32 | 58 |
| Phosphor-bronze | 25 | |
| Palladium wire | 23 | |
| Nickel | 20 | |
| Cobalt | 18 | |
| Copper, wrought | 15 | |
| Copper, cast | 9 | |
| Gun-metal and bronze | 14 | 6 |
| Brass | 8 | 4·5 |
| Soft solder | 3·2 | |
| Zinc, cast | 3·1 | |

Table 96 *continued.*—BREAKING-STRENGTH OF MATERIALS.

| Description of Materials. | Breaking Strain in Tension per Square Inch, in Tons. | Breaking Strain in Compression per Square Inch, in Tons. |
|---|---|---|
| Tin, cast | 2 | |
| Bismuth, cast | 1·42 | |
| Lead pipe | 1·00 | |
| Lead, sheet | ·86 | |
| Lead, cast | ·81 | |
| Antimony | ·46 | |
| Glass | 1 | 13 |
| Ebony, West Indian | ... | 8½ |
| Iron-wood, West Indian | ... | 7¾ |
| Lime tree | 10⅝ | |
| Lancewood | 10½ | 3 |
| Hornbeam | 9 | 3¼ |
| Apple tree | 8¾ | 2¾ |
| Boxwood | 8½ | 4½ |
| Ash | 7 | 4 |
| Birch | 6½ | 2¾ |
| Alder | 6¼ | 3 |
| Teak | 6 | 5 |
| Sycamore | 5¾ | 3 |
| Oak, English | 5 | 4 |
| Mahogany, Honduras | 5 | 3 |
| Lignumvitæ | 5 | 4¼ |
| Beech | 5 | 4 |
| Cedar | 5 | 3 |
| Yew | 3½ | |
| Mahogany, Spanish | 3 | 2 |
| Walnut and pine, each | 3 | 2 |
| Granite | ... | 4½ |
| Sandstone | ... | 2½ |
| Pressed bricks | ... | 1 |
| Stock bricks | ... | ·90 |
| Leather belting, best quality | 1·50 | |
| Stitched cotton belting, best quality | 3·04 | |
| Solid-woven cotton belting, best stout quality | 4·65 | |
| Hemp, twisted ¼ to 1 inch thick | 4 | |
| ditto 1 to 3 ditto | 3 | |
| ditto 3 to 5 ditto | 2·4 | |
| ditto 5 to 7 ditto | 2·18 | |

NOTE.—The strength of steel is diminished to the extent of from 25 to 50 per cent. by annealing, and its strength is increased from 15 to 60 per cent. by hardening in oil.

**Specific Gravity.**—The specific gravity of a body, is its weight in proportion to an equal bulk of pure water, and the standard of comparison for solids and liquids is a cubic foot of pure water at 62° F., which weighs 1,000 ounces avoirdupois.

Table 97.—Specific Gravity and Weight of Materials, and of Liquids and Gases.

| | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water = 1. | lbs. |
| **Metals.** | | |
| Platinum | 21·526 | 1344 |
| Gold | 19·258 | 1204 |
| Mercury | 13·596 | 847 |
| Lead | 11·366 | 710 |
| Silver | 10·511 | 656 |
| Bismuth | 9·900 | 618 |
| Copper, sheet | 8·806 | 549 |
| Gun metal | 8·731 | 544 |
| Copper, cast | 8·610 | 538 |
| Brass, cast | 8·400 | 525 |
| Nickel, cast | 8·280 | 515 |
| Steel | 7·856 | 490 |
| Wrought iron | 7·700 | 480 |
| Tin | 7·294 | 455 |
| Cast iron | 7·218 | 450 |
| Zinc, cast | 6·862 | 428 |
| Antimony | 6·712 | 419 |
| Arsenic | 5·763 | 360 |
| Aluminium, cast | 2·560 | 160 |
| **Minerals, etc.** | | |
| White lead | 3·164 | 198 |
| Slate | 2·834 | 176 |
| Chalk | 2·782 | 174 |
| Marble | 2·730 | 170 |
| Glass, plate | 2·700 | 168 |
| Granite | 2·662 | 166 |
| Stone, mean of various | 2·560 | 160 |
| Stone, paving | 2·416 | 151 |
| Stonework | 2·225 | 140 |
| Stone, Bath | 2·100 | 131 |
| Brick and concrete . . . . each | 2·000 | 125 |
| Sand, pure, and common clay . each | 1·900 | 119 |
| Mortar and gravel . . . . each | 1·760 | 110 |
| Brickwork and earth . . . each | 1·750 | 109 |
| Mud | 1·600 | 100 |
| Coal | 1·280 | 80 |
| Coke, hard | ·750 | 46 |
| Gas coke | ·360 | 22 |
| Snow, fresh | ·096 | 6 |
| Ice at 32° | ·93 | 58 |
| Melting ice | ·92 | 57·4 |
| Gutta percha | ·97 | 60·5 |
| Caoutchouc | ·93 | 58·0 |
| Gunpowder | ·94 | 58·6 |

Table 97 *continued.*—SPECIFIC GRAVITY AND WEIGHT OF MATERIALS.

| | Specific Gravity. | Weight of One Cubic Foot. |
|---|---|---|
| | Water = 1. | lbs. |
| LIQUIDS, ETC. | | |
| Sea water | 1·027 | 64 |
| Tar from wood | 1·015 | 63·43 |
| Vinegar, distilled | 1·009 | 68·00 |
| Water, distilled | 1·000 | 62·355 |
| Tallow and linseed oil . . each | ·940 | 58·600 |
| Rape seed oil | ·921 | 57·4 |
| Spirits, proof | ·920 | 57·4 |
| Olive oil | ·915 | 57·0 |
| Petroleum | ·880 | 54·9 |
| Turpentine | ·870 | 54·2 |
| Naphtha | ·850 | 53·1 |
| WOOD. | | |
| Lignum vitæ | 1·33 | 82·9 |
| Box, Dutch | 1·32 | 82·3 |
| Ebony | 1·20 | 74·8 |
| Heart of oak | 1·17 | 73·0 |
| Rosewood and lancewood | 1·03 | 64·2 |
| Oak, English | ·93 | 58·0 |
| Laburnum and hawthorn . . each | ·920 | 57·38 |
| Beech and Spanish mahogany . each | ·850 | 53·1 |
| Ash and plum tree . . . each | ·840 | 52·5 |
| Hornbeam, holly and crab tree . each | ·760 | 47·5 |
| Teak and maple . . . . each | ·750 | 46·8 |
| Birch, pear tree and apple tree . each | ·730 | 45·5 |
| Pine, pitch | ·730 | 45·5 |
| Pine, red | ·670 | 41·8 |
| Pine, white | ·460 | 28·7 |
| Pine, yellow | ·450 | 27·2 |
| Yew | ·740 | 46·1 |
| Cherry tree | ·715 | 45·0 |
| Walnut and plane tree, and elm . each | ·670 | 41·8 |
| Chestnut tree | ·610 | 38·0 |
| Mahogany, Honduras; and cedar each | ·560 | 34·8 |
| Larch | ·530 | 31·0 |
| Poplar | ·384 | 24·0 |
| Cork and charcoal . . . . each | ·240 | 15·0 |
| GASES, AT 32° F. | | |
| Atmospheric air being | 1·000 | ·0807 |
| Nitrogen | ·973 | ·0786 |
| Gaseous steam | ·622 | ·0502 |
| Ammoniacal gas | ·588 | ·0474 |
| Hydrogen | ·070 | ·0056 |
| Carbonic acid | 1·527 | ·1232 |
| Sulphurous acid | 2·247 | ·1815 |

Table 98.—Weight and Volume of Metals.

| | Wrought Iron, Rolled. | Wrought Iron, Forged. | Cast Iron. | Bessemer Steel. | Rolled Steel. | Copper. | Brass. | Lead. | Water. |
|---|---|---|---|---|---|---|---|---|---|
| Weight of one cubic foot . . lbs. | 480 | 487 | 450 | 492 | 490 | 549 | 525 | 710 | 62·4 |
| Weight of one cubic inch . . . lbs. | ·278 | ·282 | ·26 | ·285 | ·283 | ·318 | ·304 | ·41 | ·036 |
| Number of cubic inches in one lb. . | 3·6 | 3·55 | 3·84 | 3·51 | 3·53 | 3·15 | 3·29 | 2·43 | 27·7 |
| Weight of one square foot one inch thick . . . . . . . lbs. | 40 | 40·6 | 37·5 | 41 | 40·8 | 46 | 43 | 59 | 5·2 |
| Weight of one cylindrical foot . lbs. | 377 | 382 | 355 | 386 | 385 | 431 | 412 | 557 | 49 |
| Weight of one cylindrical inch . lbs. | ·218 | ·221 | ·205 | ·223 | ·222 | ·249 | ·238 | ·323 | ·028 |
| Number of cylindrical inches in one lb. | 4·6 | 4·5 | 4·8 | 4·47 | 4·5 | 4·0 | 4·19 | 3·10 | 35·15 |
| Weight of one circular foot one inch thick . . . . . . . lbs. | 31·41 | 31·84 | 29·7 | 32·2 | 32·05 | 35·95 | 34·36 | 46·42 | 4·1 |
| Weight of one spherical foot (ball one foot diameter) . . . . . lbs. | 251 | 255 | 236 | 258 | 257 | 288 | 275 | 372 | 32·73 |
| Weight of one spherical inch . . lbs. | ·145 | ·147 | ·137 | ·150 | ·149 | ·167 | ·159 | ·215 | ·019 |
| Number of spherical inches in one lb. . | 6·9 | 6·78 | 7·26 | 6·7 | 6·74 | 6·0 | 6·3 | 4·65 | 52·9 |
| Weight of a one-inch round bar one foot long . . . . . . . lbs. | 2·63 | 2·66 | 2·45 | 2·68 | 2·67 | 3·0 | 2·84 | 3·8 | ·341 |
| Weight of a one-inch square bar one foot long . . . . . . . lbs. | 3·35 | 3·39 | 3·15 | 3·45 | 3·43 | 3·84 | 3·65 | 5· | ·434 |
| Number of cubic feet in one ton . . | 4·67 | 4·6 | 4·98 | 4·55 | 4·59 | 4·08 | 4·28 | 3·15 | 36 |
| Diameter of a ball to weigh one ton . . . . . . inches | 25 | 24¾ | 25½ | 24½ | 24⅝ | 23¾ | 24 | 21¾ | |

## RULES FOR FINDING THE WEIGHTS OF CASTINGS, ETC.

**To find the weight of iron castings,** multiply the width in quarter inches by the thickness in eighths of an inch, or *vice versa*, and divide the product by 10; then multiply the result by the length in feet, which will give the weight in lbs. of that casting. For wrought iron, add $\frac{1}{20}$ to the result; for lead, add $\frac{1}{2}$; for brass, add $\frac{1}{7}$; and for copper, add $\frac{1}{5}$ to the result.

*To find the weight in lbs. of flat castings and bars,* multiply the width in inches by the thickness in inches; then multiply by the length in feet, and next by one of the following multipliers, viz.: for cast iron, 3·156 or $3\frac{1}{7}$; for wrought iron, 3·312 or $3\frac{1}{3}$; for lead, 4·854; for brass, 3·644; for copper, 3·87; for steel, 3·4.

*To find the weight in lbs. of round plates and bars of cast iron,* multiply the square of the diameter in inches by ·7854, then multiply the product by the depth or length in inches, and multiply the result by ·26.

*To find the weight in lbs. of a square plate or bar,* multiply the square of one of its sides in inches by the thickness in inches, and multiply the product by ·26 for cast iron; for wrought iron, multiply by ·28, and for steel, multiply by ·283.

**To find the weight in lbs. of pipes, tubes, and cylinders,** subtract the square of the inside diameter in inches from the square of the outside diameter in inches, multiply the result by 7·4, and divide by 3, then multiply by the length of the pipe in feet.

*To find the weight in lbs. of a hollow ball or spherical shell,* multiply the square of the outside diameter in inches by 3·1416; multiply the product by the thickness of metal in inches, and multiply the result by ·26 for cast iron.

*To find the weight in lbs. of the segment of a hollow ball* or spherical shell, multiply the outside diameter in inches by 3·1416, and multiply the product by the height of segment, multiply that product by the thickness of metal in inches, and multiply the result by ·26 for cast iron.

*To find the weight in lbs. of a cast iron ball,* multiply the cube of the diameter in inches by ·137. The weight in lbs. of balls of any metal may be found thus :—multiply the cube of the diameter in inches by ·5236, then multiply the result by the multiplier opposite to the required metal in table 99.

*To find the diameter of a ball* in inches when the weight in lbs. is given, multiply ·5236 by the multiplier opposite the required metal in table 99, and divide the weight of the ball by the said product, the cube root of the quotient will be the diameter in inches.

**To find the weight in lbs. of castings from their cubic contents,** multiply the cubic contents in inches by the multiplier opposite the metal in the following table.

Table 99.—Multipliers for converting Cubic Inches into Lbs.

| | | | |
|---|---|---|---|
| Platinum | ·77 | Steel, rolled | ·283 |
| Gold | ·70 | Cobalt | ·282 |
| Mercury | ·49 | Nickel | ·282 |
| Lead | ·41 | Wrought-iron, forged | ·282 |
| Silver | ·38 | Wrought-iron, rolled | ·278 |
| Bismuth | ·35 | White metal | ·270 |
| Copper, sheet | ·32 | Tin | ·268 |
| Copper, cast | ·318 | Pewter | ·261 |
| Phosphor Bronze | ·315 | Cast-iron | ·260 |
| Gun metal | ·314 | Zinc | ·253 |
| Brass wire | ·308 | Antimony | ·241 |
| Brass | ·304 | Aluminium | ·090 |
| Bell metal | ·295 | Box-wood | ·048 |
| White metal for bearings | ·290 | Teak | ·028 |
| Steel, Bessemer | ·285 | Pine, yellow | ·016 |

**Measuring Patterns.**—In order to provide against running castings short of metal, moulders in measuring patterns allow 2 lbs. per foot for straining, &c., and take the weight of 1 square foot of cast-iron 1 inch thick at 40 lbs., or 5 lbs. per superficial foot for every $\frac{1}{8}$th of an inch thickness of metal. Hence the rule to find the weight in lbs. is—multiply the length in feet by the breadth in feet, and by 5, and by the number of $\frac{1}{8}$ths of an inch the metal is thick. In measuring cores, the same rule is used, but instead of multiplying by 5, multiply by 4·7, because 40 lbs. per square foot 1 inch thick, is too much to take out for cores.

Table 100.—Decimal Approximations, etc.

| | | | |
|---|---|---|---|
| Cylindrical inches multiplied by | | ·0004545 | = cubic feet. |
| Cylindrical feet multiplied by | | ·02909 | = cubic yards. |
| Circular inches multiplied by | | ·00546 | = square feet. |
| Cylindrical inches multiplied by | | ·2049 | = lbs. of cast iron. |
| Ditto | ditto | ·22069 | = lbs. of hammered wrought-iron. |
| Ditto | ditto | ·2179 | = lbs. of rolled wrought-iron. |
| Ditto | ditto | ·2222 | = lbs. of steel. |
| Ditto | ditto | ·3854 | = lbs. of mercury. |
| Ditto | ditto | ·2505 | = lbs. of copper. |
| Ditto | ditto | ·395 | = lbs. of lead. |
| Ditto | ditto | ·2385 | = lbs. of brass. |
| Ditto | ditto | ·207 | = lbs. of tin. |
| Ditto | ditto | ·2042 | = lbs. of zinc. |
| Cubic inches multiplied by | | ·00058 | = cubic feet. |
| Cubic feet multiplied by | | ·03705 | = cubic yards. |
| Square inches multiplied by | | ·007 | = square feet. |
| Avoirdupois lbs. multiplied by | | ·009 | = cwts. |
| Ditto | ditto | ·00045 | = tons. |
| Cubic inches divided by | | 1728 | = cubic feet. |

Table 101.—Multipliers for Converting the Weight of One Metal to that of Another.

| To Convert the Weight in lbs. of the following into | Rolled Wrought Iron. | Steel. | Cast Iron. | Gun Metal. | Brass. | Copper. | Tin. | Lead. | Zinc. |
|---|---|---|---|---|---|---|---|---|---|
| Wrought iron, rolled, multiply by | ... | 1·026 | ·95 | 1·15 | 1·1 | 1·152 | ·95 | 1·5 | ·93 |
| Wrought iron, forged do. | ·988 | 1·012 | ·938 | 1·12 | 1·08 | 1·13 | ·938 | 1·46 | ·911 |
| Steel do. | ·974 | ... | ·929 | 1·12 | 1·07 | 1·12 | ·931 | 1·45 | ·919 |
| Cast iron do. | 1·05 | 1·08 | ... | 1·2 | 1·155 | 1·21 | 1·004 | 1·56 | ·988 |
| Gun metal do. | ·88 | ·90 | ·83 | ... | ·96 | 1·00 | ·83 | 1·30 | ·830 |
| Brass do. | ·915 | ·93 | ·86 | 1·04 | ... | 1·05 | ·86 | 1·35 | ·856 |
| Copper do. | ·87 | ·89 | ·83 | ·99 | ·95 | ... | ·83 | 1·30 | ·806 |
| Tin do. | 1·05 | 1·08 | 1·00 | 1·20 | 1·15 | 1·21 | ... | 1·56 | ·986 |
| Lead do. | ·67 | ·69 | ·64 | ·77 | ·74 | ·775 | ·644 | ... | ·635 |
| Zinc do. | 1·07 | 1·09 | 1·02 | 1·21 | 1·17 | 1·223 | 1·015 | 1·59 | ... |
| Pattern in yellow pine do. | 17·00 | 17·02 | 16·00 | 19·00 | 18·8 | 19·30 | 16·00 | 24·00 | 15·8 |
| Pattern in modelling clay do. | 4·05 | 4·125 | 3·85 | 4·60 | 4·44 | 4·65 | 3·86 | 6·00 | 3·85 |

Examples of the use of this table.—Example 1: a wrought-iron shaft-forging weighs 3 cwts., required the weight of a similar shaft of steel: then 3 × 1·012 = 3·036 cwts. Example 2: a cast-iron plate weighs 50 lbs., required the weight of a gun-metal plate of the same size: then 50 × 1·2 = 60 lbs. Example 3: required the weight of a cast-iron casting, cast from a solid pattern of yellow-pine weighing 2 cwts.: then 2 × 16 = 32 cwts.

**Metal Plates.**—The weights of metal plates are given at pages 282, 289—292, 300.

**A solid pattern,** without cores, weighing 1 lb., made of yellow pine, will weigh, when cast in cast iron, 16 lbs.; in zinc, 15·8 lbs.; in tin, 16 lbs.; in steel, 17·02 lbs.; in brass, 18·8 lbs.; in gun metal, 19 lbs.; in copper, 19·3 lbs.; in lead, 24 lbs.

**The Cone.**—To find the solidity or cubic contents of a cone: multiply the area of the base by one-third of the perpendicular height. To find the convex surface of a cone, multiply the circumference of the base by one half the slant height; to which add the area of the base for the whole surface.

*To find the surface of the frustrum of a cone:* multiply the sum of the perimeters of the two ends by half the slant height, and add the areas of the ends.

*To find the cubic contents of a frustrum of a cone,* add together the areas of the two ends and the mean proportional between them (that is, the square root of their product), and multiply the sum by one-third of the perpendicular height.

*To find the cubic contents of a wedge:* to twice the length of the base add the length of the edge; multiply the sum by the breadth of base, and by one-sixth of the height.

*To find the surface of a sphere or ball:* multiply the square of the diameter by 3·1416.

*To find the cubic contents of a sphere:* multiply the cube of the diameter by ·5236.

*To find the surface of a segment of a sphere:* multiply the diameter of the sphere by 3·1416, and then by the height of segment.

*To find the cubic contents of the segment of a sphere:* from three times the diameter of the sphere, subtract twice the height of segment, then multiply the difference, by the square of the height and by ·5236.

*To find the surface of a cylinder:* multiply the circumference by the length for the convex surface, to which add twice the area of one end, for its whole surface.

To find the cubic contents of a cylinder: multiply the area of one end by the length.

To find the cubic contents of a parallelopiped: multiply the length by the breadth, and multiply that product by the depth.

To find the surface of a parallelopiped: add the depth to the breadth and multiply by the length, to which add the area of the end.

To find the area of a ring included between the circumference of two concentric circles: multiply the sum of the diameters, by their difference, and by ·7854.

**Strength of Cast Iron Pillars or Columns.**—The following are Mr. Gordon's rules for columns:—

W = the breaking weight in tons; A, the sectional area of the material in inches; R, the ratio of the length to the diameter, the least diameter of the section being taken.

For solid or hollow cast iron columns

$$W = \frac{36a}{1 + \frac{R^2}{400}}.$$

For solid or hollow rectangular cast iron columns

$$W = \frac{36a}{1 + \frac{R^2}{500}}.$$

Table 102.—Safe Load on Hollow Cast-Iron Pillars.

| External Diameter. | Thickness of Metal. | Length of Pillar in Feet. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 8 | | 10 | | 12 | | 14 | | 16 | |
| Inches. | Inches. | Tons | Cwts. | Tons | Cwts. | Tons | Cwts. | Tons | Cwts. | Tons | Cwts. |
| 3 | ½ | 3 | 17 | 2 | 18 | 2 | 0 | 1 | 6 | 1 | 1 |
| 3½ | ⅝ | 6 | 16 | 5 | 0 | 3 | 18 | 2 | 18 | 2 | 1 |
| 4 | ⅝ | 8 | 19 | 6 | 19 | 5 | 3 | 4 | 0 | 3 | 5 |
| 4½ | ¾ | 14 | 4 | 11 | 2 | 8 | 5 | 6 | 17 | 5 | 15 |
| 5 | ¾ | 18 | 6 | 14 | 4 | 11 | 3 | 8 | 16 | 7 | 2 |
| 5 | 1 | 23 | 2 | 18 | 2 | 14 | 4 | 11 | 5 | 9 | 1 |
| 5½ | 1 | 27 | 3 | 22 | 18 | 18 | 6 | 14 | 19 | 12 | 0 |
| 6 | ⅝ | 22 | 18 | 18 | 16 | 15 | 1 | 12 | 3 | 10 | 0 |
| 6 | ¾ | 26 | 18 | 21 | 19 | 17 | 19 | 14 | 15 | 12 | 0 |
| 6½ | 1 | 40 | 0 | 33 | 2 | 27 | 16 | 22 | 3 | 19 | 0 |
| 7 | 1 | 45 | 18 | 38 | 17 | 32 | 16 | 27 | 3 | 23 | 0 |
| 7 | 1¼ | 55 | 5 | 46 | 11 | 39 | 4 | 33 | 0 | 28 | 0 |
| 7½ | 1 | 51 | 18 | 44 | 5 | 37 | 18 | 32 | 0 | 27 | 3 |
| 8 | 1 | 58 | 0 | 50 | 3 | 43 | 6 | 37 | 3 | 32 | 0 |
| 8 | 1¼ | 70 | 0 | 60 | 0 | 51 | 0 | 45 | 0 | 38 | 10 |
| 8½ | 1 | 64 | 0 | 56 | 4 | 49 | 3 | 42 | 12 | 37 | 0 |
| 9 | 1 | 70 | 0 | 62 | 0 | 54 | 18 | 47 | 16 | 41 | 17 |
| 9 | 1¼ | 83 | 0 | 74 | 0 | 65 | 0 | 57 | 0 | 50 | 0 |
| 10 | 1¼ | 100 | 0 | 90 | 10 | 81 | 0 | 70 | 0 | 60 | 0 |

**The Loads** given in the Table, are for hollow cast iron pillars with flat ends, and securely fixed.

Hollow columns fail principally from crushing, when the length does not exceed thirty times the diameter.

| | | |
|---|---|---|
| Cast-iron of average quality is crushed with . . | 42 | Tons per square inch. |
| Wrought-iron " " " . . . . | 16 | |
| Wrought-iron is permanently injured when crushed with . . . . . . . . . . | 12 | |
| Oak is crushed with . . . . . . . . | 4 | |
| Deal is crushed with . . . . . . . | 2 | |

Columns with both ends round are only ⅓rd, and columns with one end flat, and the other end round only ⅔rds, the strength of columns with both ends flat.

The strength of a column of a cruciform section is only ½, and of a double flanged section only $\frac{3}{4}$, that of a round hollow column, of equal weight.

In contracts for columns, a variation of from $\frac{1}{16}$ to $\frac{3}{32}$ inch in the thickness of metal is permitted in most cases.

Table 103.—Proportions of Rivets and of Single and Double-Riveted Joints for Wrought-Iron Plates.

| Thickness of Iron Plate. | Diameter of Iron Rivet. | Length of Rivet from under the Head. | Pitch of Rivets, in Inches. | | Breadth of Lap. | | Distance of each line of Rivets from each edge of Plate in the Double-Riveted Joint. |
|---|---|---|---|---|---|---|---|
| | | | Single-Riveted Joint. | Double-Riveted Zigzag Joint. Pitch along one Line. | Single-Riveted Joint. | Double-Riveted Joint. | |
| Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| $\frac{3}{16}$ | $\frac{3}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{5}{8}$ | $1\frac{1}{4}$ | $2\frac{1}{4}$ | $\frac{11}{16}$ |
| $\frac{1}{4}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 2 | $1\frac{5}{8}$ | 3 | $\frac{7}{8}$ |
| $\frac{5}{16}$ | $\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $2\frac{1}{2}$ | 2 | $3\frac{5}{8}$ | $1\frac{1}{16}$ |
| $\frac{3}{8}$ | $\frac{3}{4}$ | $1\frac{7}{8}$ | $1\frac{7}{8}$ | 3 | $2\frac{1}{4}$ | $4\frac{1}{2}$ | $1\frac{5}{16}$ |
| $\frac{7}{16}$ | $\frac{3}{4}$ | $2\frac{1}{8}$ | 2 | $3\frac{1}{4}$ | $2\frac{3}{8}$ | $4\frac{1}{2}$ | $1\frac{5}{16}$ |
| $\frac{1}{2}$ | $\frac{13}{16}$ | $2\frac{1}{4}$ | $2\frac{1}{8}$ | $3\frac{3}{8}$ | $2\frac{5}{8}$ | $4\frac{7}{8}$ | $1\frac{3}{8}$ |
| $\frac{9}{16}$ | $\frac{7}{8}$ | $2\frac{5}{8}$ | $2\frac{1}{4}$ | $3\frac{1}{2}$ | $2\frac{3}{4}$ | $5\frac{1}{4}$ | $1\frac{1}{2}$ |
| $\frac{5}{8}$ | $\frac{7}{8}$ | 3 | $2\frac{3}{8}$ | $3\frac{5}{8}$ | $2\frac{7}{8}$ | $5\frac{1}{4}$ | $1\frac{1}{2}$ |
| $\frac{3}{4}$ | 1 | $3\frac{1}{4}$ | $2\frac{1}{2}$ | $3\frac{3}{4}$ | $3\frac{1}{4}$ | 6 | $1\frac{3}{4}$ |
| $\frac{7}{8}$ | $1\frac{1}{8}$ | $3\frac{1}{2}$ | $2\frac{3}{4}$ | 4 | $3\frac{5}{8}$ | $6\frac{3}{4}$ | $1\frac{15}{16}$ |
| 1 | $1\frac{1}{4}$ | $4\frac{1}{4}$ | 3 | $4\frac{1}{2}$ | 4 | $7\frac{1}{2}$ | $2\frac{1}{8}$ |

**In Zigzag Riveting**, the rivets in one line divide the spaces between the rivets in the other line, as shown in Fig. 42, page 178. The distance between the rivet-hole and the edge of the plate, or between two rivet-holes, should never be less than the diameter of the rivet.

**Proportions of Rivets.**—A pan-shaped rivet-head should equal in diameter $1\frac{5}{8}$, and in thickness $\frac{3}{4}$ the diameter of rivet; and when a cup or snap shape, the diameter of rivet head should equal $1\frac{3}{4}$, and the depth $\frac{3}{4}$ the diameter of rivet. The diameter of a conical rivet-head should equal twice, and the depth $\frac{3}{4}$ the diameter of the rivet. The diameter of the head of a countersunk rivet should equal $1\frac{1}{2}$ times, and the thickness $\frac{1}{2}$ the diameter of the rivet. The length of rivet required to form the rivet-head is equal to the diameter of the rivet for countersunk heads, and to $1\frac{1}{4}$ times the diameter for cup and conical rivet-heads.

**All Rivet Holes** should be perfectly fair with each other, those that are not fair should be rhymed out until they become so—drifting should not be permitted. The rivets should completely fill the holes—which should be slightly countersunk under the rivet-heads,—and the rivet-heads should be true and central. When the rivet holes are drilled in "place" the plates should be taken apart and the burr removed, as it prevents the plates closing tightly to make a good joint.

**The Edges of the Plates**—in best work—should be planed to an angle of 1 in 8, so as to have a full edge for caulking, which should be done with a broad-faced fuller, so as not to injure the plates.

**Butt Strips** should be of as good a quality as the plates they cover, and should be cut from plates and not from bars. Single butt strips should be $\frac{1}{8}$ inch thicker than the plates they cover, and double butt strips should each be not less than $\frac{3}{4}$ the thickness of the plates they cover. Butt strips for the longitudinal seams of boiler should be cut across the fibre.

**Strength of Riveted-Joints.**—The percentage of strength of the *plate* at the joint as compared with the solid plate may be found by the following rule:—

$$\frac{(\text{Pitch} - \text{diameter of rivets}) \times 100}{\text{Pitch of rivets}}$$

The percentage of strength of the *rivets* as compared with the solid plate may be found by the following rule:—(For other Rules, see page 176),

$$\frac{(\text{Area of rivets} \times \text{number of rows of rivets}) \times 100}{\text{Pitch of rivets} \times \text{thickness of plate}}$$

**The Proportions of Riveted-Joints in Soft Steel Plates** recommended by Professor Kennedy in his report to the Institution of Mechanical Engineers are:—In single riveted-joints the shearing resistance of rivet-steel is about 22 tons per square inch. So long as the bearing pressure on the rivets does not exceed 43 tons per square inch, measured on the projected area of the rivets, it does not affect their strength: but pressures of 50 to 55 tons cause the rivets to shear at stresses of from 16 to 18 tons per square inch.

*For Single Riveted Lap-Joints*, the diameter of the rivet-hole should be $2\frac{1}{3}$ times the thickness of the plate and the pitch of the rivets $2\frac{3}{8}$ times the diameter of the rivet-hole, this makes the plate-area 71 per cent. of the rivet area. For any other size of rivet-hole the pitch $p = 0{\cdot}56\frac{d^2}{t} + d$, where $d$ is the diameter of the rivet-hole, and $t$ is the thickness of the steel plate in inches.

*For Double Riveted Lap-Joints*, of any thickness of plate from $\frac{3}{8}$ to $\frac{3}{4}$ inch, with rivets as large as possible:—

| | | |
|---|---|---|
| For 30-ton plate and 24-ton rivets | | $p = 1{\cdot}16\frac{d^2}{t} + d$ |
| „ 28 „ 22 „ | | |
| „ 30 „ 22 „ | | $p = 1{\cdot}06\frac{d^2}{t} + d$ |
| „ 28 „ 24 „ | | $p = 1{\cdot}24\frac{d^2}{t} + d.$ |

NOTE.—As the plate is more affected by time than the rivets, it is advisable to estimate the percentage by which the plates may be weakened by corrosion, &c., before the boiler would be unfit for use at its proper steam pressure, and to add correspondingly to the plate-area. This may be effected by proportioning the joint, not for the actual thickness of the plate, but for a nominal thickness less than the actual by the assumed percentage.

*For Double Riveted Butt-Joints* the maximum strength is obtained by making the pitch $= 4{\cdot}1$ times the diameter of rivet-hole, and the diameter of the rivet-hole $= 1{\cdot}8$ times the thickness of the plate. Prof. Kennedy's rules only refer to joints made in soft steel plates—unannealed—with steel rivets.

Table 104.—Weight of a Square Foot of Sheet-Iron and of Wrought-Iron Boiler Plates, etc.

| Thickness, in inches | $\frac{1}{32}$ | $\frac{1}{16}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{15}{16}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $1\frac{7}{8}$ | 2 | $2\frac{1}{2}$ | 3 | $3\frac{1}{2}$ | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight of a piece twelve inches square, in lbs. | $1\frac{1}{4}$ | $2\frac{1}{2}$ | 5 | $7\frac{1}{2}$ | 10 | $12\frac{1}{2}$ | 15 | $17\frac{1}{2}$ | 20 | $22\frac{1}{2}$ | 25 | $27\frac{1}{2}$ | 30 | $32\frac{1}{2}$ | 35 | $37\frac{1}{2}$ | 40 | 45 | 50 | 55 | 60 | 70 | 75 | 80 | 100 | 120 | 140 | 160 |

**Steel Boiler-Plates** weigh 1·28 lbs. per square foot $\frac{1}{32}$ inch thick, hence the rule to find the weight in lbs. of a steel plate is:—Multiply the length in feet by the breadth in feet, and by 1·28, and multiply the product by the number of $\frac{1}{32}$ds of an inch the plate is thick. For the weight of steel-plates, per square foot, to the new imperial standard wire gauge, see page 291.

Table 105.—Weight of Circular Wrought-Iron Plates.

| Thickness. | Diameter in Inches | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inches. $\frac{1}{4}$ | Weight in lbs. | 8 | $12\frac{1}{2}$ | 18 | $24\frac{1}{2}$ | 32 | 40 | 50 | 60 | 72 | 98 | 128 | 161 | 200 | 240 | 288 | 336 | 392 | 445 | 512 |
| $\frac{5}{16}$ | ,, ,, | 10 | 16 | 23 | 31 | 40 | 50 | 64 | 75 | 92 | 124 | 160 | 200 | 254 | 300 | 368 | 417 | 496 | 554 | 640 |
| $\frac{3}{8}$ | ,, ,, | 12 | 19 | 27 | 37 | 48 | 60 | 75 | 90 | 108 | 147 | 192 | 242 | 300 | 360 | 432 | 504 | 588 | 667 | 766 |
| $\frac{7}{16}$ | ,, ,, | 14 | 22 | 31 | 42 | 56 | 70 | 88 | 103 | 124 | 168 | 224 | 280 | 352 | 412 | 496 | 578 | 672 | 769 | 896 |
| $\frac{1}{2}$ | ,, ,, | 16 | 25 | 36 | 49 | 64 | 81 | 100 | 120 | 144 | 196 | 256 | 322 | 400 | 480 | 576 | 672 | 784 | 890 | 1024 |
| $\frac{5}{8}$ | ,, ,, | 20 | 32 | 46 | 62 | 80 | 100 | 128 | 150 | 184 | 248 | 320 | 400 | 508 | 600 | 736 | 834 | 992 | 1108 | 1280 |
| $\frac{3}{4}$ | ,, ,, | 24 | 38 | 54 | 73 | 96 | 120 | 150 | 180 | 216 | 294 | 384 | 483 | 600 | 720 | 864 | 1008 | 1176 | 1335 | 1536 |
| $\frac{7}{8}$ | ,, ,, | 28 | 44 | 62 | 84 | 112 | 140 | 176 | 206 | 248 | 336 | 448 | 560 | 704 | 824 | 992 | 1170 | 1344 | 1538 | 1792 |
| 1 | ,, ,, | 32 | 50 | 72 | 98 | 128 | 161 | 200 | 240 | 288 | 392 | 512 | 644 | 800 | 960 | 1152 | 1344 | 1568 | 1790 | 2048 |
| $1\frac{1}{4}$ | ,, ,, | 40 | 63 | 90 | 123 | 160 | 201 | 250 | 300 | 360 | 490 | 640 | 805 | 1000 | 1200 | 1440 | 1668 | 1960 | 2216 | 2560 |
| $1\frac{1}{2}$ | ,, ,, | 48 | 75 | 108 | 147 | 192 | 242 | 300 | 360 | 432 | 588 | 768 | 966 | 1200 | 1440 | 1728 | 2016 | 2352 | 2680 | 3172 |

Table 106.—Weight in Lbs. of 1 Dozen Whitworth's Thread Iron Bolts, with Hexagon Heads and Nuts and Round Necks; also the Weight they will safely carry, and the Weight of 1 Dozen Iron Washers.

| Length of Bolt. | Diameter of Bolt, In Inches. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{7}{8}$ | 2 |
| Inches. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| $1\frac{1}{2}$ ... ... | ·51 | 1·3 | 2·6 | 4·8 | 7·4 | 11·8 | 17·3 | | | | | | | | |
| $1\frac{3}{4}$ ... ... | ·55 | 1·4 | 2·7 | 5·1 | 7·8 | 12·4 | 18 | 27 | | | | | | | |
| 2 ... ... | ·61 | 1·6 | 2·9 | 5·3 | 8·2 | 12·9 | 19 | 28 | 34 | | | | | | |
| $2\frac{1}{2}$ ... ... | ·71 | 1·7 | 3·3 | 5·8 | 8·9 | 13·9 | 20 | 30 | 36 | 49 | | | | | |
| 3 ... ... | ·81 | 1·9 | 3·6 | 6·4 | 9·7 | 14·9 | 21 | 32 | 38 | 51 | 63 | | | | |
| $3\frac{1}{2}$ ... ... | ·91 | 2·1 | 3·9 | 6·9 | 10·4 | 15·3 | 23 | 33 | 40 | 54 | 66 | 81 | | | |
| 4 ... ... | 1·02 | 2·3 | 4·3 | 7·4 | 11·2 | 17 | 24 | 35 | 42 | 56 | 69 | 85 | 100 | | |
| $4\frac{1}{2}$ ... ... | 1·12 | 2·5 | 4·6 | 7·8 | 11·9 | 18 | 25 | 37 | 44 | 59 | 72 | 89 | 104 | 130 | |
| 5 ... ... | 1·22 | 2·7 | 5 | 8·5 | 12·6 | 19 | 27 | 38 | 46 | 61 | 75 | 92 | 108 | 134 | 158 |
| $5\frac{1}{2}$ ... ... | 1·32 | 2·9 | 5·3 | 9 | 13·4 | 20 | 28 | 40 | 48 | 63 | 78 | 96 | 112 | 139 | 164 |
| 6 ... ... | 1·4 | 3·1 | 5·7 | 9·5 | 14·1 | 21 | 29 | 42 | 50 | 66 | 81 | 99 | 116 | 146 | 169 |
| 7 ... ... | 1·6 | 3·5 | 6·3 | 10·5 | 15·6 | 23 | 32 | 45 | 55 | 71 | 87 | 106 | 125 | 153 | 179 |
| 8 ... ... | 1·8 | 3·9 | 7 | 11·6 | 17 | 25 | 34 | 48 | 59 | 76 | 92 | 113 | 133 | 162 | 190 |
| 9 ... ... | 2 | 4·4 | 7·7 | 12·6 | 18·6 | 27 | 37 | 52 | 63 | 81 | 98 | 120 | 142 | 172 | 200 |
| 10 ... ... | 2·3 | 4·8 | 8·4 | 13·6 | 20·1 | 29 | 40 | 55 | 67 | 86 | 104 | 127 | 150 | 181 | 212 |
| 11 ... ... | 2·5 | 5·2 | 9·1 | 14·7 | 21·6 | 31 | 43 | 58 | 71 | 91 | 110 | 134 | 157 | 190 | 224 |
| 12 ... ... | 2·7 | 5·6 | 9·8 | 15·7 | 23 | 33 | 46 | 62 | 75 | 94 | 116 | 140 | 166 | 200 | 236 |
| Weight of 12 washers, in lbs. | ·5 | ·6 | ·7 | ·8 | 1 | 1·3 | 2 | 2·5 | 4 | 6 | 8 | 9 | 10 | 13 | 16 |
| Thickness of washer, in inches | $\frac{1}{16}$ | $\frac{1}{16}$ | $\frac{3}{32}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ |
| Diameter of washer, in inches | $\frac{3}{4}$ | 1 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{1}{8}$ | $2\frac{1}{4}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ | 3 | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $3\frac{3}{4}$ | 4 | $4\frac{1}{4}$ |
| Working strength or load the bolt will safely carry, in cwts., if made of good iron | 1 | $2\frac{1}{2}$ | 4 | 8 | 12 | 16 | 24 | 28 | 40 | 45 | 55 | 65 | 75 | 85 | 100 |

**Strength of Bolts.**—The average tensile strength of the iron of which bolts are made is 20 tons per square inch, and the safe working load for bolts not subject to much strain, is 4 tons per square inch of area of cross section, at the bottom of the thread. For moderately tightened bolts, 2 tons per square inch; and for bolts, which, carrying a great strain, are liable to stretch after being severely tightened, such as the bolts of steam-joints, 1 ton per square inch of area of cross section, at the bottom of the thread.

**Foundation Bolts,** having a cotter through one end, should have that end swelled equal to $1\frac{1}{4}$ the diameter of the bar, and the cotter should equal $1\frac{1}{4}$ in depth and $\frac{1}{4}$ in thickness the diameter of the bar. Long bolts or tie-rods with screwed ends, should have the ends swelled, to at least the depth of thread of the screw.

**Joint with Pin,** like Fig. 52.
The diameter of the pin = the diameter of the rod, E.

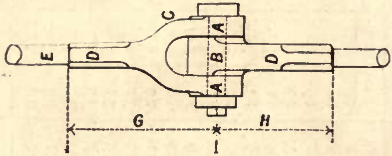


Fig. 52.

Width between the fork, B, = 1·25 diameter of the rod, E.
Width of the jaw of fork, A, = ·75 diameter of the rod, E.
Width of the jaw of fork, C, = ·62 diameter of the rod, E.
Width across cants, D, = 1·2 diameter of the rod, E.
Diameter of the boss of the fork = twice the diameter of the pin.
Diameter of the pin head and washer = 1·62 the diameter of the pin.
Thickness of head of pin and washer = one-half the diameter of the pin.
Centre of pin to end of cant, G, = $4\frac{1}{2}$ times the diameter of the pin.
Centre of pin to end of cant, H, = $3\frac{1}{2}$ times the diameter of the pin.

**Lock-Nuts** should be equal in thickness to half the diameter of the bolt.

**Square Nuts** should have the same width across the flats as hexagon nuts.

In confined spaces, both the head and nut are each made, in thickness, $\frac{5}{8}$ths of the diameter of the bolt. It has been found that a well fitted nut, equal in thickness to $\frac{3}{4}$ths the diameter of the bolt, will not strip before the bolt breaks.

## Table 107.—Size of Whitworth's Standard Hexagon Nuts.

| Size of Nuts. | Diameter of Bottom of Thread. | Width Across Corners. | Width of Nut across the Flats. | | Size of Nut. | Diameter of Bottom of Thread. | Width Across Corners. | Width of Nut across the Flats. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Exact Size. | Nearest Size. | | | | Exact Size. | Nearest Size. |
| Inch. | Inches. | Inches. | Inches. | Inches. | Inch. | Inches. | Inches. | Inches. | Inches. |
| 3/16 | ·134 | ·517 | ·448 | 7/16 and 1/32 | 1 1/4 | 1·067 | 2·365 | 2·048 | 2 1/32 |
| 1/4 | ·186 | ·606 | ·525 | 1/2 and 1/32 | 1 3/8 | 1·161 | 2·557 | 2·215 | 2 3/16 and 1/32 |
| 5/16 | ·241 | ·694 | ·601 | 5/8 | 1 1/2 | 1·286 | 2·786 | 2·413 | 2 7/16 |
| 3/8 | ·295 | ·819 | ·709 | 11/16 and 1/32 | 1 5/8 | 1·369 | 2·974 | 2·576 | 2 9/16 |
| 7/16 | ·346 | ·947 | ·820 | 13/16 | 1 3/4 | 1·494 | 3·184 | 2·758 | 2 3/4 |
| 1/2 | ·393 | 1·061 | ·919 | 15/16 | 1 7/8 | 1·590 | 3·485 | 3·018 | 3 |
| 9/16 | ·456 | 1·167 | 1·011 | 1 1/32 | 2 | 1·715 | 3·636 | 3·149 | 3 1/8 and 1/32 |
| 5/8 | ·508 | 1·271 | 1·101 | 1 1/16 and 1/32 | 2 1/8 | 1·840 | 3·853 | 3·337 | 3 5/16 and 1/32 |
| 11/16 | ·571 | 1·387 | 1·201 | 1 3/16 and 1/32 | 2 1/4 | 1·930 | 4·094 | 3·546 | 3 1/2 and 1/32 |
| 3/4 | ·622 | 1·502 | 1·301 | 1 5/16 | 2 3/8 | 2·055 | 4·33 | 3·75 | 3 3/4 |
| 13/16 | ·684 | 1·605 | 1·39 | 1 3/8 and 1/32 | 2 1/2 | 2·180 | 4·496 | 3·894 | 3 7/8 and 1/32 |
| 7/8 | ·733 | 1·707 | 1·479 | 1 7/16 and 1/32 | 2 5/8 | 2·305 | 4·675 | 4·049 | 4 1/16 |
| 15/16 | ·795 | 1·8 | 1·574 | 1 9/16 | 2 3/4 | 2·384 | 4·827 | 4·181 | 4 3/16 |
| 1 | ·840 | 1·928 | 1·67 | 1 11/16 | 2 7/8 | 2·509 | 5·017 | 4·346 | 4 5/16 and 1/32 |
| 1 1/8 | ·942 | 2·148 | 1·86 | 1 7/8 | 3 | 2·634 | 5·231 | 4·531 | 4 1/2 and 1/32 |

Note.—Thickness of Nut equal to the Diameter of the Bolt.

## Table 108.—Weights of Gas Tubes and Fittings.

| Size. | Tubes. | | | | | | | Fittings. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weight per 100 Feet. | | | Weight per 1000 Feet. | | | | Weight of 10 Elbows. | | Weight of 10 Tees. | | Weight of 10 Crosses. | |
| | cwts. | qrs. | lbs. | tons | cwts. | qrs. | lbs. | lbs. | ozs. | lbs. | ozs. | lbs. | ozs. |
| 1/8 | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 8 |
| 1/4 | 0 | 1 | 14 | 0 | 3 | 3 | 0 | 1 | 7 | 1 | 8 | 1 | 14 |
| 3/8 | 0 | 2 | 6 | 0 | 5 | 2 | 4 | 1 | 13 | 2 | 4 | 2 | 3 |
| 1/2 | 0 | 3 | 6 | 0 | 8 | 0 | 4 | 2 | 15 | 3 | 0 | 3 | 4 |
| 3/4 | 1 | 0 | 22 | 0 | 11 | 3 | 24 | 4 | 6 | 5 | 4 | 5 | 11 |
| 1 | 1 | 3 | 0 | 0 | 17 | 2 | 0 | 6 | 4 | 7 | 10 | 9 | 2 |
| 1 1/4 | 2 | 1 | 11 | 1 | 3 | 1 | 26 | 10 | 10 | 12 | 15 | 14 | 11 |
| 1 1/2 | 2 | 3 | 7 | 1 | 8 | 0 | 14 | 15 | 8 | 16 | 7 | 18 | 10 |
| 1 3/4 | 3 | 0 | 12 | 1 | 11 | 0 | 8 | 15 | 12 | 20 | 0 | 21 | 4 |
| 2 | 3 | 3 | 21 | 1 | 19 | 1 | 14 | 22 | 6 | 27 | 0 | 31 | 4 |
| 2 1/4 | 4 | 0 | 26 | 2 | 2 | 1 | 8 | 30 | 2 | 32 | 8 | 41 | 4 |
| 2 1/2 | 5 | 0 | 6 | 2 | 10 | 2 | 4 | 46 | 2 | 50 | 15 | 51 | 4 |
| 2 3/4 | 5 | 1 | 19 | 2 | 14 | 0 | 22 | 55 | 10 | 68 | 8 | 80 | 10 |
| 3 | 6 | 0 | 20 | 3 | 1 | 3 | 4 | 73 | 8 | 85 | 5 | 88 | 12 |
| 3 1/2 | 7 | 1 | 14 | 3 | 13 | 3 | 0 | 101 | 0 | 121 | 0 | 129 | 0 |
| 4 | 8 | 2 | 0 | 4 | 5 | 0 | 0 | 126 | 0 | 144 | 0 | 158 | 0 |

Table 109.—Weight of Lead and Composition Gas Pipes.

| Diameter Inside. | Light. | | Heavy. | |
|---|---|---|---|---|
| | Weight per Yard. | Lengths of Bundles usually Manufactured. | Weight per Yard. | Lengths of Bundles usually Manufactured. |
| Inches. | lbs. ozs. | yards. | lbs. ozs. | yards. |
| $\frac{1}{4}$ | 0 11$\frac{1}{2}$ | 80 | 0 15 | 67 |
| $\frac{3}{8}$ | 1 2 | 60 | 1 6$\frac{1}{2}$ | 46 |
| $\frac{1}{2}$ | 2 0 | 32 | 2 10 | 29 |
| $\frac{3}{4}$ | 3 3 | 23 | 3 12 | 19 |
| 1 | 4 8 | 26 | 6 0 | 20 |

Table 110.—Weight per Yard, of Block-tin Tubes.

| Bore. | ozs. | Bore. | lbs. ozs. | Bore. | lbs. ozs. |
|---|---|---|---|---|---|
| $\frac{1}{4}$ inch... ... | 8 | $\frac{1}{2}$ inch... ... | 1 1 | $\frac{3}{4}$ inch... ... | 1 14 |
| $\frac{3}{8}$ „ ... ... | 11 | $\frac{5}{8}$ „ ... ... | 1 7 | 1 „ ... ... | 2 15 |

Table 111.—Weight of Galvanized Corrugated-Iron Sheets.

| Number of Gauge. | Weight per Square, of 100 feet. | | | Size of Sheet. |
|---|---|---|---|---|
| | Old Gauge. | B.G. Sheet Gauge. | New Standard Wire-gauge. | |
| | cwts. qrs. lbs. | cwts. qrs. lbs. | cwts. qrs. lbs. | |
| 16 | 3 0 14 | 3 0 1 | 3 0 9 | 6 feet × 2 feet, 2 inches, with five 5-inch corrugations. |
| 18 | 2 2 11 | 2 2 9 | 2 2 0 | |
| 20 | 1 3 6 | 1 3 2 | 1 2 14 | 6 feet × 2 feet 2 inches, with eight 3-inch corrugations. |
| 22 | 1 2 6 | 1 2 7 | 1 1 18 | |
| 24 | 1 1 0 | 1 0 26 | 1 0 12 | |
| 26 | 0 3 19 | 0 3 17 | 0 3 9 | |

Table 112.—Weight of Galvanized Corrugated Iron Sheets.

| Number of Gauge. | 16 | 18 | 20 | 22 | 24 | 26 | Gauge. |
|---|---|---|---|---|---|---|---|
| Weight to the old gauge, lbs. . . . . | 52 | 34 | 25 | 21 | 16$\frac{1}{2}$ | 12$\frac{1}{2}$ | Weight in lbs. of each sheet, size 72 in. × 26 in. |
| Weight to B.G. gauge, lbs. | 50 | 33$\frac{3}{4}$ | 24$\frac{1}{2}$ | 21$\frac{1}{8}$ | 16$\frac{1}{4}$ | 12$\frac{1}{4}$ | |
| Weight to the new standard wire-gauge, lbs. . . . . | 51$\frac{1}{4}$ | 32$\frac{1}{2}$ | 22$\frac{1}{2}$ | 19 | 14$\frac{1}{2}$ | 11$\frac{1}{4}$ | |
| Square feet per ton, old gauge . . . . | 640 | 770 | 1080 | 1300 | 1680 | 2170 | Square feet per ton. |
| Square feet per ton, B. G. gauge . . . | 665 | 776 | 1132 | 1280 | 1624 | 2218 | |
| Square feet per ton, standard wire-gauge | 650 | 800 | 1231 | 1418 | 1807 | 2409 | |

Table 113.—Weight of 1 Foot in Length of Round and Square, Wrought-Iron and Steel Bars.

| Size of Bar, in Inches . . . | 1/16 | 1/8 | 3/16 | 1/4 | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 11/16 | 3/4 | 13/16 | 7/8 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Weight of round iron . | ·01 | ·042 | ·093 | ·168 | ·26 | ·36 | ·50 | ·65 | ·83 | 1·03 | 1·25 | 1·47 | 1·74 | 2·00 | 2·63 |
| Weight of round steel . | ·011 | ·043 | ·095 | ·17 | ·28 | ·38 | ·52 | ·68 | ·86 | 1·05 | 1·28 | 1·51 | 1·77 | 2·06 | 2·68 |
| Weight of square iron . | ·0125 | ·053 | ·118 | ·21 | ·33 | ·47 | ·64 | ·84 | 1·08 | 1·31 | 1·6 | 1·9 | 2·23 | 2·58 | 3·35 |
| Weight of square steel . | ·014 | ·056 | ·121 | ·23 | ·35 | ·50 | ·67 | ·87 | 1·12 | 1·35 | 1·64 | 1·95 | 2·27 | 2·65 | 3·45 |

| Size of Bar, in Inches . . . | 1 1/8 | 1 1/4 | 1 3/8 | 1 1/2 | 1 5/8 | 1 3/4 | 1 7/8 | 2 | 2 1/8 | 2 1/4 | 2 3/8 | 2 1/2 | 2 5/8 | 2 3/4 | 2 7/8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Weight of round iron . | 3·31 | 4·09 | 5· | 5·89 | 6·91 | 8·02 | 9·21 | 10·5 | 11·8 | 13·3 | 14·8 | 16·5 | 18·1 | 19·8 | 21·6 |
| Weight of round steel . | 3·37 | 4·18 | 5·12 | 6·06 | 7·12 | 8·18 | 9·43 | 10·7 | 12·1 | 13·6 | 15·1 | 16·7 | 18·5 | 20·2 | 22· |
| Weight of square iron . | 4·25 | 5·25 | 6·33 | 7·5 | 8·8 | 10·2 | 11·7 | 13·33 | 15·1 | 16·9 | 18·8 | 20·8 | 23· | 25·2 | 27·6 |
| Weight of square steel . | 4·35 | 5·36 | 6·48 | 7·7 | 8·94 | 10·47 | 11·96 | 13·68 | 15·5 | 17·3 | 19·27 | 21·3 | 23·6 | 25·9 | 28·3 |

| Size of Bar, in Inches . . . | 3 | 3 1/8 | 3 1/4 | 3 3/8 | 3 1/2 | 3 5/8 | 3 3/4 | 3 7/8 | 4 | 4 1/8 | 4 1/4 | 4 3/8 | 4 1/2 | 4 3/4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Weight of round iron . | 23·6 | 25·6 | 27·7 | 30· | 32·2 | 34·5 | 37· | 39·3 | 42· | 45 | 47 | 50 | 53·2 | 59·5 | 66· |
| Weight of round steel . | 24·1 | 26·3 | 28·3 | 30·6 | 32·8 | 35·2 | 37·7 | 40· | 42·7 | 47 | 49 | 52 | 54·7 | 60·5 | 67· |
| Weight of square iron . | 30· | 32·6 | 35·2 | 38· | 40·8 | 44· | 46·9 | 50· | 53·3 | 56 | 61 | 64 | 67·5 | 75·2 | 83·3 |
| Weight of square steel . | 30·8 | 33·4 | 36·1 | 38·9 | 41·7 | 45· | 47·9 | 51·1 | 54·5 | 58 | 64 | 67 | 69· | 76·9 | 85· |

| Size of Bar, in Inches . . . | 5 1/4 | 5 1/2 | 5 3/4 | 6 | 6 1/4 | 6 1/2 | 7 | 7 1/2 | 8 | 8 1/2 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Weight of round iron . | 72·6 | 80· | 87· | 95· | 102 | 111 | 130 | 148 | 168 | 190 | 213 | 264 | 319 | 380 | 445 |
| Weight of round steel . | 73·7 | 81·5 | 88·7 | 96·7 | 104 | 113 | 132 | 151 | 171 | 194 | 217 | 267 | 325 | 387 | 453 |
| Weight of square iron . | 92· | 101· | 111· | 120· | 131 | 141 | 164 | 190 | 215 | 243 | 272 | 336 | 407 | 485 | 560 |
| Weight of square steel . | 93·9 | 103· | 114· | 124· | 135 | 146 | 169 | 196 | 222 | 250 | 284 | 348 | 420 | 498 | 575 |

Table 114.—Weight of 1 Foot in Length of Flat Wrought-Iron and Steel Bars, Hoop Iron and Chisel Steel.

| Flat Bars, Size in Inches | $1 \times \frac{1}{4}$ | $1 \times \frac{3}{8}$ | $1\frac{1}{4} \times \frac{3}{8}$ | $1\frac{1}{4} \times \frac{1}{2}$ | $1\frac{1}{2} \times \frac{3}{8}$ | $1\frac{1}{2} \times \frac{1}{2}$ | $1\frac{3}{4} \times \frac{3}{8}$ | $1\frac{3}{4} \times \frac{1}{2}$ | $2 \times \frac{1}{2}$ | $2 \times \frac{5}{8}$ | $2\frac{1}{4} \times \frac{1}{2}$ | $2\frac{1}{4} \times \frac{3}{4}$ | $2\frac{1}{2} \times \frac{1}{2}$ | $2\frac{1}{2} \times \frac{3}{4}$ | $2\frac{3}{4} \times \frac{1}{2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Weight of flat iron | ·84 | 1·3 | 1·58 | 2·1 | 1·9 | 2·5 | 2·2 | 2·95 | 3·35 | 4·2 | 3·8 | 5·7 | 4·2 | 6·3 | 4·6 |
| Weight of flat steel | ·86 | 1·33 | 1·62 | 2·15 | 1·94 | 2·56 | 2·25 | 2·99 | 3·43 | 4·28 | 3·85 | 5·78 | 4·28 | 6·40 | 4·70 |

| Flat Bars, Size in Inches | $2\frac{3}{4} \times \frac{3}{4}$ | $3 \times \frac{1}{2}$ | $3 \times \frac{3}{4}$ | $3\frac{1}{2} \times \frac{3}{4}$ | $3\frac{1}{2} \times 1$ | $4 \times \frac{3}{4}$ | $4 \times 1\frac{1}{4}$ | $4\frac{1}{2} \times \frac{3}{4}$ | $4\frac{1}{2} \times 1\frac{1}{4}$ | $5 \times \frac{3}{4}$ | $5 \times 1\frac{1}{4}$ | $6 \times 1$ | $6 \times 1\frac{1}{2}$ | $7 \times 1\frac{1}{2}$ | $7 \times 3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Weight of flat iron | 6·9 | 5· | 7·5 | 8·8 | 11·8 | 10·1 | 16·7 | 11·4 | 19·0 | 12·6 | 21· | 20·2 | 30·3 | 35 | 70 |
| Weight of flat steel | 7·1 | 5·16 | 7·7 | 9·0 | 11·96 | 10·28 | 17·1 | 11·58 | 19·2 | 12·9 | 21·3 | 20·5 | 30·7 | 36 | 72 |

| Hoop Iron. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Width in inches | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 | $2\frac{1}{4}$ | $2\frac{1}{2}$ | 3 | $3\frac{1}{2}$ | 4 |
| Thickness, number of gauge | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 13 | 12 | 11 | 9 | 7 |
| Weight to the **B.G.** hoop gauge, lbs. | ·092 | ·125 | ·166 | ·190 | ·250 | ·350 | ·473 | ·621 | ·697 | ·882 | 1·10 | 1·81 | 2·52 |
| Weight to the standard wire-gauge, lbs. | ·085 | ·114 | ·161 | ·192 | ·256 | ·360 | ·482 | ·646 | ·727 | ·930 | 1·24 | 1·87 | 2·51 |

| Chisel Steel. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hexagon. Size across flats, in inches | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ |
| Weight, in lbs. | ·75 | 1·2 | 1·7 | 2·3 | 3· | 3·8 | 4·7 |
| Flat oval section. Size, in inches | $\frac{3}{4} \times \frac{3}{8}$ = ·9 lbs.: $1 \times \frac{1}{2}$ = 1·6 lbs.: $1\frac{1}{4} \times \frac{5}{8}$ = 2·45 lbs. | | | | | | |

Table 115.—Weight of 100 Feet in Length of Iron and Steel Wire.

| Thickness by the New Standard W. G. | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight of 100 feet in length of iron wire | ·40 | ·60 | ·80 | 1·06 | 1·33 | 1·66 | 2·16 | 2·8 | 3·47 | 4·23 | 5·34 | 6·60 | 8·0 | 9·5 | 11·6 | 13·9 | 16·4 | 19·7 | 23·2 |
| Weight of 100 feet in length of steel wire | ·41 | ·61 | ·82 | 1·08 | 1·40 | 1·69 | 2·19 | 2·11 | 3·51 | 4·28 | 5·40 | 6·67 | 8·9 | 9·6 | 11·7 | 14·0 | 16·5 | 19·9 | 23·5 |

Table 116.—WEIGHT OF 12 INCHES SQUARE OF ROLLED WROUGHT-IRON PLATES AND SHEET-IRON, THE THICKNESS BEING MEASURED BY THE SHEET GAUGE B. G. 1884, AND ALSO BY THE NEW IMPERIAL STANDARD WIRE-GAUGE.

| Number of Gauge. | Weight per Square Foot to the Sheet and Hoop-Iron **B. G.** Gauge. | | Weight per Square Foot to the new Imperial Standard Wire-Gauge. | | Number of Gauge. | Weight per Square Foot to the Sheet and Hoop-Iron **B. G.** Gauge. | | Weight per Square Foot to the new Imperial Standard Wire-Gauge. | |
|---|---|---|---|---|---|---|---|---|---|
| | lbs. | Thickness. Inch. | lbs. | Thickness. Inch. | | lbs. | Thickness. Inch. | lbs. | Thickness. Inch. |
| 7/0 | 26·67 | ·6666 | 20·00 | ·500 | 22 | 1·25 | ·0312 | 1·12 | ·028 |
| 6/0 | 25·00 | ·6250 | 18·56 | ·464 | 23 | 1·11 | ·0278 | ·96 | ·024 |
| 5/0 | 23·54 | ·5883 | 17·28 | ·432 | 24 | ·99 | ·0247 | ·88 | ·022 |
| 4/0 | 21·67 | ·5416 | 16·00 | ·400 | 25 | ·88 | ·0220 | ·80 | ·020 |
| 3/0 | 20·00 | ·5000 | 14·88 | ·372 | 26 | ·785 | ·0196 | ·72 | ·018 |
| 2/0 | 17·8 | ·4452 | 13·92 | ·348 | 27 | ·700 | ·0174 | ·65 | ·0164 |
| 1/0 | 15·8 | ·3964 | ... | ... | 28 | ·625 | ·0156 | ·59 | ·0148 |
| 0 | ... | ... | 13·0 | ·324 | 29 | ·557 | ·0139 | ·54 | ·0136 |
| 1 | 14·1 | ·3532 | 12·0 | ·300 | 30 | ·493 | ·0123 | ·495 | ·0124 |
| 2 | 12·6 | ·3147 | 11·04 | ·276 | 31 | ·440 | ·0110 | ·464 | ·0116 |
| 3 | 11·2 | ·2804 | 10·10 | ·252 | 32 | ·392 | ·0098 | ·432 | ·0108 |
| 4 | 10·0 | ·2500 | 9·25 | ·232 | 33 | ·348 | ·0087 | ·400 | ·0100 |
| 5 | 8·9 | ·2225 | 8·50 | ·212 | 34 | ·308 | ·0077 | ·368 | ·0092 |
| 6 | 7·95 | ·1981 | 7·70 | ·192 | 35 | ·276 | ·0069 | ·336 | ·0084 |
| 7 | 7·05 | ·1764 | 7·05 | ·176 | 36 | ·245 | ·0061 | ·304 | ·0076 |
| 8 | 6·30 | ·1570 | 6·40 | ·160 | 37 | ·216 | ·0054 | ·272 | ·0068 |
| 9 | 5·57 | ·1398 | 5·75 | ·144 | 38 | ·192 | ·0048 | ·240 | ·0060 |
| 10 | 5·00 | ·1250 | 5·10 | ·128 | 39 | ·172 | ·0043 | ·208 | ·0052 |
| 11 | 4·44 | ·1113 | 4·64 | ·116 | 40 | ·154 | ·00386 | ·192 | ·0048 |
| 12 | 3·87 | ·0991 | 4·16 | ·104 | 41 | ·138 | ·00343 | ·176 | ·0044 |
| 13 | 3·53 | ·0882 | 3·68 | ·092 | 42 | ·123 | ·00306 | ·160 | ·0040 |
| 14 | 3·14 | ·0785 | 3·20 | ·080 | 43 | ·109 | ·00272 | ·144 | ·0036 |
| 15 | 2·76 | ·0699 | 2·87 | ·072 | 44 | ·097 | ·00242 | ·128 | ·0032 |
| 16 | 2·50 | ·0625 | 2·55 | ·064 | 45 | ·086 | ·00215 | ·112 | ·0028 |
| 17 | 2·22 | ·0556 | 2·30 | ·056 | 46 | ·077 | ·00192 | ·096 | ·0024 |
| 18 | 1·97 | ·0495 | 1·91 | ·048 | 47 | ·068 | ·00170 | ·080 | ·0020 |
| 19 | 1·76 | ·0440 | 1·60 | ·040 | 48 | ·061 | ·00152 | ·064 | ·0016 |
| 20 | 1·57 | ·0392 | 1·44 | ·036 | 49 | ·054 | ·00135 | ·048 | ·0012 |
| 21 | 1·40 | ·0349 | 1·28 | ·032 | 50 | ·048 | ·00120 | ·040 | ·0010 |

**The Sheet and Hoop-Iron Gauge, B. G.,** was issued by the South Staffordshire Ironmasters' Association for the use of sheet and hoop-iron makers, March 1, 1884, and is adopted by the trade. It is important that in all transactions in sheet and hoop-iron, the initial letters **B. G.** should appear, to distinguish the Sheet and Hoop-Iron Gauge from the Imperial Standard Wire-Gauge.

**The Weights of Iron-Sheets and Plates** given in the above table are those rolled to the various gauges by Messrs. E. P. & W. Baldwin, Wilden Ironworks, near Stourport, to whom the Author is indebted for the information.

Table 117.—Weight of 12 Inches Square of Rolled Sheet-Copper and Sheet-Brass in Lbs. and Ounces, and also in Lbs. and Decimal Parts; the Thickness being measured by the new Imperial Standard Wire-Gauge.

| Thickness by Number of the New Standard Wire-Gauge. | Sheet-Copper. | | | Sheet-Brass. | | | Thickness by Number of the new Standard Wire-Gauge. | Sheet-Copper. | Sheet-Brass. |
|---|---|---|---|---|---|---|---|---|---|
| | Weight in lbs. and ounces. | | Weight in lbs. and Decimal parts of a lb. | Weight in lbs. and ounces. | | Weight in lbs. and Decimal parts of a lb. | | Weight in ounces and Decimal parts of an ounce. | Weight in ounces and Decimal parts of an ounce. |
| | lbs. | ozs. | lbs. | lbs. | ozs. | lbs. | | Ounces. | Ounces. |
| 7/0 | 23 | 4 | 23·250 | 21 | 9 | 21·57 | 25 | 14·93 | 13·74 |
| 6/0 | 21 | 9¼ | 21·578 | 19 | 15½ | 19·97 | 26 | 13·03 | 12·10 |
| 5/0 | 20 | 1¼ | 20·078 | 18 | 9½ | 18·59 | 27 | 12·02 | 11·16 |
| 4/0 | 18 | 9½ | 18·594 | 17 | 3½ | 17·22 | 28 | 11·00 | 10·12 |
| 3/0 | 17 | 4½ | 17·282 | 16 | 0¼ | 16·01 | 29 | 10·01 | 9·28 |
| 2/0 | 16 | 3 | 16·188 | 14 | 15¾ | 14·98 | 30 | 9·02 | 8·30 |
| 0 | 15 | 1 | 15·063 | 13 | 15½ | 13·95 | 31 | 8·63 | 7·94 |
| 1 | 13 | 15¼ | 13·954 | 12 | 15 | 12·92 | 32 | 8·03 | 7·39 |
| 2 | 12 | 13¼ | 12·828 | 11 | 14 | 11·87 | 33 | 7·44 | 5·36 |
| 3 | 11 | 11½ | 11·719 | 10 | 13½ | 10·84 | 34 | 6·84 | 6·30 |
| 4 | 10 | 12½ | 10·782 | 10 | 0 | 10·00 | 35 | 6·24 | 5·75 |
| 5 | 9 | 13¾ | 9·860 | 9 | 2 | 9·12 | 36 | 5·65 | 5·21 |
| 6 | 8 | 14½ | 8·907 | 8 | 4¼ | 8·26 | 37 | 5·05 | 4·65 |
| 7 | 8 | 3 | 8·188 | 7 | 9¼ | 7·57 | 38 | 4·46 | 4·10 |
| 8 | 7 | 7 | 7·438 | 6 | 14¾ | 6·88 | 39 | 3·86 | 3·56 |
| 9 | 6 | 11 | 6·688 | 6 | 3½ | 6·21 | 40 | 3·57 | 3·29 |
| 10 | 5 | 15¼ | 5·954 | 5 | 8¼ | 5·51 | 41 | 3·27 | 3·10 |
| 11 | 5 | 6¼ | 5·391 | 5 | 0 | 5·00 | 42 | 2·97 | 2·73 |
| 12 | 4 | 13¼ | 4·828 | 4 | 7¾ | 4·48 | 43 | 2·67 | 2·46 |
| 13 | 4 | 4½ | 4·282 | 3 | 15½ | 3·96 | 44 | 2·38 | 2·19 |
| 14 | 3 | 11½ | 3·719 | 3 | 7 | 3·44 | 45 | 2·08 | 1·92 |
| 15 | 3 | 5½ | 3·344 | 3 | 1¾ | 3·10 | 46 | 1·78 | 1·64 |
| 16 | 3 | 0 | 3·000 | 2 | 12¼ | 2·76 | 47 | 1·48 | 1·37 |
| 17 | 2 | 9½ | 2·594 | 2 | 6¾ | 2·41 | 48 | 1·19 | 1·10 |
| 18 | 2 | 4 | 2·250 | 2 | 1¼ | 2·07 | 49 | 0·89 | 0·82 |
| 19 | 1 | 13¾ | 1·860 | 1 | 11¾ | 1·72 | 50 | 0·74 | 0·68 |
| 20 | 1 | 10¾ | 1·672 | 1 | 8¾ | 1·55 | | | |
| 21 | 1 | 7¾ | 1·485 | 1 | 6¼ | 1·38 | | | |
| 22 | 1 | 4¾ | 1·297 | 1 | 3½ | 1·21 | | | |
| 23 | 1 | 1¾ | 1·110 | 1 | 0¾ | 1·04 | | | |
| 24 | 1 | 0⅜ | 1·024 | 0 | 15¼ | 0·95 | | | |

**The Weights of Copper Sheets** per square foot, given in the above Table, are those rolled to the new Imperial Standard Wire-Gauge, by Messrs. Vivian & Sons, Hafod Copper Works, Swansea, to whom the Author is indebted for the information. The equivalents in decimal parts of an inch of the New Imperial Standard Wire-Gauge are given at page 331.

Table 118.—Weight of 12 Inches Square of Bessemer Steel, and Rolled Steel Sheets, and Gun Metal Plates; the Thickness being measured by the New Imperial Standard Wire-Gauge.

| Thickness by Number of the New Standard W. G.* | Weight in lbs. | | | Thickness by Number of the New Standard W. G.* | Weight in lbs. | | |
|---|---|---|---|---|---|---|---|
| | Bessemer Steel. | Rolled Steel. | Gun Metal. | | Bessemer Steel. | Rolled Steel. | Gun Metal. |
| 7/0 | 20·50 | 20·40 | 22·00 | 11 | 4·76 | 4·74 | 5·11 |
| 6/0 | 19·03 | 18·94 | 20·42 | 12 | 4·27 | 4·25 | 4·58 |
| 5/0 | 18·72 | 17·63 | 19·00 | 13 | 3·78 | 3·76 | 4·05 |
| 4/0 | 16·40 | 16·32 | 17·60 | 14 | 3·29 | 3·27 | 3·52 |
| 3/0 | 15·25 | 15·18 | 16·37 | 15 | 2·96 | 2·94 | 3·17 |
| 2/0 | 14·27 | 14·20 | 15·32 | 16 | 2·63 | 2·61 | 2·82 |
| 0 | 13·29 | 13·22 | 14·26 | 17 | 2·30 | 2·28 | 2·47 |
| 1 | 12·30 | 12·24 | 13·20 | 18 | 1·97 | 1·96 | 2·12 |
| 2 | 11·32 | 11·27 | 12·15 | 19 | 1·65 | 1·64 | 1·76 |
| 3 | 10·34 | 10·28 | 11·09 | 20 | 1·48 | 1·47 | 1·59 |
| 4 | 9·52 | 9·47 | 10·21 | 21 | 1·32 | 1·31 | 1·41 |
| 5 | 8·70 | 8·65 | 9·33 | 22 | 1·15 | 1·14 | 1·24 |
| 6 | 7·88 | 7·84 | 8·49 | 23 | ·99 | ·98 | 1·06 |
| 7 | 7·22 | 7·18 | 7·75 | 24 | ·91 | ·90 | ·97 |
| 8 | 6·56 | 6·53 | 7·04 | 25 | ·82 | ·81 | ·88 |
| 9 | 5·91 | 5·88 | 6·34 | 26 | ·74 | ·73 | ·79 |
| 10 | 5·25 | 5·23 | 5·64 | 27 | ·68 | ·67 | ·72 |

Table 119.—Weight of 12 Inches Square of Rolled White Metal, Lead, and Zinc Sheets; the Thickness being measured by the New Imperial Standard Wire-Gauge.

| Thickness by Number of the New Standard W. G.* | Weight in lbs. | | | Thickness by Number of the New Standard W. G.* | Weight in lbs. | | |
|---|---|---|---|---|---|---|---|
| | White Metal. | Zinc. | Lead. | | White Metal. | Zinc. | Lead. |
| 7/0 | 19·50 | 18·50 | 29·50 | 11 | 4·52 | 4·30 | 6·85 |
| 6/0 | 18·01 | 17·17 | 27·38 | 12 | 4·06 | 3·85 | 6·14 |
| 5/0 | 16·85 | 16·00 | 25·49 | 13 | 3·59 | 3·41 | 5·43 |
| 4/0 | 15·60 | 14·80 | 23·60 | 14 | 3·12 | 2·96 | 4·73 |
| 3/0 | 14·51 | 13·77 | 21·95 | 15 | 2·81 | 2·67 | 4·25 |
| 2/0 | 13·58 | 12·88 | 20·54 | 16 | 2·50 | 2·37 | 3·78 |
| 0 | 12·64 | 12·00 | 19·11 | 17 | 2·19 | 2·08 | 3·31 |
| 1 | 11·70 | 11·10 | 17·70 | 18 | 1·88 | 1·78 | 2·84 |
| 2 | 10·77 | 10·22 | 16·29 | 19 | 1·56 | 1·48 | 2·37 |
| 3 | 9·83 | 9·33 | 14·87 | 20 | 1·41 | 1·34 | 2·13 |
| 4 | 9·05 | 8·59 | 13·69 | 21 | 1·25 | 1·19 | 1·89 |
| 5 | 8·27 | 7·85 | 12·51 | 22 | 1·09 | 1·04 | 1·66 |
| 6 | 7·49 | 7·11 | 11·33 | 23 | ·94 | ·89 | 1·42 |
| 7 | 6·87 | 6·52 | 10·39 | 24 | ·86 | ·82 | 1·30 |
| 8 | 6·24 | 5·93 | 9·45 | 25 | ·78 | ·74 | 1·18 |
| 9 | 5·62 | 5·33 | 8·50 | 26 | ·71 | ·67 | 1·07 |
| 10 | 5·00 | 4·74 | 7·56 | 27 | ·64 | ·61 | ·97 |

* For the equivalents in decimal parts of an inch of the numbers of the wire-gauge, see page 331.

Table 120.—Weight of 12 Inches Square of Various Metals.

| Thickness. | Wrought Iron. | Cast Iron. | Steel. | Gun-Metal. | Brass. | Copper. | Tin. | Zinc. | Lead. |
|---|---|---|---|---|---|---|---|---|---|
| Inch. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| $\frac{1}{16}$ | 2·50 | 2·34 | 2·56 | 2·75 | 2·69 | 2·87 | 2·37 | 2·25 | 3·68 |
| $\frac{1}{8}$ | 5· | 4·69 | 5·12 | 5·5 | 5·38 | 5·75 | 4·75 | 4·5 | 7·37 |
| $\frac{3}{16}$ | 7·50 | 7·03 | 7·68 | 8·25 | 8·07 | 8·62 | 7·12 | 6·75 | 11·05 |
| $\frac{1}{4}$ | 10· | 9·38 | 10·25 | 11· | 10·75 | 11·5 | 9·5 | 9· | 14·75 |
| $\frac{5}{16}$ | 12·5 | 11·72 | 12·81 | 13·75 | 13·45 | 14·37 | 11·87 | 11·25 | 18·42 |
| $\frac{3}{8}$ | 15· | 14·06 | 15·36 | 16·50 | 16·14 | 17·24 | 14·24 | 13·50 | 22·10 |
| $\frac{7}{16}$ | 17·5 | 16·41 | 17·93 | 19·25 | 18·82 | 20·12 | 16·17 | 15·75 | 25·80 |
| $\frac{1}{2}$ | 20· | 18·75 | 20·5 | 22· | 21·5 | 23· | 19· | 18· | 29·5 |
| $\frac{9}{16}$ | 22·5 | 21·10 | 23·06 | 24·75 | 24·20 | 25·87 | 21·37 | 20·25 | 33·17 |
| $\frac{5}{8}$ | 25· | 23·44 | 25·62 | 27·50 | 26·90 | 28·74 | 23·74 | 22·50 | 36·84 |
| $\frac{11}{16}$ | 27·5 | 25·79 | 28·18 | 30·25 | 29·58 | 31·62 | 26·12 | 24·75 | 40·54 |
| $\frac{3}{4}$ | 30· | 28·12 | 30·72 | 33·00 | 32·28 | 34·48 | 28·48 | 27· | 44·20 |
| $\frac{13}{16}$ | 32·5 | 30·48 | 33·28 | 35·75 | 34·95 | 37·37 | 30·87 | 29·25 | 47·92 |
| $\frac{7}{8}$ | 35· | 32·82 | 35·86 | 38·50 | 37·64 | 40·24 | 32·34 | 31·5 | 51·6 |
| $\frac{15}{16}$ | 37·5 | 35·16 | 38·43 | 41·25 | 40·32 | 43·12 | 35·61 | 33·75 | 55·36 |
| 1 | 40· | 37·5 | 41· | 44· | 43· | 46· | 38· | 36· | 59· |
| $1\frac{1}{16}$ | 42·5 | 39·84 | 43·56 | 46·75 | 46·69 | 48·87 | 40·37 | 38·25 | 62·68 |
| $1\frac{1}{8}$ | 45· | 42·19 | 46·12 | 49·50 | 48·38 | 51·75 | 42·75 | 40·5 | 66·37 |
| $1\frac{3}{16}$ | 47·5 | 44·53 | 48·68 | 52·25 | 51·07 | 54·62 | 45·12 | 42·75 | 70·05 |
| $1\frac{1}{4}$ | 50· | 46·88 | 51·25 | 55· | 53·80 | 57·48 | 47·48 | 45· | 73·75 |
| $1\frac{5}{16}$ | 52·5 | 49·22 | 53·81 | 57·75 | 56·45 | 60·37 | 49·87 | 47·25 | 77·42 |
| $1\frac{3}{8}$ | 55· | 51·56 | 56·36 | 60·50 | 59·14 | 63·24 | 52·24 | 49·50 | 81·10 |
| $1\frac{7}{16}$ | 57·5 | 53·91 | 58·93 | 63·25 | 61·82 | 66·12 | 54·17 | 51·75 | 84·80 |
| $1\frac{1}{2}$ | 60· | 56·24 | 61·5 | 66· | 64·56 | 68·96 | 56·96 | 54· | 88·40 |
| $1\frac{5}{8}$ | 65· | 60·94 | 66·62 | 71·50 | 69·90 | 74·74 | 61·74 | 58·50 | 95·84 |
| $1\frac{3}{4}$ | 70· | 65·64 | 71·28 | 77· | 75·28 | 80·48 | 64·34 | 63· | 102·12 |
| $1\frac{7}{8}$ | 75· | 70·32 | 76·86 | 82·5 | 80·64 | 86·24 | 71·22 | 67·5 | 110·72 |
| 2 | 80· | 75·00 | 82· | 88· | 86· | 92· | 76· | 72· | 118· |
| $2\frac{1}{8}$ | 85· | 79·68 | 87·12 | 93·5 | 93·38 | 97·74 | 80·74 | 77·5 | 125·36 |
| $2\frac{1}{4}$ | 90· | 84·38 | 92·25 | 99· | 96·76 | 103·50 | 85·50 | 81· | 132·74 |
| $2\frac{3}{8}$ | 95· | 89·06 | 97·36 | 104·5 | 102·14 | 109·24 | 90·24 | 85·5 | 140·10 |
| $2\frac{1}{2}$ | 100· | 93·76 | 102·5 | 110· | 107·60 | 114·96 | 94·96 | 90· | 147·5 |
| $2\frac{5}{8}$ | 105· | 98·44 | 107·62 | 115·5 | 112·90 | 120·74 | 99·74 | 95·5 | 154·84 |
| $2\frac{3}{4}$ | 110· | 103·12 | 112·72 | 121· | 118·28 | 126·48 | 104·48 | 100· | 162·20 |
| $2\frac{7}{8}$ | 115· | 107·82 | 117·86 | 126·5 | 123·64 | 132·24 | 108·34 | 103·5 | 169·60 |
| 3 | 120· | 112·50 | 123·00 | 132· | 129· | 138· | 114· | 108· | 177· |

**Hoops.**—To find the length of bar required to make a circular hoop.—*Rule:* Add the thickness of the bar to the inside diameter of the hoop, and multiply the result by $3\frac{1}{7}$. For angle-iron hoops, with the flange on the outside.—*Rule:* Add twice the thickness of the root to the inside diameter of the hoop, and multiply the result by $3\frac{1}{7}$. For angle-iron hoops with the flange inside the hoop.—*Rule:* Deduct twice the thickness of the root from the outside diameter, and multiply by $3\frac{1}{7}$.

## Table 121.—Iron Wire.

The following Table, issued by the Iron and Steel Wire Manufacturers' Association, gives the sizes, weights, lengths, and breaking strains of iron wire, according to the New Imperial Standard Wire-gauge.

| Size on Wire-Gauge. | Diameter. | | Sectional Area in Square Inches. | Weight of | | Length of Cwt. | Breaking Strain. | | Size on Wire-Gauge. |
|---|---|---|---|---|---|---|---|---|---|
| | Inch. | Millimetres. | | 100 Yards. | One Mile. | | Annealed. | Bright. | |
| | | | | lb. | lb. | yds. | lb. | lb. | |
| 7/0 | ·500 | 12·7 | ·1963 | 193·4 | 3404 | 58 | 10470 | 15700 | 7/0 |
| 6/0 | ·464 | 11·8 | ·1691 | 166·5 | 2930 | 67 | 9017 | 13525 | 6/0 |
| 5/0 | ·432 | 11· | ·1466 | 144·4 | 2541 | 78 | 7814 | 11725 | 5/0 |
| 4/0 | ·400 | 10·2 | ·1257 | 123·8 | 2179 | 91 | 6702 | 10052 | 4/0 |
| 3/0 | ·372 | 9·4 | ·1087 | 107·1 | 1885 | 105 | 5796 | 8694 | 3/0 |
| 2/0 | ·348 | 8·8 | ·0951 | 93·7 | 1649 | 120 | 5072 | 7608 | 2/0 |
| 1/0 | ·324 | 8·2 | ·0824 | 81·2 | 1429 | 138 | 4397 | 6595 | 1/0 |
| 1 | ·300 | 7·6 | ·0707 | 69·6 | 1225 | 161 | 3770 | 5655 | 1 |
| 2 | ·276 | 7· | ·0598 | 58·9 | 1037 | 190 | 3190 | 4785 | 2 |
| 3 | ·252 | 6·4 | ·0499 | 49·1 | 864 | 228 | 2660 | 3990 | 3 |
| 4 | ·232 | 5·9 | ·0423 | 41·6 | 732 | 269 | 2254 | 3381 | 4 |
| 5 | ·212 | 5·4 | ·0353 | 34·8 | 612 | 322 | 1883 | 2824 | 5 |
| 6 | ·192 | 4·9 | ·0290 | 28·5 | 502 | 393 | 1544 | 2316 | 6 |
| 7 | ·176 | 4·5 | ·0243 | 24· | 422 | 467 | 1298 | 1946 | 7 |
| 8 | ·160 | 4·1 | ·0201 | 19·8 | 348 | 566 | 1072 | 1608 | 8 |
| 9 | ·144 | 3·7 | ·0163 | 16· | 282 | 700 | 869 | 1303 | 9 |
| 10 | ·128 | 3·3 | ·0129 | 12·7 | 223 | 882 | 687 | 1030 | 10 |
| 11 | ·116 | 3· | ·0106 | 10·4 | 183 | 1077 | 564 | 845 | 11 |
| 12 | ·104 | 2·6 | ·0085 | 8·4 | 148 | 1333 | 454 | 680 | 12 |
| 13 | ·092 | 2·3 | ·0066 | 6·5 | 114 | 1723 | 355 | 532 | 13 |
| 14 | ·080 | 2· | ·0050 | 5· | 88 | 2240 | 268 | 402 | 14 |
| 15 | ·072 | 1·8 | ·0041 | 4· | 70 | 2800 | 218 | 326 | 15 |
| 16 | ·064 | 1·6 | ·0032 | 3·2 | 56 | 3500 | 172 | 257 | 16 |
| 17 | ·056 | 1·4 | ·0025 | 2·4 | 42 | 4667 | 131 | 197 | 17 |
| 18 | 048 | 1·2 | ·0018 | 1·8 | 32 | 6222 | 97 | 145 | 18 |
| 19 | ·040 | 1· | ·0013 | 1·2 | 21 | 9333 | 67 | 100 | 19 |
| 20 | ·036 | 0·9 | ·0010 | 1· | 18 | 11200 | 55 | 82 | 20 |

## Table 122.—Galvanised Wire.

| New Standard W. G. Thickness. | Length in Yards per lb. | New Standard W. G. Thickness. | Length in Yards per lb. |
|---|---|---|---|
| | yards. | | yards. |
| 3 | 2 | 13 | 15½ |
| 6 | 3½ | 14 | 20 |
| 8 | 5 | 16 | 31 |
| 10 | 7½ | 18 | 51 |
| 12 | 12 | 20 | 100 |

Table 123.—Weight of 1 Foot in Length of Angle and Tee-Iron.

| Breadth of Iron. | Thickness of the Middle of each Web or Flange. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ¼ inch. | $\frac{5}{16}$ inch. | ⅜ inch. | $\frac{7}{16}$ inch. | ½ inch. | $\frac{9}{16}$ inch. | ⅝ inch. | ¾ inch. | ⅞ inch. | 1 inch. |
| Inches. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 1 × 1 | 1·44 | 1·74 | | | | | | | | |
| 1¼ × 1¼ | 1·86 | 2·25 | 2·95 | | | | | | | |
| 1½ × 1½ | 2·30 | 2·81 | 3·30 | 3·76 | | | | | | |
| 1¾ × 1¾ | 2·73 | 3·34 | 3·93 | 4·50 | 5·05 | | | | | |
| 2 × 2 | 3·15 | 3·86 | 4·55 | 5·23 | 5·85 | 6·48 | | | | |
| 2¼ × 2¼ | 3·56 | 4·38 | 5·19 | 5·95 | 6·70 | 7·40 | 8·12 | | | |
| 2½ × 2½ | 3·98 | 4·90 | 5·81 | 6·68 | 7·54 | 8·35 | 9·16 | | | |
| 2¾ × 2¾ | 4·40 | 5·43 | 6·44 | 7·42 | 8·38 | 9·30 | 10·21 | 11·95 | | |
| 3 × 3 | 4·82 | 5·95 | 7·07 | 8·15 | 9·21 | 10·25 | 11·26 | 13·25 | | |
| 3¼ × 3¼ | 5·24 | 6·48 | 7·70 | 8·90 | 10·06 | 11·20 | 12·31 | 14·50 | | |
| 3½ × 3½ | 5·66 | 7·00 | 8·33 | 9·63 | 10·90 | 12·15 | 13·36 | 15·76 | | |
| 3¾ × 3¾ | 6·08 | 7·53 | 8·96 | 10·36 | 11·75 | 13·08 | 14·40 | 17·06 | | |
| 4 × 4 | 6·50 | 8·06 | 9·60 | 11·10 | 12·56 | 14·02 | 15·45 | 18·30 | | |
| 4¼ × 4¼ | 6·92 | 8·58 | 10·22 | 11·83 | 13·41 | 14·96 | 16·50 | 19·55 | | |
| 4½ × 4½ | 7·33 | 9·10 | 10·95 | 12·56 | 14·25 | 15·92 | 17·56 | 20·80 | | |
| 4¾ × 4¾ | 7·75 | 9·64 | 11·48 | 13·31 | 15·10 | 16·85 | 18·58 | 22·08 | | |
| 5 × 5 | | 10·15 | 12·12 | 14·04 | 15·92 | 17·80 | 19·63 | 23·33 | | |
| 5½ × 5½ | | 11·20 | 13·36 | 15·50 | 17·61 | 19·67 | 21·72 | 25·80 | 29·84 | |
| 6 × 6 | | 12·25 | 14·63 | 16·98 | 19·28 | 21·60 | 23·84 | 28·30 | 32·64 | 36·85 |
| 6½ × 6½ | | | | 18·47 | 20·96 | 23·46 | 25·93 | 30·80 | 35·52 | 40·20 |
| 7 × 7 | | | | 19·92 | 22·65 | 25·33 | 28·00 | 33·30 | 38·45 | 43·52 |

Table 124.—Strength of Lead Pipes.

| Internal Diameter. | Weight per Lineal Yard. | Bursting Pressure in lbs. per Square Inch. | Safe Working Pressure in lbs. per Square Inch. |
|---|---|---|---|
| Inches. | lbs. | | |
| ½ | 7 | 1560 | 390 |
| ⅝ | 8 | 1340 | 335 |
| ¾ | 10 | 1040 | 260 |
| 1 | 14 | 900 | 225 |
| 1¼ | 18 | 800 | 200 |
| 1½ | 22 | 700 | 175 |
| 1¾ | 24 | 600 | 150 |
| 2 | 29 | 500 | 125 |

Table 125.—Solder required for Joints.

| | | | | |
|---|---|---|---|---|
| ½ | inch pipe | takes | ¾ | lb. solder. |
| ¾ | do. | „ | 1 | do. |
| 1 | do. | „ | 1¼ | do. |
| 1¼ | do. | „ | 1½ | do. |
| 1½ | do. | „ | 1¾ | do. |
| 1¾ | do. | „ | 2 | do. |
| 2 | do. | „ | 2¼ | do. |

Table 126.—Weight of Cast-Iron Balls in Lbs.

| Diameter. | Weight. | Diameter. | Weight. | Diameter. | Weight. |
|---|---|---|---|---|---|
| Inches. | lbs. | Inches. | lbs. | Inches. | lbs. |
| $\frac{1}{2}$ | ·07 | 6 | 29·47 | $11\frac{1}{2}$ | 207·4 |
| 1 | ·14 | $6\frac{1}{2}$ | 37·46 | 12 | 235·7 |
| $1\frac{1}{2}$ | ·46 | 7 | 46·80 | 13 | 299·7 |
| 2 | 1·09 | $7\frac{1}{2}$ | 57·57 | 14 | 374·3 |
| $2\frac{1}{2}$ | 2·13 | 8 | 69·80 | 15 | 460·3 |
| 3 | 3·68 | $8\frac{1}{2}$ | 83·77 | 16 | 558·7 |
| $3\frac{1}{2}$ | 5·85 | 9 | 99·44 | 17 | 670·1 |
| 4 | 8·73 | $9\frac{1}{2}$ | 116·9 | 18 | 795·5 |
| $4\frac{1}{2}$ | 12·43 | 10 | 136·4 | 19 | 935·6 |
| 5 | 17·05 | $10\frac{1}{2}$ | 157·9 | 20 | 1091·2 |
| $5\frac{1}{2}$ | 22·60 | 11 | 181·6 | 21 | 1268·7 |

**Balls.**—To find the weight of balls of other metals: multiply the weight of cast iron balls by 1·2 for gun metal; 1·15 for brass; 1·08 for steel; and by 1·05 for wrought-iron.

**Wood Screws.**—Gauge Number, and Diameter in Decimal Parts of an Inch.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Screw Gauge No.. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Diameter, Inch. | ·066 | ·080 | ·094 | ·108 | ·122 | ·136 | ·150 | ·164 |
| Screw Gauge No.. | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Diameter, Inch. | ·178 | ·192 | ·206 | ·220 | ·234 | ·248 | ·262 | ·276 |

Table 127.—Weight of Lead Pipes.

| Inside Diameter. | Length in Feet. | Thickness in Inches. | Weight per Length. | Thickness in Inches. | Weight per Length. | Thickness in Inches. | Weight per Length. | Thickness in Inches. | Weight per Length. |
|---|---|---|---|---|---|---|---|---|---|
| Inches. | | | lbs. | | lbs. | | lbs. | | |
| $\frac{1}{2}$ | 15 | $\frac{3}{32}$ | 15 | $\frac{1}{8}$ f | 18 | $\frac{1}{8}$ f | 22 | $\frac{5}{32}$ b | 25 |
| $\frac{5}{8}$ | 15 | $\frac{1}{8}$ b | 18 | $\frac{1}{8}$ | 22 | $\frac{1}{8}$ f | 27 | $\frac{5}{32}$ | 30 |
| $\frac{3}{4}$ | 15 | $\frac{1}{8}$ b | 24 | $\frac{5}{32}$ | 28 | $\frac{3}{16}$ | 32 | $\frac{7}{32}$ | 36 |
| 1 | 15 | $\frac{1}{8}$ | 28 | $\frac{1}{8}$ f | 36 | $\frac{5}{32}$ | 42 | $\frac{3}{16}$ | 48 |
| $1\frac{1}{4}$ | 12 | $\frac{1}{8}$ f | 36 | $\frac{5}{32}$ | 42 | $\frac{3}{16}$ | 52 | $\frac{7}{32}$ | 63 |
| $1\frac{1}{2}$ | 12 | $\frac{1}{8}$ f | 42 | $\frac{5}{32}$ f | 48 | $\frac{3}{16}$ | 56 | $\frac{1}{8}$ b | 72 |
| $1\frac{3}{4}$ | 12 | $\frac{3}{16}$ | 70 | $\frac{1}{4}$ b | 84 | $\frac{1}{4}$ | 96 | | |
| 2 | 12 | $\frac{7}{32}$ | 84 | $\frac{1}{4}$ f | 96 | $\frac{9}{32}$ | 112 | | |
| $2\frac{1}{2}$ | 10 | $\frac{7}{32}$ b | 84 | $\frac{1}{4}$ | 96 | $\frac{1}{4}$ f | 112 | | |
| 3 | 10 | $\frac{1}{4}$ f | 120 | $\frac{9}{32}$ | 150 | $\frac{5}{16}$ | 188 | | |
| $3\frac{1}{2}$ | 10 | $\frac{1}{4}$ b | 135 | $\frac{1}{4}$ b | 150 | $\frac{5}{16}$ b | 184 | | |
| 4 | 10 | $\frac{7}{32}$ | 135 | $\frac{1}{4}$ f | 160 | $\frac{5}{16}$ b | 200 | | |
| $4\frac{1}{2}$ | 10 | $\frac{5}{16}$ | 200 | $\frac{5}{16}$ b | 216 | $\frac{5}{16}$ | 234 | | |
| 5 | 10 | $\frac{5}{16}$ b | 234 | $\frac{5}{16}$ b | 254 | $\frac{11}{32}$ | 280 | | |
| 6 | 10 | $\frac{5}{16}$ | 330 | | | | | | |

Note.—F means full, and B bare thickness.

Table 128.—Weight of Lead required for the Joints of Cast-Iron Socket-Pipes.

| Diameter of Pipe. | Weight of Lead. | Diameter of Pipe. | Weight of Lead. |
|---|---|---|---|
| Inches. | lbs. | Inches. | lbs. |
| 2 | 2 | 10 | 12 |
| 2½ | 2½ | 11 | 13½ |
| 3 | 3 | 12 | 15 |
| 4 | 3¾ | 14 | 18 |
| 5 | 6 | 15 | 22 |
| 6 | 7 | 16 | 24 |
| 7 | 8 | 18 | 25 |
| 8 | 9 | 20 | 27 |
| 9 | 10½ | 24 | 38 |

Table 129.—Approximate Weight of 1 Foot in Length of Brass Tubes by Outside Diameter, and also of 1 Foot in Length of Copper Tubes by Inside Diameter.

| Diameter in Inches. | Thickness in parts of an Inch, and also by the New Standard Wire-Gauge. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/32 or 21 | | 1/16 or 16 | | 3/32 or 13 | | 1/8 or 10 | | 3/16 or 6 | | 1/4 or 3 | | 5/16 or 1 | |
| | Brass. | Copper. | Brass. | Copper. | Brass. | Copper. | Brass. | Copper. | Brass. | Copper. | Brass. | Copper. | Brass. | Copper. |
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 1 | | | | ¾ | 1 | 1¼ | 1¼ | 1¾ | 2 | 2¾ | 2½ | 3¾ | 3¼ | 5 |
| 1¼ | | ½ | | 1 | 1¼ | 1¾ | 1¾ | 2¼ | 2½ | 3¼ | 3 | 4½ | 4 | 5¾ |
| 1½ | ½ | | 1 | | 1½ | 2 | 2 | 2½ | 3 | 4 | 3¾ | 5¼ | 4¾ | 7 |
| 1¾ | | | | 1¼ | 1¾ | 2¼ | 2¼ | 3 | 3½ | 4¼ | 4¼ | 6 | 5¾ | 8 |
| 2 | | ¾ | | 1½ | 2 | 2½ | 2½ | 3¼ | 4 | 5 | 5 | 6½ | 6½ | 8¾ |
| 2¼ | ¾ | | 1½ | 1¾ | 2¼ | 2¾ | 3 | 3¾ | 4½ | 5½ | 5½ | 7¼ | 7¼ | 10 |
| 2½ | | 1 | | 2 | 2½ | 3 | 3¼ | 4 | 5 | 6 | 6¼ | 8 | 8 | 10¾ |
| 2¾ | | | | | 2¾ | 3¼ | 3½ | 4½ | 5½ | 6½ | 6¾ | 9 | 9 | 11½ |
| 3 | 1 | | 2 | 2¼ | 3 | 3½ | 4 | 5 | 6 | 7 | 7½ | 10 | 9¾ | 12¾ |
| 3¼ | | 1¼ | | | 3¼ | 3¾ | 4¼ | 5½ | 6½ | 7¾ | 8 | 10½ | 10½ | 13¼ |
| 3½ | | | 2¼ | 2½ | 3½ | 4 | 4½ | 5¾ | 7 | 8¼ | 8½ | 11 | 11½ | 14½ |
| 3¾ | 1¼ | 1½ | | 2¾ | 3¾ | 4½ | 5 | 6 | 7½ | 8¾ | 9¼ | 12 | 12¼ | 15½ |
| 4 | | | 2¾ | 3 | 4 | 5 | 5¼ | 6¼ | 8 | 9¼ | 10 | 12½ | 13 | 16¾ |
| 4¼ | | | | 3¼ | 4¼ | 5¼ | 5½ | 6½ | 8½ | 9¾ | 10½ | 13¼ | 13¾ | 17¼ |
| 4½ | 1½ | 1¾ | 3 | 3½ | 4½ | 5½ | 6 | 7 | 9 | 10¼ | 11 | 14 | 14½ | 18 |
| 4¾ | | | | 3¾ | 4¾ | 6 | 6¼ | 7¼ | 9½ | 11 | 11¾ | 14½ | 15¼ | 19 |
| 5 | 1¾ | 2 | 3¼ | 4 | 5 | 6½ | 6½ | 8 | 10 | 11½ | 12½ | 15 | 16 | 20 |
| 5½ | | 2¼ | 3½ | 4½ | 5½ | 7 | 7¼ | 8½ | 11 | 12½ | 13½ | 17 | 18 | 22 |
| 6 | 2 | 2½ | 4 | 5 | 6¼ | 7½ | 8 | 10 | 12 | 14 | 15 | 18¼ | 19½ | 24 |
| 7 | 2½ | 2¾ | 4½ | 6 | 7 | 8½ | 9 | 10¾ | 14 | 16 | 7 | 21 | 23 | 28 |
| 8 | 2¾ | 3¼ | 5 | 6¾ | 8 | 10 | 10½ | 12½ | 16 | 18½ | 20 | 24 | 26 | 31 |
| 9 | 3 | 3½ | 6 | 7¾ | 9 | 11 | 12 | 13¾ | 18 | 21 | 22 | 27 | 29 | 35 |
| 10 | 3½ | 4 | 7 | 8¼ | 10 | 12 | 13 | 15½ | 20 | 23 | 25 | 30 | 32 | 38½ |
| 11 | 3¾ | 4½ | 8 | 9 | 11 | 13 | 14½ | 17 | 22 | 25½ | 27 | 33 | 36 | 42½ |
| 12 | 4 | 4¾ | 9 | 10 | 12 | 14½ | 16 | 19 | 24 | 27½ | 30 | 36 | 39 | 46 |

Table 130.—Weight of 12 Inches in Length of Cast-Iron Cylinders.

| Internal Diameter. | Thickness in Inches. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{7}{8}$ | 2 |
| Inches. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| $1\frac{1}{2}$ | 5·54 | 6·88 | 8·3 | 9·8 | 11·4 | 13·1 | 16·6 | 20·4 | 24·4 | 28·7 | 34· | 42 | 45 | 50 | 56 | 62 | 69 |
| 2 | 7·07 | 8·72 | 10·5 | 12·3 | 14·2 | 16· | 20·2 | 24·7 | 29·5 | 34·6 | 40· | 46 | 52 | 58 | 65 | 72 | 79 |
| $2\frac{1}{2}$ | 8·62 | 10·6 | 12·6 | 14·7 | 16·9 | 19·2 | 23·8 | 29· | 34·4 | 40· | 46· | 53 | 59 | 66 | 74 | 81 | 89 |
| 3 | 10·2 | 12·4 | 14·8 | 17·2 | 19·6 | 22·2 | 27·6 | 33·3 | 39·3 | 45·6 | 52· | 59 | 67 | 74 | 82 | 91 | 99 |
| $3\frac{1}{2}$ | 11·7 | 14·3 | 16·9 | 19·6 | 22·4 | 25·3 | 31·3 | 37·5 | 44·2 | 51· | 58·2 | 66 | 74 | 82 | 92 | 99 | 108 |
| 4 | 13·2 | 16·1 | 19·1 | 22·1 | 25·2 | 28·3 | 35· | 41·8 | 49· | 56·6 | 64·4 | 73 | 81 | 91 | 99 | 109 | 118 |
| $4\frac{1}{2}$ | 14·8 | 18· | 22·1 | 24·5 | 28· | 31·5 | 38·7 | 46·2 | 54· | 62·1 | 70·5 | 80 | 89 | 98 | 108 | 118 | 128 |
| 5 | 16·3 | 19·8 | 23·4 | 27· | 30·6 | 34·5 | 42·2 | 50·5 | 58·9 | 67·6 | 76·6 | 86 | 96 | 106 | 117 | 127 | 138 |
| $5\frac{1}{2}$ | 17·8 | 21·6 | 25·5 | 29·5 | 33·5 | 37·5 | 46· | 54·7 | 63·8 | 73·1 | 82·7 | 94 | 104 | 115 | 125 | 136 | 148 |
| 6 | 19·4 | 23·5 | 27·7 | 32· | 36·2 | 40·7 | 49·6 | 59· | 68·6 | 78·6 | 90· | 100 | 111 | 122 | 135 | 145 | 157 |
| $6\frac{1}{2}$ | 21· | 25·3 | 29·8 | 34·4 | 39· | 43·7 | 53·4 | 63·4 | 73·6 | 84·1 | 95· | 108 | 118 | 132 | 142 | 155 | 167 |
| 7 | 22·6 | 27·2 | 32· | 36·8 | 41·8 | 46·8 | 57·1 | 67·6 | 78·5 | 89·7 | 102· | 114 | 126 | 139 | 152 | 164 | 177 |
| $7\frac{1}{2}$ | 24·2 | 29· | 34· | 39·2 | 44·5 | 50· | 60·8 | 71·8 | 83·5 | 95·1 | 108· | 121 | 133 | 146 | 159 | 173 | 187 |
| 8 | 25·5 | 30·8 | 36·2 | 41·7 | 47·2 | 51· | 64·4 | 76·2 | 88·4 | 101· | 114· | 127 | 141 | 155 | 168 | 182 | 197 |
| $8\frac{1}{2}$ | 27·2 | 32·7 | 38·3 | 44·2 | 50· | 56· | 68· | 80·5 | 93·3 | 107· | 120· | 134 | 148 | 162 | 176 | 192 | 206 |
| 9 | 28·5 | 34·5 | 40·5 | 46·6 | 52·8 | 59· | 71·7 | 84·8 | 98· | 112· | 126· | 140 | 155 | 171 | 186 | 201 | 216 |
| $9\frac{1}{2}$ | 30·2 | 36·4 | 42·6 | 49· | 55·6 | 62· | 75·5 | 89· | 103· | 118· | 132· | 147 | 162 | 178 | 194 | 210 | 226 |
| 10 | 31·6 | 38·2 | 44·7 | 51·5 | 58·3 | 65· | 79·2 | 93·4 | 108· | 123· | 138· | 154 | 170 | 186 | 202 | 219 | 236 |
| $10\frac{1}{2}$ | 33·2 | 40· | 47· | 54· | 61· | 68·2 | 82·8 | 97·6 | 113· | 129· | 144· | 162 | 177 | 195 | 212 | 228 | 246 |
| 11 | 34·7 | 41·9 | 49· | 56·4 | 63·9 | 71·1 | 86·5 | 102· | 118· | 134· | 151· | 168 | 185 | 202 | 220 | 237 | 256 |
| $11\frac{1}{2}$ | 36·2 | 43·7 | 51·3 | 58·9 | 66·6 | 74·5 | 90·1 | 107· | 123· | 140· | 157· | 175 | 192 | 210 | 228 | 242 | 266 |
| 12 | 38· | 45·6 | 53·3 | 61·4 | 69·4 | 77·5 | 93·8 | 111· | 128· | 145· | 163· | 180 | 200 | 217 | 237 | 256 | 275 |
| 13 | 40·8 | 49·2 | 57·6 | 66·3 | 74·8 | 83·6 | 102· | 120· | 138· | 156· | 175· | 194 | 215 | 233 | 252 | 265 | 295 |

Table 130 *continued.*—WEIGHT OF TWELVE INCHES IN LENGTH OF CAST-IRON CYLINDERS.

| Internal Diameter. | Thickness in Inches. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5/16 | 3/8 | 7/16 | 1/2 | 9/16 | 5/8 | 3/4 | 7/8 | 1 | 1 1/8 | 1 1/4 | 1 3/8 | 1 1/2 | 1 5/8 | 1 3/4 | 1 7/8 | 2 |
| Inches. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 14 | 44· | 52·9 | 62· | 71·2 | 80·4 | 90· | 109 | 128 | 148 | 168 | 187 | 207 | 229 | 245 | 272 | 295 | 314 |
| 15 | 47·1 | 56· | 66·2 | 76· | 85·9 | 91· | 116 | 137 | 157 | 178 | 200 | 219 | 244 | 265 | 289 | 312 | 334 |
| 16 | 50·2 | 60·3 | 70· | 81· | 91·5 | 102· | 124 | 145 | 167 | 190 | 212 | 234 | 259 | 282 | 305 | 332 | 353 |
| 17 | 53·5 | 64· | 74·8 | 85·9 | 97· | 108· | 131 | 154 | 177 | 201 | 224 | 248 | 274 | 298 | 323 | 351 | 373 |
| 18 | 56·5 | 67·7 | 79·2 | 90·8 | 103· | 115· | 139 | 163 | 187 | 212 | 236 | 262 | 288 | 314 | 340 | 368 | 393 |
| 19 | ... | 71· | 84· | 95·7 | 108· | 121· | 146 | 170 | 197 | 222 | 249 | 275 | 303 | 330 | 357 | 386 | 413 |
| 20 | ... | 75·1 | 88· | 100·4 | 114· | 127· | 153 | 180 | 206 | 232 | 261 | 290 | 318 | 345 | 374 | 405 | 432 |
| 21 | ... | 79· | 92·1 | 105·4 | 120· | 133· | 161 | 189 | 216 | 242 | 273 | 303 | 333 | 360 | 392 | 423 | 451 |
| 22 | ... | 82·1 | 97·2 | 110·2 | 126· | 139· | 168 | 197 | 226 | 255 | 285 | 315 | 348 | 377 | 409 | 442 | 471 |
| 23 | ... | 87· | 101· | 115·2 | 132· | 145· | 176 | 205 | 236 | 267 | 304 | 330 | 362 | 394 | 426 | 460 | 491 |
| 24 | ... | 90·1 | 105· | 121· | 137· | 152· | 183 | 214 | 245 | 277 | 310 | 343 | 376 | 410 | 443 | 498 | 510 |
| 26 | ... | 97·3 | 116· | 130· | 148· | 164· | 198 | 231 | 265 | 300 | 334 | 370 | 406 | 442 | 477 | 516 | 550 |
| 28 | ... | 105· | 123· | 140· | 159· | 176· | 213 | 249 | 285 | 321 | 359 | 397 | 436 | 474 | 512 | 553 | 590 |
| 30 | ... | 112· | 133· | 150· | 170· | 188· | 228 | 265 | 304 | 344 | 383 | 423 | 466 | 505 | 547 | 591 | 628 |
| 33 | ... | 125· | 144· | 164· | 187· | 203· | 249 | 289 | 334 | 374 | 420 | 463 | 510 | 553 | 598 | 642 | 687 |
| 36 | ... | 135· | 167· | 179· | 203· | 221· | 272 | 315 | 363 | 420 | 457 | 505 | 553 | 600 | 649 | 700 | 745 |
| 42 | ... | 156· | 182· | 208· | 237· | 257· | 315 | 366 | 422 | 476 | 530 | 585 | 642 | 696 | 753 | 813 | 863 |
| 48 | ... | 178· | 207· | 238· | 270· | 295· | 360 | 417 | 481 | 553 | 604 | 668 | 730 | 792 | 855 | 922 | 982 |
| 54 | ... | ... | ... | 268· | 304· | 331· | 404 | 468 | 540 | 610 | 678 | 749 | 818 | 888 | 958 | 1036 | 1098 |
| 60 | ... | ... | ... | 297· | 337· | 367· | 448 | 519 | 598 | 675 | 751 | 830 | 907 | 983 | 1062 | 1147 | 1217 |
| 66 | ... | ... | ... | 326· | 370· | 403· | 492 | 570 | 657 | 742 | 824 | 952 | 995 | 1083 | 1166 | 1260 | 1334 |
| 72 | ... | ... | ... | 356· | 404· | 440· | 536 | 622 | 716 | 807 | 898 | 995 | 1084 | 1188 | 1270 | 1371 | 1452 |

### Table 131.—Weight of Half a Circle of Cast-Iron—Depth = Half the Diameter.

| Thickness in Inches. | Internal Diameter in Inches. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 36 | 39 | 42 | 45 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 96 |
| | cwts. | cwts. | cwts. | cwts. | cwts. | cwts. | cwts. | cwts. | cwts. | cwts. | cwts. | cwts. |
| $\frac{1}{2}$ | 2·5 | 2·96 | 3·42 | 3·8 | 4·4 | 5·57 | 6·84 | 8·26 | 9·8 | 11·5 | 13·3 | 17·3 |
| $\frac{3}{4}$ | 3·8 | 4·3 | 5·23 | 6· | 6·8 | 8·35 | 10·45 | 12·6 | 14·9 | 17·5 | 20·2 | 26·2 |
| 1 | 5·3 | 6·2 | 7·12 | 8·14 | 9·2 | 11·5 | 14·15 | 17· | 20·15 | 23·5 | 27·2 | 35·3 |
| $1\frac{1}{4}$ | 6·8 | 7·9 | 9· | 10·3 | 11·7 | 14·7 | 17·9 | 21·5 | 25·5 | 28·8 | 34·3 | 44·5 |
| $1\frac{1}{2}$ | 8·4 | 9·7 | 11·1 | 12·7 | 14·3 | 17·9 | 21·9 | 26·2 | 32· | 36·2 | 41·7 | 54· |
| $1\frac{3}{4}$ | 10· | 11·6 | 13·3 | 15·1 | 17· | 21·2 | 25·9 | 31· | 36·6 | 40·7 | 49·2 | 63·7 |
| 2 | 11·7 | 13·6 | 15·5 | 17·6 | 19·9 | 24·7 | 30·1 | 36· | 42·4 | 49·4 | 56·9 | 73·5 |

### Table 132.—Weight of Small Cast-Iron Spur Wheels, or Change-Wheels.

| Pitch per inch in diameter | 14 | 12 | 10 | 8 | 7 | 6 | 5 | 4 | $3\frac{1}{2}$ | 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Nearest circular pitch, inch . . . . | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 |
| Width of face in inches . | $\frac{11}{16}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ | 2 | $2\frac{1}{4}$ |
| Number of teeth. | Weight of each Wheel in lbs. | | | | | | | | | |
| 20 | | | 1 | 2 | $2\frac{1}{2}$ | $3\frac{1}{2}$ | 4 | 8 | 12 | 14 |
| 25 | | $\frac{1}{2}$ | $1\frac{1}{4}$ | $2\frac{1}{2}$ | 3 | 4 | 6 | 10 | 15 | 21 |
| 30 | $\frac{1}{2}$ | $\frac{3}{4}$ | $1\frac{3}{4}$ | 3 | $4\frac{1}{2}$ | 5 | 7 | 12 | 19 | 27 |
| 35 | $\frac{3}{4}$ | 1 | 2 | $3\frac{1}{2}$ | 5 | 6 | 9 | 14 | 22 | 32 |
| 40 | 1 | $1\frac{1}{4}$ | $3\frac{1}{2}$ | $4\frac{1}{4}$ | 6 | 7 | 10 | 16 | 25 | 36 |
| 45 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 4 | $4\frac{3}{4}$ | $6\frac{1}{2}$ | 8 | 12 | 18 | 28 | 41 |
| 50 | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $4\frac{1}{2}$ | $5\frac{1}{2}$ | 7 | 9 | 14 | 20 | 31 | 46 |
| 55 | $1\frac{3}{4}$ | 2 | $5\frac{1}{4}$ | 6 | 8 | 10 | 16 | 24 | 34 | 50 |
| 60 | 2 | $2\frac{1}{4}$ | 6 | $6\frac{1}{2}$ | 9 | 11 | 18 | 28 | 38 | 55 |
| 65 | $2\frac{1}{4}$ | $2\frac{1}{2}$ | $6\frac{1}{2}$ | 7 | $10\frac{1}{2}$ | $12\frac{1}{2}$ | 21 | 32 | 42 | 60 |
| 70 | $2\frac{1}{2}$ | $2\frac{3}{4}$ | 7 | $7\frac{1}{2}$ | 13 | 15 | 24 | 36 | 46 | 66 |
| 75 | $2\frac{3}{4}$ | 3 | $7\frac{1}{2}$ | 8 | 15 | 17 | 27 | 40 | 51 | 71 |
| 80 | 3 | $3\frac{1}{4}$ | 8 | 9 | 16 | 18 | 30 | 45 | 56 | 76 |
| 85 | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $8\frac{1}{2}$ | 10 | 17 | 19 | 32 | 50 | 62 | 81 |
| 90 | $3\frac{1}{2}$ | 4 | $9\frac{1}{2}$ | 11 | 18 | 20 | 35 | 55 | 67 | 84 |
| 95 | 4 | $4\frac{1}{2}$ | 10 | 12 | 19 | 21 | 38 | 60 | 73 | 89 |
| 100 | $4\frac{1}{2}$ | 5 | 11 | 13 | 20 | 22 | 42 | 65 | 78 | 92 |
| 105 | 5 | $5\frac{1}{2}$ | 12 | 14 | 21 | 23 | 48 | 70 | 83 | 96 |
| 110 | $5\frac{1}{2}$ | 6 | 13 | 15 | 22 | 24 | 53 | 75 | 88 | 100 |
| 115 | 6 | $6\frac{1}{2}$ | 14 | 16 | 23 | 25 | 60 | 81 | 93 | 105 |
| 120 | $6\frac{1}{2}$ | 7 | 15 | 17 | 24 | 26 | 66 | 86 | 98 | 112 |
| 125 | 7 | $7\frac{1}{2}$ | 16 | 18 | 25 | 27 | 73 | 92 | 103 | 117 |
| 130 | $7\frac{1}{2}$ | 8 | 17 | 19 | 26 | 28 | 80 | 97 | 108 | 122 |
| 135 | 8 | $8\frac{1}{2}$ | 18 | $20\frac{1}{2}$ | 27 | 29 | 86 | 102 | 114 | 127 |
| 140 | $8\frac{1}{2}$ | 9 | 20 | 22 | 28 | 31 | 94 | 108 | 124 | 132 |
| 150 | $9\frac{1}{2}$ | 10 | 22 | 25 | 32 | 36 | 100 | 114 | 134 | 140 |
| 160 | 11 | 12 | 25 | 30 | 37 | 44 | 107 | 122 | 145 | 153 |

Note.—To find the diameter at the pitch line of any of these wheels:—Divide the number of teeth by the given diametral pitch. The full depth of teeth of these wheels is = $\frac{3}{4}$ths the circular pitch.

Table 133.—Weight of Circular and Square Cast-Iron Plates.

| Thickness. | Size of Plate, in Inches . . | 4 | 6 | 8 | 10 | 12 | 15 | 18 | 21 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 84 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inches. 3/8 | Weight of round plate, in lbs. | 1·23 | 2·75 | 4·9 | 7·7 | 11 | 17·2 | 25 | 34 | 45 | 69 | 100 | 135 | 175 | 223 | 276 | 334 | 397 | 540 |
| | Weight of square plate, in lbs. | 1·56 | 3·5 | 6·25 | 9·75 | 14·25 | 22·25 | 31·5 | 43·25 | 56·5 | 88 | 126 | 173 | 225 | 285 | 351 | 425 | 506 | 689 |
| 1/2 | Weight of round plate, in lbs. | 1·63 | 3·68 | 6·5 | 10·2 | 15 | 23 | 34 | 45 | 59 | 72 | 134 | 180 | 235 | 298 | 368 | 450 | 529 | 720 |
| | Weight of square plate, in lbs. | 2·08 | 4·68 | 8·3 | 13 | 18·7 | 29·2 | 42 | 58 | 75 | 117 | 168 | 230 | 300 | 380 | 468 | 567 | 674 | 918 |
| 5/8 | Weight of round plate, in lbs. | 2·04 | 4·6 | 8·16 | 13 | 18·4 | 29 | 42 | 57 | 74 | 116 | 168 | 228 | 296 | 368 | 456 | 544 | 661 | 900 |
| | Weight of square plate, in lbs. | 2·6 | 5·84 | 10·4 | 16·25 | 24 | 37 | 53 | 73 | 94 | 147 | 210 | 293 | 375 | 475 | 585 | 709 | 843 | 1148 |
| 3/4 | Weight of round plate, in lbs. | 2·45 | 5·5 | 14·7 | 15·5 | 22 | 34·5 | 50·5 | 68 | 89 | 138 | 201 | 270 | 353 | 446 | 551 | 667 | 793 | 1080 |
| | Weight of square plate, in lbs. | 3·12 | 7· | 12·5 | 19·5 | 28·5 | 44·5 | 63 | 86·5 | 113 | 176 | 252 | 345 | 450 | 570 | 702 | 850 | 1011 | 1377 |
| 7/8 | Weight of round plate, in lbs. | 2·85 | 6·44 | 11·44 | 18 | 26 | 40·2 | 58 | 79 | 103 | 161 | 232 | 316 | 412 | 520 | 645 | 785 | 926 | 1264 |
| | Weight of square plate, in lbs. | 3·64 | 7·73 | 14·5 | 22·7 | 33 | 52 | 73 | 102 | 132 | 205 | 294 | 358 | 525 | 665 | 819 | 1092 | 1180 | 1607 |
| 1 | Weight of round plate, in lbs. | 3·26 | 7·35 | 13 | 20·4 | 29·4 | 46 | 67 | 90 | 118 | 184 | 268 | 360 | 470 | 595 | 735 | 889 | 1058 | 1440 |
| | Weight of square plate, in lbs. | 4·16 | 9·3 | 16·6 | 26 | 37·5 | 58·5 | 84 | 115 | 150 | 234 | 336 | 460 | 601 | 759 | 936 | 1133 | 1348 | 1835 |
| 1 1/8 | Weight of round plate, in lbs. | 3·67 | 8·28 | 14·7 | 23 | 33·4 | 52 | 75 | 102 | 133 | 208 | 300 | 408 | 532 | 666 | 832 | 1000 | 1200 | 1632 |
| | Weight of square plate, in lbs. | 4·68 | 10·5 | 18·7 | 29·25 | 42·7 | 68 | 95 | 131 | 169 | 264 | 378 | 473 | 675 | 850 | 1053 | 1276 | 1517 | 2066 |
| 1 1/4 | Weight of round plate, in lbs. | 4·08 | 9·2 | 16·3 | 26 | 37 | 58 | 84 | 114 | 148 | 232 | 336 | 456 | 592 | 736 | 912 | 1088 | 1322 | 1800 |
| | Weight of square plate, in lbs. | 5·2 | 11·6 | 20·8 | 32·5 | 48 | 74 | 106 | 146 | 188 | 294 | 420 | 586 | 750 | 950 | 1170 | 1418 | 1686 | 2296 |
| 1 3/8 | Weight of round plate, in lbs. | 4·49 | 10·1 | 18 | 28 | 41 | 64 | 92 | 124 | 163 | 256 | 368 | 496 | 652 | 818 | 1024 | 1223 | 1472 | 1985 |
| | Weight of square plate, in lbs. | 5·72 | 12·8 | 22·8 | 35·7 | 52 | 81 | 116 | 159 | 207 | 322 | 462 | 588 | 826 | 1044 | 1287 | 1558 | 1854 | 2524 |
| 1 1/2 | Weight of round plate, in lbs. | 4·9 | 11 | 19·6 | 31 | 44 | 69 | 101 | 135 | 177 | 276 | 402 | 540 | 705 | 893 | 1103 | 1334 | 1587 | 2160 |
| | Weight of square plate, in lbs. | 6·24 | 14 | 25 | 39 | 57 | 89 | 126 | 173 | 225 | 351 | 504 | 690 | 901 | 1139 | 1404 | 1700 | 2022 | 2753 |

Table 134.—Weight of 1 Foot in Length of Round and Square Cast-Brass Bars, Copper, Lead, and Zinc Bars; and also of 100 Feet in Length of Brass and Copper Wire.

| Size of Bar, in Inches . . | ½ | ⅝ | ¾ | ⅞ | 1 | 1⅛ | 1¼ | 1⅜ | 1½ | 1⅝ | 1¾ | 1⅞ | 2 | 2¼ | 2½ | 2¾ | 3 | 3½ | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| Weight of round brass | ·71 | 1·1 | 1·6 | 2·16 | 2·84 | 3·6 | 4·44 | 5·37 | 6·4 | 7·5 | 8·7 | 10· | 11·4 | 15· | 18· | 22 | 26 | 35 | 46 |
| Weight of round copper | ·75 | 1·17 | 1·7 | 2·3 | 3· | 3·8 | 4·68 | 5·66 | 6·7 | 7·9 | 9·2 | 10·5 | 12· | 16· | 19· | 23 | 27 | 37 | 48 |
| Weight of square brass | ·91 | 1·42 | 2· | 2·77 | 3·65 | 4·6 | 5·68 | 6·9 | 8·0 | 9·6 | 11· | 12·8 | 15· | 19· | 23· | 28 | 32 | 44 | 60 |
| Weight of square copper | ·96 | 1·5 | 2·16 | 2·9 | 3·84 | 4·9 | 6· | 7·26 | 8·7 | 10·1 | 11·7 | 13·5 | 16· | 20· | 24· | 29 | 35 | 47 | 63 |
| Weight of round lead . | ·95 | 1·48 | 2·14 | 2·86 | 3·8 | 4·9 | 6· | 7·25 | 8·7 | 10·1 | 11·7 | 13·5 | 16· | 20· | 24· | 29 | 35 | 47 | 63 |
| Weight of round zinc . | ·64 | ·95 | 1·36 | 1·83 | 2·5 | 3· | 3·8 | 4·5 | 5·4 | 6·3 | 7·3 | 8·4 | 9·8 | 12· | 15·2 | 18 | 22 | 30 | 40 |
| Weight of square lead . | 1·25 | 1·93 | 2·33 | 3·83 | 5· | 6·3 | 7·7 | 9·3 | 11·1 | 13·1 | 15·3 | 17·5 | 20· | 25· | 31· | 38 | 45 | 62 | 80 |
| Weight of square zinc . | ·8 | 1·21 | 1·8 | 2·4 | 3·1 | 4· | 4·9 | 5·9 | 6·9 | 8·2 | 9·6 | 11· | 13· | 16· | 20· | 24 | 28 | 38 | 50 |
| Wire, thickness by the New Standard W. G. | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Weight of 100 feet in length of brass wire, in lbs. . . . . | ·44 | ·66 | ·88 | 1·17 | 1·47 | 1·83 | 2·38 | 3·08 | 3·82 | 4·66 | 5·88 | 7·27 | 8·8 | 10·46 | 12·8 | 15·3 | 18 | 22 | 26 |
| Weight of 100 feet in length of copper wire, in lbs. . . . | ·47 | ·7 | ·93 | 1·22 | 1·55 | 1·93 | 2·5 | 3·24 | 4·02 | 4·9 | 6·18 | 7·64 | 9·3 | 11·0 | 13·5 | 16·1 | 19 | 24 | 28 |

### Table 135.—Weight and Gauges of Sheet Zinc.

| Thickness by Zinc Gauge. | Nearest Thickness by the New Standard Wire-Gauge. | Approximate Weight per Square Foot in Ounces. | Approximate Weight per Sheet. | | | |
|---|---|---|---|---|---|---|
| | | | ft. ft. in. 7 × 2 8 | ft. in. 7 × 3 | ft. ft. in. 8 × 2 8 | ft. in. 8 × 3 |
| | | | lbs. oz. | lbs. oz. | lbs. oz. | lbs. oz. |
| 4 | ... | 5 | 5 13 | 6 9 | 6 11 | 7 8 |
| 5 | ... | 6 | 7 0 | 7 14 | 8 0 | 9 0 |
| 6 | ... | 7 | 8 3 | 9 3 | 9 6 | 10 8 |
| 7 | ... | 8 | 9 5 | 10 8 | 10 10 | 12 0 |
| 8 | ... | 9 | 10 8 | 11 13 | 12 0 | 13 12 |
| 9 | 25 | 11 | 12 13 | 14 7 | 14 11 | 16 8 |
| 10 | 24 | 13 | 15 3 | 17 1 | 17 5 | 19 8 |
| 11 | 22 | 15 | 17 8 | 19 11 | 20 0 | 22 8 |
| 12 | 21 | 17 | 19 13 | 22 5 | 22 11 | 25 8 |
| 13 | 20 | 19½ | 22 12 | 25 10 | 26 0 | 29 4 |
| 14 | 19 | 22 | 25 11 | 28 14 | 29 5 | 33 0 |
| 15 | ... | 24 | 28 0 | 31 8 | 32 0 | 36 0 |
| 16 | 18 | 26 | 30 5 | 34 2 | 34 11 | 39 0 |
| 17 | 18 | 30 | 35 0 | 39 6 | 40 0 | 45 0 |

### Table 136.—Sizes and Weights of Tin Plates.

| Mark. | Size. | Sheets per Box. | Weight. |
|---|---|---|---|
| | in. in. | | cwt. qr. lb. |
| 1C | 14×10 | 225 | 1 0 0 |
| 1× | 14×10 | 225 | 1 1 0 |
| 1×× | 14×10 | 225 | 1 1 21 |
| 1××× | 14×10 | 225 | 1 2 14 |
| 1C | 14×20 | 112 | 1 0 0 |
| 1× | 14×20 | 112 | 1 1 0 |
| 1×× | 14×20 | 112 | 1 1 21 |
| 1××× | 14×20 | 112 | 1 2 14 |
| SDC | 15×11 | 200 | 1 1 27 |
| SD× | 15×11 | 200 | 1 2 20 |
| SD×× | 15×11 | 200 | 1 3 13 |
| DC | 17×12½ | 100 | 0 3 14 |
| D× | 17×12½ | 100 | 1 0 14 |
| D×× | 17×12½ | 100 | 1 1 7 |

### Table 137.—Sizes of Bore of Guns.

| Number of Gun-Gauge. | Diameter of Bore, in Decimals of an Inch. | Number of Gun-Gauge. | Diameter of Bore, in Decimals of an Inch. |
|---|---|---|---|
| 4 varies from | 1·052 to 1·000 | 14 varies from | ·693 to ·680 |
| 6 „ | ·919 „ ·900 | 16 „ | ·662 „ .650 |
| 8 „ | ·835 „ ·820 | 20 „ | ·615 „ ·610 |
| 10 „ | ·775 „ ·760 | 24 „ | ·579 „ ·577 |
| 12 „ | ·729 „ ·750 | 28 „ | ·550 „ ·548 |

Table 138.—THICKNESS AND WEIGHT OF A SUPERFICIAL FOOT OF WINDOW-GLASS.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number . . . . . . . | 12 | 13 | 15 | 16 | 17 | 19 | 21 | 24 | 26 | 32 | 36 | 42 |
| Thickness in inches . . . . . | ·059 | ·063 | ·071 | ·077 | ·083 | ·091 | ·1 | ·111 | ·125 | ·154 | ·167 | ·2 |
| Weight in ounces . . . . . | 12 | 13 | 15 | 16 | 17 | 19 | 21 | 24 | 26 | 32 | 36 | 42 |

Table 139.—WEIGHT AND THICKNESS OF SHEET-LEAD.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thickness in inches . . . . . | ·018 | ·035 | ·052 | ·068 | ·086 | ·101 | ·12 | ·136 | ·154 | ·17 | ·187 | ·205 |
| Weight in lbs. per superficial foot . . | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

Table 140.—SIZE AND WEIGHT OF IRON RIVETS AND COPPER RIVETS.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number . . . . . . . | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Diameter in inches . . . . . | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | 1 |
| Length in inches . . . . . | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{5}{16}$ | 1 | $1\frac{3}{16}$ | $1\frac{5}{16}$ | $1\frac{7}{16}$ | $1\frac{9}{16}$ | $1\frac{3}{4}$ | $1\frac{13}{16}$ | $2\frac{1}{16}$ | $2\frac{3}{8}$ |
| Number per lb. of iron rivets . . | 330 | 128 | 114 | 65 | 59 | 40 | 38 | 24 | 16 | 11·3 | 8·2 | 6·2 | 4·8 | 3·8 | 3 | 2 |
| Number per lb. of copper rivets . | 240 | 100 | 98 | 57 | 51 | 36 | 33 | 21 | 14 | 10 | 7·2 | 5·4 | 4·2 | 3·3 | 2·6 | 1·7 |

Table 141.—WEIGHT AND GAUGES OF GALVANIZED SHEET-IRON.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B. G. sheet-gauge, number . . | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 14 |
| Weight per square foot, ounces . | 8 | 9 | 10 | $11\frac{1}{2}$ | 13 | $14\frac{1}{2}$ | 16 | 18 | 20 | $22\frac{1}{2}$ | $25\frac{1}{2}$ | $28\frac{1}{2}$ | 32 | 36 | 40 | $44\frac{1}{2}$ |

Table 142.—Bulk or Stowage Capacity per Ton of Various Substances.

| Description of Goods. | Bulk of One Ton in Cubic Feet. |
|---|---|
| Hay, old and compact, and straw | 280 |
| Furniture | 260 |
| Cotton, partly pressed | 240 |
| Cotton waste | 210 |
| Peat | 200 |
| Wool | 180 |
| Branches of trees; also cork | 150 |
| Branches of trees tied in bundles | 140 |
| Wood, dry lumber | 135 |
| Vegetables | 130 |
| Cases of fruit | 128 |
| Cases of eggs | 120 |
| Grass | 110 |
| Stores, commissariat | 100 |
| Flax and hemp | 95 |
| Pressed cotton | 90 |
| Coke | 80 |
| Groceries and drugs in cases | 80 |
| Yellow pine wood | 80 |
| Sugar, soap and seeds in cases | 75 |
| White pine wood | 70 |
| Honduras mahogany | 65 |
| Red pine and walnut . . . each | 53 |
| Wheat | 50 |
| Birch, pear tree, and pitch pine . . . each | 49 |
| Teak and maple . . . „ | 48 |
| Hornbeam and crabtree . . . „ | 47 |
| Coal | 45 |
| Ash and plum tree | 43 |
| Beech and Spanish mahogany | 42 |
| Oak, English | 40 |
| Oil | 40 |
| Tallow | 39 |
| Ice | 39 |
| Water | 36 |
| Towns sewage | 36 |
| Machinery in cases | 35 |
| Ebony | 30 |
| Box, Dutch | 28 |
| Cutlery in cases | 28 |
| Loose earth | 28 |
| Lignum vitæ | 27 |
| Sand | 24 |
| Brickwork and gravel . . . each | 20 |

Table 142 *continued.*—Bulk or Stowage Capacity per Ton of Various Substances.

| Description of Goods. | | Bulk of One Ton in Cubic Feet. |
|---|---|---|
| Rubble masonry, clay, and salt | each | 19 |
| Roman cement | | 19 |
| Bricks and tiles | | 18 |
| Bath stone and concrete | each | 17 |
| Graphite and lias | ,, | 16 |
| Portland and Derby stone | ,, | 15 |
| Paving quartz and sandstone | ,, | 15 |
| Yorkshire stone and chalk | ,, | 14½ |
| Purbeck and millstone | ,, | 14 |
| Granite and Kentish rag | ,, | 13½ |
| Marble and limestone, and slate | ,, | 13 |
| Clydesdale iron ore | | 12 |
| Brown iron ore | | 9½ |
| Red iron ore | | 7 |
| Iron, cast in pigs | | 6¼ |
| White-metal, cast in pigs | | 6 |
| Bronze and gun-metal, cast in pigs | | 5½ |
| Copper, cast in pigs | | 5 |
| Lead, cast in pigs | | 4 |

Table 143.—Weight of Liquids.

| | Weight of Water = 1000. | Weight per Gallon in lbs. |
|---|---|---|
| Acid, sulphuric | 1850 | 18·5 |
| Acid, nitric | 1271 | 12·7 |
| Acid, muriate | 1200 | 12·0 |
| Alcohol of commerce | 825 | 8·2 |
| Alcohol, proof spirit | 922 | 9·2 |
| Oil, linseed | 940 | 9·4 |
| Oil, whale | 923 | 9·2 |
| Oil, turpentine | 870 | 8·7 |
| Naphtha | 848 | 8·5 |
| Petroleum | 878 | 8·8 |
| Tar | 1015 | 10·1 |
| Water, distilled | 1000 | 10·0 |
| Vinegar | 1009 | 10·1 |

**Barrels.**—To find the contents of a barrel in imperial gallons: first square the centre diameter in inches, and then multiply it by 2, to which add the square of the diameter of the end in inches; then multiply this by the length of the cask in inches, and divide by 1·122.

Table 144.—LIST OF WOODS AND THEIR USES.

The Letter H. means Hard; M., Medium, and S., Soft.

| | |
|---|---|
| Acacia, H., fencing, turnery. | Mahogany, H., furniture. |
| Alder, H., sluices, pumps. | Maple, M., furniture. |
| Almond, H., tool handles. | Mountain Ash, H., cart shafts. |
| Apple, M., turnery. | Nettle Tree, H., flutes. |
| Ash, H., wagons, implements. | Oak, H., shipbuilding, &c. |
| Beech, H., planes, boot lasts. | Olive, M., turnery, boxes. |
| Birch, H., furniture. | Partridge, H., walking sticks. |
| Boxwood, H., engraver's blocks. | Pine, S., carpentry. |
| Cedar, S., pencils, cigar boxes. | Poplar, M., furniture, turnery. |
| Cherry, European, S., Tunbridge ware, fancy work. | Rosewood, H., pianos, furniture. |
| Cherry, Australasian, H., gun stocks, cabinet work. | Sandal Wood, S., fragrant, fancy boxes, cabinet work. |
| Ebony, H., rulers, cabinet work. | Sassafras, H., turnery, screws. |
| Elder, S., rules, shuttles. | Silver Wood, beautifully marked, cabinet work, fancy boxes. |
| Elm, H., piles, pumps, pipes. | Snake Wood, nicely marked, walking sticks. |
| Fir, S., carpentry. | Sycamore, S., turnery, furniture. |
| Hawthorn, H., turnery. | Teak, H., buffer beams. |
| Hickory, H., vehicles, wheel spokes. | Thorn, H., turnery. |
| Holly, H., turnery. | Tulip Wood, H., veneers, cabinet work, fancy work. |
| Hornbeam, H., teeth of wheels. | Walnut, H., furniture, gun stocks. |
| Horsechestnut, S., brushes, turnery. | Whitewood, H., wood engravers' blocks, cabinet work. |
| Ironwood, H., teeth of wheels. | Willow, S., baskets, spoons, &c. |
| Laburnum, H., turnery. | Yew, H., walking sticks, turnery. |
| Lancewood, H., fishing rods, bows. | Zebrawood, M., brushes, cabinet work. |
| Larch, S., carpentry. | |
| Laurel, H., turnery. | |
| Lignum Vitæ, H., pestles, turnery. | |
| Lime, close grained, carving. | |

**The most beautifully marked woods are** rosewood, Italian walnut, Virginia walnut, Spanish mahogany, bird's eye maple, satin-wood, tulip-wood, snake-wood, silver-wood, laburnum, olive-wood, lemon-wood, yew, oak, pitch-pine, and coromandel-wood.

**The most even and close-grained woods are** ebony, myrtle, lime, box, olive, Virginia walnut, pear-tree, sycamore, cowrie-wood, beech, pine and holly.

**The most durable woods are** oak, ebony, cedar, box, hornbeam, poplar, larch, chestnut, lignum vitæ, teak, elm, acacia, and yellow deal.

**The most elastic woods are** lancewood, hickory, ash, hazel, snake-wood, yew and chestnut.

**The scented woods are** sandal-wood, sassafras, camphor-wood, cedar, rosewood and satin-wood.

**The dye-woods are** logwood, saunders-wood, Brazil-wood, cane-wood, fustic, zante and green ebony.

**Qualities of Timber.**—The most odoriferous kinds of woods are generally esteemed the most durable; also woods of a close and compact texture are generally more durable than those that are open and porous. In general, the quantity of charcoal afforded by woods offers a tolerably accurate indication of their durability; those most abundant in charcoal and earthy matter are most permanent; and those which contain the largest proportion of gaseous elements are the most destructible. The chestnut and the oak are pre-eminent as to durability, and the chestnut affords rather more carbonaceous matter than the oak. But this is not always the case, as red or yellow fir is as durable as the oak in many situations. An experiment to determine the comparative durability of different woods was made with planks of trees 1½ inches thick of from thirty to forty-five years' growth; after standing ten years in the weather, they were examined and found to be in the following state:—*

Cedar, perfectly sound.
Larch, the heart sound but sap quite decayed.
Spruce fir, sound.
Silver fir, in decay.
Scotch fir, much decayed.
Pinaster, quite rotten.
Chestnut, perfectly sound.
Abele, or great white poplar, sound.
Beech, sound.
Walnut, in decay.
Sycamore, much decayed.
Birch, quite rotten.

This shows the kinds of woods best adapted to resist the weather, but even in the same kind of wood there is much difference in the durability; the timber of those trees which grow in moist and shady places is not so good as that which comes from a more exposed situation, nor is it so close, substantial, and durable.

**The best Oak Timber** when new is of a pale brownish-yellow colour, with a faint shade of green, a glossy and firm surface. The more compact it is and the smaller the pores are the longer it will last; but the open, porous, and foxy-coloured oak is weak and not durable. Oak contains gallic acid which corrodes iron, therefore it should be fastened with either galvanised iron or copper screws. Oak shrinks about one thirty-second part of its width in seasoning, and warps and twists much in drying.

**Alder** is extremely durable in water or wet ground, and is valuable for piles, pumps and sluices, and for any purpose where it is constantly wet, but it soon rots when it is exposed to the weather or to damp, and in a dry state it is much subject to worms.

**Elm** is extremely durable in water and makes excellent piles and planking for wet foundations, and is used also for making pumps, keels of ships, &c. Old London Bridge stood upon piles of elm, which remained six centuries without material decay.

**Beech** is durable when constantly immersed in water and is useful for piles in situations where it will be constantly wet, but it rots quickly in damp places and is soon injured by worms.

* See "Carpentry and Joinery." Crosby Lockwood & Co.

**Ash** is durable in a dry situation, but soon rots when exposed to either damp or alternate dryness and moisture. Ash is superior to any other British timber for toughness and elasticity.

**The strength of timber** to resist breaking strains in tension and compressure is given at page 271. The tenacity along the grain is greatest in those woods which have the straightest and most distinctly marked fibres. The tenacity across the grain is about $\frac{1}{7}$ in pine-wood, and $\frac{1}{14}$ in leaf-wood of the tenacity along the grain.

**The resistance to crushing** along the grain depends upon the resistance of the fibres to being split asunder. It averages from 50 to 70 per cent. of the tenacity for dry timber, and half that per-centage for green timber. The resistance to crushing across the grain is considerably less than the resistance to crushing along the grain, in all woods excepting lignum-vitæ, which resists a crushing force with nearly equal strength along and across the grain. Ebony, iron-wood, and box-wood also offer considerable resistance to crushing across the grain.

**The toughest wood** is that which bears the greatest load and bends the most at the time of fracture. The following list shows the comparative toughness of various kinds of timber. Ash being 1·00; beech is ·85; cedar of Lebanon, ·84; larch, ·83; sycamore and common walnut, each ·68; occidental plane, ·66; oak, hornbeam, alder, and Spanish mahogany, each ·62; teak and acacia, each ·58; elm and young chestnut, each ·52.

**Trees** should not be cut down before they arrive at maturity. If cut down before maturity a great part of the tree is sap-wood and the heart-wood is deficient in strength and durability; if allowed to grow beyond maturity the wood is brittle, discoloured, devoid of elasticity, and soon decays. An oak tree arrives at maturity at 100 years of age; the average quantity of timber produced by a tree of that age is about 75 cubic feet; and it should not be felled at a less age than 60 years. Poplars should be cut down when the trees are between 30 and 50 years old; ash, larch, and elm between 50 and 100 years old, and the Norway spruce and Scotch pine between 70 and 100 years old.

**Measuring Timber.**—*To find the Solidity of Round or Unsquared Timber.—Rule:* Multiply the square of $\frac{1}{4}$ of the circumference—or quarter girth—by the length, and the product will be the content.

If the tree tapers regularly the girth must be taken in the middle of the tree. When the taper is not regular several girths must be taken, and their sum divided by their number will give the mean girth, which must be used in the above rule. An allowance for the bark, of from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch for every foot of the quarter girth for ash, elm, beech, and young oak, and of from 1 inch to 2 inches for old oak, is usually deducted from the $\frac{1}{4}$ girth.

*To find the Solidity of Squared or Four-sided Timber.—Rule:* Multiply the mean breadth by the mean thickness, and multiply the product by the length.

Table 145.—LIST OF MINERALS.*

**Arsenical Iron,** an ore containing variable proportions of iron, arsenic, and sulphur, used in the manufacture of white arsenic.

**Azurite,** a valuable azure blue ore of copper, containing about 55 per cent. copper, with carbonic acid and water.

**Bismuth Ochre,** an oxide of bismuth found in Saxony, Bohemia, and Siberia.

**Bornite,** the principal Chilian ore of copper, containing about 59 per cent. copper, with iron and sulphur.

**Cassiterite, or Tinstone,** the commonest ore of tin, containing about 93 per cent. pure tin.

**Ceruscite,** an ore of lead, containing about 83 per cent. metal.

**Chalcoite,** an ore of copper, 75 per cent. metal, with sulphur.

**Chalcopyrite,** copper 33, iron 33, sulphur 33 per cent., the principal ore in Cornwall.

**Chromic Iron** } **Chromite** } the ore of chromium, containing chromium from 27 to 40 per cent., with iron and other metals.

**Cinnabar,** sulphide of mercury; the common ore yields about 80 per cent. metal.

**Cobaltite,** cobalt 33 per cent., with iron, arsenic, and sulphur.

**Copper Pyrites,** *see* Chalcopyrite,

**Cuprite,** a Chilian ore of copper, containing about 88 per cent. of metal.

**Franklinite,** an uncommon ore of iron and zinc, containing iron 45, manganese 9, zinc 20, oxygen 26.

**Galenite,** the only important ore of lead, containing about 75 per cent. of metal, with sulphur and sometimes silver, gold, and other metals.

**Hematite,** one of the commonest iron ores, containing about 75 per cent. metal, and called by different names.

**Ilmenite,** titaniferous iron ore, sometimes containing gold.

**Iron Glance,** specular iron ore, q. v.

**Iron Minium,** red ochre, q. v.

**Kidney Ore,** a hard bubble-shaped form of hematite iron ore.

**Limonite,** the iron mineral which is the basis of bog ores, ochres, &c., containing about 60 per cent. metal.

**Magnetic Iron Ore** } **Magnetite** } the most valuable and common ore of iron, containing about 72 per cent. metal.

**Malachite,** a valuable copper ore, containing about 50 per cent. of metal, much used for ornaments.

**Manganite,** an ore of manganese, containing about 62 per cent.

**Micaceous Iron Ore,** a scaly variety of hematite.

**Millerite,** an ore of nickel, containing 64 per cent., with sulphur.

**Minium,** one of the scarcer ores of lead, containing 90 per cent. of metal, with oxygen.

* This list of minerals is extracted from "The Ironmonger's Diary."

**Niccolite,** an important ore of nickel, containing 44 per cent. of metal, with arsenic.

**Oligiste,** a specular iron ore, q. v.

**Orpiment,** a lemon-yellow arsenic ore, containing 61 arsenic, with 39 sulphur; not much used as ore.

**Puddlers' Ore,** an unctuous form of hematite used in Cumberland for lining the hearths of puddling furnaces.

**Pyrite,** a variable ore of iron, containing iron about 42, with sulphur and other metals.

**Pyrolusite,** an ore of manganese, used in glass and bleaching powder making, containing about 60 per cent. manganese.

**Realgar,** a bright red sulphide of arsenic.

**Red Hematite,** the smelter's name for all iron ores consisting chiefly of anhydrous peroxide of iron.

**Red Ochre,** a compact earthy variety of hematite.

**Rother Glaskopf,** kidney ore (iron).

**Siderite,** an important ore of iron, consisting of ferrous carbonate.

**Smaltite,** an ore of cobalt, found in Saxony, used for making smalt.

**Smithsonite,** a carbonate of zinc, much used as an ore, containing about 50 per cent. metal.

**Specular Iron Ore,** brilliant crystallised hematite.

**Sphalerite,** an abundant ore of zinc, containing about 60 per cent., with sulphur and other metals.

**Stibium** } the principal ore of antimony, containing about 70 per cent. of
**Stibnite** } metal; the black antimony of the shops is this, fused.

**Tetrahedrite,** an ore of copper of variable composition, containing 19 to 25 per cent. of copper, with sulphur and other metals.

**Tin Stone,** cassiterite.

**Titaniferous Iron Ore,** ilmenite.

**Wad,** black manganese ore, of variable composition.

**Zincite,** an ore of zinc yielding about 80 per cent.

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Table 146.—Description of Chemical and Mineral Substances.

**Acetate of Copper** is verdigris.

**Alum** is sulphate of aluminia.

**Aquafortis** is nitric acid.

**Bleaching Powder** is chloride of lime and hydrochloric acid.

**Blue Billy** for lining furnaces, is pure oxide of iron

**Blue Stone or Blue Vitriol** is sulphate of copper.

**Boiler Scale** is carbonate of calcium.

**Burnett's Disinfecting Fluid** is chloride of zinc solution.

**Calamine** is carbonate of zinc.

**Calcium** is the metallic base of lime.

**Calomel** is chloride of mercury.

**Carbon** is pure charcoal.

**Cast-Iron, Grey,** is composed of iron 90·5 parts; combined carbon 1·5; graphite 2·8; silicon 3·1; sulphur 1·1; manganese ·6; and sulphur ·4 parts.

**Chalk** is carbonate of lime.

**Chloroform** is chloride of formyle.

**Citric Acid** is a lemon juice preparation.

**Common Salt** is chloride of sodium.

**Copperas, or Green Vitriol,** is sulphate of iron.

**Corrosive Sublimate** is bichloride of mercury.

**Dentist's Succedaneum** is an amalgam of silver filings and mercury.

**Dextrine** is a gum prepared from potato starch.

**Dry Alum** is sulphate of aluminia and potash.

**Ebonite** is India-rubber mixed with half its weight of sulphur.

**Emerald Green** is sesquioxide of chromium.

**Epsom Salts** is sulphate of magnesia.

**Ethiops Mineral** is black suphide of mercury.

**Ferro-Manganese** is pig iron containing more than 20 per cent. of manganese.

**Flake White** is oxidized carbonate of lead.

**Fluor Spar** is a mineral composed of fluoride of calcium.

**Flux, Black,** is a mixture of carbonate of potash and charcoal.

**Galena** is sulphide of lead.

**Glass used for Windows** is composed of silica 68·8 parts; lime 13; alumina 7; and soda 11·2 parts.

**Glauber's Salts** is suphate of soda.

**Glucose** is grape sugar and potato starch.

**Glycerine** is fat, decomposed with high pressure steam.

**Goulard** is oxide of lead.

**Gunpowder** consists of nitre 75; charcoal 15; and sulphur 10 parts.

**Iron Pyrites** is bisulphide of iron.

**Jeweller's Putty** is oxide of tin.

**Kaolin** is a composition of silica and alumina.

**King's Yellow** is sulphide of arsenic.

**Lamp Black** is the soot from the smoke of burning pitch.

**Laughing Gas** is protoxide of nitrogen.

**Lime** is the oxide of calcium.

**Litharge** is monoxide of lead.

**Lithia** is oxide of lithium.

**Lunar Caustic** is nitrate of silver.

**Marl** is an earth, containing carbonate of lime.

**Marmolite** is silicate of magnesia.

**Massicot** is yellow oxide of lead.

**Meerschaum** is silicated magnesian clay.
**Metallic Oxide** is a metal combined with oxygen.
**Mica** is a transparent mineral.
**Mosaic Gold** is bisulphide of tin.
**Muriate of Soda** is common salt.
**Nitre, or Saltpetre,** is nitrate of potash.
**Ochre** is the hydrated sesquioxide of iron.
**Oil of Vitriol** is sulphuric acid.
**Prussian Blue** is prussiate of potash.
**Putty Powder** is levigated oxide of tin.
**Red Lead** is oxide of lead.
**Rochelle Salt** is tartrate of potash.
**Rust of Iron** is oxide of iron.
**Salt of Lemons** is oxalic acid.
**Size** is an impure gelatin, prepared from hides, &c.
**Slag of Blast Furnaces** is composed of silica 36 parts; lime 38; alumina 14; magnesia 7; ferrous oxide 1·5; manganese oxide 1·4; and calcium sulphide 2·1 parts.
**Smelling Salt** is carbonate of ammonia.
**Soap Stone** is a magnesian mineral.
**Soda** is oxide of sodium.
**Soda Ash** is carbonate of sodium.
**Spiegeleisen** is pig-iron rich in carbon and manganese.
**Spirit of Salt** is hydrochloric acid.
**Spirits of Hartshorn** is ammonia.
**Stalactite** is carbonate of lime.
**Stucco, or Plaster of Paris** is sulphate of lime.
**Sugar of Lead** is acetate of lead.
**Talc** is a magnesian mineral.
**Vermilion** is sulphide of mercury.
**Vinegar** is acetic acid.
**Volatile Alkali** is ammonia.
**Volatile Salt** is ammonia.
**Vulcanite** is India-rubber mixed with half its weight of sulphur.
**Washing Crystals** is crystallised soda and 2 per cent. borax.
**Water** is oxide of hydrogen.
**White Lead** is carbonate of lead.
**White Manganese** is carbonate of manganese.
**White Precipitate** is a compound of ammonia and corrosive sublimate.
**White Pyrites** is a sulphuret of iron.
**White Vitriol** is sulphate of zinc.
**Whiting** is purified carbonate of lime.
**Zinc Chloride** is zinc dissolved in hydrochloric acid.
**Zinc White** is oxide of zinc.
**Zinkenite** is an ore of antimony and lead.

Table 147.—Weight, Bulk, Composition, Heat, and Evaporative Power of Coal, and other Fuels.

| Description of Coal. | Specific Gravity. | Weight and Bulk. | | Composition per Cent. | | | | | | Heat in Degrees F. to which 1 lb. of Water will be raised by 1 lb. of the Fuel in conjunction with Oxygen. | Lbs. of Water heated from the Freezing Point to 212° F. by 1 lb. of Fuel. | Lbs. of Water at 212° F. converted into Steam by 1 lb. of Fuel. | Percentage of Coke produced from the Coals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 Cubic Foot Solid. | Bulk of 1 Ton Heaped. | Carbon. | Hydrogen. | Oxygen. | Nitrogen. | Sulphur. | Ash. | | | | |
| | | lbs. | Cubic ft. | | | | | | | | | | |
| Welsh . . | 1·31 | 82· | 43 | 84 | 4·6 | 4·0 | 1· | 1·5 | 4·9 | 14833 | 82·4 | 15·0 | 74 |
| Newcastle . . | 1·25 | 78·1 | 46 | 83 | 5·3 | 5·31 | 1·35 | 1·24 | 3·8 | 14796 | 82·2 | 14·9 | 61 |
| Scotch . . | 1·26 | 78·6 | 42 | 79 | 5·6 | 9·3 | 1·0 | 1·1 | 4·0 | 14150 | 78·6 | 14·3 | 54 |
| Derbyshire . | 1·29 | 80·6 | 48 | 80 | 4·9 | 10·0 | 1·4 | 1·0 | 2·7 | 13919 | 77·3 | 14·1 | 59 |
| Lancashire . | 1·27 | 79·4 | 46 | 78 | 5·3 | 9·1 | 1·3 | 1·4 | 4·9 | 13890 | 77·2 | 14·0 | 58 |
| Yorkshire . . | 1·29 | 80·6 | 48 | 80 | 4·9 | 10·0 | 1·4 | 1·0 | 2·7 | 13919 | 77·3 | 14·1 | 59 |
| Coke . . | 0·75 | 48· | 80 | 94 | ... | ... | ... | 1·0 | 5·0 | 13800 | 77·2 | 14·0 | |
| Peat, dry . . | 0·55 | 35· | 200 | 60 | 6· | 29· | 1· | ... | 4·0 | 9940 | 55·1 | 10·0 | |
| Wood, dry . | 0·54 | 34· | 140 | 50 | 6· | 41· | 1· | ... | 2·0 | 7870 | 44·3 | 8·0 | |
| Straw . . | 0·12 | 8· | 280 | 36 | 5· | 38· | ·4 | ... | 5·0 | 3935 | 22·1 | 4·0 | |

Note.—The average weight of loose coal heaped is 50 lbs. per cubic foot, and 45 cubic feet bulk per ton; and the average weight of loose coke heaped is 30 lbs. per cubic foot, and 80 cubic feet bulk per ton.

## CEMENTS FOR THE LABORATORY AND WORKSHOP.*

**Acid-proof Cement.**—Mix a concentrated solution of silicate of soda, with powdered glass to form a paste.

**Aquarium Cement.**—Mix white lead, red lead, and boiled oil together, with gold size to the consistency of putty. If required to be dark in colour, mix lamp black with it.

**Another Aquarium Cement.**—1 gill, litharge; 1 gill, plaster of paris; 1 gill, fine dry white sand; and ⅓rd gill each of powdered resin and red lead; mix into a stiff putty with boiled oil, to which a little gold size has been added.

**Waterproof Cement.**—Powdered resin, 1 oz., dissolved in 10 oz. strong ammonia.

**China and Earthenware Cement.**—Dilute white of egg with its bulk of water; mix to the consistency of paste with powdered quicklime.

**China and Earthenware Cement.**—Dissolve isinglass in hot water, and add acetic acid.

**Another China Cement.**—Finely powdered glass, mixed with white of egg.

**Office Paste.**—Strong, and does not soon turn sour: ½ oz. alum, dissolved in 1 pint of water; add flour, and when boiled, add ¼ oz. resin, and again boil until properly dissolved and mixed.

**Electric Cement for fastening Brass Work to Glass Tubes.**—Resin, 5 oz.; beeswax, 1 oz.; red ochre or Venetian red in powder, 1 oz.

**Fire-proof Cement.**—Linseed oil, 4 oz.; handful of quicklime powdered; boil till thick and cool and harden; then dissolve and use in the same way as ordinary cement.

**Elastic Glue.**—Dissolve glue in a water bath; evaporate to a thick fluid, and add an equal weight of glycerine; cool on a slab.

**Liquid Glue.**—White glue, 16 oz.; dry white lead, 4 oz.; soft water, 2 pints; alcohol, 4 oz.; stir and bottle while hot.

**Another Liquid Glue.**—Glue, 3 pints, softened in 8 parts water; add ½ pint muriatic acid and ¾ pint sulphate of zinc; heat to 176° F. for 12 hours; then allow it to settle.

**Cement for Gutta percha.**—2 parts, common black pitch; 1 part, gutta percha.

**Marine Glue.**—Pure india-rubber, 1 pint, dissolved by heat in mineral naphtha; when melted add, shellac, 2 pints, and cool on a slab.

**Marine Glue, another.**—Glue, 12 pints; water to dissolve, and yellow resin, 3 pints; melt, add turpentine, 4 pints, and mix.

**Portable Glue for Draughtsmen.**—Glue, 5 oz.; sugar, 2 oz.; water,

* The Author is indebted for some of these receipts to "The Engineer," and "The English Mechanic."

8 oz.; melt in water bath; cast in moulds; and dissolve for use in warm water.

**Portable Glue for Thin Paper.**—Gelatine, 1 lb., dissolved in water, and water evaporated till nearly expelled; add ½ lb. brown sugar, and pour into moulds.

**Glue for Damp Wood.**—Soak glue in water until soft; then dissolve in smallest amount of proof spirit by gentle heat; in 2 lbs. of the mixture dissolve 10 grains gum ammoniacum, and while liquid add half a drachm of mastic dissolved in 3 drachms rectified spirit.

**Glue to resist Damp.**—Boil linseed oil with ordinary glue.

**Gum for Paper Labels.**—Dextrine, 2 oz.; acetic acid, 1 oz.; water, 5 oz.; alcohol, 1 oz.; add the alcohol to the other ingredients when the dextrine is dissolved.

**Cement for Papier Mache, Cards, &c.**—Dissolve isinglass in alcohol and add sufficient rice flour to thicken; warm gently, and add a small quantity acetic acid.

**Tough Cement for Paper, Cards, Linen, &c.**—Mix 8 oz. rice flour with cold water; simmer gently, and then add 2 oz. glue dissolved in water, and alum 1 oz.

**Tough Glue Cement.**—Soak Russian glue for 12 hours in cold water; pour off the water, and add sufficient glacial acetic acid; dissolve in a hot water bath.

**Glue to resist Moisture.**—1 lb. glue melted in 2 quarts skimmed milk.

**Glue to resist Moisture, another.**—1 glue; 1 black resin; ¼ red ochre; melt and mix.

**Thick Glue Cement to resist Moisture.**—Shellac, 4 oz.; borax, 1 oz.; boil in a little water, and concentrate by heat to a paste.

**Tough Glue Cement.**—To ordinary glue add ¼ part vinegar and a little glycerine; mix plaster of paris with it to the required consistency.

**Cement for Parchment and Card Board.**—Powdered Chalk and a little glycerine mixed with common glue.

**Litharge Cement.**—Litharge, 1 oz.; plaster of paris, 1 oz.; powdered resin, ⅓ oz.

**Cementing Metal to Glass.**—Copal varnish, 15: drying oil, 5; turpentine, 3; melt in a water bath, and add 10 parts slacked lime.

**Cementing Metal to Glass; another.**—Mix 2 parts powdered litharge and 1 part white lead; mix 3 parts boiled linseed oil with 1 part copal varnish, and stir the powder into the liquid.

**Cement for Joining Metals to Wood.**—Dissolve in boiling water, glue, 2¼ lb.; gum ammoniacum, 2 oz.; adding, in small quantities, 2 oz. sulphuric acid.

**Cement for Joining Metals to Earthenware.**—Washed fine sand, 20 parts; litharge, 2 parts; powdered quicklime, 1 part; mix with boiled linseed oil, and colour with any pigment.

**Cement for Iron Stove Pipes and for filling Cracks in Stoves.**—Equal parts pulverised clay and fine wood ashes, and a little salt; mix with water to the consistency of putty.

**Cement for Stoves and Ranges.**—Mix fire clay, with a solution of silicate of soda.

**Cement for Chemical Apparatus.**—Melt and mix starch, glycerine, and gypsum to required consistency.

**Cement for Joining Metals to Bone, Ivory, and Wood.**—Mix litharge with glycerine to the required consistency.

**Cement for Leather, Canvas, Cloth, Parchment, &c.**—Melt and mix glycerine with glue.

**Cement for Thick Leather.**—Melt and mix glycerine with glue, and add pure tannin to proper consistency.

**Pale Tough Cement.**—Dissolve 75 parts of white indiarubber in 6 parts chloroform, and add 15 parts mastic and a little glycerine.

**Porcelain Cement.**—Add plaster of paris to a strong solution of alum.

**Cement for Fastening Metal Tops on Oil Lamps.**—5 parts water, boiled with 3 parts resin, 1 part of caustic soda, and mix with half its weight of plaster of paris.

**Cement for Fixing Brass Letters on Glass.**—Copal varnish, 15 parts; drying oil, 5 parts; turpentine, 2 parts; liquified marine glue, 5 parts; melt in a water bath, and add 10 parts dry slacked lime.

**Tough Cement for Various Purposes.**—Guttapercha, 1 lb.; indiarubber, 4 oz.; dissolved in bisulphide of carbon; pitch, 2 oz.; shellac, 2 oz.; boiled oil, 2 oz.; melted together.

**White Cement for Shells and Various Purposes.**—Best gelatine, 1 oz., dissolved in water; then add ½ drachm glacial acetic acid and a small quantity of powdered and sifted calcined oyster shells.

**Cement for Coating Acid Troughs.**—Melt together, 1 part pitch, 1 part resin, and 1 part plaster of paris.

**Thick White Cement.**—Resin, 4 oz.; beeswax, 1 oz.; plaster of paris, 5 oz.; borax, ½ oz.

**Cement for Fixing Iron Bars into Stone.**—A compound of equal parts of sulphur and pitch.

**Indiarubber Cement.**—Dissolve 2 oz. of pure white raw indiarubber in ½ pint benzoline or bisulphide of carbon; heat in a hot water bath.

**Cutlers' Cement for fastening the Blades of Knives into Handles.**—Resin, 4 parts; beeswax, 1 part; brickdust, 1 part. Another cement for the same is: resin, 4 parts; pitch, 4 parts; tallow, 2 parts; brickdust, 2 parts.

**Cement for Box Wood and other Hard Woods.**—Dissolve ½ oz. isinglass in alcohol; and mix sugar, ½ oz.; box wood filings, 1 oz.; and add a little acetic acid.

**Cement for Cementing Emery to Wood.**—Melt and mix equal parts of shellac, white resin, and carbolic acid in crystals; add the acid after the others are melted.

**Strong Paste Cement.**—Glue, 1 part; flour, 4 parts; add sufficient water and boil gently; then add a little glacial acetic acid and mix well.

**Paste for Labelling Tin and Iron, &c.**—To ordinary paste add a small quantity each of glue and chloride of calcium. Another is: to 8 oz. of paste add 20 drops of a solution of chloride of antimony. And another is: 10 oz. mucilage of gum tragacanth; 10 oz. honey of roses; and 1 oz. flour.

**Waterproof Cement.**—Gelatine, 5 parts; solution of acid chromate of lime, 1 part; after using, expose the article to sunlight.

**Waterproof Paste Cement.**—To hot starch paste, add ½ its weight of turpentine and a small piece of alum.

**Cement for Repairing Bronze and Zinc.**—Mix powdered chalk and zinc-dust, and stir them into soluble glass solution of 30 B, until the mixture is fine and plastic.

**Cement Lining for Inside of Cisterns.**—Powdered brick, 2; quick-lime, 2; wood ashes, 2; made into paste with boiled oil.

**Cement for Seams and Joints of Stone Cisterns, &c.**—Powdered brick, 6; white lead, 1; litharge, 1; mixed to a paste with boiled linseed oil.

**Cement for Joining Porcelain Heads to Metal Bars.**—Mix Portland cement with hot glue.

**Cement for Fixing Tiles in Grates and Fireplaces.**—Mix with hot glue, to the consistency of mortar, equal parts, sand, plaster of paris, and hair mortar.

**Cement for Alabaster.**—Melted alum.

**Strong White Cement.**—Mix finely powdered rice into a paste with cold water, add warm water to the proper consistency, boil for five minutes, and add a small quantity each of dissolved isinglass and acetic acid.

**White Cement.**—Plaster of paris mixed with alum water.

**White Cement.**—White lead, whiting, a small piece glycerine, well mixed with a little dissolved isinglass to the required consistency.

**Common Black Sealing Wax.**—Common resin, 6 lb.; yellow beeswax, ½ lb.; lamp black, 1 lb.

**Common Red Sealing Wax.**—Window glass resin, 6 lb.; white beeswax, ½ lb.; colour with venetian red.

**Sealing Wax.**—Venice turpentine, 4½ oz.; shellac, 9 oz.; colophony, 3 oz.; and enough pigment mixed with turpentine to colour it.

**Sealing Wax.**—Resin, 6 lb.; red ochre, 1 lb.; plaster of paris, ½ lb.; linseed oil, 1 oz.

**Sealing Wax.**—Resin, 50 parts; red lead, 37 parts; turpentine, 13 parts.

**Shoemakers' Wax.**—Melt equal parts pitch and resin; then add a little tallow; pour into water, and pull it into cords till tough; cut into pieces and keep in water.

**Heel-ball.**—Mix together beeswax and vegetable black, and enough resin to give it the required hardness.

**Strong Cement.**—Equal parts guttapercha and shellac, melted and mixed with a little white lead.

**Tough Cement.**—White raw indiarubber, 2 oz.; isinglass, ¼ oz.; guttapercha, 3 oz.; bisulphide of carbon, 8 oz.; heat in a hot water bath.

**Cement for Fixing Paper on Glass.**—Soak glue in vinegar, boil, and add flour to required consistency.

**Cement for Worm-eaten Wood.**—Mix whiting with phenic acid and essence of turpentine, and a little linseed oil; before applying, paint the wood over, and allow it to soak in, with a mixture of 1 oz. chili capsicum and 1 quart benzoline, properly dissolved

**Cement for Filling up Cracks in Stove Grates.**—Make a paste of pulverised iron and water glass.

**Waterproof Cement used by Calico Printers.**—1 lb. binacetate of copper and 3 lb. sulphate of copper, dissolved in 1 gallon of water, and the solution thickened with 2 lb. gum sanegal; 1 lb. British gum; 4 lb. pipe-clay, and 2 oz. nitrate of copper are afterwards added.

**Cement for Fastening Cloth on to Metal and Wood Rollers.**—Common glue and isinglass, equal parts; soak in small quantity of water for 10 hours; then boil, and add pure tannin till it becomes thick; apply hot.

**Cement for Marble.**—20 parts, fine sand; litharge, 2; dry slacked lime, 1; plaster of paris, 1; make into a putty with boiled linseed oil.

**Cement to resist White Heat.**—Pulverised clay, 4 parts; plumbago, 1; iron filings, free from oxide, 2; peroxide of manganese, 1; borax, ½; sea-salt, ½; mix with water to thick paste; use immediately, and heat gradually to a nearly white heat.

**Jewellers' Cement.**—Isinglass, ½ oz.; gum mastic, ½ oz.; gum ammoniacum, 1 drachm; dissolve in alcohol; heat and well mix.

**Cabinet Makers' Cement for Fastening Cloth and Leather, &c., on to Wood.**—Boil 1 lb. rye flour into a thick paste with water; next melt 3 oz. glue in a little water, and add 2 oz. treacle; add this mixture to the paste, and boil with water to the required consistency.

**Non-conducting Cement, for Covering Boilers and Steam Pipes.**—Portland cement, 1 part; flour, 2; fine sand, 1; sawdust, 4 parts; mix these dry, and then add, clay, 4 parts; plasterers' hair, ½ part; mix well together with water to the consistency of mortar; apply with a trowel to the thickness of an inch; when dry, apply successive coats of same thickness until from 5 to 7 inches thickness of composition is applied; let each coat dry before applying another, and finally give it 2 or 3 coats of tar.

**Cement for Joints, to resist Great Heat.**—Asbestos powder made into a thick paste, with liquid silicate of soda.

**Cement for Steam and Water Joints.**—Ground litharge, 10 lbs.; plaster of paris, 4 lbs.; yellow ochre, ½ lb.; red lead, 2 lbs.; hemp cut into ½ inch lengths, ½ oz.; mix with boiled linseed oil to consistency of putty.

**Cement for Steam and Water Joints.**—White lead, 10 parts; black oxide of manganese, 3; litharge, 1 part; mix with boiled linseed oil to consistency of putty.

**Cement for Cisterns and Watercourses.**—Powdered burnt clay, 50 parts; powdered fire brick, 40 parts; litharge, 10 parts; mix with boiled linseed oil to consistency of thin plaster. Wet the parts to be covered with water before applying.

**Cement for Cisterns.**—Ground litharge, 5 parts; concentrated glycerine, ½ part; plaster of paris, 4 parts; fine sand, 1 part; resin, ½ part; mix with boiled linseed oil to consistency of plaster.

**Rust Joint Cement for Cast Iron Cisterns.**—Cast iron borings, 5 lb.; powdered salammoniac, 1 oz.; flour of sulphur, 2 oz.; mix with water. If not required for immediate use, a better cement is composed of: cast iron borings, 6 lbs.; powdered salammoniac, 1 oz.; flour of sulphur, ½ oz.; mix with water.

NOTE.—The cubic contents in inches of the joint, divided by 5, will be approximately the weight of dry borings required to make the joint.

**Red Lead Cement for Faced Steam Joints.**—White lead, 1 part; red lead, 1 part; mix with boiled linseed oil to the consistency of putty.

**Cement for Faced Steam Joints to stand Great Heat.**—Plumbago, 1 part; red lead, 1; white lead, 1 part; mix with boiled linseed oil to consistency of putty.

**Steam Joints.**—Lead wire makes an excellent joint.

**Cement for Furnaces.**—Fire clay, 1 part; burnt fire clay, 1 part; mixed with sufficient silica of soda to make it plastic.

**Cement for Leather Belts.**—Guttapercha, 3; pure white raw indiarubber, 1; dissolved in 8 of bisulphide of carbon.

**Cement for Leather Belts.**—Another one is:—Guttapercha, 16; pure white raw indiarubber, 4; dissolve; then add pitch, 2; shellac, 1; boiled linseed oil, 2.

**Turners' Cement.**—Burgundy pitch, 2 lbs.; resin, 2 lbs.; yellow wax, 2 oz.; melt, and add 2 lbs. of whiting; pour out on a slab and roll into sticks.

**Enamel Glaze Cement for Coating Iron Pans.**—Flint glass, 130 parts; carb. soda, 20·5; boracic acid, 12 parts; dry at a temperature of 100 C.; heat to redness and anneal.

**Cement for Fastening Leather on Iron Pulleys.**—Soak for 10 hours 1 part crushed nut-galls in 8 parts water; strain, and apply hot to the leather. Pulley to be warmed and coated with glue mixed with a little treacle.

Another cement for same is:—1 part isinglass, 5 parts fish glue, dissolved in 6 parts water; then add gently 1 part nitric acid.

## PAINTS, WOOD STAINS, AND VARNISHES.*

**Painting Machinery.**—Rough castings spoil the look, and lower the value, of machinery. A nice smooth surface can be cheaply, and efficiently got up, as follows. First chip off all rough projections on the casting, and rub it hard all over with a piece of sandstone; next give it a coat of thin good oil paint. When dry, fill up all rough and hollow places with putty made of white lead, lampblack or dry lead paint, and gold size, which will set hard. Next thin the said mixture down to the consistency of treacle with spirits, and give the casting a coat of it. When dry, rub the casting down to a smooth surface with pumice stone and water, and give it two finishing coats of paint.

**Tar Paint for Iron Work.**—Gas tar, 7 parts; naphtha, 1 part.

**Paint for Iron Work exposed to Weather.**—Red oxide of iron, ground in oil, mixed with equal parts boiled linseed oil and turpentine, with 1 oz. of patent dryers to the lb.

**Paint to prevent Dry Rot.**—Wood tar, 1 part; train oil, 1 part; oil of cassia, 1 part; apply three coats of it.

**Paint for Stone.**—Browning's solution for protecting the surface of stone consists of 85½ per cent. by weight of benzoline; 10 of gum dammar; 2 of sugar of lead; 2 of wax, and ½ per cent. of corrosive sublimate. Apply with a brush, after having cleaned the surface of the stone.

**Paint for Wire.**—Mix linseed oil with as much litharge as will make it the required thickness; add $\frac{1}{10}$th part of lampblack. Boil for 3 hours, and apply in thin coats.

**Flexible Paint for Canvas.**—Yellow soap, 2½ lbs.; boiling water, 1½ gallons; dissolve and grind the solution while hot with 125 parts oil paint.

**Paint for Blackboards.**—Finely powdered pumice stone, 4 oz.; powdered rottenstone, 3 oz.; red lead, 1 oz.; lampblack, 8 oz.; glycerine, 1 oz.; mix and make into a paste with shellac varnish, and then add 2 quarts shellac varnish; apply 2 coats; stir well.

**Anti-oxidation Paint.**—Red lead, 8 parts; zinc in powder, 10 parts; dryers, 2 parts; linseed oil, 80 parts. Make only as much as is required for the time, and apply quickly when fresh.

Table 148.—Composition of Oil Varnishes.

| | No. 1 Varnish. | No. 2 Varnish. | No. 3 Varnish. | No. 4 Varnish. | No. 5 Varnish. |
|---|---|---|---|---|---|
| | oz. | oz. | oz. | oz. | oz. |
| Amber | 2 | 2 | 4 | ... | ... |
| Shellac | ... | ... | 1 | ... | ... |
| Pale copal | ... | ... | ... | 4 | ... |
| Pale resin | ... | ... | ... | ... | 3 |
| Drying linseed oil | 5 | 5 | 4 | 8 | ... |
| Oil of turpentine | 6 | 5 | 8 | 12 | 8 |

* The Author is indebted for some of these receipts to "The Engineer," and "The English Mechanic."

Varnishes No. 1 and 2 are dissolved by heat. No. 3 varnish:—first dissolve the shellac; then add the amber, and dissolve by heat. No. 4 varnish:—boil the copal and drying oil until stiff; thin with the oil of turpentine, and strain.—No. 5 varnish dissolve.

Table 149.—Composition of Spirit Varnishes.

| | No. 6 Varnish. | No. 7 Varnish. | No. 8 Varnish. | No. 9 Varnish. | No. 10 Varnish. | No. 11 Varnish. | No. 12 Varnish. | No. 13 Varnish. |
|---|---|---|---|---|---|---|---|---|
| | oz. | oz. | oz. | oz. | oz. | oz. | oz. | oz. |
| Sandarac | 2 | 8 | ... | 4 | 2 | ... | 1 | 1 |
| Best shellac | 1 | ... | 5 | 2 | 5 | 10 | 5 | 4 |
| Mastic | ½ | ... | ... | 1 | ... | 2 | 1 | 1 |
| Benzoin | ... | ... | ... | 1 | ... | ... | 1 | 1 |
| Powdered glass | 1 | ... | ... | 4 | 5 | ... | ... | ... |
| Venice turpentine | 1 | 2 | 1 | 2 | 2 | ... | ... | 1 |
| Elemi | ½ | ... | ... | ... | 1½ | ... | ... | ... |
| Alcohol | 6 | 32 | 32 | 32 | 24 | 32 | 32 | 32 |

Varnishes can be "paled" by adding 2 drachms of oxalic acid per pint of varnish. They can be coloured red with dragons' blood; brown, with logwood or madder; yellow, with aloes or gamboge; each digested in spirits and strained.

**Colourless Spirit Varnish.**—Dissolve 5 oz. best shellac in a quart of rectified spirits of wine; boil for a few minutes with 10 oz. of good well-burnt animal charcoal; filter first through silk and then through blotting-paper.

**Colourless Spirit Varnish.**—Dissolve bleached shellac in alcohol; when clear, pour off and add spirits of wine until the required thickness is obtained. Bleached shellac should be kept in the dark, and used immediately after bleaching.

**Black Varnish.**—Melt 1 lb. amber and add ½ pint hot linseed oil, and then add 3 oz. each of black resin and asphaltum; when nearly cold, add 1 pint oil of turpentine.

**Ebonising Wood.**—Mix logwood, 2 lbs.; tannic acid, 1 lb.; sulphate of iron, 1 lb.; apply hot.

**Ebonising Wood.**—Water, 2 gallons; logwood chips, 2 lbs.; black copperas, 1 lb.; logwood extract, 1 lb.; indigo blue, 1 lb.; lampblack, ¼ lb.; boil, cool, and strain, and add ½ oz. nut-galls.

**Brunswick Black.**—Melt 4 lbs. asphaltum; add 1 quart boiled linseed oil, and 1 gallon oil of turpentine.

**To Remove Old Paint.**—Use a strong solution of caustic soda. Another way is to use a mixture of 1 lb. pearlash and 3 lbs. quicklime and water; let it soak into the paint for 12 hours.

**Renovating Polish for Wood Work.**—Olive oil, 1 lb.; rectified oil of amber, 1 lb.; spirits of turpentine, 1 lb.; oil of lavender, 1 oz.; alkanet root, ½ oz. Another renovating polish is—pale linseed oil, 2 pints; strong distilled vinegar, ½ pint; spirit of turpentine, ¼ pint; muriatic acid, 1 oz.

**Stains for Wood.**—*Red.*—Brazil wood, 11 parts; alum, 4 parts. Boil. *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; water, 10 parts; alum, 1 part. Boil. *Purple.*—Logwood, 11 parts; alum, 3 parts; water, 29 parts. Boil.

**Walnut Stain.**—Boil 2 quarts of water, add 3 oz. washing soda, and then, by a little at a time, add 5 oz. vandyke brown; when the foaming ceases, add ½ oz. bichromate of potash.

**Brown Stain.**—Dissolve permanganate of potash in water.

**Rosewood Stain.**—Alcohol, 2 gallons; camwood, 3 lb.; red sanders, 1 lb.; aquafortis, ¼ lb. Apply 3 coats: rub with sandpaper; grain with iron rust; shade with asphaltum, thinned with turpentine. In staining wood, depth of colour may be obtained by giving several coats of stain; rub down with fine sandpaper, and give two coats of size before varnishing. For dark wood—varnish with French polish, 1 part; brown hard varnish, 2 parts. For light wood—varnish with 2 parts white French polish, and 3 parts white hard varnish.

**Staining Floors.**—*Oak Stain.* American potash, 2 oz.; pearlash, 2 oz.; water, 1 quart. *Mahogany Stain.*—Madder, 8 oz.; logwood chips, 2 oz.; boil in 1 gallon water, and apply hot. When dry, paint it over with a solution of—water, 1 quart; pearlash, 2 drachms; next, size and polish.

**Polishing Stained Floors.**—After sizing, apply the following polish, viz.: white wax, 4 parts; yellow wax, 8 parts; castile soap, 1 part; soft water, 20 parts; turpentine, 20 parts; the soap to be melted in the water, the wax to be dissolved in the turpentine. Mix the whole, brush it on the floor, and well rub with a cloth pad.

**To Darken Mahogany.**—Apply a solution of bichromate of potash.

**Green Varnish for Metals.**—Bronze green—strong vinegar, 2 quarts; mineral green, 1 oz.; raw umber, 1 oz.; salammoniac, 1 oz.; gum arabic, 4 oz.; French berries, 1 oz.; copperas, 1 oz.; dissolve with gentle heat, cool, and filter.

**Green Transparent Varnish.**—Chinese blue, 1 oz.; powdered chromate of potassa, 2 oz.; well ground and mixed; add a sufficient quantity of copal varnish and thin with turpentine.

**Waterproof Varnish.**—Dissolve guttapercha, 4 oz., resin, 2 oz., in bisulphide of carbon, and add 2 lb. hot linseed oil varnish.

**Pattern Makers' Varnish.**—Methylated spirit, 1 gallon; shellac, ½ lb.; plumbago, ½ lb.; dissolve and frequently stir.

**Varnish for Drawings.**—Dissolve by gentle heat, 8 oz. sandarac in 32 oz. alcohol. Another is—Dissolve 2 lb. mastic and 2 lb. dammar in 1 gallon turpentine, without heat. The drawing to be first sized, with a strong solution of isinglass and hot water.

## WORKSHOP RECEIPTS.

**Composition for Taking Impressions and Casts.**—4 parts black resin; 1 part yellow wax.

**Flexible Composition for Taking Impressions and Casts.**—Glue, 12 parts; melt and add treacle, 3 parts.

**Modelling Clay.**—Knead dry clay with glycerine.

**Modelling Wax.**—Equal parts of beeswax, lead plaster, olive oil, and yellow resin; add whiting enough to make a paste.

**Flux for Brass.**—1 oz. common soap; ½ oz. quicklime; ¼ oz. saltpetre; mix into a ball, and place in the crucible when lifted out of the furnace. This is sufficient for about 50 lbs. of metal.

**Dusting for Moulds for Brass Work.**—To produce castings with a clean face and fine skin: for light castings of brass and gun metal, after moulding, first dust the moulds with pea-meal, and on the top of same add a slight dust of plumbago. For heavy gun metal castings, dust only with plumbago.

**Plumbago Crucibles** are made of 2 parts graphite and 1 part fire clay.

**Fire-clay Crucibles.**—2 parts Stourbridge clay; 1 part finely powdered hard gas coke.

**Berlin Crucibles.**—8 parts Stourbridge clay; 3 old crucibles ground finely; 5 coke; 4 graphite.

**To Prevent Castings Shaking after being Cast on to Wrought Iron.**—Split the end of the wrought iron bar, and well jag the same.

**To Remove Sand and Scale from Small Castings of Iron.**—Pickle for 14 hours in a solution of water, 4 parts; oil of vitriol, 1 part.

**To Clean the Surface of Copper.**—Scour with muriatic acid and fine sand, and rinse with water.

**To Clean Tarnished Bronze and Brass Work.**—Rub with a paste made of oxalic acid, 1 oz.; rottenstone, 6 oz.; powdered gum arabic, ½ oz.; sweet oil, 1 oz.; water sufficient to make a paste; rinse with water, and finish with whiting and leather. A golden colour may be given to clean brass by first pickling it, and dipping for a few seconds in a solution of water, muriatic acid, and alum.

**To Clean Silver.**—Apply the following solution with a soft brush:—cyanide of potassium, 4 drachms; nitrate of silver, 10 grains; water, 4 oz.; afterwards wash well with water, dry, and polish with soft wash leather.

**To Clean Silver.**—Another method is to brush it, with a solution of water, and hyposulphate of soda.

**Polishing Brass Work in a Lathe.**—Use old burnt crucibles, reduced to a fine powder.

**In Turning Very Hard Iron or Steel** use a drip for the tool, of petroleum, 2 parts; turpentine, 1 part; and add a little camphor.

**Water Tests.**—To ascertain if water is hard, put a few drops of soap dissolved in alcohol into a glass of water; if the water is hard, it will become milky. To ascertain if water contains iron, put a small piece of prussiate of potash into a glass of water; if the water contains iron, it will become a blue colour.

**To Remove Nuts which have Rusted Fast on Bolts.**—Make a funnel of clay round the nut, and fill it with petroleum, and let it remain for a few hours.

**To Prevent Lamp Glasses from Breaking.**—Anneal, by placing the glass in cold water, with some common salt added; raise to a boiling heat, gently. Boil for 20 minutes, and allow to cool slowly; the glass not to be removed until the water is quite cold.

**Self-Lubricating Bearings.**—In hard gun metal bushes,—bored and fitted to the shaft to bear properly all over,—drill 4 holes per superficial inch, each $\frac{1}{4}$ inch diameter × $\frac{1}{4}$ inch deep. The holes to be flat at the bottom, and to be spaced in zigzag rows, so that the holes in one row divide the spaces between the holes in the other row—and fill the holes with the following compound, viz.:—Melt 1 lb. solid paraffin, and add a small quantity each of litharge, dissolved isinglass, and sulphur; and then add 2 lb. fine plumbago, and mix thoroughly.

**Antifriction Lubricating Compound for the Bearings of Engines and Shafting, and for Cylinders.**—Lubricating paraffin oil, 1 gallon; solid paraffin, 2 lb.; plumbago, finest, 2 lb.; melt and mix thoroughly.

**Axle Grease.**—Tallow, 8 lb.; palm oil, 1 gallon; mineral oil, 1 gallon; plumbago, 1 lb.; melt and mix.

**Axle Grease.**—Water, 1 gallon; mineral oil, 1 gallon; tallow, 4 lbs.; palm oil, 6 lb.; soda, $\frac{1}{2}$ lb.; melt and mix.

**Grease for Wood Toothed Wheels.**—Make a thin mixture of soft soap, and plumbago.

**Machinery Oil.**—A good oil for machinery consists of a mixture of good mineral oil, 15 gallons; rape oil, 6 gallons; lard oil, 4 gallons.

**To Preserve Steel Instruments from Rust.**—Rub the steel with vaseline. Another receipt for the same purpose is:—Mix equal parts of olive oil and carbolic acid. Another receipt is:—Camphor, $\frac{1}{2}$ oz., dissolved in $\frac{1}{2}$ pint olive oil. Another receipt is:—$\frac{1}{2}$ pint fat oil varnish, mixed with $2\frac{1}{2}$ pints rectified spirits of turpentine.

**To Preserve Metals from Rust** use one of the following methods:—(1.) Cover with a mixture of white lead and tallow. (2.) Mixture of equal parts beeswax and ozokerit, melted together. (3.) Camphor, $\frac{1}{2}$ oz., dissolved in 1 lb. of melted lard; take off the scum and mix in as much black lead as will give it an iron colour. Coat with this mixture, and let it remain on for 24 hours; then wipe off with a linen cloth;—or a better result will be got by leaving it on, if the articles are exposed to much damp. (4.) Coat with a mixture of paraffin oil, solid paraffin, and black lead.

**To Refine Oil for Fine Mechanism.**—Add equal parts of lead and zinc shavings to best olive oil, and leave it in a cool place until the oil becomes colourless.

**Waterproofing Canvas.**—Water, 1½ pint; hard yellow soap, 6 oz.; when boiling, add 5 lb. boiled linseed oil and ½ lb. patent dryers. Another method is to steep the canvas first in a solution of water, with 20 per cent. of soap, and afterwards into a solution containing 20 per cent. sulphate of copper.

**Waterproofing Calico.**—Boiled linseed oil, 1 quart; soft soap, 1 oz.; beeswax, 1 oz.; the whole to be boiled down to three-fourths of its previous quantity. Another method is—hard yellow soap, 4 oz., cut into shavings, and beat with sufficient water to the consistency of cream; then stir it well into 1 pint boiled linseed oil. Apply with a brush on one side of the calico only.

**Tarpaulin Dressing for Waterproofing Sheets for Railway Wagons and Carts, &c.**—Linseed oil, 95 gallons; litharge, 8 lbs.; umber, 7 lb.; boil for 24 hours, and colour with vegetable black, 8 lbs.

**Waterproofing Brick Walls.**—Soft paraffin wax, 2 lb.; shellac, ½ lb.; powdered resin, ½ lb.; benzoline spirit, 2 quarts; dissolve by gentle heat in a water bath; then add 1 gallon benzoline spirit; and apply warm. Being very inflammable, keep it away from fire.

**Waterproofing Woollen Cloth.**—Mix ½ lb. alum and ½ lb. sugar of lead in 2 gallons of rain water; stir up repeatedly at intervals during 3 hours; then allow to settle, and pour off the clear solution, in which immerse the cloth for 24 hours; after which let the cloth drip and dry, without wringing. Another method is to dissolve equal parts of isinglass, alum, and soap in water; each to be dissolved separately, and then all well mixed together; brush the solution on the wrong side of the cloth, and dry; afterwards brush the cloth well first with a dry brush, and then brush lightly with a brush dipped in rain water, and dry. Another process is:—boil the cloth in a solution of water, 1 gallon; soap, 2 oz.; glue, 4 oz., for several hours; afterwards wring and dry; and then steep for 10 hours in a solution of water, 1 gallon; alum, 13 oz.; salt. 15 oz.; wring and dry at 80° temperature.

**Waterproofing Packing Paper.**—First dissolve 1¾ lb. of white soap in 1 quart water; next dissolve 2 oz. of gum arabic and 5 oz. glue in a quart of water; mix the two solutions and heat; soak the paper in the mixture and hang up to dry.

**Waterproof Dressing for Leather.**—Beeswax, 1 oz.; powdered resin, 1 oz.; soap, 3 oz.; castor oil, 1 pint; boiled oil, 1 quart; boil, and afterwards thin to proper consistency with warm oil of turpentine.

**Mixture for Preserving Leather Belts.**—First wash the belt with warm water, and apply a mixture of castor oil, 2 quarts; tallow, 1 lb.; powdered resin, 1 oz.; hard soap, 2 oz.; melt and mix.

**Dubbing.**—Black resin, 2 lbs.; tallow, 1 lb.; train oil, 1 gallon.

FREEZING MIXTURES.

| | | |
|---|---|---|
| Sulphate of soda | 8 | parts by weight. |
| Hydrochloric acid | 5 | " |
| Pounded ice or snow | 2 | " |
| Common salt | 1 | " |
| Sulphate of soda | 3 | " |
| Dilute nitric acid | 2 | " |
| Sulphate of soda | 6 | " |
| Nitrate of ammonia | 5 | " |
| Dilute nitric acid | 4 | " |
| Phosphate of soda | 9 | " |
| Dilute nitric acid | 4 | " |

**Razor Paste.**—Mix equal parts of jewellers' rouge, blacklead, and suet. Another receipt for the same purpose is—Levigated oxide of tin or putty powder, 1 oz.; powdered oxalic acid, $\frac{1}{4}$ oz.; gum, 20 grains.

**Non-conducting Material for Clothing Steam Cylinders and Pipes, to prevent Condensation.**—Silicate cotton.

**To Harden the Surface of Wood Pulleys.**—Boil them for 10 minutes in olive oil, and allow them to dry.

**To Clean and Whiten Marble.**—Make a paste of equal parts, whiting, pearlash, and dry soap; cover the article thickly, and allow the paste to remain on for 14 days; then wash off with a sponge and water.

**Imitation Beeswax.**—Melt and mix, solid paraffin, 60 parts; yellow resin, 40 parts.

**Ink for Marking Packages.**—Boil 2 oz. shellac and 2 oz. borax in $1\frac{1}{2}$ pints of water until they are dissolved; then add 2 oz. gum arabic; when cold, add lamp-black or Venetian red to the proper colour. Keep the ink in a bottle.

**To Resharpen Files.**—Old files worn too thin to recut, may be resharpened thus:—Clean the file by immersion, first in spirits of turpentine, and next in clean warm water; then place the cleansed file point downwards in a jar containing a solution of—nitric acid, 1 pint; sulphuric acid, 1 pint; water, 1 quart; and allow the file to remain in the solution, for an hour or more, according to the depth of teeth.

**To make Small Artificial Stone Articles.**—Reduce the stone to very fine powder, and mix it with as much fine soapstone as will make a thick dough; place the dough in a mould, and subject the same to a good pressure; after leaving the mould, bake the article in an oven.

**Steam Joints made with Indiarubber.**—Where indiarubber is used to make a steam joint—such as the joint of a mud-hole door—the indiarubber, as well as the faces of the joint, should be covered with a mixture of—tallow, 1 part; blacklead, 2 parts; which greatly adds to the efficiency and durability of the joint.

**To Take the Sulphur out of Coke.**—Water it with salt and water.

## REMEDIES FOR WORKSHOP ACCIDENTS.

In cases of accident, the following instructions should be observed, pending the arrival of medical aid :—

**Apoplexy.**—Raise the head and body, bare the head and neck, and promote circulation of fresh air.

**Bleeding.**—If the blood spurts from a wound, an artery is divided; bind the limb tightly *above* the wound with a handkerchief, scarf, or strap. If the blood does not spurt, but flows freely, a vein is divided ; bind the limb tightly *below* the wound. Raise the injured limb above the level of the body, and press the place from which the blood flows with the thumb, until a pad and bandage can be got ready, with which stop up the wound. If the scalp is wounded, apply a pad of cloth, and bandage it tightly over the wound with a pocket handkerchief.

**Broken Arm.**—Pull the arm to the same length as the sound one; apply a wood splint to each side of the arm, and bind them firmly above and below the fracture, with bandages or pocket handkerchiefs.

**Broken Collar Bone.**—Bend the arm over the front of the chest, place it in a sling, and bind it in that position by a scarf, going round the chest, outside the sling.

**Broken Jaw.**—Bind a handkerchief under the chin and over the top of the head, and bind another across the chin and round the nape of the neck.

**Broken Leg.**—Pull the leg to the same length as the sound one, roll up a sack or rug into the form of a cushion, and place the leg carefully upon it, and with handkerchiefs or scarves bind the two together. Do not move the sufferer until the stretcher arrives, and use care in lifting to prevent the broken bone coming through the skin.

**Broken Ribs.**—Cause great pain when breathing; bind a long broad bandage firmly round the chest.

**Broken Thigh.**—Pull the leg to the same length as the sound one ; the knees must next be tied together, and afterwards tie the ankles together; then lay both limbs over a sack of straw or folded rug, so as to bend the knees. The sufferer not to be moved until the stretcher arrives.

**Bruises.**—Apply iced water, or ice.

**Burns.**—For slight burns, apply soft soap, or immerse the part in cold water until the pain subsides. Afterwards cover the part with flour and linseed oil, to exclude the air. For severe burns, apply cotton wool soaked in treacle and water, or in linseed oil, or oil and lime-water, and bind the same on with a handkerchief. Another remedy is—mix whiting with oil or water to the consistency of thick cream, and cover the burnt part with it.

**Choking.**—Go down on hands and knees and cough.

**Cracked Skin on Fingers.**—Apply warm shoemakers' wax.

**Cuts.**—Perchloride of iron quickly arrests bleeding in cuts and slight wounds, and it should be kept in every factory. Remove dirt from and close the wound; then apply a pad soaked in either perchloride of iron, or in Friar's balsam, and bind round with linen.

**Drowning.**—Dr. Sylvester's Method.—Take the wet clothes off the upper part of the body; lay the sufferer on his back, with his head on a folded rug for a cushion. Having cleared the mouth of any dirt, draw the tongue out of the mouth and hold it there. This opens the wind pipe. A second person kneels at the sufferer's head, and takes hold of both his arms, just below the elbows. He then draws them upwards over the sufferer's head, and holds them in that position until he counts two. This draws air into the lungs. He then lowers the arms to the sides again, and presses them firmly inwards, holding them there until he has again counted two. This forces the air out of the lungs. Continue this process until he breathes naturally, when the limbs should be rubbed in an upward direction with dry hands or with hot flannel. Finally put the sufferer to bed between blankets surrounded with hot water bottles.

**Ear.**—To remove insects, pour in oil or warm water. To remove foreign substances, syringe gently with warm water.

**Eye.**—Bruised or black, bind on a linen pad soaked in brandy. To remove dirt, use the point of a lead pencil.

**Fainting.**—Keep the head low, bare the neck, and dash cold water on the face and chest, and promote circulation of fresh air.

**Fits.**—Keep the head raised. If snoring and face flushed, bare the neck and dash cold water on the top of the head, and apply hot water bottles to the feet. If foaming at the mouth and convulsed, bare the neck and apply smelling salts, and prevent the sufferer from hurting himself until again conscious.

**Flesh Wounds.**—Wash with clean water, apply lint soaked in water, and bind round with a handkerchief.

**Frost Bites.**—Rub with snow, or pour iced water on to the part, until the colour changes and a stinging pain comes. If the frozen part turns black next day, a poultice should be applied.

**Insensibility from Wounds or Blows on the Head.**—Send the sufferer to the hospital, keeping him on his back, with his head raised and his neck bared.

**Insensibility from breathing foul gas or from being buried in falls of earth.**—Proceed as in case of drowning.

**Poisoning.**—Promote vomiting by tickling the throat, or by swallowing a cupful of warm water mixed with a teaspoonful of mustard; and swallow about a pint of sweet oil, which will quickly neutralize nearly all poisons.

**Rupture.**—Push the part back with flat hand, and apply a cold wet cloth pad. Keep the sufferer on his back.

**Scalds.**—Proceed as in the case of burns.

**Shin Wounds.**—Apply a linen pad soaked in cold water, and bind round with linen.

**Sprains.**—Foment with hot water.

**Sting of Bees and Wasps.**—Apply a few drops of liquid ammonia.

**Sunstroke.**—Apply ice or iced water to the head, and keep the sufferer in a cool place.

Table 150.—HEIGHT OF ROOFS AND WEIGHT OF ROOFING.

| Kind of Covering. | Height of Roof in parts of Span. | Weight upon a square foot of Roofing. |
|---|---|---|
| | | lbs. |
| Copper covering | $\frac{1}{48}$ | 1 |
| Roofing felt | $\frac{1}{5}$ | $1\frac{1}{4}$ |
| Corrugated iron, average | $\frac{1}{5}$ | $1\frac{1}{2}$ |
| Zinc, average | $\frac{1}{48}$ | $1\frac{3}{4}$ |
| Boarding $\frac{3}{4}$ inch thick | $\frac{1}{4}$ | 3 |
| Pantiles | $\frac{2}{9}$ | $6\frac{1}{2}$ |
| Thatch of straw or heather | $\frac{1}{2}$ | 7 |
| Lead | $\frac{1}{48}$ | 8 |
| Slates, ordinary | $\frac{1}{4}$ | 9 |
| Plain tiles | $\frac{2}{7}$ | 18 |
| Stone slate | $\frac{2}{7}$ | 24 |
| Pressure of snow per inch in depth, may be | | $0\frac{3}{4}$ |
| Pressure of wind seldom exceeds | | 40 |
| Except in great storms, when it may be | | 50 |

## DECIMAL EQUIVALENTS, ETC.

Table 151.—FRACTIONAL PARTS OF AN INCH AND THEIR DECIMAL EQUIVALENTS.

| Inch. | Inch. | Inch. | Inch. |
|---|---|---|---|
| $\frac{1}{32}$ | ·03125 | $\frac{1}{2}$ and $\frac{1}{32}$ | ·53125 |
| $\frac{1}{16}$ | ·0625 | $\frac{9}{16}$ | ·5625 |
| $\frac{3}{32}$ | ·09375 | $\frac{9}{16}$ and $\frac{1}{32}$ | ·59375 |
| $\frac{1}{8}$ | ·125 | $\frac{5}{8}$ | ·625 |
| $\frac{5}{32}$ | ·15625 | $\frac{5}{8}$ and $\frac{1}{32}$ | ·65625 |
| $\frac{3}{16}$ | ·1875 | $\frac{11}{16}$ | ·6875 |
| $\frac{7}{32}$ | ·21875 | $\frac{11}{16}$ and $\frac{1}{32}$ | ·71875 |
| $\frac{1}{4}$ | ·25 | $\frac{3}{4}$ | ·75 |
| $\frac{1}{4}$ and $\frac{1}{32}$ | ·28125 | $\frac{3}{4}$ and $\frac{1}{32}$ | ·78125 |
| $\frac{5}{16}$ | ·3125 | $\frac{13}{16}$ | ·8125 |
| $\frac{5}{16}$ and $\frac{1}{32}$ | ·34375 | $\frac{13}{16}$ and $\frac{1}{32}$ | ·84375 |
| $\frac{3}{8}$ | ·375 | $\frac{7}{8}$ | ·875 |
| $\frac{3}{8}$ and $\frac{1}{32}$ | ·40625 | $\frac{7}{8}$ and $\frac{1}{32}$ | ·90625 |
| $\frac{7}{16}$ | ·4375 | $\frac{15}{16}$ | ·9375 |
| $\frac{7}{16}$ and $\frac{1}{32}$ | ·46875 | $\frac{15}{16}$ and $\frac{1}{32}$ | ·96875 |
| $\frac{1}{2}$ | ·5 | 1 | 1·0 |

Table 152.—FRACTIONAL PARTS OF 1 FOOT AND THEIR DECIMAL EQUIVALENTS.

| Inch. | Foot. | Inch. | Foot. | Inch. | Foot. | Inch. | Foot. |
|---|---|---|---|---|---|---|---|
| $\frac{1}{8}$ | ·01041 | $\frac{3}{4}$ | ·0625 | 4 | ·3333 | 9 | ·75 |
| $\frac{1}{4}$ | ·02083 | $\frac{7}{8}$ | ·07291 | 5 | ·4166 | 10 | ·8333 |
| $\frac{3}{8}$ | ·03125 | 1 | ·0833 | 6 | ·5 | 11 | ·9166 |
| $\frac{1}{2}$ | ·04166 | 2 | ·1666 | 7 | ·5833 | 12 | 1·0000 |
| $\frac{5}{8}$ | ·05208 | 3 | ·25 | 8 | ·6666 | | |

Table 153.—SQUARE INCHES INTO DECIMAL PARTS OF 1 FOOT SQUARE.

| Inches. | Foot. | Inches. | Foot. | Inches. | Foot. | Inches. | Foot. |
|---|---|---|---|---|---|---|---|
| 144 | 1·00 | 72 | ·50 | 13 | ·09 | 7 | ·05 |
| 130 | ·90 | 57 | ·40 | 11 | ·08 | 6 | ·04 |
| 115 | ·80 | 43 | ·30 | 10 | ·07 | 4·3 | ·03 |
| 100 | ·70 | 28 | ·20 | 9 | ·06 | 2·9 | ·02 |
| 87 | ·60 | 14 | ·10 | 8 | ·056 | 1·4 | ·01 |

Table 154.—SURFACE OF TUBES, 1 FOOT LONG, IN DECIMAL PARTS OF A SQUARE FOOT.

| Bore. | Surface. | Bore. | Surface. | Bore. | Surface. | Bore. | Surface. |
|---|---|---|---|---|---|---|---|
| $\frac{5}{8}$ | ·1636 | $1\frac{1}{8}$ | ·2945 | $1\frac{5}{8}$ | ·4253 | $2\frac{1}{4}$ | ·5894 |
| $\frac{3}{4}$ | ·1963 | $1\frac{1}{4}$ | ·3270 | $1\frac{3}{4}$ | ·4580 | $2\frac{1}{2}$ | ·6540 |
| $\frac{7}{8}$ | ·2291 | $1\frac{3}{8}$ | ·3599 | $1\frac{7}{8}$ | ·4906 | $2\frac{3}{4}$ | ·7194 |
| 1 | ·2618 | $1\frac{1}{2}$ | ·3927 | 2 | ·5233 | 3 | ·7859 |

Table 155.—EQUIVALENT RATES PER LB. AND PER CWT.

| Rate per lb. | Rate per cwt. | | | Rate per lb. | Rate per cwt. | | | Rate per lb. | Rate per cwt. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pence. | £ | s. | d. | Pence. | £ | s. | d. | Pence. | £ | s. | d. |
| $\frac{1}{4}$ | 0 | 2 | 4 | $2\frac{3}{4}$ | 1 | 5 | 8 | $7\frac{1}{2}$ | 3 | 10 | 0 |
| $\frac{1}{2}$ | 0 | 4 | 8 | 3 | 1 | 8 | 0 | 8 | 3 | 14 | 8 |
| $\frac{3}{4}$ | 0 | 7 | 0 | $3\frac{1}{2}$ | 1 | 12 | 8 | $8\frac{1}{2}$ | 3 | 19 | 4 |
| 1 | 0 | 9 | 4 | 4 | 1 | 17 | 4 | 9 | 4 | 4 | 0 |
| $1\frac{1}{4}$ | 0 | 11 | 8 | $4\frac{1}{2}$ | 2 | 2 | 0 | $9\frac{1}{2}$ | 4 | 8 | 8 |
| $1\frac{1}{2}$ | 0 | 14 | 0 | 5 | 2 | 6 | 8 | 10 | 4 | 13 | 4 |
| $1\frac{3}{4}$ | 0 | 16 | 4 | $5\frac{1}{2}$ | 2 | 11 | 4 | $10\frac{1}{2}$ | 4 | 18 | 0 |
| 2 | 0 | 18 | 8 | 6 | 2 | 16 | 0 | 11 | 5 | 2 | 8 |
| $2\frac{1}{4}$ | 1 | 1 | 0 | $6\frac{1}{2}$ | 3 | 0 | 8 | $11\frac{1}{2}$ | 5 | 7 | 4 |
| $2\frac{1}{2}$ | 1 | 3 | 4 | 7 | 3 | 5 | 4 | 12 | 5 | 12 | 0 |

Table 156.—New Imperial Standard Wire Gauge.

| Descriptive Number. | Equivalents in parts of an Inch. | Descriptive Number. | Equivalents in parts of an Inch. | Descriptive Number. | Equivalents in parts of an Inch. | Descriptive Number. | Equivalents in parts of an Inch. |
|---|---|---|---|---|---|---|---|
| 7/0 | ·500 | 9 | ·144 | 23 | ·024 | 37 | ·0068 |
| 6/0 | ·464 | 10 | ·128 | 24 | ·022 | 38 | ·0060 |
| 5/0 | ·432 | 11 | ·116 | 25 | ·020 | 39 | ·0052 |
| 4/0 | ·400 | 12 | ·104 | 26 | ·018 | 40 | ·0048 |
| 3/0 | ·372 | 13 | ·092 | 27 | ·0164 | 41 | ·0044 |
| 2/0 | ·348 | 14 | ·080 | 28 | ·0148 | 42 | ·0040 |
| 0 | ·324 | 15 | ·072 | 29 | ·0136 | 43 | ·0036 |
| 1 | ·300 | 16 | ·064 | 30 | ·0124 | 44 | ·0032 |
| 2 | ·276 | 17 | ·056 | 31 | ·0116 | 45 | ·0028 |
| 3 | ·252 | 18 | ·048 | 32 | ·0108 | 46 | ·0024 |
| 4 | ·232 | 19 | ·040 | 33 | ·0100 | 47 | ·0020 |
| 5 | ·212 | 20 | ·036 | 34 | ·0092 | 48 | ·0016 |
| 6 | ·192 | 21 | ·032 | 35 | ·0084 | 49 | ·0012 |
| 7 | ·176 | 22 | ·028 | 36 | ·0076 | 50 | ·0010 |
| 8 | ·160 | | | | | | |

Table 157.—Fractional Parts of a Pound Avoirdupois and their Decimal Equivalents.

| Ounces. | Lbs. | Ounces. | Lbs. | Ounces. | Lbs. |
|---|---|---|---|---|---|
| $\frac{1}{4}$ | ·015625 | $5\frac{1}{2}$ | ·34375 | 11 | ·6875 |
| $\frac{1}{2}$ | ·03125 | 6 | ·375 | $11\frac{1}{2}$ | ·71875 |
| 1 | ·0625 | $6\frac{1}{2}$ | ·40625 | 12 | ·75 |
| $1\frac{1}{2}$ | ·09375 | 7 | ·4375 | $12\frac{1}{2}$ | ·78125 |
| 2 | ·125 | $7\frac{1}{2}$ | ·46875 | 13 | ·8125 |
| $2\frac{1}{2}$ | ·15625 | 8 | ·5 | $13\frac{1}{2}$ | ·84375 |
| 3 | ·1875 | $8\frac{1}{2}$ | ·53125 | 14 | ·875 |
| $3\frac{1}{2}$ | ·21875 | 9 | ·5625 | $14\frac{1}{2}$ | ·90625 |
| 4 | ·25 | $9\frac{1}{2}$ | ·59375 | 15 | ·9375 |
| $4\frac{1}{2}$ | ·28125 | 10 | ·625 | $15\frac{1}{2}$ | ·96875 |
| 5 | ·3125 | $10\frac{1}{2}$ | ·65625 | 16 | 1·000 |

Size and Weight of Bricks and Tiles.

| | | | | | |
|---|---|---|---|---|---|
| London stock bricks, | size in inches | $8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$ | weight each | $6\frac{3}{4}$ | lbs. |
| Red kiln . | ,, ,, | $8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$ | ,, | 7 | ,, |
| Welsh fire . | ,, ,, | $9 \times 4\frac{1}{2} \times 2\frac{3}{4}$ | ,, | $7\frac{3}{4}$ | ,, |
| Paving . | ,, ,, | $9 \times 4\frac{1}{2} \times 1\frac{3}{4}$ | ,, | 5 | ,, |
| Plain roofing tiles . | ,, | $10\frac{1}{2} \times 6\frac{1}{2} \times \frac{5}{8}$ | ,, | $2\frac{1}{2}$ | ,, |
| Pantiles . . . | ,, | $13\frac{1}{2} \times 9\frac{1}{2} \times \frac{1}{2}$ | ,, | $5\frac{1}{4}$ | ,, |
| Paving tiles . . | ,, | $6 \times 6 \times 1$ | ,, | $2\frac{1}{4}$ | ,, |
| Stone paving . | ,, | $12 \times 12 \times 2$ | ,, | 27 | ,, |

Table 158.—FRACTIONAL PARTS OF A HUNDREDWEIGHT AND THEIR DECIMAL EQUIVALENTS.

| Lbs. | Cwt. | Qrs. Lbs. | Cwt. | Qrs. Lbs. | Cwt. | Qrs. Lbs. | Cwt. |
|---|---|---|---|---|---|---|---|
| ½ | ·0044 | 1 0 | ·25 | 2 0 | ·5 | 3 0 | ·75 |
| 1 | ·0089 | 1 1 | ·2590 | 2 1 | ·5089 | 3 1 | ·7589 |
| 2 | ·0178 | 1 2 | ·2678 | 2 2 | ·5178 | 3 2 | ·7678 |
| 3 | ·0268 | 1 3 | ·2768 | 2 3 | ·5268 | 3 3 | ·7768 |
| 4 | ·0357 | 1 4 | ·2857 | 2 4 | ·5357 | 3 4 | ·7857 |
| 5 | ·0446 | 1 5 | ·2946 | 2 5 | ·5446 | 3 5 | ·7946 |
| 6 | ·0535 | 1 6 | ·3035 | 2 6 | ·5535 | 3 6 | ·8035 |
| 7 | ·0625 | 1 7 | ·3125 | 2 7 | ·5625 | 3 7 | ·8125 |
| 8 | ·0714 | 1 8 | ·3214 | 2 8 | ·5714 | 3 8 | ·8214 |
| 9 | ·0803 | 1 9 | ·3303 | 2 9 | ·5803 | 3 9 | ·8303 |
| 10 | ·0892 | 1 10 | ·3392 | 2 10 | ·5892 | 3 10 | ·8392 |
| 11 | ·0982 | 1 11 | ·3482 | 2 11 | ·5982 | 3 11 | ·8482 |
| 12 | ·1071 | 1 12 | ·3571 | 2 12 | ·6077 | 3 12 | ·8571 |
| 13 | ·1160 | 1 13 | ·3660 | 2 13 | ·6160 | 3 13 | ·8660 |
| 14 | ·1250 | 1 14 | ·375 | 2 14 | ·6250 | 3 14 | ·8750 |
| 15 | ·1339 | 1 15 | ·3839 | 2 15 | ·6339 | 3 15 | ·8839 |
| 16 | ·1429 | 1 16 | ·3930 | 2 16 | ·6429 | 3 16 | ·8929 |
| 17 | ·1518 | 1 17 | ·4018 | 2 17 | ·6518 | 3 17 | ·9018 |
| 18 | ·1607 | 1 18 | ·4107 | 2 18 | ·6607 | 3 18 | ·9107 |
| 19 | ·1696 | 1 19 | ·4196 | 2 19 | ·6696 | 3 19 | ·9196 |
| 20 | ·1786 | 1 20 | ·4286 | 2 20 | ·6786 | 3 20 | ·9286 |
| 21 | ·1876 | 1 21 | ·4375 | 2 21 | ·6875 | 3 21 | ·9375 |
| 22 | ·1964 | 1 22 | ·4464 | 2 22 | ·6964 | 3 22 | ·9464 |
| 23 | ·2054 | 1 23 | ·4554 | 2 23 | ·7054 | 3 23 | ·9554 |
| 24 | ·2143 | 1 24 | ·4643 | 2 24 | ·7143 | 3 24 | ·9643 |
| 25 | ·2232 | 1 25 | ·4732 | 2 25 | ·7232 | 3 25 | ·9732 |
| 26 | ·2321 | 1 26 | ·4821 | 2 26 | ·7321 | 3 26 | ·9821 |
| 27 | ·2411 | 1 27 | ·4911 | 2 27 | ·7411 | 3 27 | ·9911 |

## DECIMAL APPROXIMATES, ETC.

Area of a circle = diameter² × ·7854.

Area of a circle × ·6366 = area of inscribed square.

Area of an ellipse = the product of the two axes × ·7854.

Circumference of a circle = diameter × 3·1416.

The circumference of a circle is nearly equal to 22 times the diameter divided by 7.

Circumference of a circle × ·2821 = side of a square of equal area.

Diameter of a circle = circumference ÷ 3·1416.

Diameter of a circle = square root of the quotient of the area divided by ·7854.

The diameter of a circle is nearly equal to 7 times the circumference divided by 22. The difference of the diameters of any two circles, multiplied by 3·1416, will give the difference of their circumference.

Cubic inches × ·028848 = pints.
Cubic inches × ·014424 = quarts.
Cubic inches × ·003606 = gallons.
Cubic inches × ·0163 = French litres.
Cubic inches in imperial gallon = 277·274.
Cubic feet × 6·232 = imperial gallons.
Cubic feet × ·779 = bushels.
Diameter of circle × ·8862 = side of equal square.
Diameter of circle × ·7071 = side of inscribed square.
Surface of a sphere = diameter $^2$ × 3·1416.
Solidity of a sphere = diameter $^3$ × ·5236.
Diameter of a sphere × ·806 = dimensions of equal cube.
Diameter of a sphere × ·6667 =length of equal cylinder.
Side of a square × 1·1284 = diameter of a circle of equal area.
Side of a square multiplied by 3·545 = circumference of a circle of equal area.
Side of an inscribed square × 1·4142 = diameter of the circumscribing circle.
Side of an inscribed square × 4·4430 = circumference of the circumscribing circle.
Circular inches multiplied by ·7854 = square inches.
Square inches divided by ·7854 = circular inches.
Circular inches multiplied by ·00456 = square feet.
Square inches multiplied by ·00695 = square feet.
Square feet multiplied by ·111 = square yards.
Cubic inches multiplied by ·00058 = cubic feet.
Cubic feet multiplied by ·03704 = cubic yards.
Cylindrical feet multiplied by ·02909 = cubic yards.
Links multiplied by ·66 = feet.
Feet multlplied by 1·5 = links.
Square links multiplied by ·4356 = square feet.
Square feet multiplied by 2·3 = square links.
Knots multiplied by 1·15 = miles.
Miles multiplied by ·87 = knots.
Statute acres multiplied by 4840 = square yards.
Grains multiplied by ·0001429 = lbs. avoirdupois.
Pounds avoirdupois multiplied by 7000 = grains.
Pounds avoirdupois multiplied by ·009 = cwts.
Pounds avoirdupois multiplied by ·00045 = tons.
French hectolitres multiplied by 2·7512 = bushels.
French grammes multiplied by ·002205 = lbs. avoirdupois.
French kilogrammes multiplied by 2·205 = lbs. avoirdupois.
Area of egg-shaped sewer = one-half the square of the depth.

## COLOURING DRAWINGS.

| Material. | Colours. |
|---|---|
| Brick to be erected in plans and sections | Crimson lake. |
| Brickwork in elevation | Crimson lake mixed with Venetian red. |
| Plaster | Light tint of burnt umber. |
| Granite | Pale Indian ink. |
| Stone generally | Yellow ochre or pale sepia. |
| Concrete work | Sepia with dark markings. |
| Clay or earth | Burnt umber. |
| Meadows | Hooker's green. |
| Slate | Indigo and lake. |
| Light coloured wood, such as pine | Raw sienna. |
| Graining | Burnt sienna. |
| Oak or teak | Vandyke brown. |
| Wrought iron | Prussian blue. |
| Cast iron | Payn's grey. |
| Steel | Indigo tinged with lake. |
| Lead | Pale Indian ink tinged with indigo. |
| Copper | Crimson lake. |
| Brass | Pale yellow. |
| Bronze | Darker yellow than brass. |
| White metal | White tinged with indigo. |
| Guttapercha | Dark sepia. |
| Vulcanised Indiarubber | Sepia tinged with indigo. |
| Leather | Light sepia. |

### Sizes of Drawing Paper.

| | | |
|---|---|---|
| Demy | 20 × 15 | inches. |
| Medium | 22 × 17 | „ |
| Royal | 24 × 19 | „ |
| Super Royal | 27 × 19 | „ |
| Imperial | 30 × 21 | „ |
| Elephant | 28 × 22 | „ |
| Columbier | 34 × 23 | „ |
| Atlas | 33 × 26 | „ |
| Theorem | 34 × 28 | „ |
| Double Elephant | 40 × 26 | „ |
| Antiquarian | 52 × 31 | „ |
| Emperor | 72 × 48 | „ |

**Gravity.**—To find the velocity in feet per second acquired by a falling body.—*Rule:* Multiply the time in seconds by 32·2.

*To find the height of the fall* in feet.—*Rule:* Multiply the square of the time in seconds by 16·1.

*To find the time in falling* in seconds.—*Rule:* Divide the velocity in feet per second by 32·2.

*To find the velocity* in feet per second for a given height.—*Rule:* Multiply the height of the fall in feet by 64·4, and take the square root of the product.

**Work accumulated in a Moving Body.**—To find the force acquired by a weight in falling freely from a given height.—*Rule:* Multiply the weight in lbs. by the square of the velocity in feet per second, and divide by 64·4. The result is the accumulated work in foot pounds. Or another rule for the same is: Multiply the weight in lbs. by the height in feet of free fall. The product is the accumulated work in foot pounds, or the force that would raise a similar weight to a similar height.

The following examples of accumulated work show the application of these rules:—

*To find the distance in feet a ball will traverse before coming to a state of rest*, say, on a bowling green, at a velocity of 50 feet per second; weight of ball, 20 lbs., and the frictional resistance to its motion being $\frac{1}{10}$th the weight of the ball; then $\frac{50^2 \text{ velocity} \times 20 \text{ lbs. weight}}{2 \text{ lbs. frictional resistance} \times 64{\cdot}4} = 338$ feet.

*To find the distance in feet a train will move on a level rail*, whose frictional resistance is 8 lbs. per ton, and supposing that there is no other resistance; the weight of the train being, say, 100 tons, and its velocity when the steam is shut off, 50 feet per second; then $\frac{50^2 \text{ velocity} \times 100 \text{ tons weight of train} \times 2{,}240 \text{ lbs.}}{100 \text{ tons weight} \times 8 \text{ lbs. per ton frictional resistance} \times 64{\cdot}4} =$ 10869·5 feet before coming to rest.

**Punching and Shearing Iron, &c., Plates.**—*Punching.*—The resistance of a wrought-iron plate to punching is about the same as its resistance to tearing. Taking the maximum resistance at 25 tons per square inch, and the resistance to the punch being the area of the metal separated, or the circumference of the hole multiplied by the thickness of the plate, the force in tons required to punch a plate of wrought-iron is = circumference of the hole × its depth × 25. And a simple rule to find the force required to punch a plate is:—Multiply the diameter of the hole in 16ths of an inch by the thickness of plate in 16ths, and divide the product by 10; which result multiply by 3·1 for wrought iron plates; by 4·5 for steel plates; and by 2·5 for copper plates. The final product will be the required force in tons.

*The compressive strength of a hardened steel punch* is 100 tons per square inch, or four times greater than the maximum tensile strength of wrought-iron plates. The smallest size of hole that can be punched, is that of which the diameter is equal to the thickness of the plate.

*Shearing.*—The resistance of a wrought-iron plate to shearing is 20 per cent. less than its ultimate tensile strength; and the power required in tons to shear wrought-iron plates and bars may be found by the following rule: Multiply the square of the thickness of plate in 16ths of an inch by 8, and divide by 100.

**Contraction of Metal in Casting.**—Allowance per foot in length of pattern:—

| | | Inch. |
|---|---|---|
| Small cylinders (cast iron), castings | | $\frac{1}{16}$ |
| Large „ „ „ | | $\frac{3}{32}$ |
| Toothed wheels „ „ | | $\frac{1}{10}$ |
| General castings „ | | $\frac{1}{8}$ |
| Bismuth castings | | $\frac{5}{32}$ |
| Gun metal, brass, and copper castings | each | $\frac{3}{16}$ |
| Tin and zinc castings | each | $\frac{1}{4}$ |
| Lead castings | | $\frac{5}{16}$ |

**Depreciation of Machinery.**—Amount to be deducted annually, commencing from the prime cost:—

| | Per cent. |
|---|---|
| Lathes and Machine tools, first class | 5 |
| Engines, shafting, gearing, and millwork | $7\frac{1}{2}$ |
| Lathes and machine tools, second class | 10 |
| Machinery in general | 10 |
| Boilers | $12\frac{1}{2}$ |
| Leather belting | 40 |

**Depreciation of Factories.**—Amount to be deducted annually, commencing from the original cost, of well built and well cared-for factories and workshops:—

| | Per cent. |
|---|---|
| Factories, stone or brick built, without machinery | 2 |
| „ „ „ with machinery, ordinary | 3 |
| „ „ „ „ „ subjected to unusual amount of vibration | 5 |
| Factories, wooden buildings, or light iron buildings, without machinery | 5 |
| Factories, wooden buildings, or light iron buildings, with machinery | 7 |
| Foundries, stone or brick built | $7\frac{1}{2}$ |
| Forges | 10 |

When renewals are made to the carcase of the building, due to ordinary wear and tear, their cost should be added to the capital value at the date of the said renewal, and the same rate of depreciation should be continued.

Table 159.—Properties of Saturated Steam.

(An extract from a table in the "Encyclopædia Britannica," by Mr. D. K. Clark.)

| Total Pressure per Square Inch Measured from a Vacuum. | Pressure above Atmosphere. | Sensible Temperature in Fahrenheit Degrees. | Total Heat in Degrees from Zero of Fahrenheit. | Weight of One Cubic Foot of Steam. | Relative Volume of Steam compared with Water from which it was Raised. |
|---|---|---|---|---|---|
| lbs. | lbs. | | | lbs. | |
| 1 | ... | 102·1 | 1144·5 | ·0030 | 20582 |
| 2 | ... | 126·3 | 1151·7 | ·0058 | 10721 |
| 3 | ... | 141·6 | 1156·6 | ·0085 | 7322 |
| 4 | ... | 153·1 | 1160·1 | ·0112 | 5583 |
| 5 | ... | 162·3 | 1162·9 | ·0138 | 4527 |
| 6 | ... | 170·2 | 1165·3 | ·0163 | 3813 |
| 7 | ... | 176·9 | 1167·3 | ·0189 | 3298 |
| 8 | ... | 182·9 | 1169·2 | ·0214 | 2909 |
| 9 | ... | 188·3 | 1170·8 | ·0239 | 2604 |
| 10 | ... | 193·3 | 1172·3 | ·0264 | 2358 |
| 11 | ... | 197·8 | 1173·7 | ·0289 | 2157 |
| 12 | ... | 202·0 | 1175·0 | ·0314 | 1986 |
| 13 | ... | 205·9 | 1176·2 | ·0338 | 1842 |
| 14·7 | 0 | 212·0 | 1178·1 | ·0380 | 1642 |
| 15 | ·3 | 213·1 | 1178·4 | ·0387 | 1610 |
| 16 | 1·3 | 216·3 | 1179·4 | ·0411 | 1515 |
| 17 | 2·3 | 219·6 | 1180·3 | ·0435 | 1431 |
| 18 | 3·3 | 222·4 | 1181·2 | ·0459 | 1357 |
| 19 | 4·3 | 225·3 | 1182·1 | ·0483 | 1290 |
| 20 | 5·3 | 228·0 | 1182·9 | ·0507 | 1229 |
| 21 | 6·3 | 230·6 | 1183·7 | ·0531 | 1174 |
| 22 | 7·3 | 233·1 | 1184·5 | ·0555 | 1123 |
| 23 | 8·3 | 235·5 | 1185·2 | ·0580 | 1075 |
| 24 | 9·3 | 237·8 | 1185·9 | ·0601 | 1036 |
| 25 | 10·3 | 240·1 | 1186·6 | ·0625 | 996 |
| 30 | 15·3 | 250·4 | 1189·8 | ·0743 | 838 |
| 35 | 20·3 | 259·3 | 1192·5 | ·0858 | 726 |
| 40 | 25·3 | 267·3 | 1194·9 | ·0974 | 640 |
| 45 | 30·3 | 274·4 | 1197·1 | ·1089 | 572 |
| 50 | 35·3 | 281·0 | 1199·1 | ·1202 | 518 |
| 55 | 40·3 | 287·1 | 1201·0 | ·1314 | 474 |
| 60 | 45·3 | 292·7 | 1202·7 | ·1425 | 437 |
| 65 | 50·3 | 298·0 | 1204·3 | ·1538 | 405 |
| 70 | 55·3 | 302·9 | 1205·8 | ·1648 | 378 |
| 75 | 60·3 | 307·5 | 1207·2 | ·1759 | 353 |
| 80 | 65·3 | 312·0 | 1208·5 | ·1869 | 333 |
| 85 | 70·3 | 316·1 | 1209·9 | ·1980 | 314 |
| 90 | 75·3 | 320·2 | 1211·1 | ·2089 | 298 |
| 95 | 80·3 | 324·1 | 1212·3 | ·2198 | 283 |
| 100 | 85·3 | 327·9 | 1213·4 | ·2307 | 270 |
| 105 | 90·3 | 331·3 | 1214·4 | ·2414 | 257 |
| 110 | 95·3 | 334·6 | 1215·5 | ·2521 | 247 |

Table 159 *continued.*—PROPERTIES OF SATURATED STEAM.

| Total Pressure per Square Inch Measured from a Vacuum. | Pressure above Atmosphere. | Sensible Temperature in Fahrenheit Degrees. | Total Heat in Degrees from Zero of Fahrenheit. | Weight of One Cubic Foot of Steam. | Relative Volume of Steam compared with Water from which it was Raised. |
|---|---|---|---|---|---|
| lbs. | lbs. | | | lbs. | |
| 115 | 100·3 | 338·0 | 1216·5 | ·2628 | 237 |
| 120 | 105·3 | 341·1 | 1217·4 | ·2759 | 227 |
| 125 | 110·3 | 344·2 | 1218·4 | ·2867 | 219 |
| 130 | 115·3 | 347·2 | 1219·3 | ·2977 | 211 |
| 135 | 120·3 | 350·1 | 1220·2 | ·3080 | 203 |
| 140 | 125·3 | 352·9 | 1221·0 | ·3184 | 197 |
| 145 | 130·3 | 355·6 | 1221·9 | ·3294 | 190 |
| 150 | 135·3 | 358·3 | 1222·7 | ·3397 | 184 |
| 155 | 140·3 | 361·0 | 1223·5 | ·3500 | 179 |
| 160 | 145·3 | 363·4 | 1224·2 | ·3607 | 174 |
| 165 | 150·3 | 366·0 | 1224·9 | ·3714 | 169 |
| 170 | 155·3 | 368·2 | 1225·7 | ·3821 | 164 |
| 175 | 160·3 | 370·8 | 1226·4 | ·3928 | 159 |
| 180 | 165·3 | 372·9 | 1227·1 | ·4035 | 155 |
| 185 | 170·3 | 375·3 | 1227·8 | ·4142 | 151 |
| 190 | 175·3 | 377·5 | 1228·5 | ·4250 | 148 |
| 195 | 180·3 | 379·7 | 1229·2 | ·4357 | 144 |
| 200 | 185·3 | 381·7 | 1229·8 | ·4464 | 141 |
| 210 | 195·3 | 386·0 | 1231·1 | ·4668 | 135 |
| 220 | 205·3 | 389·9 | 1232·3 | ·4872 | 129 |
| 230 | 215·3 | 393·8 | 1233·5 | ·5072 | 123 |
| 240 | 225·3 | 397·5 | 1234·6 | ·5270 | 119 |
| 250 | 235·3 | 401·1 | 1235·7 | ·5471 | 114 |
| 260 | 245·3 | 404·5 | 1236·8 | ·5670 | 110 |
| 270 | 255·3 | 407·9 | 1237·8 | ·5871 | 106 |
| 280 | 265·3 | 411·2 | 1238·8 | ·6070 | 102 |
| 290 | 275·3 | 414·4 | 1239·8 | ·6268 | 99 |
| 300 | 285·3 | 417·5 | 1240·7 | ·6469 | 96 |

**One atmosphere** 14·706 lbs. pressure per square inch = 29·92 inches of mercury; each lb. pressure per square inch is equal to a column of mercury 2·035 inches, or 1·018 rise in a syphon gauge.

*To convert degrees Fahrenheit into Centigrade.—Rule:* Subtract 32 and divide the remainder by 1·8.

*To convert degrees Centigrade into Fahrenheit.—Rule:* Multiply by 1·8 and add 32 to the product.

*To convert degrees Fahrenheit into Reaumur.—Rule:* Subtract 32 and divide the remainder by 2·25.

*To convert degrees Reaumur into Fahrenheit.—Rule:* Multiply by 2·25 and add 32 to the product.

## EFFECT OF SHOT ON IRON PLATES.

**Power of Shot and Shell.**—Captain C. O. Brown, R.A., of Woolwich, in a paper read before the Institution of Mechanical Engineers, gave the following equation as the one used in the department of the Director of Artillery for calculating problems of shot:—

$$\frac{Wv}{2g} = 2\,\pi\,R \times K \times b^{1 \cdot 6}$$

where W = the weight of the shot.
$v$ = the striking velocity.
$g$ = the force of gravity.
R = the radius of the cross section of the shot.
$b$ = the depth of plate penetrated.
K = a certain constant whose value depends on the quality of the plate, &c.

The left hand side of the equation represents the power of the shot at the moment of striking. The following particulars of experiments with guns are extracted from the same paper.

"**The 38-ton gun,** whose calibre is 12·5 in., was fired with a charge of 130 lb. and a projectile of 812 lb. weight at a structure known as 'No. 40 target,' consisting of three layers of $6\frac{1}{2}$ in. of iron with 5 in. of teak between each, making a total of $19\frac{1}{2}$ in. of iron and 10 in. of teak. The projectile had a striking velocity of 1,420 feet per second. Using the expression above to obtain the penetration $b$, and writing K as 2·53, which is so taken as to give $b$ in inches, we get $b = 19{\cdot}41$. This means that the shot would just penetrate through a solid iron plate 19·41 in. thick. It ought, therefore, to pierce the three $6\frac{1}{2}$ in. plates and teak, with something to spare. It did actually pass through, excepting that a portion of the base was left in the target.

"**The 38-ton gun** was afterwards chambered, so as to enable it to take a charge of 200 lb.; and was fired at the same structure (No. 40 target) strengthened by the addition of a front plate of $6\frac{1}{2}$ in. and 5 in. additional teak. The striking velocity of the shot was now 1,525 feet per second, which gives a power to penetrate a solid plate 21 in. thick. As, however, the structure contained 26 in. of iron, the problem becomes one of partial penetration. It is a very different thing to penetrate completely through a plate 21 in. thick, and to enter 21 in. into armour 26 in. thick; because in the latter case the extra metal is backing up and adding to the strength of what might otherwise be pierced. Hence the shot's point only attained to a depth of about 20 in. of iron in all. In these two experiments it may be said that the plate-upon-plate system did well.

Table 160.—Galvanized Iron Cisterns—Stock Sizes.

| Length. | | Width. | | Depth. | | Gallons. |
|---|---|---|---|---|---|---|
| feet. | inch. | feet. | inch. | feet. | inch. | About. |
| 1 | 9 | 1 | 3 | 1 | 6 | 20 |
| 2 | 0 | 1 | 6 | 1 | 7 | 30 |
| 2 | 4 | 1 | 7 | 1 | 9 | 40 |
| 2 | 6 | 1 | 7 | 2 | 0 | 50 |
| 2 | 8 | 1 | 10 | 2 | 0 | 60 |
| 2 | 8 | 2 | 0 | 2 | 2 | 70 |
| 3 | 0 | 2 | 0 | 2 | 2 | 80 |
| 3 | 2 | 2 | 2 | 2 | 2 | 90 |
| 3 | 0 | 2 | 2 | 2 | 6 | 100 |
| 3 | 3 | 2 | 2 | 2 | 6 | 110 |
| 3 | 4 | 2 | 4 | 2 | 6 | 120 |
| 3 | 4 | 2 | 6 | 2 | 6 | 130 |
| 3 | 6 | 2 | 6 | 2 | 6 | 140 |
| 3 | 6 | 2 | 6 | 2 | 9 | 150 |
| 3 | 9 | 2 | 8 | 2 | 10 | 175 |
| 4 | 0 | 2 | 8 | 3 | 0 | 200 |
| 4 | 1 | 3 | 3 | 3 | 0 | 250 |
| 4 | 7 | 3 | 6 | 3 | 0 | 300 |

## THE NEW PATENT LAW ACT, 1883.

**An application for a patent** must be made in the prescribed form, signed by the appplicant, and must be limited to one invention.

*The application* may be made by the actual inventor or inventors, either alone or in conjunction with others, but the declaration must state which of the applicants is the inventor.

**If an inventor dies** without applying for a patent, a patent may be granted for his invention to his legal representative, if application be made within six months of the inventor's death.

*If an applicant for a patent dies*, the patent may be granted to his legal representative, and be sealed any time within twelve months after the death of the applicant.

**In applying for a patent,** the inventor must lodge at the patent office a combined declaration and petition, and a provisional specification, describing the nature of the invention, accompanied by drawings, if required, or a complete specification may be lodged in place of the provisional specification, particularly describing the nature of the invention, and in what manner it is to be performed, and accompanied by drawings, if required.

**A specification,** whether provisional or complete, must commence with the title, and a complete specification must end with a distinct statement of the invention claimed.

*The documents are scrutinized* by an official examiner, who decides whether the nature of the invention has been properly described, and whether the application, specification, and drawings (if any) have been prepared in the prescribed manner, and if the title sufficiently indicates the object of the invention; if there be any defects, the comptroller may require amendments to be made; where he does so, the applicant may appeal from his decision to the law officer.

**When an application has been accepted,** notice thereof is sent to the applicant.

*When an application is accepted,* the invention is provisionally protected.

*When a complete specification* is not filed in the first instance, it must be done within nine months, otherwise the application will be deemed to be abandoned.

*Unless a complete specification is accepted* within twelve months from the date of application, then (save in the case of an appeal having been lodged against the refusal to accept) the application will, at the expiration of the said twelve months, become void.

**When a complete specification is accepted,** the fact will be advertised, and the documents will be open to public inspection; any one may enter notice of opposition within two months from the date of the advertisement, on the ground that the invention belongs to him, or that the invention has already been patented in this country, on an application of prior date, or that the examiner has reported against it, because it covered a pending application of earlier date. On the expiration of the two months, if there be no opposition, the patent will be sealed.

**An applicant or patentee may seek leave to amend** his specification or drawings, and in case his request to amend is not granted, he may appeal to the law officer; but no amendment will be allowed which would make the specification claim an invention substantially larger or substantially different from that claimed by the specification as it stood before amendment.

**Compulsory Licences.**—If on petition to the Board of Trade it is proved that by reason of the default of a patentee to grant licences on reasonable terms, the patent is not being worked in the United Kingdom; or the reasonable requirements of the public with respect to the invention cannot be supplied; or any person is prevented from working or using to the best advantage an invention of which he is possessed; the Board may order the patentee to grant licences on such terms as it may deem just.

**Revocation of a patent** may be obtained on petition to the Court. Where a patent has been revoked on the ground of fraud, a patent may be granted to the true inventor.

**An invention may be exhibited** at an Industrial or International Exhibition certified as such by the Board of Trade, without prejudice to the right to provisional protection and a patent, provided the exhibitor, before exhibiting the invention, gives the Comptroller the prescribed notice of his intention to do so; and the application for a patent must be made before, or within six months from, the date of the opening of the Exhibition.

**The penalty** for representing an article to be patented when it is not patented, is for every offence on summary conviction a fine not exceeding £5.

**Royal Arms.**—No one is allowed to use the royal arms without authority from the Government under a penalty on summary conviction of a fine not exceeding £20.

**Cost of a Patent.**—A patent will be granted for fourteen years from its date, but it will cease unless the prescribed payments are duly made. The Government fees are—£1 for an application; £3 for a complete specification; £50 before the end of the fourth year; £100 before the end of the eighth year from the date of the patent. These two latter sums may be paid by instalments, instead of in a lump sum; viz.,—by annual payments of £10 before the end of the fourth, fifth, sixth, and seventh years; £15 before the end of the eighth and ninth years; and £20 before the end of the tenth, eleventh, twelfth, and thirteenth years. If, through accident or mistake, these payments are not made within the prescribed time, the Comptroller can extend the time for not more than three months.

**Before applying for a patent,** it is advisable to search the records of the patent office to ascertain whether a patent has been previously granted for the same invention, or anything approaching it; for this purpose and in order to protect the inventor's own interest, as well as to insure the preparation of a sound specification clearly embracing all the points of the invention without infringing the rights of others, it is desirable to employ professional aid. Large experience and great care are required in preparing a specification, otherwise the patent may be invalid, and the patentee may become involved in a lawsuit; hence the necessity of obtaining the services and advice of an experienced patent agent, who generally charges as follows for obtaining a patent, exclusive of drawings, viz. :—

| | | | |
|---|---|---|---|
| Search at the patent office and report thereon as to the novelty of the invention | £3 | 3 | 0 |
| Provisional protection for one year, preparing specification and documents, including stamp (£1) | 4 | 4 | 0 |
| Royal letters patent, preparing complete specification including stamp (£3) and professional advice | 8 | 8 | 0 |
| Cost of four years' patent | £15 | 15 | 0 |
| Government fee before the end of the fourth year (£50) and agency costs (£1 15*s.*) | 51 | 15 | 0 |
| Government fee before the end of the eighth year (£100) and agency costs (£2 10*s.*) | 102 | 10 | 0 |
| Total cost of patent for fourteen years | £170 | 0 | 0 |

## LEGAL MEMORANDA.

**Bills of Exchange.**—It is not legal to issue a bill of less value than twenty shillings.

A person under age is not liable on a bill, but it is valid against all other competent parties thereto.

A creditor having taken a bill in payment of a debt, is debarred from suing for the debt during the currency of the bill, but if the bill is dishonoured he can then sue for the original debt.

When a bill is taken in full satisfaction and full discharge of a debt, the debt is extinguished, and the creditor's remedy is on the bill alone, except where a bill is taken as collateral security.

**A bill may be void** if the consideration given is illegal; want of sufficient consideration may be insisted on in defence to an action on a bill. A forged bill cannot be sued upon even by an innocent holder for value. An innocent holder for value can recover on a bill although it was given without consideration. The drawer or the acceptor of an accommodation bill, may recover against the party accommodated. The holder for value of an accommodation bill may recover. Payment of a lost bill can be enforced, but the plaintiff must give indemnity against other claims arising on the bill; the holder of a bill that has been lost, or fraudulently obtained must, if he sue for payment, prove he obtained it upon good consideration. When a bill is lost, notice thereof should immediately be sent to all parties concerned.

**Date of a bill.**—When the date of a bill has been omitted, it will be intended to bear date on the day when it was made, but if the date be omitted for the purpose of the holder supplying the date at his convenience, the bill will be void. If a bill after it has been drawn, accepted, or indorsed be altered in any material respect, without the consent of the parties bound therein, it will discharge them from all liability. An innocent holder for value cannot recover, when the date of a bill has been altered after acceptance, whereby the payment would be accelerated.

**Payment of a bill** may be refused, unless the holder produce and deliver up the bill.

When a sum of money is paid into a bank for the stated and specific purpose of meeting a bill, the banker cannot place that money to the credit of the customer's overdraft.

**The holder of a dishonoured bill** may sue the acceptor, drawer and all the endorsers at the same time, but although he may obtain judgment in all the actions, he can only recover one satisfaction for the value of the bill, but he may sue out executions against all the rest for the cost of their separate actions.

**Cheques.**—When a banker pays a forged cheque, he cannot charge his customer with the loss, and when he pays a cheque which has been improperly altered in the amount he has no claim against the customer who drew it, except for the original sum, unless the careless way the cheque was drawn enabled the fraud to be effected. A cheque should be presented not later than the day after its receipt, after which time the holder keeps it at his own risk against the insolvency of the banker.

An **I. O. U.** is merely an acknowledgment of a debt, it is not negotiable and does not require a stamp.

**Goods Sold.**—When goods have been sold on credit, and their purchaser becomes insolvent before the delivery of the goods, the seller may countermand the delivery of them, while in transit before they are actually delivered to the purchaser, so long as they are in the possession of the carrier: but the seller cannot retake the goods for non-payment after they are in the purchaser's possession.

**Goods Sold on Sale or Return** must be returned in a reasonable time, otherwise the sale will stand as an absolute sale, and the price of the goods may be recovered in an action for goods sold and delivered.

**A Guarantee** must be in writing. The guarantee to or for a firm will cease upon a change of the members of a firm, unless it be expressly stipulated to the contrary.

**The New Bankruptcy Act, 1883.**—The following is a brief summary of the Act:—Acts of bankruptcy are, the making by a debtor of a conveyance or assignment for the benefit of his creditors, or of a fraudulent conveyance of his property; or if he absents himself, or departs from his dwelling-house, or leaves England for the purpose of defeating or delaying his creditors; or if his goods have been seized and sold under legal process; or if he files in the Court a declaration of his inability to pay his debts, or presents a bankruptcy petition against himself; or if a creditor has obtained a final judgment against the debtor and, execution thereon having been stayed, has served on him a bankruptcy notice and the debtor fails to secure or compound the debt, or satisfy the Court that he has a sufficient cross demand; or if the debtor gives notice to any of his creditors that he has suspended, or is about to suspend payment of his debts. A bankruptcy notice must be in the prescribed form and served in the prescribed manner. A debtor may present a petition on alleging that he is unable to pay his debts. No petition may be withdrawn without leave of the Court.

**Petition by a Creditor.—Conditions of.**—A creditor may present a petition if the debt owing to one or more creditors amounts to £50 and is a liquidated sum; or if the act of bankruptcy has occurred within three months before presenting the petition; or if the debtor is domiciled in England; or within a year before the date of the presentation of the petition, has ordinarily resided or had a dwelling-house, or place of business, in England. A secured creditor may give up, or give an estimate of the value of his security, when he may be admitted as a petitioning creditor to the extent of the unsecured debt.

**Petitions where the Assets are under £300.**—When a petition is presented by or against a debtor, if the Court is satisfied that the property of the debtor is not likely to exceed £300 in value, the Court may make an order that the debtor's estate be administered in a summary manner.

**Where the Indebtedness is under £50.**—Where a County Court judgment has been obtained against a debtor, who is unable to pay the amount forthwith, and alleges that his whole indebtedness, including the debt for which the judgment has been obtained does not exceed £50, the County Court may make an order providing for the administration of his estate, by instalments or otherwise, and subject to any conditions as to his future earnings or income, which the Court may think just.

Any creditor of a deceased debtor whose debt is sufficient, may petition the Court for the administration of the estate of the deceased debtor.

**Discharge of a Bankrupt.**—A bankrupt may apply to the Court for an order of discharge, and the Court may refuse the application, if it is found that the bankrupt did not keep such books of account, as are usual and proper in the business carried on by him, and as sufficiently disclose his business transactions and financial position, within the three years immediately preceding his bankruptcy; or that he had continued to trade after knowing himself to be insolvent; or that he had contracted a debt without having at the time of contracting it, any reasonable ground of expectation of being able to pay it; or that he had brought on his bankruptcy by rash and hazardous speculations, or unjustifiable extravagance in living; or that he has put any of his creditors to unnecessary expense, by a frivolous or vexatious defence to any action properly brought against him; or that he has within three months preceding the date of the receiving order, when unable to pay his debts as they became due, given an undue preference to any of his creditors; or that he has on any previous occasion been adjudicated bankrupt, or made a statutory composition or arrangement with his creditors; or that he has been guilty of any fraud or fraudulent breach of trust.

---

## WEIGHTS AND MEASURES.

### Liquid Measure.

| | | | Cubic Inches. |
|---|---|---|---|
| 5 oz. avoir. of pure water at 62° Fah. . . . . | = | 1 gill or quartern = | 8·665 |
| 4 gills . . . . . . | = | 1 pint . . = | 34·659 |
| 2 pints . . . . . | = | 1 quart . . . = | 69·318 |
| 4 quarts . . . . . | = | 1 gallon . . = | 277·274 |
| 6·2355 gallons . . . | = | 1 cubic foot. | |

## Angular Measure.

| | |
|---|---|
| 60 seconds | 1 minute |
| 60 minutes | 1 degree |
| 30 degrees | 1 sign |
| 90 " | 1 quadrant |
| 4 quadrants or 360 degrees | 1 circumference or great circle |

## Apothecaries' Weight.

| | |
|---|---|
| 20 grains | 1 scruple |
| 3 scruples | 1 drachm |
| 8 drachms | 1 ounce |
| 1 drop | 1 grain |
| 60 drops | 1 drachm |
| 4 drachms | 1 tablespoonful |
| 2 ounces water (875 grains) | 1 wine-glass |
| 20 ounces | 1 pint |

## Avoirdupois Weight.

Used in almost all commercial transactions.

| | | Grains. |
|---|---|---|
| $27\frac{1}{3}$ grains | 1 drachm = | $27\frac{1}{3}$ |
| 16 drachms | 1 ounce = | $437\frac{1}{2}$ |
| 16 ounces | 1 pound = | 7000 |
| 14 pounds | 1 stone | |
| 28 " | 1 quarter | |
| 4 quarters | 1 cwt. | |
| 20 cwts. | 1 ton | |
| 1 cwt. of coals | 1 small sack | |
| 2 " " | 1 double sack | |
| 20 " " or 10 double sacks | 1 ton | |

The butchers' and fishmongers' stone is 8 lbs.

## Beer Measure.

| | |
|---|---|
| 9 gallons | 1 firkin |
| 18 " | 1 kilderkin |
| 36 " | 1 barrel |
| 54 " | 1 hogshead |

## Bread.

| | |
|---|---|
| 2 pounds | $\frac{1}{2}$ quartern loaf |
| 4 " | 1 " |

## Bricks.

| | |
|---|---|
| 500 | 1 load |

## Candles.

| | |
|---|---|
| 120 pounds | 1 barrel |

### Cheese and Butter.

| | |
|---|---|
| 8 pounds | 1 clove |
| 32 cloves | 1 wey (Essex) |
| 42 " | 1 " (Suffolk) |
| 56 pounds | 1 firkin |
| 224 " | 1 barrel |

### Cloth.

| | |
|---|---|
| $2\frac{1}{4}$ inches | 1 nail |
| 4 nails, or 9 inches | 1 quarter. |
| 3 quarters | 1 Flemish ell |
| 4 " | 1 yard |
| 5 " | 1 English ell |
| 6 " | 1 French ell |

### Coals.

| | |
|---|---|
| 88 pounds | 1 bushel |
| 3168 pounds | 1 chaldron |
| 224 " | 1 sack |
| 10 sacks | 1 ton |
| 1 ton of coals . . . . . about | 25 bushels |
| 1 barge or keel of coals | 21 tons, 4 cwt. |

### Coins.

| | Weight. |
|---|---|
| 1 farthing is ·8 inch diameter | $\frac{1}{10}$ ounce. |
| 1 halfpenny is 1 inch diameter | $\frac{1}{5}$ " |
| 1 penny is 1·2 inch diameter | $\frac{1}{3}$ " |
| 1 threepenny piece | $\frac{1}{20}$ " |
| 1 fourpenny piece | $\frac{1}{15}$ " |
| 1 sixpence | $\frac{1}{10}$ " |
| 1 shilling | $\frac{1}{5}$ " |
| 1 florin | $\frac{2}{5}$ " |
| 1 halfcrown | $\frac{1}{2}$ " |
| 5 shillings | 1 " |
| 1 sovereign . . . . nearly | $\frac{1}{4}$ " |

### Corn.

| | |
|---|---|
| 5 bushels | 1 load |
| 40 " | 1 cart |
| 60 pounds | 1 bushel of wheat |
| 52 " | 1 " rye |
| 47 " | 1 " barley |
| 88 " | 1 " oats |
| 6 bushels of wheat should yield | 1 sack of flour |

### Cubic Measure.

| | |
|---|---|
| 1728 cubic inches | 1 cubic foot |
| 27 cubic feet | 1 cubic yard or load |
| 40 " unhewn or 50 of hewn timber | 1 ton or load |
| 42 " | 1 ton shipping |
| A load or yard of earth | 27 cubic feet |

A cubic foot of water weighs 1000 ounces
1 ton of sea water = $218\frac{1}{4}$ gallons

### Diamond Weight.

| | |
|---|---|
| 16 parts | 1 grain |
| 4 grains | 1 carat |

### Dry Measure.

| | |
|---|---|
| 4 quarts | 1 gallon |
| 2 gallons | 1 peck |
| 4 pecks | 1 bushel |
| 3 bushels | 1 sack |
| 12 sacks | 1 chaldron |
| 8 bushels | 1 quarter |
| 5 quarters | 1 load |
| 1 gallon of water | 10 pounds |
| 1 pint ,, | $1\frac{1}{4}$ ,, |
| 1 bushel ,, | 80 ,, |
| 1 ,, wheat | 60 ,, |
| 1 ,, barley | 47 ,, |
| 1 ,, oats | 38–40 pounds |
| 1 truss straw | 36 pounds. |
| 1 ,, old hay | 56 ,, |
| 1 ,, new hay until September 1 | 60 ,, |
| 36 trusses | 1 load |

### Flour.

| | |
|---|---|
| 14 pounds | 1 peck |
| 56 ,, | 1 bushel |
| 280 ,, | 1 sack |
| 5 bushels | 1 ,, |

### Glass.

| | |
|---|---|
| 120 pounds | 1 seam |

### Hay (New).

| | |
|---|---|
| 60 pounds | 1 truss |
| A cubic yard new hay | = 6 stone |
| Load of new hay | = 19 cwt. 32 lbs. |

### Hay (Old).

| | |
|---|---|
| 56 pounds | 1 truss |
| 36 trusses | 1 load |
| Load of old hay | 18 cwts. |
| A cubic yard old hay | 9 stone |

### Hops.

| | |
|---|---|
| 112 pounds | 1 pocket (Surrey and Sussex) |
| 250 ,, | 1 bag (Kent) |

### Long Measure.

| | |
|---|---|
| 12 lines | 1 inch |
| 3 barleycorns | = 1 inch |

| | |
|---|---|
| 1000 mils | = 1 inch |
| 3 inches | 1 palm |
| 4 " | 1 hand |
| 8 " | 1 link |
| 9 " | 1 span |
| 12 " | 1 foot |
| 18 " | 1 cubit |
| $2\frac{1}{2}$ feet | = 1 military pace |
| 3 " | 1 yard |
| 6 " | 1 fathom |
| $5\frac{1}{2}$ yards | 1 rod, pole, or perch |
| 4 poles | 1 chain |
| 40 " | 1 furlong |
| 8 furlongs or 1760 yards | 1 mile |
| 3 miles (nautical) | 1 league |
| 6082·6 feet or 2027·5 yards | = 1 nautical mile or knot |
| 60 nautical miles | 1 degree |
| $69\frac{1}{2}$ geographical miles | 1 " |

### Meat.

| | |
|---|---|
| 8 pounds | 1 stone |

### Milk.

| | |
|---|---|
| The barn-gallon for milk is equal to | 2 imperial gallons |

### Oatmeal.

| | |
|---|---|
| 200 pounds | 1 barrel |

### Oil (Train).

| | |
|---|---|
| 9 pounds 6 oz. | 1 gallon |

### Oil (Sweet).

| | |
|---|---|
| 236 pounds | 1 tun |

### Paper.

| | |
|---|---|
| 20 sheets | 1 quire, outsides |
| 24 " | 1 " insides |
| 20 quires | 1 ream |
| $21\frac{1}{2}$ quires | 1 printer's ream |
| 2 reams | 1 bundle |
| 10 " | 1 bale |

### Parchment.

| | |
|---|---|
| 60 skins | 1 roll |

### Potatoes.

| | |
|---|---|
| 200 pounds | 1 barrel |

### Raisins.

| | |
|---|---|
| 112 pounds | 1 barrel |

### Rice.

| | |
|---|---|
| 168 pounds | 1 barrel |

### SALT.

| | |
|---|---|
| 14 pounds . . . . . . . | 1 peck |
| 56 " . . . . . . . . . | 1 bushel |
| 42 bushels . . . . . . . | 1 ton |

### SOAP.

| | |
|---|---|
| 64 pounds or 8 gallons . . . . | 1 firkin |
| 256 " . . . . . . . . . | 1 barrel |

### SQUARE MEASURE.

| | |
|---|---|
| 144 square inches . . . . . . | 1 square foot |
| 9 square feet . . . . . . | 1 square yard |
| $30\frac{1}{4}$ square yards . . . . . . | 1 rod, pole, or perch |
| 16 poles . . . . . . . . | 1 chain |
| 40 square poles . . . . . . . | 1 rood |
| 4 roods or 10 square chains . . . | 1 acre |
| 640 square acres . . . . . . . | 1 square mile |
| 100 square feet . . . . . | .=1 square |
| $272\frac{1}{4}$ square feet or $30\frac{1}{4}$ square yards . | .=1 rod |

### STRAW.

| | |
|---|---|
| 36 pounds . . . . . . . | 1 truss |
| Load of straw . . . . . . | .=11 cwt. 64 lbs. |

### TEA.

| | |
|---|---|
| 48 pounds (about) . . . . . . | 1 chest |

### TILES.

| | |
|---|---|
| 1000 . . . . . . . . . | 1 load |

### TOBACCO.

| | |
|---|---|
| 2 to 3 cwt. . . . . . . . | 1 barrel |

### TROY WEIGHT.

| | |
|---|---|
| 1 grain troy . . . . . . . | 1 grain avoirdupois |
| 24 grains . . . . . . . | 1 pennyweight = 24 grains |
| 20 pennyweights . . . . . . | 1 ounce = 480 grs. |
| 12 ounces . . . . . . . | 1 pound = 5760 grs. |

### WATER.

| | |
|---|---|
| 1000 ounces . . . . . . . | 1 cubic foot |
| 10 pounds . . . . . . . | 1 gallon |

### WINE.

| | |
|---|---|
| 138 gallons . . . . . . . . | 1 pipe of port |
| 140 " . . . . . . . . | 1 " Lisbon |
| 110 " . . . . . . . . . | 1 " Madeira |
| 120 " . . . . . . . . | 1 " Teneriffe |
| 57 " . . . . . . . . . | 1 hogshead of claret |
| 36 " . . . . . . . . | 1 aum of hock |
| 20 " . . . . . . . . . | 1 hogshead of sherry |
| 130 " . . . . . . . . | 1 butt of sherry |

### Wood.

| | |
|---|---|
| 1000 billets | 1 cord |
| 10 cwt. | 1 „ |
| 108 feet | 1 stack |
| 128 feet | 1 cord |

### Wool.

| | |
|---|---|
| 7 pounds | 1 clove |
| 2 cloves | 1 stone |
| 2 stones | 1 tod |
| $6\frac{1}{2}$ tods | 1 wey |
| 2 weys | 1 sack |
| 12 sacks or 4368 pounds | 1 last |
| 240 pounds | 1 pack |

### Miscellaneous Measures and Weights.

| | |
|---|---|
| The Chinese li | 632 yards |
| French kilomètre | 1093 „ |
| The Russian mile | 1100 „ |
| The Italian mile | 1467 „ |
| The Roman mile | 1628 „ |
| The Turkish Berri | 1826 „ |
| The Arabian mile | 2148 „ |
| Irish and Scotch | 2200 „ |
| The Polish mile | 4400 „ |
| The Spanish mile | 5028 „ |
| The German mile | 5866 „ |
| Persian Parasang | 6086 „ |
| Flanders League | 6864 „ |
| The Swedish and Danish mile | 7233 „ |
| The Dutch mile | 8101 „ |
| Hungarian mile | 8800 „ |
| Bale of flax, Russian | 5 to 6 cwt. |
| Barrel of tar | $26\frac{1}{2}$ gallons |
| Cable's length | 240 yards |
| Cask of black lead | $11\frac{1}{2}$ cwt. |
| Chaldron of coke | $12\frac{1}{2}$ to 15 cwt. |
| Cran of herrings | $37\frac{1}{2}$ gallons |
| Barrel of herrings | $26\frac{2}{3}$ „ |
| Barrel of turpentine | 2 to $2\frac{1}{2}$ cwt. |
| Barrel of gunpowder | 100 lbs. |
| Last of gunpowder | 24 barrels |
| Last of potash, cod-fish, white herrings, meal, pitch, tar | 12 „ |
| Dicker of hides | = 10 skins |
| Last of hides | = 20 dickers |
| Faggot of steel | 120 lbs. |
| Mat of flax, Dutch | 126 lbs. |
| Pig of ballast | 56 lbs. |
| Ton of displacement of a ship | 35 cubic feet |
| Ton registered of internal capacity of a ship | = 100 cubic feet |

### Measures relating to Building.

Rood of masonry = 36 square yards face, 2 feet thick.

Load of sand = 36 bushels.

Load of unhewn or rough timber = 40 cubic feet.

Load of hewn or squared timber, reckoned to weigh 20 cwt. = 50 cubic feet.

Load of 1 inch plank = 600 square feet.

Load of plank more than 1 inch thick = 600 divided by the thickness in inches. Thus—a load of 2 inch planks equals 300 square feet.

Planks, section 11 × 3 inches. Deals, section 9 × 3 inches. Battens, section 7 × $2\frac{1}{2}$ inches. A reduced deal is $1\frac{1}{2}$ inches thick × 11 inches wide × 12 feet long.

Load of lime = 32 bushels.

A load of mortar is equal to 1 cubic yard.

A hod of mortar measures 9 × 9 inches.

2 hods of mortar are nearly equal to a bushel.

The mortar in a rod of brick work (4,500 bricks) is taken at $1\frac{1}{2}$ cwt. of chalk lime and 2 loads of sand, or 1 cwt. of stone lime and $2\frac{1}{2}$ loads of sand.

Load of bricks = 500.

Size of bricks = 9 inches long × $4\frac{1}{2}$ inches broad × $2\frac{3}{4}$ inches thick.

32 bricks laid flat, or 48 laid on edge will pave 1 square yard.

Number of bricks in a cubic yard = 384.

A rod of brick work measures $16\frac{1}{2}$ feet × $16\frac{1}{2}$ feet × $1\frac{1}{8}$ foot = 306 cubic feet or $11\frac{1}{3}$ cubic yards.

A rod of brick work = 272 superficial feet, $1\frac{1}{2}$ brick thick.

To reduce brick work from superficial feet of 9 inches thick, to the standard thickness of $13\frac{1}{2}$ inches, deduct $\frac{1}{3}$rd.

To reduce brick work from cubic feet, to superficial feet of the standard thickness of $13\frac{1}{2}$ inches, deduct $\frac{1}{9}$th.

Rod of brickwork = 15 tons

1000 plain tiles = 21 cwt.

1000 pantiles = 47 cwt.

1000 9-inch paving tiles = 58 cwt.

1000 10-inch paving tiles = 72 cwt.

1000 12-inch paving tiles = 107 cwt.

1000 stock bricks = 45 cwt.

1000 paviors = 49 cwt.

Hundred of lime = 35 bushels.

Hundred of nails or tacks = 120 in number.

Thousand of nails or tacks = 1,200 in number.

Hundred of lead = 112 lbs.

A fodder of lead = $19\frac{1}{2}$ cwt.

Sheet lead = 6 to 10 lbs. per square foot.

Table of glass = 5 feet.
Case of glass = 45 tables.
Case of Newcastle and Normandy glass = 25 tables.
Stone of glass = 5 lbs.
Square of flooring = 100 square feet.
Hundred of deals = 120 in number.
A cord of wood = 4 feet × 4 feet × 8 feet = 128 cubic feet.
Stack of wood = 108 cubic feet.
A load of mortar, 27 cubic feet, requires 9 bushels of lime and 1 yard of sand.

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## VOCABULARY OF FRENCH AND ENGLISH ENGINEERING TERMS.

The following List of French words for English Engineering Terms will be found useful, as very few Engineering terms are given in French Dictionaries.

| FRENCH. | ENGLISH. |
|---|---|
| | A. |
| *ACCOUPLÉ.* | Connected, coupled. |
| *Acier.* | Steel. |
| *Affinage.* | Refining. |
| *Affouiller.* | To undermine. |
| *Aiguilles.* | Points. |
| *Aiguille mobile.* | Tongue rail. |
| *Air chaud, fab. de fonte.* | Hot blast. |
| *Air froid* ,, | Cold blast. |
| *Airain.* | Brass. |
| *Ajuster.* | To fit. |
| *Ajusteur.* | Fitter. |
| *Ajutage or Ajutoir.* | Tube or pipe, nozzle. |
| *Alêne.* | Awl. |
| *Alésage.* | Boring metals. |
| *Alèsé.* | Polished, finished. |
| *Aléser.* | To bore metals. |
| *Alésures.* | Iron borings. |
| *Alignement.* | Straight length, row, line. |
| *Aligner.* | To level, to lay out by line. |
| *Alliage.* | Alloy, mixture of metals. |
| *Alluchon.* | Tooth of a wheel, catch. |
| *Alumelle.* | Blade of a knife. |
| *Amarre.* | Rope, cable. |
| *Ame d'un canon.* | Bore of a gun. |

| FRENCH. | ENGLISH. |
| --- | --- |
| *Ame d'un souflet.* | Valve, of a bellows. |
| *Ancre.* | Anchor. |
| *Angle.* | Angle, corner. |
| *Angle droit.* | Right angle. |
| *Antimoine.* | Antimony. |
| *Appentis.* | Shed, outhouse. |
| *Approvisionnement.* | Materials supplied. |
| *Aqueduc.* | Aqueduct, waterpipe. |
| *Arborer.* | To hoist. |
| *Arbre.* | Shaft, spindle. |
| *Arbre moteur.* | Driving shaft. |
| *Arbre à noyau.* | Core bar. |
| *Arc-boutant.* | Buttress, support, strut. |
| *Arête.* | Edge. |
| *Argeat.* | Canted. |
| *Armature.* | Fastening bars, of iron. |
| *Armature du tiroir.* | Valve fittings. |
| *Arrimage.* | Stowage. |
| *Articulé.* | Jointed. |
| *Articulation.* | Moveable joint. |
| *Assemblage.* | Framing. |
| *Assembler à mortaise.* | Morticed. |
| *Assembler.* | To frame. |
| *Assembler à queue d'aronde.* | To dovetail. |
| *Assist.* | A lift, a stage. |
| *Atelier.* | Workshop. |
| *Attaché, callé.* | Fastened. |
| *Atteinte.* | Flaw, injury. |
| *Attelage.* | Coupling, railway coupling. |
| *Aube.* | Float. |
| *Auge.* | Trough. |
| *Automatique.* | Self-acting. |
| *Automobile.* | Traction engine. |
| *Avance du tiroir.* | Lead of slide valve. |
| *Avant-train.* | Leading wheels. |
| *Aviver.* | To brighten, to polish. |
| *Axe.* | Axis, centre, centre line |
| *Axe d'axe en.* | From centre to centre. |
| *Axe goujon.* | Spindle. |
| *Axe coudé, ou à manivelle.* | Crank axle. |

B.

| | |
| --- | --- |
| *BACHE.* | Cart, or tilt wagon. |
| *Bague.* | Ring. |

| FRENCH. | ENGLISH. |
|---|---|
| *Balance à ressort.* | Spring balance. |
| *Balancier.* | Beam. |
| *Balancier à vis.* | Screw lever, wrench. |
| *Balustrade.* | Fence. |
| *Balustrer.* | To rail in. |
| *Balle.* | Ball. |
| *Banc de tour.* | Bed (of a lathe). |
| *Bandages des roues.* | Wheel tyres. |
| *Bandes plattes.* | Plate rails. |
| *Bandin ou vourrelet.* | Flange. |
| *Bandoir.* | Pulley, wheel, spring. |
| *Baquet.* | Bucket, tub, trough. |
| *Barbelé.* | Spiked. |
| *Barbure.* | Rough parts of moulded metal. |
| *Barrage.* | Dam, weir. |
| *Barre plate.* | Flat bars. |
| *Barreaux.* | Fire bars. |
| *Barres.* | Bars. |
| *Barres du foyer.* | Fire bars. |
| *Bascule.* | Weighing machine. |
| *Bascule à percer.* | Cramp for drilling. |
| *Basse pression.* | Low pressure. |
| *Bec d'ane.* | Crosscut chisel. |
| *Beton.* | Concrete. |
| *Biais.* | Slope. |
| *Bielle.* | Connecting rod. |
| *Bielle d'accouplement.* | Coupling bar. |
| *Biez.* | Millpool. |
| *Boite.* | Box, case, chest. |
| *Boite à étoupe.* | Stuffing box. |
| *Boite à feu.* | Fire box. |
| *Boite à graisse.* | Axle box. |
| *Boite à huile.* | Oil cup. |
| *Boite à noyau.* | Core box. |
| *Boite à sable.* | Sand box. |
| *Boite à tiroir.* | Slide valve case. |
| *Boite à vapeur.* | Steam chest. |
| *Bombée.* | Rounded. |
| *Bouchon.* | Plug. |
| *Bouchon en plomb.* | Lead plug. |
| *Bouchon à vis.* | Screw plug. |
| *Boucle.* | Buckle. |
| *Boudin.* | Flange of tyres. |
| *Boule ou boulet.* | Ball. |

| FRENCH. | ENGLISH. |
| --- | --- |
| *Boulette.* | A little ball. |
| *Boulin.* | Putlog. |
| *Boulon.* | Bolt. |
| *Boulon à clavette.* | Cotter bolt. |
| *Boulon à écrou.* | Bolt and nut. |
| *Boulon d'éclissage.* | Fish bolt. |
| *Boulonne.* | A large auger. |
| *Boulonnée.* | Bolted. |
| *Boulonner.* | To bolt. |
| *Bout.* | The end, point. |
| *Bouterolle.* | Snap. |
| *Braser.* | To braze or solder. |
| *Bride.* | Flange, lug, strap. |
| *Bronze.* | Brass, bronze. |
| *Bronzer le fer.* | To brown iron. |
| *Brouette.* | Wheel barrow. |
| *Broyeur.* | Pug mill. |
| *Burin, ciseau.* | Chisel. |
| *Buriner.* | To chip iron. |
| *Buveau or Beauveau.* | Bevel. |
| *Buze.* | Nozzle. |

## C.

| | |
| --- | --- |
| *CABESTAN.* | Cabstan, crab. |
| *Cable, chaine.* | Chain cable. |
| *Cadre.* | Frame. |
| *Caisse.* | Box. |
| *Caisse à eau.* | Water tank. |
| *Cale.* | Wedge or packing. |
| *Caler.* | To wedge or pack up. |
| *Caler les roues.* | To chock railway wheels. |
| *Calfater.* | To calk. |
| *Calquer.* | To trace drawings. |
| *Cambré.* | Arched, warped. |
| *Cannelée.* | Grooved, fluted, channelled. |
| *Cendrier.* | Ash pan. |
| *Çercle.* | Ring. |
| *Cercle primitif.* | Pitch circle of a toothed wheel. |
| *Cercler.* | To hoop. |
| *Ceruse.* | White lead. |
| *Chaine.* | Chain. |
| *Chainon.* | Link of a chain. |
| *Chaleur.* | Heat. |

| FRENCH. | ENGLISH. |
|---|---|
| *Chambre de vapeur.* | Steam chest. |
| *Champon.* | Spike. |
| *Changement de voie.* | Changing rail points. |
| *Chantier.* | Works. |
| *Chantignole.* | Bracket. |
| *Chape.* | Strap of connecting rod. |
| *Chapelet.* | Chain pump. |
| *Charbon.* | Coal. |
| *Charger.* | To load. |
| *Charnières.* | Hinges. |
| *Charpente.* | Woodwork. |
| *Charpentier.* | Carpenter. |
| *Charron.* | Wheelwright. |
| *Chasse-pierre.* | Rail guard. |
| *Chassis.* | Frame. |
| *Chassis extérieur.* | Outside frame. |
| *Chassis intérieur.* | Inside frame. |
| *Chaudière.* | Boiler. |
| *Chaudière tubulaire.* | Tubular boiler. |
| *Chauffe.* | Furnace. |
| *Chemin de fer.* | Railway. |
| *Cheval vapeur.* | Horse power. |
| *Cheville.* | Iron pin or spike. |
| *Cheville en bois.* | Treenails. |
| *Chèvre.* | Shear legs with crab. |
| *Chiasse.* | Dross, scum. |
| *Cintre.* | Arch. |
| *Circonférence.* | Circumference. |
| *Circulaire.* | Circular. |
| *Ciré.* | Oil cloth. |
| *Ciseau burin.* | Chisel. |
| *Citerne.* | Cistern. |
| *Clapet.* | Clack of a pump. |
| *Clapet, tiroirs, soupapes.* | Valves. |
| *Clavette et contre-clavette.* | Gib and cotter. |
| *Clavetter une roue.* | To key a wheel on a shaft. |
| *Clefs de calage.* | Wedging keys. |
| *Cliquet à percer.* | Ratchet brace. |
| *Cloures.* | Jointing. |
| *Coin.* | Wedge. |
| *Coinsage.* | Wedging. |
| *Collé.* | Glued. |
| *Collet.* | Collar of a shaft. |
| *Colonne.* | Column, pillar. |

| FRENCH. | ENGLISH. |
|---|---|
| *Colonne cannelée.* | Fluted column. |
| *Combustible.* | Fuel. |
| *Compteur à gaz.* | Gas meter. |
| *Concentrique.* | Concentric. |
| *Contre clavette.* | Gib. |
| *Contre-fiche.* | Brace, strut, stay. |
| *Conduit d'échappement.* | Blast pipe. |
| *Conique.* | Conical. |
| *Constructeur.* | Builder. |
| *Contrefort.* | Shoulder. |
| *Copeaux.* | Chippings. |
| *Cornière.* | Angle iron. |
| *Corps de pompe.* | Pump barrel. |
| *Cote.* | Figured dimension. |
| *Couche.* | Coat (of paint). |
| *Couchis.* | Lagging. |
| *Coudé.* | Cranked. |
| *Coulage.* | Casting. |
| *Couler.* | To cast, to melt. |
| *Coulisse.* | Sliding socket |
| *Coup d'arrière.* | Back stroke. |
| *Coup d'avant.* | Fore stroke. |
| *Coup de piston.* | Stroke of the piston. |
| *Coupant.* | Cutting, dividing. |
| *Coupe.* | Section. |
| *Couperose.* | Copperas. |
| *Couple.* | Couple, a pair. |
| *Courbe.* | Railway curve, bent. |
| *Couronnement.* | Coping. |
| *Courroie.* | Leather strap. |
| *Course.* | Length of stroke. |
| *Coussinet.* | Bush, bearing of shafts. |
| *Couvercle de cylindre.* | Cylinder cover. |
| *Crampon.* | Cramp. |
| *Cran.* | Notch. |
| *Crapaudine.* | Foot-step of a shaft. |
| *Crèche.* | Crib, manger. |
| *Crémaillère.* | Rack. |
| *Créneler une roue.* | To notch a wheel. |
| *Créneleure.* | Notching, indenting. |
| *Crible.* | Sieve, riddle. |
| *Cribler.* | To sift. |
| *Cric à vis.* | Screw lifting jack. |

| FRENCH. | ENGLISH. |
|---|---|
| *Croc.* | Hook. |
| *Crochet.* | Hook, link. |
| *Crochet d'attelage.* | Draw link. |
| *Croisée de fenêtre.* | Window frame. |
| *Croisement.* | Crossing. |
| *Cuir.* | Leather. |
| *Cuivre.* | Copper. |
| *Cuivré.* | Copper coloured. |
| *Cul.* | Breech. |
| *Culasse.* | The breech of a gun. |
| *Culée.* | Abutment. |
| *Cuve.* | Tub, vat. |
| *Cuvelage.* | Tubbing, lining mines. |
| *Cylindre.* | Cylinder. |
| *Cylindre, rouleau.* | Roller. |
| *Cylindrique.* | Cylindrical. |

## D.

| | |
|---|---|
| *DAME.* | Rammer. |
| *Déballer.* | To unpack. |
| *Débander.* | To untie, to slacken. |
| *Débarber.* | To fettle castings. |
| *Débarquer.* | To disembark. |
| *Déboucher.* | To unstop. |
| *Déboucler.* | To unbuckle. |
| *Décalage.* | Taking out wedges, unkeying. |
| *Décalquer.* | To copy a drawing on tracing paper |
| *De champs.* | Edgeways. |
| *Déchargé.* | Unloaded. |
| *Déchat.* | Wear and tear. |
| *Décintrer.* | To strike the centre. |
| *Défaut.* | Flaw, defect. |
| *Dégrener.* | To throw out of gear. |
| *Dent d'un roue.* | Tooth or cog of a wheel. |
| *Dépôt de machine.* | Engine-house or shed. |
| *Depouille de Modèle.* | Draw or taper of patterns. |
| *Dessein.* | Design. |
| *Dessin.* | Drawing, plan. |
| *Détente ou dilatation.* | Expansion. |
| *Diamètre extérieur.* | Outside diameter. |
| *Diamètre intérieur.* | Inside diameter. |
| *Dôme.* | Dome. |
| *Double fonds.* | Double casing. |

| FRENCH. | ENGLISH. |
|---|---|
| *Doublure.* | Lining. |
| *Drague.* | Dredger. |
| *Dur comme du fer.* | As hard as iron. |

## E.

| | |
|---|---|
| *ÉCHALAT.* | Stay. |
| *Échappement.* | Escaping, eduction. |
| *Échelle.* | Scale, ladder. |
| *Échenal.* | Wooden gutter. |
| *Éclisse.* | Splint, fishplate. |
| *Écluse.* | Sluice, dam. |
| *Écrou.* | Nut of a screw. |
| *Écrou à six pans.* | Hexagon nut. |
| *Écume de métal.* | Dross. |
| *Effort.* | Strain. |
| *Égohine.* | Hand saw. |
| *Égout.* | Sewer, drain, gutter. |
| *Élingue.* | Sling. |
| *Émail.* | Enamel. |
| *Emballage.* | Packing. |
| *Embâtage.* | Hooping, tyreing. |
| *Embellir.* | To decorate, to embellish. |
| *Emboîter.* | To joint, to put in a box, to clamp. |
| *Emboîtement.* | Socket, shrouding. |
| *Emboîtement et cordon.* | Socket and spigot. |
| *Embranchement.* | Framing, branch line. |
| *Embrasure.* | Port-hole. |
| *Émission.* | Eduction. |
| *Emmanchement.* | To put a handle in a hammer. |
| *Empater.* | To foot, to scarf. |
| *En plein cintre.* | Circular. |
| *Enarbrer.* | To key a wheel on a shaft. |
| *Encastrer une poutre.* | To fit one end of a beam in a wall. |
| *Enclave.* | Recess. |
| *Enclouer.* | To nail up. |
| *Enclume.* | Anvil. |
| *Encocher.* | To notch. |
| *Enduire.* | To coat, to plaster. |
| *Endurcir.* | To harden. |
| *Enfoncer.* | To hollow, to sink. |
| *Engrenage.* | Wheel gearing. |
| *Engrenage conique.* | Bevel and mitre wheels. |

| FRENCH. | ENGLISH. |
|---|---|
| *Engrener.* | To put into gear. |
| *Enlacure.* | Bolting a tenon into its mortice. |
| *Enligner.* | To straighten or level. |
| *Entailler.* | To notch, to dovetail. |
| *Entretoise.* | Stay. |
| *Épisser.* | Splice. |
| *Épuisement.* | Pumping. |
| *Équerre.* | Square. |
| *Estamper.* | To swage. |
| *Essieu.* | Axle. |
| *Essieu coude.* | Crank axle. |
| *Essieu d'arrière.* | Trailing axle. |
| *Essieu d'avant.* | Leading axle. |
| *Essieu moteur.* | Driving axle. |
| *Étain.* | Pewter, tin. |
| *Étamer de fer.* | To tin iron. |
| *Étanche contenant l'eau.* | Water-tight. |
| *Étanche de vapeur.* | Steam-tight. |
| *Étai.* | Brace. |
| *Étançon.* | Prop, stay, stanchion. |
| *Étau.* | Vice. |
| *Étirer le fer sous le marteau.* | To draw out, to lengthen by hammering. |
| *Étoupe.* | Flax, hemp, tow. |
| *Étreignoir.* | Cramp, hand screw. |
| *Étrier.* | Strap. |
| *Étuve.* | Drying stove. |
| *Éventer.* | To ventilate. |
| *Excentrique.* | Eccentric. |

## F.

| | |
|---|---|
| *FABRICANT.* | Manufacturer. |
| *Fardier.* | Truck. |
| *Fenderie.* | Cutting iron into strips. |
| *Fer.* | Iron, wrought iron. |
| *Fer aciéreux.* | Steely iron. |
| *Fer affiné.* | Refined iron. |
| *Fer d'angle.* | Angle iron. |
| *Fer en barres.* | Bar iron. |
| *Fer en barres dentelé.* | Notched bar iron. |
| *Fer en barres méplat.* | Flat iron, flat bar iron. |
| *Fer battu meplattes.* | Hammered iron. |

| FRENCH. | ENGLISH. |
|---|---|
| *Fer à biseau.* | Wedge shape iron. |
| *Fer blanc.* | White iron. |
| *Fer en charbon de bois.* | Charcoal iron. |
| *Fer en bottes.* | Iron in bundles. |
| *Fer à boulon.* | Bolt iron. |
| *Fer à calfat.* | Calking iron. |
| *Fer en barres carrées.* | Square bar iron. |
| *Fer en barres rond.* | Round bar iron. |
| *Fer en barres de profile circulaire.* | Round bar iron. |
| *Fer à cheval.* | Horse shoe. |
| *Fer à clou.* | Nail rod iron. |
| *Fer à clou pour fer de cheval.* | Horse nail iron. |
| *Fer à cornière.* | Angle iron. |
| *Fer de roulage.* | Iron-wire. |
| *Fer à côtés.* | Channel iron. |
| *Fer coulé.* | Cast iron work. |
| *Fer creux.* | Hollow iron. |
| *Fer cru.* | Pig iron. |
| *Fer demi rond.* | Half round iron. |
| *Fer dentelé.* | Notched iron. |
| *Fer doux.* | Soft iron. |
| *Fer ébauché.* | Puddled bar iron. |
| *Fer de forge écailleux.* | Scaly wrought iron. |
| *Fer écroui.* | Cold hammered iron. |
| *Fer tiré en tubes.* | Iron drawn into tubes. |
| *Fer ferraciereux.* | Hard iron. |
| *Fer en feuilles.* | Sheet iron. |
| *Fer fin.* | Fine iron. |
| *Fer de fonte.* | Cast iron. |
| *Fer forgé.* | Forged iron. |
| *Fer forgé par le martinet.* | Hammered wrought iron. |
| *Fer fort.* | Best wrought iron. |
| *Fer fondu en coquilles.* | Chilled cast iron. |
| *Fer galvanisé.* | Galvanized iron. |
| *Fer à glace.* | Frost shoe. |
| *Fer en grain gros.* | Coarse grained iron. |
| *Fer homogène.* | Homogeneous iron. |
| *Fer en lames cylindré.* | Rolled plate or sheet iron. |
| *Fer en lames étamé.* | Tinned plate iron. |
| *Fer en lames forgé.* | Forged plate iron. |
| *Fer laminé cylindré.* | Drawn out or rolled iron. |
| *Fer en loupes.* | Iron blooms. |
| *Fer marchand.* | Merchant iron. |

| FRENCH. | ENGLISH. |
|---|---|
| *Fer martelé.* | Hammered wrought iron. |
| *Fer martiné.* | Tilted iron. |
| *Fer fondu.* | Melted iron. |
| *Fer noir, en lames noir.* | Black plate or sheet iron. |
| *Fer en perche.* | Iron rod. |
| *Fer en plaques.* | Iron in slabs. |
| *Fer plat.* | Flat bar iron. |
| *Fer platiné.* | Flat iron for rolling. |
| *Fer à plater.* | Flattening iron. |
| *Fer à rabot.* | Plane iron. |
| *Fer à repasser.* | Ironing iron. |
| *Fer à rivet.* | Rivet iron. |
| *Fer rond.* | Round iron. |
| *Fer à ruban.* | Hoop iron. |
| *Fer soudé.* | Welded iron. |
| *Fer superfin.* | Superfine iron. |
| *Fer tiré.* | Drawn-out iron. |
| *Fer à tringles.* | Rod iron. |
| *Fer en tôle.* | Plate iron. |
| *Fer en tôle, forté.* | Boiler plate iron. |
| *Fer en tôle gaufrée, ondulée.* | Corrugated plate iron. |
| *Fer étiré en tubes.* | Tubular iron, drawn. |
| *Fer en verges.* | Iron rods. |
| *Fer zinqué.* | Galvanized iron. |
| *Ferraille.* | Scrap iron. |
| *Fers d'ouvrage.* | Ironwork. |
| *Feuille de fer.* | Sheet of iron. |
| *Fil d'acier.* | Steel wire. |
| *Fil de caret.* | Rope yarn. |
| *Fil de fer.* | Iron wire. |
| *Fil à plomb.* | Plumb line. |
| *Filière.* | Screw plate, stocks. |
| *Filière à coussinet.* | Stocks and dies. |
| *Fondant.* | Flux. |
| *Fonderie de fer.* | Iron foundry. |
| *Fondre à découvert.* | To cast in open sand |
| *Fondu.* | Melted. |
| *Fonte.* | Casting, melting. |
| *Fonte blanche.* | White iron. |
| *Fonte de deuxième fusion.* | Casting run from the cupola. |
| *Fonte de fer.* | Cast iron. |
| *Fonte de fer malléable.* | Malleable cast iron. |
| *Fonte de première fusion.* | Casting run from the blast furnace. |

| FRENCH. | ENGLISH. |
|---|---|
| *Fonte grise.* | Grey iron. |
| *Fonte moulée.* | Iron castings. |
| *Fonte truitée.* | Mottled iron. |
| *Forer ou foret.* | To bore, to drill. |
| *Forge.* | Forge, smithy. |
| *Forge portative.* | Portable forge. |
| *Forger.* | To forge, to hammer. |
| *Forgeron.* | Smith. |
| *Fosse.* | Pit. |
| *Fosse à piquer le feu.* | Ash pit. |
| *Foulant.* | Pressing down. |
| *Four.* | Furnace. |
| *Four à pudder.* | Puddling furnace. |
| *Four à reverbère.* | Air furnace. |
| *Fourgon.* | Luggage wagon. |
| *Fourneau.* | Furnace, cupola. |
| *Fraise.* | Countersunk. |
| *Frein.* | Brake. |
| *Frein de chemin de fer.* | Railway brake. |
| *Frette.* | Tyre, ring, hoop. |
| *Fumage.* | Lacquering. |
| *Fuseau.* | Spindle, spool. |
| *Fusée.* | Toe of a vertical shaft. |
| *Fut d'une colonne.* | Shaft of a column. |
| *Fut à percer.* | Brace for drilling. |

## G.

| | |
|---|---|
| *GABARE.* | Lighter. |
| *Gabarit.* | Gauge, template. |
| *Gache.* | Staple. |
| *Gaine.* | Sheath, stand, case. |
| *Galandages.* | Brick partitions. |
| *Galaubans.* | Backstays. |
| *Galerie.* | Footplate, gangway. |
| *Galet.* | Roller. |
| *Galonner.* | To lace. |
| *Garage des trains.* | Shunting trains. |
| *Garde cendre.* | Fender. |
| *Garde corps.* | Hand railing. |
| *Garde crotte.* | Splasher. |
| *Gare de marchandises.* | Goods station. |

| FRENCH. | ENGLISH. |
| --- | --- |
| *Garniture de boite à étoupe.* | Packing. |
| *Gaufrée, ondulée.* | Corrugated. |
| *Gaz.* | Gas. |
| *Gêner.* | To cramp. |
| *Giron.* | Tread of a step. |
| *Glissoirs, tiroirs.* | Slides. |
| *Godet.* | Grease cup. |
| *Goujon.* | Iron pin, gudgeon, stud. |
| *Goujon central.* | Centre pin. |
| *Gousset.* | Gusset. |
| *Gratte brosse.* | Wire scratch brush. |
| *Grattoir.* | Scraper. |
| *Grelet.* | Mason's hammer. |
| *Grelin.* | A small cable. |
| *Grenouillère.* | Rose for watering. |
| *Grillage.* | Grating. |
| *Grille du foyer.* | Fire grate. |
| *Grue.* | A crane, a hoist. |
| *Grue hydraulique.* | Hydraulic crane. |
| *Grue roulante.* | Travelling crane. |
| *Gueuse.* | Pig iron. |
| *Guindage.* | Hoisting loads. |
| *Guindal.* | Windlass. |

## H.

| | |
| --- | --- |
| *HACHE.* | Axe, hatchet. |
| *Haler.* | To draw with a rope. |
| *Hangar.* | A shed. |
| *Haquet.* | A dray. |
| *Harnais.* | Harness, armour. |
| *Hauban.* | Guy. |
| *Haut fourneau.* | Blast furnace. |
| *Hélice.* | Spiral. |
| *Hématite.* | Hematite. |
| *Hie.* | Rammer, beetle. |
| *Hisser.* | To hoist. |
| *Houillère.* | Colliery. |
| *Huile.* | Oil. |

## I.

| | |
| --- | --- |
| *INDICATEUR.* | Indicator. |
| *Ingénieur.* | Engineer. |
| *Injecteur.* | Injector. |

| FRENCH. | ENGLISH. |
|---|---|
| | **J.** |
| *JAUGE.* | Gauge. |
| *Joint.* | Joint. |
| *Joint à boule.* | Universal joint. |
| *Jointoyer.* | To cement, to point. |
| *Joue.* | Cheek. |
| *Jouillières.* | The cheeks of a sluice. |
| | **K.** |
| *KAOLIN.* | China clay. |
| *Kas.* | Bottom of paper-mill trough. |
| *Kilogramme.* | One thousand grammes. |
| | **L.** |
| *LAMBOURDE.* | Joist. |
| *Lame.* | Thin plate or web of metal. |
| *Laminage.* | Flattening of metals. |
| *Laminer.* | To roll metals. |
| *Laminoir.* | Rolling mill. |
| *Lancière.* | Sluice. |
| *Lançoir.* | Mill dam. |
| *Largeur.* | Width, breadth. |
| *Largeur de la voie.* | Rail gauge. |
| *Larmier.* | Coping of a wall. |
| *L'arsenic.* | Arsenic. |
| *L'eau entramée.* | Priming in boilers. |
| *Levée.* | Embankment. |
| *Levier.* | Lever. |
| *Levier de reversement.* | Reversing lever. |
| *Liaison (pièces de).* | Strengthening pieces. |
| *Ligne.* | Line. |
| *Ligne ponctué.* | Dotted line. |
| *Ligne principale.* | Main line. |
| *Limaille.* | Filings. |
| *Limaille de fer.* | Iron filings. |
| *Lime.* | File. |
| *Limer.* | To file. |
| *Limure.* | Filings. |
| *Lin.* | Lint, flax. |
| *Liteau.* | Chipping piece. |

| FRENCH. | ENGLISH. |
| --- | --- |
| *Livraison.* | Delivery of goods. |
| *Locomotive.* | Locomotive. |
| *Longeur.* | Length. |
| *Longeur de la course.* | Length of stroke. |
| *Longrine.* | Longitudinal sleeper. |
| *Loquet à ressort.* | Spring latch. |
| *Lumière d'admission.* | Steam port. |
| *Lumière d'échappement.* | Exhaust port. |

## M.

| | |
| --- | --- |
| *MACHINE.* | Engine, machine. |
| *Machine à cintrer la tôle.* | Plate bending machine. |
| *Machine à chariot.* | Sliding table machine. |
| *Machine à façonner.* | Shaping machine. |
| *Machine à percer.* | Drilling machine. |
| *Machine à raboter.* | Planing machine. |
| *Machine à poinçonner.* | Punching machine. |
| *Machine à vapeur.* | Steam engine. |
| *Machine à drauger.* | Dredging machine. |
| *Machine fixe.* | Stationary engine. |
| *Machine outils.* | Machine tools. |
| *Machine soufflante.* | Blowing engine. |
| *Maçonnerie.* | Masonry. |
| *Maçonnerie en brique.* | Brickwork. |
| *Maille.* | Mesh of net or link of chain. |
| *Maillon.* | Link of a chain. |
| *Main courante.* | Hand rail. |
| *Main d'œuvre.* | Workmanship. |
| *Manche.* | Handle. |
| *Manchon.* | Socket. |
| *Mandrain.* | Mandrel. |
| *Manivelle.* | Crank. |
| *Manomètre à mercure.* | Mercurial pressure gauge. |
| *Manutention.* | Loading and unloading. |
| *Marbre.* | Surface-plate. |
| *Marteau de grosse forge.* | Forge hammer. |
| *Marteau pilon.* | Steam hammer. |
| *Martelé.* | Hammered. |
| *Massif.* | Massive, foundation. |
| *Matériel.* | Material. |
| *Matériel roulant.* | Rolling stock. |
| *Mauvais ouvrage.* | Bad work. |

| FRENCH. | ENGLISH |
| --- | --- |
| *Mécanique.* | Mechanical. |
| *Mèche de coton.* | Cotton wick. |
| *Mèche à syphon.* | Wick for oil syphons. |
| *Mesure du niveau de l'eau.* | Water gauge. |
| *Mesure en ruban.* | Tape measure. |
| *Métail.* | Metallic composition. |
| *Meulière.* | Millstone. |
| *Mi.* | Half. |
| *Mille.* | A thousand. |
| *Minéral de fer.* | Iron ore. |
| *Minium.* | Red lead. |
| *Modèle.* | Pattern to cast from. |
| *Moitié bois.* | Halved. |
| *Montant.* | Upright post. |
| *Monte-charge.* | Lift, hoist. |
| *Mortaise.* | Mortice. |
| *Moteur, motrice.* | Mover, driving. |
| *Moufle.* | Pulley block for lifting. |
| *Moulage.* | Moulding, casting. |
| *Moule.* | Mould, model. |
| *Mouler.* | To mould, to cast. |
| *Moulerie.* | Iron foundry. |
| *Moyeu.* | Nave. |
| *Mur.* | Wall. |

## N.

| | |
| --- | --- |
| *NERVURE.* | Moulding, or rib on a casting. |
| *Niveau.* | Level. |
| *Nivelette.* | A level. |
| *Noyau.* | Core. |
| *Noye.* | Let in flush, countersunk. |

## O.

| | |
| --- | --- |
| *OLLURE.* | Leather apron. |
| *Oreille.* | Lug. |
| *Ornière.* | Rut of a wheel, tram. |
| *Outil.* | Tool. |
| *Outil (machine).* | Machine tool. |
| *Outil automatique.* | Self-acting tool. |
| *Ouvrage.* | Work. |

| FRENCH. | ENGLISH. |
|---|---|
| *Ouvrage en fer.* | Ironwork. |
| *Ouvragé.* | Wrought. |
| *Ouvré.* | Diapered. |
| *Ouvrier.* | Workman. |
| *Ovale.* | Oval. |

P.

| | |
|---|---|
| *PALIER.* | Plummer-block. |
| *Pas.* | Pitch of screws. |
| *Passerelle.* | Foot bridge. |
| *Pautre.* | Beam, girder. |
| *Pelle.* | Shovel. |
| *Percage.* | Piercing, drilling. |
| *Percer.* | To bore, to drill. |
| *Percer à foret.* | To drill. |
| *Pesage.* | Weighing. |
| *Petard.* | Fog signal. |
| *Pétrole.* | Petroleum. |
| *Pic.* | Pick, pickaxe. |
| *Pic feu.* | Poker. |
| *Pied carré.* | Square foot. |
| *Pierre.* | Stone. |
| *Pilon.* | Rammer. |
| *Pince en fer.* | Crow-bar. |
| *Pinces.* | Tongs. |
| *Pioche.* | Pickaxe, mattock. |
| *Piston.* | Piston. |
| *Pivot à crapaudine.* | Toe bearing. |
| *Plaque.* | Plate. |
| *Plaque tournante.* | Turn-table. |
| *Plateau à griffes.* | Dog-chuck. |
| *Plateau de tour.* | Face plate of a lathe. |
| *Plateau Universel.* | Universal Chuck. |
| *Plomb.* | Lead. |
| *Plongeur.* | Plunger. |
| *Poche.* | Ladle, pocket. |
| *Pompe.* | Pump. |
| *Pompe à air.* | Air pump. |
| *Pompe à double effet.* | Double-acting pump. |
| *Pompe à eau chaude.* | Hot-water pump. |
| *Pompe alimentaire.* | Feed pump. |
| *Pompe aspirante.* | Suction pump. |
| *Pompe foulante.* | Force pump. |

| FRENCH. | ENGLISH. |
| --- | --- |
| *Pompe à incendie.* | Fire engine. |
| *Pont.* | Bridge. |
| *Pont aquéduc.* | Aqueduct. |
| *Pont en pierre.* | Stone bridge. |
| *Pont en fonte.* | Cast-iron bridge. |
| *Pont en tôle.* | Iron plate bridge. |
| *Pont de poutre en tôle.* | Girder bridge. |
| *Pont oblique.* | Skew bridge. |
| *Pont en treillis.* | Lattice bridge. |
| *Pont tournant.* | Swing bridge. |
| *Pont tubulaire.* | Tubular bridge. |
| *Porte de la boite à fumée.* | Smoke-box door. |
| *Poseur.* | Plate layer. |
| *Poster.* | To fix, to lay, to set. |
| *Potée d'étain.* | Pewter. |
| *Potelot.* | Black lead. |
| *Pouce.* | Inch. |
| *Poudre à souder.* | Welding powder. |
| *Poulie.* | Pulley. |
| *Poussière de fer.* | Irondust. |
| *Poutre.* | Beam, girder. |
| *Poutre en fonte.* | Cast-iron girder. |
| *Poutre en tôle.* | Iron plate girder. |
| *Poutre en treillis.* | Lattice girder. |
| *Poutrelle.* | Small beam, small girder. |
| *Presse à cingler.* | Squeezer. |
| *Presse étoupe.* | Gland of a piston rod. |
| *Presse hydraulique.* | Hydraulic press. |
| *Presson.* | Crow bar. |
| *Puits.* | Well, shaft of a mine. |

Q.

| | |
| --- | --- |
| *QUADRANT* | Quadrant. |
| *Quarteron.* | Quarter. |
| *Queue d'hironde.* | Dovetail. |
| *Quincaille.* | Hardware. |

R.

| | |
| --- | --- |
| *RABOT.* | Plane. |
| *Raboter.* | To plane. |
| *Raies (d'un roue).* | Spokes. |
| *Raies creux.* | Hollow spokes. |
| *Rail.* | Rail. |

| FRENCH. | ENGLISH. |
| --- | --- |
| *Rail en acier.* | Steel rail. |
| *Rail à double champignon.* | Double-headed rail. |
| *Rail à simple champignon.* | Single-headed rail. |
| *Rail à ventre de poisson.* | Fish-bellied rail. |
| *Rainure.* | Groove. |
| *Rampe.* | Slope, gradient. |
| *Rauder.* | To grind (cocks). |
| *Rayon.* | Radius. |
| *Rebord.* | Flange. |
| *Rebord des bandages des roues.* | Flange of tyres. |
| *Rebours.* | Cross-grained. |
| *Recouvrement.* | Overlap. |
| *Recouvrement extérieur du tiroir.* | Lap of valve. |
| *Régistre.* | Damper. |
| *Régulateur.* | Regulator. |
| *Renflement central.* | Centre boss. |
| *Ressorts.* | Springs. |
| *Ressort de tampon.* | Buffer spring. |
| *Riblons.* | Scrap iron. |
| *River.* | To clench or rivet. |
| *Rivet.* | Rivet. |
| *Robinet.* | Cock. |
| *Robinet petit.* | Pet cock. |
| *Robinet de jauge.* | Gauge cock. |
| *Robinet pour mesurer le niveau.* | Gauge cock. |
| *Robinet de vidange.* | Waste cock. |
| *Rondelle.* | Washer. |
| *Roue.* | Wheel. |
| *Roue à aubes.* | Paddle wheel of a steamer. |
| *Roue à aubes.* | Undershot water wheel. |
| *Roue à auget.* | Overshot water wheel. |
| *Roue d'arrière.* | Trailing wheel. |
| *Roue d'avant.* | Leading wheel. |
| *Roue motrice.* | Driving wheel. |
| *Roue à axe vertical.* | Turbine. |
| *Roue de côte.* | Breast wheel. |
| *Roue d'engrenage.* | Cog wheel. |
| *Roue hydraulique.* | Water wheel. |
| *Roues accouplées.* | Coupled wheels. |
| *Roues de moulins motrice.* | Mill driving-wheel. |
| *Rougir le fer.* | To heat iron. |
| *Rougissure.* | Copper colour. |
| *Rouillé.* | Rusty. |

| FRENCH. | ENGLISH. |
|---|---|
| *Rouillure.* | Rust. |
| *Roulage.* | Rolling. |
| *Rouleau.* | Roll, roller. |
| *Rouverin.* | Brittle. |

S.

| | |
|---|---|
| *SABLE.* | Sand, ballast. |
| *Salpêtre.* | Saltpetre. |
| *Sas.* | Sieve. |
| *Scie.* | Saw. |
| *Scie circulaire.* | Circular saw. |
| *Sciérie.* | Saw bench. |
| *Scorie de la fonte.* | Slag, iron dross. |
| *Seau.* | Bucket, pail. |
| *Serre joint.* | Cramp. |
| *Siège de la soupape.* | Valve seat. |
| *Sifflet.* | Whistle. |
| *Similor.* | Pinchbeck. |
| *Siphon.* | Syphon. |
| *Socle.* | Stand, footing, socket. |
| *Solive.* | Joist, rafter. |
| *Soliveau.* | Little joist. |
| *Sonnette.* | Pile-driving machine. |
| *Sonnette à déclic.* | Pile-driving machine. |
| *Sonnette à vapeur.* | Steam pile-driving machine. |
| *Souder.* | To solder, to weld. |
| *Soudoir.* | Soldering iron. |
| *Soufre.* | Sulphur. |
| *Soufflage.* | Blast. |
| *Soufflant.* | Blowing. |
| *Soupape.* | Valve. |
| *Soupape à tiroir.* | Slide valve. |
| *Soupape à boule.* | Ball valve. |
| *Soupape de sureté.* | Safety valve. |
| *Stoc.* | The lower part of an anvil |
| *Suif.* | Tallow. |
| *Surface de chauffe.* | Heating surface. |
| *Surface de grille.* | Grate surface. |
| *Surplomb.* | Slope. |

T.

| | |
|---|---|
| *TABLE.* | Table, flange. |
| *Table inférieure.* | Bottom flange. |

| FRENCH. | ENGLISH. |
| --- | --- |
| *Table première.* | Top flange. |
| *Tampon.* | Buffer. |
| *Taranche.* | Iron bar to turn the screw of a press. |
| *Taraud.* | Tap, screw tap. |
| *Tarauder.* | To tap. |
| *Tarière.* | Auger, wimble. |
| *Tas.* | Small anvil, dolly. |
| *Tas bouterollé.* | Cup-headed riveting tool. |
| *Tasseau.* | Block of iron. |
| *Tenailles.* | Gas tongs, nippers. |
| *Terre grasse.* | Loam, clay. |
| *Tête.* | Head. |
| *Tête croisée.* | Cross head. |
| *Tête fraisée.* | Countersunk head. |
| *Tête à six pans.* | Hexagon head. |
| *Tige.* | Rod. |
| *Tige de choc.* | Buffer rod. |
| *Tige du piston.* | Piston rod. |
| *Tige de sonde.* | Boring rod. |
| *Tige des tiroirs.* | Slide bars. |
| *Tirant.* | Tie rod. |
| *Tirant ou barre d'eccentrique.* | Eccentric rod. |
| *Tiroir.* | Slide valve. |
| *Toit en fer.* | Iron roofing. |
| *Tôle.* | Iron plate. |
| *Tombereau.* | Cart for one horse. |
| *Tonnelier.* | Cooper. |
| *Tour à chariot.* | Slide lathe. |
| *Tourillon.* | Gudgeon of a beam. |
| *Tourner.* | To turn. |
| *Train de marchandises.* | Goods train. |
| *Train de plaisir.* | Excursion train. |
| *Traverse.* | Sleeper. |
| *Traverse frontale.* | Buffer beam. |
| *Treillis.* | Lattice work. |
| *Trempée.* | Tempered. |
| *Trépan.* | A strong auger. |
| *Tréteau.* | Trestle. |
| *Treuil.* | Windlass, crab. |
| *Tronchet.* | Block. |
| *Trottoir.* | Platform. |
| *Trou d'homme.* | Manhole. |
| *Tube.* | Tube. |

| FRENCH. | ENGLISH. |
|---|---|
| *Tube à manchon.* | Socket-pipe. |
| *Tube de verre.* | Glass tube. |
| *Tunnel.* | Tunnel. |
| *Turbine.* | Turbine. |
| *Tuyau.* | Pipe. |
| *Tuyau d'alimentation.* | Feed pipe. |
| *Tuyau d'aspiration.* | Suction pipe. |
| *Tuyau d'échappement.* | Exhaust pipe. |
| *Tuyau à bride.* | Flange pipe. |
| *Tuyau à emboitement à manchon.* | Socket and spigot pipe. |
| *Tuyau en fonte.* | Cast iron pipe. |
| *Tuyau à vapeur.* | Steam pipe. |
| *Tuyère.* | Tuyere. |

U.

| | |
|---|---|
| *USINE.* | Manufactory. |
| *Usine à fer.* | Ironwork. |
| *Usne.* | A very strong cable. |
| *Usure.* | Wear and tear. |
| *Utinet.* | Mallet used by coopers. |

V.

| | |
|---|---|
| *VEINÉ.* | Veined, streaked. |
| *Vélocité.* | Velocity. |
| *Veltage.* | Gauging. |
| *Ventilateur.* | Ventilator, fan. |
| *Venue à la fonte.* | Rope sling. |
| *Verbouquet.* | Cast on. |
| *Verge de fer.* | Iron rod. |
| *Verin.* | Screw jack. |
| *Vermeil.* | Silver-gilt. |
| *Vermeil, le.* | Red coral. |
| *Vernis.* | Varnish. |
| *Verre.* | Glass. |
| *Verrine.* | A strong screw. |
| *Verrou.* | Bolt. |
| *Verrouillé.* | Bolted. |
| *Vert-de-gris.* | Verdigris. |
| *Vertevelles.* | Staples of a bolt. |
| *Vidange.* | Act of emptying. |
| *Vieux fer.* | Old iron. |
| *Vieille ferraille.* | Old scrap iron. |

| FRENCH. | ENGLISH. |
|---|---|
| *Vif-argent.* | Quicksilver. |
| *Vindas.* | A windlass. |
| *Vireveau.* | A windlass. |
| *Virole.* | Ferrule. |
| *Vis.* | Screw. |
| *Vis à bois.* | Wood screw. |
| *Visser.* | To screw. |
| *Voie.* | Line, permanent way. |
| *Voie simple.* | Single line. |
| *Voie double.* | Double line. |
| *Voiture.* | Carriage. |
| *Volant.* | Fly wheel. |
| *Volige.* | A thin plank of deal. |
| *Voute.* | Arch. |
| *Vrille.* | Gimlet, borer. |

## W.

| | |
|---|---|
| *WAGON.* | Wagon. |
| *Wagon à bagage.* | Luggage van. |
| *Wagon à ballast.* | Ballast wagon. |
| *Wagon écurie.* | Horse box. |
| *Wagon à marchandises.* | Goods wagon. |
| *Wagon à houille.* | Coal wagon. |
| *Wagon de terrassement.* | Earth wagon. |
| *Wagon pour les transport des voyageurs.* | Passenger carriage. |
| *Waggonet de tournée.* | Trolly. |

Table 161.—Fractional Parts of a Millimetre and their Equivalents in Decimal Parts of an English Inch.

| Millimètre. | Inches. | Millimètre. | Inches. | Millimètre. | Inches. |
|---|---|---|---|---|---|
| $\frac{1}{10}$ | ·003937 | $\frac{4}{10}$ | ·015748 | $\frac{8}{10}$ | ·031496 |
| $\frac{2}{10}$ | ·007874 | $\frac{5}{10}$ | ·019685 | $\frac{9}{10}$ | ·035433 |
| $\frac{3}{10}$ | ·011811 | $\frac{6}{10}$ | ·023622 | 1 | ·039370 |
| | | $\frac{7}{10}$ | ·027559 | | |

*Scale, One Decimetre or 100 Millimetres long — One Tenth of a Metre*

Table 162.—Millimetres and their Equivalents in Inches.

| Milli-mètres. | Inches. | Milli-mètres. | Inches. | Milli-mètres. | Inches. | Milli-mètres. | Inches. |
|---|---|---|---|---|---|---|---|
| 1 | ·0394 | 47 | 1·8504 | 93 | 3·6614 | 139 | 5·472 |
| 2 | ·0787 | 48 | 1·8898 | 94 | 3·7008 | 140 | 5·511 |
| 3 | ·1181 | 49 | 1·9291 | 95 | 3·7402 | 141 | 5·551 |
| 4 | ·1575 | 50 | 1·9685 | 96 | 3·7796 | 142 | 5·590 |
| 5 | ·1968 | 51 | 2·0079 | 97 | 3·8189 | 143 | 5·630 |
| 6 | ·2362 | 52 | 2·0473 | 98 | 3·8583 | 144 | 5·670 |
| 7 | ·2756 | 53 | 2·0866 | 99 | 3·8977 | 145 | 5·708 |
| 8 | ·3149 | 54 | 2·1260 | 100 | 3·9370 | 146 | 5·748 |
| 9 | ·3543 | 55 | 2·1654 | 101 | 3·976 | 147 | 5·787 |
| 10 | ·3937 | 56 | 2·2047 | 102 | 4·015 | 148 | 5·826 |
| 11 | ·4331 | 57 | 2·2441 | 103 | 4·055 | 149 | 5·866 |
| 12 | ·4724 | 58 | 2·2835 | 104 | 4·094 | 150 | 5·905 |
| 13 | ·5118 | 59 | 2·3228 | 105 | 4·133 | 151 | 5·944 |
| 14 | ·5511 | 60 | 2·3622 | 106 | 4·173 | 152 | 5·984 |
| 15 | ·5906 | 61 | 2·4016 | 107 | 4·212 | 153 | 6·023 |
| 16 | ·6299 | 62 | 2·4410 | 108 | 4·252 | 154 | 6·063 |
| 17 | ·6693 | 63 | 2·4803 | 109 | 4·291 | 155 | 6·102 |
| 18 | ·7087 | 64 | 2·5197 | 110 | 4·330 | 156 | 6·141 |
| 19 | ·7480 | 65 | 2·5591 | 111 | 4·370 | 157 | 6·181 |
| 20 | ·7874 | 66 | 2·5984 | 112 | 4·409 | 158 | 6·220 |
| 21 | ·8267 | 67 | 2·6378 | 113 | 4·448 | 159 | 6·259 |
| 22 | ·8661 | 68 | 2·6772 | 114 | 4·488 | 160 | 6·299 |
| 23 | ·9055 | 69 | 2·7166 | 115 | 4·527 | 161 | 6·338 |
| 24 | ·9448 | 70 | 2·7559 | 116 | 4·567 | 162 | 6·378 |
| 25 | ·9842 | 71 | 2·7953 | 117 | 4·606 | 163 | 6·417 |
| 26 | 1·0236 | 72 | 2·8347 | 118 | 4·645 | 164 | 6·456 |
| 27 | 1·0630 | 73 | 2·8740 | 119 | 4·685 | 165 | 6·496 |
| 28 | 1·1023 | 74 | 2·9134 | 120 | 4·724 | 166 | 6·535 |
| 29 | 1·1417 | 75 | 2·9528 | 121 | 4·763 | 167 | 6·574 |
| 30 | 1·1811 | 76 | 2·9922 | 122 | 4·803 | 168 | 6·614 |
| 31 | 1·2205 | 77 | 3·0315 | 123 | 4·842 | 169 | 6·654 |
| 32 | 1·2598 | 78 | 3·0709 | 124 | 4·881 | 170 | 6·693 |
| 33 | 1·2992 | 79 | 3·1103 | 125 | 4·921 | 171 | 6·732 |
| 34 | 1·3386 | 80 | 3·1496 | 126 | 4·960 | 172 | 6·771 |
| 35 | 1·3780 | 81 | 3·1890 | 127 | 5·000 | 173 | 6·811 |
| 36 | 1·4173 | 82 | 3·2284 | 128 | 5·039 | 174 | 6·850 |
| 37 | 1·4567 | 83 | 3·2677 | 129 | 5·078 | 175 | 6·890 |
| 38 | 1·4961 | 84 | 3·3071 | 130 | 5·118 | 176 | 6·930 |
| 39 | 1·5354 | 85 | 3·3465 | 131 | 5·157 | 177 | 6·968 |
| 40 | 1·5748 | 86 | 3·3859 | 132 | 5·196 | 178 | 7·008 |
| 41 | 1·6142 | 87 | 3·4252 | 133 | 5·236 | 179 | 7·047 |
| 42 | 1·6536 | 88 | 3·4646 | 134 | 5·275 | 180 | 7·086 |
| 43 | 1·6929 | 89 | 3·5040 | 135 | 5·315 | 181 | 7·126 |
| 44 | 1·7323 | 90 | 3·5433 | 136 | 5·354 | 182 | 7·165 |
| 45 | 1·7717 | 91 | 3·5827 | 137 | 5·393 | 183 | 7·204 |
| 46 | 1·8110 | 92 | 3·6221 | 138 | 5·433 | 184 | 7·244 |

Table 162 *con.*—Millimetres and their Equivalents in Inches.

| Milli-mètres. | Inches. | Milli-mètres. | Inches. | Milli-mètres. | Inches. | Milli-mètres. | Inches. |
|---|---|---|---|---|---|---|---|
| 185 | 7·283 | 231 | 9·094 | 277 | 10·905 | 323 | 12·716 |
| 186 | 7·322 | 232 | 9·134 | 278 | 10·945 | 324 | 12·756 |
| 187 | 7·362 | 233 | 9·173 | 279 | 10·984 | 325 | 12·795 |
| 188 | 7·402 | 234 | 9·212 | 280 | 11·023 | 326 | 12·834 |
| 189 | 7·441 | 235 | 9·252 | 281 | 11·063 | 327 | 12·874 |
| 190 | 7·480 | 236 | 9·291 | 282 | 11·102 | 328 | 12·913 |
| 191 | 7·520 | 237 | 9·330 | 283 | 11·141 | 329 | 12·952 |
| 192 | 7·560 | 238 | 9·370 | 284 | 11·181 | 330 | 12·992 |
| 193 | 7·598 | 239 | 9·409 | 285 | 11·220 | 331 | 13·031 |
| 194 | 7·637 | 240 | 9·448 | 286 | 11·260 | 332 | 13·071 |
| 195 | 7·677 | 241 | 9·488 | 287 | 11·299 | 333 | 13·110 |
| 196 | 7·716 | 242 | 9·527 | 288 | 11·338 | 334 | 13·149 |
| 197 | 7·757 | 243 | 9·567 | 289 | 11·378 | 335 | 13·189 |
| 198 | 7·795 | 244 | 9·606 | 290 | 11·417 | 336 | 13·228 |
| 199 | 7·834 | 245 | 9·645 | 291 | 11·456 | 337 | 13·267 |
| 200 | 7·874 | 246 | 9·685 | 292 | 11·496 | 338 | 13·307 |
| 201 | 7·913 | 247 | 9·724 | 293 | 11·535 | 339 | 13·346 |
| 202 | 7·952 | 248 | 9·763 | 294 | 11·575 | 340 | 13·386 |
| 203 | 7·992 | 249 | 9·803 | 295 | 11·614 | 341 | 13·425 |
| 204 | 8·031 | 250 | 9·842 | 296 | 11·653 | 342 | 13·464 |
| 205 | 8·071 | 251 | 9·882 | 297 | 11·693 | 343 | 13·504 |
| 206 | 8·110 | 252 | 9·921 | 298 | 11·732 | 344 | 13·543 |
| 207 | 8·150 | 253 | 9·960 | 299 | 11·771 | 345 | 13·582 |
| 208 | 8·190 | 254 | 10·000 | 300 | 11·811 | 346 | 13·622 |
| 209 | 8·228 | 255 | 10·04 | 301 | 11·850 | 347 | 13·661 |
| 210 | 8·267 | 256 | 10·078 | 302 | 11·889 | 348 | 13·701 |
| 211 | 8·307 | 257 | 10·118 | 303 | 11·929 | 349 | 13·740 |
| 212 | 8·346 | 258 | 10·157 | 304 | 11·968 | 350 | 13·780 |
| 213 | 8·385 | 259 | 10·197 | 305 | 12·008 | 351 | 13·820 |
| 214 | 8·425 | 260 | 10·236 | 306 | 12·047 | 352 | 13·858 |
| 215 | 8·464 | 261 | 10·275 | 307 | 12·086 | 353 | 13·897 |
| 216 | 8·504 | 262 | 10·315 | 308 | 12·126 | 354 | 13·937 |
| 217 | 8·543 | 263 | 10·354 | 309 | 12·165 | 355 | 13·976 |
| 218 | 8·582 | 264 | 10·393 | 310 | 12·205 | 356 | 14·016 |
| 219 | 8·622 | 265 | 10·433 | 311 | 12·244 | 357 | 14·055 |
| 220 | 8·661 | 266 | 10·472 | 312 | 12·283 | 358 | 14·094 |
| 221 | 8·700 | 267 | 10·512 | 313 | 12·323 | 359 | 14·134 |
| 222 | 8·740 | 268 | 10·551 | 314 | 12·362 | 360 | 14·173 |
| 223 | 8·780 | 269 | 10·590 | 315 | 12·401 | 361 | 14·212 |
| 224 | 8·819 | 270 | 10·630 | 316 | 12·441 | 362 | 14·252 |
| 225 | 8·858 | 271 | 10·669 | 317 | 12·480 | 363 | 14·291 |
| 226 | 8·897 | 272 | 10·708 | 318 | 12·519 | 364 | 14·330 |
| 227 | 8·937 | 273 | 10·748 | 319 | 12·560 | 365 | 14·370 |
| 228 | 8·976 | 274 | 10·787 | 320 | 12·598 | 366 | 14·409 |
| 229 | 9·015 | 275 | 10·826 | 321 | 12·638 | 367 | 14·449 |
| 230 | 9·055 | 276 | 10·866 | 322 | 12·677 | 368 | 14·488 |

Table 162 *con.*—Millimetres and their Equivalents in Inches.

| Millimètres. | Inches. | Millimètres. | Inches. | Millimètres. | Inches. | Millimètres. | Inches. |
|---|---|---|---|---|---|---|---|
| 369 | 14·527 | 415 | 16·338 | 461 | 18·149 | 507 | 19·961 |
| 370 | 14·567 | 416 | 16·378 | 462 | 18·189 | 508 | 20·000 |
| 371 | 14·606 | 417 | 16·417 | 463 | 18·228 | 509 | 20·039 |
| 372 | 14·645 | 418 | 16·456 | 464 | 18·268 | 510 | 20·080 |
| 373 | 14·685 | 419 | 16·496 | 465 | 18·307 | 511 | 20·118 |
| 374 | 14·724 | 420 | 16·536 | 466 | 18·346 | 512 | 20·157 |
| 375 | 14·764 | 421 | 16·576 | 467 | 18·386 | 513 | 20·197 |
| 376 | 14·803 | 422 | 16·614 | 468 | 18·425 | 514 | 20·236 |
| 377 | 14·842 | 423 | 16·653 | 469 | 18·464 | 515 | 20·275 |
| 378 | 14·882 | 424 | 16·693 | 470 | 18·504 | 516 | 20·315 |
| 379 | 14·921 | 425 | 16·732 | 471 | 18·543 | 517 | 20·354 |
| 380 | 14·961 | 426 | 16·771 | 472 | 18·583 | 518 | 20·394 |
| 381 | 15·000 | 427 | 16·811 | 473 | 18·622 | 519 | 20·433 |
| 382 | 15·040 | 428 | 16·850 | 474 | 18·661 | 520 | 20·473 |
| 383 | 15·080 | 429 | 16·890 | 475 | 18·701 | 521 | 20·513 |
| 384 | 15·118 | 430 | 16·929 | 476 | 18·740 | 522 | 20·551 |
| 385 | 15·157 | 431 | 16·968 | 477 | 18·780 | 523 | 20·590 |
| 386 | 15·197 | 432 | 17·008 | 478 | 18·820 | 524 | 20·630 |
| 387 | 15·236 | 433 | 17·047 | 479 | 18·858 | 525 | 20·669 |
| 388 | 15·275 | 434 | 17·086 | 480 | 18·898 | 526 | 20·709 |
| 389 | 15·315 | 435 | 17·126 | 481 | 18·938 | 527 | 20·748 |
| 390 | 15·354 | 436 | 17·165 | 482 | 18·976 | 528 | 20·787 |
| 391 | 15·393 | 437 | 17·205 | 483 | 19·016 | 529 | 20·827 |
| 392 | 15·433 | 438 | 17·244 | 484 | 19·055 | 530 | 20·866 |
| 393 | 15·472 | 439 | 17·283 | 485 | 19·094 | 531 | 20·905 |
| 394 | 15·512 | 440 | 17·323 | 486 | 19·134 | 532 | 20·945 |
| 395 | 15·551 | 441 | 17·362 | 487 | 19·173 | 533 | 20·984 |
| 396 | 15·590 | 442 | 17·402 | 488 | 19·212 | 534 | 21·024 |
| 397 | 15·630 | 443 | 17·441 | 489 | 19·252 | 535 | 21·063 |
| 398 | 15·670 | 444 | 17·480 | 490 | 19·291 | 536 | 21·102 |
| 399 | 15·708 | 445 | 17·520 | 491 | 19·331 | 537 | 21·142 |
| 400 | 15·748 | 446 | 17·560 | 492 | 19·370 | 538 | 21·181 |
| 401 | 15·787 | 447 | 17·598 | 493 | 19·409 | 539 | 21·220 |
| 402 | 15·827 | 448 | 17·638 | 494 | 19·449 | 540 | 21·260 |
| 403 | 15·866 | 449 | 17·677 | 495 | 19·488 | 541 | 21·299 |
| 404 | 15·905 | 450 | 17·717 | 496 | 19·527 | 542 | 21·338 |
| 405 | 15·945 | 451 | 17·757 | 497 | 19·567 | 543 | 21·378 |
| 406 | 15·984 | 452 | 17·795 | 498 | 19·606 | 544 | 21·417 |
| 407 | 16·023 | 453 | 17·834 | 499 | 19·646 | 545 | 21·457 |
| 408 | 16·063 | 454 | 17·874 | 500 | 19·685 | 546 | 21·496 |
| 409 | 16·102 | 455 | 17·913 | 501 | 19·724 | 547 | 21·535 |
| 410 | 16·142 | 456 | 17·953 | 502 | 19·764 | 548 | 21·575 |
| 411 | 16·181 | 457 | 17·992 | 503 | 19·803 | 549 | 21·614 |
| 412 | 16·220 | 458 | 18·031 | 504 | 19·842 | 550 | 21·654 |
| 413 | 16·260 | 459 | 18·071 | 505 | 19·882 | 551 | 21·693 |
| 414 | 16·299 | 460 | 18·110 | 506 | 19·921 | 552 | 21·732 |

Table 162 *con.*—Millimetres and their Equivalents in Inches.

| Milli-mètres. | Inches. | Milli-mètres. | Inches. | Milli-mètres. | Inches. | Milli-mètres. | Inches. |
|---|---|---|---|---|---|---|---|
| 553 | 21·772 | 599 | 23·583 | 645 | 25·394 | 691 | 27·206 |
| 554 | 21·811 | 600 | 23·622 | 646 | 25·433 | 692 | 27·244 |
| 555 | 21·850 | 601 | 23·661 | 647 | 25·472 | 693 | 27·283 |
| 556 | 21·890 | 602 | 23·701 | 648 | 25·512 | 694 | 27·323 |
| 557 | 21·930 | 603 | 23·740 | 649 | 25·551 | 695 | 27·362 |
| 558 | 21·968 | 604 | 23·780 | 650 | 25·591 | 696 | 27·402 |
| 559 | 22·008 | 605 | 23·819 | 651 | 25·630 | 697 | 27·441 |
| 560 | 22·047 | 606 | 23·858 | 652 | 25·669 | 698 | 27·480 |
| 561 | 22·087 | 607 | 23·898 | 653 | 25·709 | 699 | 27·520 |
| 562 | 22·126 | 608 | 23·937 | 654 | 25·748 | 700 | 27·559 |
| 563 | 22·165 | 609 | 23·976 | 655 | 25·787 | 701 | 27·598 |
| 564 | 22·205 | 610 | 24·016 | 656 | 25·827 | 702 | 27·638 |
| 565 | 22·244 | 611 | 24·055 | 657 | 25·866 | 703 | 27·677 |
| 566 | 22·283 | 612 | 24·094 | 658 | 25·906 | 704 | 27·717 |
| 567 | 22·323 | 613 | 24·134 | 659 | 25·945 | 705 | 27·756 |
| 568 | 22·362 | 614 | 24·173 | 660 | 25·984 | 706 | 27·795 |
| 569 | 22·401 | 615 | 24·213 | 661 | 26·024 | 707 | 27·835 |
| 570 | 22·441 | 616 | 24·252 | 662 | 26·063 | 708 | 27·874 |
| 571 | 22·480 | 617 | 24·291 | 663 | 26·102 | 709 | 27·913 |
| 572 | 22·520 | 618 | 24·331 | 664 | 26·142 | 710 | 27·953 |
| 573 | 22·559 | 619 | 24·370 | 665 | 26·181 | 711 | 27·992 |
| 574 | 22·598 | 620 | 24·410 | 666 | 26·220 | 712 | 28·032 |
| 575 | 22·638 | 621 | 24·450 | 667 | 26·260 | 713 | 28·071 |
| 576 | 22·677 | 622 | 24·488 | 668 | 26·299 | 714 | 28·110 |
| 577 | 22·716 | 623 | 24·528 | 669 | 26·339 | 715 | 28·150 |
| 578 | 22·756 | 624 | 24·567 | 670 | 26·378 | 716 | 28·189 |
| 579 | 22·795 | 625 | 24·606 | 671 | 26·417 | 717 | 28·228 |
| 580 | 22·835 | 626 | 24·646 | 672 | 26·457 | 718 | 28·268 |
| 581 | 22·874 | 627 | 24·685 | 673 | 26·496 | 719 | 28·307 |
| 582 | 22·913 | 628 | 24·724 | 674 | 26·535 | 720 | 28·347 |
| 583 | 22·953 | 629 | 24·764 | 675 | 26·575 | 721 | 28·386 |
| 584 | 22·992 | 630 | 24·803 | 676 | 26·614 | 722 | 28·425 |
| 585 | 23·031 | 631 | 24·842 | 677 | 26·654 | 723 | 28·465 |
| 586 | 23·071 | 632 | 24·882 | 678 | 26·693 | 724 | 28·504 |
| 587 | 23·110 | 633 | 24·921 | 679 | 26·732 | 725 | 28·543 |
| 588 | 23·150 | 634 | 24·961 | 680 | 26·772 | 726 | 28·583 |
| 589 | 23·190 | 635 | 25·000 | 681 | 26·811 | 727 | 28·622 |
| 590 | 23·228 | 636 | 25·039 | 682 | 26·850 | 728 | 28·661 |
| 591 | 23·268 | 637 | 25·079 | 683 | 26·890 | 729 | 28·701 |
| 592 | 23·307 | 638 | 25·118 | 684 | 26·930 | 730 | 28·740 |
| 593 | 23·346 | 639 | 25·157 | 685 | 26·970 | 731 | 28·780 |
| 594 | 23·386 | 640 | 25·197 | 686 | 27·008 | 732 | 28·819 |
| 595 | 23·425 | 641 | 25·236 | 687 | 27·047 | 733 | 28·858 |
| 596 | 23·465 | 642 | 25·276 | 688 | 27·087 | 734 | 28·898 |
| 597 | 23·504 | 643 | 25·315 | 689 | 27·126 | 735 | 28·937 |
| 598 | 23·543 | 644 | 25·354 | 690 | 27·166 | 736 | 28·976 |

Table 162 *con.*—MILLIMETRES AND THEIR EQUIVALENTS IN INCHES.

| Millimètres. | Inches. | Millimètres. | Inches. | Millimètres. | Inches. | Millimètres. | Inches. |
|---|---|---|---|---|---|---|---|
| 737 | 29·016 | 783 | 30·827 | 829 | 32·638 | 875 | 34·450 |
| 738 | 29·055 | 784 | 30·866 | 830 | 32·677 | 876 | 34·488 |
| 739 | 29·095 | 785 | 30·906 | 831 | 32·717 | 877 | 34·528 |
| 740 | 29·134 | 786 | 30·945 | 832 | 32·756 | 878 | 34·567 |
| 741 | 29·173 | 787 | 30·984 | 833 | 32·795 | 879 | 34·606 |
| 742 | 29·213 | 788 | 31·024 | 834 | 32·835 | 880 | 34·646 |
| 743 | 29·252 | 789 | 31·063 | 835 | 32·874 | 881 | 34·685 |
| 744 | 29·291 | 790 | 31·103 | 836 | 32·913 | 882 | 34·725 |
| 745 | 29·331 | 791 | 31·143 | 837 | 32·953 | 883 | 34·764 |
| 746 | 29·370 | 792 | 31·181 | 838 | 32·992 | 884 | 34·803 |
| 747 | 29·410 | 793 | 31·221 | 839 | 33·032 | 885 | 34·843 |
| 748 | 29·450 | 794 | 31·260 | 840 | 33·071 | 886 | 34·882 |
| 749 | 29·488 | 795 | 31·299 | 841 | 33·110 | 887 | 34·921 |
| 750 | 29·528 | 796 | 31·339 | 842 | 33·150 | 888 | 34·961 |
| 751 | 29·567 | 797 | 31·378 | 843 | 33·190 | 889 | 35·000 |
| 752 | 29·606 | 798 | 31·417 | 844 | 33·228 | 890 | 35·040 |
| 753 | 29·646 | 799 | 31·457 | 845 | 33·268 | 891 | 35·080 |
| 754 | 29·685 | 800 | 31·496 | 846 | 33·307 | 892 | 35·118 |
| 755 | 29·724 | 801 | 31·536 | 847 | 33·347 | 893 | 35·158 |
| 756 | 29·764 | 802 | 31·575 | 848 | 33·386 | 894 | 35·197 |
| 757 | 29·803 | 803 | 31·614 | 849 | 33·425 | 895 | 35·236 |
| 758 | 29·843 | 804 | 31·654 | 850 | 33·465 | 896 | 35·276 |
| 759 | 29·882 | 805 | 31·693 | 851 | 33·504 | 897 | 35·315 |
| 760 | 29·922 | 806 | 31·732 | 852 | 33·543 | 898 | 35·354 |
| 761 | 29·962 | 807 | 31·772 | 853 | 33·583 | 899 | 35·394 |
| 762 | 30·000 | 808 | 31·811 | 854 | 33·622 | 900 | 35·433 |
| 763 | 30·040 | 809 | 31·850 | 855 | 33·662 | 901 | 35·473 |
| 764 | 30·080 | 810 | 31·890 | 856 | 33·701 | 902 | 35·512 |
| 765 | 30·118 | 811 | 31·930 | 857 | 33·740 | 903 | 35·551 |
| 766 | 30·158 | 812 | 31·970 | 858 | 33·780 | 904 | 35·591 |
| 767 | 30·197 | 813 | 32·008 | 859 | 33·819 | 905 | 35·630 |
| 768 | 30·236 | 814 | 32·047 | 860 | 33·859 | 906 | 35·670 |
| 769 | 30·276 | 815 | 32·087 | 861 | 33·899 | 907 | 35·709 |
| 770 | 30·315 | 816 | 32·126 | 862 | 33·937 | 908 | 35·748 |
| 771 | 30·354 | 817 | 32·165 | 863 | 33·977 | 909 | 35·788 |
| 772 | 30·394 | 818 | 32·205 | 864 | 34·016 | 910 | 35·827 |
| 773 | 30·433 | 819 | 32·244 | 865 | 34·055 | 911 | 35·866 |
| 774 | 30·472 | 820 | 32·284 | 866 | 34·095 | 912 | 35·906 |
| 775 | 30·512 | 821 | 32·323 | 867 | 34·134 | 913 | 35·945 |
| 776 | 30·551 | 822 | 32·362 | 868 | 34·173 | 914 | 35·984 |
| 777 | 30·591 | 823 | 32·402 | 869 | 34·213 | 915 | 36·024 |
| 778 | 30·630 | 824 | 32·441 | 870 | 34·252 | 916 | 36·063 |
| 779 | 30·670 | 825 | 32·480 | 871 | 34·291 | 917 | 36·103 |
| 780 | 30·709 | 826 | 32·520 | 872 | 34·331 | 918 | 36·142 |
| 781 | 30·748 | 827 | 32·560 | 873 | 34·370 | 919 | 36·181 |
| 782 | 30·787 | 828 | 32·600 | 874 | 34·410 | 920 | 36·221 |

Table 162 *con.*—MILLIMETRES AND THEIR EQUIVALENTS IN INCHES.

| Millimètres. | Inches. | Millimètres. | Inches. | Millimètres. | Inches. | Millimètres. | Inches. |
|---|---|---|---|---|---|---|---|
| 921 | 36·260 | 941 | 37·047 | 961 | 37·836 | 981 | 38·622 |
| 922 | 36·300 | 942 | 37·087 | 962 | 37·874 | 982 | 38·662 |
| 923 | 36·339 | 943 | 37·126 | 963 | 37·914 | 983 | 38·701 |
| 924 | 36·378 | 944 | 37·166 | 964 | 37·953 | 984 | 38·740 |
| 925 | 36·418 | 945 | 37·205 | 965 | 37·992 | 985 | 38·780 |
| 926 | 36·457 | 946 | 37·244 | 966 | 38·032 | 986 | 38·819 |
| 927 | 36·496 | 947 | 37·284 | 967 | 38·071 | 987 | 38·858 |
| 928 | 36·536 | 948 | 37·323 | 968 | 38·110 | 988 | 38·898 |
| 929 | 36·575 | 949 | 37·362 | 969 | 38·150 | 989 | 38·937 |
| 930 | 36·614 | 950 | 37·402 | 970 | 38·189 | 990 | 38·977 |
| 931 | 36·654 | 951 | 37·441 | 971 | 38·229 | 991 | 39·016 |
| 932 | 36·693 | 952 | 37·481 | 972 | 38·268 | 992 | 39·055 |
| 933 | 36·732 | 953 | 37·520 | 973 | 38·307 | 993 | 39·095 |
| 934 | 36·772 | 954 | 37·560 | 974 | 38·347 | 994 | 39·134 |
| 935 | 36·811 | 955 | 37·599 | 975 | 38·386 | 995 | 39·173 |
| 936 | 36·851 | 956 | 37·638 | 976 | 38·425 | 996 | 39·213 |
| 937 | 36·890 | 957 | 37·677 | 977 | 38·465 | 997 | 39·252 |
| 938 | 36·929 | 958 | 37·717 | 978 | 38·504 | 998 | 39·292 |
| 939 | 36·969 | 959 | 37·756 | 979 | 38·544 | 999 | 39·331 |
| 940 | 37·008 | 960 | 37·796 | 980 | 38·583 | 1000 | 39·370 |

NOTE.—To convert Metres into Inches (approximately) multiply by 40, and to convert Inches into Metres (approximately) divide by 40.

One millimetre ($\frac{1}{1000}$ part of a metre). = ·03937 inches.
One centimetre . . . . . = 10 millimetres, or = ·3937 inches.
One decimetre . . . . . = 10 centimetres, or 3·937 inches.
One metre . . . . . . = 10 decimetres, or 39·370 inches.
One square millimetre . . . = ·00155 square inches.
One square centimetre . . . = ·155 square inches.
One square decimetre . . . = 15·55 square inches.
One square metre . . . . = 1550·06 square inches.
One inch . . . . . . = ·0254 metre.
One foot . . . . . . = ·3048 metre.
One yard . . . . . . = ·9143 metre.
One square inch . . . . . = ·000645 square metre.
One square foot . . . . = ·0928 square metre.
One square yard . . . . . = ·8360 square metre.
One cubic inch . . . . = 16·387 cubic centimetres.
One cubic foot . . . . . = 28·3153 cubic decimetres.
One cubic yard . . . . = ·7645 cubic metre.
Millimetres multiplied by ·03937 . . = inches.
Inches multiplied by 25·4 . . . = millimetres.

## French Weights and Measures.

| | Troy ounces. | Avoirdupois lb. | Cwt. — 112 lb. |
|---|---|---|---|
| Milligramme | 0·000032 | 0·0000022 | 0·0000000 |
| Centigramme | 0·000322 | 0·0000220 | 0·0000002 |
| Décigramme | 0·003215 | 0·0002205 | 0·0000020 |
| Gramme | 0·032151 | 0·0022046 | 0·0000197 |
| Décagramme | 0·321507 | 0·0220462 | 0·0001968 |
| Hectogramme | 3·215073 | 0·2204621 | 0·0019684 |
| Kilogramme | 32·150727 | 2·2046213 | 0·0196841 |
| Myrigramme | 321·507267 | 22·0462126 | 0·1968412 |

Grain . . . . . . . = 0·064799 gramme.
Troy ounce . . . . . . . = 31·103496 grammes.
Pound avoirdupois . . . . = 0·453593 kilogrammes.
Cwt. . . . . . . . . = 50·802377 kilogrammes.
One centilitre . . . . . = ·0176 pint.
One decilitre . . . . . = ·1760 pint.
One litre . . . . . . = 1·7607 pints.
One litre . . . . . . . = 61·02524 cubic inches.
One litre is a little over $1\frac{3}{4}$ pints.
Litres multiplied by ·2201 . . . = imperial gallons.
Hectolitre multiplied by 2·7512 . . = bushels.
Grammes multiplied by ·002205 . = pounds avoirdupois.
Kilogrammes multiplied by 2·205 . = pounds avoirdupois.
51 kilogrammes . . . . = nearly 1 cwt.
One metric ton . . . . . = 1000 kilogrammes.
Tons multiplied by ·984 . . . = French tonnes.

Table 163.—French Measures and Weights of Various Metals.

| | Wrought Iron. | Cast Iron. | Steel. | Copper. | Brass. | Lead. |
|---|---|---|---|---|---|---|
| One circular mètre, one millimètre thick. Weight in kilogrammes | 6·04 | 5·8 | 6·16 | 6·96 | 6·65 | 8·95 |
| One cubic mètre. Weight in kilogrammes | 7690· | 7280· | 7840· | 8800· | 8420· | 1135· |
| One cylindrical mètre. Weight in kilogrammes | 6040· | 5720· | 6160· | 6910· | 6610· | 8920· |
| One square mètre, one millimètre thick. Weight in kilogrammes | 7·70 | 7·30 | 7·85 | 8·85 | 8·45 | 11·40 |

**The French unit of work** is one kilogrammetre, or a pressure of one kilogramme exerted through a space of one metre.

One kilogramme is equal to 7·233 foot pounds.

**The French horse-power,** or cheval vapeur, is equal to 75 kilogrammetres of work done per second; or equal to 75 × 7·233 = 542·47 foot pounds of work per second.

**The French unit of heat** is the amount required to raise the temperature of 1 kilogramme of water through 1 C.

Table 164.—Containing the Tested Performances of Men and Animals—The Velocity of Air, Wind, Light, and Sound—The Velocity of Shot and Shell from Light and Heavy Guns—The Velocity of the Current of Sewers, Water Pipes, Canals, Rivers, and Oceans—The Average Speed of Boats, Sailing Vessels, Yachts, Steamboats, Steamships, Torpedo Boats, and of Railway Trains, Tramcars, and other Conveyances, etc.

| Description. | Velocity in Feet per Second. |
|---|---|
| Man carrying a load in a wheelbarrow up an incline of 1 in 12. Force, 132 lbs. during 10 hours . . . . . . | ·06 |
| Man carrying a load on his back up a slight incline or stairs. Force, 142 lbs. during 6 hours . . . . . | ·13 |
| Man raising earth with a spade to a height of 5 feet. Force, 60 lbs. during 10 hours . . . . . . . . | ·14 |
| Man ascending a slight incline or stairs without a load. Force, 142 lbs. during 8 hours . . . . . . . | ·50 |
| Man on a treadwheel. Force, 144 lbs. during 8 hours . | ·50 |
| Man elevating a weight by hand. Force, 44 lbs. during 6 hours . . . . . . . . . . . . | ·56 |
| Man elevating a weight by pulling a cord downwards over a pulley. Force, 40 lbs. during 6 hours . . . . | ·65 |
| Man pushing or pulling horizontally. Force, 30 lbs. during 8 hours . . . . . . . . . . . . | 2 |
| Ox turning a mill at a moderate pace. Force, 144 lbs. during 8 hours . . . . . . . . . . | 2 |
| Ass turning a mill at a moderate pace. Force, 33 lbs. during 8 hours . . . . . . . . . . . | 2·65 |
| Horse drawing a carriage at an ordinary pace. Force, 155 lbs. during 10 hours . . . . . . . . | 2·96 |
| Horse turning a mill at an ordinary pace. Force, 100 lbs. during 8 hours . . . . . . . . . . . | 3 |
| Mule turning a mill at an ordinary pace. Force, 70 lbs. during 8 hours . . . . . . . . . . | 3 |
| Man pushing and pulling alternately in a vertical direction. Force, 11 lbs. during 8 hours . . . . . . . | 3·6 |
| Man turning the handle of a crane. Force, 15 lbs. during 8 hours . . . . . . . . . . . | 3·67 |
| Man turning the handle of a screw-lifting jack. Force, 20 lbs. during 8 hours . . . . . . . . . | 4 |
| Horse turning a mill at a trot. Force, 70 lbs. during 5 hours . . . . . . . . . . . | 9 |
| Circumferential velocity of waterwheels . . . . . | 5 |
| Velocity of mercury into a vacuum . . . . . . . | 13 |
| Velocity of air into a vacuum . . . . . . . . | 1300 |
| Velocity of steam of all pressures into a vacuum . . | 1900 |
| Rifle ball. Muzzle velocity . . . . . . . . . | 1400 |

Table 164 *continued.*

| Description. | Velocity in Feet per Second. |
| --- | --- |
| 6-inch Austrian bronze steel gun, with 18 lb. charge of powder, and with a shell weighing $85\frac{1}{2}$ lbs. Velocity at the muzzle . . . . . . . . . . . | 1476 |
| 7-inch Woolwich gun. Charge of powder, 30 lbs.; projectile, $114\frac{5}{8}$ lbs. Muzzle velocity . . . . . . . | 1561 |
| 80-ton Woolwich gun. Diameter of bore, 16 inches; length of bore, 288 inches; weight of projectile, 1700 lbs.; pressure, $21\frac{1}{2}$ tons. Muzzle velocity . . . . . . | 1657 |
| 71-ton Krupp gun. Diameter of bore, $15\frac{3}{4}$ inches; length of bore, 343 inches; weight of projectile, 1715 lbs.; pressure, 21 tons, nearly. Muzzle velocity . . . . | 1703 |
| 24-centimètre Krupp gun. Charge of powder, 171 lbs.; weight of projectile, 308 lbs. Muzzle velocity . . | 2000 |
| 100-ton Woolwich gun. Weight of projectile, 2000 lb. Muzzle velocity . . . . . . . . . . | 2000 |
| Velocity of sound in air at 62° . . . . . . . . | 1125 |
| Ditto ditto water . . . . . . . | 5060 |
| Ditto ditto copper . . . . . . . . | 11000 |
| Ditto ditto wood . . . . . . . | 13000 |
| Ditto ditto iron . . . . . . . . . | 19000 |
| Sewers. For drain pipes under 6 inches diameter . . | 4 |
| Ditto. Ditto from 6 to 10 inches diameter . . | $3\frac{3}{4}$ |
| Ditto. Ditto „ 12 to 17 ditto . . | $3\frac{1}{2}$ |
| Ditto. Ditto „ 18 to 24 ditto . . | 3 |
| Ditto. Ditto above 24 ditto . . | $2\frac{1}{2}$ |
| Water pipes. Town's supply under pressure, from 20 to . | 30 |
| | **Velocity in Miles per Hour.** |
| Artificial canals . . . . . . . . . . | $\frac{1}{2}$ |
| Rivers with sluggish current . . . . . . . . | 1 |
| Ditto ordinary „ . . . . . . . | $1\frac{1}{2}$ |
| Ditto strong „ . . . . . . . . | 2 |
| Ditto rapid „ . . . . . . . | 3 |
| Ditto very rapid „ . . . . . . . . | 4 |
| Ditto torrent-like „ . . . . . . . | 6 |
| River torrent caused by melting snow . . . . . . | 10 |
| Thames at London flood-tide, mean . . . . . . | 2 |
| Ocean current, entrance to Dover . . . . . . . | $4\frac{1}{2}$ |
| Ditto ditto Calais . . . . . . | $5\frac{1}{2}$ |
| Greatest tidal current . . . . . . . . . . | 10 |
| Wind, gentle breeze, pressure per square foot . 0 lbs. ·83 oz. | 3·25 |
| „ pleasant breeze „ „ . 0 lbs. 3·33 oz. | 6·5 |
| „ high wind „ „ . 1 lbs. 5· oz. | 16·25 |

Table 164 *continued.*

| Description. | | | Velocity in Miles per Hour. |
|---|---|---|---|
| | lbs. | oz. | |
| Wind, storm or gale, pressure per square foot . | 5 | 3 | 32·5 |
| ,, great storm ,, ,, . | 15 | 9 | 56·29 |
| ,, hurricane ,, ,, . | 31 | 3 | 79·61 |
| ,, tremendous hurricane ,, . | 46 | 12 | 97·5 |
| Soldier on march, common time . . . . . | | | $2\frac{1}{2}$ |
| Ditto quick time . . . . . . . | | | 3 |
| Ditto double quick time . . . . . | | | $3\frac{3}{4}$ |
| Man walking . . . . . . . . . . . | | | 3 |
| Horse towing a boat, exerting a pulling force of 120 lbs. during 10 hours . . . . . . . . . . | | | $2\frac{1}{2}$ |
| Omnibus . . . . . . . . . . . . | | | 5 |
| Tram cars, driven by horses . . . . . . . | | | 6 |
| Ditto driven by steam-engine . . . . . | | | 10 |
| Horse trotting . . . . . . . . . . . | | | 8 |
| Horse racing on a racecourse . . . . . . . | | | 30 |
| Tricycles . . . . . . . . . . . . | | | 10 |
| Bicycles . . . . . . . . . . . . | | | 12 |
| Steam tugs . . . . . . . . . . . | | | 8 |
| Small steamboats on rivers . . . . . . . | | | 10 |
| 8-oar boats on rivers, racing . . . . . . . | | | 12 |
| Sailing vessels . . . . . . . . . . | | | 12 |
| Steam ships, ordinary . . . . . . . . | | | 16 |
| Ditto fast . . . . . . . . . . | | | 20 |
| Steam yachts . . . . . . . . . . . | | | 22 |
| Torpedo boats . . . . . . . . . . | | | 25 |
| Railway trains, goods . . . . . . . . | | | 25 |
| Ditto ordinary passenger . . . . . | | | 40 |
| Ditto first-class express . . . . . . | | | 60 |
| Velocity of light, 186,600 miles per second; solids must be heated to about 700° to produce light in the dark, and to about 1000° to produce light in daylight. | | | |
| Lightning travels at such a velocity that it would go 480 times round the earth in one minute. | | | |
| Thunder travels 380 yards in one second. | | | |
| Clouds travel in a high wind at a velocity of 60 miles an hour. | | | |
| The earth turns round upon its axis from west to east, at the rate of 1042 miles an hour at the Equator. | | | |
| Sound travels 13 miles in a minute in the air. | | | |
| A human voice on a calm day, may be heard at a distance of 460 feet. | | | |
| The report of a rifle ditto ditto 3 miles. | | | |
| A military band ditto ditto 3 ,, | | | |
| The report of a cannon ditto ditto 20 ,, | | | |
| Heavy bombardment ditto ditto 100 ,, | | | |

Table 164 *continued.*

Mr. Mallet found that the shock produced by the explosion of gunpowder, travelled at the rate per second of 951 feet in wet sand; 1283 feet in friable granite; and 1640 feet in solid granite.
The shock of an earthquake travels with a velocity of from 1000 to 1600 feet per second, on an average; but in some cases the velocity has been as high as 2860 feet per second.
A velocity of 1 mile per hour = 1·46 feet per second, or 88 feet per minute, or 5280 feet per hour.
A velocity of 1 foot per second = 60 feet per minute, or 3600 feet per hour, or ·6818 miles per hour.

## QUALITIES OF METALS.

**Gold** of fine or pure quality is nearly as soft as lead. To enable it to resist wear, it is hardened by alloying with copper and silver. The fineness of gold is denoted by the number of carats present in 24 carats of the alloy, pure gold being 24 carats fine; standard or sovereign gold is 22 carats fine, and is a mixture of 22 parts gold and 2 parts copper. A new sovereign weighs 123·27447 grains, or a little more than 123¼ grains, and when its weight is reduced by wear to under 122½ grains it is not a legal tender. A new half-sovereign weighs 61·63723 grains, and when its weight is reduced by wear to under 61·125 grains, it is not a legal tender. After a sovereign has been in circulation for 20 years, its weight will have been reduced by wear to a little below the minimum legal weight. The gold coinage of this country weighs about 800 tons. The gold used for the best class of jewellery is 18 carats fine, and is a mixture of 18 parts gold and 6 parts copper. The gold used for common jewellery is 9 carats fine and is a mixture of 9 parts gold and 15 parts copper. Jewellers test gold with nitric acid, which leaves a stain on metal which is much alloyed, the colour of the stain varying according to the quality of the metal. Nitric acid does not affect 18 carat gold, but produces a dark stain on 9 carat gold, and a green stain upon the metal when a large proportion of copper, brass, or German silver is present. Gold dissolves in aqua regia or a mixture of one part nitric acid and four parts hydrochloric acid.

**Silver** of fine or pure quality is soft and ductile; its power of conducting electricity and heat is superior to all other metals. Standard silver used for coins, is a mixture of 92½ parts silver and 7½ parts copper, 1 lb. of which contains 11 oz. 2 dwts. silver and 18 dwts. copper. The fineness of silver is denoted by the number of dwts. it is better or worse in quality than standard silver. Nitric acid produces a black mark on fine silver, and a green mark on silver which is much alloyed.

**Copper** being more malleable than ductile, is more suitable for being hammered and rolled into plates, than being drawn into wire; its malleability and ductility depend greatly upon its purity. Copper, during the process of being hammered, rolled, or drawn into wire, becomes hard, stiff, and liable to crack, and requires to be frequently annealed to restore it to its normal quality; when these processes are carefully carried out, the strength of copper is thereby considerably increased. Bean-shot copper is obtained by pouring melted copper into hot water, and feathered-shot copper by pouring melted copper into cold water. The bronze coinage of this country and of France is a mixture of 95 parts copper, 4 parts tin, and 1 part zinc.

**Tin** possesses very little tenacity, but is very malleable, and may be beaten and rolled into thin leaves of tin-foil of the one-thousandth part of an inch in thickness; when quickly bent tin gives a creaking sound. Tin is not much affected by weak acids, or by exposure to the air. Tin-plate is sheet-iron coated with tin. Tin-salt is obtained by dissolving tin in hydrochloric acid. Tin is dissolved by mercury, and an amalgam of tin and mercury is used for silvering mirrors. Grain-tin is made by heating tin of very pure quality to nearly the melting point—when it becomes brittle—and dropping it from a height, which breaks it into prismatic pieces. The quality of tin may be tested by casting it in a stone mould, and when it is cold, the impure tin will be frosted all over, the common tin partly frosted, and the refined tin will be smooth and bright.

**Zinc** is brittle both at ordinary and at high temperatures, but is malleable at a temperature of 250° F., when it may be rolled into sheets or drawn into moderately fine wire. Zinc is very little affected by exposure to the air. A coating of zinc on iron prevents its oxidation. The addition of 10 per cent. of bismuth makes it more easily melted, and the addition of 10 per cent. of chloride of ammonium is said to increase its hardness.

**Lead** is very malleable but is not tenacious, and cannot be drawn into very fine wire; it resists the action of muriatic, sulphuric, and other acids, strong nitric acid does not affect it much, but diluted nitric acid soon dissolves it. The addition of a little lead makes brass more ductile, but a large addition makes it brittle, and causes the metals to separate during solidification. The addition of a little resin to lead just before pouring, prevents the metal scattering, when being poured round a damp joint.

**Antimony** is a very brittle and a comparatively light metal, it is used principally for alloying with other metals, to harden tin and lead in making white-metal for bearings, &c., type-metal, and stereotype metal. It melts at 810° F.

**Bismuth** is a very brittle, reddish-white crystalline metal. It is used principally for imparting fusibility to other metals. It possesses the property of expanding considerably during solidification, and is useful for taking impressions of dies. It melts at 507° F.

**Cadmium** is a silver-white crystalline metal, similiar in appearance to tin, but harder and more tenacious. It is malleable and ductile at the ordinary temperature, but is brittle at 185° F. It melts at the low temperature of 442° F., but it is difficult to use as an ingredient of alloys, because it volatilises rapidly at the ordinary temperatures necessary for making alloys. It is dissolved easily by mineral acids.

**The quality of Iron and Steel** may be ascertained by immersing a small well-polished piece in diluted nitric acid for 12 hours, when its structure will be exposed by the action of the acid, and best steel will appear frosted; common steel honeycombed; best wrought-iron will show fine fibres; common wrought-iron, coarse fibres; and grey cast-iron will show well defined crystals of carbon.

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Table 165.—PROFIT AND DISCOUNT.

| Cost. | 1¼ °/. | 2½ °/. | 5 °/. | 7½ °/. | 10 °/. | 15 °/. | 20 °/. | 25 °/. | 30 °/. | 35 °/. | 40 °/. | 45 °/. | 50 °/. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* | *s. d.* |
| 0 1 | | | | | | ¼ | ¼ | ¼ | ¼ | ¼ | ½ | ½ | ½ |
| 0 2 | | | | ¼ | ¼ | ¼ | ½ | ½ | ½ | ¾ | ¾ | 1 | 1 |
| 0 3 | | | ¼ | ¼ | ¼ | ½ | ½ | ¾ | 1 | 1 | 1¼ | 1¼ | 1½ |
| 0 6 | | | ¼ | ½ | ½ | 1 | 1¼ | 1½ | 1¾ | 2 | 2½ | 2¾ | 3 |
| 0 9 | | | ½ | ¾ | 1 | 1¼ | 1¾ | 2¼ | 2¾ | 3¼ | 3½ | 4 | 4½ |
| 1 0 | ¼ | ¼ | ½ | 1 | 1¼ | 1¾ | 2½ | 3 | 3½ | 4¼ | 4¾ | 5½ | 6 |
| 1 3 | ¼ | ½ | ¾ | 1¼ | 1½ | 2¼ | 3 | 3¾ | 4½ | 5¼ | 6 | 6¾ | 7½ |
| 1 6 | ¼ | ½ | 1 | 1¼ | 1¾ | 2¾ | 3½ | 4½ | 5½ | 6¼ | 7¼ | 8 | 9 |
| 1 9 | ¼ | ½ | 1 | 1½ | 2 | 3¼ | 4¼ | 5¼ | 6¼ | 7¼ | 8½ | 9½ | 10½ |
| 2 0 | ¼ | ½ | 1¼ | 1¾ | 2½ | 3½ | 4¾ | 6 | 7¼ | 8½ | 9½ | 10¾ | 1 0 |
| 2 6 | ½ | ¾ | 1½ | 2¼ | 3 | 4½ | 6 | 7½ | 9 | 10½ | 1 0 | 1 1½ | 1 3 |
| 3 0 | ½ | 1 | 1¾ | 2¾ | 3½ | 5½ | 7¼ | 9 | 10¾ | 1 0½ | 1 2½ | 1 4¼ | 1 6 |
| 4 0 | ½ | 1¼ | 2½ | 3½ | 4¾ | 7¼ | 9½ | 1 0 | 1 2½ | 1 4¾ | 1 7¼ | 1 9½ | 2 0 |
| 5 0 | ¾ | 1½ | 3 | 4½ | 6 | 9 | 1 0 | 1 3 | 1 6 | 1 9 | 2 0 | 2 3 | 2 6 |
| 6 0 | 1 | 1¾ | 3½ | 5½ | 7¼ | 10¾ | 1 2½ | 1 6 | 1 9½ | 2 1¼ | 2 4¾ | 2 8½ | 3 0 |
| 7 0 | 1 | 2 | 4¼ | 6¼ | 8½ | 1 0½ | 1 4¾ | 1 9 | 2 1¼ | 2 5½ | 2 9½ | 3 1¾ | 3 6 |
| 8 0 | 1¼ | 2½ | 4¾ | 7¼ | 9½ | 1 2½ | 1 7¼ | 2 0 | 2 4¾ | 2 9½ | 3 2½ | 3 7¼ | 4 0 |
| 9 0 | 1¼ | 2¾ | 5½ | 8 | 10¾ | 1 4¼ | 1 9½ | 2 3 | 2 8½ | 3 1¾ | 3 7¼ | 4 0½ | 4 6 |
| 10 0 | 1½ | 3 | 6 | 9 | 1 0 | 1 6 | 2 0 | 2 6 | 3 0 | 3 6 | 4 0 | 4 6 | 5 0 |
| 11 0 | 1¾ | 3¼ | 6½ | 10 | 1 1¼ | 1 7¾ | 2 2½ | 2 9 | 3 3½ | 3 10¼ | 4 4¾ | 4 11½ | 5 6 |
| 12 0 | 1¾ | 3½ | 7¼ | 10¾ | 1 2½ | 1 9½ | 2 4¾ | 3 0 | 3 7¼ | 4 2½ | 4 9½ | 5 4¾ | 6 0 |
| 13 0 | 2 | 4 | 7¾ | 11¾ | 1 3½ | 1 11½ | 2 7¼ | 3 3 | 3 10¾ | 4 6½ | 5 2½ | 5 10¼ | 6 6 |
| 14 0 | 2 | 4¼ | 8½ | 1 0½ | 1 4¾ | 2 1¼ | 2 9½ | 3 6 | 4 2½ | 4 10¾ | 5 7¼ | 6 3½ | 7 0 |
| 15 0 | 2¼ | 4½ | 9 | 1 1½ | 1 6 | 2 3 | 3 0 | 3 9 | 4 6 | 5 3 | 6 0 | 6 9 | 7 6 |
| 16 0 | 2½ | 4¾ | 9½ | 1 2½ | 1 7¼ | 2 4¾ | 3 2½ | 4 0 | 4 9½ | 5 7¼ | 6 4¾ | 7 2½ | 8 0 |
| 17 0 | 2½ | 5 | 10¼ | 1 3¼ | 1 8½ | 2 6½ | 3 4¾ | 4 3 | 5 1¼ | 5 11½ | 6 9½ | 7 7¾ | 8 6 |
| 18 0 | 2¾ | 5½ | 10¾ | 1 4¼ | 1 9½ | 2 8½ | 3 7¼ | 4 6 | 5 4¾ | 6 3½ | 7 2½ | 8 1¼ | 9 0 |
| 19 0 | 2¾ | 5¾ | 11½ | 1 5 | 1 10¾ | 2 10¼ | 3 9½ | 4 9 | 5 8½ | 6 7¾ | 7 7¼ | 8 6½ | 9 6 |
| 20 0 | 3 | 6 | 1 0 | 1 6 | 2 0 | 3 0 | 4 0 | 5 0 | 6 0 | 7 0 | 8 0 | 9 0 | 10 0 |

**The selling price of goods** to leave a given per-centage of profit on the whole returns may be found by the following rule:—Multiply the cost price by 100, and divide the product by 100, *minus* the required profit.

**The interest for any number of days** due on any principal, may be found approximately by the following rule:—Multiply the principal by the number of days to run, and divide the product by one of the following constant numbers, according to the rate of interest required, viz.:— By 121 for 3 °/₀; 91 for 4 °/₀; 73 for 5 °/₀; 60·5 for 6 °/₀; 53 for 7 °/₀; 48·5 for 7½ °/₀; 45 for 8 °/₀; 40 for 9 °/₀; 36 for 10 °/₀; 29 for 12½ °/₀; 24 for 15 °/₀; 20 for 18 °/₀; 18 for 20 °/₀; and finally divide the quotient by 100.

Table 166.—Properties of Air, from Observations at Greenwich Observatory.—Barometer 30 inches at 60° Fahrenheit.

| Temperature of the Air. | Force of Vapour in Inches of Mercury. | Weight of Vapour per cubic foot of saturated Air. | Weight per cubic foot. | | Temperature of the Air. | Force of Vapour in Inches of Mercury. | Weight of Vapour per cubic foot of saturated Air. | Weight per cubic foot. | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Dry Air | Saturated Air | | | | Dry Air | Saturated Air |
| ° Fahr. | Inches. | Grains. | Grains. | Grains. | ° Fahr. | Inches. | Grains. | Grains. | Grains. |
| 10 | ·089 | 1·11 | 590·0 | 589·4 | 52 | ·400 | 4·56 | 540·5 | 537·9 |
| 12 | ·096 | 1·19 | 587·5 | 586·8 | 54 | ·428 | 4·86 | 538·3 | 535·5 |
| 14 | ·104 | 1·28 | 584·9 | 584·2 | 56 | ·458 | 5·18 | 536·2 | 533·2 |
| 16 | ·112 | 1·37 | 582·4 | 581·6 | 58 | ·489 | 5·51 | 534·1 | 530·9 |
| 18 | ·120 | 1·47 | 579·9 | 579·1 | 60 | ·523 | 5·87 | 532·0 | 528·6 |
| 20 | ·129 | 1·58 | 577·4 | 576·5 | 62 | ·559 | 6·25 | 529·9 | 526·3 |
| 22 | ·139 | 1·69 | 575·0 | 574·0 | 64 | ·597 | 6·65 | 527·8 | 524·0 |
| 24 | ·150 | 1·81 | 572·5 | 571·5 | 66 | ·638 | 7·08 | 525·8 | 521·7 |
| 26 | ·161 | 1·93 | 570·1 | 569·0 | 68 | ·681 | 7·53 | 523·7 | 519·4 |
| 28 | ·173 | 2·07 | 567·7 | 566·5 | 70 | ·727 | 8·00 | 521·7 | 517·2 |
| 30 | ·186 | 2·21 | 565·3 | 564·1 | 72 | ·776 | 8·50 | 519·7 | 514·9 |
| 32 | ·199 | 2·37 | 563·0 | 561·6 | 74 | ·827 | 9·04 | 517·7 | 512·6 |
| 34 | ·214 | 2·53 | 560·7 | 559·2 | 76 | ·882 | 9·60 | 515·7 | 510·3 |
| 36 | ·230 | 2·71 | 558·3 | 556·8 | 78 | ·940 | 10·19 | 513·8 | 508·0 |
| 38 | ·246 | 2·89 | 556·0 | 554·4 | 80 | 1·001 | 10·81 | 511·8 | 505·7 |
| 40 | ·264 | 3·09 | 553·8 | 552·0 | 82 | 1·067 | 11·47 | 509·9 | 503·4 |
| 42 | ·283 | 3·30 | 551·5 | 549·6 | 84 | 1·136 | 12·17 | 508·0 | 501·1 |
| 44 | ·304 | 3·52 | 549·3 | 547·2 | 86 | 1·209 | 12·91 | 506·1 | 498·9 |
| 46 | ·326 | 3·76 | 547·0 | 544·9 | 88 | 1·286 | 13·68 | 504·2 | 496·6 |
| 48 | ·349 | 4·01 | 544·8 | 542·5 | 90 | 1·368 | 14·50 | 502·3 | 494·3 |
| 50 | ·373 | 4·28 | 542·6 | 540·2 | 92 | 1·456 | 15·33 | 500·4 | 492·0 |

Table 167. Mean Temperature of the Air at Various Places.

| Name of place. | Mean Temp. | | Height above the Sea. Feet. | Name of Place. | Mean Temp. | | Height above the Sea. Feet. |
|---|---|---|---|---|---|---|---|
| | Summer | Winter | | | Summer | Winter | |
| | ° Fahr. | ° Fahr. | | | ° Fahr. | ° Fahr. | |
| Algiers . . . . | 75 | 54 | 310 | Madrid . . . | 74 | 42 | 2175 |
| Berlin . . . . | 63 | 31 | 128 | Mexico, City. . | 64 | 60 | 6993 |
| Berne . . . . | 61 | 31 | 1918 | Montreal . . . | 69 | 18 | — |
| Boston, America . | 66 | 28 | 71 | Moscow. . . | 63 | 14 | 480 |
| Buenos Ayres. . | 73 | 53 | — | Naples. . . . | 75 | 50 | 180 |
| Cairo. . . . . | 85 | 59 | — | New Orleans. . | 84 | 57 | 22 |
| Calcutta . . . | 84 | 68 | — | New York. . . | 72 | 33 | 21 |
| Canton . . . . | 82 | 55 | 11 | New Zealand. . | 67 | 54 | — |
| Cape of Good Hope. | 75 | 59 | — | Nice . . . . . | 73 | 49 | — |
| Ceylon, Candy . . | 73 | 72 | 1684 | Paramatta, Australia | 74 | 55 | — |
| Christiania . . . | 60 | 26 | 74 | Paris . . . . | 65 | 38 | 210 |
| Constantinople . | 74 | 41 | 150 | Pekin, China . . | 78 | 29 | 97 |
| Copenhagen . . . | 63 | 32 | 20 | Philadelphia . . | 75 | 34 | 30 |
| Dresden . . . . | 63 | 32 | 397 | Quito, Ecuador . . | 61 | 60 | 9560 |
| Edinburgh . . . | 58 | 39 | 288 | Rio Janeiro . . | 79 | 69 | 11 |
| Hobart Town. . | 63 | 42 | — | Rome . . . . . | 74 | 47 | 174 |
| Jamaica . . . . | 82 | 77 | 10 | San Francisco. . | 59 | 53 | 150 |
| Jerusalem . . . | 73 | 50 | 2500 | Stockholm . . . | 61 | 26 | 134 |
| Lima, Peru . . . | 74 | 60 | 511 | St. Petersburg . | 61 | 17 | 10 |
| Lisbon . . . . | 72 | 53 | 236 | St. Bernard Alps . | 43 | 18 | 8180 |
| London . . . . | 62 | 40 | 50 | Siberia, Irkutsk . | 63 | −38 | — |
| Madeira, Funchal . | 70 | 62 | — | Vienna. . . . . | 69 | 34 | 500 |

Table 168.—Mean Annual Rainfall in Inches at various places.

| | Inches. | | Inches. |
|---|---|---|---|
| Algiers | 37·00 | Lancashire, Marple | 36·56 |
| Baltimore | 42·00 | Lancashire, Bury | 41·70 |
| Bengal, on Khasia Hills | 600·00 | Lancashire, Coombs | 45·80 |
| Bergen, Norway | 87·60 | Lancashire, Rochdale | 46·75 |
| Berlin, Prussia | 23·56 | Lancashire, Bolton | 49·50 |
| Berks, Reading | 25·40 | Lancashire, Crawshawbooth | 60·00 |
| Berks, Hungerf6rd | 26·58 | Lille, France | 29·00 |
| Bombay, India | 110·00 | Lima, Peru | 13·50 |
| Bordeaux | 25·80 | Lincolnshire, Lincoln | 20·20 |
| Boston, North America | 44·50 | Lincolnshire, Boston | 23·10 |
| Bucks, Aylesbury | 28·40 | London | 24·00 |
| Buffalo, North America | 27·36 | Madeira Islands | 30·87 |
| Calcutta, India | 73·00 | Middlesex, Chiswick | 24·00 |
| Canton, China | 69·30 | Middlesex, Tottenham | 24·80 |
| Charleston, North America | 48·30 | Milan, Italy | 38·00 |
| Cheshire, Todd's Brook R'voir | 38·40 | Mississippi State | 53·00 |
| Cheshire, Coomb's Reservoir | 51·30 | New Orleans | 52·32 |
| Copenhagen | 18·36 | New York | 42·24 |
| Cornwall, Penzance | 41·10 | Norfolk, Felthorp | 22·60 |
| Cornwall, Pencarran | 45·30 | Norfolk, Dickleborough | 25·00 |
| Cumberland, Stye-in-Borrowdale | 165·00 | Northampton, Wellingborough | 24·90 |
| Cumberland, Keswick | 67·50 | Ohio State | 22·65 |
| Cumberland, Whitehaven | 47·00 | Paris | 22·65 |
| Cumberland, Cockermouth | 45·40 | Pekin | 26·92 |
| Derbyshire, Chatsworth | 27·80 | Pentland Hills | 36·12 |
| Derbyshire, Chapel-en-le-Frith | 43·00 | Peru, Carabaya | 355·00 |
| Devonshire, Exeter | 29·20 | Philadelphia | 48·20 |
| Devonshire, Honiton | 33·20 | Pisa | 49·00 |
| Devonshire, Plymouth | 35·70 | Rivington Pike | 56·50 |
| Devonshire, Goodamoor | 56·80 | Rome, Italy | 30·80 |
| Dover, Kent | 37·50 | San Francisco | 83·10 |
| Dublin | 25·00 | Somersetshire, Bridgewater | 29·30 |
| Edinburgh | 27·00 | Somersetshire, Bath | 32·40 |
| England, average for whole of | 36·00 | St. Petersburg, Russia | 17·64 |
| Essex | 21·00 | Stockholm | 19·68 |
| Genoa, Italy | 56·00 | Surrey, Cobham | 24·42 |
| Glasgow | 28·00 | Sussex, Hastings | 32·00 |
| Granada, Colombia | 115·00 | Swineshaw Brook, near Staley Bridge | 49·30 |
| Greenock | 60·00 | Tiflis | 19·25 |
| Hampshire, Fyfield | 25·90 | Venice | 31·12 |
| Hampshire. Gosport | 30·20 | Viviers | 34·10 |
| Hampshire, Southampton | 30·30 | Washington | 41·25 |
| Hampshire, Selborne | 37·20 | Westmorland, Waith Sutton | 40·62 |
| Havannah | 91·20 | Westmorland, Kendal | 58·12 |
| Island of Cuba | 141·00 | Westmorland, Grasmere | 107·51 |
| Island of San Domingo | d120·00 | Westmorland, Gatesgarth | 117·20 |
| Lancashire, Moss Lock, near Rochdale | 30·30 | Westmorland, Seathwaite | 140·60 |
| Lancashire, Liverpool | 34·70 | Yorkshire, York | 22·30 |
| Lancashire, Blackstone-edge | 36·30 | Yorkshire, Sowerby Bridge | 27·00 |
| Lancashire, Manchester | 37·30 | Yorkshire, Barrowsby | 27·51 |

**An inch of rainfall** on a square yard of surface represents a fall of 46·74 lbs., or 4·67 gallons: on an acre it represents a fall of 22,622 gallons, equal to about one hundred tons per inch in depth per acre.

**Inches of rainfall** × 14·501 = millions of gallons per square mile: ditto × 2,323,200 = cubic feet per square mile: ditto × 3630 = cubic feet per acre.

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